REPORT

Tonkin+Taylor

Coastal Hazard Assessment

Beachlands South Private Plan Change

Prepared for
Beachlands South Limited Partnership

Prepared by
Tonkin & Taylor Ltd

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Executive summary

Beachlands South Limited Partnership (BSLP) is seeking a Private Plan Change (PPC) to re-zone the Formosa Golf Course and an adjacent area of currently rural and private property land in Beachlands, Auckland to facilitate urban development of that area.

BSLP engaged Tonkin & Taylor Ltd (T+T) to undertake a site-specific coastal hazards and issues assessment to inform the structure planning and private plan change.

The PPC area covers approximately 307 ha and consists primarily of two properties, Formosa Golf Resort and 620 Maraetai-Whitford Road (620 site). Several smaller lots between 678 and 770 Whitford-Maraetai Road are also included in the PPC.

The site is generally a cliff coast fronted along the north-west side by a narrow shelly beach and to the south-west by low lying salt marsh and mangrove habitat, some of which has been converted to flood prone paddocks. The area is generally characterised as a low energy sheltered environment with relatively low waves and currents, but susceptible to tropical storm generated waves during high tide.

This study includes a local scale assessment of Areas Susceptible to Coastal Instability and Erosion (ASCIE) of both consolidated (cliff/ terrace) and unconsolidated (beach) shorelines, and an assessment of the inundation hazard of the site based on scenarios supplied by Auckland Council.

For this assessment, present day ASCIE and two future ASCIE (2080 and 2130) were evaluated. Present day ASCIE is based on the current stability of the shoreline and potential erosion to occur after large storm events, and future ASCIE is based on present day values, plus a future long-term regression rate, including a sea level rise component (using the RCP 8.5+ scenario).

All property parcels, key assets and infrastructure are located landward of the 2130 area susceptible to coastal instability and erosion. No coastal inundation or tsunami hazard will occur on property parcels, key assets and infrastructure, even with a consideration of 2 m sea level rise. The AUP framework for addressing natural hazards and climate change will be sufficient for addressing coastal instability and erosion and no specific mitigation is required.

Only beach and salt-marsh areas are susceptible to coastal inundation and are also the most likely to be affected by tsunami. These low-lying areas around the coastal edge have only been considered for recreational amenity and no habitable buildings should be located on these areas. The walkway is situated sufficiently landward and is of an elevation that reduces the risk of inundation to negligible for sea level rise of up to 1.5m. Adaptation responses can be considered to raise or relocate in the long term.

The AUP currently requires a 30 m coastal yard for buildings measured from MHWS under the AUP framework. This yard is for a range of purposes and is considered to be adequate for managing the development of buildings and structures adjacent to this coastal edge but there is no reason from a coastal hazard perspective to change this setback standard.

The assessment meets the requirement of Policy 24 of the NZCPS and the proposed structure plan meets both Objective 5 of the NZCPS ensuring that coastal hazard risks, taking into account of climate change are managed by locating new development away from areas prone to such risks, and Policy 25 by avoiding any increased risk of adverse effects from coastal hazards. By avoiding the setback areas along the coastal edge, the proposal recognises and protects the existing natural defences of vegetated slopes and wetlands, meeting requirements of Policy 26 of the NZCPS.

1 Introduction

1.1 Purpose

Beachlands South Limited Partnership (BSLP) is seeking a Private Plan Change (PPC) to re-zone the Formosa Golf Course and an adjacent area of currently rural and private property land in Beachlands, Auckland to facilitate urban development of that area.

BSLP engaged Tonkin & Taylor Ltd (T T) to undertake a site-specific coastal hazards and issues assessment to inform the structure planning and private plan change.

1.2 Proposed structure plan and Private Plan Change

The PPC area covers approximately 307 ha and consists primarily of two properties, Formosa Golf Resort and 620 Maraetai-Whitford Road (620 site). Several smaller lots between 678 and 770 Whitford-Maraetai Road are also included in the PPC. The Structure Plan proposes a village centre in the northwest of the site, with a central business village centre surrounded by mixed used land and higher density housing, giving way to medium and lower density housing with increasing distance from the centre. Ecological open space areas are proposed throughout the Plan area, generally in gullies, coastal areas and as linkages between key locations. A secondary mixed use area is proposed at the north-eastern corner of the Plan area, adjacent to Whitford Maraetai Road.

1.3 Purpose of this report

This report has been prepared to support the Structure Plan and Plan Change application for Beachlands South, and to assist Auckland Council and decision makers in approving this application.

1.4 Scope

This coastal hazard assessment of the site recognises the issues associated with physical coastal processes and effects over at least the next 100 years to provide consistency with the New Zealand Coastal Policy Statement (NZCPS) and Auckland Unitary Plan (AUP) requirements. These policies encourage redevelopment, or change in land use, where that would reduce the risk ofadverse effects from coastal hazard and to encourage the location of infrastructure away from areasof hazard risk where practicable.

The coastal hazard assessment was largely by a desktop study providing information on the present day and future erosion and inundation risk based on existing published information. It includes information on published tsunami inundation mapping used for civil defence, but also provides additional information and context on this data.

1.5 Report outline

The statutory and physical settings are described in Section 2 to 4. Section 2 provides the base framework for the assessment and Sections 3 and 4 describe the physical environment that contributes to the hazard assessment. Sections 5 to 7 describe the hazards and the assessment of the impact of these hazards on the proposal. Section 5 describes the coastal erosion hazard assessment; Section 6 describes the coastal inundation hazard assessment and Section 7 describes tsunami. Section 7 and 8 include the summary and conclusion.

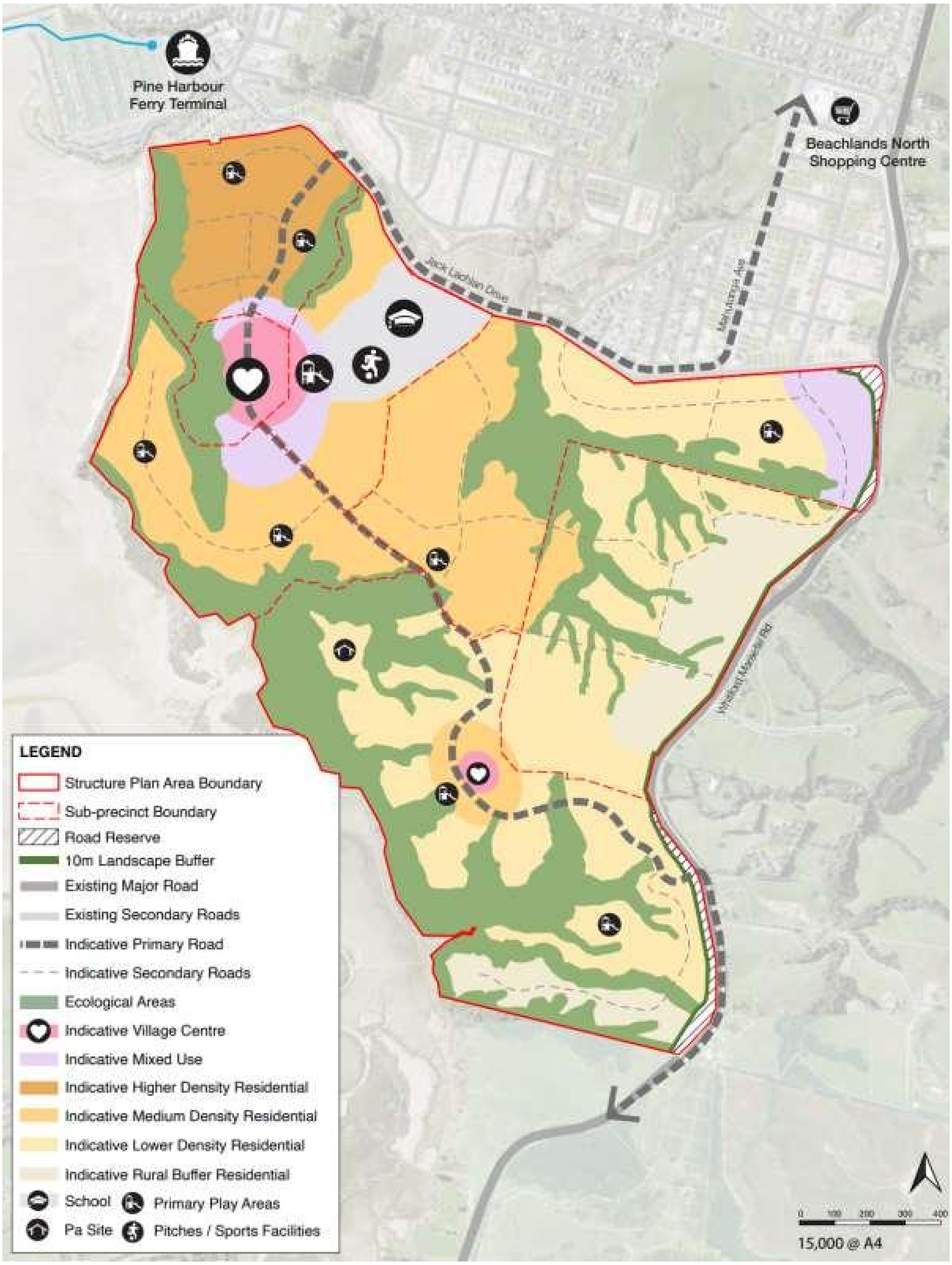


Figure 1-1: Structure Plan map (Source: Unio Environmental, 2021)

2 Statutory setting

This section sets out the various statutory documents that require consideration of coastal hazards including the Resource Management Act, the New Zealand Coastal Policy Statement and the Auckland Unitary Plan.

2.1 Resource Management Act

The purpose of the Resource Management Act 1991 (RMA) is to promote the sustainable management of natural and physical resources (Section 5). It provides that the functions of district and regional councils include controlling the use of land for the purpose of avoiding or mitigating natural hazards[1]. One method by which this is achieved is through the use of objectives, policies and rules in district and regional plans (and unitary plans in the case of Auckland).

In developing provisions in plans to address natural hazards in the form of coastal erosion, the process requires technical assessment of the erosion hazard susceptibility and the risk posed by any such identified hazards, and a robust process for developing and testing plan provisions. Drafting provisions that help to achieve the sustainable management purpose of the RMA requires consideration of how to manage the hazard risk and provide for the social, economic and cultural wellbeing needs of the community.

2.2 New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement 2010 (NZCPS, 2010), prepared by the Minister of Conservation, sets out objectives and policies in order to achieve the purpose of the RMA with regard to the coastal environment of New Zealand. It contains objectives and policies that include those aimed at safeguarding the integrity, form, functioning and resilience of the coastal environment and sustaining its ecosystems, and preserving the natural character of the coastal environment. Local authorities are required by the RMA to give effect to the NZCPS through plans and policy statements. Of relevance to this assessment are Objective 5, Policy 24, Policy 25 and Policy 26. These are set out below.

Objective 5:To ensure that coastal hazard risks, taking account of climate change, are managed by:

- *locating new development away from areas prone to such risks*;
- *considering responses, including managed retreat, for existing development in this situation; and*
- *protecting or restoring natural defences to coastal hazards."*

Policy 24: the identification of areas that are potentially affected by coastal hazards:

> *''Identify 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, overat least 100 years, are to 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;

[1] Section 30 sets out the functions of regional councils, including section 30(c) which is *"the control of the use of land for the purpose of...(iv) The avoidance or mitigation of natural hazards"*. Section 31 sets out the functions of territorial authorities which includes (b) "*the control of any actual or potential effects of the use, development, or protection of land,including for the purpose of avoidance or mitigation of natural hazards …"*

geomorphological character;

the potential for inundation of the coastal environment, taking into account potential sources, inundation pathways and overland extent;

cumulative effects of sea level rise, storm surge and wave height under storm conditions;

influences that humans have had or are having on the coast;

the extent and permanence of built development; and

the effects of climate change on:

- i. *matters (a) to (g) above;*
- ii. *storm frequency, intensity and surges; and*
- iii. *coastal sediment dynamics;*

taking into account national guidance and the best available information on the likely effects ofclimate change on the region or district.''

Policy 25: subdivision, use, and development in areas of coastal hazard risk

In areas potentially affected by coastal hazards over at least the next 100 years:

a *avoid increasing the risk*[10] *of social, environmental and economic harm from coastal hazards;*

avoid redevelopment, or change in land use, that would increase the risk of adverse effectsfrom coastal hazards;

encourage redevelopment, or change in land use, where that would reduce the risk of adverse effects from coastal hazards, including managed retreat by relocation or removal ofexisting structures or their abandonment in extreme circumstances, and designing for relocatability or recoverability from hazard events;

encourage the location of infrastructure away from areas of hazard risk where practicable;

discourage hard protection structures and promote the use of alternatives to them, includingnatural defences; and

consider the potential effects of tsunami and how to avoid or mitigate them.

Policy 26: Natural defences against coastal hazards

1 Provide where appropriate for the protection, restoration or enhancement of natural defences that protect coastal land uses, or sites of significant biodiversity, cultural or historic heritage or geological value, from coastal hazards.

2 Recognise that such natural defences include beaches, estuaries, wetlands, intertidal areas, coastal vegetation, dunes and barrier islands.

2.3 Auckland Unitary Plan

The Auckland Unitary Plan – Operative in part (2016) (AUP) combines Auckland's regional policy statement (RPS) and district, regional, and regional coastal plans. Together, these set out the objectives, policies and methods that allow Auckland Council to meet its obligations under the RMA, including its functions specified in Sections 30 and 31 of the RMA. As noted in the previous section, these functions include the avoidance or mitigation of natural hazards.

Objectives and policies in the RPS (Chapter B of the AUP) set strong directives to manage the risk of coastal hazards (Chapters B8 and B10). Subdivision, use and development in areas potentially affected by coastal hazards must not increase the risk of social, environmental and economic harm (Objective B3.1(7)), and the effects of climate change on natural hazards (including the effects of sea level rise and on the frequency and severity of storm events) are to be recognised and provided for (Objective B10.2.1(4)). This is supported particularly by the regional and district plan provisions in

Chapters E36 (Natural Hazards and Flooding) and Chapter F (Coastal) of the AUP which require resource consents for certain activities and for coastal hazard risks to be assessed and managed.

Chapter E36 of the AUP includes rules for activities on land in the “coastal erosion hazard area”. E36.9 requires that a hazard risk assessment is undertaken when subdivision, use or development requiring a resource consent is to be undertaken on land that may be subject to natural hazards. It states that an assessment of coastal hazards should include consideration of the effects of climate change over at least a 100-year timeframe and cover storm inundation of the 1 percent annual exceedance probability (AEP) plus 1 m of sea level rise.

3 Setting

3.1 Location

The site is located south of the Pine Harbour marina, on the western coastline of the Beachlands suburb in Auckland (Figure 3-1) and follows the length of the Jack Lachlan Esplanade Reserve. The northern end of the site is separated from the Pine Harbour marina by a small unnamed tributary (hereby referred to in this report as Stream A). The shoreline is inter-tidal with estuarine/ mudstone flats seaward and can be characterised by the following sections.

- Approx. 0.8 km long section of high tide beach/chenier ridge backed by consolidated terraceof varying width (5 to 60 m) with high cliff sections landward, leading up to the Formosa GolfClub course.
- Approx. 0.3 km long section of cliff headland backed by the Formosa Golf Club.
- Approx. 0.8 km long section of salt marsh of varying width (90 to 180 m) backed by farmland extending to Whitford-Maraetai Road.
- Approx. 0.6 km long section of mangrove forests protecting vegetated cliff/embankment shoreline seaward of farmland extending to Whitford-Maraetai Road.

