REPORT

Whangarei District Council

Coastal Erosion Hazard Zone Review

Report prepared for:

Whangarei District Council

Report prepared by:

Tonkin & Taylor Ltd

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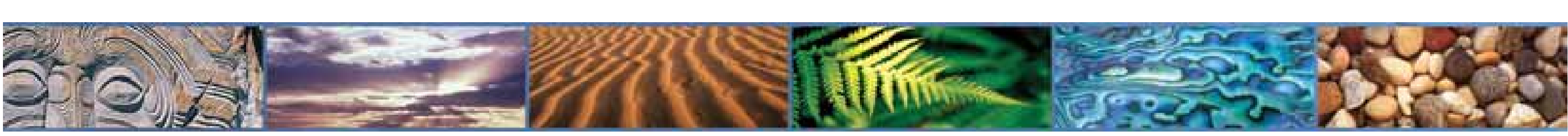

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Executive summary

Whangarei District Council (WDC) commissioned Tonkin & Taylor Ltd (T&T) to review and update the coastal erosion hazard zones (CEHZ's) covering the One Tree Point, Marsden Bay and Bream Bay coastline.

The existing coastal erosion hazard zones (CEHZ) along the study area were originally established as a result of studies carried out in 1998 (Gibb, 1998). As WDC is currently reviewing its Operative District Plan, it was considered timely to undertake a review of the existing CEHZ. Department of Conservation (DoC) land along the coastal margins is unlikely to be developed into the future. Therefore, DOC coastal land bounded by the existing CEHZ (1998) was not reviewed.

This report sets out the outcomes of a review of the WDC CEHZ. The CEHZ assesses coastal erosion risk only. This report does not specifically assess inundation/flooding risk due to storm effects, tsunami or predicted Sea Level Rise (SLR).

The study area included three distinct coastal areas.

One Tree Point cliffs

The cliff shoreline along the study site can be described as a soft cliff type due to the weakly cemented nature of the Pleistocene sand material. Due to the soft, readily erodible nature of the cliff, the rates of coastal erosion may potentially increase due to SLR, with more hydraulic action acting on the cliff toe.

The effects of SLR were not accounted for in the 1998 CEHZ setbacks along the One Tree Point cliffs. Therefore, when including the potential effects of sea level rise, the CEHZ setbacks CEHZ1 and CEHZ2 increase significantly. CEHZ1 increases between 15 m and 17 m while CEHZ2 by increases between 43 m and 48 m.

The consented cliff toe protection has a limited consent period (maximum of 35 years). After this period there is no guarantee that the consent will be renewed and the protection to remain. Therefore, we recommend that in areas where consented coastal cliff protection exists; the CEHZ should still represent the potential retreat to 2110. However, allowance should be made through policy to account for the coastal cliff protection.

Marsden Bay harbour shore

Marsden Bay has been significantly modified since the last coastal hazard study, over ten years ago. The modifications that are likely to alter coastal process and hazards include:

- NorthPort reclamation at Marsden Point
- training groyne at the entrance to Blacksmith Creek at the eastern end of the bay
- Marsden Cove access channel
- beach re-nourishment along the Marsden Bay shoreline.

The effects of the NorthPort reclamation on Marsden Bay (west from Blacksmith creek) is difficult to assess considering the other modifications (training groynes, access channel and re-nourishment) that have occurred in the Marsden Bay area. However, we consider the modifications within Marsden Bay have significantly decreased the risk of coastal erosion in the short to medium term.

Therefore, CEHZ in this area have not changes significantly.

However, this area is likely to be at risk from inundation from storm surge and predicted sea level rise to both 2060 and 2110. We recommend an assessment of inundation risk for Marsden Bay is undertaken which considers the effect of SLR to 2110.

Bream Bay open coast

The Bream Bay coastline comprises sandy beach backed by sand dunes and can be described as a soft shore coast. The average sand dune height along Bream Bay is 6.7 m above Mean Sea Level (MSL). Sandy soft shore coasts are a dynamic environment, where the morphology is dependent on seasonal and climatic cycles. The beach profiles are dominated by the cut and fill cycle.

Soft shores are also affected by increasing sea level rise. Sandy coasts that have been relatively stable over time are likely to show a bias towards erosion with rising sea levels, unless the supply of sand to the beaches can keep pace with erosion.

The 1998 CEHZ's used the position of the shoreline (Dune Toe) derived from historical aerial photography and a GPS survey to determine long term trends of shoreline movement. We recommend using beach profile data over the last ~ 30 years to derive both long term and short term trends on shoreline position.

We have determined, based on beach profile analysis, that much of the Bream Bay shoreline is at dynamic equilibrium (i.e. no significant long term trends), apart from areas along the northern (Marsden point)) and southern (Waipu) shores, which have an erosion trend.

Short term fluctuations also occur due to storm events and climate change. Again using the beach profiles data we have estimated that the maximum short term fluctuation along the open coast is 30m.

At Mair Road (near Marsden Point) CEHZ1 moved seaward 14 m and CEHZ2 12 m seaward. Near the 'Village' CEHZ1 moved seaward 19 m and CEHZ2 18 m seaward. However at the 'Cove' the CEHZ1 has moved 49 m landward and CEHZ2 77 m landward. The landward movement at the Cove is primarily due to Gibb using a long term erosion rate of 0 m per year, while we have assessed there to be long term retreat of up to 0.4 m per year.

The 1998 CEHZ at the Ruakaka Estuary mouth may not represent the potential risk of coastal hazards. Gibb (1998a) based the CEHZ width in this area on historic shoreline positions and evidence of short term fluctuations. However, the existing CEHZ (1998) are seaward of surveyed historic shoreline positions.

In our opinion, the existing CEHZ (1998) do not appropriately delineate the coastal erosion risk in this area Therefore, we recommend further investigation is undertaken to better determine the coastal erosion hazard risk in this area.

Additional assessments

In addition to the original work scope, broad based assessments on predicted sea level rise were undertaken for Takahiwhai Estuary and Marsden Bay. We recommend further investigations to more accurately determine effects caused by predicted sea level rise.

1 Introduction

1.1 Background

Whangarei District Council (WDC) commissioned Tonkin & Taylor Ltd (T&T) to review and update the coastal erosion hazard zones (CEHZ's) covering the One Tree Point, Marsden Bay and Bream Bay coastline (refer to Location Plan, Appendix A).

The existing coastal erosion hazard zones were established as a result of studies carried out in 1998 (Gibb, 1998). WDC has been committed to regular reviews of the hazard zones taking into account any new information, the ongoing profile monitoring, and changes in direction from central government.

As WDC is currently reviewing its Operative District Plan, it was considered timely to undertake a review of the existing CEHZ. A review of the CEHZ's is also prudent due to changes in development the coastal environment over the last 12 years. There have also been updates of climate change effects and new guidelines on managing coastal hazards from the Ministry for the Environment (MfE, 2008).

Additional information is also now available to augment the original assessment and provide an extended data set. New information includes beach profile monitoring at 16 open coast beach profile monitoring stations, LiDAR survey and georeferenced aerial photographs.

The primary use of the CEHZ is to reduce the risk of coastal erosion impacting on future development along the coast. Department of Conservation (DoC) land is unlikely to be developed into the future. Therefore, DoC coastal land bounded by the existing CEHZ (1998) was not reviewed in this study.

This report sets out the outcomes of a review of the WDC coastal erosion hazard zones. The CEHZ assesses coastal erosion risk only. This report does not specifically assess inundation/flooding risk due to storm effects, tsunami or predicted sea level rise.

1.2 Project brief

This project involved the following scope of work:

- review the existing CEHZ's undertaken in 1998 incorporating:
  - assessment of shoreline fluctuations up to 2009
  - the effect of recent developments and coastal erosion mitigation
  - the effect of latest climate change predictions on future sea level rise
  - the effect of land level rise
- delineate the revised CEHZ's in digital GIS format
- document the review of the CEHZ including the methodologies used
- WDC have requested all methodology to be consistent with that used in 1998 to enable consistency with objectives, policies and rules of the District Plan.

Additional work was undertaken as per WDC request during the project. The additional work scope included:

- broad base assessment of future shoreline position of the Takahiwai Estuary
- broad base assessment of inundation along Marsden Bay.

2 Context

2.1 Site location

The review will incorporate the areas from One Tree Point to Waipu Cove where the CEHZ (1998) has been previously assessed (except for DoC land as referred to in Section 1.1). Refer to Appendix A for a location plan of the study area.

2.2 Site description

2.2.1 Soft shore (Bream Bay open coast)

The Bream Bay coastline comprises sandy beach backed by sand dunes and can be described as a soft shore coast. The average sand dune height along Bream Bay is 6.7 m above MSL.

Bream Bay is located on the north east coast of North Island New Zealand. The Bream Bay study area is bound by Marsden Point in the north and Waipu Cove in the south. The bay is generally aligned to the north east and is approximately 23 km long.

Bream Bay is a sandy beach which is intersected by both the Ruakaka and Waipu Rivers. The primary sediment source for Bream Bay has been nearshore and inner shelf deposits which were delivered by the Waikato River during the low sea level of the last glacial maximum (Nichol, 2002).

Bream Bay experiences a low to moderate energy wave climate, in the New Zealand context. The maximum recorded wave height for Bream Bay is 9m (H_{max}), which occurred during the July 1978 storm event (Duder and Christian, 1983). This record appears consistent with other more recent observed maximum wave heights in the area.

The mean significant wave height for Bream Bay was recorded at 0.7m for the period March 1995 to June 1997 (Nichol, 2002). The principal direction of swell incidence to the Bream Bay coast is from the north east to east sector. The Bream Bay coast is partially sheltered from this direction by the promontory of Bream Head. Bream Head forces waves from the north east direction to refract fully before reaching the shoreline.

