REPORT

Tonkin+Taylor

# First Pass Coastal Erosion Assessment and Identification of High Risk Areas

**Prepared for**
New Plymouth District Council
**Prepared by**
Tonkin & Taylor Ltd
**Date**
July 2019
**Job Number**
1001955.v5

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## Document Control

| Title: First Pass Coastal Erosion Assessment and Identification of High Risk Areas | | | | | |
|---|---|---|---|---|---|
| **Date** | **Version** | **Description** | **Prepared by:** | **Reviewed by:** | **Authorised by:** |
| July 2017 | Draft | Preliminary draft | Tom Shand | | |
| October 2017 | Draft V2 | Addition of risk assessment | Rebekah Haughey | Tom Shand | Richard Reinen-Hamill |
| August 2018 | Draft V3 | Addition of RCP SLR scenarios and future ASCE updated to 2130 | Rebekah Haughey | Tom Shand | |
| January 2019 | Final draft V4 | Update with client comments | Rebekah Haughey | Tom Shand | Richard Reinen-Hamill |
| July 2019 | Final V5 | Final report | Rebekah Haughey | Tom Shand | Richard Reinen-Hamill |

**Distribution:**

| | |
|---|---|
| New Plymouth District Council | 1 PDF copy |
| Tonkin & Taylor Ltd (FILE) | 1 PDF copy |

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## Executive summary

The New Plymouth District Council (NPDC) coastline is almost 100 km long and extends from just south of the Stony River almost to Mokau in the North. This coast comprises approximately 71 km of cliff (consolidated) shoreline and 29 km of unconsolidated shoreline with the coast to the west of Motunui being primarily of volcanic origin (mainly lahar deposits) while the coast east/north of Motunui is primarily of sedimentary origin (mainly siltstone 'papa' rock).

Most of the district coastline has either experienced or is predicted to be at risk from coastal erosion. NPDC is currently reviewing its District Plan which needs to be prepared in accordance with the New Zealand Coastal Policy Statement 2010 (NZCPS), so areas at risk of coastal hazards need to be identified. The erosion hazard provisions in the Operative District Plan are some 30 years old and since that time understanding of processes has advanced, data availability has increased, and official guidance including the need to predict the effects of future climate change scenarios must be incorporated.

To this end, Tonkin + Taylor (T+T) were commissioned by NPDC to undertake a "first pass" coastal erosion assessment to identify areas potentially susceptible to coastal erosion along the district's coastline. Output consists of three lines which define the following:

- the current area susceptible to coastal erosion (Current ASCE);
- the future (2130) area susceptible to coastal erosion excluding the effects of projected sea-level rise (Future $ASCE_1$); and
- the future (2130) area susceptible to coastal erosion including the effect of future projected sea-level rise (Future $ASCE_2$).

This desktop assessment is based primarily on the following (existing) information:

- previous assessments, which were located and reviewed;
- historical and current shoreline data from vertical aerial photographs, which were located, digitised and georeferenced;
- profile and bathymetric data were located and reviewed; and
- terrestrial elevation (contour) data were located and used to construct digital terrain models (DTMs).

The erosion assessment model used is based on industry best practice. In particular, the model consists of the following four, essentially independent, components:

- the long-term trend in shoreline behaviour for both consolidated and unconsolidated coasts as derived from historical shoreline data;
- the shorter-term shoreline fluctuation also derived from historical data but applicable only to unconsolidated shorelines;
- shoreline erosion resulting from official sea-level rise scenarios using consolidated and unconsolidated shoreline response models; and
- a slope adjustment to account for a typically over-steepened slope following an episode of erosion to adjust back to a naturally stable angle on both consolidated and unconsolidated coasts.

A first pass coastal erosion assessment should be undertaken at a "high level" which means a large area (typically a district or region) is covered with the coast then being divided into cells with similar characteristics and a high-end value selected for each component within each cell. The resulting ASCE values are therefore expected to be conservative and this approach is consistent with NZCPS (2010) Policy 24 which requires: the identification of areas that are potentially affected by coastal erosion hazards giving priority to high risk areas.

The assessed areas susceptible to coastal erosion may be superseded by local scale or site-specific assessment undertaken by qualified and experienced practitioner using improved or higher resolution data than presented in this report. This could include site specific geotechnical information to confirm stable angles of repose, better topographic data as well as site specific consideration and analysis of erosion rates. Additionally, future ASCE lines have been assessed assuming no coastal protection structures are present. If structures remain effective, then the current ASCE will apply.

The present first pass assessment for unconsolidated (beach/dune) shorelines shows the current ASCE ranges between 7 and 53 m (mean of 31 m) with the highest values occurring along the central coast. Future $ASCE_1$ widths (excludes sea-level rise (SLR)) range between 17 and 174 m (mean of 72 m) with minimum values along the south coast and higher values along the central/north coast with particular focus about Waitara. Once the effects of SLR projections are incorporated the $ASCE_2$ range increases to between 23 and 200 m (mean of 90m) and again the lowest values are in the south and highest values along the Waitara coast.

These unconsolidated ASCE results were compared with those used for the operative District Plan, i.e. the Taranaki Catchment Commission [TCC] assessment of 1987/88. The earlier assessment's values were found to approximate the $ASCE_1$ values (no SLR effect) with the exception of East Waitara which was substantially higher at 227 m. Once SLR was incorporated ($ASEC_2$), the values exceed the TCC values by up to 62 m (excluding the East Waitara); a result to be expected as there was no SLR adjustment allowance in the TCC assessment.

The first-pass assessment for consolidated (cliffed) shorelines shows the current ASCE ranges from 7 m along south Messenger Terrace, up to 69 m along the coast north of Waiiti and a local increase to 238 m at Whitecliffs. The much larger Whitecliffs value results from the substantial increase in elevation compared with the rest of the coast. Future $ASCE_1$ widths range between 18 m along south Messenger Terrace, (Oakura), up to 168 m along the highly unstable airport cliffs and increasing locally to 306 m at Whitecliffs. Incorporating the effects of projected SLR, the future $ASCE_2$ range increases to 34 m at Messenger Terrace, up to 340 m at the airport and with the Whitecliffs section at 342 m.

Comparing the present cliff coast results with those from the TCC (1987/88) assessment shows the TCC values were consistently less than the $ASCE_1$ values. Excluding the distorting Whitecliffs value, the mean difference is 35 m and this is attributed to the TCC model not including a slope stability adjustment. Once the SLR response is included ($ASEC_2$) the differences (again excluding the Whitecliffs value) increase further with a mean difference of 88 m. Again this was an expected result given that the TCC method also made no allowance for this component. It should be noted that the current District Plan hazard line (based on the TCC 1987/88 assessment) and the newly mapped ASEC lines are separated by more than the modelled differences as the predicted erosion distances are measured landward from the current coastline (the reference shoreline), so during the 30 year interim the reference shoreline has moved landward by up to 30 m in places.

It is likely that the actual future area susceptible to erosion hazard will be located somewhere between the future $ASCE_1$ and $ASCE_2$ depending on the actual sea level rise that occurs in the future and coastal response to that SLR.

A preliminary screening exercise has been undertaken to identify what is contained within areas identified as being susceptible to coastal erosion. This screening exercise has been undertaken to assist in prioritising areas which may be most exposed to adverse effects and for which more detailed "*second-pass*" assessments should be completed. Four main elements were assessed including economic, social, cultural and environmental elements with a range of specific indicators used for each. Results showed that the coastal cells with the highest economic and social risk are:

- Oakura where several multiple dwellings, roading and water infrastructure are potentially susceptible to erosion at the current timeframes, increasing in the future.
- Fitzroy where the coastal walkway, surf club, sand dunes and part of the holiday park are currently at risk increasing to include residential properties and additional water and roading infrastructure in the future.
- Bell Block where a seawall currently provides some protection but residential dwellings and roading infrastructure may be at risk in the future.
- Waitara East and West where residential dwellings, roading and water infrastructure and parts of Marine Park at currently at risk, increasing in the future.
- Motunui where the Methanex plant may be at risk to future erosion hazard.
- Onaero residential dwellings, roading and water infrastructure and parts of Marine Park at currently at risk, increasing in the future.
- Urenui where roading infrastructure, parts of the holiday park and the golf course (if the seawall were to fail) are currently at risk, increasing in the future.

Second pass assessments are recommended for these sites. These more detailed assessments would further analyse available data at a higher resolution to more thoroughly understand the likelihood of hazard occurrence, uncertainties and the effects of different future sea level rise scenarios. These assessments will assist stakeholders in understanding the consequence and risk posed by the hazard and as a basis for decision-making in the land use and adaptation planning processes.

Additionally, the Belt Road to East End extent would be susceptible to erosion if the current seawall were to fail or be removed exposing a large amount of transport and water infrastructure, residential dwellings, business, parks and heritage areas to hazard. While additional analysis of the potential hazard is unlikely to be justified while the seawall remains effective, this susceptibility should be considered in the future when making decisions on maintenance and upgrade. Additional analysis could be undertaken at that time to provide more certainty around risk.

We also recommend that a programme of beach profile data collection is established with partners to better understand short- and long-term trends along the New Plymouth coastline, particularly the unconsolidated coastlines (beaches) at Oakura, Fitzroy, Waitara and Urenui. These have traditionally been undertaken using topographic survey but the use of an Unmanned Aerial Vehicle (UAV) could be investigated as a more cost effective method. Light Detection and Ranging (LiDAR) would assist in the more detailed assessment and aerial photography should be continued at regular intervals.

# 1 Introduction

## 1.1 Background

New Plymouth District Council (NPDC), is currently reviewing its District Plan (the Plan) which needs to be prepared in accordance with the New Zealand Coastal Policy Statement (NZCPS). The Plan was released in draft form for initial public input in 2017 before the Proposed Plan is notified.

Most of the NPDC coastline has either experienced or is predicted to be at risk from coastal erosion (Gibb, 1978; TCC 1987/88). The spatial layout of the district coastline (approximately 100 km long) and chainage adopted for the present study, are shown in Figure 1-1.

A range of studies have previously been undertaken regarding coastal erosion and management in the New Plymouth District including Kirk 1978; McLennan 1982; TCC 1987; OCEL 1994; NPDC 1995; Gibb 1998; T&T 2001, McComb 2005, 2006, 2016; Bergin et al. 2007; TRC 2009; T+T 2013, TRC 2017. However, most of these studies did not attempt to predict future erosion and those that did often considered a limited area, and/or were not sufficiently quantitative, and/or were based on old data, and/or did not consider the potential effects of climate change, in particular, projected sea-level rise (SLR) as required under the NZCPS (2010).

## 1.2 Statutory considerations

The Resource Management Act 1991 (RMA) planning process for the consideration of natural hazard within a District or Regional Plan 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 (including objectives, policies and rules) intended to manage the hazard risk to suit the needs of the community.

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

*"Identify areas in the coastal environmental that are potentially affected by coastal hazards (including tsunami), giving priority to the identification of areas at high risk of being affected. Hazard risks, over at least 100 years, are to be assessed…"*

The Ministry for the Environment coastal hazards and climate change guidelines (MfE, 2017) advocate use of a two- level assessment:

- A first-pass assessment that takes into account the various hazard drivers as outlined in the NZCPS Policy 24 (1) (a) – (h).
- A more detailed, second-pass or low level assessment that enables a more thorough understanding of the coastal processes, uncertainties and the effects of different future sea level rise scenarios, and thus the likelihood of hazard occurrence.

A first-pass assessment should be undertaken at a "high level" and generally, at a district-wide scale; which means using existing information and a high sea-level rise estimate. Results will be conservative due to the assumptions made during calculations. Erosion susceptibility mapping should be included to facilitate the identification of areas potentially exposed to the effects of coastal hazards. A preliminary screening exercise of what is contained within those areas can then be applied to define the level of hazard risk. This screening would include identifying areas and features that are valued, such as areas of existing development, proposed new development, natural or man-made defences, and significant ecological, social or cultural sites. This screening exercise will assist in prioritising areas which may be most exposed to adverse effects of erosion (i.e. at high risk) for which more detailed "*second-pass*" assessment can then be undertaken.

The more detailed, second-pass or low level assessment enables a more thorough understanding of the coastal processes, uncertainties and the effects of different future sea level rise scenarios, and thus the likelihood of hazard occurrence. These assessments will assist stakeholders in understanding the consequence and risk posed by the hazard and is a basis for decision-making in the land use and adaptation planning processes. The stages of such a technical risk assessment are schematically depicted in Figure 1-2.

## 1.3 Study scope

Tonkin & Taylor Ltd (T+T) have been commissioned by New Plymouth District Council (NPDC) to undertake the following:

1 ***First pass coastal erosion assessment***

This high-level assessment will identify areas potentially susceptible to coastal erosion along the district's coastline.

The assessment is to exclude the protected coast around the Port, but areas elsewhere that have consented protection/structures are to be included within the assessment irrespective of these works.

Output will consist of six lines (provided in electronic format) which define the following scenarios (Table 1-1):

- Current susceptibility to coastal erosion (called ASCE);
- Future (2130) susceptibility to coastal erosion **excluding** the effects of projected sea-level rise ($ASCE_1$); and
- Future (2130) susceptibility to future erosion **including** the effect of future projected sea-level rise ($ASCE_2$). There are four lines within the $ASCE_2$, each representing a different RCP sea level rise scenario.

**Table 1-1 Summary of scenarios assessed and mapped within the first pass coastal erosion assessment.**

| Scenario | Year | Sea level rise scenario |
|---|---|---|
| ASCE | 2030 (current) | N/A |
| $ASCE_1$ | 2130 | N/A |
| $ASCE_2$ | 2130 | RCP2.6 |
| | 2130 | RCP4.5 |
| | 2130 | RCP8.5 |
| | 2130 | RCP8.5H+ |

This study is based primarily on existing information and is limited to desktop analysis together with expert opinion and limited site inspection to determine the extent of very unlikely to worst case erosion.

***2. Identify high risk areas***

This desktop assessment will then use existing data in conjunction with Council to identify threatened areas that are particularly valued.

***3. Provide recommendations*** for areas requiring more detailed second-pass assessment**.**

## 1.4 Report layout

The physical environment, previous erosion hazard assessments and available data for the present assessment are described in Section 2. Section 3 describes conceptual erosion prediction modelling. Section 4 describes component derivation. Section 5 defines potential erosion susceptibility of the district's coast, and Section 6 identifies assets at high risk from coastal erosion.

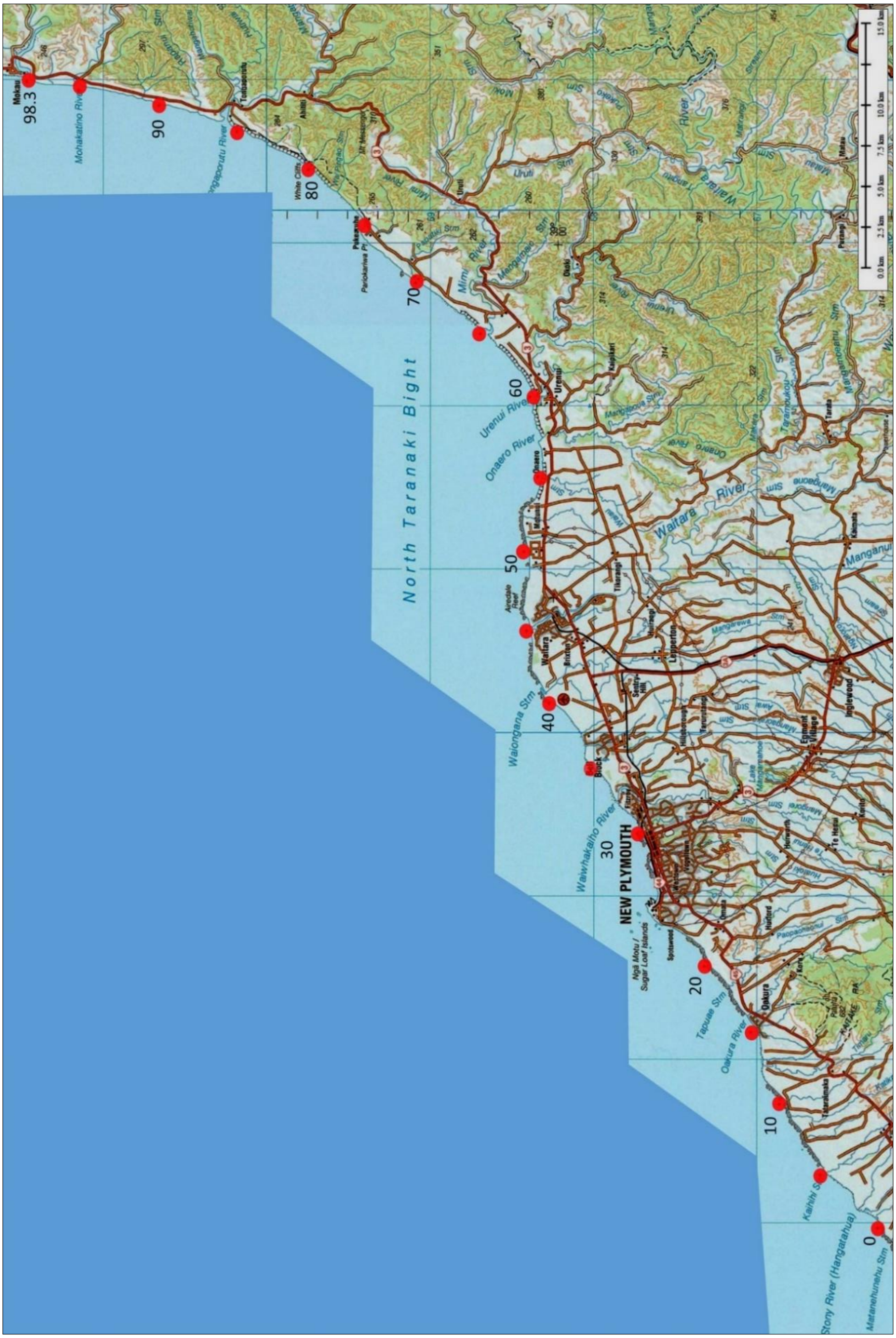


*Figure 1-1 Location map showing the NPDC coast and distance in km from the southernmost extent*

