REPORT

Tonkin+Taylor

Mount Maunganui to Papamoa Coastal Erosion Assessment

Prepared for
Tauranga City Council

Prepared by
Tonkin & Taylor Ltd

Date
February 2020

Job Number
1009598.v2

Exceptional thinking together

www.tonkintaylor.co.nz

Document Control

Title: Mount Maunganui to Papamoa Coastal Erosion Assessment					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
Nov 2019	V1	Draft report for client review	Rebekah Haughey	Jonathan Clarke /Tom Shand	Richard Reinen-Hamill
Feb 2020	V2	Final report with updates from client review	Rebekah Haughey		Richard Reinen-Hamill

Distribution:

Tauranga City Council 1 electronic copy

Tonkin & Taylor Ltd (FILE) 1 electronic copy

Table of contents

Executive summary

The Mount Maunganui to Papamoa shoreline includes 19 km of northeast facing beach located in the Bay of Plenty, south of the Tauranga Harbour entrance. The shoreline is part of a long gently curving sandy barrier coastline and is typically characterised by a dune, berm and offshore bar.

Tonkin + Taylor Ltd (T+T) were commissioned by Tauranga City Council to undertake a detailed coastal erosion hazard assessment for the Mount Maunganui to Papamoa shoreline. The assessment constitutes an update of the previous erosion hazard assessment completed by T+T in 2009, utilising an improved methodology in conjunction with additional beach monitoring data and storm observations over the last decade.

The coastal erosion hazard areas were defined using a probabilistic approach which combines standard and well-tested methods. The approach is based on a stochastic method of combining erosion parameter distributions to allow for inherent variance and uncertainty. Results provide a range of potential erosion hazard distances for current and future timeframes (e.g. 2080 and 2130) including different sea level rise scenarios.

The current CEHA averages -12 m and -17 m ($P_{66\%}$ and $P_{5\%}$). The future 100 year CEHA based on the 1.6m SLR scenario, ranges from -12 to -53 m for the $P_{66\%}$ and is up to -86 m for the $P_{5\%}$. Overall, the updated erosion hazard areas are comparable with the previous setbacks defined by T+T (2009), but provide a probabilistic understanding of the impacts of different sea level rise scenarios. Key conclusions are as follows:

- The current erosion hazard is dominated by short-term erosion processes and is relatively consistent along the Mount Maunganui to Papamoa shoreline. The current erosion hazard is smallest at Mount Main (cell A).
- The future erosion hazard is determined by the effects of sea level rise balanced by long-term accretion with the larger future sea level rise values causing larger erosion hazard.
- The future CEHA is smallest along Marine Parade (cell C) where long-term trends have been dominated by accretion. The shoreline accretion is likely to be linked with the nearshore deposition of dredged sediment which first began in 1991.
- The future CEHA is largest within cell E (Wairariki St to Harrison's Cut) which has shown a slight erosional trend.

A key uncertainty is the future nearshore deposition of dredged material and its contribution to the shoreline accretion rates. To account for this future uncertainty, the lower bound long-term component for all accreting cells have been set to zero. Subsequently, the lower probability distances (i.e. $P_{5\%}$) are representative of future scenarios where there is no long term accretion.

We recommend that this hazard assessment is updated at intervals of no more than 10 years or following significant changes in data availability, or best practice guidance or methods.

Overall, this study has assessed coastal erosion hazard areas at a local scale and may be superseded by details, site-specific assessment undertaken by qualified and experienced practitioners using improved or higher resolution data than presented in this report.

1 Introduction

The Mount Maunganui to Papamoa shoreline is 19 km of northeast facing beach located in the Bay of Plenty, south of the Tauranga Harbour entrance.

Tauranga City Council (TCC) have engaged Tonkin + Taylor Ltd (T+T) to complete a coastal erosion assessment for the open-coast between Mauoa and Papamoa East. The assessment constitutes an update of the previous erosion hazard assessment completed by T+T in 2009, utilising an improved methodology in conjunction with additional beach monitoring data and storm observations over the last decade.

1.1 Study scope

The purpose of the Mount Maunganui to Papamoa coastal erosion hazard assessment is to identify and map areas of land potentially exposed to coastal erosion. The assessment is based on the following scope of works:

- Assess values of components contributing to coastal erosion along the Mount Maunganui to Papamoa shoreline
- Calculate probabilistic coastal erosion distances for the site using the T+T stochastic forecast methodology (Shand et al., 2015)
- Apply the coastal erosion methodology for current and future sea level scenarios in accordance with the requirements of:
    - New Zealand Coastal Policy Statement (NZCPS)
    - Natural hazard provisions of the Bay of Plenty Regional Policy Statement (RPS)
    - Proposed Regional Coastal Environment Plan (PRCEP)
    - Ministry for the Environment (MfE) Coastal Hazard Guidelines (2017).
- Map coastal erosion hazard distances for present day, 50 year and 100 year timeframes for all SLR scenarios and for 66% and 5% exceedance probabilities
- Produce a technical report describing the methodology and a discussion of the results.

1.2 Report layout

The report is structured as follows:

- Coastal setting is described in Section 2
- Data sources are outlined in Section 3
- Methodology for deriving coastal erosion hazard areas in Section 4
- Derivation of component for coastal erosion in Section 5
- Results and discussion of the erosion hazard assessment in Section 6
- A summary of the assessment and recommendations are outlined in Section 7.

1.3 Datums and coordinates

All elevations (levels) within this report are presented in terms of Moturiki Vertical Datum 1953 (MVD53 or Reduced Level, RL). Coordinates are presented in terms of New Zealand Transverse Mercator (NZTM).

2 Coastal setting

2.1 General setting

The study site is located within the Bay of Plenty, on the east coast of the North Island. The site includes 19 km of northeast-facing, sandy shoreline extending from the base of Mount Maunganui to the eastern extent of Papamoa (Figure 2.1). The shoreline is part of a long gently curving sandy barrier coastline. The beach is typically characterised by a dune, berm and offshore bar. The are several offshore islands including Motiti Island which is approximately 10 km offshore from the eastern end of Papamoa, Motuotau Island which is approximately 0.6 km offshore from Marine Parade, and Moturiki Island which is approximately 0.7 km east of Mauao.

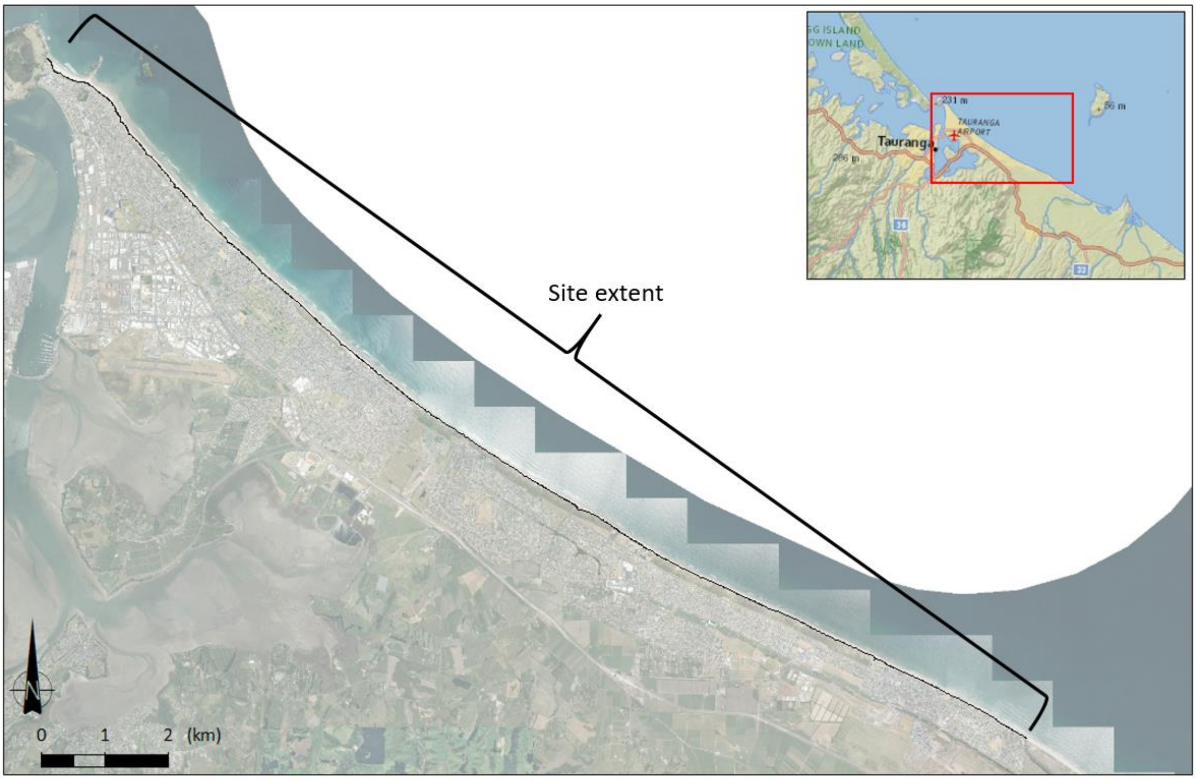


Figure 2.1: Overview of site location (site extent shown by black line)

2.2 Geology

The shoreline is backed by a coastal plain of parallel dune ridges which were constructed during the last 7,000 years during a period of relatively stable sea-level. The urban area of Mount Maunganui sits on a sandy tombolo which links the large lava dome of Mauao to the mainland. The tombolo is a deposition feature resulting from the convergence of longshore drift. There is also a smaller tombolo present in the lee of Moturiki Island. The tombolos are landforms that have formed over the last 2 to 3,000 years and were fully established by 1852 (Gibb, 1996). Papamoa has been developed on a cuspate foreland (another accretional landform) which has formed in the lee of Motiti Island. During last the 2,000 years the duneline has advanced about 70 to 80 m seaward as coast approaches state of dynamic equilibrium (Gibb, 1996).

2.3 Sediments

Sediment along the Mount Maungaui to Papamoa shoreline are typically medium to fine quartzo-feldspathic beach sand of primarily volcanic origin (Gibb, 1996). Foster (1991) found the beach and nearshore sands are moderately well sorted. The finer sands tend to have a higher pumice content while the medium to coarse sands have higher quartz, feldspar and heavy mineral content.

The sediment is primarily sourced from littoral drift, which in the Bay of Plenty is generally northwest to southeast (Smale, 1993). Although, Gibb (1996) indicates there is also net northwest drift between the Kaituna River mouth and Papamoa Domain. Littoral drift rates along the Mount Maunganui to Papamoa shoreline are estimated to be 10,000 to 50,000 m^3/year (Healy et al., 1977).

Healy et al. (1977) suggests that most of the littoral sediment is sourced from the central volcanic plateau and the long term contribution from the continental shelf is relatively minor. The Wairoa River (within Tauranga Harbour) and the Kaituna River are likely to be key sources of the sediment. The Wairoa River is a significant contributor of sediment loads into Tauranga Harbour with a catchment size of 2,132 km^2 (Smale, 1993). Some of the sediment within the Harbour is likely to be transported seaward on to the open coast.

There is also net south-eastwards sediment transport along Matakana Island, however Healy et al. (1977) notes that due to the orientation of the Tauranga Harbour entrance, it does not permit large quantities of sediment to by-pass the deep tidal gorge. The sediments that are transported along Matakana Island tend to be recirculated through the entrance and back on to the Matakana Bank.

2.4 Vertical land movement

Beavan and Litchfield (2012) assessed vertical land movement (VLM) around New Zealand's coastline. They found the land around Tauranga relatively stable or slightly uplifting, with the rate of VLM in the Papamoa hills being +0.5 mm/year, measured over approximately nine years. Rates of VLM can change significantly over 10's of kilometres, so the rate measured in the Papamoa hills may not be accurate for the open coast. For this assessment we have assumed zero VLM.

2.5 Water levels

Water levels play an important role in determining coastal erosion hazard. Water levels influence the amount of wave energy reaching the backshore, causing erosion during storm events and by controlling the mean shoreline position on longer time scales. The key components that determine water level are:

- Astronomical tides
- Barometric and wind effects, generally referred to as storm surge
- Medium term fluctuations, including El Niño–Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO) effects
- Long term changes in sea level
- Wave transformation processes through wave setup and run-up.

2.5.1 Astronomical tide

Tidal levels for primary and secondary ports of New Zealand are provided by LINZ (2019) based on average predicted values over the 19 year tidal cycle. Values for Tauranga in terms of Chart Datum and Moturiki Vertical Datum 1953 are presented within Table 2.1. The astronomical tide in the Bay of Plenty is micro-tidal with a spring tidal range of 1.8 m.

Table 2.1: Tidal levels given for the Moturiki tide gauge (LINZ, 2019)

Tide state	Chart Datum (m CD)	Moturiki Vertical Datum 1953 (m MVD53)	New Zealand Vertical Datum 2016 (m NZVD16)
Highest Astronomical Tide (HAT)	2.14	1.17	0.98
Mean High Water Springs (MHWS)	1.95	0.98	0.79
Mean High Water Neaps (MHWN)	1.67	0.70	0.51
Mean Sea Level (MSL)	1.09	0.12	-0.07
Mean Low Water Neaps (MLWN)	0.50	-0.47	-0.66
Mean Low Water Springs (MLWS)	0.15	-0.82	-1.01
Lowest Astronomical Tide (LAT)	-0.05	-1.02	-1.21

2.5.2 Storm surge

Storm surge results from the combination of barometric setup from low atmospheric pressure and wind stress from winds blowing along or onshore which elevates the water level above the predicted tide (Figure 2.2). The combined elevation of the predicted tide and storm surge is known as the storm tide. Storm surges are generated in the Bay of Plenty region by revolving (clockwise) wind storms including mid-latitude depressions and extra-tropical cyclones (Hay et al. 1991).

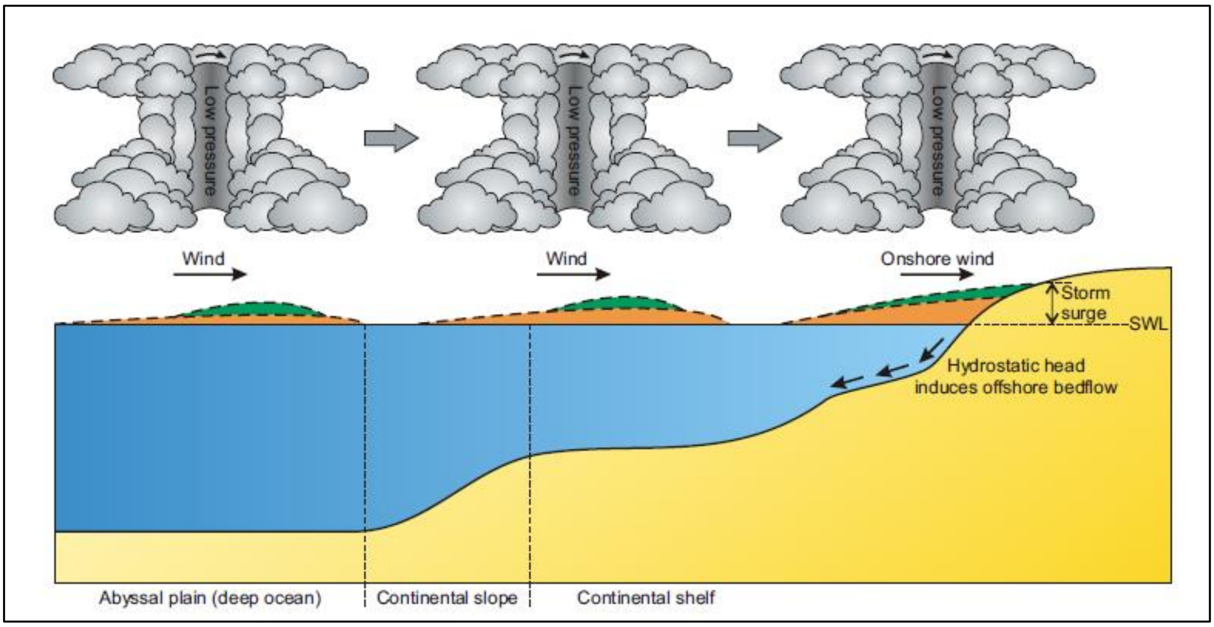


Figure 2.2: Processes causing storm surge (source: Shand, 2010)

2.5.3 Storm tide levels

The combined elevation of the predicted tide, storm surge and medium term fluctuations is known as the storm tide. The NIWA Coastal Calculator assesses the storm tide and wave hazard for 21 sites along the Bay of Plenty coastline. Extreme water levels predicted for Mount Maunganui and Papamoa are shown in Table 2.2.

Table 2.2: Extreme water level values for 10 year, 50 year and 100 year ARI events based on the NIWA Coastal Calculator (NIWA, 2013)

	Average Recurrence Interval (ARI)		
Location	**10 year ARI**	**50 year ARI**	**100 year ARI**
Mount Maunganui	1.35	1.46	1.50
Papamoa	1.35	1.45	1.50

2.5.4 Long term sea levels

Historic sea level rise in New Zealand has averaged 1.7 ± 0.1 mm/year (Hannah and Bell, 2012) with Bay of Plenty exhibiting a slightly higher rate of 1.9 ± 0.1 mm/year. Climate change is predicted to accelerate this rate of sea level rise into the future.

The Ministry for the Environment (MfE, 2017) guideline recommends using four scenarios to cover a range of predicted future sea levels that reflect the inherent uncertainty. The scenarios are based on the most recent IPCC report (IPCC, 2013) (Figure 2.3).

1. Low to eventual net-zero emission scenario (RCP2.6 median projection)
2. Intermediate-low scenario (RCP4.5 median projection)
3. High-emissions scenario (RCP8.5 median projection)
4. Higher extreme H+ scenario, based on the RCP8.5 83rd percentile projection from Kopp et al. (2014).