Based on hydrographical charts the 10 m depth contour is approximately 830 m offshore along the majority of the Bay (i.e. slope of 0.012). The offshore bathymetry changes north of the Ruakaka River mouth, where the Whangarei Harbour ebb tide delta reduces the offshore slope to 0.0045. The wide, low gradient nearshore zone associated with the ebb tide delta has a dissipative effect of incident waves in this area.

Sandy soft shore coasts are a dynamic environment, where the morphology is dependent on seasonal and climatic cycles. The beach profiles are dominated by the cut and fill cycle. Beach sediment volumes decrease over the winter months as storm waves cut sand from the backshore. This sand is placed in the nearshore to form alongshore bars. Over the summer months the beach volume generally increases as sand is transported onshore forming a berm and high tide beach.

Soft shores are also affected by increasing sea level rise. Sandy coasts that have been relatively stable over time are likely to show a bias towards erosion with rising sea levels, unless the supply of sand to the beaches can keep pace with erosion.

2.2.2 Cliff shore (One Tree Point)

The coastal barrier plain between One Tree Point and Marsden Bay is a cliff shore comprising Pleistocene coastal sand deposits. The Pleistocene barrier plain includes One Tree Point and is bound by Takahiwai estuary to the west and Blacksmiths Creek to the East. The Pleistocene deposits comprise cemented dune sands overlying sandy beach and nearshore seabed deposits.

The crest elevation of the ridges at One Tree Point ranges from 8-11 m. This stratigraphy was formed as the shoreline advanced under falling sea level during the last interglacial period approximately 125,000 years ago (Nichol, 2002).

The land between Blacksmiths Creek and the current open coast shoreline comprises sand dunes formed during the Holocene under prograding conditions after sea level reached its present level approximately 6,500 years ago.

Cliff shores are prone to long term erosion because unlike soft shores, cliff erosion is a one way process. The main causes of cliff erosion in the coastal environment include:

- mechanical erosion, whereby the movement of rock and sand by wave action causes abrasion of cliff surfaces
- hydraulic action, by which the shock force of breaking waves and rapid increases and decreases of pressure in cracks and crevices cause rock to break down
- mechanical weathering, which involves processes such as wet/dry cycles, water absorption, unloading and frost and salt weathering
- chemical weathering from chemical reactions e.g. breaking down the existing rock structure to clay particles
- mass movement, which generally includes falls, slides, and flows. These movements occur primarily along defects or after other erosional processes have weakened or destabilised sections of cliff
- wind erosion, which can remove loose material from a cliff face or toe.

The cliff shoreline along the study site can be described as a soft cliff type due to the weakly cemented nature of the Pleistocene sand material. Due to the soft, readily erodible nature of the soft cliff, rates of erosion may potentially increase due to sea level rise, with more hydraulic action acting on the cliff toe (Defra, 2002).

2.2.3 Harbour shore (Marsden Bay)

Marsden Bay consists of a sandy beach shoreline with a low backshore berm height of approximately 1.5 - 2 m above Mean Sea Level (MSL). The sandy beach is approximately 40 -50 m wide and is fronted by an intertidal flat that extends approximately 500 m out to the main harbour channel. Marsden bay is relatively sheltered from incident wave energy and can be classified as a harbour shore. Marsden Bay has been largely modified since the last coastal hazard study. The main modifications to Marsden Bay include:

- NorthPort reclamation at Marsden Point
- training groyne at the entrance to Blacksmith Creek at the eastern end of the bay
- creation of a lagoon at the western end of the bay (Marsden Cove) including entrance training groynes
- beach re-nourishment along the entire Marsden bay shoreline.

The modifications to Marsden Bay have transformed the shoreline into a typical ‘pocket beach’ with control structures (i.e. groynes) at either end retaining the beach sand. The effects of these modifications on coastal processes within Marsden Bay are discussed further in Section 3.

The natural backshore topography at Marsden Bay (excluding Marsden Cove) is low lying (<2 m above MSL) and includes existing residential development. This area is likely to be at risk from inundation from storm surge and predicted sea level rise to both 2060 and 2110. We recommend an assessment of inundation risk for Marsden Bay is also undertaken which considers the effect of SLR to 2110 (refer section 7.2).

2.3 Previous methodology

This section sets out a summary of the previous hazard zone equations and the parameters used by Gibb (1998a and 1998b).

The coastal erosion hazard zone for soft shore beaches (CEHZ) was based on the following equation:

$$\boldsymbol{CEHZ = [(X + R)T + S + D]F} \qquad \textbf{(1)}$$

The coastal landslide hazard zone for cliff shores (CLHZ) was based on Equation 2:

$$\boldsymbol{CLHZ = [(R \times T) + S]F} \qquad \textbf{(2)}$$

Where:

X was the horizontal rate of shore retreat as a result of future sea level rise based on the Bruun Rule. Sea level rise based on the IPCC (1996) sea level rise estimates of 0.2 m by 2050 and 0.49 m by 2100. The closure depth below MSL was based on surveyed profiles and studies from other parts of New Zealand (Hume and Hicks, 1993; Gibb and Reinen-Hamill, 1997). The closure depths ranged from -4.0 to -6.0 m for sheltered locations and from -10.2 to -16.0 m for more exposed beaches. The crest height of the dune was taken from field survey.

R was the long term rate of erosion or accretion which was calculated from the aerial plans measured at a scale of 1:2,000 to 1:5,000 and a field survey of the 1998 dune toe position. Where the R was accretionary (i.e. historically the beach has been accreting) and the accretion rate exceeded the potential erosion effects of sea level rise effects (i.e. R greater than X), the X+R components were removed from the equation. If R was accretionary but did not exceed X there was a reduced set back due to climate change. This method created significant fluctuation along short stretches of coast where R values varied from negative (erosion) to positive over stretches of less than several kilometres. This has an effect of creating areas where there was little horizontal distance between the two hazard zones.

T was the time scale to 2050 (55 years) and 2100 (105 years).

S was the maximum potential short-term dune line fluctuation or cliff crest retreat based on field investigations and anecdotal observation. The observations were translated to horizontal distances from the dune and cliff toe.

D was the horizontal distance of retreat of the top seaward edge of the dune erosion scarp, which was based on half the height of the dune above MSL divided by the angle of repose of sand, which was taken to be 33 degrees.

F was a factor of safety, taken to be a factor of 1.3 for the CEHZ and 1.4 for the CLHZ.

Both the CEHZ and CLHZ were divided into two zones:

- CHZ_1 based on a time scale of 2050AD
- CHZ_2 based on a time scale of 2100AD.

The hazard zone widths were derived at specific stations. The hazard zone width between stations was interpolated based on aerial plans and field mapping.

2.4 Information sources

This coastal erosion hazard review is based on the following updated information:

- extended Northland Regional Council (NRC) beach profile dataset
- historical aerial imagery
- topographic GPS surveys
- topographic LiDAR information
- updated IPCC reporting on the effects of climate change on sea level rise
- Ministry for the Environment guidelines on managing coastal hazards (MfE, 2008)
- relevant reports, research papers and thesis.

A comprehensive listing of references is contained in the bibliography.

3 Review of new development and erosion mitigation works

3.1 Marsden Bay

Marsden Bay has been significantly modified since the last coastal hazard study, over ten years ago. The modifications that are likely to alter coastal process and hazards include:

- NorthPort reclamation at Marsden Point
- training groyne at the entrance to Blacksmith Creek at the eastern end of the bay
- Marsden Cove access channel
- beach re-nourishment along the Marsden Bay shoreline.

The following sections will discuss the changes and implications on coastal processes and hazards.

3.1.1 NorthPort Ltd reclamation

A 30 hectare reclamation as part of NorthPort Ltd expansion was constructed from 2000 to June 2002. As part of the Resource Consent process an environmental impact assessment (EIA) was undertaken (Den Ouden Asssociates 1993). The aim of the AEE was to assess the effects of the reclamation, including coastal process, particularly changes in water currents and associated sediment transport.

A numerical model was used to assess the effects of the reclamation on water movement (Barnett Consultants Limited 1993). The results of the modelling concluded that the current and sediment regime in the Blacksmiths Creek/Marsden Bay would be little changed with the reclamation.

However, evidence below suggests that sediment regime along the coast has been affected by the reclamation.

The reclamation is located along the southern shoreline of Whangarei Harbour, near the harbour entrance. Along this shoreline the predominant westerly along shore transport is likely to be due to the predominant wave direction from the east entering the harbour (especially low period swell). However, considering the predominant wind direction is from the west, there are likely to be periods of easterly along shore transport.

Evidence for net westerly along shore transport is shown by the orientation of the spit at Blacksmiths Creek pre-reclamation. More recent evidence of westerly alongshore transport is the accumulation of sediment immediately east of the reclamation, resulting in significant progradation of the shoreline.

The resulting decrease of along shore sediment supply due to the reclamation has caused the shoreline east of Blacksmiths creek to significantly erode. The eroding shoreline is likely to reach an equilibrium position sometime in the future. However, the location of the equilibrium shoreline is difficult to predict. Increased wave energy may enter Blacksmiths creek, should the shoreline erode further. The possible increased wave energy may cause accelerated erosion along the shoreline south of the Blacksmiths Creek training groyne .

However, due to the significant amount of recent modifications of Marsden Bay (refer sections below) the effects on Marsden Bay east of the training groyne from the modifications are difficult (impossible) to quantify at this stage.

3.1.2 Training of Blacksmiths creek

A realignment of Blacksmiths Creek was undertaken in the late 1990's. The realignment consists of two groynes extending ~ 168 m from the shoreline adjacent to the mouth of Blacksmiths Creek.

The landward groyne extends ~100 m with the seaward 55 m of the groyne offset to the east by ~ 10 m. The offset is presumably for sediment bypassing through the groyne.