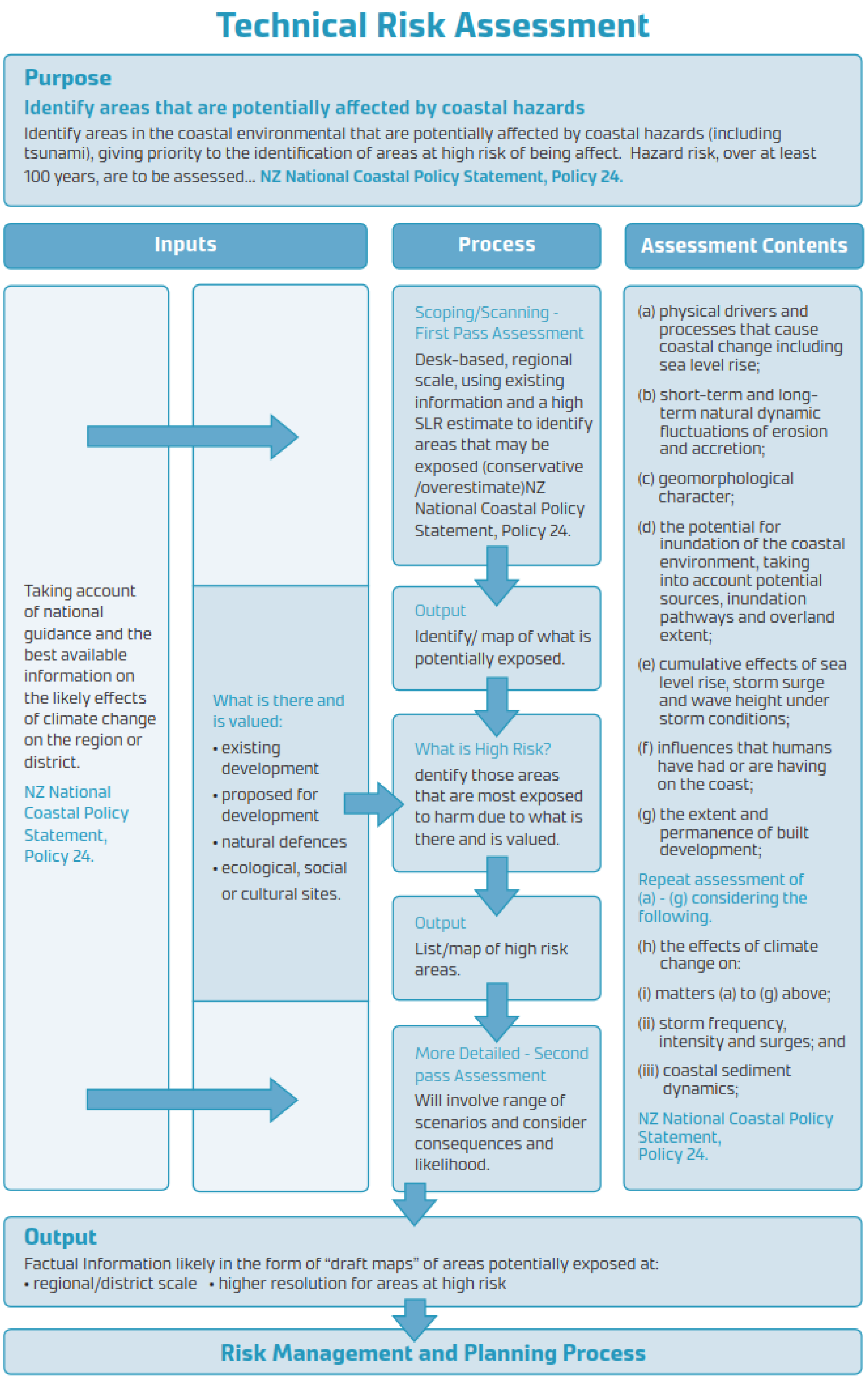


*Figure 1-2 Technical Risk Assessment flow diagram (T+T).*

# 2 Background information and analysis

## 2.1 Geology and geomorphology

The New Plymouth District stretches some 98 km from just beyond the Stony River in the south to the Mokau River's left bank in the north. The region's physiography is dominated by the 2516 m high stratovolcano, Mount Taranaki and remnants of Pouakai and Kaitai volcanos aligned to the northwest. The volcanic coastal topography gives way to a sedimentary environment in the north with fine grained "papa" seacliffs fronted by a sandy nearshore occurring north of MotunuiOnaero. The primary sources for the following description are Neall 2003, Edbrooke 2005, and Townsend et al. 2008.

The volcanic provence consists of several geological "formations" resulting from mud or debris flows ("lahas") as well as debris avalanches and alluvial deposits all associated with cone collapses of the various stratovolcanos (Kaitai c. 600 ka, Pouakai c. 250 ka, Egmont <130 ka and Phantoms Peak < 3.2 ka). This resulted in "ring plain" forming around each volcano with wave erosion resulting in a cliffed coastline exposing gravels[1], breccia[2], and sedimentary clasts[3] together with intervening clay deposits. As the lahas followed topographic lows such as river and stream valleys, the geological composition and level of lithification[4] can vary considerably alongshore. The resulting geomorphology is thus generally irregular along relatively small stretches of coastline with cobbles, boulders and conglomerate (laha remnants) forming reefs that are often attached to mixed sand and gravel beaches. At a few locations, river/stream valleys, deltas or other littoral barriers have enabled predominantly sandy "pocket" or "ribbon" beaches to form along with some sand dune development. However, the coast is also characterised by minimal inlet/estuary development.

The sand and gravel supply to this coast will vary temporally in associated with volcanic eruptions – the most recent being the Tahurangi eruptive episode of 1755 (Neall 2002). De Jardine (1993) and Gibb (1998) provide evidence that there has been a significant reduction in the sand to gravel ratio along the central Taranaki coast during the 20th century. Gibb (1998) speculates that this may (a) be associated with diminishing eruptive sediment supply, (b) driven by 14 to 19 million cubic metres of littoral sediment having been dredged and dumped seaward of the littoral system since 1889 by the New Plymouth port maintenance operation. It is noted that since 2004 clean dredgings which make up about 75% of the total, are dumped at an inshore site with a view to it rejoining the littoral stream (TRC 2017b), and (c ) 2.3 million cubic metres of sand and gravel were extracted from rivers and beaches during the 20$^{th}$ century – a practice now discontinued. While less significant than fluvial inputs from volcanic events, input from catchment instability does occur and has implications for littoral drift (see section 2.6). The most recent such event was in 1998 when a slip in the upper Stony River catchment resulted in millions of cubic metres of sand accreting the beach in the vicinity of the river delta (McComb, 2006).

From the south, volcanic formations outcropping along the coast consist of: Pungarehu (c 20 ka) between the Stony R to Kaihihi Stream; Maitahi (250 ka) from the Kaihihi Stream to just south of Back Beach, Motunui (c. 160 ka) from Bell Block to Buchanan's Beach, and Okawa (c. 100 ka) in the vicinity of the Waitara Rivermouth.

The Sedimentary Provence consists of a sequence of Tertiary marine sediments (siltstone, fine grained sandstone and limestone ("papa") in various thicknesses and bedding configurations) that

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[1] *The sedimentological definition of gravel is used in this report: unsorted rock fragments comprising boulders (>25cm), cobbles (6.4 to 25 cm), and pebbles (2 to 6.4 cm).*

[2] *Breccia refers to large angular rock fragments with spaces filled with a matrix of smaller particles or a mineral binding cement.*

[3] *A clast refers to chunks and smaller grains of rock broken off other rocks by physical weathering.*

[4] *Lithification relates to hardness resulting from the conversion of unconsolidated sediments into sedimentary rock through compaction and cementation.*

form a series of Pleistocene uplifted marine terraces with the region having an average annual uplift rate of 0.1 mm/year (see Figure 2-1). The marine formations are most exposed along the northern coast although absent at Whitecliffs. The volcanic provence is itself super imposed upon the marine sediments with some terrace outcrops evident along the coast close to New Plymouth. Offshore reefs are largely absent along the sedimentary northern coast with sand usually dominating the nearshore and intersecting the cliff. There is limited estuary and sand dune development within the infilled river/stream valleys.

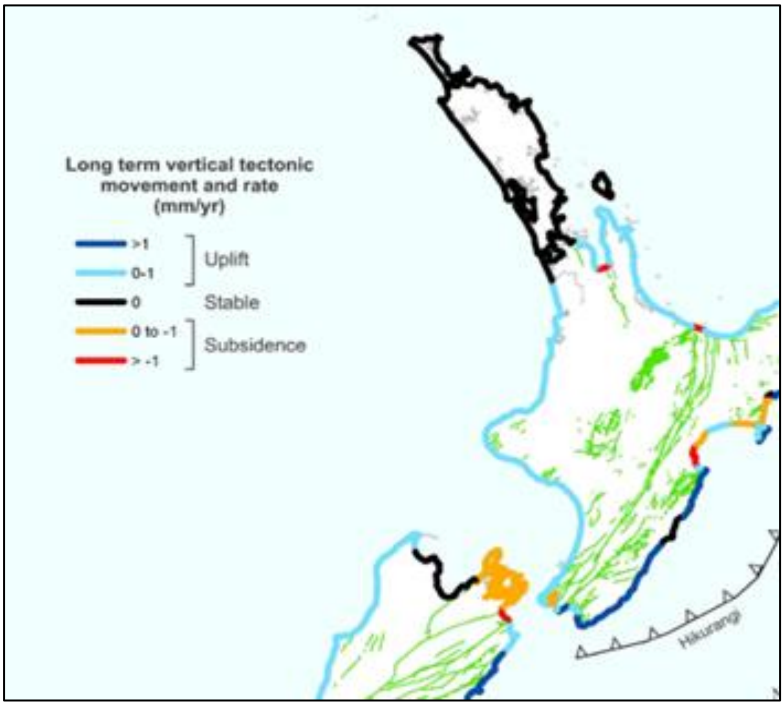


*Figure 2-1 Long-term vertical tectonic movements of New Zealand coastline compiled from geological markers. Source: Beavan and Litchfield (2012)*

From Buchanan's Bay north, the Late Miocene (C 11 ma) strata consist of the Kiaore Formation to Onaero, the Urenui formation from Onaero to Pukearuhe, the Mount Messenger formation between Pukearuhe to just south of Mokau, and the Mohakatino Formation around Mokau.

## 2.2 Coastal types

This subsection partitions the coast into types based on geological/geomorphological characteristics identified in the literature - with TRC (2017) being particularly informative, a partial field inspection carried out on the 7 and 8 May 2017, oblique aerial photographs collected by the Taranaki Regional Council in 2012, and various vertical aerial photography and photogrammetrically derived contour data described at the end of this section. Each partition is defined by distances from the southern boundary as well as an area name.

Between 0 and 13.2 km (Stony River mouth to the Ahu Ahu stream) the coast is fronted by boulder reefs and predominantly gravel beaches that may extend back into river/stream valleys, thus forming ribbon and pocket beaches between and/or fronting relict cliffs/headlands with some extensive colluvial foot slopes in places. Some significant sand deposits are also evident along with some dune development (Appendix B, photos 1 and 2).

Between 13.2 and 15.1 km (Ahu Ahu Stream to the Oakura Surf Club) boulder reefs front a beach comprising a sand veneer covering a wave cut platform. Unconsolidated deposits to the rear are, in some places, capped by sand dunes. Oakura Beach in the vicinity of the camp ground has, in the past, undergone reclamation. The shoreline fronting the Surf Club is presently protected by (consented) rock riprap and concrete a boat ramp (Appendix B, photo 3).

Between 15.1 km and 24.4 km (Oakura Surf Club to Paritutu) the shoreline is backed by a particularly non-uniform cliff with height ranging up to 45 m. Sandy beaches characterise the Oakura and New Plymouth ends of this reach with gravels capping the wave cut platform for much of the intervening stretch. The Messenger Terrace shore is now protected with (consented) stone rip rap, after having earlier had gravel removed for New Plymouth Harbour development and occasional private protection works (Appendix B, photo 4).

Between 24.4 and 26.8 km (Port to Belt Road) the shoreline here is substantially reclaimed and protected by hard structures. The exception is Ngamotu Beach, a sheltered, generally natural beach within the Port environs.

Between 26.9 and 30.7 km (Belt Road to East End) the shoreline is controlled by hard structures and protection works that have coastal consents. The backshore is high marine terrace at the western end, dropping in elevation through the Puke Ariki area where the backshore is likely marine deposits (and likely fill) and increasing again at the eastern end to marine terrace around Woolcombe Terrace and Mt Bryan Reserve. East End Beach reduces in elevation but also fronted by seawall and stream training works at the mouth of the Te Henui Stream.

Between 30.7 and 32.2 km (Fitzroy Beach) the shoreline sits upon the western flank of the Waiwhakaiho River delta and consists of a thin veneer of sand covering an inter-tidal wave cut platform with gravels further offshore. Littoral drift disruption associated with the Port has been associated with long-term erosion on Fitzroy beach and groynes were established here in the 1940s. Nourishment trials have occurred over the past 30 years. A 100 m long stone groyne (consented) was established at the mouth of the Waiwhakaiho River during the 1970s and this resulted in an accretionary fillet to the west (along eastern Fitzroy beach) and starvation of the coast to the east of the river mouth (T+T 2001). The Fitzroy shoreline is backed by sand dunes and relict sea cliff some 70 to 200 m landward. The Fitzroy Surf Club is fronted with a (consented) boulder seawall and concrete boat ramp.

Between 32.2 and 33.7 (Waiwhakaiho River mouth to New Plymouth Golf Club) is a sandy upper beach and low-tide /subtidal gravels of the Waiwhakaiho River delta. As with Fitzroy Beach, the backshore is unconsolidated with sand dunes.

Between 33.7 and 36.2 km (New Plymouth Golf Club to the Mangati Stream mouth - at the western end of Bell Block Beach), is a gravel beach overlying the wave cut platform. Substantial reef development occurs around the point immediately west of Bell Block Beach. The backshore is unconsolidated with substantial areas of sand dunes.

Between 36.2 and 40.9 km (Bell Block Beach to the Waiongana Stream mouth including the airport) is a cliffed shoreline fronted predominantly by a gravel beach sitting upon the wave cut platform. The extensive Waiongana Stream gravel delta occurs at the eastern end of this reach. The cliffs range in height up to 24 m adjacent to the airport and in places are capped by sand dunes. A (consented) stone revetment fronts the Bell Block beach settlement at the western end of this reach (Appendix B, photo 5).

Between 40.9 and 41.7 km (Waiongana East) is a pocket-ribbon beach formed within the recessed cliff line previously cut by an extreme eastward offset of the Waiongana River. The mixed sand-gravel upper beach is fronted by the gravel river delta and backed by gravels/sand/lagoon and relict cliff about 80 m landward.

Between 41.7 and 44.1 km (Browns Road reach) is a cliff shoreline fronted by a sand and gravel upper beach and gravel reef system. The cliff height ranges to almost 10 m with cliff-top dunes occurring in many places.

<u>Between 41.1 and 45.1 km</u> (West Waitara Beach) is a gravel beach fronted by a wide gravel reef and river mouth delta. This area was occupied by the river mouth at times prior to the breakwater construction in 1885 and the present (consented) western mole extends seaward of the shoreline by about 45 m. The western beach is consequently backed by unconsolidated infill with some sand dune development.

<u>Between 45.1 and 46.7 km</u> (East Waitara Beach) is a gravel-sand beach fronted by the river mouth delta at the west and Airedale reef at the east. The eastern mole has undergone several episodes of strengthening and modification and these have had a significant effect on sediment supply and shoreline behaviour (Gibb 1998). The present (consented) structure extends seaward of the shoreline by about 210 m. It is assumed that the beach is backed by unconsolidated sediment. Sand dunes occur in several places to landward (Appendix B, photo 6).

<u>Between 46.7 and 47.0 km</u> (Waitara Golf Course cliffs) is a cliff fronted by gravel beach and narrowed reef. Sand dunes extend inland from the 8 to 13 m high cliff.

<u>Between 47.0 and 48.3 km</u> (Motunui western bay) is a pocket-ribbon gravel sand beach fronted by three shore-attached reefs. It is assumed that unconsolidated sediments back the shoreline. The relict cliff is up to 110 m landward.

<u>Between 48.3 and 51.1 km</u> (Motunui cliffs) is a gravel upper beach and sandy lower beach, backed by a 19 m high cliff.

<u>Between 51.1 and 52.5 km</u> (Motunui eastern bay) is a pocket-ribbon mixed sand-gravel upper beach fronted a gravel lower beach and reef that into Buchanan's Bay at its eastern end. This marks the end of the volcanic provence's laha cliffs and reef system and the beginning of the sedimentary provence of papa cliffs fronted by a sandy surf zone and offshore. It is assumed that unconsolidated sediments back the Motunui eastern bay shoreline. Some dune development is evident and the relict cliff up to 150 m landward.

<u>Between 52.5 and 59.6 km</u> (Motunui to Urenui River Inc. Onaero) is a cliff coast of marine sediment and terrestrial cover beds fronted by a mid to low tide sandy beach. The cliff height ranges up to 28 m. Onaero settlement lies in the centre of this reach and is fronted by a (consented) rock revetment and concrete boat ramp.

<u>Between 59.6 and 60.2 km</u> (Urenui Bay) is a mixed sand and gravel pocket beach fronted by an extensive gravel (Urenui River) delta which tapers toward the eastern end of the embayment. It is assumed unconsolidated sediment backs the shoreline at this site (Appendix B, photo 7).

<u>Between 60.2 and 76.3 km</u> (Urenui to Whitecliffs) is a cliff coast of marine sediment and cover beds fronted in parts by a mid to low tide sandy beach and in parts a subtidal sand-cliff intersection is evident. Maximum cliff heights range from 28 m in the west to 58 m in the east where there are some substantial areas of clifftop sand dunes. There are also two main embayments along this stretch of coast: Mimi (63.8 to 65.0 km) where the Mimi and Waitoetoe Rivers meet the coast; and Waiiti (69.8 to 70.3 km) where the Waiiti and Papatiki Streams meet the coast. At each place it is assumed the low cliffs are composed of consolidated material.

<u>Between 76.3 and 79.7 km</u> (Whitecliffs) is a dominating cliff line with no marine terraces. The cliff height ranges between about 100 and 200 m. The fronting beach again appears to have an intertidal cliff intersect and, in contrast with the rest of the papa coast, is dominated with gravels – this material coming from the Wai Pingao Stream which drains the Whitecliffs-Mt Messenger hinterland (Appendix B, photo 8).

<u>Between 79.7 and 98.2 km</u> (Whitecliffs to Mokau) is a cliff coast backed by marine sediments and wave cut terraces with height ranging up to 44 m (Appendix B, photo 8). The cliffs are notable for their three-dimensional plan view (caves, bays, bluffs and stacks), landforms indicative of jointing

and fracture. This morphology is also evident on the coast to the west of Whitecliffs. Several rivers meet the coast along this reach and their sand contribution appears to result in a sandy inter-tidal cliff intersect less evident to the west of Whitecliffs. Along this reach the main rivers: Tongaporutu, Mohakatino and Mokau, have minimal development around the inlets/estuaries and their shorelines are assumed to be backed by consolidated material.

## 2.3 Previous coastal erosion assessments

**Gibb (1978)** first quantified rates of coastal erosion and accretion in New Zealand by analysing historical survey (cadastral) plans together with limited use of vertical aerial photographs and field measurements. In the New Plymouth District, Gibb recorded shoreline data from 36 measurement sites or stations between Leith Road in the south and the Mohakatino River in the north spanning the period 1842 and 1980. However, the bracketing dates for each site vary depending on plan availability/existence. Sites were necessarily selected based on the existence of a temporally comparable feature (e.g. a trig station), rather than spatial characteristics/variation. Other limitations resulted in a range of potential errors including temporal variation in shoreline indicators, accuracy of the field surveys in detecting the indicators, accuracy in plan drawing, accuracy in scanning the plan and accuracies in abstracting (shoreline) data. The combined errors in shoreline data derived from such sources is typically assumed to be 20 to 30 m. Nonetheless, Gibb's results were broadly indicative of coastal change: accretion predominated south of new Plymouth with a maximum (end-point[5]) rate of 0.67 m/yr at Oakura Beach, and erosion at and to the north of New Plymouth with a maximum value of 2.89 m/yr at East Waitara. While Gibb's work did not extend to predicting future shoreline location, it did nonetheless provide a quantitative starting point in defining long-term erosion trends, and the present study makes use of some of Gibb's results.