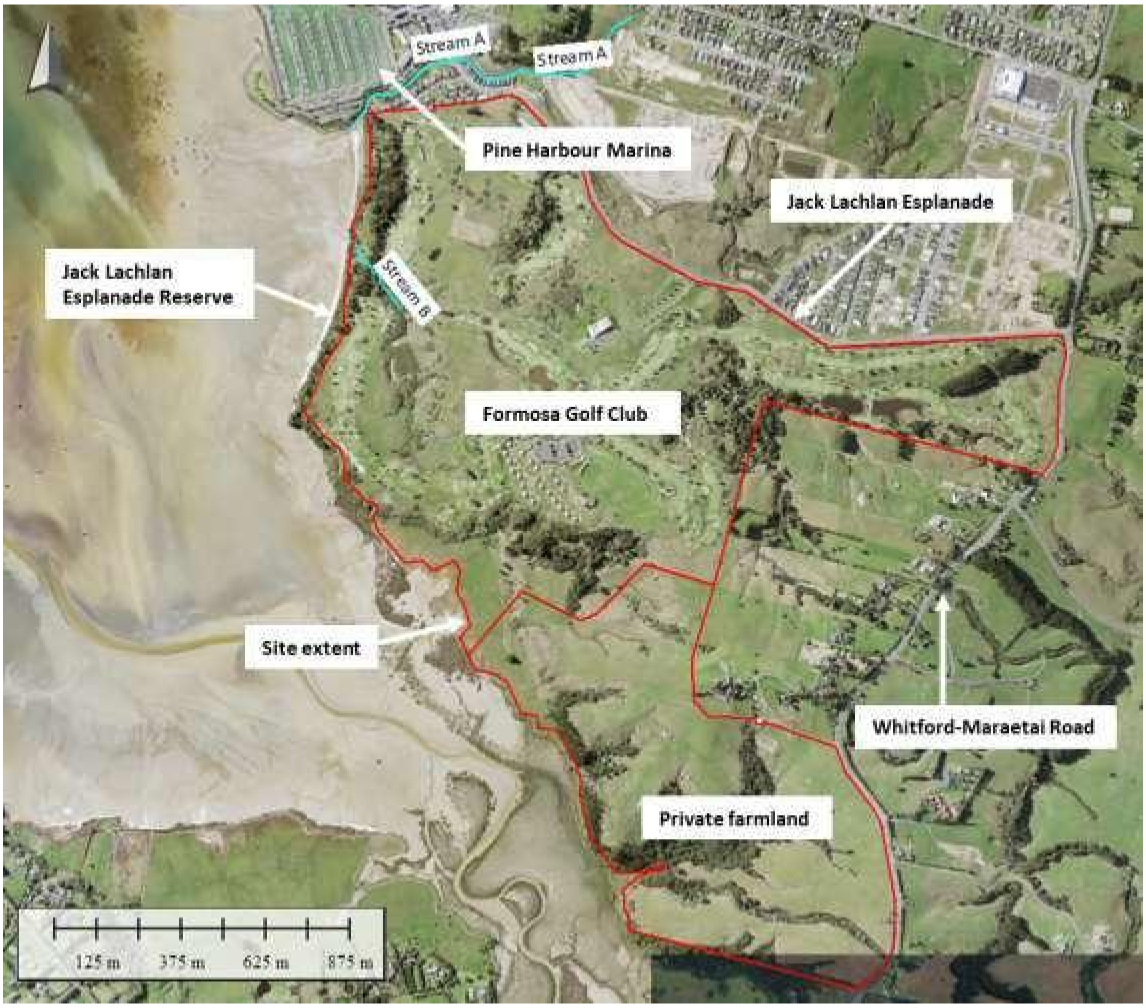


Figure 3-1: Location map of the site

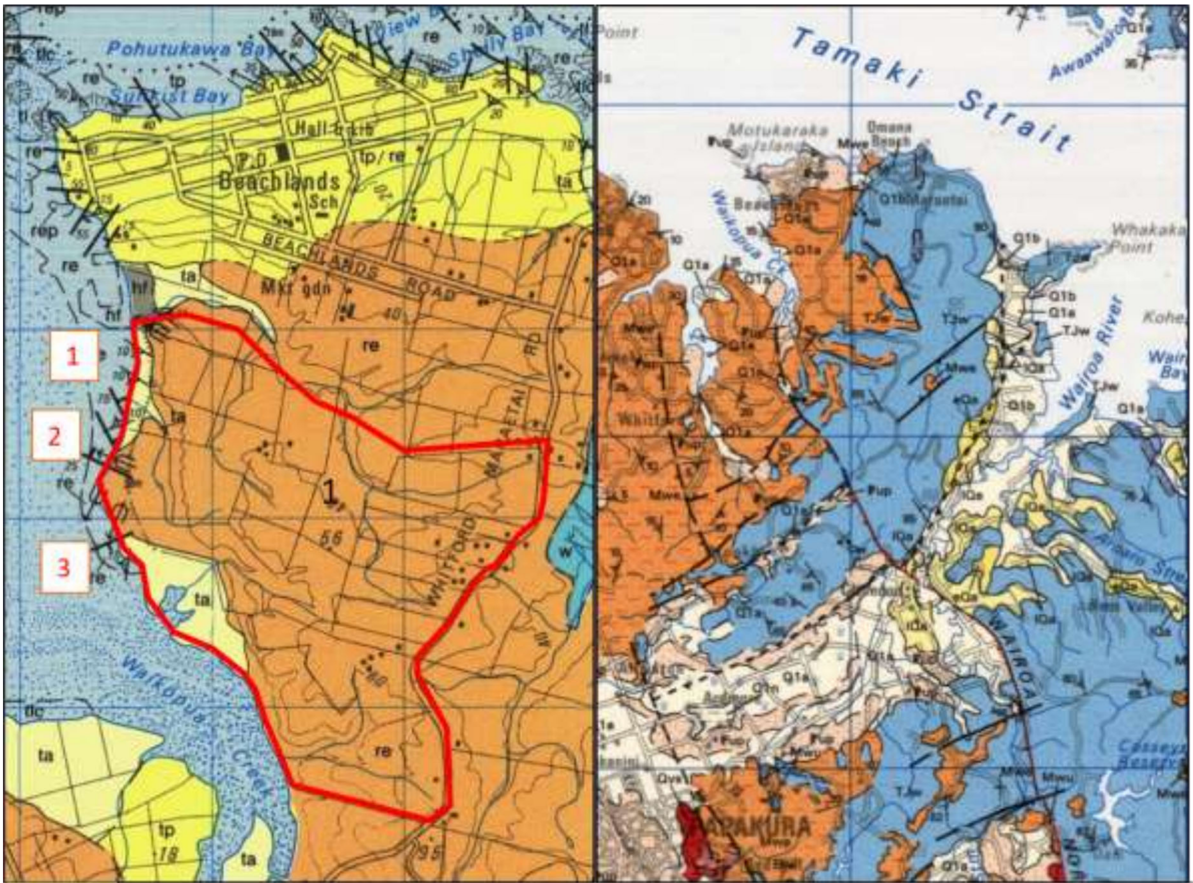
3.2 Geology

3.2.1 Regional geological review

As shown on the geological maps shown in Figure 3-2, the site is expected to be generally underlain by East Coast Bays Formation flysch, consisting of alternating beds of greyish grey, muddy sandstone and siltstones East Coast Bays Formation with occasional undifferentiated Tauranga Group alluvium comprising mud, sand and gravel located along the coast, and within the stream channels across the site (T+T, 2021). No argillite or greywacke is expected at the location of the site, the nearest expression of Waipapa Group greywacke on the eastern side of the Whitford – Maraetai Road. Inactive faults have been mapped to the east and south of the site. There are four faults shown on the geological map which are described as, from north to south:

1. two normal fault dipping 70° to the northeast into the coastal slope (striking NW-SE).
2. a reverse fault with 38m throw (displacement) dipping 25° to the North, perpendicular to the coastal slope (striking E-W).
3. a normal fault dipping 25° to the southeast, perpendicular to the coastal slope (striking NE-SW).

The nearest known active fault is the Wairoa North fault, approximately 6.5 km to the south.



ta	Holocene Tauranga Group, undifferentiated alluvium
re	Miocene Waitemata Group, East Coast Bays Formation, flysch
w / TJw	Jurassic Waipapa Group, massive to thin-bedded, lithic volcaniclastic sandstone and argillite

Figure 3-2: Published geological maps of the location (site outlined in red).
Left: *1:50,000 scale map showing general geology of the site.* ***Right:*** *1:250,000 scale map showing regional geology and proximity to faults. Source: IGNS[iii].*

3.2.2 Site walkover

The site walkover observations confirm the regional geological review. The northern section of coastline is protected by an accretion sand and shell spit, with an area of angular to sub rounded cobbles and boulders over and underlain by shell layers (shown as 1 on **Error! Reference source not found.**, and Figure 3-3). The origin and depositional timing of this material is unclear due to the shell layers. This area is backed by ECBF slopes which are generally very weak to weak thin to thickly bedded light yellow brown sandstones with very weak very thin to thinly bedded yellow brown to grey mudstones. Thesurface of the ECBF has decomposed on exposure to the atmosphere and weathering events and isfriable to the touch.

Further south, the ECBF varies between very thin (6-20 mm) to very thick (>2 m) beds of cyclic mudstone and sandstone. The thinner beds are dominated by the exceptionally weak to weak mudstones units, generally between 6 to 40 mm, with very weak to weak sandstone beds from20 mm to 2 m, as shown in Figure 3-3.

The ECBF is variable along the coastal section due to the reported faulting. These were confirmed on the site walkover. In these locations the faults and faulted material act as large land drains and can be traced landwards through the topography (Faults 2 and 3 above, as shown in Figure 3.5). They have been eroded out and therefore pose a hazard to surface construction with the potential for washout voids.

A progression south along the coastline there are a series of debris fans or colluvium which has been washed out of the streams and stormwater channels and built up on the salt marshes. These areas do not represent the toe of the slope and will be removed with a rise in sea level. There are two locations of coastal instability, shown on **Error! Reference source not found.** as X1 and X2.

Figure 3-3: Shell layers above and below a heterogenous conglomerate. Shown as 1 in ***Error! Reference source not found.***

Figure 3-4: ECBF bedded mudstones and sandstones, dipping 06/180. Shown as 2 in ***Error! Reference source not found.***

Figure 3-5: Two faults, within the coastline as shown in ***Error! Reference source not found.***

3.3 Beach sediments

Between the marina and the headlands to the south, observations on site note that the beach sediments primarily consist of calcium carbonate (shell) overlying fine sand (Figure 3-6), which is typical of sheltered estuarine sites within the inner Hauraki Gulf (Klinac, 2002). Some sections were noted to have a scattering of rocks, possibly from embankment erosion. Mudstone flats extend seaward from the beach toe. South of the headlands, muddy fine sand is more abundant, with some shell deposits forming ridges in front of the vegetated shoreline (Figure 3-7).

Figure 3-6: Beach section north of headland

Figure 3-7: Chenier ridge seaward of salt marsh south of headlands

3.4 Topography and bathymetry

Topographic information is available from a 2016 LiDAR survey conducted by Auckland Council, from which topographic contours have been generated and is shown in Figure 3.8. Contours shown in grey are at 2 m increments. Major contours (0, 5, 10, 20 and 50 m AVD46 (hereby referred to in this report as m RL)) are shown as red lines. Another major contour line is shown at 1.5 m RL (approximately MHWS) in blue. Levels within the bay, along the intertidal flats, range from around -1 m to 1 m.

The 2016 LiDAR survey captured the intertidal area down to at least -0.5 m RL. On the northern end of the site, the nearshore slope (between 0.7 and 1.5 m RL contours) is around 1(V):10(H) and the intertidal area (between -0.5 and 0.5 m RL contours) is around 1(V):300(H).

The bathymetry offshore from Beachlands is shown in Appendix E and is based of levels from chart NZ 532 published in 1975.

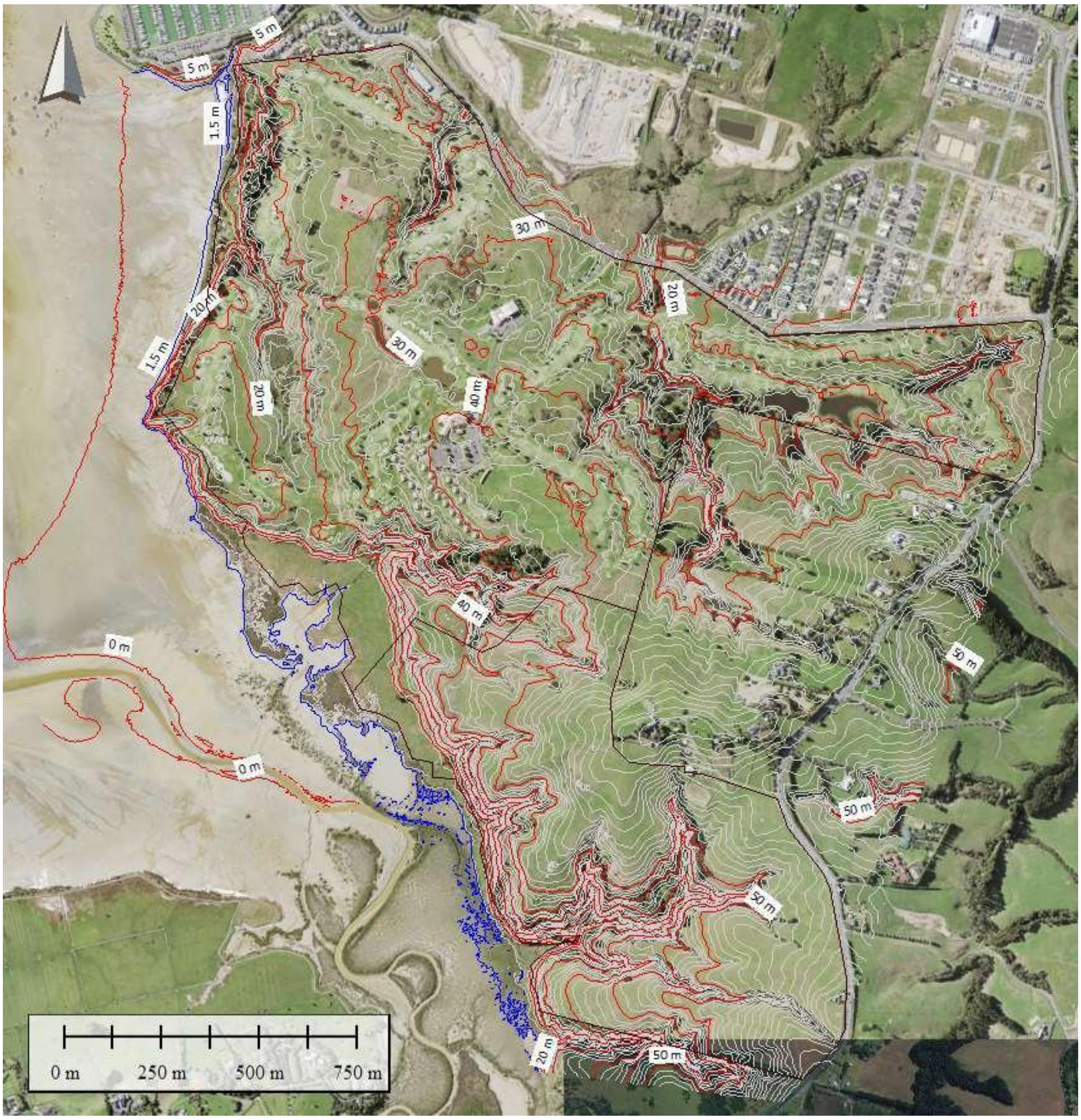


Figure 3-8: Site contours based off 2016 AC LiDAR data. Minor contours in grey, major contours in red, indicative MHWS level (m RL) in blue.