The original alignment of Blacksmiths Creek travelled approximately 250 m along the eastern end of Marsden Bay, parallel to the foreshore. The original alignment caused erosion along the eastern end of Marsden Bay.

Since construction of the groynes, the risk of erosion along Marsden Bay has been significantly reduced. In conjunction with beach re-nourishment (Section 3.1.4) the beach width has increased some 40 m.

3.1.3 Marsden Cove access channel

Marsden Cove is a canal development built in 2007. To access the sea, an access channel was built through the existing foreshore, through the intertidal flats out to deepwater. Training groynes were built along the flanks of the channel as it passed through the beach system. The groynes are approximately 50m long. The access channel and groynes have now essentially split Marsden Bay into two separate systems.

Both systems are now contained within control structures at their western and eastern ends, limiting along shore transport out of each system. Therefore, the access channel is unlikely to significantly exacerbate sand loss from the beach system due to the channel groynes.

3.1.4 Marsden Bay beach nourishment

Approximately, 90,000 cubic meters of sand from capital dredging of the Marsden Cove access channel has been placed onto Marsden Bay as part of a beach re-nourishment project. The initial 90,000 cubic metres has been spread along the foreshore/beach system between the existing groynes/control structures. The re-nourishment has widened the beach by some 40 m.

Material from periodic maintenance dredging of the access channel (approximately 5,000 to 10,000 cubic meters annually) will be placed along the beach to ‘top up’ the initial re-nourished beach. The beach re-nourishment program is also a significant contributor to reduced risk of coastal erosion in the short to medium term.

3.1.5 Marsden Bay summary

The effects of the NorthPort reclamation on Marsden Bay (west from Blacksmith Creek) is difficult to assess considering the other modifications (training groynes, access channel and re-nourishment) that have occurred in the Marsden Bay area. However, we consider the modifications within Marsden Bay have significantly decreased the risk of coastal erosion in the short to medium term.

3.2 One Tree Point

The cliff shore west of One Tree Point currently has consented structures (rock riprap and timber walls) at the base of the cliffs. Rock rip rap protection along the base of the cliff areas east of One Tree Point is currently under construction. The structures are to protect the base of the cliffs from erosion caused by the action of tides and waves.

While the structures are likely to reduce the current rate of erosion due to coastal processes, they are unlikely to mitigate other mechanisms that contribute to retreat of the cliff top. The rate of cliff retreat is likely to be much more sensitive to changes in drainage and moisture processes, such as extremes of drought and heavy rainfall. Human interference is also likely to cause some cliff top retreat.

The consented cliff toe protection has a limited consent period (maximum of 35 years). After this period there is no guarantee that the consent for the works will be renewed. Therefore, we recommend that in areas where consented coastal cliff protection exists; the CEHZ should still represent the potential retreat to 2110 using Equation 6 (Section 4.2). However, allowance should be made through policy to account for the coastal cliff protection (refer to Section 6).

4 Coastal erosion hazard assessment

4.1 Soft shore coastal erosion hazard methodology

The methodology to determine the coastal erosion hazard zones includes the cumulative addition of:

- episodic storm induced erosion
- short term fluctuations in shoreline movement
- expected long term erosion rates
- dune stability
- predicted climate change effects.

The coastal erosion hazard methodology used in this review is based on the original methodology developed by Gibb (1998) as described in Section 2.3 (Equation 1). However, we recommend modifying Equation 1 to account for increased accuracy of underlying datasets and methods. The key difference is the factor of safety (F) is only applied to the short term fluctuation (S) and long term rate (R).

No safety factor is required to account for inaccuracies in determining dune stability (D) as the LiDAR survey data and GIS techniques provide a high degree of accuracy. Also, the upper bounds of recommended sea level rise estimates have been used to calculate X, which is considered a precautionary approach and a further safety factor is not required.

Following this methodology, Equation 3 was used to determine the width of the coastal erosion hazard zone, for soft shores.

$$\boldsymbol{CEHZ_{soft\,shore} = [X + (R \times F)]T + (S)F + D} \qquad \textbf{(3)}$$

Where:

CEHZ$_{\textbf{soft shore}}$ is the width of the coastal erosion hazard zone for soft shores (i.e. Bream Bay open coast sandy beach).

X = Horizontal coastline retreat due to possible accelerated sea level rise (m/yr).

R = Historic long term rate of horizontal shoreline movement (m/yr).

T = Planning time frame (years).

S = Horizontal distance of shoreline retreat from both storm induced erosion and short term fluctuations in the long term trend of shoreline movement (m).

F = Factor of safety.

D = Horizontal retreat of the vertical erosion scarp based on the angle of repose for loose sand (m).

Further descriptions of the coastal erosion hazard components are set out in the following sections.

4.1.1 Long term rates of shoreline movement (R)

The long term retreat rate (R) is an estimate of the average shoreline movement at the toe of the dune. The rates defined by Gibb (1998) were based on an end point rate (EPR) measured from the oldest reliable survey plan to the 1998 field survey (spanning approximately 35 years). The EPR method is influenced by the timing of the surveys in relation to storm events and may underestimate rates in areas where no storm cut occurred prior to the survey being undertaken (Dolan *et. al.,* 1991). Gibb (1998) applied this methodology to 45 discrete sections along Bream Bay. The adopted rates ranged from -0.48 m/yr of erosion to 3.78 m/yr of accretion and no longshore trend was apparent.

The long term trends calculated for this latest review were based on linear regression analysis of the dune toe from the extended NRC beach profile dataset (1976 – 2009). The results of the beach profile analysis are presented in Appendix B. The analysis provides a linear regression rate (LRR), which utilises all data points over the survey period and is more sensitive to cyclic trends (Dolan *et. al.,* 1991). The results show the majority of Bream Bay shoreline between Marsden Point and Waipu Cove is dynamically stable with no apparent long term trend of erosion. However, the two profile sites at either end of the bay show a trend of long term erosion. In our opinion the Bream Bay coastline can be split into three sections with distinct long term trends:

- Northern Section (s8) - erosion trend of approximately -0.26 m/yr.
- Central Section (s11– s17) - dynamic equilibrium with no discernable long term movement.
- Southern Section (s22) - erosion trend of approximately -0.30 m/yr.

The longshore extent of the three sections was defined by analysing ortho-rectified aerial photographs covering the same period. The results of this analysis are presented in Appendix C.

The Northern Section includes approximately 150 m of accreting shoreline that is partially sheltered by the ebb tide delta (Mair Bank) (Appendix C). The accretionary trend may change during the planning time frame as increasing sea level rise reduces the wave buffering effect of Mair Bank over time.

Furthermore, the ebb tide delta is a dynamic feature that changes morphology in response to wave climate and sediment transport patterns (Morgan, 2008). Mair Bank alters the relative wave energy along the lee coast acting as a control feature on shoreline behaviour. Therefore, the shoreline in this area is more dynamic than the Bream Bay shoreline outside the influence of the ebb tide delta.

Following the precautionary approach of this study, the accreting shoreline in lee of Mair Bank is included in the Northern Section as having an erosion trend.

Future shoreline movement may differ from historic trends due to climatic patterns associated with Interdecadal Pacific Oscillation (IPO) and global climate change. To provide an appropriate precautionary approach, areas of inferred long term accretion as well as areas showing dynamic stability had the long term erosion component set to zero. This means that historic accretion is not extrapolated into the future.

4.1.2 Short term shoreline movement (S)

The short term erosion rate (factor **S**) takes account of both storm induced erosion and fluctuations around the observed long term trend of shoreline movement.

Short term erosion may occur in response to severe wave storms moving toward the coast from the north to north east quadrant. However, there are also short term fluctuations in shoreline position over a longer period than an individual storm event. These fluctuations are in response to natural variations in climatic conditions and sediment supply. For example, there may be variations in the direction and magnitude of shoreline movements associated with El Nino Southern Oscillation (ENSO), which typically occur within a three to seven year cycle.

Short term erosion was analysed using a number of different methods based on the beach profile data set (the results of this analysis are presented in Appendix B). For the purposes of this study it was considered important to define a suitably precautionary level of risk. In our opinion, the fluctuation defined by the maximum movement in an erosion phase appears in the right order at this location to represent the maximum extent of shoreline movement that could occur due to significant storm events and cyclical shoreline movement. Therefore, the maximum observed value of -29 m (rounded to 30 m) over the 33 year dataset was taken as the short term erosion component (factor **S**) of the upper beach/dune toe for this study.

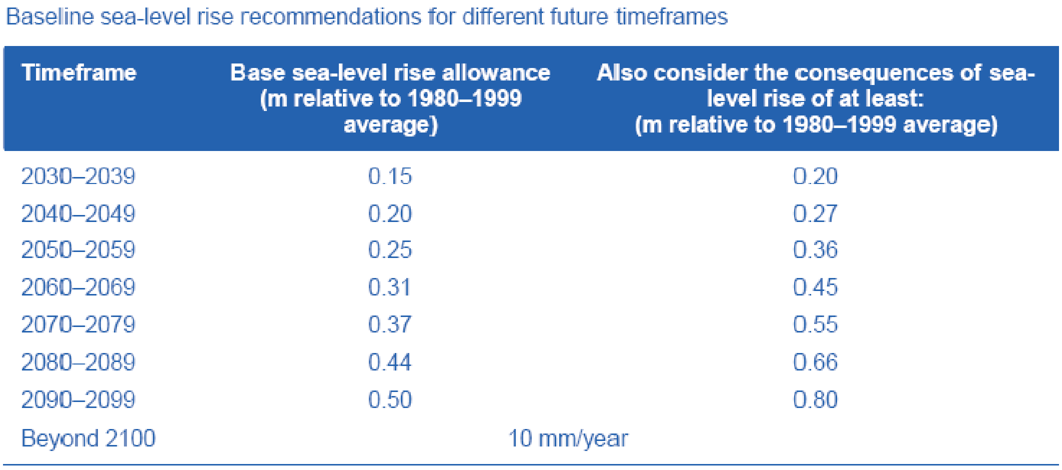
This approach differs from the approach used by Gibb (1998) in terms of applying a single value to represent short term erosion along the entire shoreline. Gibb (1998) used range of short term erosion values between Marsden Point and Waipu Cove, ranging from 10 - 40 m with an average of 30 m (Gibb, 1998a). The approach proposed through this review is considered the most appropriate after careful assessment of the updated information and data sets, and compares well with the previous study (Gibb, 1998).