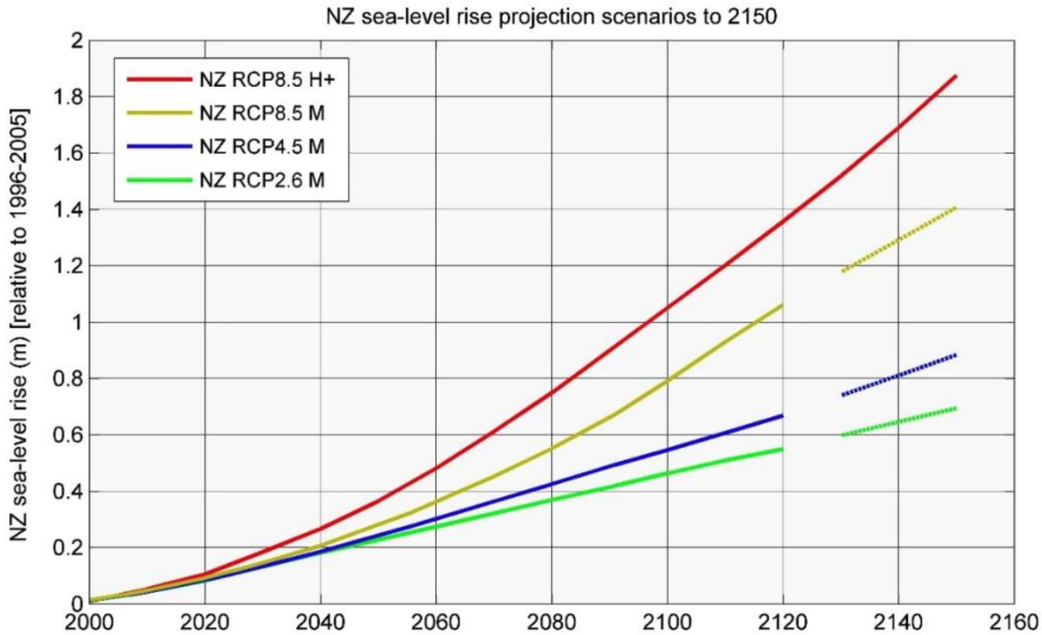


Figure 2.3: Four scenarios of New Zealand-wide regional sea-level rise projections as stipulated by the MfE 2017 guidance, with extensions to 2150 based on Kopp et al. (2014). No further extrapolation of the IPCC scenarios beyond 2120 was possible, hence the rate of rise for K14 median projections for RCP2.6, RCP4.5 and RCP8.5 are shown as dashed lines from 2130, to provide extended projections to 2150 (Source: MfE, 2017)

2.6 Winds

The prevailing wind direction for the Bay of Plenty is from west to southwest (Figure 2.4) which results in offshore winds along most of the shoreline. The region tends to be most affected by occasional extropical cyclones and intense depressions which form in north Tasman Sea and move over New Zealand resulting in strong northeast winds. Such north-easterly events typically promote beach erosion along the Mount Maunganui to Papamoa shoreline (Healy et al., 1977).

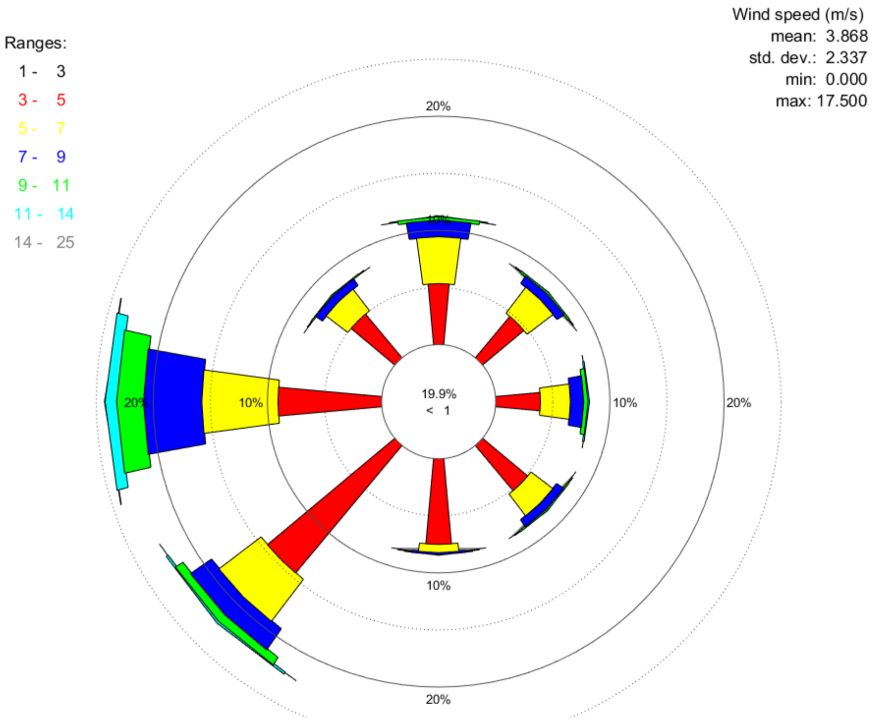


Figure 2.4: Wind rose for Tauranga Airport 1995 – 2016 (Source: MetService, 2018)

2.7 Waves

The Mount Maunganui to Papamoa shoreline can be classified as a mild-meso energy swell wave environment (Davis-Colley, 1976). The shoreline is exposed to waves from the north to east with the dominant swell direction from the northeast which is approximately normal to the coast. Wave conditions in the Bay of Plenty are moderately influenced by the El Niño Southern Oscillation (ENSO). During La Niña periods there tends to be on average more stormy conditions which are associated with an increase in north-easterlies in the New Zealand region. During El Niño years there is a higher occurrence of south-westerlies and wave conditions in the Bay of Plenty tend to be reduced, although episodic extropical cyclones still occur (Iremonger, 2011). Extreme significant wave heights based on the NIWA Coastal Calculator are summarised in Table 2.3. Figure 2.5 provides an example of the wave heights and period measured at A Beacon (outside Tauranga Harbour entrance) during a series of storms that occurred July 2008.

Table 2.3: Extreme offshore significant wave heights (m) based on the NIWA Coastal Calculator (NIWA, 2013)

	Average Recurrence Interval		
Location	**10 year**	**50 year**	**100 year**
Mount Maunganui	5.95	6.74	7.04
Papamoa	6.30	7.08	7.36

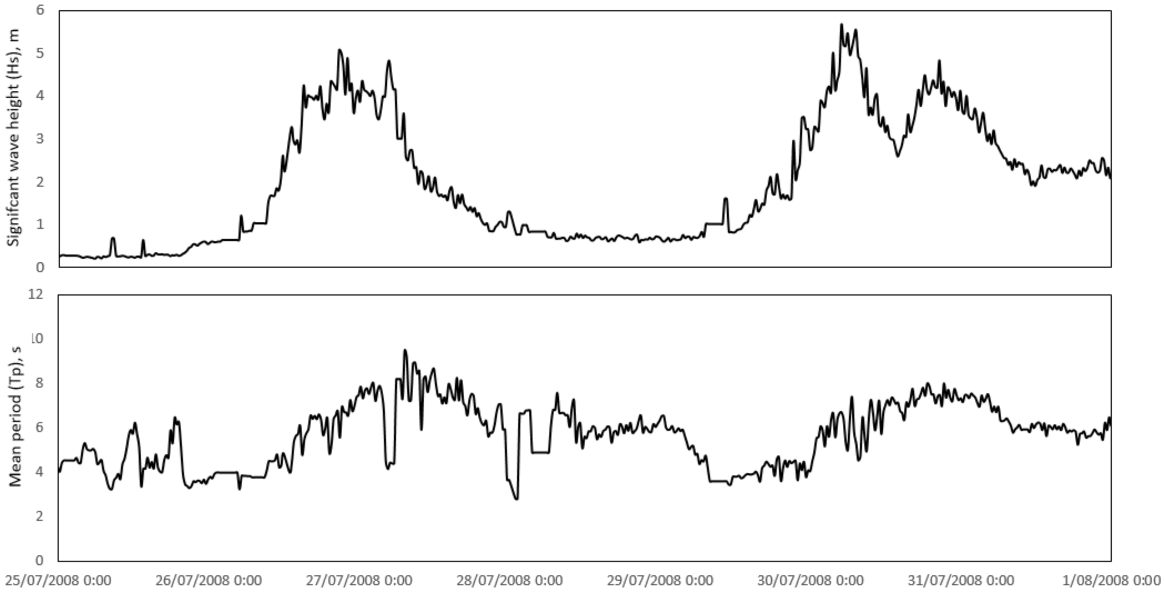


Figure 2.5: Example of offshore wave heights and period measured at A Beacon during July 2008 storms

2.8 Shoreline modifications

The Mount Maunganui to Papamoa shoreline has had various shoreline modifications including dune bulldozing, sand extraction, dune planting and the deposition of dredge material in the nearshore.

2.8.1 Dune bulldozing

One of the main historic modifications to the Mount Main Beach (Marine Parade) was dune bulldozing which occurred in 1965, with the intention of allowing more carpark space. Removing the natural dune system had a detrimental impact with windblown sand being lost from the system and often covering the road and carparks. The effects of the dune bulldozing were endured for more than 35 years until rehabilitation of the dune and planting commenced in 2001. The current dune is now well-established and continuing to accrete with spinifex and pingao vegetation.

In addition to the dune bulldozing along Marine Parade, there were several other locations dune levelling occurred during the 1960s, including Surf Road, Omanu and Papamoa Domain.

Figure 2.6: Dune bulldozing along the Mount Maunganui Main Beach in 1965 (Source: Jenks (2013)

2.8.2 Sand extraction

Another significant modification that has historically occurred along the shoreline was the sand extraction during 1965 to 1975. Approximately 330,000 m^3 of sand was extracted directly from the beach near Papamoa Domain. The rate of sand extraction exceeded the capability of the system to replenish sand naturally by littoral drift and subsequently there was loss of the offshore bar and significant recession of frontal dune. Healy et al. (1977) suggests that the sand extraction contributed to 40 to 60 m of erosion.

2.8.3 Stream diversion

Harrisons Cut, which is approximately 1 km west from Papamoa Domain, is another man-made feature along the Mount Maunganui-Papamoa shoreline. The Cut is a watercourse channel which was cut through the dunes and onto the beach to drain inland swamp areas for farming in the 1940s. As a result of the Cut there was beach lowering and dune erosion associated with meandering of the flow. In attempt to reduce the dune erosion, geotextile sand bags were placed along the side of the channel (Figure 2.7).

Another stream diversion has occurred at the Wairakei Stream which previously flowed out of the dunes in the area which is now known as Taylors Reserve (Figure 2.8). During 1956 the stream was infilled and the dunes were levelled between Taylors Reserve and Karewa Parade for the Marjorie Lane development. The front dune was destroyed by being bulldozed back into the stream to create more building sections. There is no longer a direct flow path out to sea and so now the water reaches the sea via groundwater.

Figure 2.7: Harrisons Cut, Papamoa

Figure 2.8: 1939 aerial showing the original flow path of the Wairakei Stream out through the dune system (source: Retrolens)

2.8.4 Nourishment from offshore dredge disposal

Material dredged from the Tauranga Harbour channel has been and continues to be, deposited at dredge disposal sites offshore from the Mount Maunganui shoreline. The dredged material was first placed in 1991 offshore from Mount Main at approximately 8 m water depth (Site A) (Figure 2.9). Foster (1991) found that the sediment deposited in the nearshore zone moved onshore to renourish the lower beach, particularly with material building up alongside Moturiki Island. Sediment has also been placed offshore from Marine Parade (Sites B and C) (Figure 2.9). Harms (1989) analysed movement from the inner shelf dump-mound and concluded that fine sand and pumice from the dumped material was not effective for beach nourishment as it tends to be washed offshore. Spiers & Healy (2005) also analysed the movement of sediment from the dump-mounds. They concluded that most of the sediment eroded from the mounds is likely to be redistributed within the dump ground with minimal amounts reaching the sub-aerial beach.

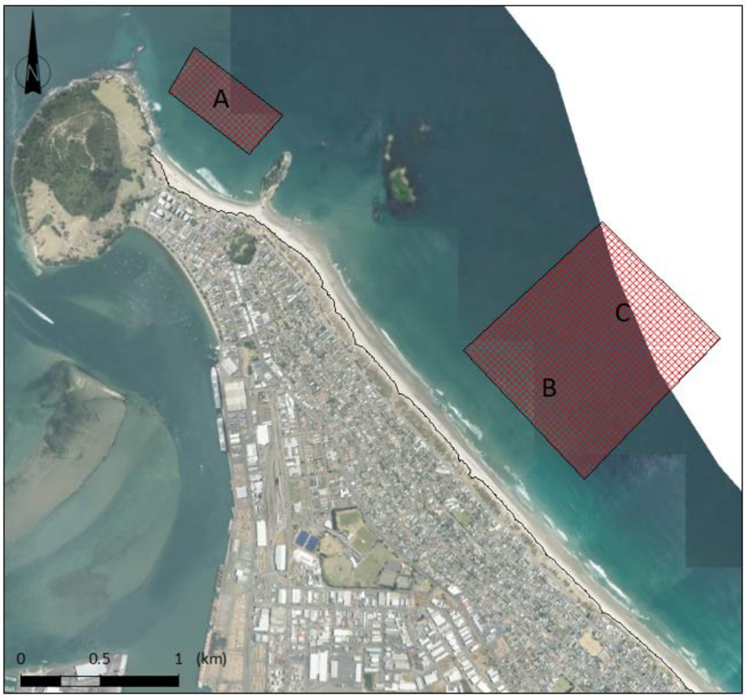


Figure 2.9: Approximate locations for deposition of dredge material

2.8.5 Artificial surf reef

In 2008 a pilot offshore submerged reef was constructed approximately 250 m offshore from the junction of Tay Street and Marine Parade (Figure 2.10). The reef was constructed over a three year period with a range of research investigations and monitoring undertaken to assess the effects of the structure. The reef generated unforeseen impacts on nearshore processes such as creating a scour hole in the lee of the structure and increasing the frequency and intensity of rip currents (Dahm & Gibberd, 2013). Subsequently, due to the hazard it created for swimmers, the structure was completely removed by the end of 2014.

Figure 2.10: Location of artificial surf reef constructed in 2008 offshore from Tay Street

2.8.6 Erosion protection structures

The earliest documented shoreline modification was the construction of a 20 m revetment at the end of Adams Avenue during the 1930s. This structure is now completely buried in sand. Adjacent to this section of coast another 180 m revetment was constructed along the Motor Camp Domain in the 1980s. During the 1970s there were two revetments constructed, one along the Papamoa Domain and another near Motiti Road (Gibb, 1996). These structures are no longer visible, however their existence suggests there has been historic erosion.

2.8.7 Stormwater outfalls

There are multiple stormwater outfalls along the Mount Maunganui to Papamoa shoreline (Figure 2.11). Stormwater outfalls discharging onto the beach liquefy sand, preventing natural accretion fronting the outlets and typically cause localised erosion of the dune.

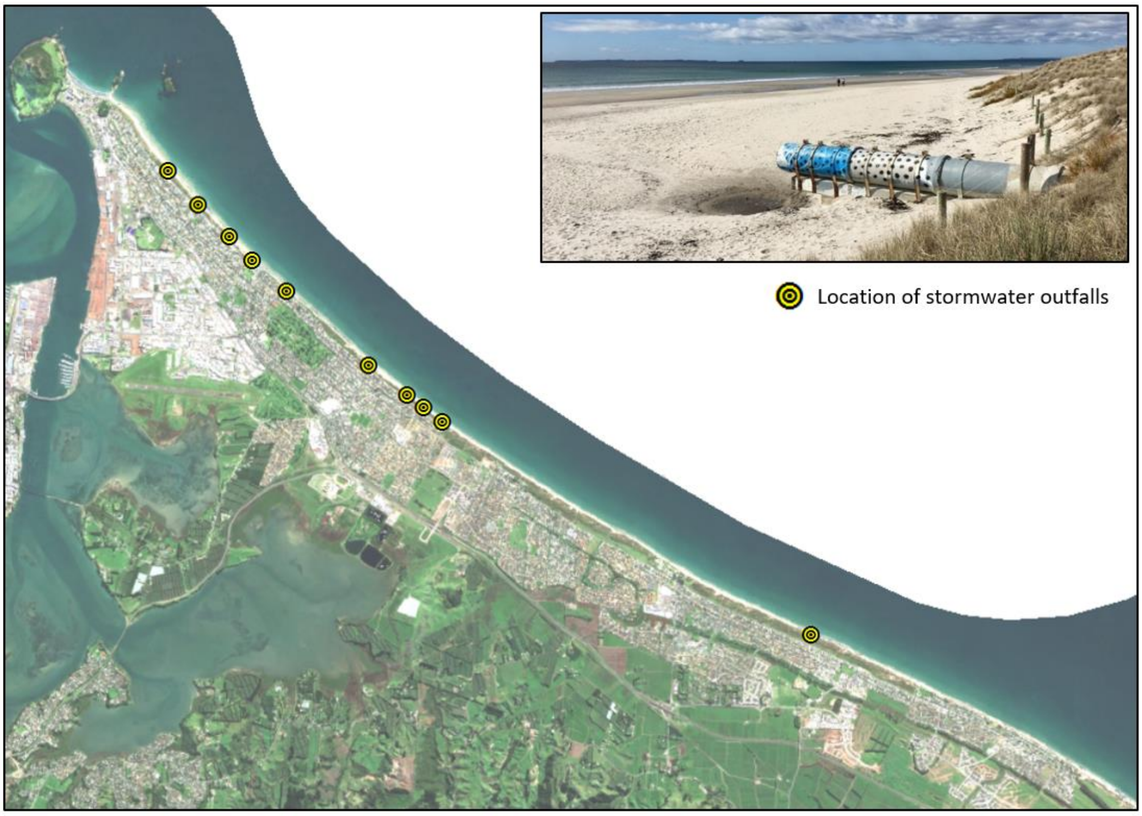


Figure 2.11: Locations and an example of stormwater outfalls along the Mount Maunganui to Papamoa shoreline

2.8.8 Dune planting

Large and small scale dune planting has occurred many sections of the Mount Maunganui shoreline (Figure 2.12). The planting of native dune plants has helped with binding the sand and stabilizing the dunes which in some places has resulted in accretion of the dune.