**The Taranaki Catchment Commission (1987/88)** carried out a district-wide erosion hazard assessment using shoreline data prepared by the Photogrammetric Division of the Land and Survey Department in the mid 1980's. The Division prepared 16 Coastal Resource Maps (CRM) which overlaid shorelines derived from both early cadastral plans and vertical aerial photographs, with shoreline indicators being the cliff top and/or toe, and the vegetation-front for non-cliff coasts. Each map covered approximately 2 km of coast.

Two methods were used to define and predict future coastal erosion with the larger value adopted for each section of coastline. Both methods determined the end-point rate at several locations along each CRM.

<u>Method 1</u> used the average value to represent a section of coastline. Each representative long-term rate (LT) was then multiplied by 100 years (the prediction period) and a factor of safety (FOS) = 1.667 applied to width of the hazard area. Method 1 can be expressed by equation 2-1.

$$CHZ = (LT * T) + (LT * T) * FOS \qquad (2\text{-}1)$$

Where CHZ = coastal hazard zone, LT = long-term rate, T = 100 years (the prediction period) and a FOS of 1.667 (Factor of Safety)

<u>Method 2</u> was based on the maximum inter-survey rate of change ($ST_{max}$) and has no FOS. The method can be expressed as equation 2-2.

$$CHZ = ST_{max} * 100 \qquad (2\text{-}2)$$

[5] *An end-point derived rate is based on the shoreline change (distance) between the first and last survey divided by the intervening time interval, so intermediate shorelines are not included in the analysis. This method is appropriate where a systematic shoreline change occurs; however, where a fluctuating change occurs a regression-based approach (which accounts for such variation) is preferable.*

Compared with present best practice potential erosion modelling, these methods are overly simplistic. However, the high FOS in Method 1 and reliance on $ST_{max}$ (which is invariable high compared with LT) in Method 2, means the TCC approach could provide plausible output.

The resulting erosion distances for the district averaged 74.5 m and ranged between 33 m and 227 metres. The values are listed in Table 2-1.

The actual hazard line location was measured inland of a reference shoreline (defined on the most recent aerial photo at that time). In particular: the base of the cliff where the cliff was vegetated; the top of the cliff where it was non-vegetated, or the vegetation front for non-cliff areas. The resulting erosion hazard lines are those found in the currently Operative District Plan. Note that present best practice is to use only one such cliff feature, commonly the cliff base.

**Gibb (1998)** carried out a localized erosion hazard assessment of a 500 m reach immediately east of the Waitara East Mole to determine "the appropriateness of allowing additional dwellings in this area". The site is composed of unconsolidated sediment with a mixed sand-gravel beach and fronting reef and is backed by sand dunes. Gibb's erosion assessment model incorporated five components and can be expressed as equation 2-3.

$$CEHZ = [(LT + RSLR)*T + ST + SS] * FOS \qquad (2\text{-}3)$$

Where CEHZ is the cross-shore width of the coastal erosion hazard zone, LT is the long-term rate of shoreline change based on end-point analysis using cadastral and aerial data collected between 1840 to 1996, ST is the maximum inter-survey change, RSLR is the annual retreat rate associated with a predicted sea-level change of 0.49 m over time period (T) = 102 years and using a profile translation based on an offshore closure depth, SS is the slope stability adjustment based on the angle of repose of dry sand (33 degrees), and the factor of safety (FOS) was 1.2 (20%).

Gibb applied the assessment at 50 m intervals alongshore and the resulting CEPD values ranged systematically from 101 m adjacent to the river mouth to 164 m some 500 m eastward (Table 2-1).

Tonkin + Taylor (2013) carried out an erosion hazard assessment for Onaero Beach as part of a management options (to mitigate erosion) investigation. In contrast to Waitara, the Onareo site has a cliff shoreline that is fronted by a predominantly sand beach with an inter-tidal intersect. Furthermore, 220 m of the shoreline is protected by boulder rip rap.

The assessment method used by T+T involved three components: long-term erosion, erosion resulting from climate-induced sea-level rise and a slope adjustment term to achieve a stable configuration following an episode of cliff retreat (collapse). The model is expressed as equation 2-4

$$CEHZ = [[h_C/\tan\alpha] + (LT_H \times LT_F) \times T] \qquad (2\text{-}4)$$

Where: CEHZ is the cross-shore width of the erosion hazard zone, $h_C$ is the height, $\alpha$ is the characteristic composite stable angle of repose, $LT_H$ is the historic long-term retreat (regression rate), $LT_F$ is the potential increase in future long-term retreat due to SLR effects, and T is the timeframe of interest.

The T+T analysis was carried out at 10 m intervals in the alongshore direction, this being optimal for local-level assessment and results ranged between 50 and 100 m (Table 2-1).

In summary, while the past assessments have provided useful information; aspects of the methodologies and/or official guidance on some inputs have changed. The TCC assessments were overly simplistic compared with current best practice, the Gibb local assessment at East Waitara the components used in current assessments of unconsolidated coasts; however, some component derivation methods have been improved. While the T+T local assessment at Onaero uses the current methodology, some input values such as SLR have been modified by later guidelines.

**Table 2-1 Coastal erosion prediction distances from previous assessments**

| Location | Previous erosion hazard widths (m) for ~100 yr assessment period | | |
|---|---|---|---|
| | **TCC 1987/88** | **Gibb 1998** | **T+T 2013** |
| Oakura Beach | 33 | | |
| Waireka | 60 | | |
| Paritutu | 62 | | |
| Fitzroy | 40 | | |
| Waiwhakao West | 112 | | |
| Waiwhakao East | 52 | | |
| Bell Block | 53 | | |
| Airport | 100 | | |
| Waitara West | 90 | | |
| Waitara East | 227 | 101 to 164 | |
| Onaero | 52 | | 50 to 100 |
| Urenui cliffs | 68 | | |
| Urenui bay | 98 | | |
| Mimi | 53 | | |
| Waikeikei | 63 | | |
| Tongaparutu | 33 | | |

The Taranaki Catchment Commission (1987/88) district-wide assessment was based on 16 samples each covering 2 km; the Gibb (1998) local assessment of 450 m long East Beach, Waitara, and the T+T (2013) local assessment of 700 m long reach at the Onaero Beach settlement.

## 2.4 Topographic and bathymetric information

The terrestrial coast is covered by the 1:50,000 topographic map series (Topo50) sheets BH28, BH29, BH30 and BG31. In addition, the NPDC has provided photogrammetrically derived contour data at 10 m intervals for the entire district and at 0.5 m intervals for the urban and coastal settlement areas.

Bathymetric charts NZ43 (1:300,000) and NZ443 (1:150,000) cover the district coast with NZ4432 (1:25,000) covering New Plymouth City to the airport at higher resolution.

Beach profile data are available from two sources:

i Between 1979 and 1982 the Taranaki Catchment Commission (TCC) profile surveyed 30 sites along the entire district's coastline, repeating the surveys 6 to 8 times. These data were collected for State of the Environment purposes and have been provided by the Taranaki Regional Council (TRC). Despite the limited temporal coverage, the spatial extent and contemporaneous sampling means it is suitable for the present district wide high-level coastal erosion assessment.

ii Beginning in the 1990s the NPDC, in association with the TRC, commissioned beach profiles at select sites along the district coast and these are held at the office of surveyors Bland and Howarth Ltd in New Plymouth. The profiling concentrates at East End-Waiwhakao during the 1990s and at Waitara 1997 to 2003. Other areas are East End early 2000s, Bell Block mid-

2000s, Urenui 1996-2003, Onareo 2003 and Oakura 2008. It seems that these surveys were carried out either as a condition of a coastal consent or to investigate a particular problem. The spatial limitations, temporally sporadic and non-contemporaneous sampling, and lack of a comprehensive filing of the NPDC data means it not so suitable for the present high-level erosion assessment.

## 2.5 Water levels

Water level at any coastal location varies across a range of timescales. Key components that determine water level relevant to a coastal erosion assessment are:

- Mean sea level (MSL).
- Astronomical tides.
- Long-term changes in sea level.

### 2.5.1 Mean sea level

In Taranaki, mean sea level usually relates to the local Taranaki Vertical Datum (TVD)-1970 which is a fixed survey datum based on the mean level of the sea between 1918 and 1921. Bell et al. (2000) point out that the actual mean level of the sea from year to year varies depending on cyclical changes such as the 2-4 year El Nino-Southern Oscillation (ENSO) cycle and the 20-30 year Inter-decadal Pacific Oscillation (IPO) and long-term sea level changes. LINZ (2017) give the present mean sea level at 0.125 m above TVD-1970.

### 2.5.2 Tides

Tides along the NPDC coast are semi-diurnal with fortnightly spring-neap cycles and monthly perigean - apogean cycles apparent. Tides for Port Taranaki are presented in **Table 2-2** and show the mean spring tide range is 3.26 m or 1.62 m above MSL.

**Table 2-2 Astronomical tidal levels for the 2012 - 2013 period at Port Taranaki (LINZ, 2017)**

| Tide stage | | Level (m) | | |
|---|---|---|---|---|
| | | **CD[1]** | **TVD-70** | **NZVD2009[2]** |
| HAT | Highest Astronomical Tide | 3.88 | 2.065 | 1.745 |
| MHWS | Mean High Water Spring | 3.56 | 1.745 | 1.425 |
| MHWN | Mean High Water Neap | 2.77 | 0.955 | 0.635 |
| MSL | Mean Sea Level | 1.94 | 0.125 | -0.195 |
| MLWN | Mean Low Water Neap | 1.08 | -0.735 | -1.055 |
| MLWS | Mean Low Water Spring | 0.29 | -1.525 | -1.845 |
| LAT | Lowest Astronomical Tide | -0.05 | -1.865 | -2.185 |

[1]Chart Datum at Port of Taranaki defined at 2.065m below TVD-70.

[2]New Zealand Vertical Datum 2009

### 2.5.2 Future sea-level change

Historic sea-level rise in New Zealand has averaged 1.7 ± 0.1 mm/year (Hannah and Bell, 2012). Climate change is predicted to accelerate this rate of sea level rise into the future. NZCPS (2010) requires that the identification of coastal hazards includes consideration of sea-level rise over at least a 100 year planning period. Potential sea-level rise over this time frame is likely to significantly alter the coastal hazard risk.

The Ministry for the Environment (2017) guideline outlines four SLR scenarios which have been developed for New Zealand to cover a range of possible sea-level futures (Table 2-3). Three of the scenarios (RCP2.6, RCP4.5, RCP8.5) are derived from the median projections of global sea-level rise for the RCPs presented by the IPCC in its Fifth Assessment Report (Church et al, 2013a). The fourth scenario, NZRCP8.5H+ is at the upper end of the 'likely range' (83rd percentile) of SLR projections based on RCP8.5. This higher scenario is representative of a situation where more rapid rates of SLR could occur early next century due to dynamic ice sheet processes and instability thresholds that were not fully quantified in the IPCC AR5 projections (MFE, 2017).

**Table 2-3 Projected sea level rise values (metres above 1986-2005 baseline) for New Zealand for the RCP2.6, 4.5, 8.5 and 8.5H+ scenarios (Source: MFE, 2017)**

| NZ SLR scenario Year | NZ RCP2.6 M (median) [m] | NZ RCP4.5 M (median) [m] | NZ RCP8.5 M (median) [m] | NZ RCP8.5 H+ (83rd percentile) [m] |
|---|---|---|---|---|
| 1986–2005 | 0 | 0 | 0 | 0 |
| 2020 | 0.08 | 0.08 | 0.09 | 0.11 |
| 2030 | 0.13 | 0.13 | 0.15 | 0.18 |
| 2040 | 0.18 | 0.19 | 0.21 | 0.27 |
| 2050 | 0.23 | 0.24 | 0.28 | 0.37 |
| 2060 | 0.27 | 0.30 | 0.36 | 0.48 |
| 2070 | 0.32 | 0.36 | 0.45 | 0.61 |
| 2080 | 0.37 | 0.42 | 0.55 | 0.75 |
| 2090 | 0.42 | 0.49 | 0.67 | 0.90 |
| 2100 | 0.46 | 0.55 | 0.79 | 1.05 |
| 2110 | 0.51 | 0.61 | 0.93 | 1.20 |
| 2120 | 0.55 | 0.67 | 1.06 | 1.36 |
| 2130 | 0.60* | 0.74* | 1.18* | 1.52 |
| 2140 | 0.65* | 0.81* | 1.29* | 1.69 |
| 2150 | 0.69* | 0.88* | 1.41* | 1.88 |

*Extended set 2130-50 based on applying the same rate of rise of the relevant representative concentration pathway (RCP) median trajectories from Kopp et al, 2014 (K14) to the end values of the Intergovernmental Panel on Climate Change Firth Assessment Report (IPCC AR5) projections.

## 2.6 Waves

Bell et al. (2008) determined a deepwater mean significant wave height ($H_s$) for the North Taranaki coast (from a 20-year model hindcast) of 1.6 m and maximum $H_s$ of 8.1 m. Swell waves (peak period of 11 to 13 s) were found to occur 40% of the time with dominant waves occurring from the westerly quarter.

However, wave height near the coast can be substantially smaller due to wave refraction is accounted for. Consequently, a detailed wave assessment was undertaken by MetOceans Solutions Ltd as part of the T+T (2016) Coastal Management Review for the NPDC. This was done using a high resolution (0.007˚ by 0.007˚ in longitude and latitude) SWAN (Simulating WAves Nearshore) model. The hindcast extended over a 37-year period between 1979 and 2015 and provided 3-hourly frequency-direction wave spectra.

Wave heights were extracted at 12 locations (Figure 2-2) in 10 m water depth. Omni-directional return period values at ARIs of 1, 5, 10, 25, 50, and 100 years were calculated from the hindcast time series of significant wave height. Extreme wave characteristics for the 12 offshore locations are presented in **Table 2-4** and show the 100 year ARI wave height to range from 2.97 m to 5.92 m with a wave period of 14.2 s period.

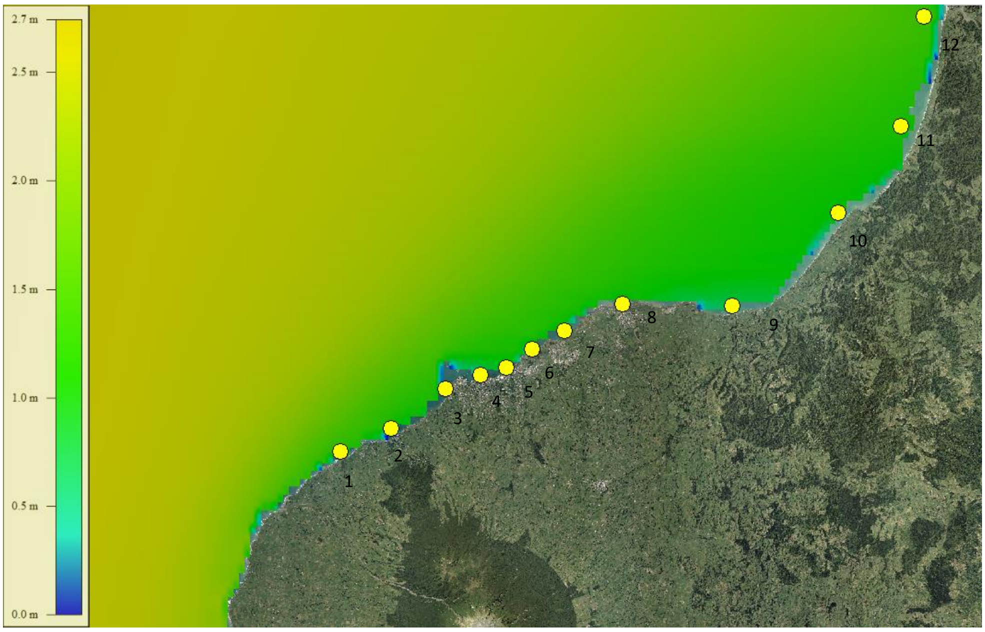


*Figure 2-2 Mean significant wave height and locations of 12 representative reporting sites*

**Table 2-4 Extreme wave characteristics for offshore locations shown on Figure 2-22 (10m water depth) provided by MetOcean Solutions Ltd in T+T (2016)**

| Site | ARI (years) | $H_s$ (m) | $T_p$ (s) | Site | ARI (years) | $H_s$ (m) | $T_p$ (s) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 4.45 | 13.1 | 7 | 1 | 3.72 | 13.1 |
| | 10 | 5.10 | 13.8 | | 10 | 4.05 | 13.8 |
| | 100 | 5.50 | 14.2 | | 100 | 4.19 | 14.2 |
| 2 | 1 | 3.59 | 13.1 | 8 | 1 | 4.18 | 13.1 |
| | 10 | 3.93 | 13.8 | | 10 | 4.65 | 13.8 |
| | 100 | 4.10 | 14.2 | | 100 | 4.87 | 14.2 |
| 3 | 1 | 3.82 | 13.1 | 9 | 1 | 3.74 | 13.1 |
| | 10 | 4.13 | 13.8 | | 10 | 4.40 | 13.8 |
| | 100 | 4.49 | 14.2 | | 100 | 4.83 | 14.2 |
| 4 | 1 | 2.57 | 13.1 | 10 | 1 | 3.89 | 13.1 |
| | 10 | 2.84 | 13.8 | | 10 | 4.62 | 13.8 |
| | 100 | 2.97 | 14.2 | | 100 | 5.09 | 14.2 |
| 5 | 1 | 3.38 | 13.1 | 11 | 1 | 3.98 | 13.1 |
| | 10 | 3.56 | 13.8 | | 10 | 4.18 | 13.8 |
| | 100 | 3.63 | 14.2 | | 100 | 4.24 | 14.2 |
| 6 | 1 | 2.97 | 13.1 | 12 | 1 | 4.33 | 13.1 |
| | 10 | 3.11 | 13.8 | | 10 | 4.61 | 13.8 |
| | 100 | 3.17 | 14.2 | | 100 | 4.70 | 14.2 |

The relevance of waves to coastal erosion goes beyond their ability to breakdown and remove material seaward during storm conditions. In particular, waves are the primary force in transporting sediment alongshore, a process also referred to as “littoral drift”. Where the littoral drift potential exceeds available sediment, the shoreline is more likely to undergo erosion. Littoral drift also redistributes sediment alongshore from its source (typically cliff erosion or input from rivers and streams). The net drift direction thus becomes important and is a product of wave characteristics and also wind which can significantly influence coastal current.

The net direction of alongshore sediment transport for the NPDC coast is from south/west to north/east and the annual rate at New Plymouth has been estimated to be between 130,000 and 170,000 $m^3$ based on port dredging records kept since the Port breakwater was constructed in the 1880s (Gibb, 1996; McComb, 2001).

## 2.7 Historical shoreline information

As noted earlier in Section 2.3, Gibb (1978) and Gibb (1998) made extensive use of early survey (cadastral) plans and the derived shorelines (clifftop, cliff base for consolidated shorelines or high-water mark (HWM) for unconsolidated shorelines). However, such data can contain a plethora of errors (up to 30 m) which can result in noise obscuring the long-term signal for use in shoreline change analysis. By contrast, use of the seaward extent of vegetation for beach shorelines has the advantage of filtering change induced by short-term marine processes (tides and waves) so is a more stable indicator and can remain effective where samplings are separated by several years. Consequently, the present assessment focuses on the 70 year record of vertical aerial photographs (1943 to 2013).