4.1.3 Sea level rise effects including land movement (X)

The Ministry of Environment (2008) guideline recommends a base value sea level rise of 0.5 m by 2100 (relative to the 1980-1999 average). Furthermore, the Ministry of Environment (2008) suggest assessing the potential consequences from a range of possible higher sea level rises, with, at the very least, consideration of the consequences of mean sea-level rise of at least 0.8 m and an additional sea level rise of 10 mm per year beyond 2100. Figure 4-1 shows the recommendations as set out by MfE.

The time lines used for this study are 2060 and 2110 (i.e. approximately 50 and 100 years from present). The resulting sea level rise components are 0.36 m and 0.9 m respectively from 1990 levels (taken as the mid range of 1980 to 1999). Therefore, the rate of sea level rise from 1990 to 2060 and 2110 is calculated as 0.00514 m/yr and 0.0075 m/yr respectively.

The study site is regarded to be relatively stable from tectonic effects during the Holocene period (Gibb, 1984; Pillians, 1990 &1991; Nichol, 2002). In our opinion, no adjustments for vertical land displacement are required for sea level rise during the planning period of 2110.



Baseline sea-level rise recommendations for different future timeframes

Timeframe	Base sea-level rise allowance (m relative to 1980–1999 average)	Also consider the consequences of sea-level rise of at least: (m relative to 1980–1999 average)
2030–2039	0.15	0.20
2040–2049	0.20	0.27
2050–2059	0.25	0.36
2060–2069	0.31	0.45
2070–2079	0.37	0.55
2080–2089	0.44	0.66
2090–2099	0.50	0.80
Beyond 2100	10 mm/year	

Figure 4-1 Extract from MfE 2008 showing baseline sea level rise recommendations for different future timeframes

Future sea level rise will permit waves to attack the backshore and fore dunes more frequently. Sandy open coasts that have been relatively stable over time are likely to show a bias towards erosion with rising sea levels, unless the supply of sand to the beaches can keep pace with erosion.

The potential shoreline change due to accelerated Sea Level Rise (SLR) is assessed using the Bruun Rule. The Bruun Rule predicts the effect of SLR is a corresponding upward and landward movement of the shoreline (Figure 4-2).

The rate of shoreline retreat from the effects of sea level rise is defined by the Bruun Rule given as:

$$\boldsymbol{X} = \frac{\boldsymbol{a \times l}}{\boldsymbol{h+d}} \qquad \textbf{(4)}$$

Where:

X is the rate of shoreline retreat from the effects of sea level rise (m/yr).

a = Rate of sea level rise (SLR). Estimates of sea level rise were derived from the most recent climate change guidelines published from the Ministry for Environment (MfE). No factor of safety will be used on sea level rise effects as the upper levels of estimates recommended by MfE have been used.

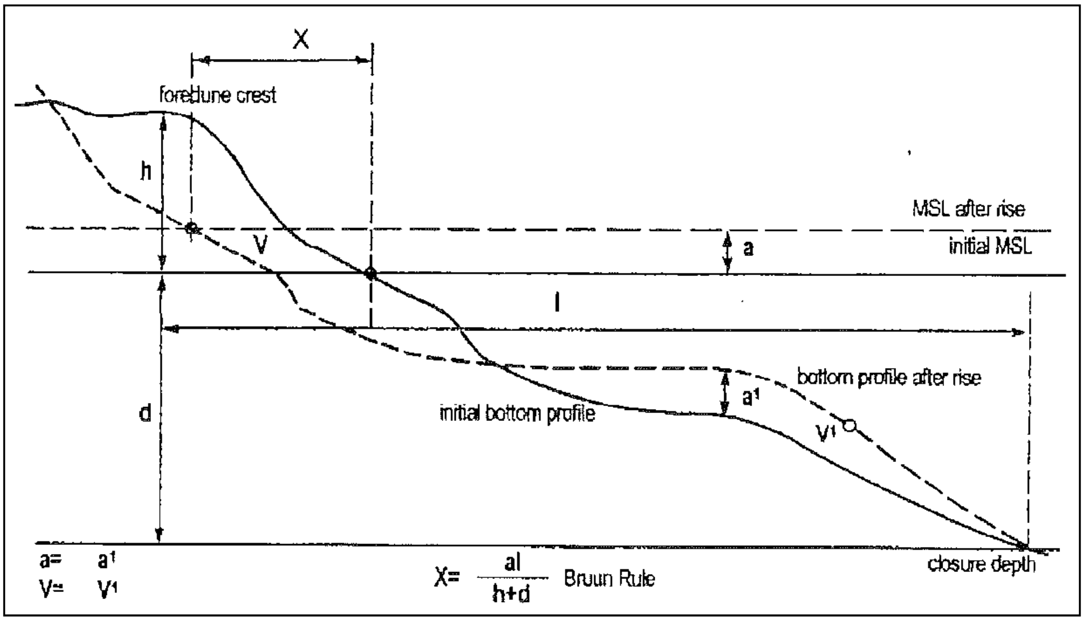


Figure 4-2 Diagram showing the response of the beach and nearshore to sea level rise (adopted from Gibb and Aburn, 1986). Refer to text below for component description.

l = Distance from fore dune crest to the contour representing the closure depth (m).

h = Height of fore dune crest above MSL. The height of the fore dune crest above MSL is captured at each transect from a DTM based on the 2007 LiDAR survey.

d = Closure depth is the seaward limit of nearshore transport and is delineated as a depth or position offshore. Gibb (1998b) determined a range of closure depths over the study area based on hydrographic survey work, which was validated against previous studies within the Bay of Plenty (Gibb & Abum, 1986; Harray & Healy, 1978; Hume & Hicks, 1993). Two other local studies that report on closure depth have also been reviewed as part of this assessment. The results of these studies along with those reported in Gibb (1998b) are shown in Table 4-1 below.

Table 4-1 Closure depth values from previous studies

Location	Method	Value (m)
[1]Marsden Point to Ruakaka	Survey analysis	5.0-14.0
[1]Ruakaka to Waipu	Survey analysis	16.0
[2]Mangawhai - Parkiri	Inner Hallermeier Limit	10.1
[3]Parkiri	Survey, sediment, profiles, and wave climate	10.0
Source: [1](Gibb, 1998b); [2](Hesp and Hilton, 1996); [3](Hume *et. al,* 2000).		

The offshore limits of sediment transport from waves can be determined using the Hallermeier (1981a, 1981b) method. The inner limit (HIL) defines the littoral zone, which is the area of intense diabathic (onshore – offshore) transport. For the purposes of this study the inner depth limit has been used to define closure depth (Equation 5).

$$\boldsymbol{HIL = 2H_S + 11\sigma} \qquad \textbf{(5}$$

Where:

HIL is the inner Hallermeier limit.

H_s = Annual mean significant wave height (m).

σ = Annual standard deviation wave height (m).

Wave parameters for the site were reviewed from existing literature (Duder and Christian, 1985; Hesp and Hilton, 1996; Gorman et al, 2003) to determine the approximate values of H_s and σ. Based on this review, H_s ranged from 1.19-1.5 m and the resulting closure depth was in the order of 9 – 10 m below MSL.

The upper end of this range is in good agreement with the estimate of closure depth for the Mangawhai-Pakiri embayment of approximately 10 m (Hesp and Hilton, 1996; Hume *et. al.,* 2000) (Table 4-1). The Mangawhai-Pakiri embayment is located directly south of Bream Bay, and can be considered of similar wave climate.

The offshore distance of the closure depth was determined from LINZ Hydrographic chart NZ52. The 10 m depth contour is approximately 900 m offshore from Waipu to Ruakaka. The area between Ruakaka and Marsden Point has a lower nearshore slope associated with the Whangarei Harbour ebb tide delta. The 10 m depth contour ranges from 1 km to 4.8 km in this area. The 10 m depth contour was used in the GIS model to represent closure depth feature for this project.

4.1.4 Dune stability (D)

The dune stability factor delineates the area of potential risk landward of the erosion scarp. This parameter is based on the angle of repose for loose dune sand (33°). The dune stability factor is applied as a horizontal distance from the resulting short term erosion dune toe position at Mean Sea Level (MSL). Following the original methodology of Gibb (1998), the horizontal distance is halved to provide a more representative distance as the recovered dune toe is unlikely to extend down to MSL. The dune stability components are detailed in Appendix D. This component is the same as used by Gibb (1998), although the LiDAR survey has improved the assessments of the dune crest elevation.

4.1.5 Planning time frame (T)

To provide a sufficient time scale for planning and accommodating development, around a 50 year and 100 year planning horizon were adopted for the purposes of this study:

- 51 years (2009 – 2060) which equates to $CEHZ_1$
- 101 years (2009 – 2110) which equates to $CEHZ_2$.

4.1.6 Factor of safety (F)

A safety factor of 1.3 was adopted to accommodate uncertainties in factor S and R for both the Southern and Central Sections. This is a same safety factor derived by Gibb. An increased safety factor of 1.5 is used for the Northern Section to allow for uncertainty due to the unknown effects of the ebb tide delta on controlling shoreline movement.

4.2 Cliff shore coastal erosion hazard methodology

The coastal erosion hazard methodology is based on the original methodology developed by Gibb (1998) as described in Section 2.3 (Equation 2). However, a modification of Equation 2 is recommended to include the effects of accelerated sea level rise.