3.5 Hydraulic environment

3.5.1 Water levels

The tide and nearshore seabed levels controls the amount of time coastal processes interact with the shoreline. With the beach and cliff toe at around 0.6 to 1.4 m RL, erosion from coastal processes is limited to higher tide levels and is exacerbated by storm surge that combine with high tide conditions. At spring high tides, the water depth at the toe of the beach/cliff shoreline is around 0.2 to 1.0 m.

3.5.1.1 Astronomical tide

The closest long-term tidal station to Beachlands is at the Port of Auckland located some 18 km northwest of the site (see Table 3.1 for tide levels at the Port). Typically, the tidal variation range is 2.88 m and 1.80 m for spring and neap tides, respectively. The perigean mean high water springs level (MHWPS) is 1.67 m RL. This is the high tide level that will only be exceeded by 6% of all high tides over the next 100 years, excluding the effects of sea level rise. Numerical modelling has been carried out to identify MHWPS levels around the coastline (Ramsay et al., 2008). The predicted level at Beachlands is 1.75 m.

Table 3.1: Predicted tide levels at Port of Auckland[1] and Beachlands

Nominal level	Water level CD (m)	Water level RL[2] (m)
Highest Astronomical Tide (HAT)	3.72	1.98
Mean High Water Perigean Springs (MHWPS)	3.49	1.75 m at Beachlands[3]
Mean High Water Springs (MHWS)	3.36	1.62
Mean High Water Neaps (MHWN)	2.83	1.09
Mean Sea Level (MSL)	1.91	0.17
Mean Low Water Neaps (MLWN)	1.03	-0.71
Mean Low Water Springs (MLWS)	0.48	-1.26
Lowest Astronomical Tide (LAT)	0.06	-1.68

1 New Zealand Nautical Almanac (LINZ, 2020)
2 Levels in Auckland Vertical Datum 1946, which is 1.74 m lower than Chart Datum (CD)
3 Ramsay et al. (2008)

3.5.1.2 Storm surge

Storm surge results from the combination of barometric setup from low atmospheric pressure and wind stress from winds blowing along or onshore. This process, described in Figure 3.9, elevates the water level above the predicted tide. The combined elevation of the predicted tide and storm surge is known as the storm tide.

In 2013, NIWA modelled coastal-storm inundation around the coastline of the Auckland region (Stephens et al., 2013). The predicted storm tide levels for a range of return periods for Beachlands at the open coast are presented in Table 3.2. These levels exclude local effects of wave set-up that are likely to be relatively minor in a shallow estuary environment.

Table 3.2: Storm tide levels for Beachlands (Stephens et al., 2013)

Annual Exceedance Probability(AEP)	39%	18%	10%	5%	2%	1%	0.5%
Average Recurrence Interval (ARI)	2 yr	5 yr	10 yr	20 yr	50 yr	100 yr	200 yr
Elevation RL[1] (m)	1.94	2.00	2.05	2.09	2.14	2.18	2.20

1 Elevations in Auckland Vertical Datum 1946

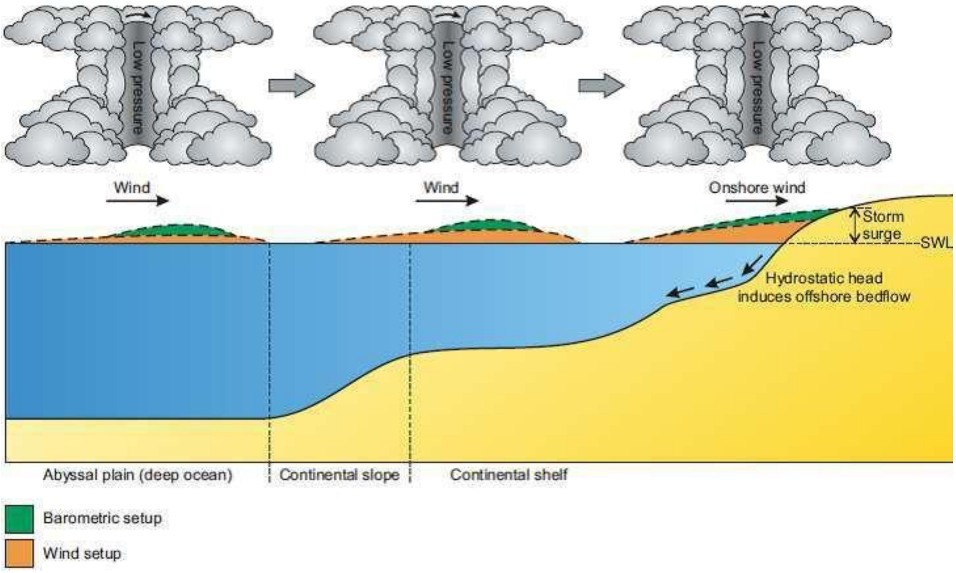


Figure 3-9: Storm surge processes (Shand et al., 2010)

3.5.2 Medium-term fluctuations

Natural fluctuations in New Zealand's (and the Pacific's) climate are influenced by two key natural cycles operating over timescales of years: the El Niño–Southern Oscillation (ENSO) and the longer Inter-decadal Pacific Oscillation (IPO). These natural phenomena operate over the entire Pacific Ocean and beyond, in response to changes in ocean temperature, prevailing trade winds and the strength of the subtropical high-pressure belt. El Niño and La Niña occur irregularly over about two-to-seven years, with each phase lasting from nine months to two years.

These natural fluctuations can change the mean level of the sea at a specific time. The combined effect of these is shown in Figure 3.10 and show a combined effect of up to ± 0.25 m.

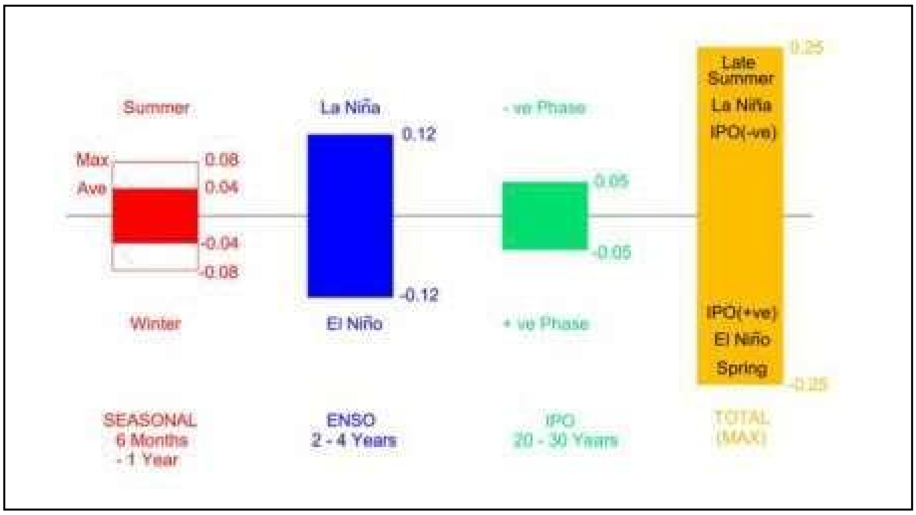


Figure 3-10: Factors influencing long-term sea level fluctuations (NIWA,2011)

3.5.3 Long-term changes

Historic sea level rise (SLR) in New Zealand has averaged 1.81 ± 0.05 mm/year to 2018, with rates at Auckland averaging 1 .67 ± 0.08 mm/year[2] (1899-2018) and climate change is predicted to accelerate this rate into the future.

The Ministry for the Environment (MfE, 2017) guidelines on climate change use four sea level rise scenarios based on the Intergovernmental national Panel on Climate Change (IPCC, 2015) projections of three Representative Concentration Pathway (RCP) emission scenarios. These are the median projections of the RCP 2.6, RCP 4.5 and RCP 8.5, and RCP 8.5+ the upper end of the 'likely range' (i.e., 83rd percentile) of the RCP 8.5 projection. The latter is primarily for the purposes of stress-testing adaptation plans where the risk tolerance is low and / or future adaptation options are limited, and for setting a SLR for greenfield development or major new infrastructure where the foreseeable risk is to be avoided (MfE, 2017). The projections of the potential future scenarios adjusted to the New Zealand regional scale shownin Table 3.3.

Table 3.3: Sea level rise projections from the 1986-2005 baseline (MfE, 2017) adjusted for historic sea level rise

	Emission Scenario			
Horizon	**RCP 2.6M**	**RCP 4.5M**	**RCP 8.5M**	**RCP 8.5+**
2060	0.27	0.30	0.36	0.48
2080	0.37	0.42	0.55	0.75
2100	0.46	0.55	0.79	1.05
2130	0.60	0.74	1.18	1.52

3.5.4 Wind climate

The Musick Point weather station provides the closest long-term wind dataset for the site. The station is located approximately 9 km to the northwest and is representative of the wind climate at the site. Continuous one hourly wind data was available for Musick Point from June 2000 to July 2015.

Figure 3-11 presents this data as a wind rose showing the direction and strength of where the wind iscoming from. The predominant wind direction at Musick Point to be from the west to southwest sector, occurring 47% of the time. Maximum wind speeds typically occur from the northeast to east during tropical storms and cyclones. The predominant sector for strong winds that would directly affect this coastline is from the north to easterly fetches.

[2] https://www.stats.govt.nz/indicators/coastal-sea-level-rise#:~:text=Our%20long%2Dterm%20records%20show,Wellington%2C%20Dunedin%2C%20and%20 Lyttelton.

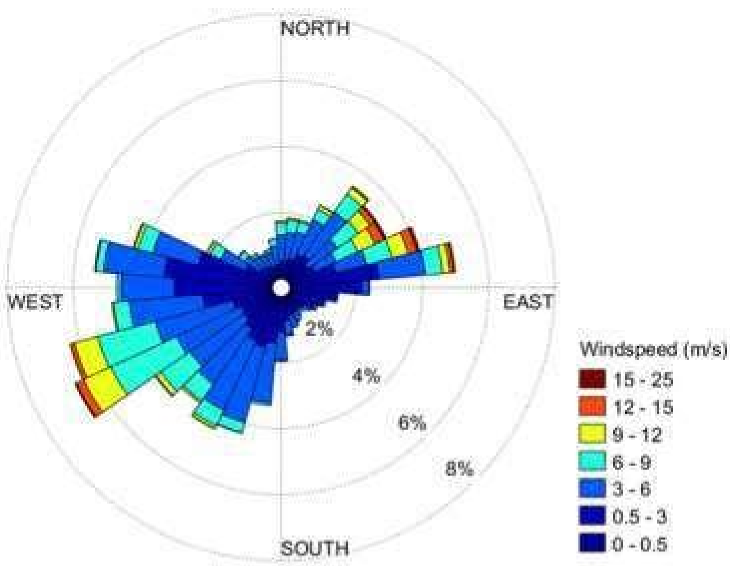


Figure 3-11: Wind rose of Musick point, 2000-2010 (source: NIWA Clifo)

3.5.5 Wave climate

Due to the sheltering from the westerly winds and the generally low wind speeds, wave heights are generally low apart from periods of strong winds from the north to east. In addition, the shoreline is only affected by waves during high tide levels. The construction of the marina has also provided shelter to parts of this coast from north-easterly waves

The local extreme wave heights were assessed using a shallow water SWAN (Simulating Waves Nearshore) wave model of the Tamaki Straight. The model comprises of two computational grids of varying resolution. Results have been extracted from the finest grid (50 m by 50 m).

Winds speeds inputted in SWAN to develop wave heights were derived from AS/NZS 1170.2 2011. Wind speed and subsequent wave height at the 2 m contour (CD) are shown in Table 3.4 below. These waves will further shoal and reduce in height towards the coast.

Table 3.4: Extreme wave heights from SWAN hindcast model

Wind direction	100-year wind speed (m/s)	Water depth (m) at 2m contour	Significant wave height, H_s (m)	Peak wave period, T_p (s)
N - 0°	24.5	5.93	1.52	4.46
NW - 315°	27.4	5.93	1.78	4.53

Boat-generated waves also have the potential to create additional wave energy reaching the site that could potentially affect sediment transport. The ferry terminal and marina at Pine Harbour is situated on the northern edge of the site, with frequent vessel movement occurring throughout the day. However, large vessel (ferry) movement is restricted to the thin channel extending north-west out from Pine Harbour and generally approach and leave the marina at low speeds. Therefore, it is unlikely for boat-generated waves from this movement to have a significant impact on sediment transport along the northwest section of the site and will have no effect on the southwest facing shoreline.

4 Coastal characterisation

4.1 Shoreline position

Historical aerial photographs have been obtained from Crown archives (via Retrolens) for the years 1939, 1955, 1972, 1980 and 1987. Present-day (captured in 2017) high resolution aerial photographs have also been obtained from LINZ. These photographs located in Appendix A.

The shoreline position has been mapped for the years 1955, 1972, 1987 and 2017 based on theaerial photographs, as seen in Appendix D.

4.1.1 Before marina construction

From 1939 through to 1980, much of the northern section of the shoreline fluctuates between the two stream outlets (Stream A & B). as the outlet of Stream A moves northward, the shoreline position in between the two stream moves landward, shown in Figure 4-1.