Figure 2.12: Example of native dune planting along the Mount Maunganui to Papamoa shoreline

The Coast Care programme has had several successful dune plantings along the Mount Maunganui to Papamoa shoreline including Kawera Parade, Motiti Road, Papamoa Domain, Papamoa Surf Club and Yale Street. Figure 2.13 shows an example of how dune planting near Kawera Parade increased the dune by up to 10 m.

Figure 2.13: Example of successful dune planting completed near Kawera Parade (Source: Coast Care BOP)

3 Data sources

3.1 Previous studies

Several erosion hazard studies have been completed for the Mount Maunganui to Papamoa shoreline, including Healy et al. (1977), Gibb (1994), Gibb (1996) and T+T (2009).

The Healy et al. (1977) study was the first study and included a coastal erosion survey for the entire Bay of Plenty Coastal coastline. The study was completed following a severe erosion episode during 1976 which was apparent along many of the Bay of Plenty beaches. One of the major areas identified as undergoing consistent erosion was Mount Maunganui. Healy et al. (1977) concluded three key factors contributing to the erosion:

1. Intensive coastal subdivision and intense population pressure degrading the dune instability
2. Location of the shoreline downdrift from the Tauranga Harbour entrance which acts as a major interruption to the littoral drift system
3. Extensive sand extraction from the foreshore exceeding the natural replenishment rate from littoral drift.

Following the Healy et al. (1977) study beach profile monitoring was established in select locations along the Mount Maunganui to Papamoa shoreline.

Foster (1991) also identified erosion along the Mount Maunganui shoreline between 1943 and 1977 but also notes that the shoreline tended to stabilise after the 1970's. The stabilisation and subsequent accretion of the Mount Maunganui shoreline is possibly linked in part with the shoreward migration of dumped dredge spoil.

Gibb (1994) identified Areas Sensitive to Coastal Hazards (ASCH). The ASCH line was intended as a screening tool to identify areas where further coastal hazard analysis would be required. The ASCH setback ranged from 150 m along Mount Maunganui to 170 m along Papamoa.

In 1996 the "Dune Watch" project was completed which involved the assessment of Coastal Hazard Zones (CHZ) for three developed areas between Mauoa and Papamoa (Gibb, 1996). The three areas included:

1. Mauao to 273 Papamoa Beach Road
2. Domain Road area between 500 and 560 Papamoa Beach Road
3. Papamoa Township area between 1009 and 1340 Papamoa Beach Road.

The study found that in the vicinity of Papamoa the shoreline trends over the last 79 years have ranged from dynamic equilibrium in the southeast to slow erosion along south-eastern Kawera Parade to accretion along north-eastern Kawera Parade, Motiti and Taylor Road. The shoreline between Te Ara Place and Mauao has generally advanced while there had been dynamic equilibrium between Tay and Clyde Street and a trend of erosion near Surf Road and the centre of Main Mount Beach. Four Coastal Erosion Hazard Zones (CEHZ) were defined, comprising an Extreme Risk Erosion Zone, High Risk Erosion Zone, Moderate Risk Erosion Zone and a Safety Buffer Zone.

In 2009 T+T completed an updated coastal erosion hazard assessment. The assessment was an update and review of Gibb (1996) using best available data and guidance at the time. In general the assessment found most of the shoreline to have a long term accretion trend, consequently long term rates were set to zero for the assessment. Three refined Coastal Erosion Risk Zones were defined and these included the Current Erosion Risk Zone, the 2060 Erosion Risk Zone and the 2110 Erosion Risk Zone.

3.2 Site inspections

A site inspection was completed on 28 August 2019 by a T+T coastal scientist and coastal engineer. During the inspection coastal cell boundaries were defined and site photos were taken (Figure 3.1). An aerial survey along the Bay of Plenty shoreline was undertaken in November 2019. The purpose of this survey was to obtain high resolution oblique photographs of the shoreline. Aerial photographs of the Mount Maunganui to Papamoa shoreline are provided in Appendix A.

Figure 3.1: Site photos along the Mount Maunganui to Papamoa shoreline. (A) Motiti Road, Papamoa East (B) Back dune system near Papamoa Pony Club, (C) Vegetated dune at Wairiki Street, (D) Dune and stormwater outfall near Omanu Surf Club, (E) Low accreting dunes along Marine Parade near Sutherland Ave, (F) Mount Main Beach

3.3 Profile data

Bay of Plenty Regional Council (BoPRC) and TCC have collected beach profile data for a total of 24 locations along the Mount Maunganui to Papamoa shoreline (Figure 3.2). The earliest of these surveys was completed in 1977. All profiles are surveyed on an annual basis with some sites monitored quarterly and additional surveys as necessary (i.e. following significant storm events). Since the 2009 assessment there has been an additional ten years of beach profile data collected and six additional profile locations added. An outline of the latest available beach profile data is provided in Table 3.1. All beach profile plots are included in Appendix B.

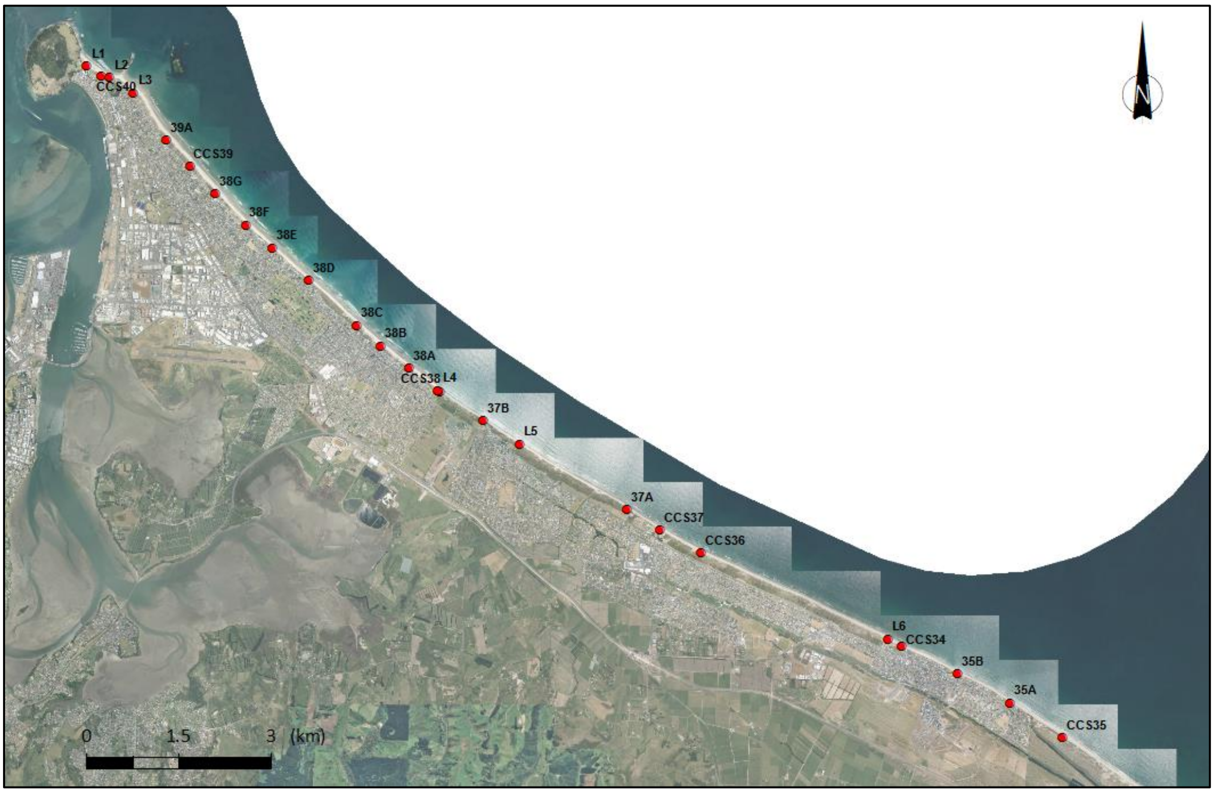


Figure 3.2: Beach profile locations along the Mount Maunganui to Papamoa shoreline

Table 3.1: Summary of available beach profile data for the Mount Maunganui to Papamoa shoreline

Profile	Start date	End date	Length (years)	No. surveys
CCS34	5/02/1978	5/02/2019	41.0	103
CCS35	20/10/1999	1/04/2019	19.5	81
CCS36	2/02/1977	5/02/2019	42.0	106
CCS37	10/12/1996	5/02/2019	22.2	78
CCS38	5/02/1978	5/02/2019	41.0	127
CCS39	2/06/1978	5/02/2019	40.7	121
CCS40	6/02/1978	5/02/2019	41.0	120
39a	20/10/1999	1/04/2019	19.5	76
35a	20/10/1999	1/04/2019	19.5	78
35b	20/10/1999	1/04/2019	19.5	76

Profile	Start date	End date	Length (years)	No. surveys
37a	20/10/1999	1/04/2019	19.5	76
37b	20/10/1999	1/04/2019	19.5	76
38a	20/10/1999	1/04/2019	19.5	76
38b	20/10/1999	1/04/2019	19.5	77
38c	20/10/1999	1/04/2019	19.5	77
38d	20/10/1999	1/04/2019	19.5	76
38e	20/10/1999	1/04/2019	19.5	75
38f	20/10/1999	1/04/2019	19.5	78
38g	20/10/1999	1/04/2019	19.5	78
L1	14/01/2016	4/04/2019	3.3	13
L2	14/01/2016	4/04/2019	3.3	14
L3	14/01/2016	4/04/2019	3.3	14
L4	14/01/2016	4/04/2019	3.3	14
L5	14/01/2016	4/04/2019	3.3	14
L6	14/01/2016	4/04/2019	3.3	14

3.4 Aerial photographs

Historic shoreline data was processed from aerial images using standard geo-referencing and digitising GIS methods using ArcGIS and Global Mapper software. Available aerial photographs were sourced from BoPRC, TCC and Retrolens. A summary of aerial photographs sourced for this study is provided in Table 3.2.

The seaward edge of the dune vegetation was digitised to represent the dune toe, which was taken as the shoreline proxy.

There are three main sources of potential error when estimating the shoreline position:

1 Geo-referencing error (Er)
2 Shoreline proxy error (Es)
3 Digitising error (Ed).

The geo-referencing error is the potential offset of an image from a known point based on ground control points collected during the geo-referencing process. This potential error does not apply to GPS data and increases with the age of the photograph due to scale and lower number of suitable ground control points.

The shoreline proxy is the estimated uncertainty in identifying the shoreline, which is more apparent for black and white images. Example of features that cause shoreline proxy error include scale, shadow, overhanging trees and the uncertainty in identifying the correct dune vegetation edge based on black and white contrast.

The digitising error is the potential operator inconsistency in digitising a shoreline using ArcGIS software. For example, if the operator was to digitise the same shoreline on two separate occasions there is likely to be an offset between the two lines, which is the digitising error. The digitising error does not apply for the GPS data and remains constant for all historic shorelines based on aerial photographs.

The resultant potential error in shoreline position can be calculated using a sum of independent errors approach whereby:

$$E_{sum} = \sqrt{E_r^2 + E_s^2 + E_d^2} \quad (3\text{-}1)$$

Based on the resolution of the aerial photographs the overall error associated with the shoreline position the total error has been estimated, which tends to be greatest for the oldest aerial photographs.

Table 3.2: Summary of historic aerial photographs sourced for long-term trend analysis

Year	Source	Error +/- (m)	Comment
1943	Retrolens	10	Not included in LT analysis due to georeferencing inaccuracy around Papamoa
1959	Retrolens	10	Not included in LT analysis due to georeferencing inaccuracy around Papamoa
1977	TCC Mapi	5	
2011	BOPRC GIS server	2	
2019	BOPRC GIS server	2	

3.5 Topography and bathymetry

Topography has been assessed using LiDAR (Light Detection and Ranging) data captured in 2018-2019. The LiDAR was sourced from TCC as a 1 m by 1 m Digital Elevation Model (DEM) (Figure 3.3). Modern LiDAR in developed areas generally achieves an accuracy greater than +/- 100 mm. The DEM was used for determining both the location and elevation of the dune toe along the Mount Maunganui to Papamoa shoreline.

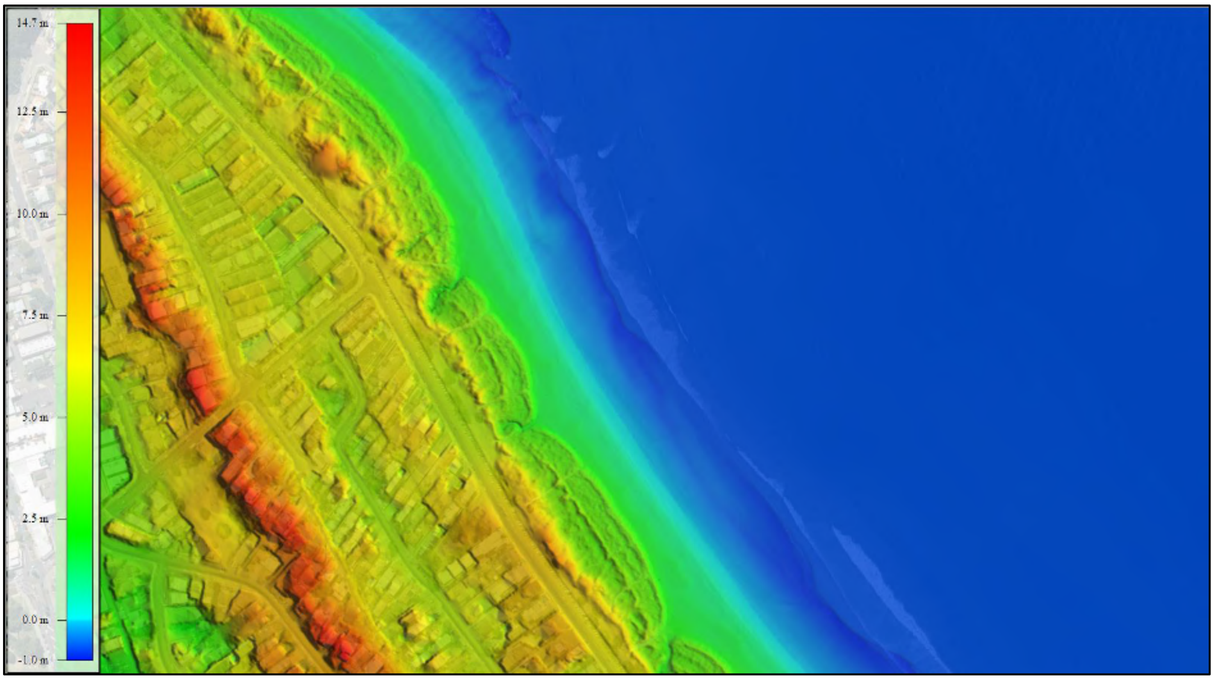


Figure 3.3: Example of 2018-2019 DEM available for Mount Maunganui to Papamoa shoreline

4 Methodology

4.1 Statutory considerations

4.1.1 New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement (NZCPS) is a national policy statement under the Resource Management Act 1991. The NZCPS states policies in order to achieve the purpose of the Act in relation to the coastal environments of New Zealand. Regional policy statements and plans must give effect to (be consistent with) the NZCPS.

A number of the Objectives and Policies of the NZCPS are directly relevant to the assessment of coastal erosion hazard. Relevant policies include:

- Policy 3 - requires a precautionary approach in the use and management of coastal resources potentially vulnerable to effects from climate change so that avoidable social and economic loss and harm to communities does not occur.
- Policy 24 - requires identification of areas in the coastal environment that are potentially affected by coastal hazards (including Tsunami) giving priority to the identification of areas at high risk of being affected. Hazard risks, over at least 100 years, should be assessed having regard to:
  - physical drivers and processes that cause coastal change including sea level rise
  - short term and long term natural dynamic fluctuations of erosion and accretion
  - geomorphological character
  - cumulative effects of sea level rise, storm surge and wave height under storm conditions
  - anthropogenic influences
  - extent and permanence of built development
  - effects of climate change on the above matters, on storm frequency and intensity and on natural sediment dynamics.

  These should take into account national guidance and the best available information on the likely effects of climate change for each region.
- Policy 25 - promotes avoiding increasing the risk of social, environmental and economic to erosion hazard in areas potentially affected by coastal hazards over at least the next 100 years.
- Policy 27 - promotes reducing hazard risk in areas of significant existing development likely to be affected by coastal hazards.

4.1.2 Regional Policy Statement

The Bay of Plenty Regional Policy Statement (RPS) outlines the Natural Hazard Policies for the region. The following Policy is relevant to this assessment:

- Policy NH 7A – Identify areas susceptible to natural hazards. Map hazard susceptibility area (HAS) for the following natural hazards:

a Coastal and marine processes

i) Coastal erosion

- Policy NH 11B – Incorporate the effects of climate change in natural hazard risk assessment and use the following projections as minimum values when undertaking coastal hazard assessments:

a A 100 year timeframe;

b A projection of a base sea level rise of at least 0.6 m (above the 1980-1999 average) for activities/developments which are relocatable;

c A projection of a base sea level rise of 0.9 m (above 1980-1999 average) for activities where future adaptation options are limited, such as regionally significant infrastructure and developments which cannot be relocated

d An additional sea level rise of 10 mm/annum for activities with life spans beyond 2112.

4.1.3 Proposed Regional Coastal Environment Plan

The Bay of Plenty Regional Proposed Coastal Environment Plan (PRCEP) was publicly notified on 24 July 2014. The PRCEP manages the natural and physical resources of the Bay of Plenty coastal environment. This is a review of the operative Bay of Plenty Regional Coastal Environment Plan.

Chapter 5 of the PRCEP covers coastal hazards and section 5.1.3 specifically details the following policies on coastal hazard for sandy coasts and river mouth shorelines.

- Policy CH 11 – Identify and map erosion and inundation zones over a 100 year timeframe in high priority areas
- Policy CH 12 – apply an appropriate method to identify the erosion extent taking into account best practice guidelines, scientific guidance and relevant components including shoreline response to sea level rise.

This study maps erosion in accordance with the RRCEP policy above and also the RPS requirements for hazard susceptibility areas.