A cliff face erodes back episodically at a rate not less than the rate of cliff toe retreat. The cliff top can erode back faster than the toe due to cliff lithology and geologic structure (Figure 4-3). Using long term retreat solely, gives no allowance for the episodic events that may cause large retreat in localised areas. A precautionary approach is used to make allowance for these one-off events and the methodology takes into account the following components:

- gradual long term retreat caused by weathering, marine and bio-erosion processes
- short term episodic failures due to cliff lithology and geologic structure
- predicted climate change effects.

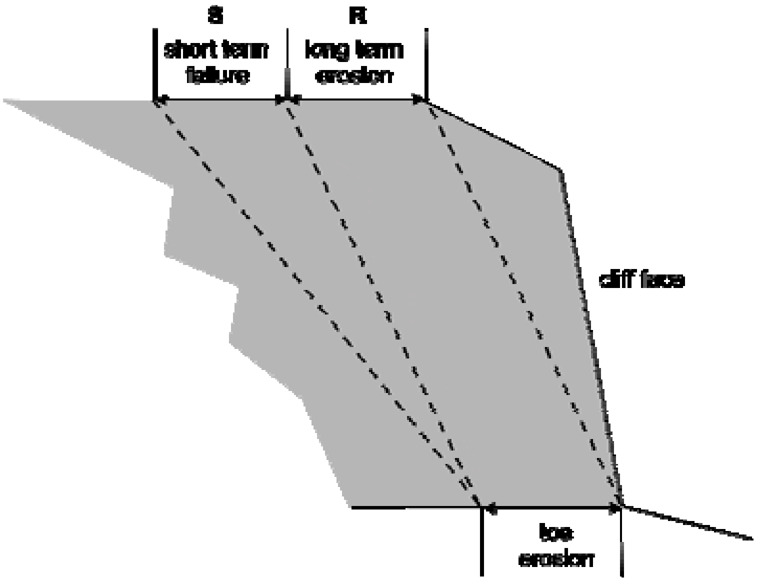


Figure 4-3 Components of cliff shore retreat

The revision to the Gibb (1998) cliff hazard methodology (Equation 2) used to determine the width of the coastal erosion hazard zone, for cliff shores is defined as:

$$\boldsymbol{CEHZ_{cliff\ shore} = (X \times T) + (S)F} \quad \textbf{(6)}$$

Where:

X = Horizontal long term retreat due to possible accelerated sea level rise (m/yr).

T = Planning time frame of 51 and 101 (years).

S = Horizontal of shoreline retreat from short term episodic cliff failure events (m).

F = Factor of safety.

Further descriptions of the coastal erosion hazard components are set out in the following sections.

4.2.1 Sea level rise effects (X)

Due to the weakly cemented nature of the cliff material, rates of erosion may potentially increase due to sea level rise, with more hydraulic action acting on the face of the cliff (Defra, 2002). Therefore allowance needs to be included for accelerated sea level rise effects. This was done by applying a factor to the historic long term retreat rate based on the predicted relative increase in sea level (refer to Section 4.1.3). The formula for accelerated sea-level rise induced retreat is given as:

$$\boldsymbol{X = R \times \left(\frac{SLR_F}{SLR_H}\right)} \quad \textbf{(7)}$$

Where:

R = Historic long term rate of horizontal shoreline movement (m/yr)

SLR_H = Historic sea level rise rate for Auckland of 1.4 mm/yr, (Bell, pers comm. 2009)

SLR_F = Future sea-level rise rate of 5 mm/yr, based on 0.36 m increase at 2060 from 1990 levels, and 7.5 mm/yr, based on 0.90 m increase at 2110 from 1990 levels (MfE, 2008).

This formula is used by the National Research Council in the UK to assess cliff erosion effects of sea level rise (Defra, 2002). The formula assumes that future erosion will be proportional to the ratio of future to past sea-level rise.

4.2.2 Long term retreat (R)

The long term retreat rate (R) is an estimate of the average shoreline retreat at the toe of the cliff. Gibb (1998) analysed long term retreat rates for the cliff shores from aerial photographs (1942, 1985 and 1997). This method is influenced by the timing of the aerial photographs in relation to cliff failure events and may underestimate rates in areas where no recent slips occurred prior to the photograph being taken.

Gibb (1998) adopted a series of rates for discrete sections of coast ranging from -0.02 to -0.10 m/yr. The maximum value of -0.10 m/yr was recorded at a number of locations within each section of cliff shore and no longshore trend was apparent.

The long term erosion rate is expected to be relatively constant along the cliff shore due to the uniform cliff geology. Therefore, for the purposes of this study, the maximum long term erosion value of -0.10 m/yr was adopted for the entire cliff shore.

A large proportion of the cliff shore is fronted by ad-hoc erosion protection structures. The structures are in a varied state of condition and some sections have failed. We understand the majority of structures are privately owned and do not have resource consent. Therefore in terms of long term retreat, this methodology assumes the absence of erosion protection structures, which is consistent with the previous approach (Gibb, 1998b).

However, there are consented sea wall structures west of One Tree Point and a seawall east of One Tree Point is being constructed. These seawalls and the implications for long term cliff movement are discussed in Section 6.

4.2.3 Planning time frame (T)

To provide a sufficient time scale for planning and accommodating development, around a 50 year and 100 year planning horizon were adopted for the purposes of this study:

- 51 years (2009 – 2060) which equates to $CEHZ_1$
- 101 years (2009 – 2110) which equates to $CEHZ_2$.

4.2.4 Short term cliff crest movement (S)

The short term erosion rate (factor **S**) takes account of maximum potential instantaneous retreat of the cliff crest. Gibb (1998b) adopted two short term erosion values of 4.0 m for cliff shore east of One Tree Point and 6.0 m for cliff shore west of One Tree Point. The 2009 survey, undertaken as part of this study, captured the cliff top edge position for sections that had recent failure events. The maximum horizontal retreat recorded in these areas between the 1997 and 2009 surveys was 3.5 m. Therefore, the values calculated by Gibb (1998) for short term cliff retreat are still considered appropriate and are retained for this study.

4.2.5 Factor of safety (F)

There is large uncertainty associated with the effects of climate change and an increase in sea level rise on cliff shores. The upper bounds of recommended sea level rise estimates have been used to calculate X, which is considered a precautionary approach. Therefore, no safety factor is required for the X component. Short term cliff retreat is likely to be much more sensitive to changes in drainage and moisture processes, such as extremes of drought and heavy rainfall. A safety factor of 1.4 was adopted to accommodate uncertainties, which is the same safety factor derived by Gibb (1998).

4.3 Harbour shore coastal erosion hazard methodology

The coastal erosion hazard methodology for Marsden Bay is based on the original methodology developed by Gibb (1998) as described in Section 2.3 (Equation 1) and is similar to Equation 3 for soft shores (Section 4.1). However, the effect of sea level rise on harbour shores is calculated by a different method, where the output is a horizontal distance rather than a rate over time.

Following this methodology, Equation 8 was used to determine the width of the coastal erosion hazard zone, for soft shores.

$$\boldsymbol{CEHZ_{harbour\ shore}} = [\boldsymbol{X} + \boldsymbol{S} + (\boldsymbol{R} \times \boldsymbol{T})]\boldsymbol{F} + \boldsymbol{D} \qquad \textbf{(8)}$$

Where:

$CEHZ_{harbour\ shore}$ is the width of the coastal erosion hazard zone for harbour shores (i.e. Marsden Bay)

X = Horizontal coastline retreat due to possible accelerated sea level rise (m)

R = Historic long term rate of horizontal shoreline movement (m/yr)

T = Planning time frame (years)

S = Horizontal distance of shoreline retreat from both storm induced erosion and short term fluctuations in the long term trend of shoreline movement (m)

F = Factor of safety

D = Horizontal retreat of the vertical erosion scarp based on the angle of repose for loose sand (m)

Further descriptions of the coastal erosion hazard components are set out in the following sections.

4.3.1 Effect of sea level rise on harbour shores

The effects of sea level rise on harbour beach shoreline position will depend on a complex interrelationship between:

- the topography of the estuary/harbour
- the increase in tidal prism volume
- the estuary's sediment storage
- river and open ocean inputs of sediment
- erosion of adjacent beaches.

Sedimentation rates in most North Island estuaries have been 2-4 mm per year thus far, keeping up with the present rise in sea level. Eventually, the acceleration in sea level rise is likely to exceed sedimentation (MfE, 2008). This may occur more quickly in urban areas where catchments are developed and restrict sediment supply.

Where the landward retreat of the high water mark is constrained due to morphology, geology or coastal defences, intertidal areas and their associated ecosystems may be reduced and potentially 'squeezed out'.

The dynamics of coastal and estuarine/river processes and multi-year cycles of sand exchange between the estuary, ebb and/or flood deltas and the adjacent coastline are very complex. Thus any reliable statement about how individual inlet systems may respond to climate change effects is extremely difficult to make. However, it is probable that there would be some shoreline retreat under accelerated SLR conditions.

One approach is to assume that the sediment supply and active beach width remains constant during a change in sea level. The beach profile is likely to respond to these conditions with an upward and landward translation over time (Komar, 1998). The landward translation of the beach profile (**T**) can be defined as a function of SLR (**Δs**) and the active beach slope (**tanα**) out to the beach toe (Komar, 1991; Hennecke and Cowell, 2000). This relationship is given in Equation 9 and displayed in Figure 4-4.

$$X = \frac{\Delta s}{\tan \alpha} \quad (9)$$

Where:

X is the landward translation of the beach profile due to sea level rise (m).

Δs = increase in sea level rise (m).

tanα = average slope of the embayment.