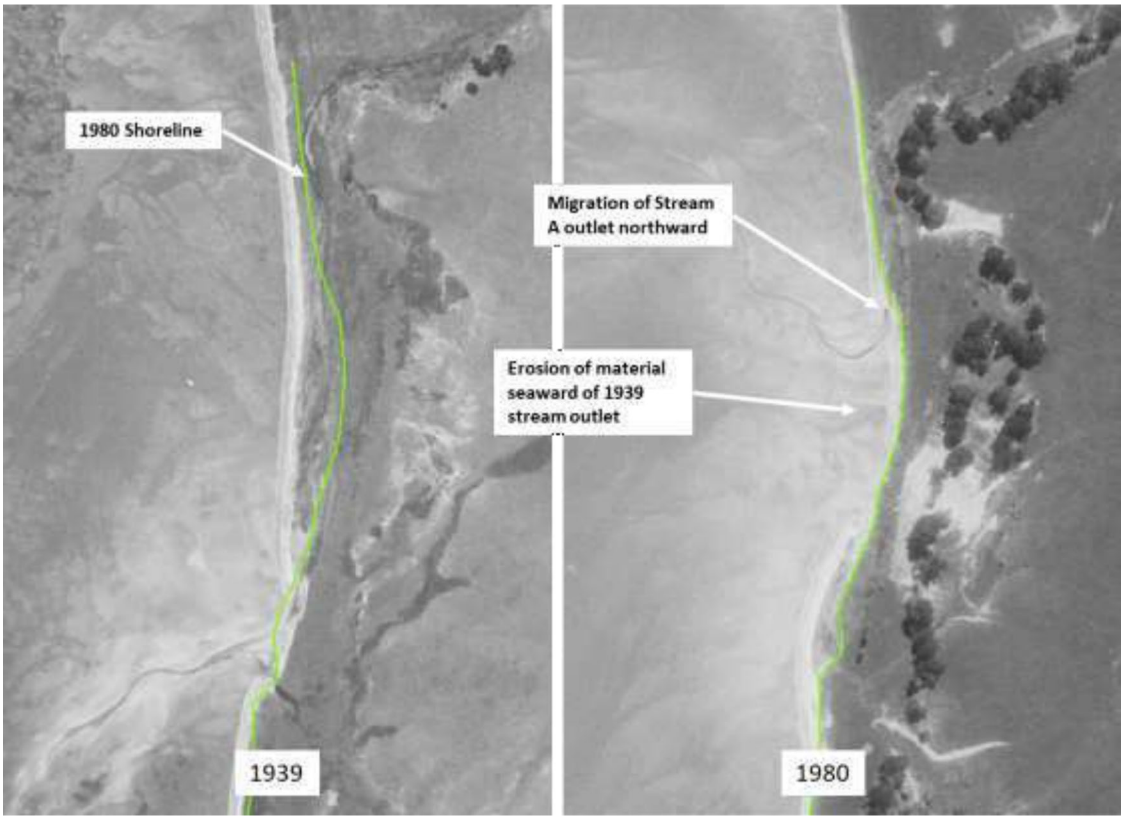


Figure 4-1: Comparison of 1939 and 1980 historic photographs showing movement of shoreline landward to 1939 stream bank

4.1.2 After marina construction

A major anthropogenic change occurred in the late 1980's with the construction of the Pine Harbour marina, subsequent reclamation of the shoreline north of the site, realignment of an unnamed stream outlet (Stream A) and possible fill material placement (unknown source) along parts of the northern shoreline of the site, shown in Figure 4-2.

After the construction of the marina, a chenier ridge started to form at the northern end of the site, shown in Figure 4-3, likely due to the sheltering effect of the marina. Directly south of the chenier ridge to an unnamed river outlet (Stream B) (approx. 130 m), there appears to be some erosion of the shoreline which has been occurring since 1987 at approximately -0.05 m/yr.

The southern beach section seems to be accreting since 1987 and looks to be straightening in between the headlands to the south and the river outlet to the north (Stream B). The cliff section around the headlands has experienced some erosion since 1955, atapproximately -0.05 m/yr. South of the headland, there is a section of salt marsh which has fluctuated in shape and size since1955, with the western section eroding and the eastern section accreting.

For the remainder of the site, the shoreline position appears relatively unchanged, indicating the shoreline here is less susceptible to erosion due to exposure, due to the south-west orientation with chenier ridge and dense mangrove growth seaward of the shoreline.

Figure 4-2: Comparison of 1980 and 1987 aerial photographs at the present location of Pine Harbour marina

Figure 4-3: Growth of the chenier ridge at the northern end of the site since 1987

4.2 Coastline delineation

The site was divided into 6 coastal cells based on shoreline behaviour which can influence the resultant hazard. Factors which may influence the behaviour of a cell include:

- Historical shoreline trend.
- Cell morphology and lithology.
- Profile geometry.
- Backshore elevation.

The coastal cell splits for each site are outlined in Appendix G.

5 Coastal erosion hazard

5.1 Coastal erosion mechanisms and assessments

5.1.1 Cliff shorelines

Consolidated shorelines, which include soil and rock cliffs and coastal terraces, are not able to rebuild following periods of erosion but rather are subject to a one-way process of degradation. Areas susceptible to coastal erosion and coastal land instability along cliff (consolidated) shorelines typically has two components:

- **Toe erosion**

  A gradual retreat of the cliff toe caused by weathering, marine and bio-erosion processes. Thisretreat will be affected by global process such as SLR and potentially increase soil moisture.

  Future cliff toe position based on historic erosion rates with a factor applied to allow for theeffect of future sea level rise.

- **Cliff instability**

  Episodic instability events are predominately due to the decrease in material properties of thecliff or yielding along a geological structure. Instability causes the cliff slope to flatten to an angle under which it is 'stable'. Cliff slope instabilities are influenced by processes that erode and destabilise the cliff toe, including marine processes, weathering and biological erosion or change the stress within the cliff slope. Instability events may range from small-scale instabilities (block or rock falls) or discontinuities, to cliff slope instability cause by large-scale and deep-seated mass movement.

These types of instability events cannot be predicted with certainty. They can only be monitored once signs of movement are observed. To generate a rate from episodic events the period needs to be long enough to enable the cliffs to undergo a full cycle of regression; toe erosion, oversteepening, instability, removal of failed material, toe erosion.

If erosion of the cliff toe is halted through either natural (i.e., establishment of a beach) or artificial (i.e., through rock protection) processes, then the above cliff will continue to retreat until a stable angle is reached. After which time vegetation often becomes established as there is no further removal of material.

The conceptual models for the toe erosion component and cliff instability component are as follows:

$$\textit{Cliff Instability} = (h_C / \tan\alpha) \quad \text{(Equation 1)}$$

$$\textit{Cliff Toe Erosion} = (R \times T) \quad \text{(Equation 2)}$$

Where:

h_C	=	Height (m) of cliff based on DEM
α	=	The characteristic composite slope angle (i.e., composite of lower rock and upper soilslope angle if applicable)
R	=	Future recession rate, see Equation 7
T	=	Timeframe over which erosion occurs.

These can then be combined into the models for consolidated shoreline for the present day ASCIE and future ASCIE. The present day ASCIE is a function of the cliff instability component only as regression of the cliff toe is a long-term process. The future ASCIE is a function of both cliff instability and cliff toe regression, with the latter likely being affected by increased SLR rate effects.

The models for consolidated shorelines are expressed in Equation 3 (current ASCIE) and Equation 4 (future ASCIE), where the ASCIE is established from the cumulative effect of the components (Figure 5-1):

$$\text{Current ASCIE} = (h_C/\tan\alpha) \qquad \text{(Equation 3)}$$

$$\text{Future ASCIE} = (R \times T) + (h_C/\tan\alpha) \qquad \text{(Equation 4)}$$

Note that coastal cliffs may be comprised of more than one geological type with different characteristics. If the cliff slope is comprised of two geotechnical domains, soil and rock, they will have different observed field angles. The height and slope for each domain are assessed separately and are combined to derive the ASCIE (see definition sketch Figure 5-1). For those cliffs where the cliff height (h_c) and the slope angle (α) are subdivided in an upper "soil" (h_{cs} and α_s) and lower "rock" (h_{cR} and α_R) section, the overall slope angle (OSA) is the composite angle α based on a combination of the upper and lower slope angles.

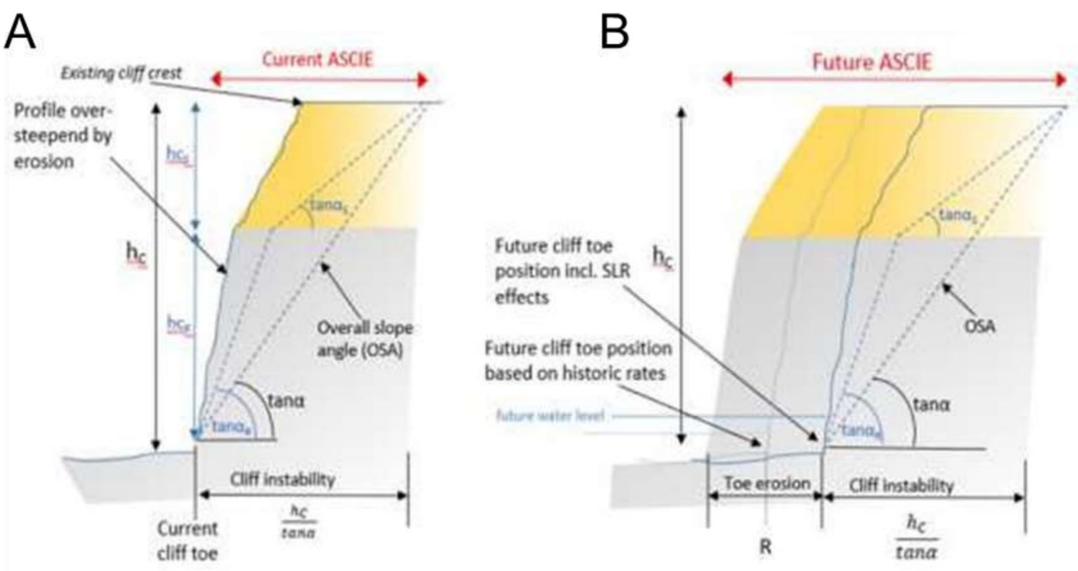


Figure 5-1: Definition sketch for Areas Susceptible to Coastal Instability and/or Erosion on consolidated (cliff) shoreline for current (a) and future (b) states

5.1.2 Beach shoreline

Conceptual models for coastal erosion differ slightly unconsolidated beaches compared to cliffs and estuarine shorelines. The model for unconsolidated beach shorelines is expressed in Equation 5 (Current ASCIE) and Equation 6 (Future ASCIE), where the ASCIE is established from the cumulative effect of six main components (Figure 5-2 & Figure 5-3).

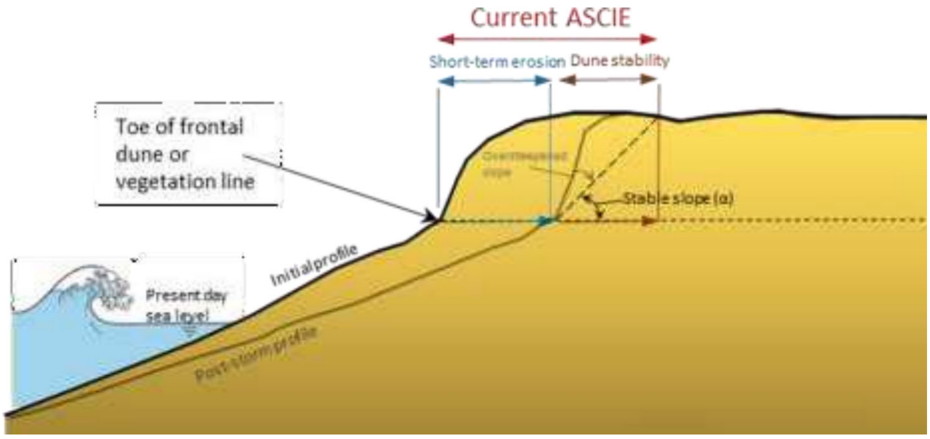


Figure 5-2: Definition sketch for current Areas Susceptible to Coastal Instability and/or Erosion on a beach shoreline

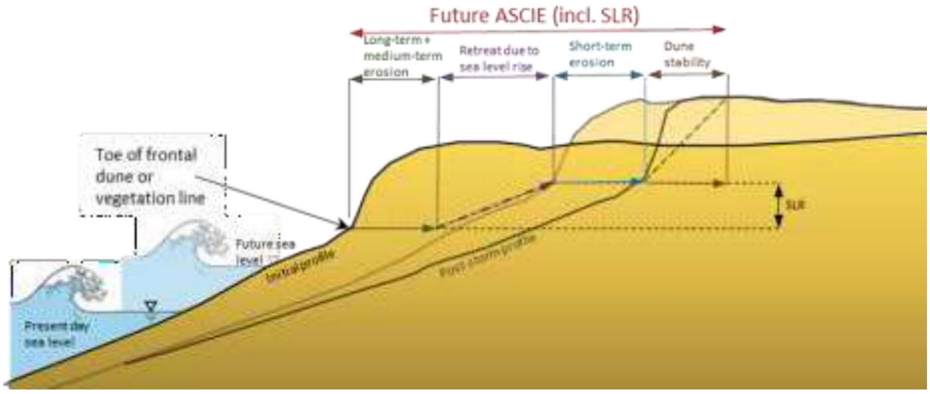


Figure 5-3: Definition sketch of future Areas Susceptible to Coastal Instability and/or erosion on a beach shoreline

$$Current\ ASCIE_{Beach} = ST + DS \qquad \text{(Equation 5)}$$

$$Future\ ASCIE_{Beach} = ((LT \times T) + SL + ST + DS) \times F \qquad \text{(Equation 6)}$$

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 erodeddune to the dune crest at a stable angle of repose (m).

LT = Long-term erosion rate of horizontal shoreline movement (m/year), excludingmedium-term fluctuations. For accretive shorelines LT is set to zero.

T = Timeframe (year).

SL = Horizontal shoreline retreat because of increased mean sea level m).

F = Factor of uncertainty, taken as 2.0 for this assessment.

5.2 Effects of sea level rise

5.2.1 Adopted SLR values

The SLR values included in MfE (2017) based on the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) have been adjusted from the 1986-2005 baseline to the present-day baseline, which is 2016 as the LiDAR DEM was captured between 2016 and 2018. For consolidated cliff and embankment shorelines these adjusted SLR values are used to assess the effect of SLR (refer to Section 5.1.1). For unconsolidated beach shorelines the average historic rate of sea level rise of 1.7 mm/year has been deducted from the projected sea level rise value to provide an 'effective' SLR for use in this assessment on the basis that the existing long-term trends and processes already incorporate the response to the historic situation (see Table 5.1). For this assessment, only the RCP 8.5+ SLR scenario to 2080 and 2130 were mapped.

Table 5.1: Adopted sea level rise values used in analysis (m)

Timeframe	SLR scenario	Projected SLR relative to 1985-2005 basline[1]	SLR from present day baseline[2,3]	'Effective' SLR from present day baseline[2,4,5]
2080	RCP8.5	0.55	0.47	0.36
	RCP8.5H+	0.75	0.65	0.55
2130	RCP8.5	1.18	1.10	0.91
	RCP8.5H+	1.52	1.42	1.23

[1] Source: Projected SLR from MfE (2017) referencing IPCC (2013) Assessment Report 5

[2]Correction applied to adjust from 1986-2005 (taken to be 1995) to 2016 (baseline derived from 2016 LiDAR DEM)[3]Utilised for consolidated cliff and embankment shorelines

[4]Subtracts assumed historic rate of 1.7 mm/year (Hannah & Bell, 2012) to avoid double-counting erosion response

[5]Used for unconsolidated beach shorelines

There is a new IPCC assessment report (AR6), released on 9 August 2021 which gives the latest summary of climate change and projected climate change. This report includes five emission scenarios with the 2.6, 4.5 and 8.5 scenarios that are similar, but not exactly the same, as the AR5 report. The modelling projects slightly more warming for a given pathway than AR5 scenarios. Downscaled data for this is not yet available for New Zealand from NIWA, and this is expected in 2022. However, based on available data from NASA, (Sea Level Projection Tool – NASA Sea Level Change Portal) that gives AR6 sea level rise information. Adjusting this information to the base baseline as the AR 6 assessment (see Figure 5-4) the AR6 projects are within the bounds of AR5 to 2080. Increases occur for the SSP8.5M and SSP8.5(83rd) scenarios at 2130 by around 0.07m and 0.2m respectively. Using existing MfE data from AR5 remains acceptable, and still provides a more conservative 100 year sea level rise condition than included in the current Unitary Plan (refer Section 2.3).