4.2 Risk-based approach

A risk-based approach to managing coastal hazard is advocated by the NZCPS and endorsed by BOPRC's RPS, with both the likelihood and consequence of hazard occurrence requiring consideration. For example, the NZCPS suggests consideration of areas both 'likely' to be affected by hazard and areas 'potentially' affected by hazard. The term likely may be related to a likelihood over a defined timeframe based on guidance provided by MfE (2017). This assessment aims to derive a range of hazard zones corresponding to differing likelihoods which may be applied to a risk assessment.

4.3 Stochastic forecast approach

This study combines standard and well-tested approaches for defining coastal erosion hazard zones by addition of component parameters (Gibb, 1978; T+T, 2004; 2006; 2012) over a selected timeframe. However, in this report, rather than including single values for each component and a factor for uncertainty, parameter bounds are specified for each parameter and combined by stochastic simulation. The resulting distribution is a probabilistic forecast of potential hazard zone width over a selected timeframe.

The method is based on the premise that uncertainty is inherent in individual components due to an imprecise understanding of the natural processes and due to alongshore variability within individual study cells. Stochastic simulation allows the effect of these uncertainties to be explored simultaneously providing estimates of the combined hazard extent (i.e. the central tendency) and information on potential ranges and upper limit values. This contrasts with deterministic models where the combination of individual conservative parameters with additional factors for uncertainty often result in very conservative products and limited understanding of potential uncertainty range.

The stochastic method is described in Cowell et al. (2006). The methods used to define probability distribution functions (pdfs) for each parameter are described within the parameter descriptions below. Where pdfs are not defined empirically (i.e. based on data or model results), simple triangular distributions have been assumed with bounding (minimum and maximum) and modal parameters. These triangular distributions can be constructed with very little information yet approximate a normal distribution and permit flexibility in defining range and skewed asymmetry.

4.4 Coastal erosion methodology

4.4.1 Unconsolidated beaches

Coastal erosion hazard methodologies are different for unconsolidated beaches, cliffs, estuarine and river inlet shorelines. The Mount Maunganui to Papamoa shoreline can be characterised as an unconsolidated beach. The method for unconsolidated beach shorelines is expressed in Equation 4-1, where the coastal erosion hazard area (CEHA) is established from cumulative effect of five main parameters (Figure 4.1):

$$CEHA_{Beach} = ST + DS + (LT \; x \; T) + SLR \qquad (4\text{-}1)$$

Where:

ST	=	Short-term changes in horizontal shoreline position related to storm erosion due to singular or a cluster of storm events or fluctuations in sediment supply and demand, beach rotation and cyclical changes in wave climate (m)
DS	=	Dune stability allowance. This is the horizontal distance from the base of the eroded dune to the dune crest at a stable angle of repose (m)
LT	=	Long term rate of horizontal coastline movement (m/yr)
T	=	Timeframe (yr)
SLR	=	Horizontal coastline retreat due to the effects of increased mean sea level (m).

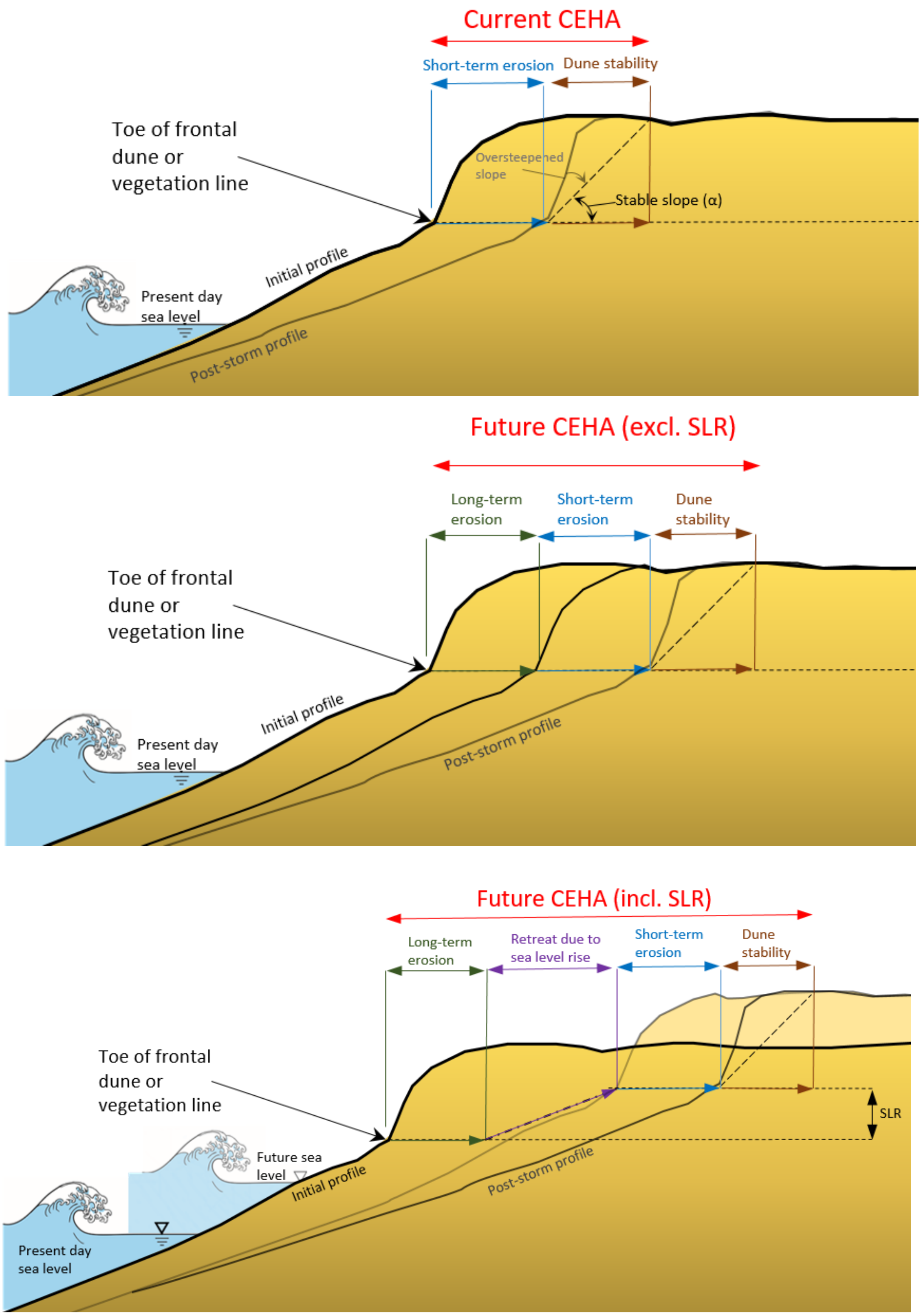


Figure 4.1: Definition sketch for coastal erosion hazard area on open coast beach shoreline

5 Component derivation

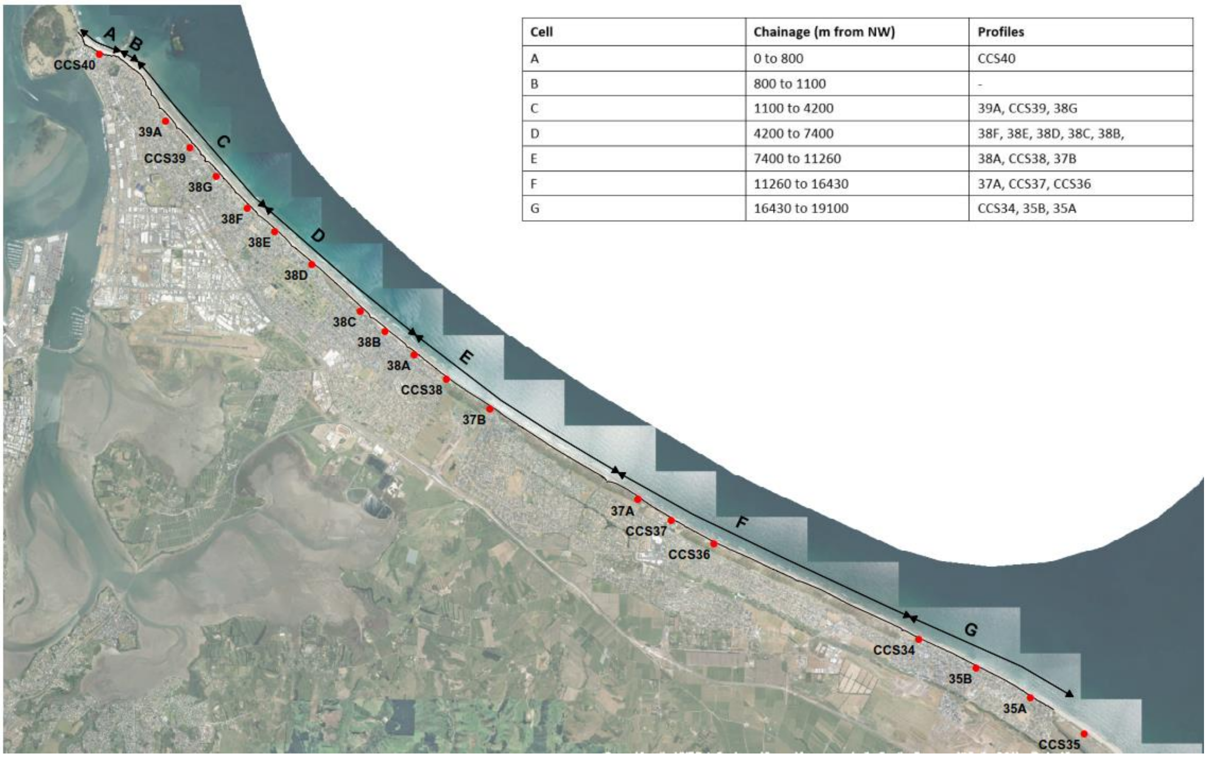
5.1 Baseline

The baseline is used to offset the coastal erosion hazard area. For this assessment the baseline is equivalent to the dune toe and has been identified using a combination of the most recent aerial photograph and LiDAR data (2019).

5.2 Coastal cells

The Mount Maunganui to Papamoa shoreline has been divided into seven coastal cells based on shoreline behaviour which can influence the resultant hazard (Figure 5.1). Factors which may influence the behaviour of a cell include:

- Historic shoreline trends
- Cell morphology and lithology
- Profile geometry
- Backshore elevation.



Cell	Chainage (m from NW)	Profiles
A	0 to 800	CCS40
B	800 to 1100	-
C	1100 to 4200	39A, CCS39, 38G
D	4200 to 7400	38F, 38E, 38D, 38C, 38B,
E	7400 to 11260	38A, CCS38, 37B
F	11260 to 16430	37A, CCS37, CCS36
G	16430 to 19100	CCS34, 35B, 35A

Figure 5.1: Cell splits along the Mount Maunganui to Papamoa shoreline

5.3 Assessment timeframe (T)

Three different planning timeframes have been applied to provide information on current hazards and information at sufficient time scales for planning and accommodating future development (Table 5.1). These timeframes have been selected to ensure the results are relevant until a future update is carried out in up to 10 years' time, and to ensure that results are relevant for at least the next 100 years in alignment with NZCPS (2010).

Table 5.1: Planning timeframes and equivalent Coastal Erosion Hazard Area scenarios used within the assessment

Planning timeframe (year)	Timeframe scenario
Current (applicable to 2030)	Current CEHA
50 years (2080)	2080 CEHA
100 years (2130)	2130 CEHA

5.4 Short-term storm cut (ST)

Shorelines undergo short-term cycles of storm-induced erosion (i.e. storm cut) followed by periods of re-building. Where a coast experiences shoreline erosion (i.e. landward movements) due to single or clusters of storms, the short-term erosional component of the cycle needs to be accounted for in any coastal hazard assessment. The post-storm recovery, or accretional part of such cycles, does not need to be accounted for in this short-term (storm cut) component. This is because short-term accretion is not a local coastal hazard. Long-term trends in accretion should already be accounted for in the long-term shoreline trend component (refer to Section 5.6).

The short-term shoreline movements can be assessed from analysis of:

- Existing information sources such as previous reports and anecdotal evidence
- Statistical analysis of shoreline position obtained from beach profile analysis
- Numerical assessment of storm erosion potential using semi-process based methods.

Both numerical modelling and statistical methods were used to assess the short-term storm cut potential along the Mount Maunganui to Papamoa shoreline. However, in this instance the numerical model assessment was found to underestimate the storm cut compared to measured data and therefore was not used for this study (refer to Appendix C for numerical model assessment). The adopted short-term component has been derived based on statistical analysis of the measured profile data.

5.4.1 Statistical method

The horizontal movement of the shoreline (i.e. dune toe) based on the Mount Maunganui to Papamoa beach profiles was used to assess the short-term storm cut using inter-survey erosion distances. The inter-survey erosion distance is the landward horizontal retreat distance measured between two consecutive surveys (i.e. distance between excursion distances). Figure 5.2 shows an example of the measured excursion distances over time for profile CCS34. In some cases where there are relatively long periods between surveys, the dataset may not represent the largest excursion that may have occurred between the surveys and on the other hand the distances could be a result of multiple storms that occurred within the survey period. However, the data set provides the best source of information to analyse. We note that historically BOPRC have collected post storm surveys and therefore the existing dataset is likely to include some of the largest excursion distances.

It can be seen from Figure 5.2 that while the beach has been relatively stable with slight accretion, the shoreline fluctuates over time.

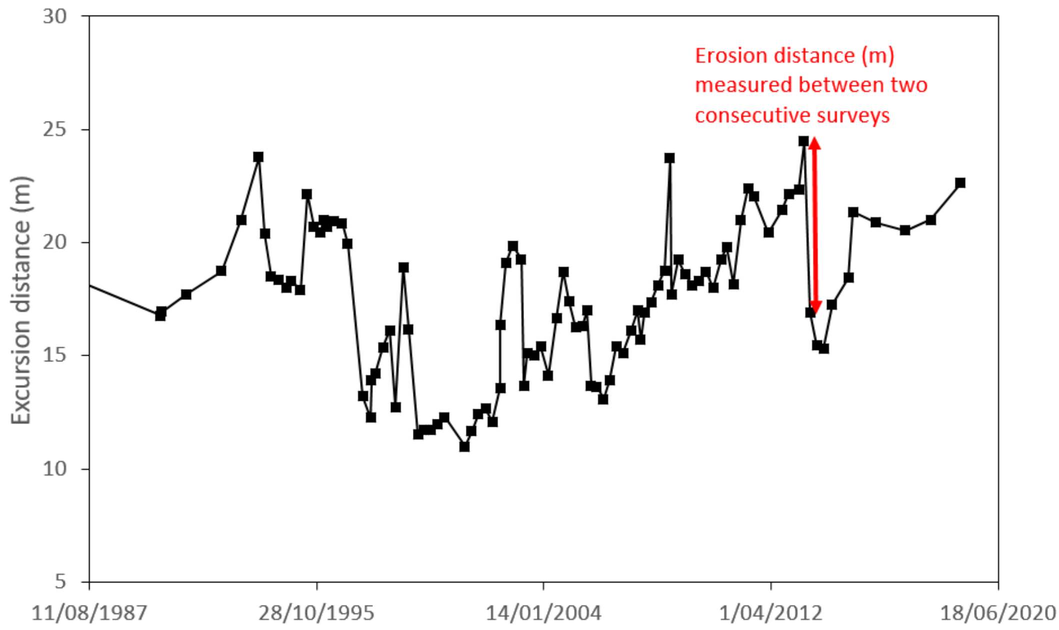


Figure 5.2: Example of excursion distance of dune toe (3 m RL) over time at profile CCS34

Figure 5.3 shows some examples of the storm cut that occurred near Papamoa East over the 1998 to 1999 period. In this case the frequency of profile data does not capture the exact storm cut from the individual storm events, but it does show that if several storm events occur over a short timeframe it can have a cumulative effect on the total storm cut. For example, 8 m of retreat at the dune toe (3 m RL) was measured between December 1998 and June 1999 at profile CCS34 which is near Motiti Reserve.

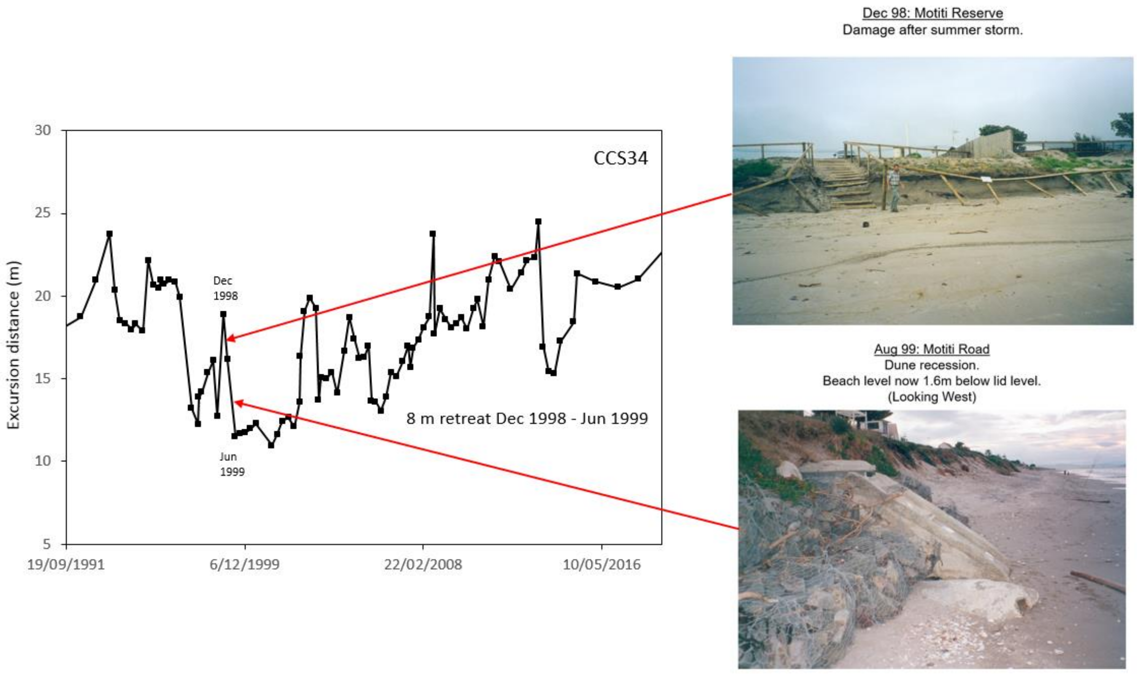


Figure 5.3: Example of storm cut measured near Motiti Road during 1998 and 1999 storm events (Photos sourced from Greg Jenks)

In order to estimate the short-term erosion distances for larger return periods, which may not been captured within the profile dataset, extreme value analyses were undertaken for each profile location separately by including all the inter-survey erosion distances. Analyses were undertaken using the methods described in Mariani et al. (2012) using toolboxes provided in WAFO (2012). The extreme value curve using the Weibull method was found to reasonably fit the observed datasets and was therefore adopted. Figure 5.4 presents an example of the extreme value curve for profile CCS34.