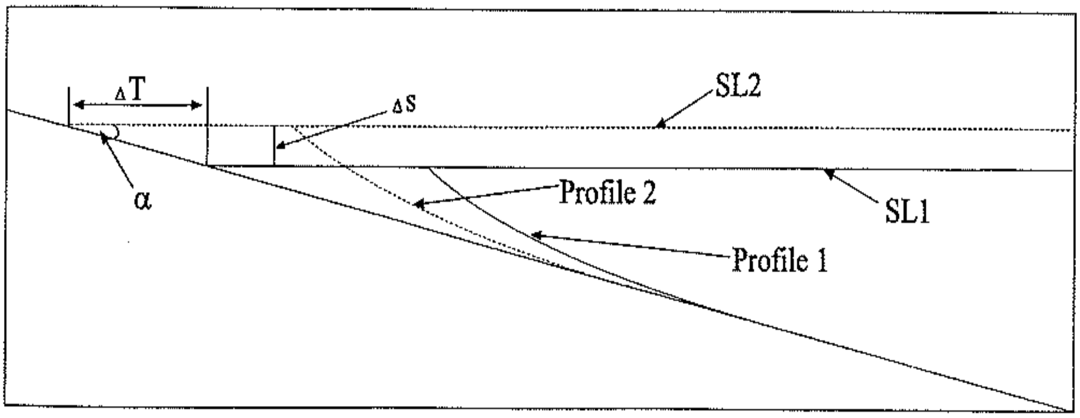


Figure 4-4 Horizontal translation distance of the beach profile under SLR (adopted from Hennecke and Cowell, 2000).

Assuming a predicted sea level rise rate of 0.00514 m/yr to 2060 (0.36 m increase) and 0.0075 m/yr to 2110 (0.9 m increase) (refer to Section 4.1.3 and MfE, 2008), the landward movement of the beach profile (slope 0.02) would be approximately 13 m and 38 m by 2060 and 2110 respectively.

A high degree of conservatism is especially necessary in this particular environment due to the low lying nature of the backshore. Based on the latest LiDAR survey much of the back shore (area of current development) is likely to be inundated by 2060 during storm events (refer to Section 7.2). Therefore, while no accurate inundation assessment has been carried out for this area to date, we feel that the conservative CEHZ assessment highlights the risk from coastal hazards.

4.3.2 Long term retreat (R)

The long term retreat rate (R) is an estimate of the average shoreline retreat at the dune toe. The rates defined by Gibb (1998) were based on an end point rate (EPR) measured from the oldest reliable survey plan to the 1998 field survey (spanning approximately 35 years). This method is influenced by the timing of the surveys in relation to storm events and may underestimate rates in areas where no storm cut occurred prior to the survey being undertaken (Dolan *et. al.,* 1991). Gibb (1998) applied this methodology to 8 discrete sections along Marsden Bay. The adopted rates ranged from -0.21 m/yr of erosion to 0.38 m/yr of accretion and no longshore trend was apparent.

The Marsden Bay shoreline has been modified over the last ten years since the last coastal hazard study (refer Section 3.1). The modifications to Marsden Bay include:

- NorthPort reclamation at Marsden Point
- training groyne at the entrance to Blacksmith Creek at the end of the bay
- creation of a lagoon at the western end of the bay (Marsden Cove) including entrance training groynes
- artificial beach re-nourishment along the entire Marsden bay shoreline.

The modifications to Marsden Bay have transformed the shoreline into a typical ‘pocket beach’ with control structures (i.e. groynes) at either end retaining the beach sand. Therefore, the historic rates of shoreline movement are unlikely to be suitable to assess future shoreline position over the planning time frame. Based on the recent modifications to stabilise Marsden Bay we recommend that the long term retreat rate (R) be set to 0.

4.3.3 Planning time frame (T)

To provide a sufficient time scale for planning and accommodating development, around a 50 year and 100 year planning horizons were adopted for the purposes of this study:

- 51 years (2009 – 2060) which equates to $CEHZ_1$
- 101 years (2009 – 2110) which equates to $CEHZ_2$.

4.3.4 Short term shoreline movement (S)

The short term erosion rate (factor **S**) takes account of maximum potential shoreline retreat. Gibb (1998b) adopted a short term erosion values of 5.0 m for Marsden bay. We consider the values calculated by Gibb (1998) for short term shoreline movement are still appropriate and are retained for this study.

4.3.5 Factor of safety (F)

A safety factor of 2 was adopted to accommodate uncertainties in factors X, S and R. The conservative approach is justified due to the uncertainties involved with estimating future shoreline position in this low lying and dynamic environment.

No safety factor is required to account for inaccuracies in determining dune stability (D) as the LiDAR survey data and GIS techniques provide a high degree of accuracy.

4.3.6 Dune stability (D)

The dune stability factor delineates the area of potential risk landward of the erosion scarp. This parameter is based on the angle of repose for loose dune sand (33^o). The dune stability factor is applied as a horizontal distance from the resulting short term erosion dune toe position at Mean Sea Level (MSL). Following the original methodology of Gibb (1998), the horizontal distance is halved to provide a more representative distance as the recovered dune toe is unlikely to extend down to MSL. The dune stability components are detailed in Appendix D. This component is the same as used by Gibb (1998), although the LiDAR survey has improved the assessments of the dune crest elevation.

4.4 Coastal erosion hazard risk zones

Following the previous methodology (Gibb, 1998a and 1998b), the CEHZ for all shore types were divided into two zones:

- $CEHZ_1$ based a time scale of 2060AD
- $CEHZ_2$ based a time scale of 2110AD.

The hazard zone widths were calculated at 10 m spacing along the shoreline. The CEHZ’s were derived and plotted using a GIS model (refer to Section 5).

4.5 CEHZ setback baseline determination

Following the original methodology of Gibb (1998a & 1998b), the start point of the CEHZ for both the soft and harbour shores is the toe of dune. The dune toe was re-surveyed for this study on 17 September 2009 using a Differentially Corrected GPS.

The start point of the CEHZ for the cliff shore is the seaward edge of the cliff top. The cliff top feature is relatively stable compared to the dune toe The same cliff top, as measured by Gibb (1998), was used as the baseline for the cliff shore CEHZ for this project. The coastal erosion hazard zone is measured horizontally inland from the baseline feature at right angles from the general alignment of the shoreline.

4.6 Impact of river mouths

Flows from river catchments can have a significant effect on local beach profiles and fluctuation of the outlet position. Shorelines adjacent river mouths are dynamic features and can often experience a larger magnitude of shoreline change than the open coast. The Ruakaka River bisects the study shoreline approximately 400 m north of Ruakaka Village.

Gibb (1998a) based the CEHZ width in this area on historic shoreline positions and evidence of short term fluctuations. However, the existing CEHZ (1998) are seaward of surveyed historic shoreline positions (i.e. 1920and 1961). Refer to Appendix E for a location plan of Ruakaka including historic shorelines. In our opinion, the existing CEHZ setbacks (1998) do not appropriately delineate the coastal erosion risk in this area between survey points Z and AA as defined by Gibb (1998a). Therefore, we recommend further investigation is undertaken for the coastal erosion hazard risk in this area. Table 4-2 provides the location of the Gibb (1998a) survey sites at Ruakaka.

Table 4-2 Gibb (1998a) survey sites at Ruakaka

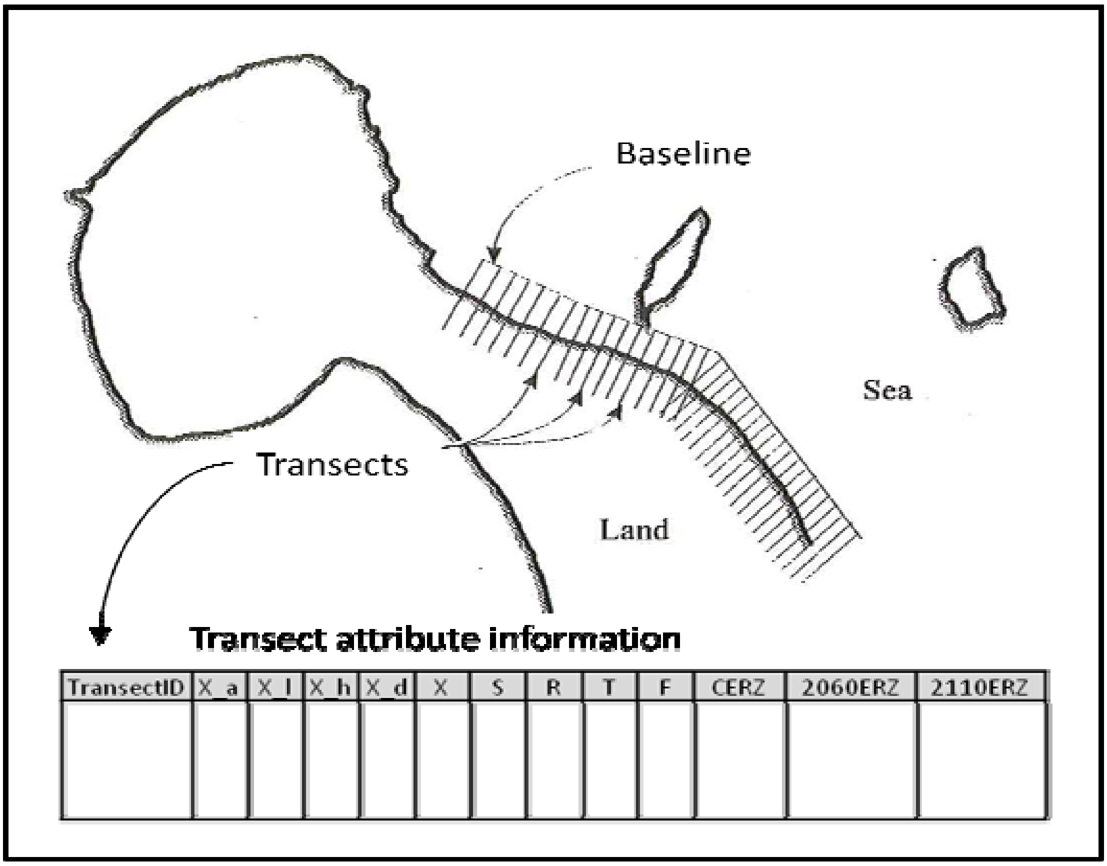
Name	Location	Easting (m)	Northing (m)
Z	Ruakaka River mouth north	1732020	6026339
AA	Ruakaka River mouth south	1731861	6025283

Note: Coordinate system NZTM.