MfE (2017) recommends avoiding coastal hazard risk for new coastal new subdivisions using the RCP8.5+ for over 100 years. This means that building lots should be landward of the erosion hazard zone for the RCP8.5+ scenario at 2130.

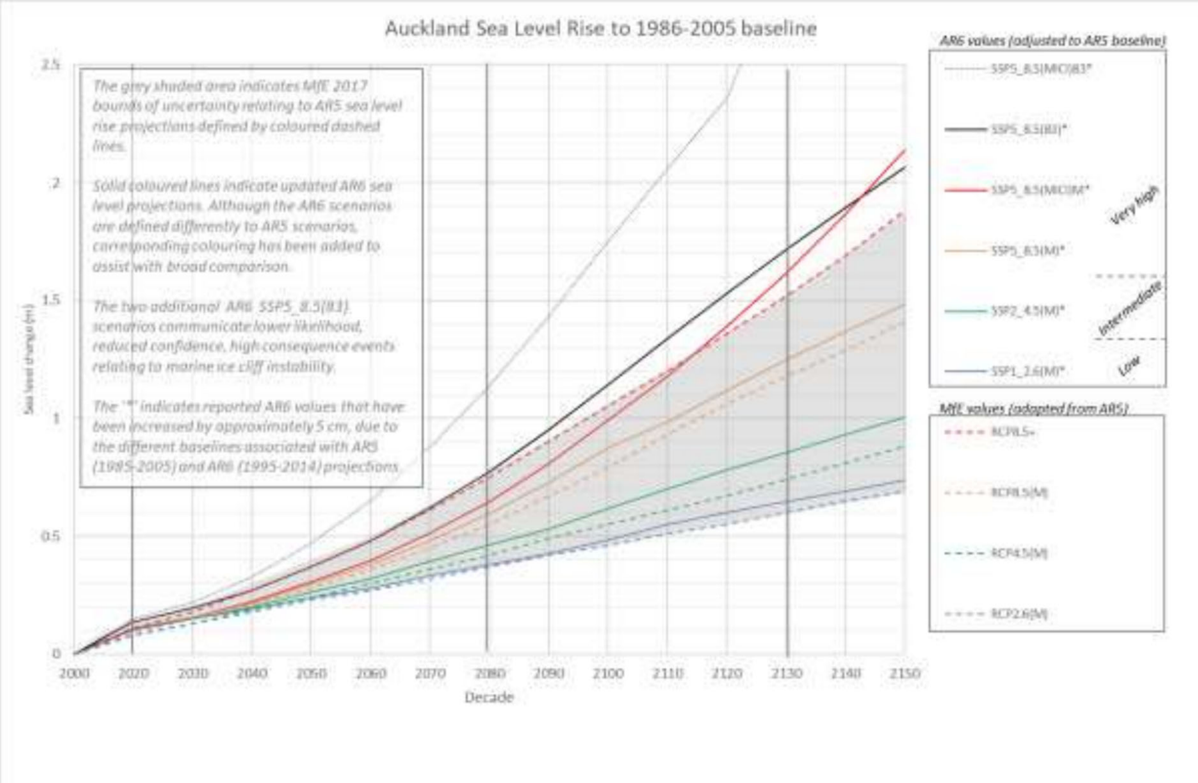


Figure 5-4: Comparison of AR5 and AR6 sea level rise levels

5.2.2 Cliff response to SLR

Erosion of a consolidated shoreline is a one-way process of material removal, which typically can be divided into components. Gradual recession caused by weathering and coastal processes and episodic failures due to cliff lithology and geologic structure and process triggers (e.g., extreme rainfall, leaking utilities).

This section describes the method for assessing gradual recession as a result of rising sea levels. This process is due to weathering and is a function of climatic conditions, exposure and cliff material.

Marine hydraulic processes affect cliffs either by wave action causing erosion at the toe, or by removing slope debris deposited at the toe following subsequent cliff-face collapse. Sea level rise increases the amount of wave energy able to propagate over a fronting platform or beach to reach a cliff toe, removing talus more effectively and increasing the potential for hydraulic processes to affect erosion and recession. However, in some locations, the existence of a talus will provide self-armouring, and may slow cliff recession due to waves.

Ashton et al. (2011) proposed a generalised expression for future recession rates of cliff shorelines shown in Equation 4.8 and Figure 5-4 where m is the coefficient, determined by the response system (sea level rise response factor). The future rate of SLR S_F is based on the adjusted SLR values as set out in Table 5.1 divided by the relevant timeframes. The historic rate of SLR S_H is based on Hannah and Bell (2012). LTH is the historic long-term retreat (regression rate), m/year. Measured from digitised historic shorelines.

$$R = LT_H \left(\frac{S_F}{S_H}\right)^m$$

(Equation 7)

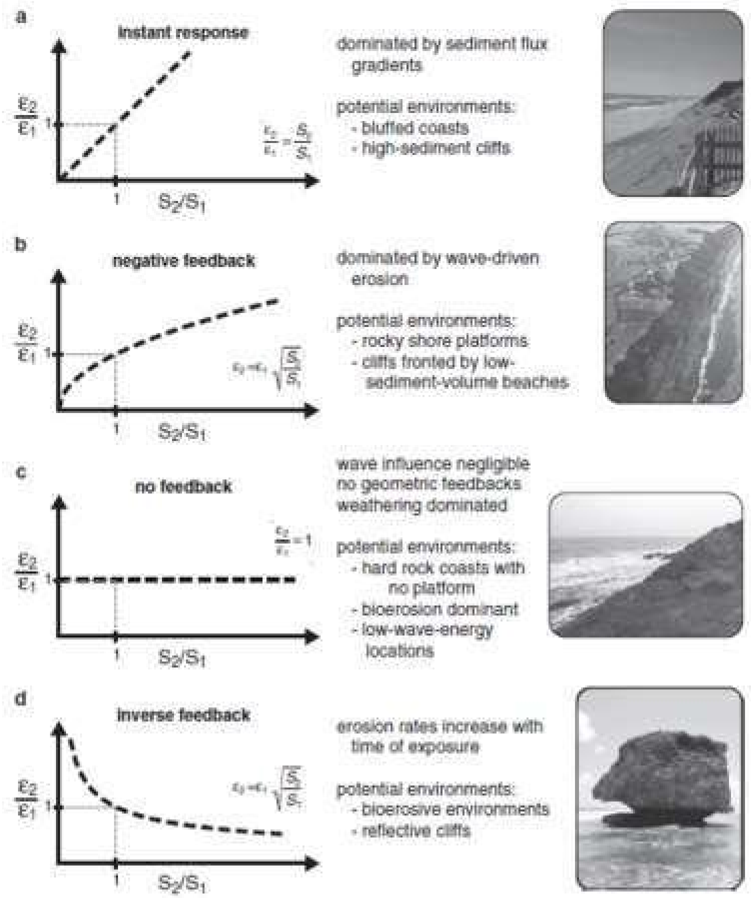


Figure 5-5: Possible modes of cliff response to SLR (adapted from Ashton et al., 2011)

An instantaneous response (m = 1) is where the rate of future recession is proportional to the increase in SLR. An instant response is typical of unconsolidated or weakly consolidated shorelines. No feedback (m = 0) indicates that wave influence is negligible, and weathering dominates. The most likely response of consolidated shorelines is a negative/damped feedback system (m = 0.5), where rates of recession are slowed by development of a shore platform (see Figure 5-4). Ashton et al. (2011) also suggests an additional case of inverse feedback when m < 0 indicating a reduction in recession with increasing sea levels. They suggest this could occur when erosion is controlled by bio-erosion which may reduce with additional submergence. The approach suggested by Ashton et al. (2011) is conceptually plausible and has the potential to predict recession rates on a wide variety of rock types with further analysis.

5.2.3 Beach response to SLR

Geometric response models propose that as sea level is raised, the equilibrium profile is moved upward and landward conserving mass and original shape (see Figure 5-5). The most well-known of these geometric response models is that of 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 model may be defined by the following equation:

$$SL = \frac{L_*}{B + d_*} S$$

(Equation 8)

Where SL is the landward retreat, d_* defines the maximum depth of sediment exchange, L_* is the horizontal distance from the shoreline to the offshore position of d_*, B is the height of the berm/dune crest within the eroded backshore and S is the sea level rise. Figure 5-5 shows the schematic diagrams of the Bruun models, with the Standard Bruun rule used for this assessment.

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.

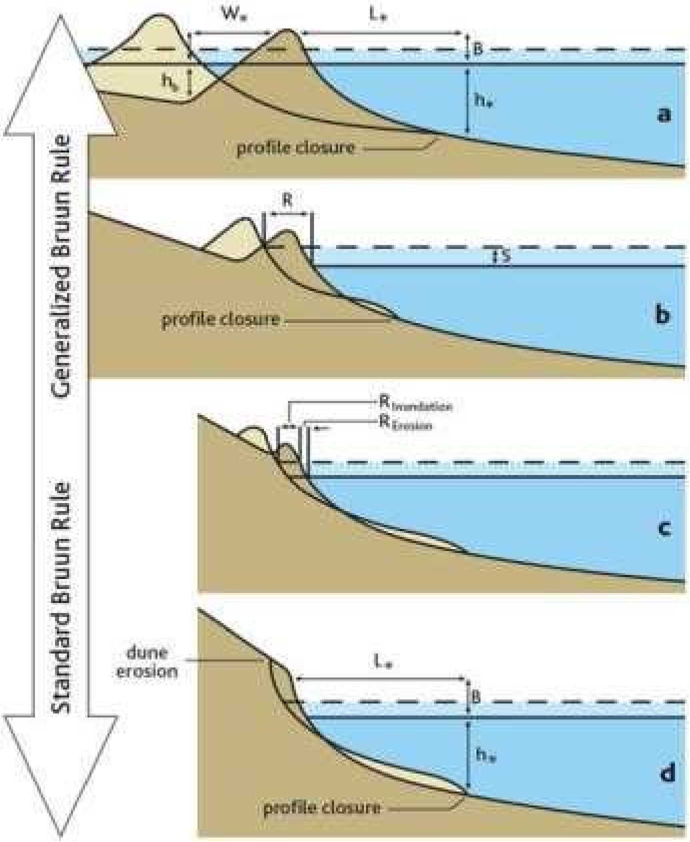


Figure 5-6: Schematic diagrams of the Bruun model modes of shoreline response (after Cowell and Kench, 2001)

5.3 Resulting Areas Susceptible to Coastal Instability and Erosion (ASCIE)

The resulting setback distances for ASCIE along the shoreline for the site are given in Table 5.2 and Figure 5-7. These areas have been mapped and are shown in Appendix G in more detail. Minimum values were adopted for cliff/terrace cells as -5 m, -10 m and -15 m for current, 2080 and 2130 ASCIE respectively.

Table 5.2: ASCIE for all cells

Cell	Current ASCIE (m)	2080 ASCIE (m)	2130 ASCIE (m)
A[1]	-9	-19	-32
B[2]	-5	-10	-15
C[1]	-9	-19	-32
D[2]	-27	-33	-38
E[2]	-52	-62	-72
F[2]	-52	-58	-64
G[2]	-5	-10	-15
H[2]	-5	-10	-15

1 calculated using the beach method, see Section 5.1.2.

2 calculated using the cliff method, see Section 5.1.1.

5.4 Assessment of impact of coastal instability and erosion on the proposed structure plan and plan change

The coastal erosion susceptibility extents have been overlain on the live-zone plan to assess the potential impact of coastal erosion susceptibility on the proposed development (see Figure 5-7). This shows that all property parcels, key assets and infrastructure are located landward of the 2130 area susceptible to coastal instability and erosion. The AUP framework for addressing natural hazards and climate change will be sufficient for addressing coastal instability and erosion and no specific mitigation is required.

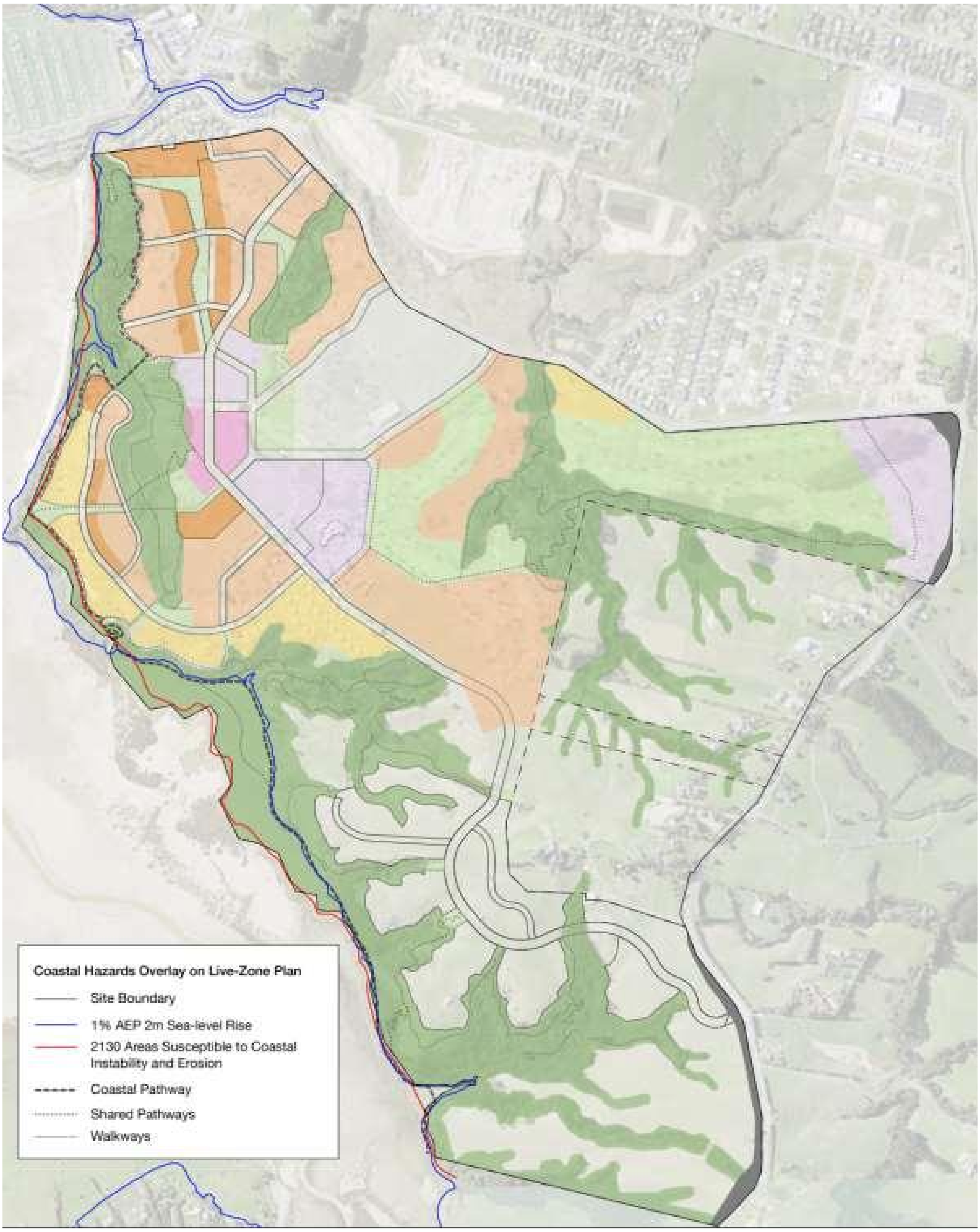


Figure 5-7: Overlay of coastal hazards on the Live-Zone plan

6 Coastal inundation hazard

6.1 Coastal inundation extents

Coastal storm inundation is an acute natural event arising from extreme weather events in which normally dry but low-lying coastal land is flooded. This occurs when high tides combine with storm surge, wave setup and run-up, and the higher than average monthly mean sea level due to climate cycles and variability.