In particular, the aerial photo-based shorelines used in the present assessment are those provided in the Coastal Resource Map (CRM) series described earlier in Section 2.3. In each of the 16 maps, at least 3 historic aerial photo-based shorelines dating back to the 1940s were overlaid upon the most recent (at that time) aerial photo. Each map was drawn on A0 acetate at 1:2500 and covered approximately 2 km of shoreline such that sampling was concentrated along the urban and rural beach settlement coast (Figure 3-2). The original acetate tracings were located in the TRC archive and scanned at high resolution and georeferenced in-house to the latest available aerial orthophotography: 2012 for the district available from LINZ, and 2013 for urban and settlements held by the NPDC. In addition, vertical aerial photography from 1996, 2001 and 2007 were made available by the TRC and NPDC.

While inaccuracies in shoreline data abstracted from vertical aerial photographs can be as low as 1 m from large scale images with good ground control with geo-referencing and the shoreline detection is carried out by expert practitioners, in the present case we have found Coastal Resource Map shorelines typically contain errors of 3 to 6 m. Given the degree of shoreline change occurring on the Taranaki coast, the long-term signal is still discernible and this level of inaccuracy is acceptable for a high-level assessment.

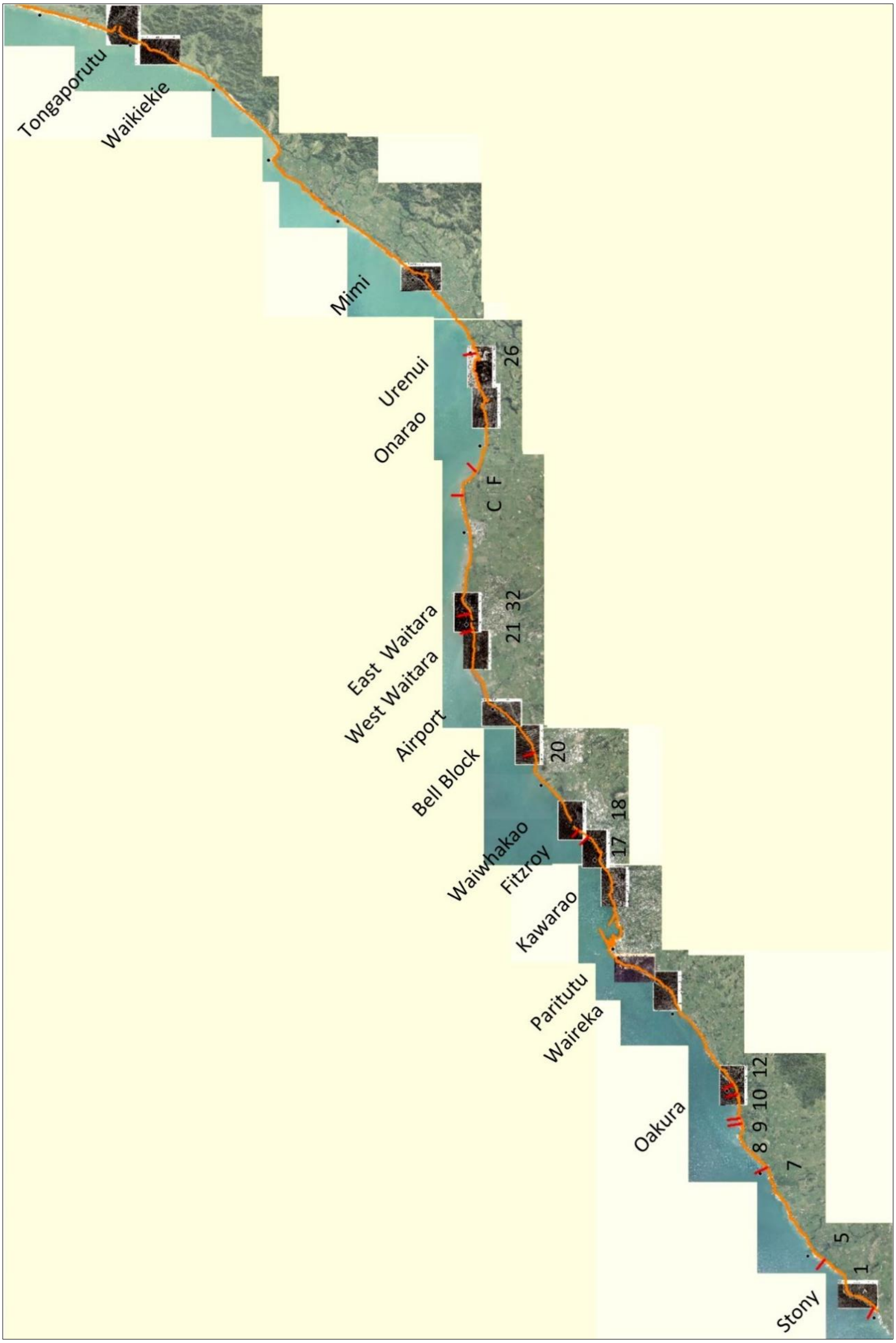


*Figure 2-3 Reaches covered by the 16 Coastal Resource Maps. These areas are thus measurement site samples data from which was used in the present study. Numbered red segments denote TCC profile sites used in this assessment.*

# 3 Conceptual models

Conceptual models have been adopted to assess areas susceptible to erosion as part of a first-pass assessment. These models are well tested within New Zealand, being based on models originally developed by Gibb (summarised Gibb, 1998b) and subsequently refined within peer reviewed studies by T+T (2006, 2014).

## 3.1 Unconsolidated shorelines

Unconsolidated shorelines are those fronted by beaches and backed by sand and/or gravels. Such sediments are derived either from marine processes or by hinterland erosion and are shaped by ongoing marine and aeolian processes. Beaches respond to periods of storminess and calm by changes in the profile shape and level; they also respond to longer-term changes in modal wave climate or water level by adjusting orientation or position. Modification of the sediment budget (supply and/or loss) can similarly change the volume, shape and position of a beach. Hazard occurs where such fluctuations or ongoing changes adversely affect human values, activities or assets.

The identification of such **A**reas which may be **S**usceptible to **C**oastal **E**rosion (ASCE) on unconsolidated shorelines has been based on industry-standard and best-practice methodology (i.e. Ramsey et al., 2012) which involves combining 4 essentially independent components. Three potential erosion scenarios are considered and these are expressed as equations 3-1, 3-2 and 3-3, with the terms illustrated in Figure 3-1. The *Current ASCE* for beaches accounts for the short-term fluctuation (ST) plus an allowance an eroded dune scarp reduced to the stable angle of repose. The *Future* $ASCE_1$ for an unconsolidated coastline also includes application of the historical erosion rate, while the final scenario (*Future* $ASCE_2$) includes a factor allowing for the effects of projected sea-level rise.

$$\text{Current ASCE} = [ST + DS] \qquad (3\text{-}1)$$

$$\text{Future } ASCE_1 = [ST + DS + (LT \times T)] \qquad (3\text{-}2)$$

$$\text{Future } ASCE_2 = [ST + DS + (LT \times T) + SL] \qquad (3\text{-}3)$$

Where:

ST = Short-term changes in horizontal shoreline position (m)

DS = Dune stability allowance (m)

LT = Long term rate of horizontal coastline movement (m/year)

T = Timeframe (years)

SL = Horizontal coastline retreat due to the effects of increased mean sea level (m).

For each component a range of values can be derived corresponding to different probabilities of occurrence which, when combined, indicate the range of possible coastal erosion. When defining the ASCE for a first-pass assessment, values are chosen such that their combined probability is extremely unlikely. This conservative approach is consistent with the provisions of the NZCPS (2010) and enables the identification of sections of coast potentially susceptible to erosion hazard risk. However, results of a first pass assessment are not intended to replace more detailed investigation which should subsequently be undertaken to more accurately define the hazard in such specific areas.

While a factor of safety based on errors incorporated within component derivations was included in the earlier assessments (TCC, 1987/88 and Gibb, 1998, described in Section 2.3), this is omitted from current assessments as the quality of the data base and methodologies have improved coupled with the use of typically conservative component values and output probabilities.

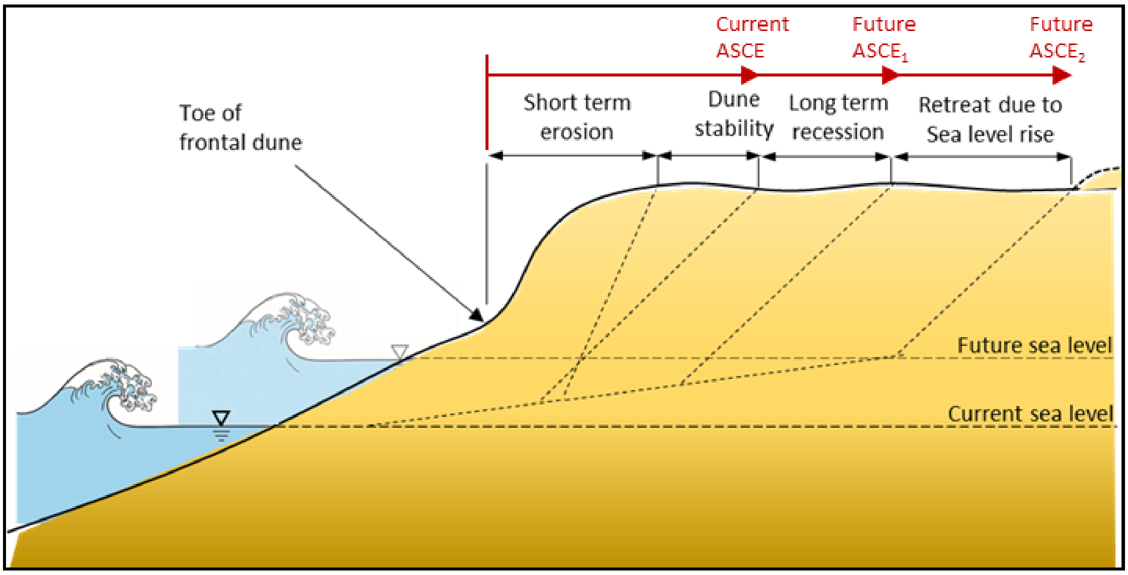


*Figure 3-1 Definition sketch of erosion assessment components for a unconsolidated coast*

## 3.2 Consolidated coastline

Consolidated coastlines including cliffs and estuarine banks respond differently to coastal processes than beaches backed by unconsolidated material. Cliffs are not able to rebuild following periods of erosion but rather are subject to a systematic one way process. Cliff erosion typically has two components; a gradual retreat caused by weathering, marine and bio-erosion processes, and episodic failures due to over-steepening of the cliff base by wave action. These processes may range from small-scale slips to large scale and deep-seated mass movement. Cliff debris accumulating at the base is subsequently removed by marine processes. Cliff lithology, geological structure and wave climate influence the erosion characteristics.

If systematic erosion of the cliff toe is slowed or halted through either natural processes such changes in the sediment supply and the subsequent formation of a protective beach, or anthropogenic intervention such as armouring the shoreline or structures trapping littoral drift sediment, then terrestrial processes will cause the cliff above the toe to continue to retreat until a stable angle of repose is reached and vegetation is able to establish.

Three potential erosion scenarios for consolidated coastlines are used in the present assessment and these are expressed as equations 3-4, 3-5 and 3-6 with the terms illustrated in Figure 3-2. The *Current ASCE* for cliffs accounts for the present slope reducing to the associated stable angle of repose. The *Future ASCE₁* for a consolidated coastline is based on application of the historical erosion rate followed by adjustment to the stable cliff angle. The final scenario (*Future ASCE₂*) includes a factor allowing for the effects of projected sea-level rise.

$$Current\ ASCE = [h_C/\tan\alpha] \qquad (3\text{-}4)$$

$$Future\ ASCE_1 = [[h_C/\tan\alpha] + (LT_H \times T)] \qquad (3\text{-}5)$$

$$Future\ ASCE_2 = [[h_C/\tan\alpha] + (LT_H \times LT_F) \times T] \qquad (3\text{-}6)$$

Where:

$h_C$ = Height of cliff (m)

| | | |
|---|---|---|
| α | = | The characteristic composite stable angle of repose (degrees) |
| $LT_H$ | = | Historic long-term rate of retreat (m/year) |
| $LT_F$ | = | Factor for the potential increase in future long-term retreat due to SLR effects. |

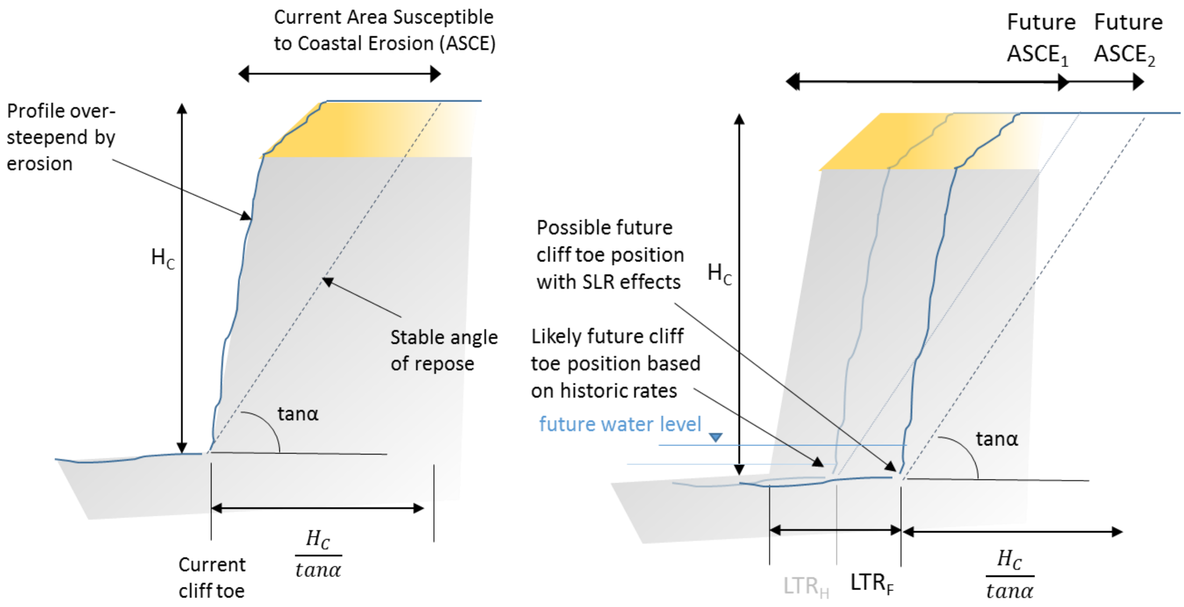


*Figure 3-2 Definition sketch for erosion assessment components for a cliff shoreline*

# 4 Component derivation

## 4.1 Sectors and cells

Component parameter values have been listed in Appendix B. For each component, a single (high end) value representative of a particular reach of coast was determined and recorded in the modelling spreadsheet (Appendix C). The coast is thus sectorised for each component. However, the sector boundaries for different components do not necessarily coincide, and this resulted in numerous ***cells*** that each have unique combinations of parameter values. The cells, numbered 1 to 35, and their corresponding parameter values, are listed in Appendix C.

## 4.2 Planning timeframe (T)

In the present assessment, the planning timeframe, also referred to as the planning horizon or prediction period, is 2130, consistent with Policy 25 of the NZCPS (i.e. consideration of at least 100 years). This timeframe allows for identification of hazards that may occur over the design life of new development. Additionally, as outlined in the previous section, the current erosion values have also been calculated.

## 4.3 Short-term erosion (ST)

Short-term erosion relates to the change in horizontal shoreline position due to storm erosion caused by singular or clusters of storms events, seasonal fluctuations in wave climate and sediment supply variation over several years. As noted in Section 3, short-term change applies to the open coast environment where shoreline fluctuations can occur, i.e. it requires the occurrence of unconsolidated sediment.

In the present study, ST was determined at several such locations where historical shoreline data were available, this consisting of several samples between the 1940s and 2012/3. The ST value was statistically derived using linear regression, in particular, by computing the standard error of estimate (SEE) which parameterises the variation about the temporal average (regression line). The actual ST value used in this assessment is 3 x SEE which provides 99% certainty of capturing the actual (population) value.

Results for SEE are listed in Appendix B and the associated ST values in Appendix C where the component values ranged between 17 and 32 m. Particularly high values occurred at Waitara but the residual distribution from which SEE is calculated was not normal, i.e. it failed the required normality assumption (Wilkinson, 1996), so these values were discarded as potential outliers. Inspection of the Waitara shoreline record showed an atypically large fluctuation within the early data that was not consistent with later shoreline behaviour.

## 4.4 Stable angles ($\alpha$) and heights (h)

### 4.4.1 Unconsolidated beach coasts

The dune stability allowance delineates the area landward of a wave cut erosion scarp that may subsequently become unstable for building foundations due to loss or reduction of toe support. This parameter is required as storm wave erosion causes in an over-steepened face (scarp) which then adjusts by slumping and avalanching until a stable angle is attained. The extend of landward retreat of the scarp top (the dune stability width) is dependent on the height between scarp base and the existing dune surface, and the angle of repose for loose dry dune sand (33 degrees). Dune height was determined from a DTM constructed with the 0.5 m contour data set; this enabled identification of the maximum elevation at an inland distance erosion could reach during the prediction period. The scarp base was estimated to be 1.6 m, this approximating the MHWS level which monitoring of storm cut on west coast beaches has shown to be a suitably conservative value. Dune height values ranged between 4.5 and 13.5 m (Appendix B). The dune stability (DS) component is computed using equation 4-1.

$$DS = \frac{h_{dune}}{2(\tan \alpha_{sand})} \qquad (4\text{-}1)$$

Where $h_{dune}$ is the dune height from the eroded base to the crest and $\alpha_{sand}$ is the stable angle of repose.

### 4.4.2 Consolidated (cliff) coasts

The stable slope angle along cliff shorelines is dependent on a range of factors such as geological type, weathering profile, local bedding and faulting characteristics, groundwater level, overland flow paths and vegetation cover. Furthermore, if a slope comprises multiple rock types (for example a competent under layer and weathered cover material), each type of material may well have a different stability angle (e.g. see Figure 4-1), and the resulting parameter value must incorporate this variation.


*Figure 4-1 Example of a composite slope developed on the siltstone and cover materials at Onaero*

For the present study, stable cliff angles have been identified using a DTM constructed from the provided contour data and overlaid by aerial photographs. Vegetated cliffs were assumed to be stable and sample profiles were abstracted and analysed. A best-fit line was used to define the overall stable slope angle with the minimum value used to represent a particular reach. The cliff top and base elevations were determined from the DTM. In particular, the top elevation being the maximum over an inland distance erosion could reach, and the cliff base elevation being the minimum value with this latter level varying alongshore from 0.5 m from Buchanan's Bay to Whitecliffs then increasing to 1.5 m to the south/west and north/east. The resulting cliff heights are listed in Appendix B and can be seen to vary between 45 m south of New Plymouth and north of Whitecliffs, 24 m adjacent to the airport, 9 to 13 m west and east of Waitara then increasing to 58 m by Whitecliffs and in excess of 200 m at the Whitecliffs. Stable angles ranged between 31 to 36 degrees for laha cliffs and 38 to 40.5 degrees for papa cliffs (Appendix B).