5 CEHZ mapping

5.1 CEHZ mapping methodology

The foundation for the GIS mapping methodology is a series of shore normal (perpendicular) transects, with equal spacing along the coast. The transects were constructed from the baseline which follows the general shape of the coast (Figure 5-1).



TransectID	X_a	X_l	X_h	X_d	X	S	R	T	F	CERZ	2060ERZ	2110ERZ

Figure 5-1 Conceptual diagram of the shore normal transects (Adapted from Gibb, 1996).

The GIS methodology builds up the attribute information for each transect from the input data as described in Section 4. When all necessary attribute information is captured, the coastal erosion hazard zone distances can be calculated based on Equations 3, 6 and 8.

The CEHZ horizontal distances are measured inland from the dune toe along each transect. The two distances are transformed into XY coordinate points for each transect. The positions are then joined to form two shore parallel polylines, which delineate the coastal erosion hazard risk zones (Figure 5-2).

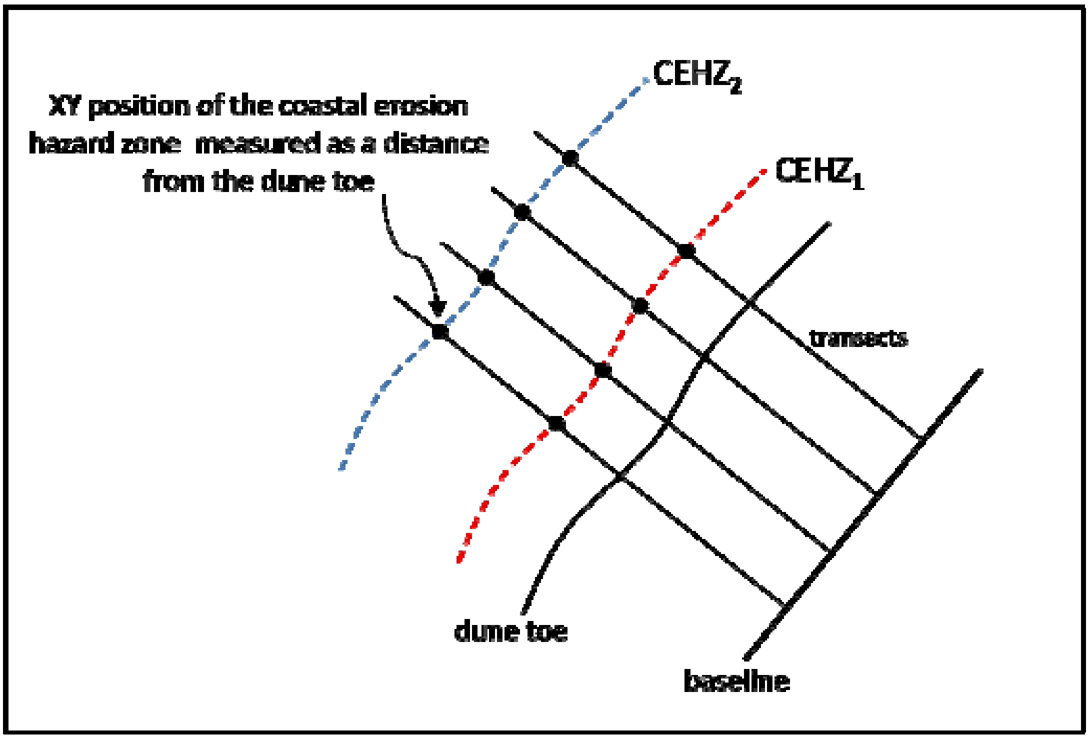


Figure 5-2 Conceptual diagram of the coastal erosion hazard risk zone delineation.

A summary of the GIS mapping methodology is provided in Table 5-1.

Table 5-1 GIS model methodology summary

Pre-processing	- Prepare model input data - Create transects
Processing	- Calculate coastal erosion hazard components based on model input data - Calculate the two coastal erosion hazard zones as a horizontal distance from the dune toe along each transect - Convert the horizontal distances into three XY points along each transect based on trigonometry - Map the following coastal erosion hazard zones from joining the XY points into poylines: $CEHZ_1$ and $CEHZ_2$.

5.2 CEHZ mapping validation

The GIS model has been tested and validated during development in terms of ensuring the calculations are correct and the results verify what is occurring on the ground.

The model output (i.e. the two coastal erosion hazard risk zones) was validated at 7 locations

- One Tree Point West
- One Tree Point East
- Marsden Bay
- Marsden Point

- Village beach profile location
- Ruakaka
- Waipu Cove.

The following validation checks were made at each of the seven locations:

i. The coastal erosion hazard risk zone distances are an accumulation of the correct coastal erosion hazard components (i.e. the correct equation has been applied).

ii. The coastal erosion hazard risk zones are plotted at the correct distance from the dune toe feature (i.e. the correct transformation from horizontal distance to XY position has been applied).

All seven locations passed the two validation checks listed above. CEHZ maps for each of the seven locations are provided in Appendix F. The maps plot both the CEHZ calculated as part of this study and the existing CEHZ (1998).

6 Integration of CEHZ into District Plan

This section of the report presents a brief discussion of considerations for the current review of the operative Whangarei District Plan (‘the District Plan’) with respect to coastal hazards. Please be aware that this section does not purport to be planning advice, but provides some initial thoughts on matters that need to be considered when considering the CEHZ in the context of the District Plan.

6.1 District Plan considerations

We understand that the District Plan is going through a period of review in order to improve the effects-based approach and to produce a new District Plan structure. This review may present a timely opportunity for Council to “step back” and review their overall strategy and approach to climate change and coastal hazards. This review can take into account the findings of this report and other knowledge gained since the drafting of the operative District Plan, together with changes to the Resource Management Act (the Act), proposed changes to the New Zealand Coastal Policy Statement and the updated Ministry for the Environment (MfE) guidance made available since the drafting of the operative District Plan.

In undertaking such a review, Council should consider what environmental outcomes for the coast they are trying to achieve (for example are you wanting to achieve managed retreat?), and whether the current objectives, policies and methods (including rules) of the District Plan are therefore still relevant and current.

Your s32 report required as part of the District Plan review will need to examine the extent to which each objective is the most appropriate way to achieve the purpose of the Act. The s32 report will also require an analysis of whether, having regard to their efficiency and effectiveness, the policies, rules or other methods are the most appropriate for achieving the objectives.

6.1.1 MfE Guidance

MfE’s guidance manual for local government “*Coastal Hazards and Climate Change: A Guidance manual for Local Government in New Zealand*” was updated in July 2008. Changes in the updated manual include the provision of guidance and recommendations relevant to coastal margin issues and a new chapter on local government response to climate change, emphasising how climate change adaptation fits within the key principles that local authorities should incorporate into their decision-making about coastal margins. This document is a good resource for helping to ensure that the approach Council takes to the coastal hazard is in keeping with the purpose of the Act and with local government's responsibilities to take account of climate change.

6.1.2 Use of the CEHZ for District Plan Rules

Should Council decide to use the CEHZ to structure District Plan provisions around it may be appropriate that the provisions of the District Plan differ depending on the accuracy of the CEHZ. Where the underlying data of a CEHZ is very good, policies/rules can be quite ‘tight’/prescriptive in terms of regulating future development. However, for areas that have less accurate data, the policies/rules may allow for more flexibility on future development.

An example of such a flexible approach would be Council requiring a resource consent applicant to submit a coastal hazard assessment report as part of the application documents. This coastal hazard assessment would be required to identify a “trigger point” for the site. If Council considers it appropriate to grant resource consent, then conditions of consent may be applied which incorporate mitigation measures once this trigger point is reached (i.e. once coastal erosion has reached this point). A likely mitigation measure may be relocation of the dwelling on the site, or full removal of the dwelling. This likely resource consent condition should be alerted in the District Plan text.

6.2 Integration with Northland Regional Council

The challenge for consent authorities in managing cross-boundary issues such as coastal hazards, is achieving effective integration of District and Regional planning documents. There are a number of RMA mechanisms that have been implemented throughout the country to address this issue, and relevant examples of these mechanisms are set out below:

- developing combined plans within one authority (eg, Horizons One Plan, which is a combined Regional Policy Statement, Regional Coastal Plan and Regional Plan)
- developing complementary provisions in plans with a common boundary to address issues across the land/sea interface (eg, policy 4.2.45 of the Wellington Regional Coastal Plan has policies that recognise the design guides in the Wellington City District Plan for the Lambton Harbour Development Area)
- preparing non-statutory strategies that integrate the functions of regional councils and territorial authorities (eg, the Wairarapa Coastal Strategy)

Council may consider undertaking further investigations in conjunction with Northland Regional Council to determine if any such mechanisms would be appropriate for addressing an integrated approach to the revised CHEZ.

6.3 Mapping and implementation considerations

If the derived CEHZ’s are included in the draft and operative plan maps, they are likely to be lines/zones overlaid on aerial photographs and a cadastre (property boundaries). This process is undertaken using a GIS using available up-to-date electronic datasets. A significant issue when overlaying these datasets is the relative accuracy of these electronic datasets.

In some cases the absolute (i.e. real world) accuracy of the cadastre (especially in rural areas) can be out by as much as 30 m. The accuracy of the aerial photograph may also be out by the same amount as the cadastre is used to position the aerial photograph. While 30 m accuracy may be an extreme case, even with the latest technology the accuracy of the cadastre and aerial photo may vary between 0.5 m to 10 m.