The likelihood and magnitude of coastal inundation during storms is highly dependent on the timing of spring high tides, storm surge and wave conditions. The area and depth of inundation depends on the physical characteristics of the shoreline and hinterland topography. If sea levels rise as predicted, then coastal inundation will be exacerbated.

Several coastal inundation scenarios have been mapped by Auckland Council based on the storm surge modelling carried out by Stephens et al. (2016). Published maps of the coastal inundation extents for 1% Annual Exceedance Probability (AEP) event at present day and with 1 m and 2 m sea level rise have been obtained from Auckland Council and are presented in Appendix H. The 1%AEP storm surge with 1 m sea level rise is the current requirement for consideration within the Unitary Plan, but MfE guidance suggests considering the potential consequence of 2 m sea level rise for new subdivisions and development.

For the present-day scenario inundation rises over much of the low lying chenier ridge, shell beach and salt marsh cells and propagates some 250 m up Stream A to the north of the site, however much of the coastal terrace on the northwest side of the site remains above the 1% AEP storm surge level. With the future 1 m and 2 m SLR scenarios, the majority of the Jack Lachlan Esplanade Reserve seaward of the cliff toe becomes inundated and propagates some 450-500 m up Stream A. There is relatively little difference in flood extent between the 1 m and 2 m sea level rise scenario and this is due to inundation reaching the toe of the cliffs, so the main difference between 1 m and 2 m sea level rise is the depth of inundation during storm surges. While such water level is not expected to flood the site landward of the cliff sections, it would leave the much of the cliff toe previously protected by low-lying coastal terraces more vulnerable to wave action and subsequent coastal erosion. However, due to the relatively low water depth and the sheltered location of these cliffs, this is not anticipated to be an issue for the next 100 years.

6.2 Assessment of impact of coastal inundation on the proposed structure plan and plan change

The coastal inundation extents have been overlain on the live-zone plan to assess the potential impact of coastal inundation on the proposed development (see Figure 5-7) including an allowance for 2 m sea level rise. An area of low lying reserve will be periodically inundated, but no flooding will occur on residential or commercial land or road corridors. With the consideration of inundation impacts of up to 2 m sea level rise, the AUP framework for addressing hazards and climate change will be sufficient for addressing coastal inundation hazards and no specific mitigation is required. The coastal pathway through the wetland area is located within the area of inundation with a 1%AEP storm surge and sea level rise of between 1 and 2m sufficiently. It is sufficiently landward and elevated that it is unlikely to be at risk until sea level rise exceeds 1.5m, and it has the ability to be raised as required.

7 Tsunami

Tsunami are long-period water waves generated by undersea shallow-focus earthquakes or by undersea crustal displacements (subduction of tectonic plates), landslides, or volcanic activity. Tsunamis can travel great distances, undetected in deep water, but shoaling rapidly in coastal waters and producing a series of large waves capable of destroying harbour facilities, shore protection structures, and upland buildings (FEMA, 2008).

Tsunami may be broadly categorised as being either local (wave arriving within 1 hour of associated event), regional (wave arriving between 1 and 3 hours of associated event), or distant (wave arriving more than 3 hours after associated event). Along Auckland's east coast, the most significant local Tsunami source is from an earthquake along the Kermadec Arc, a subduction zone that extends northwards from East Cape to just south of Fiji (Gillibrand et al., 2010).

Tsunami wave characteristics at the coast can vary substantially, depending on several factors, including: the generating mechanism; the location, size and orientation of the initial source; source-to-locality distance; and local seabed and coastal margin bathymetry and topography. The timing and height of high tide with the tsunami peak waves are also important factors in determining the extent and magnitude of inundation. Sea-level rise will also exacerbate tsunami inundation and increase flow depths relative to present day for the same event.

The mapped tsunami evacuation zones included in the Auckland Council GIS maps are a conservative estimate of possible inundation threat (see Figure 7-1) for civil defence purposes (GNS, 2012, 2013). The red tsunami evacuation zone represents the highest risk zone and is the first area people should evacuate from in all types of tsunami warnings. This area includes all of Auckland's beaches and foreshore areas. The orange evacuation zone includes a range of tsunami scenarios, both distant and regional that could generate a 3 m high tsunami (return period in the order of 200 to 300 years) and a maximum amplitude (2,500 year return period at 84% – yellow evacuation zone) tsunami. They are mapped using first order attenuation approaches within shallow harbours and estuaries.

These levels suggest tsunami inundation extents for tsunami's with return periods of up to 200 years are likely to be within storm surge inundation levels at this location, although the potential of greater scour and erosion forces acting along the shoreline. Larger tsunamis may cause slightly greater inundation extents, but likely to still be within the inundation extents indicated by inundation maps inclusive of 2 m sea level rise.

All key infrastructure and developments are located landward of the tsunami inundation extents. The AUP framework for addressing hazards will be sufficient for addressing tsunami hazards and no specific mitigation is required.

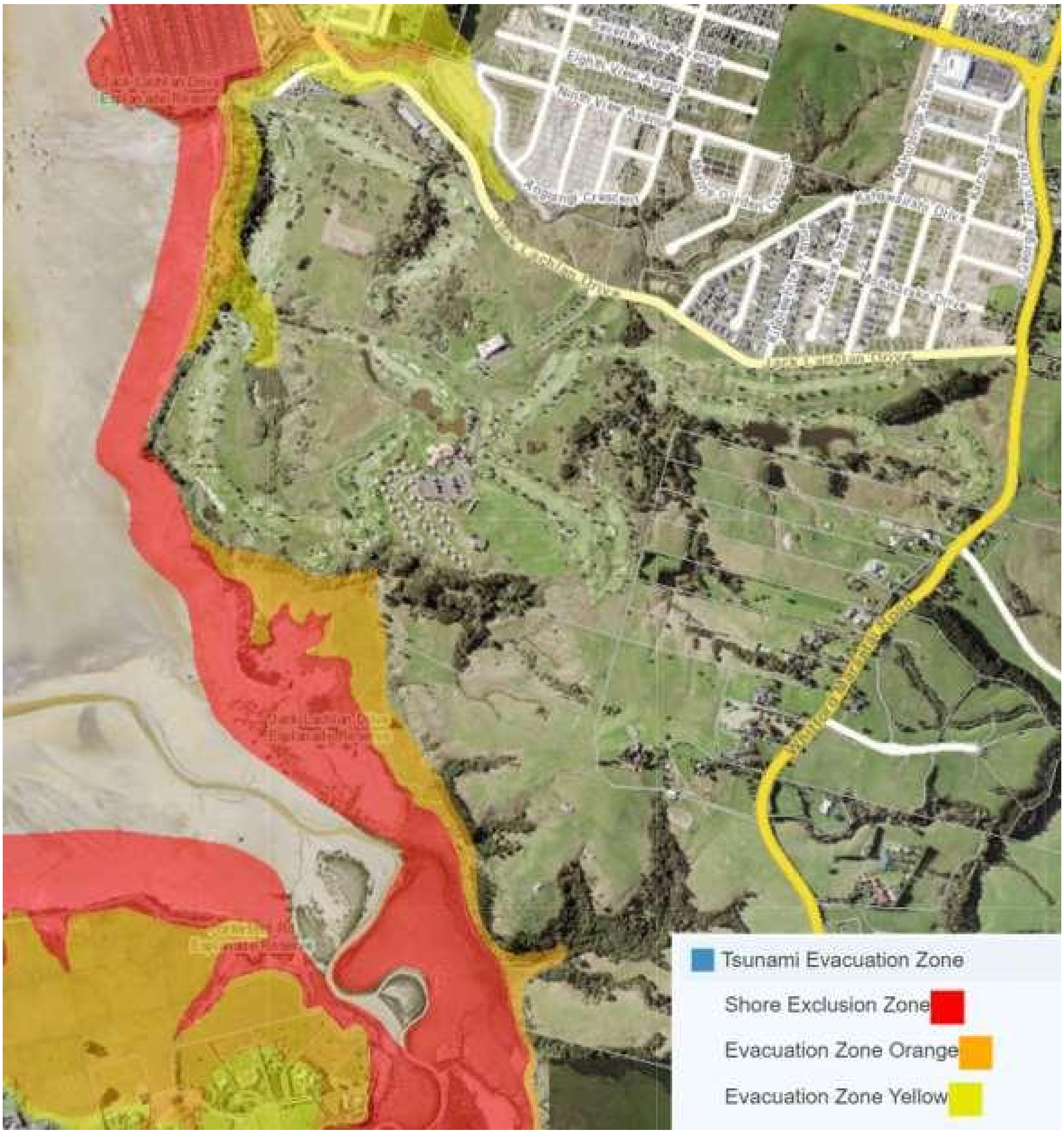


Figure 7-1: Tsunami evacuation zone (Source: Auckland Council GeoMaps)

8 Conclusion

The intention of this assessment is to provide Beachlands South Limited Partnership information on potential coastal hazard issues to inform the structure planning process and private plan change for rezoning of the land for future urban development. This study includes a local scale assessment of Areas Susceptible to Coastal Instability and Erosion (ASCIE) of both consolidated (cliff/ terrace) and unconsolidated (beach) shorelines, and an assessment of the inundation hazard of the site based on scenarios supplied by Auckland Council.

This assessment meets the objectives and policies in the RPS (Chapter B of the AUP) that set strong directives to manage the risk of coastal hazards (Chapters B8 and B10) by considering natural hazards and the effects of climate change on natural hazards for at least 100 years.

All property parcels, key assets and infrastructure are located landward of the 2130 area susceptible to coastal instability and erosion. No coastal inundation or tsunami hazard will occur on property parcels, key assets and infrastructure, even with a consideration of 2 m sea level rise. The AUP framework for addressing natural hazards and climate change will be sufficient for addressing coastal instability and erosion and no specific mitigation is required.

The AUP currently requires a 30 m coastal yard for buildings measured from MHWS under the AUP framework. This yard is for a range of purposes and is considered to be adequate for managing the development of buildings and structures adjacent to this coastal edge but there is no reason from a coastal hazard perspective to change this setback standard.

With the development situated to avoid coastal hazards the proposed development will not exacerbate or accelerate any of the existing hazards present. Any structures or development within the future inundation areas should be landward of the erosion susceptibility extent and designed to accommodate or be adaptable to coastal inundation hazards complying with the rules in Chapter E36 of the AUP. This should reduce and manage the coastal inundation hazard risk to the proposed development.

9 Summary and recommendation

This study includes a local scale assessment of Areas Susceptible to Coastal Instability and Erosion (ASCIE) of both consolidated (cliff/ terrace) and unconsolidated (beach) shorelines, and an assessment of the inundation hazard and tsunami hazard based on scenarios supplied by Auckland Council.

The present day ASCIE and two future ASCIE (2080 and 2130) were evaluated. Present day ASCIE is based on the current stability of the shoreline and potential erosion to occurafter large storm events, and future ASCIE is based on present day values, plus a future long-termregression rate, including a sea level rise component (using the RCP 8.5+ scenario). The resulting setback distances have been determined for ASCIE along the shoreline for the site. These areas have been mapped and are shown in Appendix G and overlain on the live-zone plan (Figure 5-7). Inundation extents including 1%AEP storm surge and 1 m and 2 m sea level rise have been considered and these are included in Appendix H and Figure 5-7.

All property parcels, key assets and infrastructure are located landward of the 2130 area susceptible to coastal instability and erosion. No coastal inundation or tsunami hazard will occur on property parcels, key assets and infrastructure, even with a consideration of 2 m sea level rise. The AUP framework for addressing natural hazards and climate change will be sufficient for addressing coastal instability and erosion and no specific mitigation is required.

Only beach and salt-marsh areas are susceptible to coastal inundation and are also the most likely to be affected by tsunami. These low-lying areas around the coastal edge have only been considered for recreational amenity and no habitable buildings should be located on these areas. The walkway is situated sufficiently landward and is of an elevation that reduces the risk of inundation to negligible for sea level rise of up to 1.5m. Adaptation responses can be considered to raise or relocate in the long term.

Any structures or development within the future inundation areas should be landward of the erosion susceptibility extent and designed to accommodate or be adaptable to coastal inundation hazards. This should reduce the coastal hazard risk to any the proposed development within these areas.

The assessment meets the requirement of Policy 24 of the NZCPS and the proposed structure plan meets both Objective 5 of the NZCPS ensuring that coastal hazard risks, taking into account of climate change are managed by locating new development away from areas prone to such risks, and Policy 25 by avoiding any increased risk of adverse effects from coastal hazards. By avoiding providing the setback areas along the coastal edge, the proposal recognises and protects the existing natural defences of vegetated slopes and wetlands, meeting requirements of Policy 26 of the NZCPS.

We note that the AUP currently requires a 30 m coastal yard for buildings measured from MHWS under the AUP framework. This yard is for a range of purposes and is considered to be adequate for managing the development of buildings and structures adjacent to this coastal edge but there is no reason from a coastal hazard perspective to change this setback standard.

10 Applicability

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

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11 References

Ashton, A.D., Walkden, M.J. and Dickson, M.E. (2011). Equilibrium responses of cliffed coasts tochanges in the rate of SLR. Marine Geology. 284 (2011) 217-229.

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.Cai, M.,

FEMA (2008). Guidelines for Design of Structures for Vertical Evacuation from Tsunamis. FEMA P- 646A, prepared by the Applied Technology Council for the Federal Emergency Management Agency,Washington, D.C.

Gillibrand, P. W. Power, E. Lane, X. Wang, J. Sykes, H. Brackley, J. Arnold (2010) Probabilistic hazard analysis and modelling of tsunami inundation for the Auckland Region from Regional Source Tsunami, NIWA Report CHC2010-102, GNS Report 2010fe/200 for Auckland Regional Council, August2010.

GNS (2012) An initial GIS-based tsunami inundation area for a three-metre wave height in Auckland.GNS letter report 2012/208LR for Auckland Council, 30 July 2012.

GNS (2013) A GIS-Based tsunami inundation area for the maximum credible wave height inAuckland. GNS letter report 2013/240LR for Auckland Council, 20 November 2013

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.Hamill P.F. and Balance P.F. (1985). Heavy mineral rich beach sands of the Waitakere coast, Auckland, New Zealand, New Zealand Journal of Geology and Geophysics. 28:503-511.

Kermode, L.O. (1992). Geology of the Auckland urban area. Scale 1:50 000. Institute of Geological &Nuclear Sciences geological map 2. 1 sheet + 63 p. Institute of Geological & Nuclear Sciences Ltd., Lower Hutt, New Zealand.

Klinac, P. (2002) Sediment dynamics of the sheltered East Coast beaches of Auckland. Thesis,University of Waikato.

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

LINZ (2012). Tidal levels for surveyors. http://www.linz.govt.nz/geodetic/datums-projections-heights/vertical-datums/tidal-level-information-for-surveyors.