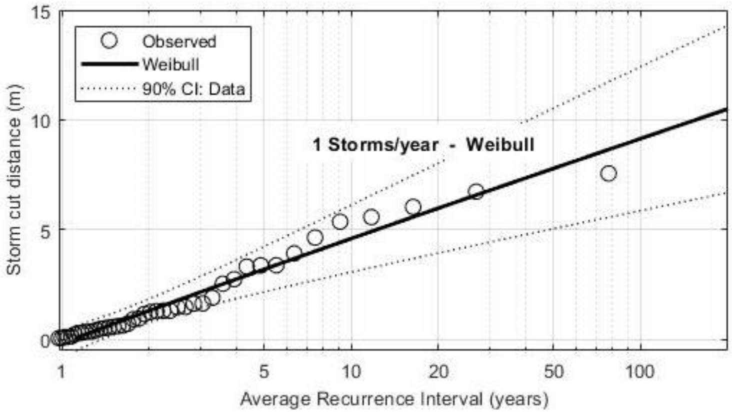


Figure 5.4: Example of extreme value analysis curve based on the inter-survey distances from profile CCS34

The short-term storm cut distribution for each coastal cell is based on the erosion distances and related return periods derived from the extreme value curves for each profile. The short-term timeframe for this assessment is taken to be 10 years. Therefore the short-term erosion distances and corresponding Annual Recurrence Intervals (ARIs) have been related to percentages of likelihood and probabilities of exceedance within a 10-year timeframe (Table 5.2).

The extreme value analysis of profile data shows slight variations between profiles, however in general the magnitude of storm cut potential is relatively consistent along the Mount Maunganui to Papamoa shoreline. A 5 year ARI event ranges from 2 to 4 m storm cut whereas a 100 year ARI event ranges from 5 to 14 m storm cut (Table 5.2).

Table 5.2: Potential storm cut distances (m) and likelihood percentages for Annual Recurrence Interval (ARI) events over a 10-year timeframe

ARI	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**200**
Probability of event occurrence within 10 years	**100%**	**99%**	**86%**	**63%**	**39%**	**18%**	**10%**	**5%**
CCS40	1	2	3	4	5	6	7	8
39a	0	1	2	3	4	4	5	5
CCS39	0	1	3	4	5	7	9	10
38g	0	2	4	6	8	10	13	15
38f	0	1	3	3	4	5	6	7
38e	0	2	4	5	7	10	12	14
38d	1	1	2	2	3	4	4	5
38c	0	1	3	4	5	7	9	10
38b	1	2	4	5	6	8	10	11

ARI	1	2	5	10	20	50	100	200
Probability of event occurrence within 10 years	**100%**	**99%**	**86%**	**63%**	**39%**	**18%**	**10%**	**5%**
38a	1	2	3	4	4	5	6	6
CCS38	0	1	3	4	6	7	9	11
37b	0	2	4	6	8	11	14	16
37a	0	1	3	4	6	8	10	11
CCS37	1	2	3	4	5	6	8	9
CCS36	0	1	2	3	4	5	6	7
CCS34	0	1	3	5	6	8	9	10
35b	1	2	3	4	5	7	8	9
35a	1	2	4	5	7	9	10	11

Based on the distribution of storm cut values from the extreme value analysis of each beach profile the adopted short-term component values for the coastal cells is are defined as in Table 5.3. The adopted values have been based on the largest profile distribution within each cell. The lower, mode and upper bounds are assumed to equate to 5 year, 50 year and 200 year ARI events (86%, 18% and 5% likelihood of occurring over 10 years). CCS40 which is the only representative profile for cell A (Mount Main), shows a slightly lower storm cut distribution compared to the rest of the shoreline.

Table 5.3: Adopted short-term storm cut values

Cells	Lower (m)	Mode (m)	Upper (m)
A	3	6	8
B - G	4	10	15

5.5 Dune stability (DS)

The dune stability factor delineates the area potentially susceptible to erosion landward of the erosion scarp. The parameter assumes that storm erosion results in an over-steepened scarp which must adjust to a stable angle of repose for loose sand. The dune stability width is dependent on the height of the existing dune and the angle of repose for loose sand. The dune stability factor is outlined in Equation 5-1.

$$DS = \frac{H}{2(\tan \alpha_{sand})} \tag{5-1}$$

Where H is the dune height from the eroded base to the crest and α_{sand} is the stable angle of repose for beach sand (ranging from 30 to 34 degrees). In reality, the formation of a talus slope at the toe will allow the scarp to stand at steeper slopes (unless subsequently removed), hence the dune height is divided by 2. Dune heights were obtained from LiDAR and checked against beach profile data. Dune crest elevations were extracted at 100 m intervals along. The average dune toe elevation (3 m RL) was subtracted from the dune crest elevations, resulting in the dune height. In some locations the existing dune system comprises a low seaward dune with higher landward dunes. If the higher dune is less than 15 m from the existing dune toe (i.e. upper limit for short-term storm cut potential), then the higher dune crest height has been adopted. Parameter bounds for the dune stability factor are defined based on the variation in dune height along the coastal cell and potential range in stable angle of repose (Table 5.4 and Table 5.5). Figure 5.5 shows the average beach profiles for each coastal cell.

Table 5.4: Adopted dune stability values

Cells	Lower (degrees)	Mode (degrees)	Upper (degrees)
A - G	30	32	34

Table 5.5: Adopted dune height values (m above dune toe, 3 m RL)

Cell	Lower (m)	Mode (m)	Upper (m)
A	1.5	2	2.5
B	3	4	5
C	1.5	3	5
D	3.5	4	7
E	3.5	4	5
F	4	5	7
G	2.5	3.5	5

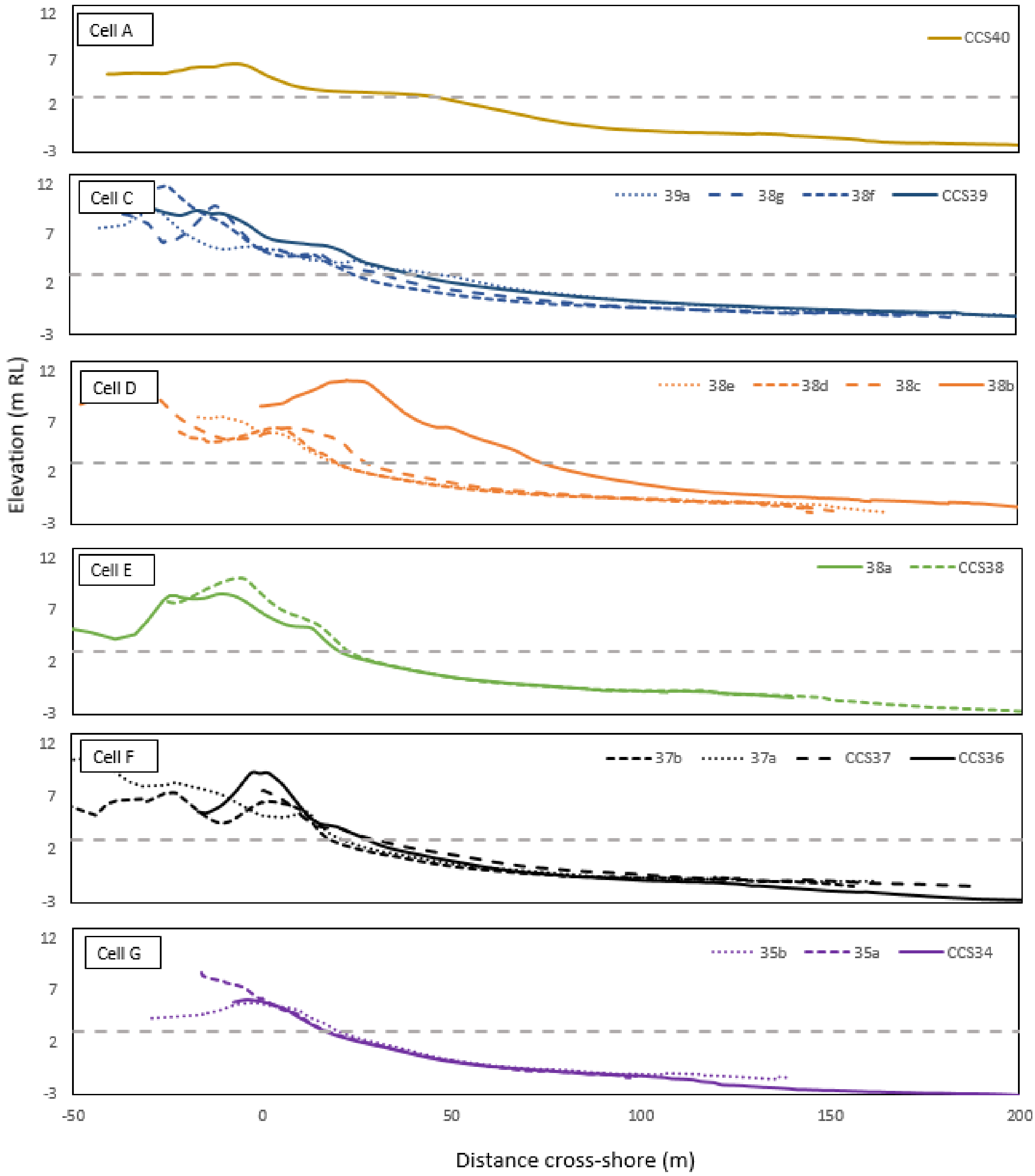


Figure 5.5: Average beach profiles for each coastal cell. Note, there are no beach profiles within cell B

5.6 Long-term trends (LT)

The long-term rate of horizontal coastline movement includes both ongoing trends and long-term cyclical fluctuations. These may be due to changes in sea level, fluctuations in coastal sediment supply or associated with long-term climatic cycles such as IPO.

Both beach profile data and historic shorelines have been used to assess the long-term trends along the Mount Maunganui to Papamoa shoreline. Linear regression analysis has been completed for both datasets and comparisons have been made to infer the long-term rates for each coastal cell.

5.6.1 Beach profiles

Linear regression analysis was completed for the horizontal excursion distances of the dune toe (3 m RL contour) at each beach profile. The average regression rates and 95% confidence intervals for the excursion distances measured at each beach profile are summarised in Table 5.6. Regression plots for each profile are provided in Appendix B. Note, the six most recently added profiles (L1 to L6) were excluded from the long-term analysis due to the short data record (3 years).

Overall, most of the beach profiles show long-term accretion of the dune toe. The highest rate of accretion has been measured at profile 39a which has been accreting on average at 1.98 m/yr since monitoring began in 1999. Profiles CCS39 to 38d also show accretion, although the rate of accretion decreases with distance eastward. The profiles west from Yale St to Coast Boulevard (38a, CCS38 and C7b) indicate an area of long-term erosion. The highest erosion rate has been measured at CCS38 which has been eroding on average at -0.35 m/yr since monitoring began in 1978. The Papamoa beach profiles (37a to 35a) all show slight accretion, except at 35a where there is minor erosion (on average -0.07 m/yr) Table 5.7.

The length of beach profile records varies from 20 years to 42 years. The longer BOPRC profile datasets have been plotted in Figure 5.6 to give an overview of the long-term patterns along the shoreline. CCS40 is representative of Mount Main and shows stability of the dune toe up until the early-1990s. Since 1992 the profile has shown overall accretion at the dune toe.

CCS39 is representative of the shoreline along Marine Parade. The profile shows accretion followed by relative stability from 1977 to 1995, followed by a period of erosion lasting until 1999. Since 1999 the profile has shown significant accretion (Figure 5.6).

CCS38 is located near the centre of the Mount Maunganui to Papamoa shoreline. The profile shows relative stability in the dune toe position up until 2003, however from 2003 to 2011 there was a period of erosion. Since 2011 the dune toe appears to be accreting (Figure 5.6).

Data records for CCS37 only exist from 1996 onwards. Over the last 23 years the profile has shown long-term accretion. CCS36 is the longest profile record, starting in 1977. The profile shows a period of erosion during the late 1970’s which is possibly linked to the sand extraction that occurred between 1965 and 1975 (see Section 2.8.2). Since 1980 the profile has shown a trend of accretion.

CCS34 is located at Papamoa East, near Taylor’s Reserve. The profile shows a similar pattern to CCS36 with erosion during the late 1970’s. There appears to have been a period of erosion from 1995 to 1999 which was also evident at CCS39. Since 1999 the profile has shown a slight accretional trend (Figure 5.6).

Table 5.6: Long-term trends calculated for the dune toe (3 m RL) at each beach profile along the Mount Maunganui shoreline

Profile	Time period	Regression rate (m/yr)	Upper 95% confidence interval (m/yr)	Lower 95% confidence interval (m/yr)
CCS40[1]	1978 - 2019	0.37	0.4	0.30
39a	1999 - 2019	1.98	2.05	1.94
CCS39	1978 - 2019	0.50	0.59	0.41
38g	1999 – 2019	1.26	1.33	1.19
38f	1999 – 2019	0.51	0.55	0.46
38e	1999 – 2019	0.32	0.40	0.23
38d	1999 – 2019	0.01	0.10	-0.09

Profile	Time period	Regression rate (m/yr)	Upper 95% confidence interval (m/yr)	Lower 95% confidence interval (m/yr)
38c	1999 – 2019	0.14	0.20	0.09
38b	1999 – 2019	0.22	0.28	0.15
38a	1999 – 2019	-0.19	-0.12	-0.27
CCS38	1978 – 2019	-0.35	-0.29	-0.41
37b	1999 – 2019	-0.05	0.03	-0.14
37a	1999 – 2019	0.09	0.16	0.01
CCS37	1996 – 2019	0.40	0.45	0.28
CCS36	1977 – 2019	0.36	0.40	0.32
CCS34	1978 – 2019	0.14	0.20	0.08
35b	1999 – 2019	0.27	0.35	0.20
35a	1999 – 2019	-0.07	0.02	-0.16

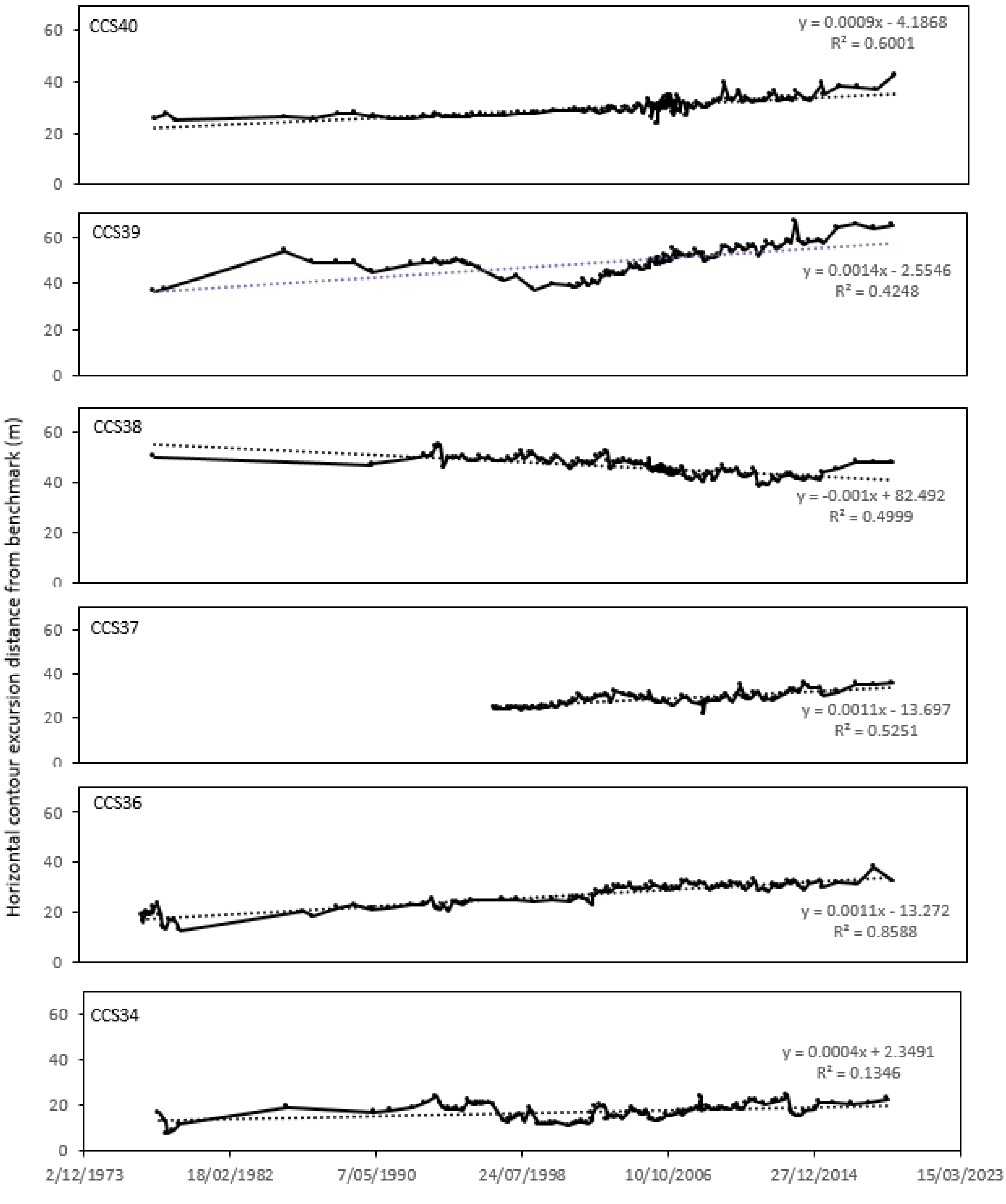


Figure 5.6: Long term movement of dune toe (3 m RL, except for CCS40 where 4 m RL used) for BOPRC profiles along the Mount Maunganui to Papamoa shoreline

5.6.2 Historic aerials

Shoreline data has been derived from geo-referenced historic aerial photographs (see Section 3.4). Software developed by T+T has been used to measure the distance to each shoreline from an assumed baseline at 50 m increments. A weighted linear regression analysis has then been undertaken on each set of the shoreline measurements to estimate long-term rates between 1977 and 2019. In weighted linear regression, more reliable data (lower error values) are given greater emphasis or weight towards determining a best-fit line.