Therefore, mapped CEHZ’s in planning documents may not accurately represent the position of the CEHZ’s relative to property boundaries and dwellings. As a result, maps showing the CEHZ’s with aerial/cadastre information should have caveats outlining the map accuracy to provide better guidance to the public.

The only way to accurately assess if a property is within a CEHZ is to have the CEHZ and property boundaries surveyed by a registered surveyor.

7 Additional assessments

In addition to the original work scope, WDC has asked for comments on the effects of sea level rise (effect of shoreline position) for Takahiwai Estuary and Marsden Bay (inundation/flooding). The additional assessments are considered to be preliminary and further investigation is required to confirm the output.

7.1 Future Shoreline Position of Takahiwai Estuary

This preliminary assessment estimates the horizontal translation of the Takahiwai Estuary shoreline due to the effects of sea level rise (SLR) to 2060 and 2110.

The current shoreline position for this assessment was taken as the mean high water spring mark (MHWS) as plotted on LiDAR derived Digital Terrain Model (DTM). The MHWS level for Takahiwai was assumed to be the same as Whangarei Port located approximately 11 km to the north west. The New Zealand Nautical Almanac (LINZ 2008/2009) gives a MHWS level of 1.3 m above mean sea level (MSL) for Whangarei Port. This level was rounded up to 1.5 m to account for the accuracy (+/- 0.2 m) of the LiDAR derived Digital Terrain Model (DTM) used to extract elevation contours.

This estimate considers the horizontal translation of the Takahiwai shoreline position due to SLR of 0.36 m to 2060 and 0.9 m to 2110 (MfE,2008. Estimating future shoreline position is difficult as the shoreline position is due to the combination and interaction of a number of parameters such as water level, topography, geology, wave energy, sediment transport, sedimentation and mangrove colonisation.

However, a preliminary ‘back of the envelope’ estimate can provide useful information. Therefore, a simple pragmatic approach was adopted which assumes the shoreline position will move inland to a new MHWS level of 1.86 m (1.5 m + 0.36 m) and 2.4 m (1.5 m + 0.9 m) for 2060 and 2110 respectively. This method provides a conservative estimate of shoreline position and does not allow for future control structures (e.g. stop banks) or morphological change.

Appendix G shows the two shorelines plotted over the 2007 aerial photograph where:

- Shoreline A (2.4 m contour) = 2110 shoreline based on retreat due to SLR of 0.9 m.
- Shoreline B (1.86 m contour) = 2060 shoreline based on retreat due to SLR of 0.36 m.

The two elevation contours were derived from a DTM, based on LiDAR spot heights provided by Northland Regional Council (NRC). Therefore, the extent of this assessment is limited to the extent of the LiDAR survey (approximate extent of aerial image). The results of this assessment could be extended across the entire Takahiwai Estuary if further LiDAR information is acquired. We note that both shoreline positions are within the current Flood Susceptibility Area identified on the WDC Operative Planning Map 51 (April 2007).

The intertidal flats of Takahiwai Estuary are densely colonized by Mangroves. Mangroves attenuate incident wave energy and can reduce the erosion effects of storm surge events. Therefore, Mangrove removal is likely to result in an increase in erosion along the Takahiwai Estuary shoreline.

The shorelines delineated in Appendix G are indicative only and should not be used directly into any planning documents.

7.2 Inundation risk along Marsden Bay

The natural backshore topography at Marsden Bay (excluding Marsden Cove) is low lying (<2 m above MSL) and includes existing residential development. This area is likely to be at risk from inundation from storm surge and predicted sea level rise to both 2060 and 2110.

Appendix H shows the topography for Marsden Bay based on LiDAR spot heights. The light blue shade represents the area below the current MHWS (1.1m above MSL). The red shade represents the area at risk to coastal inundation to the year 2060. The yellow shade represents the area at risk from coastal inundation to the year 2110. The green shade represents areas considered not to be at risk from coastal inundation to the year 2110. Table 7-1 shows the components that make up the preliminary flood levels.

Table 7-1 Preliminary coastal inundation components for Marsden Bay

Component	**2060 flood level**	**2110 flood level**
MHWS	1.1	1.1
SLR	0.36	0.9
Storm Surge	0.6	0.6
SV	0.25	0.25
Total	**2.3 m**	**2.85 m**
MHWS = mean high water spring SLR = sea level rise SV= seasonal variation including ENSO		

Based on the latest LiDAR survey much of the back shore (area of current development) is likely to be inundated by 2060 during storm events (refer to Appendix H). This area is not currently shown as susceptible to flooding in the Operative Whangarei District Plan 2007. Therefore, we recommend an assessment of inundation risk for Marsden Bay is also undertaken which considers the effect of SLR to 2110.

8 Summary and Recommendation

The existing coastal erosion hazard zones (CEHZ) along the study area were originally established as a result of studies carried out in 1998 (Gibb, 1998). As WDC is currently reviewing its Operative District Plan, it was considered timely to undertake a review of the existing CEHZ. Department of Conservation (DoC) land along the coastal margins is unlikely to be developed into the future. Therefore, DOC coastal land bounded by the existing CEHZ (1998) was not reviewed.

This report sets out the outcomes of a review of the WDC CEHZ. The CEHZ assesses coastal erosion risk only. This report does not specifically assess inundation/flooding risk due to storm effects, tsunami or predicted Sea Level Rise (SLR).

The study area included three distinct coastal areas.

One Tree Point cliffs

The cliff shoreline along the study site can be described as a soft cliff type due to the weakly cemented nature of the Pleistocene sand material. Due to the soft, readily erodible nature of the cliff, the rates of coastal erosion may potentially increase due to SLR, with more hydraulic action acting on the cliff toe.

The effects of SLR were not accounted for in the 1998 CEHZ setbacks along the One Tree Point cliffs. Therefore, when including the potential effects of sea level rise, the CEHZ setbacks CEHZ1 and CEHZ2 increase significantly. CEHZ1 increases between 15 m and 17 m while CEHZ2 by increases between 43 m and 48 m.

The consented cliff toe protection has a limited consent period (maximum of 35 years). After this period there is no guarantee that the consent will be renewed and the protection to remain. Therefore, we recommend that in areas where consented coastal cliff protection exists; the CEHZ should still represent the potential retreat to 2110. However, allowance should be made through policy to account for the coastal cliff protection.

Marsden Bay harbour shore

Marsden Bay has been significantly modified since the last coastal hazard study, over ten years ago. The modifications that are likely to alter coastal process and hazards include:

- NorthPort reclamation at Marsden Point
- training groyne at the entrance to Blacksmith Creek at the eastern end of the bay
- Marsden Cove access channel
- beach re-nourishment along the Marsden Bay shoreline.

The effects of the NorthPort reclamation on Marsden Bay (west from Blacksmith creek) is difficult to assess considering the other modifications (training groynes, access channel and re-nourishment) that have occurred in the Marsden Bay area. However, we consider the modifications within Marsden Bay have significantly decreased the risk of coastal erosion in the short to medium term.

Therefore, CEHZ in this area have not changes significantly.

However, this area is likely to be at risk from inundation from storm surge and predicted sea level rise to both 2060 and 2110. We recommend an assessment of inundation risk for Marsden Bay is undertaken which considers the effect of SLR to 2110.

Bream Bay open coast

The Bream Bay coastline comprises sandy beach backed by sand dunes and can be described as a soft shore coast. The average sand dune height along Bream Bay is 6.7 m above Mean Sea Level (MSL). Sandy soft shore coasts are a dynamic environment, where the morphology is dependent on seasonal and climatic cycles. The beach profiles are dominated by the cut and fill cycle.

Soft shores are also affected by increasing sea level rise. Sandy coasts that have been relatively stable over time are likely to show a bias towards erosion with rising sea levels, unless the supply of sand to the beaches can keep pace with erosion.

The 1998 CEHZ's used the position of the shoreline (Dune Toe) derived from historical aerial photography and a GPS survey to determine long term trends of shoreline movement. We recommend using beach profile data over the last ~ 30 years to derive both long term and short term trends on shoreline position.

We have determined, based on beach profile analysis, that much of the Bream Bay shoreline is at dynamic equilibrium (i.e. no significant long term trends), apart from areas along the northern (Marsden point)) and southern (Waipu) shores, which have an erosion trend.

Short term fluctuations also occur due to storm events and climate change. Again using the beach profiles data we have estimated that the maximum short term fluctuation along the open coast is 30m.

At Mair Road (near Marsden Point) CEHZ1 moved seaward 14 m and CEHZ2 12 m seaward. Near the 'Village' CEHZ1 moved seaward 19 m and CEHZ2 18 m seaward. However at the 'Cove' the CEHZ1 has moved 49 m landward and CEHZ2 77 m landward. The landward movement at the Cove is primarily due to Gibb using a long term erosion rate of 0 m per year, while we have assessed there to be long term retreat of up to 0.4 m per year.

The 1998 CEHZ at the Ruakaka Estuary mouth may not represent the potential risk of coastal hazards. Gibb (1998a) based the CEHZ width in this area on historic shoreline positions and evidence of short term fluctuations. However, the existing CEHZ (1998) are seaward of surveyed historic shoreline positions.

In our opinion, the existing CEHZ (1998) do not appropriately delineate the coastal erosion risk in this area Therefore, we recommend further investigation is undertaken to better determine the coastal erosion hazard risk in this area.

Additional assessments

In addition to the original work scope, broad based assessments on predicted sea level rise were undertaken for Takahiwhai Estuary and Marsden Bay. We recommend further investigations to more accurately determine effects caused by predicted sea level rise.

9 Applicability

This report has been prepared for the benefit of Whangarei District 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 without our prior review and agreement.

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