At Onaero, T+T (2013) derived composite stable angles of repose based on geological mapping, site observation and geometrical configuration from the digital terrain model. Using this more theoretical approach that study found a *cliff less than 3 m high has a stable angle of 26.6°, increasing to a composite angle of 40° for cliffs above 7 m*. This agreed well with the present study which found a value of 40.5 degrees for the Onaero section of coast. Forty degrees was subsequently selected to represent the entire papa coastline in Appendix C. While this simplification was required due to lack of high resolution contour data for most of this coast, the results we did derive provided consistent results.

## 4.5 Long-term trends (LT)

Long-term trends describe ongoing horizontal coastline movement (erosion or accretion) that may be caused by systematic changes in the sediment supply, wave conditions or sea level. As discussed earlier in Section 2.7, for the present exercise historical rates were determined from shorelines presented in the CRMs and updated by more recent aerial photography. The map locations, local name and distance, are recorded in Appendix B. The 2 km coastlines covered by these maps are thus samples and suitable for the present potential erosion assessment exercise because their original spatial selection ensured areas of value were covered.

Each CRM was sampled up to 20 times (i.e. at 20 cross-shore transects) such that a higher number were made where there was greater spatial variation. End-point rates determined, unless fluctuations dominated the record and linear regression was then used. The largest value was then selected, or an upper-end value where a large number of measurement transects were used, to represent a particular reach. Results are listed in Appendix B.

Several data exclusions were required to avoid artefact or outlier contamination. Where a shoreline is protected, data was excluded after the protection was in place. Rates for the city shoreline were based on 1905 to 1950 with the latter value constrained by seawall effects form 1950 and the former value necessarily being from an early cadastral map. Messenger Terrace at Oakura, Bell Block, Onaero, and Urenui all had truncated data sets following the erection of hard protection (in the main) between 1980's and 2000's. Also, at the far south of the district (as noted earlier in Section 2.1), a large sediment input from the Stony River in 1998 contaminated the shoreline data as a substantial berm formed against the shoreline with sand subsequently blowing landward and burying vegetation, thus implying shoreline retreat (erosion) rather than accretion.

Appendix B also lists values from Gibb (1978) for sites between the CRM coverage. These values provided some assistance when interpolating between the CRM representative values and identifying the LT sectors in Appendix C.

Results showed the coast to be stable with some accretion from central Oakura southward so an LT value of 0 was selected for this southernmost sector (Appendix B). Erosion characterised the coast to the north with representative values of -0.24 m/y from Oakura to New Plymouth, -0.14 to -0.19 m/y from Fitzroy and Waiwhakao, -0.35 m/y at Bell Block, -1.1 m/y along the airport cliffs, -0.75 m/y at west Waitara, -1.1 m/y at east Waitara, -0.44 m/y along the Motunui coast and -0.58 m/y from Onaero northward. Data was lacking along the New Plymouth urban coast where most of the shoreline has been protected by seawalls for some decades. However, early studies (TCC, 1984) indicated that historically (1905-1950), the coastline between East End Beach and Pari Street and also around Kawaroa Park had been retreating at rates of approximately -0.5m/yr. If the seawalls were to fail or be removed, these long-term rates may resume.

## 4.6 Effects of sea-level rise

### 4.6.1 Adopted SLR values

For this assessment, the $ASCE_2$ considers the mean sea level rise (SLR) associated for all four RCP projections (Table 4-1).These have been adjusted relative to the adopted shoreline 'baseline' year (2015) and the average historic rate of sea level rise of 1.5 mm/year has been deducted from the adjusted SLR values for use in assessment on the basis that the existing long term trends and processes already incorporate the response to the historic situation. Thus an 'effective' future sea level rise values for 2130 has been adopted (Table 4-1).

**Table 4-1 Adopted sea level rise (SLR) values (m)**

| SLR scenario | 2130 SLR[1] | Adjusted relative to the baseline year[2] | 'Effective' SLR[3] |
|---|---|---|---|
| RCP2.6 (median) | 0.60 | 0.54 | 0.36 |
| RCP4.5 (median) | 0.74 | 0.68 | 0.50 |
| RCP8.5 (median) | 1.18 | 1.12 | 0.94 |
| RCP8.5 H+ (83rd percentile) | 1.52 | 1.46 | 1.28 |

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

[2]Correction of 0.07m applied to adjust from 1996 to 2015 (current baseline derived from 2015 aerial photographs).

[3]Subtracts assumed historic rate of 1.5 mm/year (Hannah & Bell, 2012) to avoid double-counting erosion response

### 4.6.2 Beach response

Geometric response models propose that as sea level is raised, the equilibrium profile translates upward and landward thus conserving mass and the original shape (Figure 4-2). The most well-known of these geometric response models is Bruun (1988) which proposes that with increased sea level, material is eroded from the upper beach and deposited offshore at the "closure depth". The increase in sea-bed level is equivalent to the rise in sea level and results in landward recession of the shoreline. The model may be defined by equation 4-2 which the equivalent to the average cross-shore slope *S.

$$SL = \frac{L_*}{h + d_*} S \qquad (4\text{-}2)$$

Where SL is the landward retreat, d* defines the maximum depth of sediment exchange, h is the height of the berm/dune crest within the eroded backshore, L* is the horizontal distance from the eroded berm/dune crests to the offshore position of d*, and S is the sea-level rise.

When applied over a large area with sediment budget imbalances accounted for by the long-term trends component, the model has shown reasonable agreement with observed changes.

However, for the off-shore closure model to apply the coast must have abundant sand, no offshore or onshore losses or gains, and an instantaneous profile response following sea-level change. Several methods have been used to define the point of closure including changes in sediment characteristics and/or the profile shape, profile change or using wave based modelling. With the increasing availability of wave data for virtually any location, the wave-based approach (referred to as the Hallermeier technique) is now the preferred approach used in offshore-closure-based erosion assessments.

Hallermeier (1983) defines closure depth, to be a function of sediment characteristics and local wave climate and for a sandy beach; this can be approximated as:

$$d_l = 2.28H_{s,t} - 68.5(H_{s,t}^2 / gT_s^2) \cong 2 \times H_{s,t} \qquad (4\text{-}3)$$

where $d_l$ is the closure depth below mean low water spring, $H_{s,t}$ is non-breaking significant wave height exceeded for 12 hours in a defined time period, nominally one year, and $T_s$ is the associated period. For the present assessment, $H_{s,t}$ has been approximated by the 1 year return period $H_s$ as provided Table 2.4. The corresponding distance to closure has been estimated using the bathymetric charts referenced in Section 2.4 and a DTM constructed from the NPDC 0.5 m contour data.

However, the beach and nearshore of the southern and central NPDC coast has a sandy seabed (on average) for only 25 to 30% (on average) of the area and this limited supply of mobile sediments does not always allow for cross-shore sediment exchange (McComb, 2006). Indeed, much of the south/central coast is fronted by wave cut platforms mantled with sand and boulders or a thin veer of sand (TRC 2017). In such situations of constrained cross-shore sediment exchange, closure is based on observed morphological and/or sediment characteristics and this partition has typically been found to occur about the MHWS level. The associated cross-shore slopes were derived from the TCC profile set with values of 0.04 for the sandy beaches, 0.05 for the central gravel beaches and up to 0.1 for southern and northern gravel beaches.

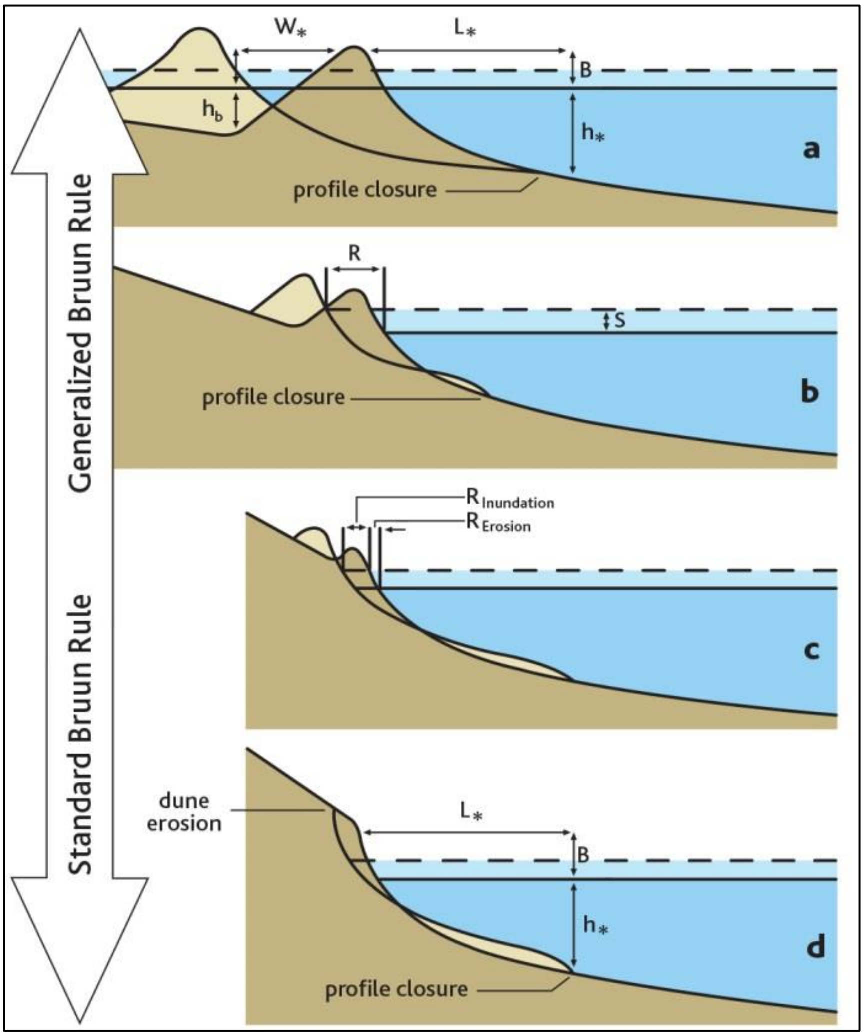


*Figure 4-2 Schematic diagrams of the Bruun model's modes of shoreline response*

### 4.6.3 Cliff response

As discussed within Section 4.6.1, sea levels have been rising over the 20th century with rates in New Zealand averaging +1.7 mm/year (Bell and Hannah, 2012) and this is expected to increase in the future as a warming climate causes thermal expansion of the oceans and increased terrestrial glacier melt – both of which lead to sea-level rise (IPCC, 2013).

While the effects of long-term sea-level rise on beaches backed by unconsolidated material is well documented, such increases are also expected to affect the retreat rates of softer cliffed shorelines (Defra, 2002) as more wave energy is able to reach the cliff base increasing hydraulic erosion and the removal of toe-protecting debris. Walkden and Dickson (2006) found that recession rates of sea cliffs are influenced by the fronting beach volume. For the soft cliffs tested, they found that cliff erosion became independent of fronting beach volume when the volume is less than approximately 20 $m^3$/m. In the absence of such frontal protection, they found that for the soft cliff tested (historic rates of recession of 0.8 to 1.0 m/year), an equilibrium recession rate could be described by the following equation.

$$R_2 = R_1\sqrt{\frac{S_2}{S_1}} \qquad (4\text{-}4)$$

Where $R_2$ is the future rate of retreat, $R_1$ is the current rate, $S_2$ is the future rate of sea level rise and $S_1$ is the past rate of sea level rise.

Aston et al. (2011) propose a generalised expression for future recession rates of cliff coastlines as expressed by Eqn. 4-5 and illustrated in Figure 4-3. The coefficient m is determined by the response system. An instantaneous response (m = 1) gives a rate of future recession proportional to the increase in SLR. A negative/damped feedback system occurs where rates of recession are slowed by development of a shore platform or fronting beach. No feedback ($m \rightarrow 0$) indicates that wave influence is negligible and weathering dominates. They suggest 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. It was noted, however, that equilibrium conditions take some time to develop, with the case tested taking nearly 1000 years to adjust from a past SLR rate of 2 mm/year to a future rate of 6 mm/year, although the majority of the increase occurred in the first century. As the relationship likely to be conservative for the shorter timespan erosion assessments are based on, and as it can potentially be applied to a wide variety of rock types, it is now the preferred erosion assessment approach for SLR-induced erosion of non-cohesive coasts.

$$R_2 = R_1\left(\frac{S_2}{S_1}\right)^m \qquad (4\text{-}5)$$

For the present study, a negative feedback (m=0.5) is assumed for the laha cliffed coast and m=0.25 for the para cliffs. For historic rates of sea-level rise ($S_1$) of 1.5 mm/year, and an average future rate ($S_2$) of 9.4 mm/year to 2130, a potential increase in recession rates by a factor of 1.6 (papa cliffs) to 2.5 (lahar cliffs) could be expected based on Eqn. 4-5.

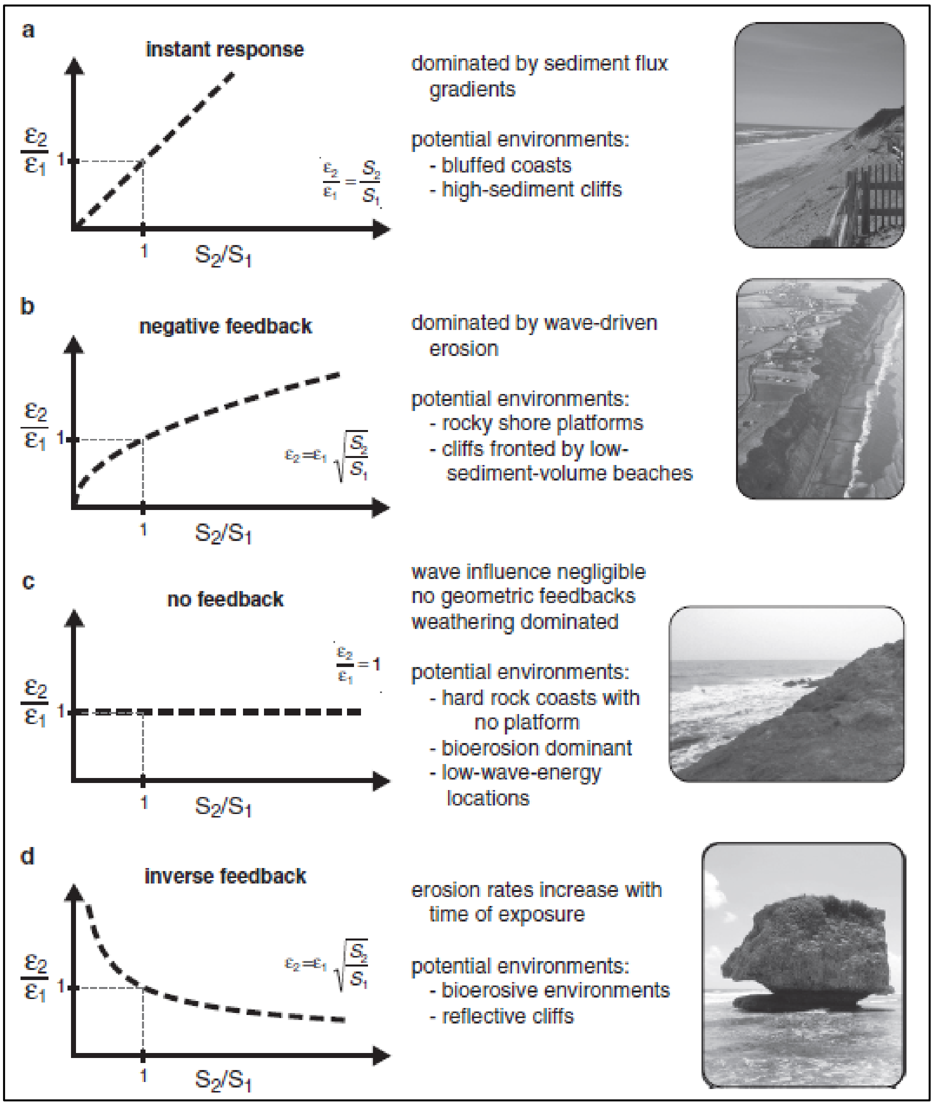


*Figure 4-3 Possible modes of cliff response to SLR (adapted from Ashton et al., 2011)*

## 4.7 Seawall protected coast

Much of the New Plymouth urban shoreline between the Port and East End is protected by consented seawalls. However, if the walls were to fail or be removed the land behind would be vulnerable to erosion processes including erosion of the cliff and beach toe, and instability of the land above.

As is usual with first-pass assessments, the potential current and future ASCE values have been determined assuming no seawall is present. This due to the limited design life of coastal structures and the potential for structures to not be renewed in the future. It also allows for a measure of the value provided by the walls and justification for their ongoing maintenance and renewal. Long-term rates have been determined based on historic (pre-seawall) rates as described in Section 4.5. If the seawalls were to fail or be removed, these long-term rates may resume.

# 5 Coastal erosion susceptibility

## 5.1 Coastal cell definition and analysis

The New Plymouth District coastline has been split into 35 Coastal Cells which reflect the underlying geological and morphology characteristics. Each cell has a distinct set of parameter values and these are listed in Appendix C. Parameters are combined based on the conceptual models presented within Section 3 to derive Current ASCE, Future $ASCE_1$ and Future $ASCE_2$ and these computation results appear on the right side of Appendix C. Maps depicting these potential erosion scenarios are presented in Appendix C and have also been supplied electronically. A summary of the ASCE distances for beach and cliff shorelines is presented within Table 5-1.

**Table 5-1 Summary of ASCE values**

| ASCE distance (m) | | Current | 2130 - SLR at historic rate | 2130 - RCP2.6 | 2130 - RCP4.5 | 2130 - RCP8.5 | 2130 RCP8.5H+ |
|---|---|---|---|---|---|---|---|
| Beach | Maximum | -53 | -174 | -181 | -184 | -193 | -200 |
| | Mean | -31 | -72 | -80 | -84 | -94 | -101 |
| | Minimum | -7 | -17 | -23 | -25 | -33 | -38 |
| Cliff | Maximum | -238 | -306 | -320 | -326 | -342 | -390 |
| | Mean | -39 | -104 | -127 | -139 | -169 | -186 |
| | Minimum | -7 | -18 | -28 | -29 | -34 | -36 |

## 5.2 Beaches (unconsolidated coast)

Results show that current ASCEs for unconsolidated shorelines range from 7 to 53 m with the highest values occurring along the central coast where short-term fluctuation values are high and there are other standout characteristics such as high dunes or high long-term retreat adjacent to inlets. An example of the ASCE lines along an unconsolidated section of coast is presented in Figure 5-1.

Future $ASCE_1$ widths range between 17 and 174 m with minimum values along the south coast where LT = 0, and higher values along the central/north coast with particular focus about Waitara – a reflection of the highest LT values at this location. Once the effects of SLR projections are incorporated into the modelling the $ASCE_2$ range increases to between 23 and 200 m and again lowest values are in the south and highest values along the Waitara coast.

The SLR response at the two most sandy beaches (Oakura and Fitzroy) was modelled using both the lower foreshore closure depth as used for the rest of the districts coast, and also the offshore closure depth (Section 4.6.2). This resulted in an increase retreat of 14 m for Oakura Beach and 12 m for Fitzroy Beach (details in Appendix C). Given the noted high likelihood that these sites fail to meet the requirement of unimpeded sediment exchange from dune to offshore (Section 4.6.2), the foreshore-based closure output will be incorporated into this assessment.