The historic shorelines were assessed to give an indication of the alongshore variation which is not captured by the profile data due to profiles only occurring at discrete locations along the shoreline. However, due to the higher frequency of data from beach profiles there is increased certainty around the results, and therefore we have based the long-term trends on the profile regression analysis and used the historic shorelines to validate the calculated rates. The average long-term rates measured from the beach profiles have also been plotted for comparison with the long-term historic shoreline trends (Figure 5.7). Smaller scale maps of the historic shorelines are provided in Appendix A.

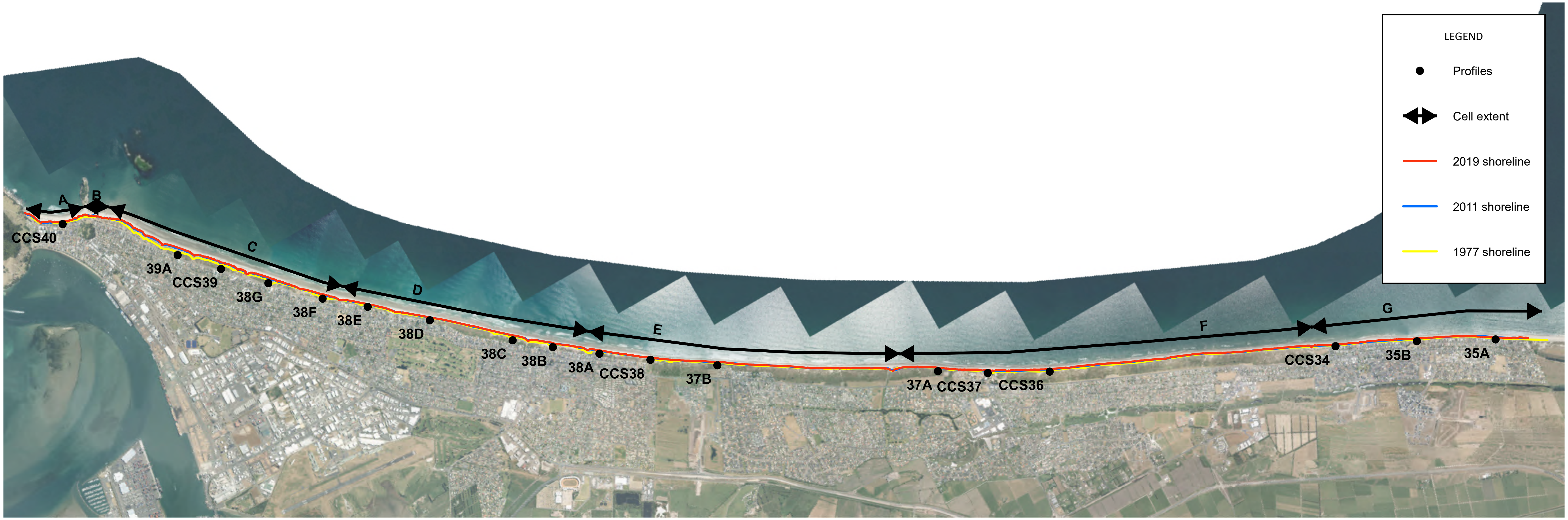
Overall the long-term rates calculated from beach profile data shows good comparison with the historic shorelines. The high accretion rate measured at 39a is larger than the rate measured from the shorelines. This is likely due to the 39a data record only starting in 1999 from which there has been a period of significant accretion.

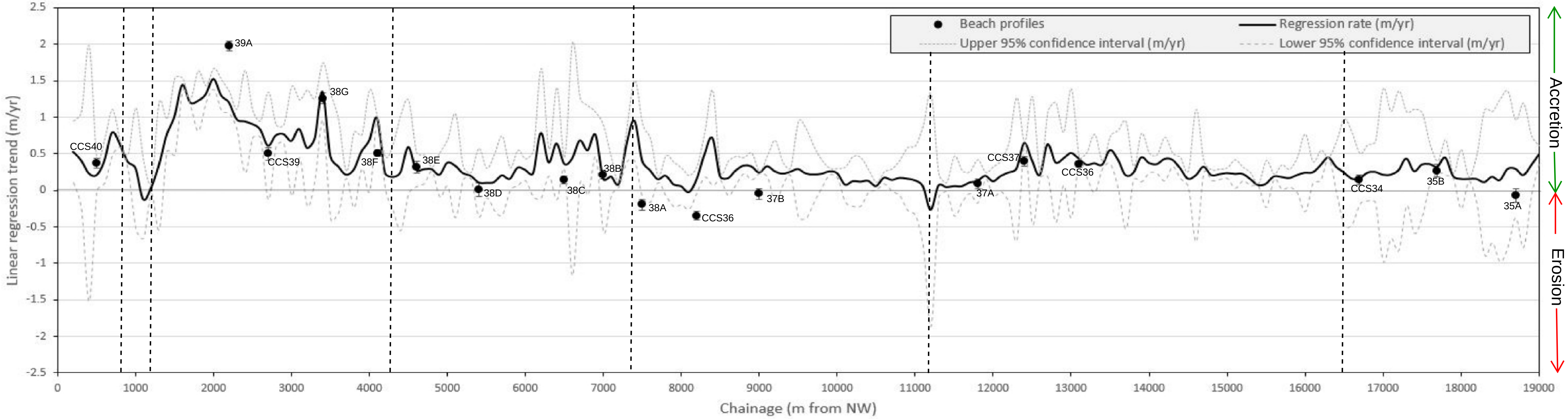
The shorelines indicate accretion rates reduce with distance eastward which is consistent with the beach profile trends. The erosion at CCS38 is also evident in the shoreline data although the magnitude of erosion measured from the shoreline data is slightly less (Figure 5.7).

Based on the regression rates measured from the beach profile data and the historic shorelines long-term rates have been adopted for each coastal cell (Table 5.7).

Table 5.7: Adopted long-term rates (m/yr)

Cell	Upper	Mode	Lower
A	0.00	0.35	0.60
B	0.00	0.35	0.60
C	0.00	0.70	1.50
D	0.00	0.25	0.50
E	-0.25	0.00	0.25
F	0.00	0.25	0.50
G	0.00	0.20	0.40





Notes:

A3 SCALE 1:50,000

0 1.5 3 (km)

Location Plan

Tonkin+Taylor
105 Carlton Gore Rd, Newmarket, Auckland
www.tonkintaylor.co.nz

DRAWN	RHAU	Oct.19
CHECKED		
APPROVED		
ARCFILE LT_ShorelineAnalysis2.mxd		
SCALE (AT A3 SIZE) 1:50,000		
PROJECT No. 1009598		

Mount to Papamoa Coastal Erosion
Long term trend analysis
Figure 5.7

FIGURE No. Rev. 0

Path: P:\1009598\WorkingMaterial\GIS\LT_ShorelineAnalysis2.mxd Date: 25/10/2019 Time: 1:25:40 PM

5.6.3 Potential drivers of long-term trends

5.6.3.1 Nourishment from offshore dredge disposal

Sediment sources contributing to the long-term accretion trends are not completely certain, however, one factor that appears to be contributing to the accretion rates along Mount Main and Marine Parade is the nearshore deposition of dredged sediment. Over the last 28 years there has been approximately 2,903,000 m^3 of sediment deposited offshore from Mount Maunganui. The locations of the deposition grounds relative to the beach profiles are shown in Figure 5.8. The contour excursion distances measured at CCS40 have been compared with the timing of deposition at site A (Figure 5.9). Dredged sediment was first deposited offshore from Mount Main (site A) in 1991. Figure 5.9 shows that since approximately 1991 there has been a trend of accretion at the 2 m RL contour at profile CCS40. The dune toe (4 m RL) has also shown accretion, although the trend is less apparent. This is consistent with the findings from Harms (1989) and Spier & Healy (2005) who conclude the dredged material is only likely to influence the lower beach face.

The excursion distances measured at the dune toe for the profiles along Marine Parade have been compared with the timing of deposition at sites B and C Figure 5.10. Profile CCS39 shows that soon after the first deposition occurred at sites B and C in 2000, there has been a trend of accretion at the dune toe Figure 5.10. The other profiles along Marine Parade also show trends of accretion since 2000. Interestingly, the rate of accretion generally decreases with distance from the deposition grounds. These observations suggest that the deposition of dredged sediment in the nearshore does contribute to accretion of the dune toe.

However, there does not appear to be a strong correlation between the amount of sediment deposited nearshore and the amount of accretion, likewise there does not appear to be pulses of sediment accretion following deposition but instead it appears that ongoing deposition of dredge sediment is causing gradual accretion of the dune toe.

It should be noted that the long-term accretion rates adopted in this assessment are based on the assumption that there is continued deposition of dredged material at the nearshore sites. Previous studies have identified that historic erosion of the Mount Maunganui shoreline has occurred between 1943 and 1974. This suggests that if offshore conditions change and deposition of dredged material stops then there is potential for the long term trend to change and become erosional.

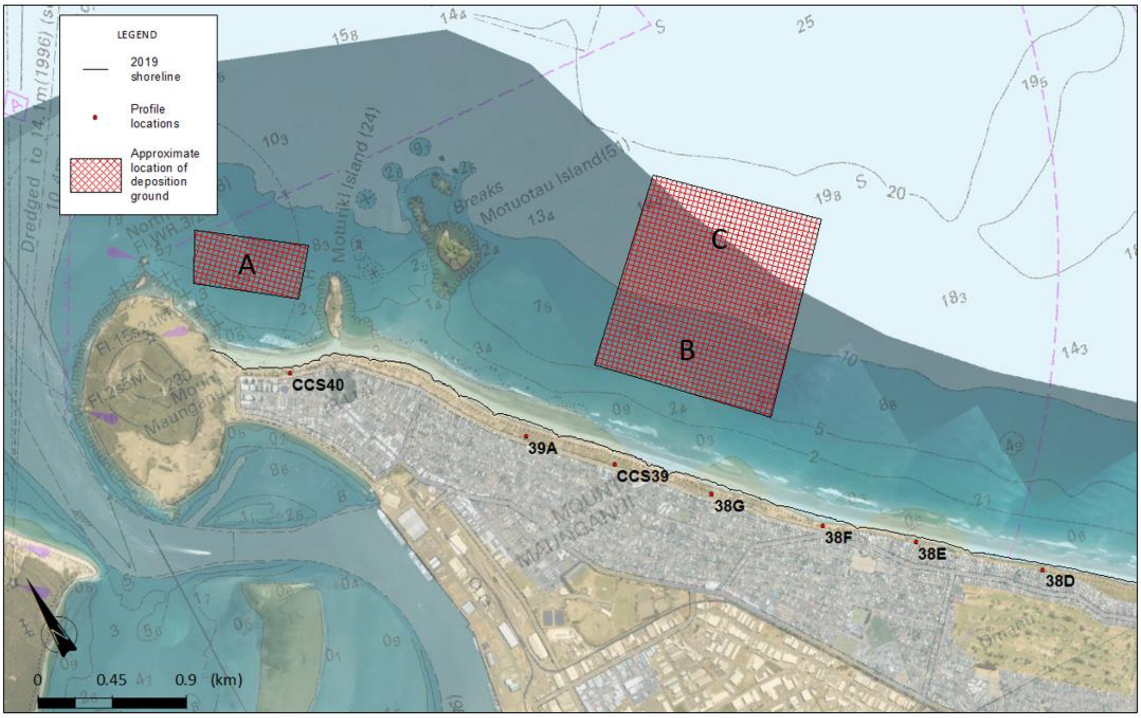


Figure 5.8: Locations of dredge deposition grounds and beach profiles

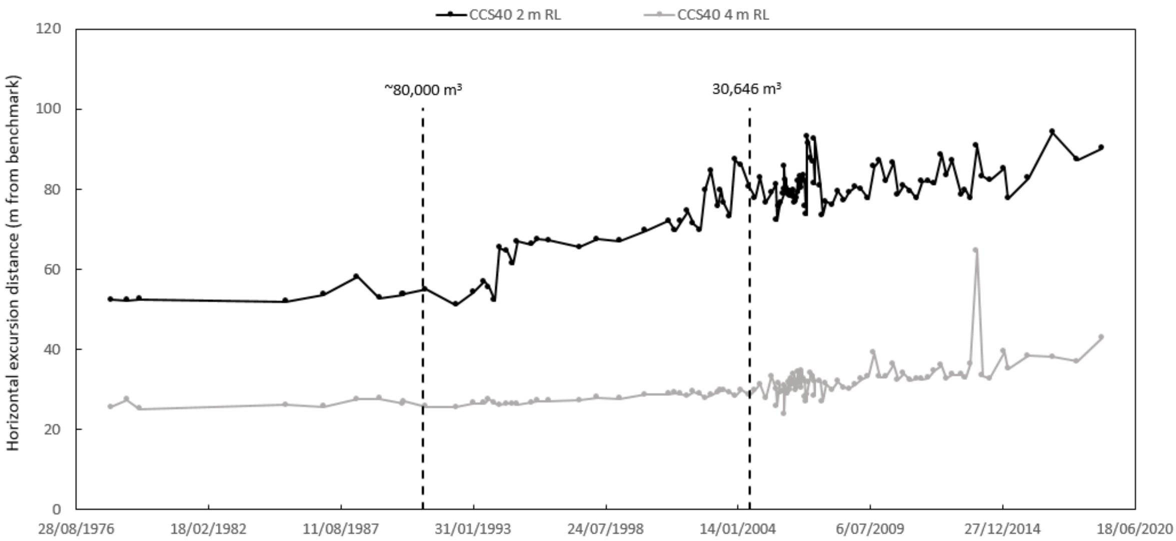


Figure 5.9: Contour excursion distances for 2 m RL and 4 m RL (dune toe) contours at CCS40 (Mount Main). Dashed lines indicate timing of dredged sediment being placed offshore at Site A

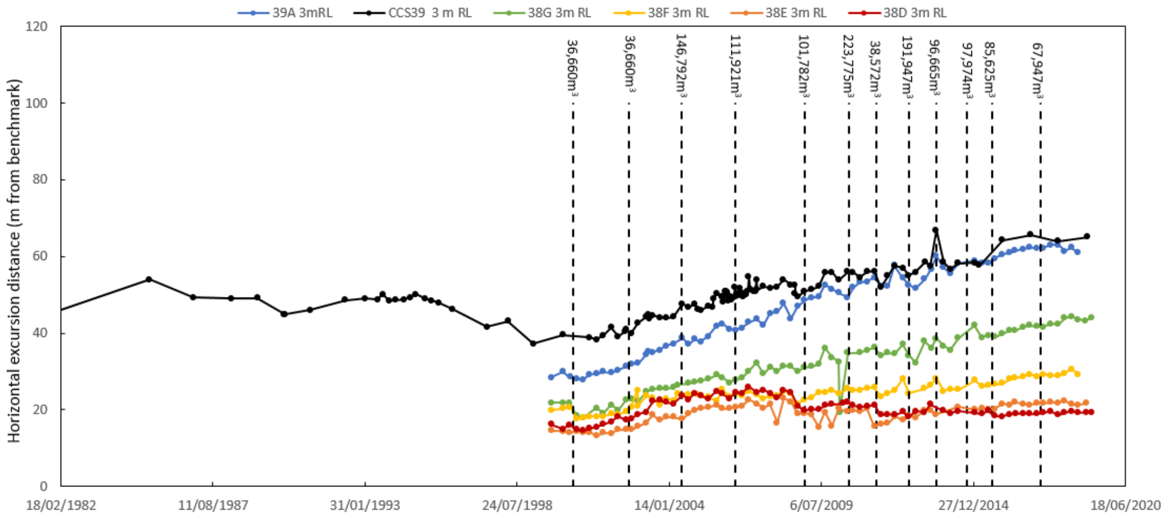


Figure 5.10: Contour excursion distances for 3 m RL contour (dune toe) for the profiles along Marine Parade. Dashed lines indicate timing of dredged sediment being placed offshore at Sites B and C

The slight erosion identified near the centre of the shoreline (Cell E) is possibly due to a combined effect of the shoreline being outside the influence of nourishment from dredge deposition grounds and outside the shadow effect of Motiti Island. Therefore, this section is likely to be slightly more exposed than the rest of the shoreline.

5.6.3.2 Climatic variations

Some of the shoreline trends on New Zealand's beaches can be driven by climatic variations, such as the Interdecadal Pacific Oscillation (IPO) and the El Niño–Southern Oscillation (ENSO) (Blue & Kench, 2017).

The IPO is a long-term oscillation of sea-surface temperatures in the Pacific Ocean that can last from 20 to 30 years Figure 5.11. In New Zealand, the negative phase is linked to stronger north to north-easterly winds, which in theory would result in increased erosion along Bay of Plenty beaches. This trend is reversed during positive phases.