MfE (2017). Coastal Hazards and Climate Change: Guidance for Local Government. Published by the Ministry for the Environment (MfE) December 2017. https://www.mfe.govt.nz/publications/climate-change/coastal-hazards-and-climate-change-guidance-local-government

Nicholls, RJ., Laron, M., Capobianco, M. and Birkemeier, W.A. (1998) Depth of Closure: ImprovingUnderstanding and Prediction. ICCE 1998.

Ramsay, D., Altenberger, A., Bell, R., Oldman, J., Stephens, S. (2008a) Review of rainfall intensity curves and sea levels in Manukau City. Part 2: Sea levels. Consulting Report to Manukau City Council,No. HAM2007-168: 74.

Reinen-Hamill, R., Hegan, B., Shand, T., et al. (2006). Regional Assessment of Areas Susceptible to Coastal Erosion (Technical Report Volume 1). Prepared for Auckland Regional Council by Tonkin &Taylor Ltd.

Inundation Hazard Study: Coastal Storms and Extreme Waves, WRL TR2010/16.

Stephens et al. (2016). Coastal Inundation by Storm-tides and Waves in the Auckland Region. Prepared by the National Institute for Water and Atmospheric Research, NIWA and DHI Ltd forAuckland Council. Auckland Council technical report, TR2016/017.

T+T (2020). Auckland Costal Erosion Study (Final Draft). Prepared for Auckland Council by Tonkin &Taylor Ltd. March 2020.

T+T (2021). Beachlands South Structure Plan Change: geotechnical report. Unpublished report for Bechlands South Limited Partnership, dated 1 December 2021.

Appendix A: Geotechnical supporting data

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A1 Statistical method for slope angles

To create a statistical method for determining the Areas Susceptible to Coastal Instability (ASCI) slope angles a dataset was required to be created for the Beachlands area. Therefore, each lithological domain or sub domain was analysed at 15 to 25 m section spacing for different coastal environments. For each profile the cliff toe, crest of the rock layer and crest of the soil layer were derived to obtain the height and slope of both the rock and soil layers (see sketch in Figure Appendix A.1).

Figure Appendix A.1: Cliff profile sketch showing identified rock toe, rock crest and soil crest to derive angles and heights

The derived heights and angles from each profile were then analysed and combined to derive combined slope angles for each lithology. The combined slope angles were plotted as scatter plots (see Figure Appendix A.2) and slope angle statistics were derived. Figure Appendix A.3 shows the distribution of combined slope angles for the site including the medium, unlikely, and exceptionally unlikely likelihood slope angles. The definitions of the likelihood of occurrence adopted here have been taken from the Intergovernmental Panel on Climate Change (IPCC) methodology (using the lower three categories: Medium (33-66% - 50% Mean adopted), Unlikely (10-33% - 10% adopted) and Exceptionally Unlikely (1% adopted)).

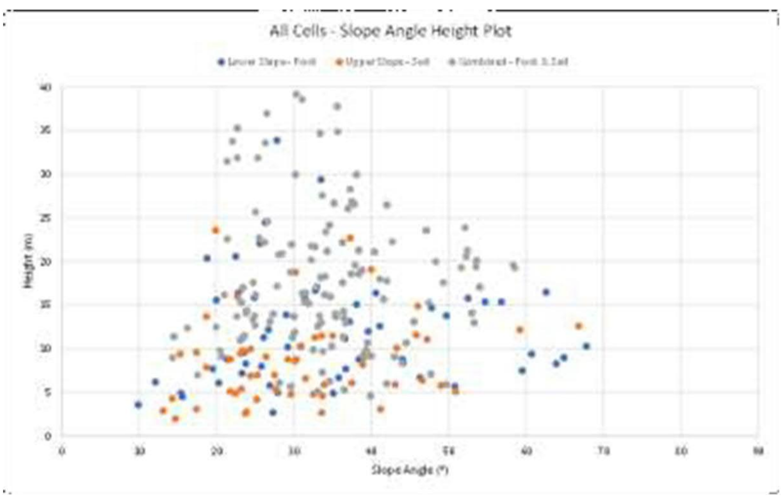

Figure Appendix A.2: Statistical evaluation of ASCI height and slope profiles for Beachlands

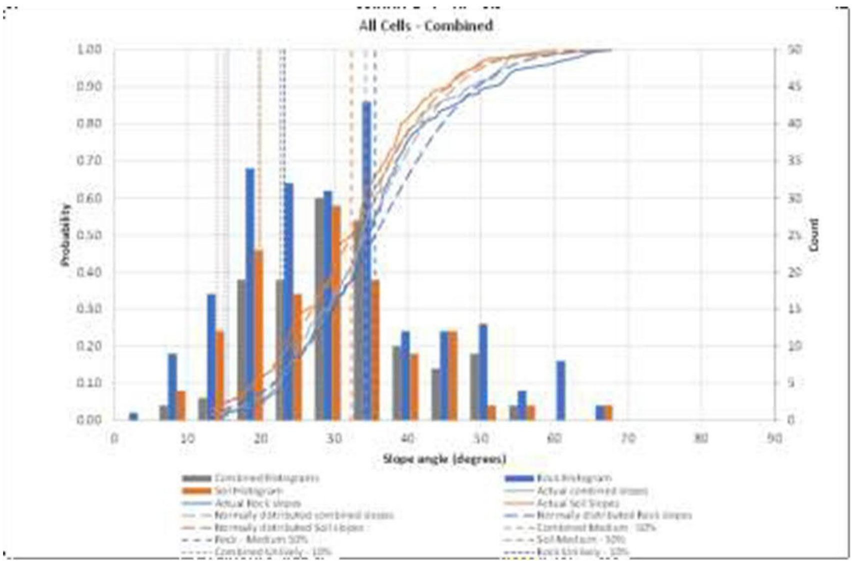

Figure Appendix A.3: Statistical evaluation of ASCI slope profiles for Beachlands

A2 Beachlands site specific ASCI slope angles

A detailed assessment was undertaken for Beachlands to define ASCI slope angles based on the digital elevation model (DEM) of the site. To refine DEM the coastline was divided into five (5) cells as shown below and on Figure Appendix A.4.

- Cliff Cell A – accretion beach with vegetated cliff slopes. This cell contains a man-made slope that has been excluded from the analysis.
- Cliff Cell B – rock outcrop in the toe, with exposed face.
- Cliff Cell C – sheltered shore platform with rock outcrop toe, including an unstable soil slope.
- Cliff Cell D – salt marsh toe zone, including an unstable soil slope.
- Cliff Cell E – estuarine zones with low vegetation coverage.
- Cliff Cell F – estuarine zones with pine woodland indicating potentially a deeper soil profile.

Each cell was divided into a series of cliff profiles at a spacing of 15-25 m. The spacing depended on the crest length of the cell to facilitative the statistical evaluation of the profiles. These were then graphed and the Medium (50%), Unlikely (10%) and Exceptionally Unlikely (1%) probabilities tabulated, as shown in Appendix A Table 1, Figure Appendix A.2 and Figure Appendix A.3.

On reviewing the statistics from the soil, rock and combined slope angles at the various probabilities are minimal. Therefore, for simplicity in approach the Unlikely composite slope angles of 23° (Table 3.2) should be used for the toe projection.

There were two areas where previous historical instability events have occurred, these are shown on Figure 3-2 by X1 and X2. The slope angle for the unstable slopes are between 15 to 36°. Therefore, the lower 'Unlikely' slope angle of 23° should be applied.

Cliff Cell B was identified as having the steepest slope angle, this was identified in the site walk over as the most recently unstable with a series of rockfalls observed at the toe. The rock falls are high probably events with a low consequence for coastal instability due to the size of the blocks being released (0.03 to 0.15 m^3). Therefore, the cell has the potential to be over steepened and closer to equilibrium.

Appendix A Table 1: ASCI slope angles for Beachlands cells

Lithology	Rock (°)			Soil (°)			Composite (°)		
	50%	10%	1%	50%	10%	1%	50%	10%	1%
Beachlands Average	36	23	15	32	20	14	34	23	15
Cliff Cell A	35	24	24	23	13	13	35	24	24
Cliff Cell B	50	36	27	42	25	16	47	36	31
Cliff Cell C	41	21	20	32	22	18	38	25	22
Cliff Cell D	25	15	13	28	23	19	25	15	14
Cliff Cell E	34	25	19	34	27	24	34	28	21
Cliff Cell F	32	24	23	27	17	16	31	23	22

Figure Appendix A.4: Cliff cell locations

A3 Assessment for Auckland Council Code of Practice (2013)

A slope stability analysis was undertaken for one of the two slope instabilities recorded during the site walk. The site chosen was site X2 as shown in Figure Appendix A.5. The stability analysis was undertaken in Limit Equilibrium software SlopeW (Geostudio) to ensure that they conformed to the current ACCoP (2013) and that the statistical approach provides parity of results. The material parameters used in the analysis are shown below in Appendix A Table 2.

The morphology of the adjacent slope was modelled with a rise in groundwater to re-created the instability with a Factor of Safety (FoS) approximately 1.0 or slope equilibrium, with a slope angle of 36°. The model was then re-run to generate a FoS of 1.5 and compliance with ACCoP (2013).This resulted in a slope angle of (15°) and a toe to crest distance of 62 m.

To validate the slop stability model a ground investigation should be undertaken adjacent to the site to confirm material properties and groundwater conditions. The resulting data should be used in ground model validation and re-assessment of the slope stability.

Appendix A Table 2: Adopted ASCI cliff angles

Geotechnical domain	Unit weight	Cohesion	Friction Angle	GSI	UCS
	kN/m³	kPa	°		kPa
Waitemata Group - Soil	19	4	28		
Waitemata Group - ECBF	20	25	35	35	1000

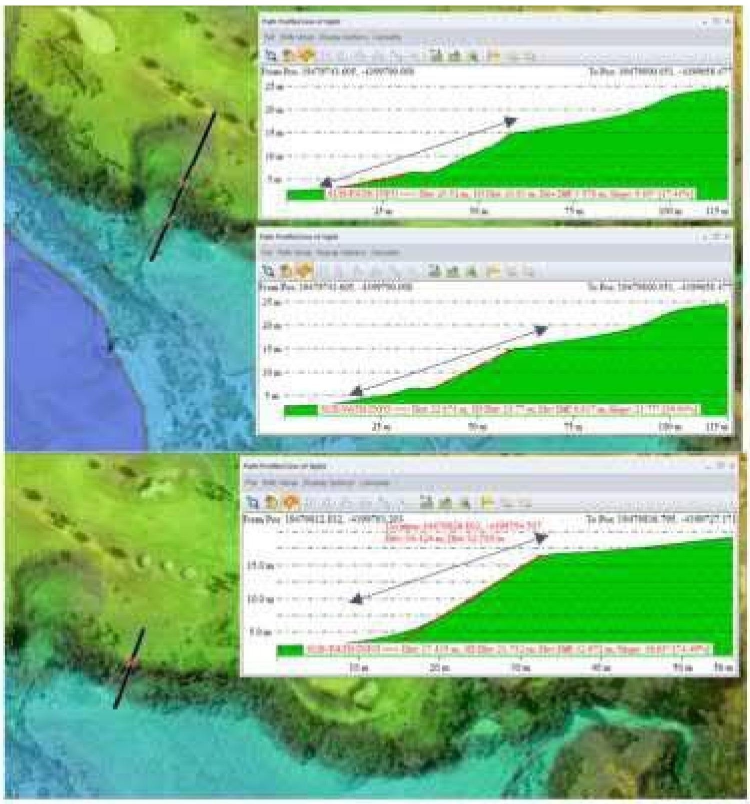

Figure Appendix A.5: Slope instability in the Beachlands coastal section

Appendix B: Aerial images

Figure Appendix B.1: Historic aerial photograph of the site dated 1939 (Source: Retrolens)

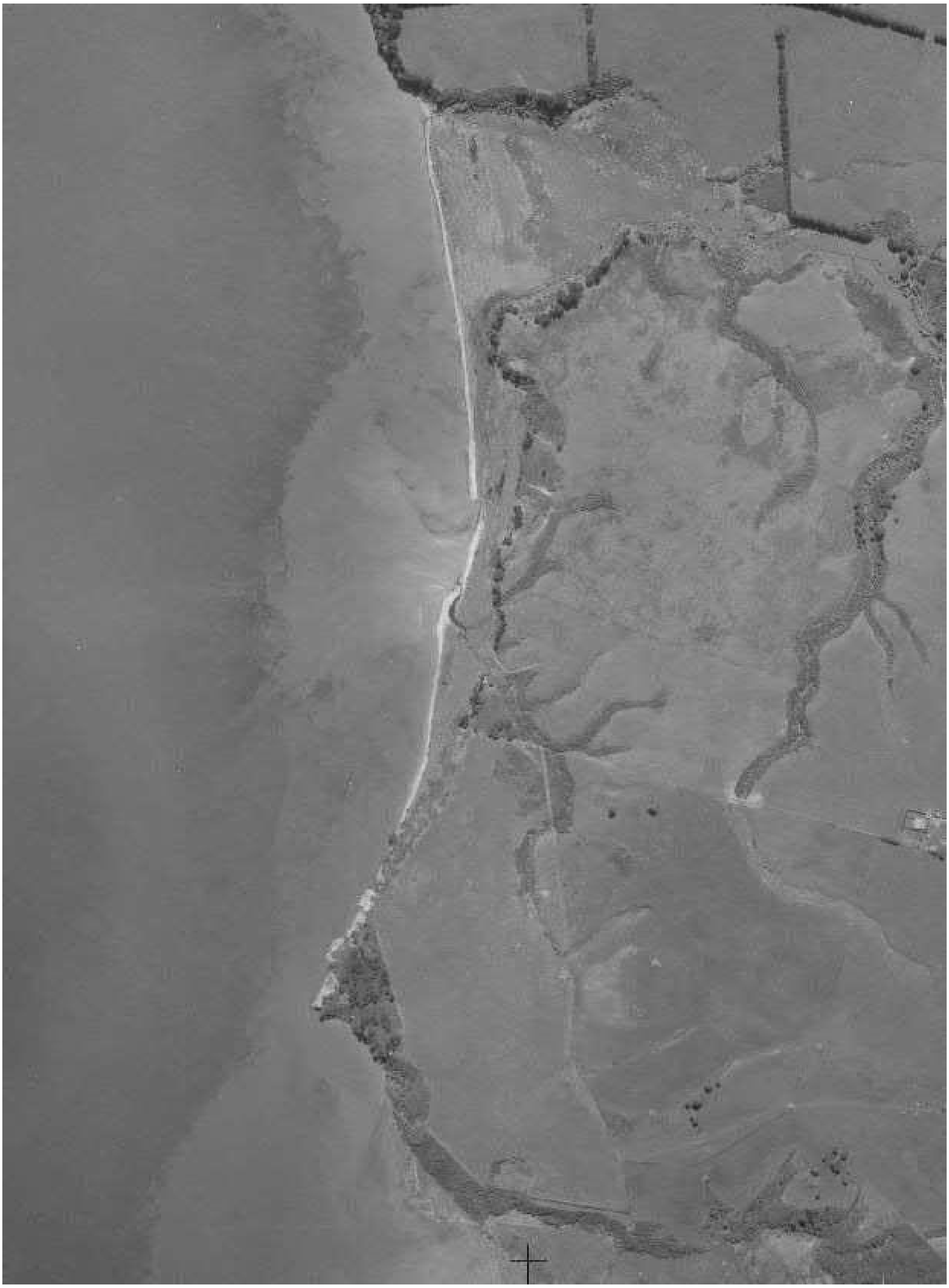

Figure Appendix B.2: Historical aerial photograph of the site dated 1955 (Source: Restrolens)