Comparing the present results with those from the initial TCC (1987/88) district wide assessment (Table 2.1) shows the TCC values approximated the $ASCE_1$ values (mean difference -3.4 m, range -24 to +7 m). However, as the TCC did not account for SLR they are notably lower than the $ASCE_2$ values (mean difference -23.3 m, range -2 to -62 m). Excluded from the comparison is East Waitara where the TCC prediction of 227 m is greater than our $ASCE_2$ prediction of 193 m. This large TCC output appears to have resulted from the occurrence of some very large ST values at this site and their use of the short-term based prediction model option (*CEHD = $ST_{max}$ * 100,* equation 2-2); this situation makes the TCC's East Waitara value a statistical outlier. It is also noted that the mapped TCC and ASEC lines will be separated by more than the modelled differences as the interim 30 years of erosion separates the reference shorelines.

The East Waitara area was also the focus of the Gibb (1998) assessment which predicted a potential future retreat excluding SLR of up to 135 m c.f. our value of 174 m with the difference due to the current assessment's higher LT and ST values. However, it is noted that Gibb's study area extended only 450 m from the east mole while ours extended a further 1100 m. Gibb's estimate including SLR came to 165 m c.f. our value of 193 m with the difference in SLR (Gibb used 0.49 c.f. the current assessment using 0.94 m) contributing to his lower output.

The East Waitara results show an area with high erosion potential coupled with a complex morphological history which includes substantial anthropogenic influence.

## 5.3 Cliffs (consolidated coast)

The results in Appendix C show that current ASCEs for consolidated coasts range from 7 m along south Messenger Terrace, up to 69 m along the coast north of Waiiti and a spike of 238 m at Whitecliffs, with the primary control being variation in cliff height and thus the slope stability adjustment. An example of the ASCE lines for the consolidated coast is presented within Figure 5-2.

Future $ASCE_1$ widths range between 18 m along the relatively stable southern end of Messenger Terrace, up to 168 m along the highly unstable airport cliffs and again there is the localised spike at Whitecliffs – 306 m in this case. The inclusion of LT erosion has increased the $ASCE_1$ values above current ASCE values by several times in areas with lesser cliff height, and at least doubled the predicted future value in areas with greater cliff height with the exception of Whitecliffs were height remains the dominant control. Incorporating the effects of projected SLR increases the future $ASCE_2$ range to 34 m at south Messenger Terrace, up to 340 m along the airport cliffs and up to 342 m at Whitecliffs. The $ASCE_2$ values have a similar distribution to the $ASCE_1$ distribution as the SLR response being based on LT. The maximum $ASCE_2$ value occurs at Whitecliffs for all different RCP SLR scenarios, except for with the RCP8.5+ scenario, where the $ASCE_2$ along the airport cliffs is 40 m greater than the $ASCE_2$ at Whitecliffs.

Comparing the present results with those from the earlier TCC (1987/88) assessment shows the TCC values were consistently less than the $ASCE_1$ values (mean difference -27 m, range -87 to -9 m); this difference resulting from the TCC model not including a slope stability adjustment and the factor of safety not able to fully compensate. Excluded from the comparison is the Whitecliffs spike (difference -243 m). As the Whitecliffs height far in excess of the remaining 95% of the cliff coastline at 5 to 58 m, this makes Whitecliffs a statistical outlier. Once the SLR response is included ($ASCE_2$) the differences increase further with the mean = -72 m and range = -240 to -54 m, excluding the Whitecliffs spike (difference -279 m).

The T+T 2013 Onaero result (50 to 100 m), however, compares well with the present assessment's $ASCE_2$ value of 106 m for the bracketing sector (Buchanan's Bay to Onaero River). The T+T (2013) assessment is an example of a more detailed 'local assessment' and its lines should be used in preference to this district-wide study once updated to include the newer MfE (2017) guidance.

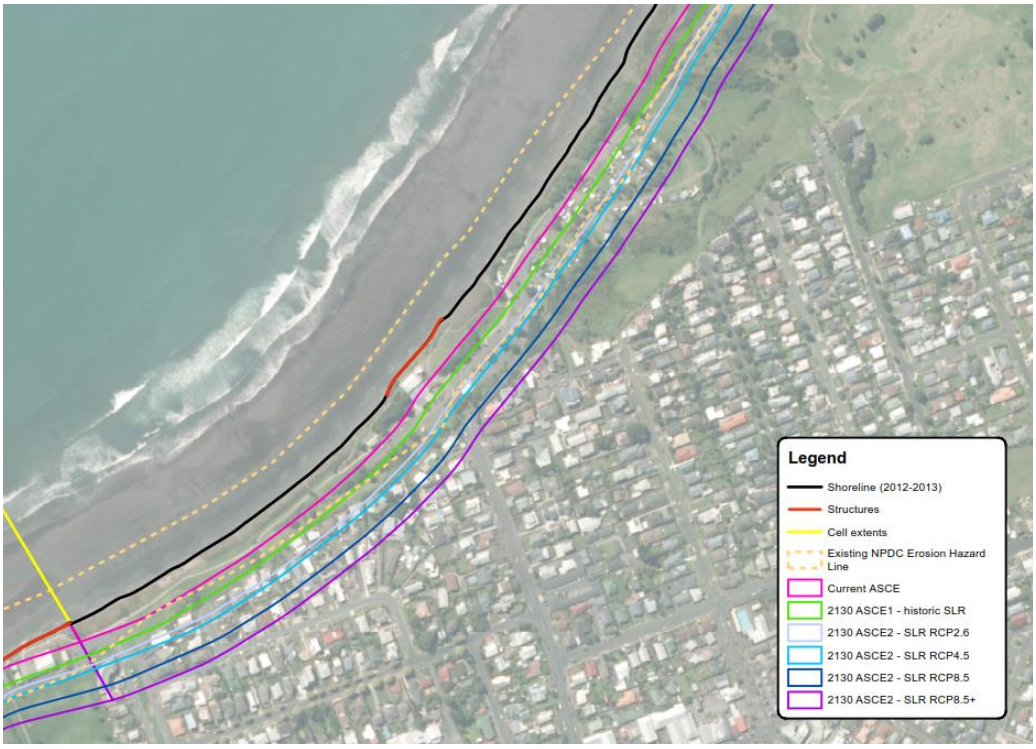


*Figure 5-1 Example of ASCE lines for unconsolidated coastline at Fitzroy compared to the existing NPDC Erosion Hazard line.*

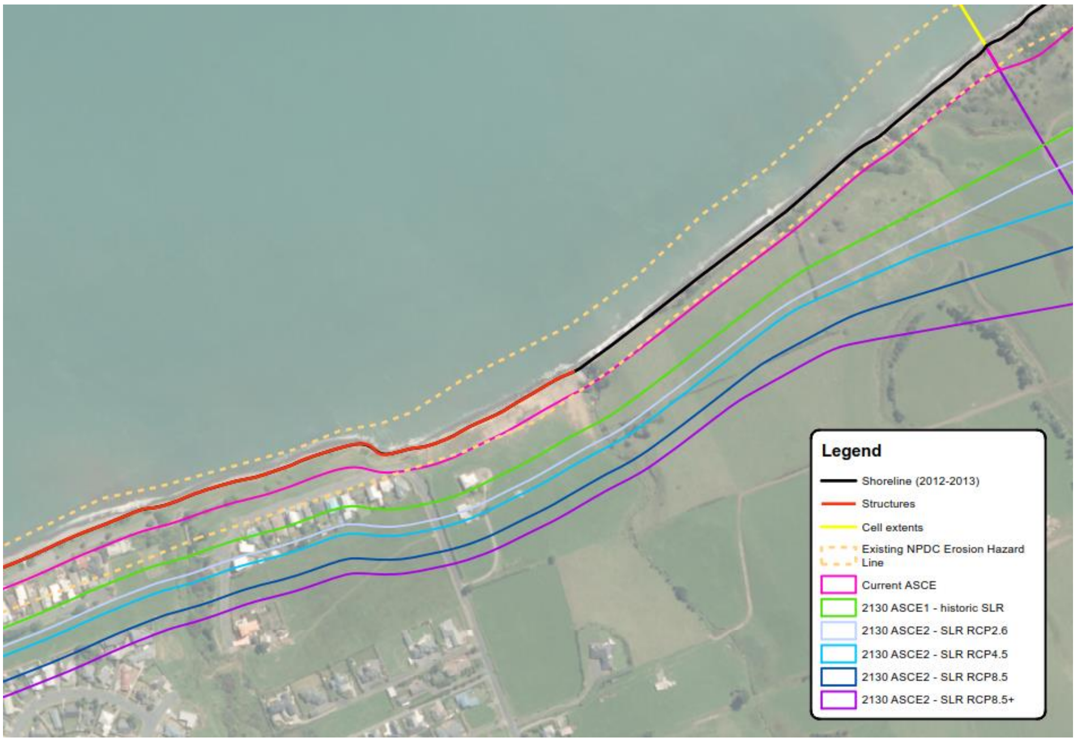


*Figure 5-2 Example of ASCE lines for cliff coastline at Bell Block compared to the existing NPDC Erosion Hazard line.*

# 6 Identification of high risk areas

## 6.1 Introduction

A preliminary screening exercise has been undertaken in conjunction with council to identify what is contained within areas identified as being susceptible to coastal erosion. This screening exercise has been undertaken to assist in prioritising areas which may be most exposed to adverse effects and for which more detailed *"second-pass"* assessments be recommended for.

The following risk assessment considers the risk of coastal erosion for four different elements; economic, social, cultural and environmental (Table 6- 1). Economic risk includes all transport infrastructure, water infrastructure and tourism facilities. Indicators of social risk include the number of residential dwellings, recreational facilities, schools, community and medical centres. Cultural risk considers the number of marae, churches, archaeological and heritage sites, and environmental risk includes national/regional parks, conservation areas, natural coastal defences, marine biodiversity inventory, and areas with outstanding natural landscapes or outstanding coastal natural character. Data sources have included NPDC GIS (maps.npdc.govt.nz), NPDC Coastal Reserves (NPDC, 2015) and Google Maps.

The risk assessment involved identifying which indicators are affected within each cell, and to what extent, by the current and future ASCE.

**Table 6- 1 Elements and indicators used for coastal erosion risk assessment**

| Element | Indicator | Description | Source |
|---|---|---|---|
| Economic | Transport infrastructure | State highways, local roads, airport, port, railway | NPDC GIS |
| | Water infrastructure | Storm water pipes, waste water pipes and treatment plants | NPDC GIS |
| | Tourism facilities | Camp grounds, holiday parks | Google Maps |
| | Business/industry | Shops, cafes, businesses, farm land | NPDC GIS + Google Maps |
| Social | Resident population/dwellings | Houses, residential property | Google Maps (aerial image) |
| | Recreational facilities | Parks, playgrounds, footpath/walkways, reserve, golf course, swimming pools, skate parks | NPDC GIS + Google Maps (aerial image) + NPDC Coastal Reserves |
| | Schools | Schools, kindergartens, day care | Google Maps |
| | Community Centres | Town halls, Surf lifesaving clubs, board riders clubs, yacht/boat clubs | Google Maps |
| | Medical centres | Hospitals, medical centres | Google Maps |
| Environmental | Marine biodiversity inventory | | NPDC GIS |
| | National/Regional Park | | Google Maps |
| | Conservation Area | | NPDC GIS |
| | Natural coastal defences | Sand dunes | Google Maps (aerial image) |
| | Outstanding natural landscapes and character | | NPDC GIS |

| Element | Indicator | Description | Source |
|---|---|---|---|
| Cultural | Archaeological sites | Waihi Taapu sites | NPDC GIS |
| | Heritage sites | | NPDC GIS |
| | Churches | | Google Maps |
| | Marae | | Google Maps |

## 6.2 Value indicators

### 6.2.1 Economic

**Transport infrastructure:**

One section of State Highway 3 (Mokau Road), between Rapanui and Mohakatino is at risk to future coastal erosion. In addition to SH3 there are several local roads that are at risk to both current and future coastal erosion. These include Tasman Parade (Oakura), Belt Road, Woolcombe Terrace, Mangati Road (Bell Block), East Beach Road (Waitara) and Onaero Beach Road.

The number of local roads at risk to coastal erosion increases for future timeframes and SLR scenarios. For example, in North Messenger Terrace the $ASCE_1$ only includes Messenger Terrace. Whereas when SLR scenarios are accounted for ($ASCE_2$) the seaward end of McFarlane Street and Dixion Street also identified at risk.

For the areas at risk to future coastal erosion ($ASCE_2$), the extent of the transport infrastructure at risk is dependent on the RCP SLR scenario.

Areas where local roads are at risk within the RCP8.5 $ASCE_2$ include:

- Oakura (almost all of Messenger Terrace).
- New Plymouth City (Belt Rd, Kawaroa Lane, Kawaroa Close, Bulkeley Terrace, Tisch Avenue, Hine Street, Dawson St, Regina Place, St Aubyn Street, Molesworth Street, Buller Street, Octavius Place, Nobs Line, Beach Street).
- Bell Block (all of Wanaka Terrace and most of Tiromoana Crescent).
- Waitara (Battiscombe Terrace, West Beach Road, Browne Street Extension, Howard Street and Mouatt Street).Onaero (half of Sutton Road and Onaero Beach Road).
- Urenui Bay (all of the avenues within the Urenui Domain are at risk from future coastal erosion.

The end of the runway at New Plymouth airport is also within the RCP8.5 $ASCE_{2.}$

**Water infrastructure:**

The three main water infrastructure features that are at risk from coastal erosion are storm water, waste water and water supply pipe networks. Water infrastructure that is most at risk to future coastal erosion is predominately within Oakura, New Plymouth City (from Belt Road to Fitzroy), Bell Block, Waitara, Onaero and Urenui.

Along the coast from Waiiti to Mokau there is also small sections of the energy pipeline within the Future ASCE2.

For the areas at risk to future coastal erosion (Future $ASCE_2$), the extent of the water infrastructure at risk is dependent on the RCP SLR scenario.

**Tourism facilities:**

Between Oakura and Waiiti Beach there are several campgrounds and holiday parks at risk to coastal erosion. The campground in Oakura and Urenui are at risk from both current and future coastal erosion, while the campgrounds at Belt Road, Fitzroy and Waiiti are only at risk to future coastal erosion. The entire campground on Belt Road and at Waiiti are at risk to future erosion, even without SLR ($ASCE_1$). For the Oakura and Fitzroy campgrounds only part of the facilities are within the $ASCE_1$, however almost the entire facility is within the RCP8.5 $ASCE_2$.

The visitor centre within New Plymouth City is another tourism facility that is within the RCP8.5$ASCE_2$.

**Business/industry:**

The main business at risk to future coastal erosion are around those within New Plymouth City, including those at the north end of Dawson Street, several along St Aubyn Street and the western end of Molesworth Street. Most of the businesses within New Plymouth City are only at risk to future coastal erosion and the number of business at risk increases with increasing SLR scenarios. A café within Waiiti is another small business that is at risk from future coastal erosion.

North from New Plymouth are multiple sections of farm land that are at risk from both current and future coastal erosion. The regions with greatest areas of farmland affected are from Urenui to Waiiti and Rapanui to Mohakatino. The area of farm land at risk is significantly more for future erosion compared to the current erosion risk and the extent of farmland at risk increases with increasing SLR scenarios

The Methanex New Zealand plant, east from Waitara, is another industry that is at risk of coastal erosion with future SLR.

### 6.2.2 Social

**Resident dwellings:**

The main region with residential dwellings at risk to current coastal erosion is Oakura, with over 20 dwellings on the seaward side of Messenger Terrace partially within the current ASCE. Onaero is another region with several residential dwellings located within the current ASCE. Other areas that have approximately 10 or less residential dwellings at risk to current coastal erosion include Bell Block and Waitara East.

The number of residential dwellings at risk to coastal erosion increases for future timeframes. There are several areas where there are no dwellings within the current ASCE but over 20 dwellings within the Future $ASCE_2$. These areas include around Belt Road, Kawaroa Park and Woolcombe Terrace if the seawall were to fail or be removed. Other regions with dwellings at risk of future coastal erosion are Puritutu, Fitzroy and Waitara West. There is also several rural dwellings between Urenui and Whitecliffs within the Future $ASCE_2$. There are several areas where the future $ASCE_2$ shows large variation dependant on the RCP SLR scenario. In some of these locations the number of residential dwellings at risk to future coastal erosion varies dependant on the RCP scenario. These locations include Belt Road, Kawaroa Park, Woolcombe Terrace, Fitzroy and Oakura. The number of dwellings at risk along Hume St (Waitara West/Brown Road) is also largely dependent on the RCP SLR scenario.

**Recreational facilities/parks:**

The New Plymouth Coastal Walkway is one of the main recreational facilities at risk from both current and future coastal erosion if the seawall were to fail or be removed. South from Oakura there are several coastal reserves within both the current and future ASCE. Within Oakura, Shearer's Park is not at risk to current coastal erosion and is only just within the future $ASCE_{1.}$ However, when accounting for future SLR ($ASCE_2$) the skate park, carpark and toilets are at risk.

Significant portions of Corbett Park, Paritutu Centennial Park and Ngamotu Beach Reserve, including the carparks and toilet blocks are at risk to both current and future coastal erosion. Around Kawaroa Park the current coastal erosion risk is only for the seaward edge of the reserve (along the New Plymouth Coastal Walkway) but the future erosion risk includes facilities such as the tennis/squash club and the swimming pool complex if the seawall were to fail or be removed.

Mount Bryan Reserve is another recreational facility at risk, with the edge of the reserve in the current ASCE and the entire reserve within the future $ASCE_2$. Similarly, at East End the current ASCE only includes the dunes but the future $ASCE_1$ extends back to the reserve and includes the carpark. When accounting for future SLR ($ASCE_2$) the skatepark is also at risk. The coastal reserves at both Fitzroy and Waitara are within both the current and future ASCE. More than half of the Waitara Golf Course area is within the future $ASCE_2$.

Both Onaero and Urenui are other locations where there is a significant amount of recreational reserve at risk to coastal erosion.

**Schools:**

No schools were identified within the areas susceptible to coastal erosion.

**Community centres:**

There are four community centres that are at high risk to both current and future coastal erosion. These centres include the Oakura Board Riders Club, The New Plymouth Yacht Club, the Fitzroy Surf Life Saving Club and the club building at Corbett Park, Oakura. The East End surf club is also on the edge of the current ASCE and the entire building is within the future $ASCE_2$. The RSA on Octavius Place and the boating club in Waitara are two community centres that are only at risk future coastal erosion.

**Medical centres:**

No medical centres were identified within the areas susceptible to coastal erosion.

### 6.2.3 Cultural

**Archaeological sites:**

Waahi Tapu identifies areas, places or sites that are significant to Maori. Coastal cells with over 5 Waahi Tapu identified within the future $ASCE_2$ are Oakura to Paritutu, Motunui Cliffs, Onaero West, Mimi to Waiiti, Waiiti to White Cliffs and Rapanui to Mohakatino. No further information was available on what the Waahi Tapu sites specifically are.