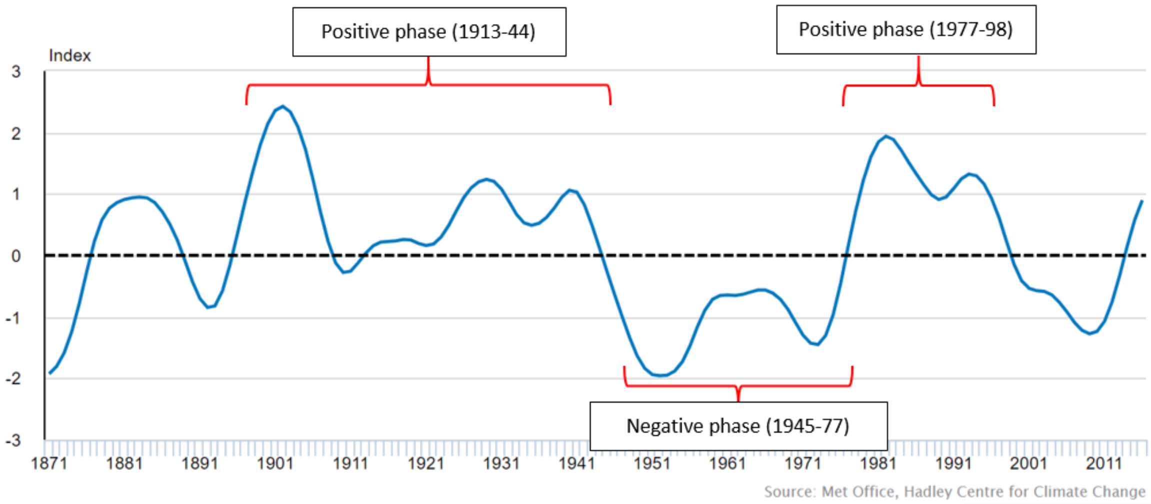


Figure 5.11: Interdecadal Pacific Oscillation (IPO) from 1871 to 2007

The ENSO, characterised by the Southern Oscillation Index (SOI), is the movement of water equatorial water across the Pacific Ocean and the atmospheric response. It occurs every 2 to 7 years, typically lasting 6 to 18 months. There are three ENSO phases: neutral, El Niño and La Niña. In New Zealand a La Nina phase typically results in more north-easterly winds, wetter conditions in the north and east, and higher sea levels. Whereas during an El Niño phase there can be increased westerly winds, rain in the west and drought in the east.

The longer profile datasets were compared against the SOI and IPO, however due to the various shoreline modifications that have occurred along the Mount Maunganui to Papamoa shoreline it is difficult to identify a correlation with the profile trends. However, Healy et al. (1977) and Foster (1991) both describe an erosive period along Mount Maunganui and Papamoa between 1945 and 1976, which does correlate with the negative phase in the IPO (Figure 5.11).

5.7 Effects of sea level rise (SLR)

5.7.1 Adopted SLR values

We have adopted a range of sea level rise (SLR) values over the two required future timeframes of 2080 and 2130 (i.e. 50 and 100 years respectively). The range of SLR values for each timeframe are based on three RCP scenarios consistent with the guidance provided within MfE (2017). Table 5-8 presents the SLR values used in this present assessment. The 2130 RCP8.5 value of 1.25m SLR is in accordance with the RPS (Policy NH11B).

An average historic rate of SLR of 1.9 mm/year for Tauranga Harbour was subtracted from the adopted SLR values for use in assessment. This approach is required because the existing long term trends and processes already incorporate the response to the historic SLR. Therefore the historic rate must be subtracted to avoid double counting.

Table 5-8 Sea level rise values (m) utilised in assessment

Year	Timeframe (year)	SLR (m)	RCP Scenario
Current	0	0.03*	N/A
2080	50	0.12*	N/A
2080	50	0.4	RCP4.5 (approx.)
2080	50	0.6	RCP8.5
2130	100	0.22*	N/A
2130	100	0.8	RCP4.5
2130	100	1.25	RCP8.5
2130	100	1.6	RCP8.5H+

*Historic sea level rise

5.7.2 Beach response

Geometric response models propose that as sea level is raised, the equilibrium profile is moved upward and landward conserving mass and original shape. The most well-known of these geometric response models is that of Bruun (Bruun, 1962, 1988) which proposes that with increased sea level, material is eroded from the upper beach and deposited offshore to a maximum depth, termed closure depth. The increase in seabed level is equivalent to the rise in sea level and results in landward recession of the shoreline.

The inner parts of the profile exposed to higher wave energy are likely to respond more rapidly to changes in sea level. For example, Komar (1999) proposes that the beach face slope is used to predict coastal erosion due to individual storms. Deeper definitions of closure including extreme wave height-based definitions (Hallermeier, 1983), sediment characteristics and profile adjustment records (Nicholls et al., 1998) are only affected during infrequent large-wave events and therefore may exhibit response-lag.

For this assessment, the shoreline response to SLR has been assessed using the Profile Translation Model (PTM) (Atkinson et al., 2018). The PTM is similar to the modified Brunn Rule in that it assumes a constant profile shape and conservation of volume. The model proposes to initially raise the active profile by the increase in water level, connecting the original profile and the raised profile with a vertical line. As volumes are not conserved between the initial and raised profile following the initial translation, the raised profile is incrementally shifted landward until the volumes balance (i.e. eroded vs accreted volumes are equal). An example of the PTM is shown in Figure 5.12.

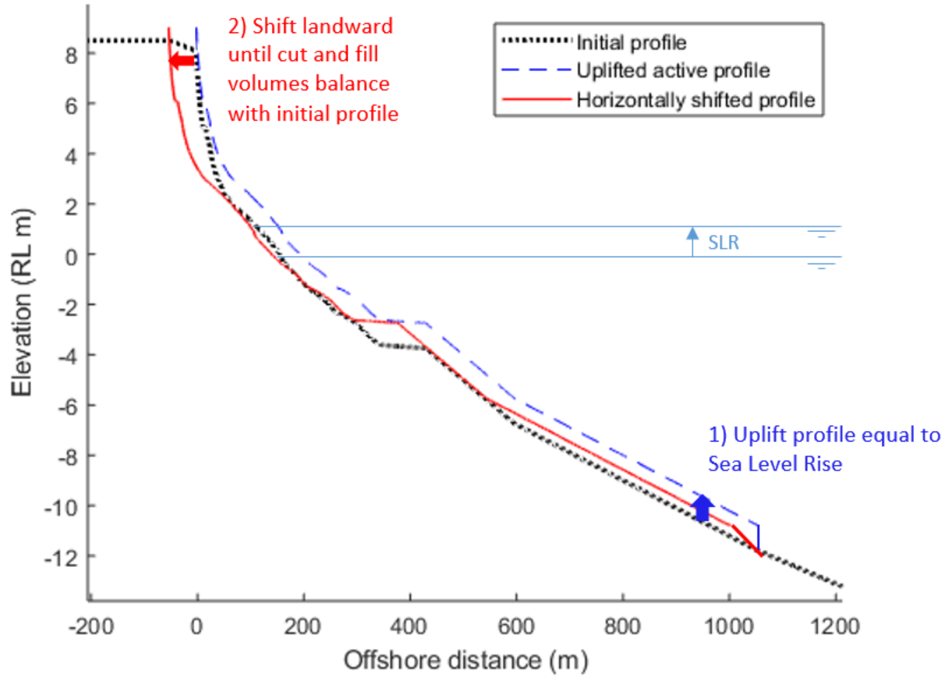


Figure 5.12: Example of PTM method showing initial profile (dotted black line), the uplifted active profile (dashed blue line) and the final horizontally shifted profile (solid red line)

To define parameter distributions, the PTM has been used to assess the landward retreat of three different active beach slope profiles based on average beach profiles along the Mount Maunganui to Papamoa shoreline. The three slope profiles include:

1 Active beach face, average dune toe position to low water mark (lower bound)
2 Inner closure slope, average dune crest to inner Hallermeier closure depth (modal value)
3 Outer closure slope, average dune crest to outer Hallermeier closure depth (upper bound).

The Hallermeier closure definitions are defined as follows (Nicholls et al., 1998):

$$d_l = 2.28H_{s,t} - 68.5\left(\frac{H_{s,t}^2}{gT_s^2}\right) \cong 2\ x\ H_{s,t} \quad (5\text{-}2)$$

$$d_i = 1.5\ x\ d_l \quad (5\text{-}3)$$

Where d_l is the inner closure depth below mean low water spring, $H_{s,t}$ is the non-breaking significant wave height exceeded for 12 hours in a defined time period, nominally 1 year, and T_s is the associated period. d_i is the outer closure depth below mean low water springs.

For this study the deep water (non-breaking) wave climate parameters of $H_{s,t}$ and T_s were based on the MetOcean View hindcast data (Table 5.9).

Table 5.9: Wave climate parameters based on MetOcean View hindcast data, with inner and outer closure depths based on Equations 5-2 and 5-3

Location	Significant wave height (Hs), m	Wave period (Ts), s	Inner closure depth, m	Outer closure depth, m
Mount Maunganui	4.0	11.5	9.1	13.6
Papamoa	3.5	10.0	7.9	11.9

Based on these wave climate parameters the inner closure depth along Mount Maunganui is calculated as 8.3 m below mean low water spring using the Hallermeier method defined in Equation 5-2 (equivalent to 9.1 m below mean sea level). The outer closure depth (Equation 5-3) is calculated at 12.8 m (equivalent to 13.6 m below mean sea level). The average dune crest is approximately 6 m above mean sea level. This results in an average active profile height of between 15 m to 20 m (6 m dune height and 9.1 m to 13.6 m closure depth). Figure 5.13 shows the extents of the active profiles including inner and outer closure depths, and active beach face.

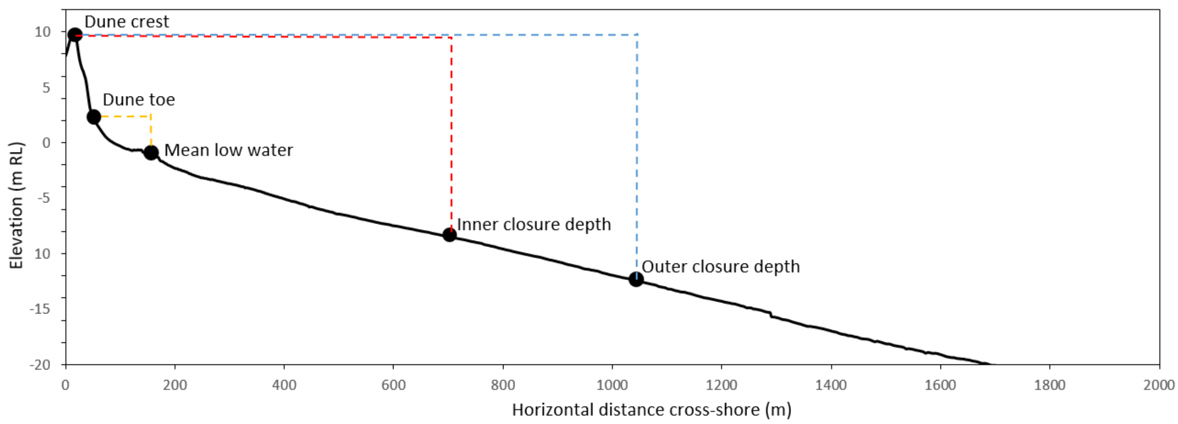


Figure 5.13: Extents of active profiles for the Mount Maunganui to Papamoa shoreline

The adopted upper and lower bound contour levels indicating the extents of the active profiles applicable to each coastal cell are shown in Table 5.10.

Table 5.10: Contour levels used to assess the effects of SLR on extents of active profiles

Parameter bounds	Contour levels (m RL)	Cell A	Cell B - C	Cell D	Cell E	Cell F	Cell G
		(CCS40)	(CCS39)	(38B)	(CCS38)	(CCS36)	(CCS34)
Lower bound slope	Average dune toe	4	3	3	3	3	3
	Average low water mark	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Modal slope	Average dune crest	6	5.5	6.5	8	8	6
	Inner Hallermeier closure depth	-9.1	-9.1	-9.1	-9.1	-7.9	-7.9
	Average dune crest	6	5.5	6.5	8	8	6

Parameter bounds	Contour levels (m RL)	Cell A	Cell B - C	Cell D	Cell E	Cell F	Cell G
		(CCS40)	(CCS39)	(38B)	(CCS38)	(CCS36)	(CCS34)
Upper bound slope	Outer Hallermeier closure depth	-13.6	-13.6	-13.6	-13.6	-11.9	-11.9

6 Coastal erosion assessment

6.1 Combination of parameter components to derive CEHA

For each coastal cell, the relevant parameters influencing the CEHA and parameter bounds have been defined according to the methods described above as summarised in Table 6.1. Probability distributions constructed for each parameter are randomly sampled and the extracted values used to define a potential CEHA distance. This process is repeated 10,000 times using a Monte Carlo technique and probability distribution of the resultant CEHA width is forecasted

Table 6.1: Summary of adopted erosion hazard parameter bounds

Parameter	Lower bound	Mode	Upper bound
Short-term (m)	5 year ARI inter-survey storm cut	50 year ARI inter-survey storm cut	200 year ARI inter-survey storm cut
Slope stability (m)	Hmax & αmin	Hmean & αmean	Hmin & αmax
Long-term (m/yr)	Upper 95% confidence interval amalgamated from profile data and historic shoreline analysis	Average regression rate amalgamated from profile data and historic shoreline analysis	Lower 95% confidence interval amalgamated from profile data and historic shoreline analysis
Closure slope	Slope across active beach face to swash excursion	Slope from dune crest to inner Hallermeier depth	Slope from dune crest to outer Hallermeier closure depth

6.2 Component values

Components have been assessed for each coastal cell based on the data and methodologies described in the preceding sections. Adopted components are presented for each cell within Table 6.2.

Table 6.2: Adopted component values for the Mount Maunganui to Papamoa coastal erosion hazard assessment

Cell		A	B	C	D	E	F	G
Cell centre (NZTM)	E	1880594	1881027	1882037	1884310	1887269	1891071	1894579
	N	5830246	5830075	582888	5826628	5824302	5822156	5820485
Chainage, m (from NW)		0 to 800	800 to 1100	1100 to 4200	4200 to 7400	7400 to 11260	11260 to 16430	16430 to 19100
Morphology		Dune	Dune	Dune	Dune	Dune	Dune	Dune
Short-term (m)	Min	3	4	4	4	4	4	4
	Mode	6	10	10	10	10	10	10
	Max	8	15	15	15	15	15	15
Dune (m above toe)	Min	1.5	3.0	1.5	3.5	3.5	4.0	2.5
	Mode	2.0	4.0	3.0	4.0	4.0	5.0	3.5
	Max	2.5	5.0	5.0	7.0	5.0	7.0	5.0
	Min	30	30	30	30	30	30	30

Cell		A	B	C	D	E	F	G
Stable angle (deg)	Mode	32	32	32	32	32	32	32
	Max	34	34	34	34	34	34	34
Long-term (m) -ve erosion +ve accretion	Min	0.00	0.00	0.00	0.00	-0.25	0.00	0.00
	Mode	0.35	0.35	0.70	0.25	0.00	0.25	0.20
	Max	0.60	0.60	1.50	0.50	0.25	0.50	0.40
Closure depth (m below MSL)	Min	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
	Mode	-9.1	-9.1	-9.1	-9.1	-9.1	-7.9	-7.9
	Max	-13.6	-13.6	-13.6	-13.6	-13.6	-11.9	-11.9

6.3 Results

Figure 6.1 presents an example component and CEHA histogram cumulative distribution functions for Cell E. The curved lines represent probability of exceedance by 2130, measured on the right-hand axis. Results show that the possible erosion distances for Cell E in 2130 range from 0 to -107 m. Histograms and cumulative distribution function plots for all cells are included in Appendix E.

CEHA distances based on the cumulative distribution functions for all cells along the Mount Maunganui to Papamoa shoreline are presented in Table 6.3. $P_{50\%}$ means that there is 50% chance of an erosion distance being exceeded within that timeframe. $P_{66\%}$ can be considered a likely scenario and $P_{5\%}$ can be considered a very unlikely scenario.

The current timeframe has one scenario which represents the erosion hazard from short-term storm cut and dune stability. The future timeframes include the long-term trends, the shoreline response to a range of RCP SLR scenarios, as well as the short-term storm cut and dune stability.