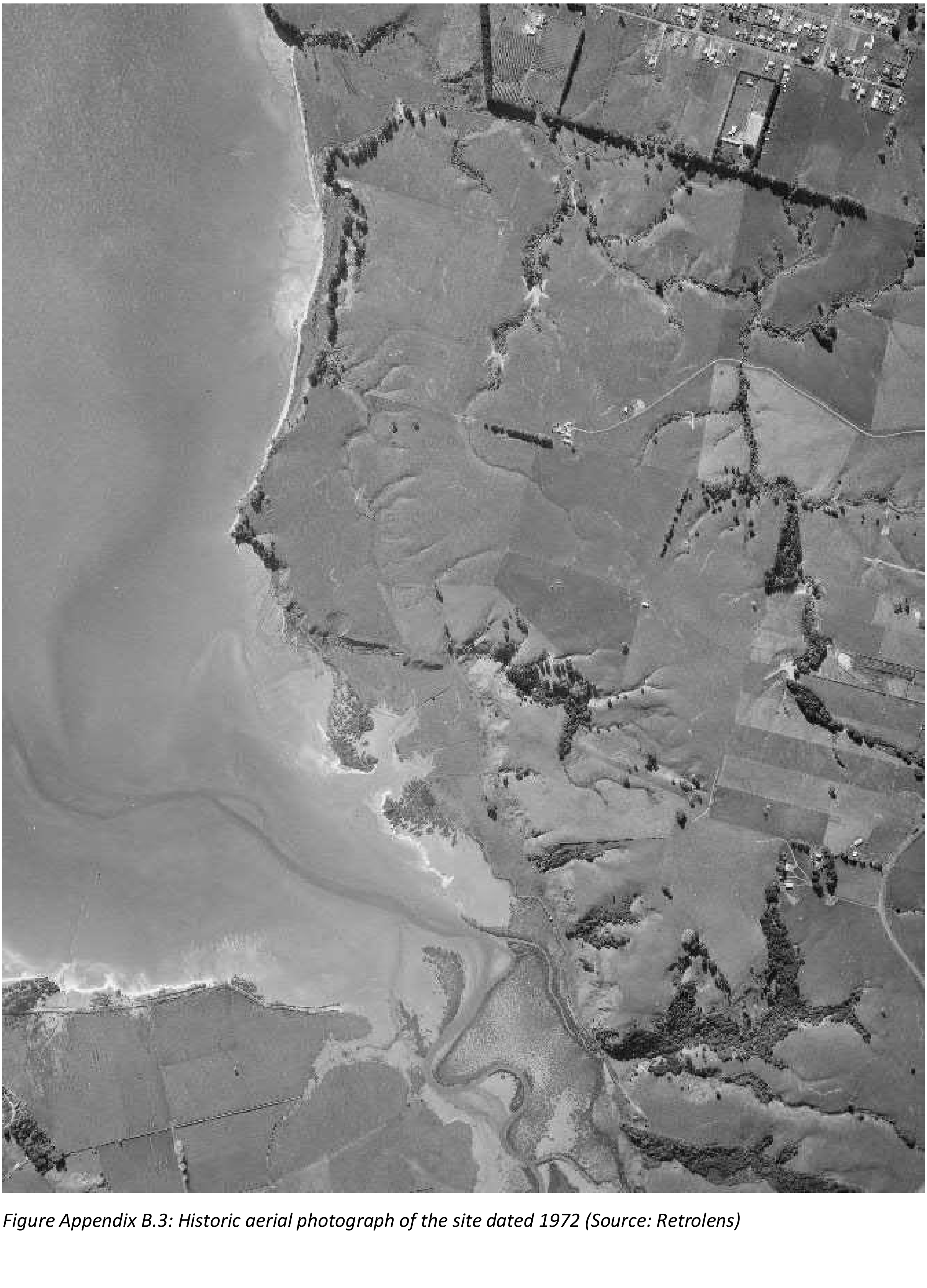

Figure Appendix B.3: Historic aerial photograph of the site dated 1972 (Source: Retrolens)

Figure Appendix B.4: Historic aerial photograph of the site dated 1980 (Source: Retrolens)

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Figure Appendix B.5: Historic aerial photograph of the site dated 1987 (Source: Retrolens)

Figure Appendix B.6: Present day aerial photograph of the site dated 2017 (source: LINZ data service)

Appendix C: Site photographs

Figure Appendix C.1: View (looking south) of the chenier ridge building out on the left with stream outlet in front

Figure Appendix C.2: View (looking east) of eroding terrace, the loose rock seaward of terrace is an indication of erosion

Figure Appendix C.3: View (looking north) of 'Stream B'

Figure Appendix C.4: View (looking south) of beach section with cliff headlands in the background

Figure Appendix C.5: View (looking southeast) of cliff headlands, with mudstone flats seaward

Figure Appendix C.6: View (looking east) of cliff section south of headlands showing signs of erosion

Figure Appendix C.7: View (looking west) of salt marsh and mangrove scattering

Appendix D: Historic shorelines

Notes: Historic shorelines drawn based on aerials sourced from Retrolens

0 0.1 0.2 0.3 0.4 0.5 (km)

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APPROVED		
ARCFILE Beachlands_Historic.mxd		
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Historic Shorelines
Beachlands South Limited Partnership

Sheet: 1

FIGURE No. Figure D.1

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Appendix E: Local bathymetry

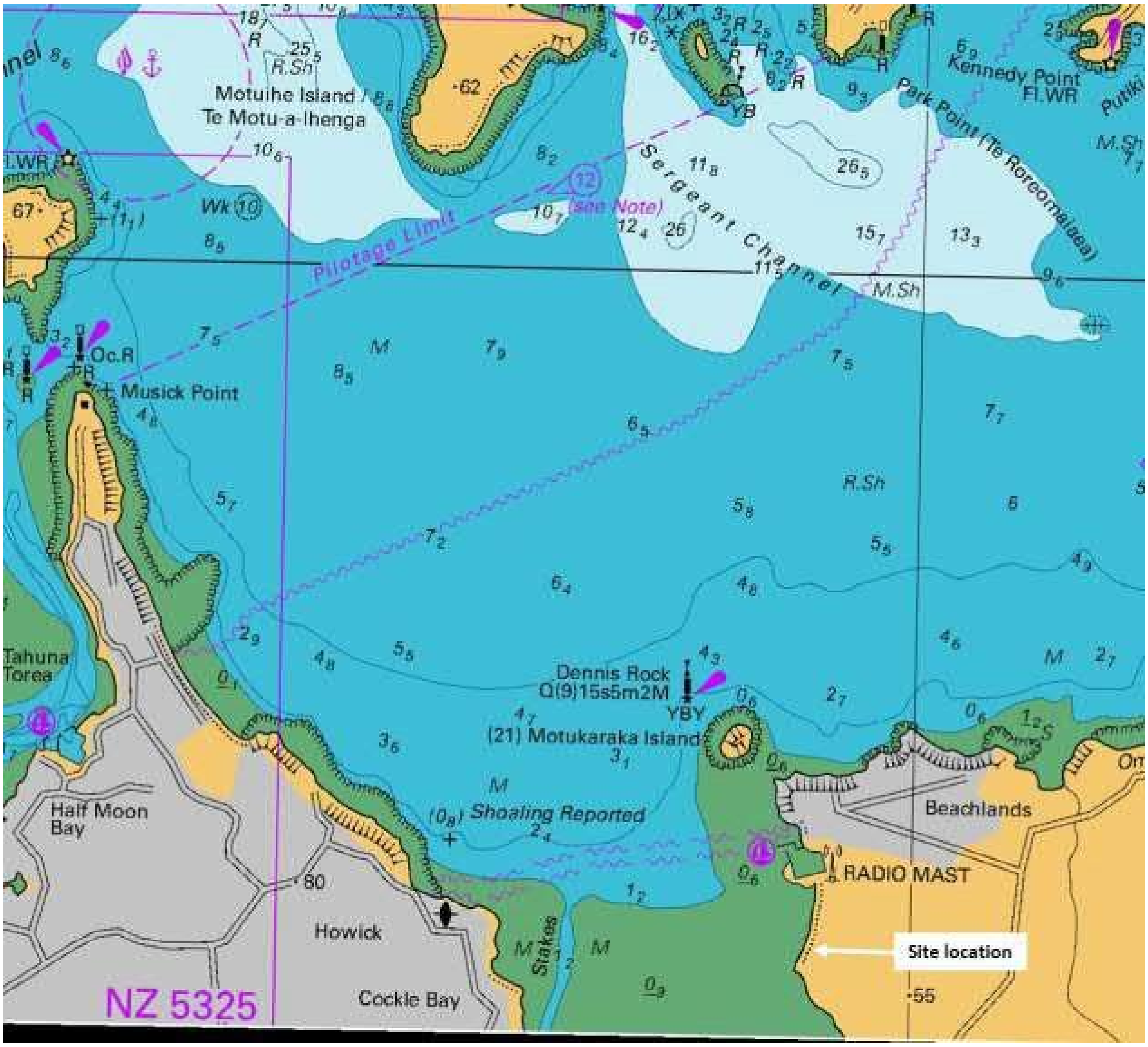


Figure Appendix E.1: Excerpt of hydrographic chart NZ 532 Approaches to Auckland (Source: LINZ data service). Note that levels are expressed in Chart Datum (CD) which is 1.743 m below AVD46 (RL)

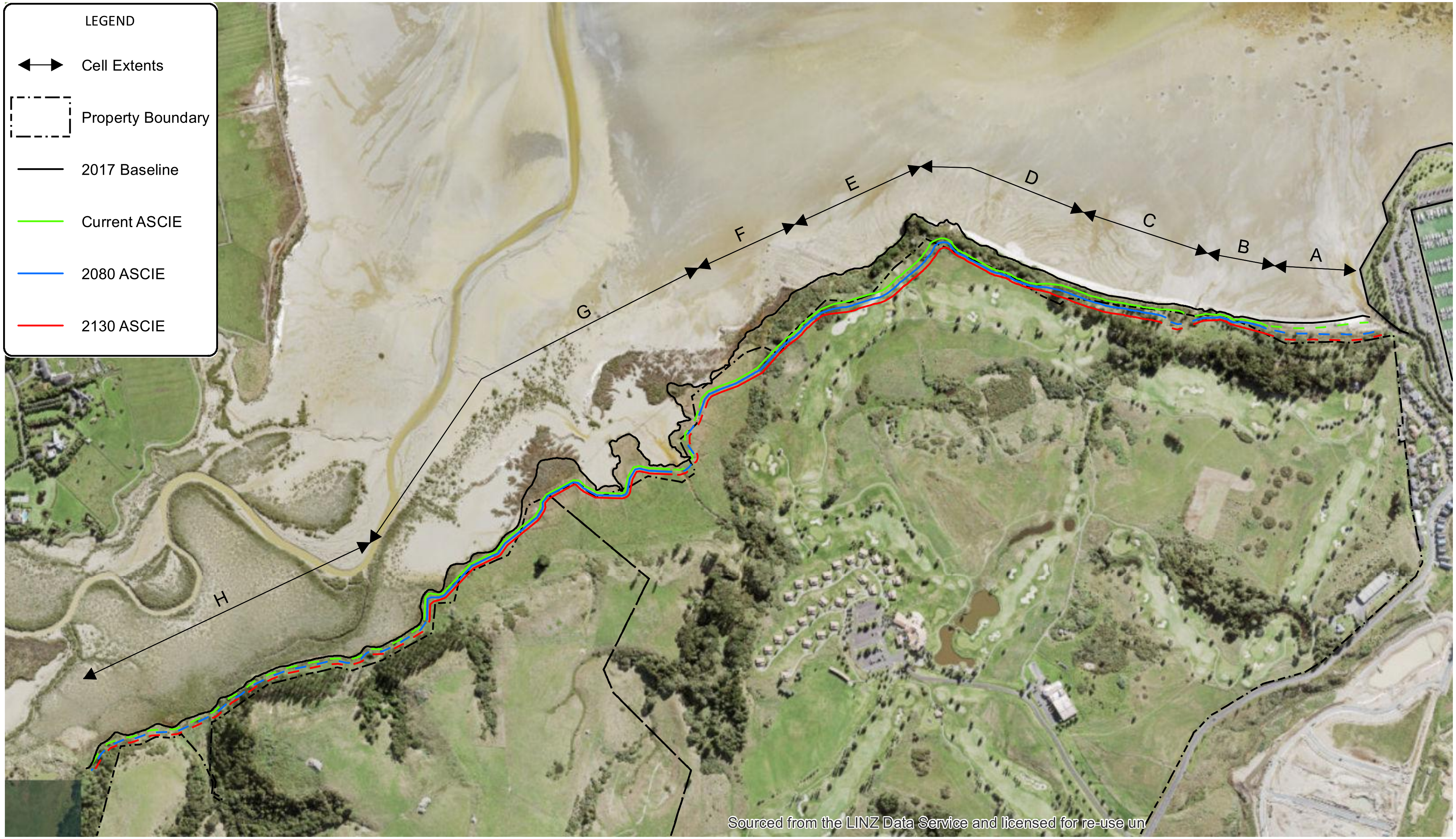
Appendix F: Erosion input values

Appendix F Table 1: Component values for erosion hazard assessment

Cell	A[1]	B	C[1]	D	E	F	G	H
Morphology	Sand/shell chenier ridge	Soft consolidated terrace⁺	Sand/shell beach	Exposed ECBF cliff	Vegetated ECBF cliff	Vegetated ECBF cliff with salt marsh at toe	Salt marsh with chenier ridge formations	Coastal terrace with dense mangroves seaward
Short-term (m)	3	0	3	0	0	0	0	0
Dune Stability (m)	1.7	0	1.7	0	0	0	0	0
Dune/Cliff elevation (m above toe or scarp)	0.7	0.9	0.9	20	22	18	1	1.5
Stable angle/ angle of repose (deg)	34	23	34	36	23	23	23	23
Long-term (m/yr) -ve erosion +ve accretion	*0*	-0.05	*0*	-0.05	-0.1	*-0.05*	0	0
Closure slope (beaches) / Cliff response factor	0.11	0.4	0.11	0.3	0.3	0.4	0.4	0.4

1: Calculated using the beach methodology, otherwise cliff methodology was used.

Appendix G: Mapped ASCIE



Notes: Dashed ASCIE indicates greater uncertainty around stream mouths and backshore topography.

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Coastal erosion hazard map

Beachlands South Limited Partnership

Areas Susceptible to Coastal Instability and Erosion (ASCIE)

Sheet: 1

FIGURE No. Figure G.1

Rev. 0

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Appendix H: Mapped AC inundation layers

Notes: Inundation layers sourced from Auckland Council.

0 0.1 0.2 0.3 0.4 0.5 (km)

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Coastal inundation hazard map

Beachlands South Limited Partnership
1% AEP storm surge with 0 m SLR & 1 m SLR cases
Sheet: 1

FIGURE No.: Figure H.1
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Notes: Inundation layers sourced from Auckland Council.

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Coastal inundation hazard map
Beachlands South Limited Partnership
1% AEP storm surge with 2m SLR
Sheet: 2

FIGURE No. Figure H.2
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