**Heritage sites:**

The most heritage sites at risk to future coastal erosion are within the Kawaroa Park coastal cell. The heritage sites include several heritage houses, Kawaroa Park Howitzer, Kawaroa Pool and Mosaic Wall, Honeyfield Drinking Foundation, Richmond Estate, Taranaki Club Building, St Aubyn Chambers, Cenotaph, Stone Wall and Stone Seats. The Taranaki Club Building and the St Aubyn Chambers are considered to have very great cultural heritage value. These would only be affected if the coastal seawall were to fail or be removed.

Other heritage sites at risk to future coastal erosion include the Oakura Board Riders Club, New Plymouth Yacht Club, Beam Oil Pump (Ngamotu Beach), the Te Henui Railway Bridge, East End Reserve Gates and the Waitara Boating Club. There are also several heritage houses around Belt Road that are within the future $ASCE_2$.

Further north from New Plymouth City there are two heritage sites at risk to coastal erosion. One site is the Wilkinson's Castle (between Waiiti and Whitecliffs) which is at risk to both current and future coastal erosion. The Wilkinson's Castle is considered to have very great cultural heritage value. The other site at risk to future coastal erosion is the Whiteley Memorial.

**Churches:**

No churches were identified within the areas susceptible to coastal erosion.

**Marae:**

No marae were identified within the areas susceptible to coastal erosion.

### 6.2.4 Environmental

**Marine biodiversity inventory:**

No marine biodiversity inventory was identified within the areas susceptible to coastal erosion.

**National/Regional Parks:**

No national or regional parks were identified within the areas susceptible to coastal erosion.

**Conservation area:**

No conservation areas were identified within the areas susceptible to coastal erosion.

**Natural coastal defences:**

The main natural coastal defences that are at risk to coastal erosion are the dunes at Oakura, East End, Fitzroy, Bell Block and Waitara. Erosion of these natural coastal defences could increase the risk of coastal erosion for the areas landward from the defences.

**Outstanding Natural Landscapes and features:**

There are several Outstanding Natural Landscapes and Features that are at risk to current and future coastal erosion. Four of the landscapes are around river mouths including the Mimi River mouth, Urenui River mouth, Onaero River mouth and the Waiongana Stream Inlet. The Whitecliffs and The Tree Sisters are also Outstanding Natural Features within the current and future ASCE.

## 6.3 Qualitative risk assessment

The following qualitative risk assessment involved ascribing a risk level to each of the indicators, based on the quantity and/or value of the indicator within the area susceptible to erosion for each coastal cell. A description of each risk level is outlined in Table 6-2 .

**Table 6-2 Description of the risk level utilised in the qualitative risk assessment**

| Risk | Description |
|---|---|
| High | High value or quantity of indicator within area susceptible to coastal erosion |
| Medium | Moderate value or quantity of indicator within area susceptible to coastal erosion |
| Low | Low value or quantity of indicator within area susceptible to coastal erosion |
| Zero | Indicator not within area susceptible to coastal erosion |

Overall the coastal erosion risk is greatest for economic and social indicators, in particular for infrastructure (transport and water), resident dwellings and recreational facilities. Cultural risk is mostly associated with future coastal erosion risk of heritage sites, which are at most risk within New Plymouth City (Kawaora Park). Environmental risk is mostly associated with the Outstanding Natural Landscapes and Features and these are at most risk north from Bell Block.

The current coastal erosion risk is greatest within Oakura and Waitara. Both areas have a significant number of residential dwellings, roads and water infrastructure within the current ASCE. In both locations the risk to these indicators also increases for the future erosion scenarios. The areas with the highest risk for future coastal erosion are within New Plymouth City (Belt Road, Kawaroa Park, Puke Ariki and Woolcombe Terrace). There is almost no current coastal erosion hazard within these coastal cells due to the presence of the sea wall. However, if the sea wall was to fail the risk profile would be significantly different in the future, with many roads, water pipes, businesses, heritage sites, over 20 resident dwellings and all of the New Plymouth Coastal Walkway reserve at risk. The risk profile is high for both future scenarios, with and without sea level rise (SLR) accounted for.

Other regions with high risk of future coastal erosion include Fitzroy, Bell Block, Waitara, Onaero and Urenui. For most of these regions the level of overall risk is not significantly different between the future $ASCE_1$ scenario (without SLR) and the future $ASCE_2$ scenario (with SLR). Although within Fitzroy the future $ASCE_1$ risk does not include any residential dwellings and only a small portion of the holiday park but the risk is significantly increased when SLR is included, with over 10 residential dwellings and all of the holiday park within the future $ASCE_2$.

# 7 Summary and recommendations

The New Plymouth District Council (NPDC) coastline is almost 100 km long and extends from just south of the Stony River almost to Mokau in the North. This coast comprises approximately 71 km of cliff (consolidated) shoreline and 29 km of unconsolidated (beach) shoreline New Plymouth District Council is currently reviewing its District Plan which needs to be prepared in accordance with the New Zealand Coastal Policy Statement (NZCPS), so areas at risk of coastal hazards need to be identified. The erosion hazard provisions in the Operative District Plan are some 30 years old and since that time the shoreline position has migrated inland, understanding of processes has advanced, data availability has increased, and official guidance including the need to predict the effects of future climate change scenarios must be incorporated.

Tonkin + Taylor (T+T) were commissioned by NPDC to undertake a “first pass” coastal erosion assessment to identify areas potentially susceptible to coastal erosion along the district’s coastline. Output consists of three lines which define the following:

- the current area susceptible to coastal erosion (Current ASCE),
- the future (2130) area susceptible to coastal erosion excluding the effects of projected sea-level rise (Future $ASCE_1$), and
- the future (2130) area susceptible to coastal erosion including the effect of future projected sea-level rise (Future $ASCE_2$).

For shorelines protected by coastal protection structures, the area susceptible to erosion has been assessed excluding the effects of the structure. This is undertaken as information on the condition of the structure is not available and to provide an indication of the assets protected by the structure.

A first pass coastal erosion assessment should be undertaken at a “high level” which means a large area (typically a district or region) is covered with the coast then being divided into reaches with similar characteristics and a high-end value selected for each component within each reach. The resulting ASCE values are therefore expected to be conservative and this approach is consistent with NZCPS (2010) Policy 24 which requires: the identification of areas that are potentially affected by coastal erosion hazards giving priority to high risk areas.

The present first pass assessment for unconsolidated (beach/dune) shorelines shows the current ASCE ranges between 7 and 53 m (mean of 31 m) with the highest values occurring along the central coast. Future $ASCE_1$ widths (excludes sea-level rise) range between 17 and 174 m (mean of 72 m) with minimum values along the south coast and higher values along the central/north coast with particular focus about Waitara. Once the effects of SLR projections are incorporated the $ASCE_2$ range increases to between 23 and 200 m (mean of 90 m) and again the lowest values are in the south and highest values along the Waitara coast.

The first-pass assessment for consolidated (cliffed) shorelines shows the current ASCE ranges from 7 m along south Messenger Terrace, up to 69 m along the coast north of Waiiti and a local increase to 238 m at Whitecliffs. The much larger Whitecliffs value results from the substantial increase in elevation compared with the rest of the coast. Future $ASCE_1$ widths range between 18 m along Messenger Terrace, (Oakura), up to 168 m along the highly unstable airport cliffs and increasing locally to 306 m at Whitecliffs. Incorporating the effects of projected SLR, the future $ASCE_2$ range increases to 34 m at south Messenger Terrace, up to 340 m at the airport and up to 342 m at the Whitecliffs.

It is likely that the actual future area susceptible to erosion hazard will be located somewhere between the future $ASCE_1$ and $ASCE_2$ depending on the actual sea level rise that occurs in the future and coastal response to that SLR.

A preliminary screening exercise has been undertaken to identify what is contained within areas identified as being susceptible to coastal erosion. This screening exercise has been undertaken to assist in prioritising areas which may be most exposed to adverse effects and for which more detailed "*second-pass*" assessments should be completed. Four main elements were assessed including economic, social, cultural and environmental elements with a range of specific indicators used for each. Results showed that the coastal cells with the highest economic and social risk are:

- Oakura where several multiple dwellings, roading and water infrastructure are potentially susceptible to erosion at the current timeframes, increasing in the future.
- Fitzroy where the coastal walkway, surf club, sand dunes and part of the holiday park are currently at risk increasing to include residential properties and additional water and roading infrastructure in the future.
- Bell block where a seawall currently provides some protection but residential dwellings and roading infrastructure may be at risk in the future
- Waitara East and West where residential dwellings, roading and water infrastructure and parts of Marine Park at currently at risk, increasing in the future.
- Motunui where the Methanex plant may be at risk to future erosion hazard
- Onaero residential dwellings, roading and water infrastructure and parts of Marine Park at currently at risk, increasing in the future
- Urenui where roading infrastructure, parts of the holiday park and the golf course (if the seawall were to fail) are currently at risk, increasing in the future.

Second pass assessments are recommended for these sites. These more detailed assessments would further analyse available data at a higher resolution to more thoroughly understand the likelihood of hazard occurrence, uncertainties and the effects of different future sea level rise scenarios. These assessments will assist stakeholders in understanding the consequence and risk posed by the hazard and as a basis for decision-making in the land use and adaptation planning processes.

Additionally, the Belt Road to East End extent would be susceptible to erosion if the current seawall were to fail or be removed exposing a large amount of transport and water infrastructure, residential dwellings, business, parks and heritage areas to hazard. While additional analysis of the potential hazard is unlikely to be justified while the seawall remains effective, this susceptibility should be considered in the future when making decisions on maintenance and upgrade. Additional analysis could be undertaken at that time to provide more certainty around risk.

We also recommend that a programme of beach profile data collection is established with partners to better understand short- and long-term trends along the New Plymouth coastline, particularly the unconsolidated coastlines (beaches) at Oakura, Fitzroy, Waitara and Urenui. These have traditionally been undertaken using topographic survey but the use of UAV could be investigated as a more cost effective method. LiDAR would assist in the more detailed assessment and aerial photography should be continued at regular intervals.

This study has assessed areas susceptible to coastal erosion at district-wide scale and may be superseded by local site-specific assessment undertaken by qualified and experienced practitioner using improved or higher resolution data than presented in this report. This could include site specific geotechnical information to confirm stable angles of repose, better topographic data as well as site specific consideration and analysis of erosion rates.

# 8 Applicability

This report has been prepared for the exclusive use of our client, the New Plymouth District Council, with respect to a specific Terms of Reference, and T+T does not accept responsibility for its use for any other purpose without written agreement.

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# Appendix A Selected photographs

These oblique aerial photographs we taken by the TRC on 5 May 2012. The selection illustrates significant coastal types referred to in the assessment.

*Photograph 1. Stony River mouth with gravel delta fronting a mixed sand-gravel upper beach backed by sand dunes. The stony river is a significant source of coastal sediment. A lagoon on the far side of the river is evidence of a past phase of rapid accretion and the wide backshore (littered with driftwood) is a consequence of the 1998 sediment pulse impacting the shoreline and then wind-blown sand burying landward vegetation.*

*Photograph 2.Greenwood Road between the Stony River and Oakura. Stable coast comprising a "ribbon beach" with sandy upper beach and gravel lower beach-reef and backed by sand dunes, swamp and relict sea cliff.*

*Photograph 3. Central Oakura Beach. One of only two sandy beaches in the New Plymouth district. The beach sand mantles a wave cut platform. Landward of this relatively stable shoreline is a narrow band of sand dune then laha material with the remnant Kaitai volcano in the background.*

*Photograph 4. Waireka shoreline between Oakura and Paritutu. These cliffs reach 45 m and are cut into laha deposits. The cliff is fronted by inter-tidal sand and gravels with gravel reefs to seaward. The shoreline is slowly retreating at up to 0.24 m/yr; however, sections are also stable as indicated by the vegetation in the centre right. Mount Egmont in the distance and Pouakai in the middle distance.*

*Photograph 5. Airport cliffs. These cliffs reach 24 m in height and are retreating up to 1.1 m/yr. The cliffs are fronted by a wave cut platform and sand-gravel inter-tidal beach with offshore reefs in places. These cliffs are cut into lahar deposits and in places are capped by sand dunes.*

*Photograph 6. East Beach, Waitara. This gravel-sand beach is fronted by the Waitara River mouth delta in the distance and Airedale reef in the foreground – remnants of the laha deposits. The shoreline is eroding at up to 1.1 m/yr and sand dunes occur to landward.*

*Photograph 7. Urenui Beach on right and papa (silt stone and fine sandstone) cliffs capped with terrestrial cover beds centre and left. Such terraces extend east to Whitecliffs. This shoreline is retreating at up to 0.58 m/yr. Urenui Beach is a pocket beach that is now protected by a boulder revetment and fronted by a sand-gravel foreshore. The cliffs are up to 28 m high, have a mid-tide sand intersect, and the embayed/stacks morphology infers substantial jointing and fracture of the lower strata.*

*8. Whitecliffs and terrace of papa and cover beds which characterises the coast north. Whitecliffs range up to 200 m high and the terraced coast up to 44 m. The shoreline is eroding at up to -0.58 m/yr and the sand intersection occurs at or below the high tide level.*

# Appendix B Parameter measurements

| Location name | Distance (km) | Sampling sources | Morphological Type | Lithological Type | Rate (m/yr) | | Standard error (SEE) | Profile slope (tanB) | Dune height(m) (veg base to 60 inland) | Cliff height (m) | Stable cliff angle (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | End point | Regression | | | | | |
| Stony River south | 0.3 | TCC #1 | Gravel beach | Unconsolidated | | | | 0.080 | | | |
| Stony River | 0.3-2.8 | CRM #1 | Gravel beach | Unconsolidated | 0.06 | 0.02 | 5.9 | | | | |
| Kahihi Road | 5 | TCC #5 | Gravel beach | Unconsolidated | | | | 0.150 | | | |
| Leith Road | 7.8 | Gibb #146 | Gravel beach | Unconsolidated | 0 | | | | | | |
| Pitone Road | 10.1 | TCC #7 | Gravel beach | Unconsolidated | | | | 0.100 | | | |
| Weld Road | 13.2 | TCC #8 | Gravel beach | Unconsolidated | | | | 0.080 | | | |
| Ahu Ahu Bay | 13.4 | TCC #9 | Sand-gravel beach | Unconsolidated | | | | 0.060 | | | |
| South Oakura | 13.7-14.4 | NPDC 0.5m | Sand-gravel beach | Unconsolidated | | | | | 6.5 | | |
| Ahu Ahu Road | 13.8 | Gibb #147 | Sand-gravel beach | Unconsolidated | 0.21 | | | | | | |
| Central Oakura | 14.2-15 | CRM #2 | Sand beach | Unconsolidated | 0.2 | 0.12 | 4.6 | | | | |
| Central Oakura | 14.4-15.1 | NPDC 0.5m | Sand beach | Unconsolidated | | | | | 6.5 | | |
| Central Oakura | 14.6 | TCC #10 | Sand beach | Unconsolidated | | | | 0.050 | | | |
| Central Oakura | 14.6-14.9 | NZ443/NPDC 0.5m | Sand beach | Unconsolidated | | | | 0.020 | | | |
| Central Oakura | 14.9 | TCC #12 | Sand beach | Unconsolidated | | | | 0.030 | | | |
| Messenger Tce | 15.1-15.9 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 19 | 36 |
| Messenger Tce | 15.1-15.4 | CRM #2 | Laha cliff | Consolidated | 0 | | | | | | |
| Messenger Tce | 15.4-15.9 | CRM #2 | Laha cliff | Consolidated | -0.22 | | | | | | |
| Oakura-Paritutu | 15.9-24.4 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 45 | 36 |
| Waireka | 20.2-22.1 | CRM #3 | Laha cliff | Consolidated | -0.23 | | | | | | |
| Centennial Drive | 22.1-24.4 | CRM #4 | Laha cliff | Consolidated | -0.24 | | | | | | |
| City | 27.3-29.4 | CRM #5 | Laha cliff | Consolidated | -0.64 | | | | | | |
| East End | 29.4-30.7 | CRM #6 | Laha cliff | Consolidated | -0.56 | | | | | | |
| Fitzroy | 30.7-31.6 | CRM #6 | Sand beach | Unconsolidated | -0.11 | -0.14 | 5.7 | | | | |
| Fitzroy | 30.7-31.6 | NZ443/NPDC 0.5m | Sand beach | Unconsolidated | | | | 0.020 | | | |
| Fitzroy | 30.7-32.2 | NPDC 0.5m | Sand beach | Unconsolidated | | | | | 9 | | |
| Fitzroy | 31.2 | TCC #17 | Sand beach | Unconsolidated | | | | 0.040 | | | |
| Fitzroy | 31.6-33.8 | CRM #7 | Sand-gravel beach | Unconsolidated | -0.18 | -0.19 | 2.4 | | | | |
| Fitzroy | 31.8 | TCC #18 | Sand beach | Unconsolidated | | | | 0.030 | | | |
| Waiwhako Golf | 32.2-33.7 | NPDC 0.5m | Gravel beach | Unconsolidated | | | | | 10.5 | | |
| Bell Block west | 33.7-36.5 | NPDC 0.5m | Gravel beach | Unconsolidated | | | | | 13.5 | | |
| Bell Block west | 36 | Gibb #157 | Gravel beach | Unconsolidated | -0.42 | | | | | | |
| Bell Block west | 36.3-36.6 | CRM #8 | Gravel beach | Unconsolidated | -0.22 | -0.35 | 10.6 | | | | |
| Bell Block | 36.6-37.9 | CRM #8 | Laha cliff | Consolidated | -0.35 | | | | | | |
| Bell Block | 36.6-38 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 13 | |
| Bell Block | 36.9 | TCC #20 | Laha cliff | Consolidated | | | | 0.070 | | | |
| Bell Block east | 37.9-38.5 | CRM #8 | Laha cliff | Consolidated | -0.71 | | | | | | |
| Airport | 38-40.5 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 24 | |
| Airport | 38.5-40.5 | CRM #9 | Laha cliff | Consolidated | -1.1 | | | | | | |
| Waiongana west | 40.5-41.7 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 9 | |
| Waiongana bay | 40.9-41.7 | NPDC 0.5m | Gravel beach | Unconsolidated | | | | | 6.3 | | |
| Browns Road | 41.7-44.1 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 9.2 | 31 |
| West Waitara | 42.6-44.6 | CRM #10 | Gravel beach | Unconsolidated | -0.75 | -0.46 | 10.1 | | | | |
| West Waitara | 44.1-45.1 | NPDC 0.5m | Gravel beach | Unconsolidated | | | | | 4.5 | | |