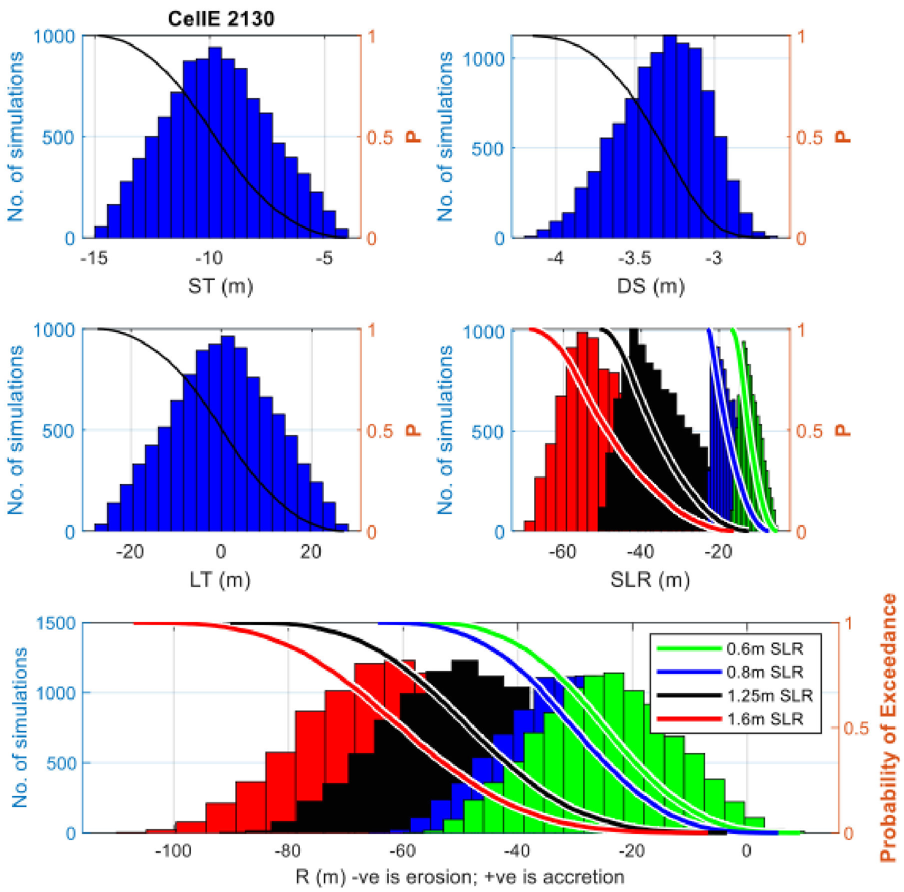


Figure 6.1: Example of component and CEHA histogram cumulative distribution functions of parameter samples and resultant CEHA distances for Cell E in 2130

Table 6.3: CEHA distances for Mount Maunganui to Papamoa shoreline

Cell	Timeframe	SLR (m)	Probability of exceedance				
			Min	P66%	P50%	P5%	Max
	Current	0.03	-4	-7	-7	-9	-10
		0.2	23	3	0	-14	-26
		0.4	19	-7	-11	-28	-42
A	50yr (2080)	0.6	19	-14	-19	-39	-55
		0.6	51	17	10	-15	-36
		0.8	47	5	-2	-30	-55
		1.25	35	-20	-29	-64	-95
	100 yr (2130)	1.6	38	-29	-39	-76	-106
	Current	0.03	-7	-12	-13	-17	-19
		0.2	19	-1	-4	-18	-28
B		0.4	11	-9	-13	-27	-39
	50yr (2080)	0.6	11	-15	-18	-33	-45
		0.6	42	13	7	-17	-33
	100 yr (2130)	0.8	39	4	-2	-26	-41

Cell	Timeframe	SLR (m)	Probability of exceedance				
			Min	**P66%**	**P50%**	**P5%**	**Max**
		1.25	29	-13	-19	-46	-63
		1.6	16	-25	-32	-60	-78
C	Current	0.03	-5	-11	-12	-16	-18
	50yr (2080)	0.2	74	30	21	-8	-25
		0.4	65	21	12	-18	-36
		0.6	63	15	7	-23	-40
	100 yr (2130)	0.6	139	67	52	-4	-31
		0.8	132	58	44	-12	-41
		1.25	123	41	27	-30	-59
		1.6	117	29	14	-44	-77
D	Current	0.03	-7	-13	-14	-17	-20
	50yr (2080)	0.2	14	-4	-7	-18	-27
		0.4	10	-12	-15	-27	-37
		0.6	14	-15	-19	-34	-45
	100 yr (2130)	0.6	30	4	-1	-21	-36
		0.8	33	-1	-6	-26	-40
		1.25	20	-15	-21	-43	-59
		1.6	21	-26	-33	-57	-80
E	Current	0.03	-7	-12	-13	-17	-19
	50yr (2080)	0.2	-1	-19	-21	-32	-42
		0.4	-3	-25	-29	-40	-52
		0.6	-9	-30	-34	-46	-56
	100 yr (2130)	0.6	9	-20	-25	-44	-57
		0.8	5	-25	-30	-50	-64
		1.25	-4	-42	-49	-71	-90
		1.6	-7	-53	-60	-86	-107
F	Current	0.03	-8	-13	-14	-18	-20
	50yr (2080)	0.2	13	-4	-7	-18	-28
		0.4	10	-11	-14	-26	-37
		0.6	10	-17	-20	-33	-45
	100 yr (2130)	0.6	33	6	1	-18	-31
		0.8	31	0	-6	-26	-40
		1.25	22	-17	-23	-47	-65
		1.6	18	-28	-35	-61	-81
G	Current	0.03	-6	-12	-13	-16	-19
	50yr (2080)	0.2	10	-6	-9	-18	-26
		0.4	7	-13	-16	-27	-36
		0.6	4	-19	-22	-33	-45
	100 yr (2130)	0.6	27	1	-3	-19	-30

Cell	Timeframe	SLR (m)	Probability of exceedance				
			Min	P66%	P50%	P5%	Max
		0.8	23	-6	-10	-27	-40
		1.25	14	-22	-28	-48	-64
		1.6	13	-34	-40	-64	-85

6.4 Mapping of the CEHA

Table 6.4 summarises the nine erosion hazard scenarios which have been mapped. The premise of the nine scenarios is based on the key requirements of the New Zealand Coastal Policy Statement (NZCPS), Bay of Plenty Regional Policy Statement (RPS) and the recent guidance provided by the Ministry for the Environment (MfE, 2017) for dynamic adaption pathway planning.

Table 6.4: Timeframes, likelihood and SLR scenarios for adopted mapping scenarios

Scenario	Timeframe in years	Likelihood of occurring over timeframe (Exceedance Probability)	SLR (m)	Equivalent RCP Scenario[2]
1	Current	66%	n/a	n/a
2	Current	5%	n/a	n/a
3	50 (2080)	66%	0.4	RCP4.5
4	50 (2080)	66%	0.6	RCP8.5
5	50 (2080)	5%	0.6	RCP8.5
6[1]	100 (2130)	66%	0.8	RCP4.5
7[1]	100 (2130)	66%	1.25	RCP8.5
8[1]	100 (2130)	5%	1.25	RCP8.5
9[1]	100 (2130)	5%	1.6	RCP8.5 H+

[1]Regional Policy Statement requirements

[2]Approximate RCP scenario

The nine scenarios were selected for mapping purposes to support the following local government decision making processes:

- Plan Change/Adaption Planning
- RPS Primary and Secondary Risk Assessments
- Regional Policy Statement requirements including, hazard susceptibility area and potentially affected areas
- Building Act
- RMA (subdivision).

CEHAs are mapped as offsets to the existing baseline (2019 shoreline). Where the hazard values differ between coastal cells, the mapped CEHA is merged over a distance of at least 10 times the differences between values providing smooth transitions. In accretion dominated areas where the future CEHA is seaward of the current CEHA, the future CEHA has been mapped equivalent to the current CEHA.

6.5 Discussion

Overall, the coastal erosion hazard along the Mount Maunganui to Papamoa shoreline is relatively consistent, with some variations which are mainly driven by differences in the long-term trends and dune heights.

The current $P_{66\%}$ and $P_{5\%}$ are on average -12 m and -17 m, respectively. The current hazard is smallest at Mount Main where the $P_{66\%}$ is -7 m. The future 100 year CEHA based on the 1.6 m SLR scenario, ranges from -12 to -53 m for the $P_{66\%}$ and is up to -86 m for the $P_{5\%.}$ The future erosion hazard is greatest in cell E, where there has been some long-term erosion.

Most of the cells along the shoreline have historically shown long-term accretion trends and consequently there are several scenarios where the future CEHA is further seaward than the current CEHA. Although the future CEHA also takes into account SLR, for the lower SLR scenarios, the impact from long term accretion is likely to override any potential recession due to SLR. The $P_{5\%}$ represents the 'no accretion' scenario and subsequently the future $P_{5\%}$ CEHA are landward of the current CEHA. Within cell C the dune heights are relatively low as a result of them rapidly building seaward in response to the continued offshore nourishment. The lower dune morphology does make this section of the coast slightly more exposed to the effects of SLR.

The previous 2009 Erosion Risk Zones (ERZs) have been overlaid with the updated CEHA (Appendix B). Overall, the lines show relatively good comparison, however as expected there are differences due to the different timeframes, adopted SLR and long-term rates as well as overall methodology. Through cells D, F and G the upper estimate scenario (2130 1.6m SLR $P_{5\%}$) is relatively consistent with the previous 2110 ERZ. At Mount Main the updated upper estimate scenario (2130 1.6m SLR $P_{5\%}$) is further landward than the previous 2110 ERZ. Along cell C (Marine Parade) the updated CEHA are reduced compared with the previous ERZ, this is largely due to the long term accretion component that has been considered within the recent assessment. Within cell E the 2130 1.6m SLR $P_{5\%}$ line is landward of the previous 2110 ERZ. This is due to the long term erosion trend which has been identified in the recent assessment.

6.6 Uncertainties and limitations

Limitation and uncertainties associated with this study include:

- There is some uncertainty around the accretion rates continuing in the future. For example, if the future dredging regime was to discontinue or change with sediment being deposited elsewhere, the accretion rates observed along the Mount Maunganui shoreline may cease due to limited sediment supply. Similarly, the past accretion rates measured along Marine Parade are very high, so even if the offshore deposition of dredged material continues, it is likely that the shoreline will eventually reach a point of equilibrium and accretion rates will decrease. To account for this future uncertainty, the lower bound long-term component for all accreting cells has been set to zero. Subsequently, the lower probability distances (i.e. $P_{5\%}$) are representative of future scenarios where there is no long term accretion.
- The size of the coastal cells used to define the erosion hazard. There will always be some alongshore variance within a defined cell, however this can be reduced by splitting the shoreline into continually smaller cells. We consider the cells are refined as far as practical based on factors which could significantly affect results. Residual uncertainty may be allowed for by selecting a lower probability CEHA value.

Overall, this study has assessed coastal erosion hazard areas at a local scale and may be superseded by details, site-specific assessment undertaken by qualified and experienced practitioners using improved or higher resolution data than presented in this report.

7 Summary and recommendations

The Mount Maunganui to Papamoa shoreline includes 19 km of northeast facing beach located in the Bay of Plenty, south of the Tauranga Harbour entrance. The shoreline is part of a long gently curving sandy barrier coastline and is typically characterised by a dune, berm and offshore bar.

Tonkin + Taylor Ltd were commissioned by Tauranga City Council to undertake a detailed coastal erosion hazard assessment for the Mount Maunganui to Papamoa shoreline. The assessment constitutes an update of the previous erosion hazard assessment completed by T+T in 2009, utilising an improved methodology in conjunction with additional beach monitoring data and storm observations over the last decade.

The coastal erosion hazard areas were defined using a probabilistic approach which combines standard and well-tested methods. The approach is based on a stochastic method of combining erosion parameter distributions to allow for inherent variance and uncertainty. Results provide a range of potential erosion hazard distances for current and future timeframes (e.g. 2080 and 2130) including different sea level rise scenarios.

The current CEHA averages -12 m and -17 m ($P_{66\%}$ and $P_{5\%}$). The future 100 year CEHA based on the RCP8.5H+ SLR scenario, ranges from -12 to -53 m for the $P_{66\%}$ and is up to -86 m for the $P_{5\%}$. Overall, the updated erosion hazard areas are comparable with the previous setbacks defined by T+T (2009), but provide a probabilistic understanding of the impacts of different sea level rise scenarios. Key conclusions are as follows:

- The current erosion hazard is dominated by short-term erosion processes and is relatively consistent along the Mount Maunganui to Papamoa shoreline. The current erosion hazard is smallest at Mount Main (cell A).
- The future erosion hazard is determined by the effects of sea level rise balanced by long-term accretion with the larger future sea level rise values causing larger erosion hazard areas.
- The future CEHA is smallest along Marine Parade (cell C) where long-term trends have been dominated by accretion. The shoreline accretion is likely to be linked with the nearshore deposition of dredged sediment which first began in 1991.
- The future CEHA is largest within cell E (Wairariki St to Harrison’s Cut) which has historically demonstrated a small erosional trend.

A key uncertainty is the future nearshore deposition of dredged material and its contribution to the shoreline accretion rates.

Based on the findings from this study we recommend the following:

- Continue quarterly monitoring of existing beach profiles
- Include an additional profile within the vicinity of Cell B (Pacific Ave)
- Continue to collect post-storm profiles
- Consider the use of UAV (Unmanned Automated Vehicle) and photogrammetry as a more efficient data collection method
- Improve the record from the Port dredging including the volume and placement of dredge spoil
- Update the hazard assessment at intervals of no more than 10 years or following significant changes in data availability, or best practice guidance or methods.

Overall, this study has assessed coastal erosion hazard areas at a local scale and may be superseded by details, site-specific assessment undertaken by qualified and experienced practitioners using improved or higher resolution data than presented in this report.

8 Applicability

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

Tonkin & Taylor Ltd

Report prepared by:	Authorised for Tonkin + Taylor Ltd by:
....	....
Rebekah Haughey	Richard Reinen-Hamill
Coastal Scientist	Project Director

Report review by:	
....	....
Jonathan Clarke	Dr Tom Shand
Senior Coastal Engineer	Coastal Technical Director

rhau
\\ttgroup.local\files\tgaprojects\1009598\issueddocuments\r2020205.mountcoastalerosionassessment_reportstage2.final_v2.docx

9 References

Atkinson, A.I., Baldock, T.E., Birrien, F., Callaghan, D.P., Nielsen, P., Beuzen, T., Turner, I.L., Blenkinsopp, C.E. and Ranasinghe, R. (2018) Laboratory investigation of the Bruun Rule and beach response to sea level rise. Coastal Engineering 136, 183-202.

Beavan R.J. and Litchfield, N.J. (2012) Vertical land movement around the New Zealand coastline: implications for sea-level rise, GNS Science Report 2012/29. 41p.

Bruun P (1962) Sea-level rise as a cause of shore erosion. J. Waterways Harbors Div 88:117–130.

Bruun, P., (1988) The Bruun Rule of erosion by sea level rise: a discussion on large-scale two-andthree-dimensional usages. JCR, 4, 627–648.

Cowell, P.J., Thom, B.G., Jones, R.A., Everts, C.H. and Simanovic, D. (2006) Management of Uncertainty in Predicting Climate-Change Impacts on Beaches. JCR 22(1)232-245.

Dahm, J. & Gibberd, B. (2013). Mount Maunganui Reef – Assessment of Management Options. Report prepared for Bay of Plenty Regional Council.

Davis-Colley, R. J. (1976). Sediment dynamics of Tauranga Harbour. Unpublished MSc thesis, University of Waikato, New Zealand.

Foster, G. (1991). Beach nourishment from a nearshore dredge spoil dump at Mount Maunganui Beach. Masters thesis, University of Waikato.

Gibb, J. (1994). Initial assessment of areas sensitive to coastal hazards for selected parts of the Bay of Plenty coast. Report prepared for Bay of Plenty Regional Council.

Gibb, J. (1996). Project Dune Watch: Coastal hazard risk assessment between Mauao and Papamoa, Tauranga District, Bay of Plenty. Report prepared for Tauranga District Council.

Hallermeier, R.J. (1983) Sand transport limits in coastal structure designs. Proc. of Conf. on Design, Construction, Maintenance and Performance of Coastal Structures. ASCE, Arlington, pp 703–716.

Hannah, J. and Bell, R.G. (2012) Regional sea level trends in New Zealand. Journal of Geophysical Research 117: C01004.

Harms, C. (1989). Dredge spoil dispersion from an inner shelf dump-mound. PhD thesis, University of Waikato.

Hay, D. N., de Lange, W. P. & Healy, T. R. (1991). Storm and Oceanographic Databases for the Western Bay of Plenty. Coastal Engineering – Climate for Change, 10th Australasian Conference on Coastal and Ocean Engineering.

Healy, T., Harray, K. & Richmond, B. (1977). Bay of Plenty Coastal Erosion Survey. Occasional Report No. 3, University of Waikato, Department of Earth Sciences.

IPCC (2013). Working Group I contribution to the IPCC 5th Assessment Report "Climate Change 2013: The Physical Science Basis". DRAFT report by Intergovernmental Panel on Climate Change. June, 2013.

Iremonger, S. (2011). NERM beach profile monitoring 2011. Bay of Plenty Regional Council, Whakatane.

Jenks, G (2013). Dunes: Case Studies. IGCI.

Komar, P.D., McDougal, W.G., Marra, J.J. and Ruggiero, P. (1999). The Rational Analysis of Setback Distances: Application to the Oregon Coast. Shore and Beach Vol. 67 (1) 41-49.

Kopp RE, Horton RM, Little CM, Mitrovica JX, Oppenheimer M, Rasmussen DJ, Strauss BH, Tebaldi C. 2014. Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. Earth's Future 2(8): 383–406.

Larson, M and Kraus, N C (1989), "SBEACH: Numerical Model for Simulating Storm-Induced Beach Change, Report 1: Theory and Model Foundation". Technical Report CERC-89-9, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg USA.

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

Mariani A., Shand, T.D., Carley, J.T., Goodwin, I.D., Splinter, K., Davey, E.K., Flocard, F. and Turner, I.L. (2012). Generic Design Coastal Erosion Volumes and Setbacks for Australia. Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

MetOcean Data View (2019). https://app.metoceanview.com/hindcast/

MfE (2017) Coastal Hazards and Climate Change. Guidance for Local Government in New Zealand. 3rd edition. Prepared for Ministry for the Environment. Ramsey, D., Gibberd, B., Dahm, J., Bell, R. (2012) Defining coastal hazard zones for setback lines: A guide to good practice. NIWA Ltd. 91 p.

Nicholls, R. J., Laron, M., Capobianco, M. and Birkemeier, W.A. (1998) Depth of Closure: Improving Understanding and Prediction. ICCE 1998.

NIWA (2013). Bay of Plenty storm tide and wave hazard. Report prepared for Bay of Plenty Regional Council.

Shand, T. D., Reinen-Hamill, R., Kench, P., Ivamy, M., Knook, P. and Howse, B. (2015). Methods for Probabilistic Coastal Erosion Hazard Assessments. Australasian Coasts & Ports Conference 2015, Auckland, New Zealand.

Smale, D. (1993). Sediment source and movement in Tauranga Harbour and nearshore Bay of Plenty. Institute of Geological & Nuclear Sciences Limited, New Zealand.

Spiers, K. & Healy, T. (2005). Continued beach renourishment from dredge spoil disposal, Bay of Plenty, New Zealand.

T+T (2004). Hawkes Bay Regional Coastal Hazard Assessment. Report prepared for Hawkes Bay Regional Council.

T+T (2006). Regional assessment of areas susceptible to coastal erosion. Technical report prepared for Auckland Regional Council.

T+T (2012). Coastal Hazard Assessment: Waikawa to Waitarere. Technical report prepared for Horizons Regional Council.

T+T Ltd. (2009). Coastal Erosion Hazard Zone Update: Tauranga Open Coast. Report prepared for Tauranga City Council.

WAFO (2012). A Matlab Toolbox for Analysis of Random Waves and Loads. Prepared by the WAFO Group. Lund University