| Location name | Distance (km) | Sampling sources | Morphological Type | Lithological Type | Rate (m/yr) | | Standard error (SEE) | Profile slope (tanB) | Dune height(m) (veg base to 60 inland) | Cliff height (m) | Stable cliff angle (degrees) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | End point | Regression | | | | | |
| East Waitara | 44.6-46.7 | CRM #11 | Gravel beach | Unconsolidated | -1.1 | -1.04 | 15.2 | | | | |
| West Waitara | 44.7 | TCC #21 | Gravel beach | Unconsolidated | | | | 0.060 | | | |
| East Waitara | 45.1-46.7 | NPDC 0.5m | Gravel beach | Unconsolidated | | | | | 9.5 | | |
| East Waitara | 45.5 | TCC #32 | Gravel beach | Unconsolidated | | | | 0.050 | | | |
| Waitara Golf | 46.7-47.0 | CRM #11 | Laha cliff | Consolidated | -1.18 | | | | | | |
| Waitara Golf | 46.7-47.0 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 13 | |
| Motunui west bay | 47-48.3 | TRC 2012 | Gravel beach | Unconsolidated | | | | | 4.5 | | |
| Motunui | 48.3-51.1 | NPDC 0.5m | Laha cliff | Consolidated | | | | | | 19 | 31 |
| Motunui east bay | 51.1-52.5 | TRC 2012 | Gravel beach | Unconsolidated | | | | | 6.5 | | |
| Otaraoa Road | 49 | Gibb #163 | Laha cliff | Consolidated | -0.43 | | | | | | |
| Epiha/Turangi Rd | 52 | TCC #C | Gravel beach | Unconsolidated | | | | 0.100 | | | |
| Buchanan's Bay | 53.7 | TCC #F | Gravel beach | Unconsolidated | | | | 0.100 | | | |
| Onaero west | 56-57.4 | CRM #12 | Papa cliff | Consolidated | -0.44 | | | | | | |
| Onaero west | 56-57.4 | NPDC 0.5m | Papa cliff | Consolidated | | | | | | 23 | 41 |
| Onaero east | 57.4-58.3 | CRM #12 | Papa cliff | Consolidated | -0.53 | | | | | | |
| Urenui west | 58.3-59.6 | CRM #13 | Papa cliff | Consolidated | -0.56 | | | | | | |
| Urenui west | 59.3-59.6 | NPDC 0.5m | Papa cliff | Consolidated | | | | | | 28 | |
| Urenui bay | 59.6-60.2 | CRM #13 | Gravel beach | Unconsolidated | -0.58 | -0.33 | 8.4 | | | | |
| Urenui bay | 59.6-60.2 | NPDC 0.5m | Gravel beach | Unconsolidated | | | | | 5 | | |
| Urenui bay | 60 | TCC #26 | Gravel beach | Unconsolidated | | | | 0.090 | | | |
| Urenui to Mimi | 60.2-63.8 | NPDC 10m | Papa cliff | Consolidated | | | | | | 28 | |
| Urenui to Mimi | 61.7 | Gibb #169 | Papa cliff | Consolidated | 0 | | | | | | |
| Urenui to Mimi | 62.4 | Gibb #170 | Papa cliff | Consolidated | -0.23 | | | | | | |
| Urenui to Mimi | 63.2 | Gibb #171 | Papa cliff | Consolidated | -0.16 | | | | | | |
| Mimi bay | 63.8-65 | NPDC 10m | Papa cliff | Consolidated | | | | | | 10 | |
| Mimi | 64-65.8 | CRM #14 | Papa cliff | Consolidated | -0.32 | | | | | | |
| Mimi to Waiiti | 65-69.8 | NPDC 10m | Papa cliff | Consolidated | | | | | | 48 | |
| Waiiti bay | 69.8-70.3 | NPDC 10m | Papa cliff | Consolidated | | | | | | 15 | |
| Waiiti to Whitecliffs | 70.3-76.3 | NPDC 10m | Papa cliff | Consolidated | | | | | | 58 | |
| Waiiti north | 73 | Gibb #175 | Papa cliff | Consolidated | -0.29 | | | | | | |
| Pariokariwa Bay | 75.8 | Gibb #177 | Papa cliff | Consolidated | -0.38 | | | | | | |
| Whitecliffs | 76.3-79.7 | NPDC 10m | Papa Cliff | Consolidated | | | | | | 200 | 38 |
| Whitecliffs to Tonga | 79.7 to 85.9 | NPDC 10m | Papa Cliff | Consolidated | | | | | | 44 | |
| Waikiekie | 82.2-84.7 | CRM #15 | Papa cliff | Consolidated | -0.58 | | | | | | |
| Tongaporutu | 84.7-86.4 | CRM #16 | Papa cliff/Inlet | Consolidated | -0.29 | | | | | | |
| Tonga-Rapanui | 85.9-87.7 | NPDC 10m | Papa Cliff | Consolidated | | | | | | 36 | |
| Rapanui-Mohakatino | 87.7-95.1 | NPDC 10m | Papa Cliff | Consolidated | | | | | | 21 | |
| Rapanui | 87.8 | Gibb #180 | Papa cliff | Consolidated | -0.11 | | | | | | |
| Mohakatino south | 94 | Gibb #181 | Papa cliff | Consolidated | -0.5 | | | | | | |
| Mohakatino river | 94.9 | Gibb #182 | Papa cliff | Consolidated | -0.09 | | | | | | |
| Mohakatino to Mahaka | 95.1-98.2 | NPDC 10m | Papa Cliff | Consolidated | | | | | | 36 | |

Where

TCC: Taranaki Catchment Commission profiles 1979 to 1982

CRM: Coastal Resource Maps

NPDC 0.5m: New Plymouth District Council 0.5 m countour data 2013 (urban and settlements only)

NPDC 10m: New0 Plymouth District Councicl 10 m contour data 2007 (entire district)

Gibb: rates of change from Gibb (1978) for sites outside the CRM areas

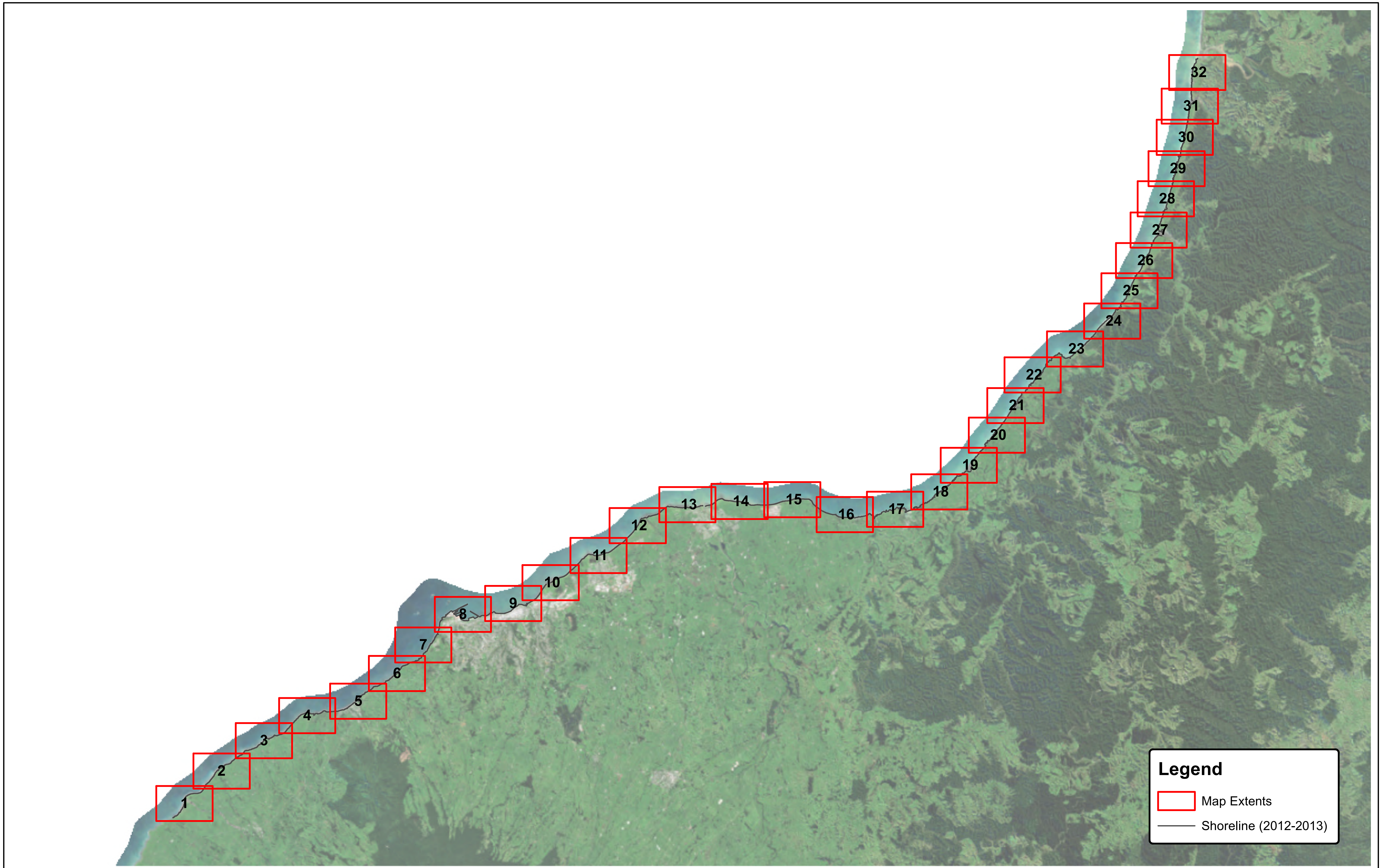
TDC 2012: oblique aerial photo series. Relative change.

# Appendix C ASCE values

| Cell No. | Name | Chainage (km) | Morphological Type | Lithological Type | State | ST (m) | LT (m) | Stable Slope (°) | Height (m) | SLRF | Closure Slope | ASCE | ASCE$_1$ | ASCE$_2$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 2030 - Current (m) | 2130 - No SLR (m) | 2130 - RCP2.6 (m) | 2130 - RCP4.5 (m) | 2130 - RCP8.5 (m) | 2130 - RCP8.5H+ (m) |
| 1 | Stony R - Weld R | 0 to 13.2 | Gravel beach | Unconsolidated | Natural | -18 | 0 | 33 | 6.5 | | 0.08 | -28 | -28 | -33 | -34 | -40 | -44 |
| 2 | Ahu Ahu - Oakura Campground | 13.2 to 14.4 | Sand-gravel beach | Unconsolidated | Natural | -18 | 0 | 33 | 6.5 | | 0.06 | -28 | -28 | -34 | -36 | -44 | -49 |
| 3 | Oakura Campground to Surf Club | 14.4 to 15.1 | Sand beach | Unconsolidated | Natural | -18 | 0 | 33 | 6.5 | | 0.02 | -28 | -28 | -46 | -53 | -75 | -92 |
| 4 | Sth Messanger Tce | 15.1 to 15.6 | Laha cliff | Consolidated | Seawall | 0 | -10 | 36 | 5-9 | 0.5 | | -7 | -18 | -28 | -29 | -34 | -36 |
| 5 | Nth Messanger Tce | 15.6 to 15.9 | Laha cliff | Consolidated | Seawall | 0 | -22 | 36 | 15-19 | 0.5 | | -21 | -46 | -60 | -64 | -73 | -79 |
| 6 | Oakura-Paritutu | 15.9 to 24.4 | Laha cliff | Consolidated | Natural | 0 | -24 | 36 | 45 | 0.5 | | -62 | -90 | -102 | -110 | -127 | -138 |
| 7a | Port - West | 24.4 to 25.9 | Reclamation | Unconsolidated | Seawall | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 7b | Ngamotu Beach | 25.9 to 26.3 | Harbour beach | Unconsolidated | Natural | -10 | 0 | 33 | 4.5 | | 0.06 | -17 | -17 | -23 | -25 | -33 | -38 |
| 7c | Port-East | 26.3 to 26.8 | Reclamation | Unconsolidated | Seawall | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| 8a | Belt Rd | 26.8 to 27.7 | Marine Terrace | Consolidated | Seawall | 0 | -50 | 36 | 16 | 0.5 | | -22 | -80 | -106 | -121 | -158 | -181 |
| 8b | Kawaroa Park | 27.7 to 28.3 | Marine Terrace | Consolidated | Seawall | 0 | -50 | 36 | 9 | 0.5 | | -12 | -70 | -97 | -112 | -149 | -172 |
| 8c | Puke Ariki | 28.3 to 29.0 | Marine deposits | Unconsolidated | Seawall | 0 | -50 | 33 | 4.5 | | 0.03 | -7 | -65 | -77 | -82 | -96 | -108 |
| 8d | Woolcombe Tce | 29.0 to 30.0 | Marine Terrace | Consolidated | Seawall | 0 | -50 | 36 | 18 | 0.5 | | -25 | -83 | -109 | -124 | -161 | -184 |
| 8e | East End | 30.0 to 30.7 | Marine deposits | Unconsolidated | Seawall | 0 | -14 | 33 | 4.5 | | 0.03 | -7 | -23 | -35 | -40 | -55 | -66 |
| 9 | Fitzroy | 30.7 to 32.2 | Sand beach | Unconsolidated | Part seawall, Jetty at east | -17 | -14 | 33 | 9 | | 0.02 | -31 | -47 | -65 | -72 | -94 | -111 |
| 10 | Waiwhakao Golfcourse | 32.2 to 33.7 | Gravel beach | Unconsolidated | Jetty at west | -17 | -19 | 33 | 10.5 | | 0.05 | -33 | -55 | -62 | -65 | -74 | -81 |
| 11 | West Bell Block | 33.7 to 36.5 | Gravel beach | Unconsolidated | Natural | -32 | -35 | 33 | 13.5 | | 0.05 | -53 | -93 | -101 | -103 | -112 | -119 |
| 12 | Bell Block | 36.5 to 38.0 | Laha cliff | Consolidated | Seawall at west | 0 | -35 | 31 | 13 | 0.5 | | -22 | -62 | -81 | -91 | -117 | -133 |
| 13 | Airport Cliffs | 38.0 to 40.5 | Laha cliff | Consolidated | Natural | 0 | -110 | 31 | 24 | 0.5 | | -40 | -168 | -226 | -259 | -340 | -390 |
| 14 | Waiongona West | 40.5 to 40.9 | Laha cliff | Consolidated | Natural | 0 | -75 | 31 | 9 | 0.5 | | -15 | -102 | -142 | -164 | -220 | -254 |
| 15 | Waiongona East | 40.9 to 41.7 | Gravel beach | Unconsolidated | Natural | -32 | -75 | 33 | 6.3 | | 0.05 | -42 | -129 | -136 | -139 | -148 | -154 |
| 16 | Brown Road | 41.7 to 44.1 | Laha cliff | Consolidated | Natural | 0 | -75 | 31 | 9.2 | 0.5 | | -15 | -102 | -142 | -165 | -220 | -254 |
| 17 | Waitara West | 44.1 to 45.1 | Gravel beach | Unconsolidated | Jetty east end (rivermouth) | -32 | -75 | 33 | 4.5 | | 0.05 | -39 | -126 | -133 | -136 | -145 | -152 |
| 18 | Waitara East | 45.1 to 46.7 | Gravel beach | Unconsolidated | Jetty west end (rivermouth) | -32 | -110 | 33 | 9.5 | | 0.05 | -47 | -174 | -181 | -184 | -193 | -200 |
| 19 | Waitara Golfcourse | 46.7 to 47.0 | Laha cliff | Consolidated | Natural | 0 | -110 | 31 | 13 | 0.5 | | -22 | -149 | -207 | -240 | -322 | -372 |
| 20 | Motunui West | 47.0 to 48.3 | Gravel beach | Unconsolidated | Natural | -25 | -44 | 33 | 4.5 | | 0.1 | -32 | -83 | -87 | -88 | -92 | -96 |
| 21 | Motunui Cliffs | 48.3 to 51.1 | Laha cliff | Consolidated | Natural | 0 | -44 | 31 | 19 | 0.5 | | -32 | -83 | -106 | -119 | -152 | -172 |

| Cell No. | Name | Chainage (km) | Morphological Type | Lithological Type | State | ST (m) | LT (m) | Stable Slope (°) | Height (m) | SLRF | Closure Slope | ASCE | ASCE$_1$ | ASCE$_2$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 2030 - Current (m) | 2130 - No SLR (m) | 2130 - RCP2.6 (m) | 2130 - RCP4.5 (m) | 2130 - RCP8.5 (m) | 2130 - RCP8.5H+ (m) |
| 22 | Motunui East | 51.1 to 52.5 | Gravel beach | Unconsolidated | Natural | -25 | -44 | 33 | 6.5 | | 0.1 | -35 | -86 | -90 | -91 | -95 | -99 |
| 23 | Onaero West | 52.5 to 57.4 | Papa Cliff | Consolidated | Part seawall at Onaero | 0 | -44 | 40 | 23 | 0.25 | | -27 | -78 | -89 | -94 | -106 | -112 |
| 24 | Onaero R to Urenui R | 57.4 to 59.6 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 28 | 0.25 | | -33 | -101 | -115 | -121 | -137 | -145 |
| 25 | Urenui Bay | 59.6 to 60.2 | Gravel beach | Unconsolidated | Part seawall | -25 | -58 | 33 | 5 | | 0.09 | -33 | -100 | -104 | -106 | -110 | -114 |
| 26 | Urenui to Mimi | 60.2 to 63.8 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 28 | 0.25 | | -33 | -101 | -115 | -121 | -137 | -145 |
| 27 | Mimi River | 63.8 to 65.0 | Papa cliff (ash/alluvium/sand) | Consolidated | Natural | 0 | -58 | 40 | 10 | 0.5 | | -12 | -79 | -110 | -127 | -170 | -197 |
| 28 | Mimi to Waiiti | 65.0 to 69.8 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 48 | 0.25 | | -57 | -124 | -138 | -145 | -160 | -169 |
| 29 | Waiiti Stream | 69.8 to 70.3 | Papa cliff (ash/alluvium/sand) | Consolidated | Natural | 0 | -58 | 40 | 15 | 0.5 | | -18 | -85 | -116 | -133 | -176 | -202 |
| 30 | Waiiti to Whitecliffs | 70.3 to76.3 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 58 | 0.25 | | -69 | -136 | -150 | -157 | -172 | -181 |
| 31 | Whitecliffs | 76.3 to 79.7 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 200 | 0.25 | | -238 | -306 | -320 | -326 | -342 | -350 |
| 32 | Whitecliffs to Tongaporutu | 79.7 to 85.9 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 44 | 0.25 | | -52 | -120 | -134 | -141 | -156 | -164 |
| 33 | Tongaporutu to Rapanui | 85.9 to 87.7 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 36 | 0.25 | | -43 | -110 | -124 | -131 | -146 | -154 |
| 34 | Rapanui to Mohakatino | 87.7 to 95.2 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 21 | 0.25 | | -25 | -92 | -106 | -113 | -128 | -136 |
| 35 | Mohakatino to Mokau | 95.2 to 98.2 | Papa Cliff | Consolidated | Natural | 0 | -58 | 40 | 36 | 0.25 | | -43 | -110 | -124 | -131 | -146 | -154 |

# Appendix D ASCE maps




Notes: - Aerial photograph sourced from LINZ Data Service (2013)
- Future ASCE lines assume no structures are present on shoreline. If structures remain effective then current ASCE applies.
- ASCE lines have been developed on a district scale as part of a first-pass assessment and may be superseded by local scale or site-specific assessment undertaken by qualified and experienced practitioner.

A3 SCALE 1:240,000

0 2.5 5 7.5 10 12.5 (km)

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# New Plymouth District Council
Coastal Erosion Hazard
Map Overview

FIGURE No.

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Path: T:\Auckland\Projects\1001955\WorkingMaterial\GIS\1001955-000-MAP002.mxd Date: 15/07/2019 Time: 11:36:37 AM


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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New Plymouth District Council
Coastal Erosion Hazard
Site Detail
Sheet: 1

FIGURE No. Figure 2.1

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Site Detail
Sheet: 2

FIGURE No. Figure 2.2

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A3 SCALE 1:10,000

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FIGURE No. Figure 2.3

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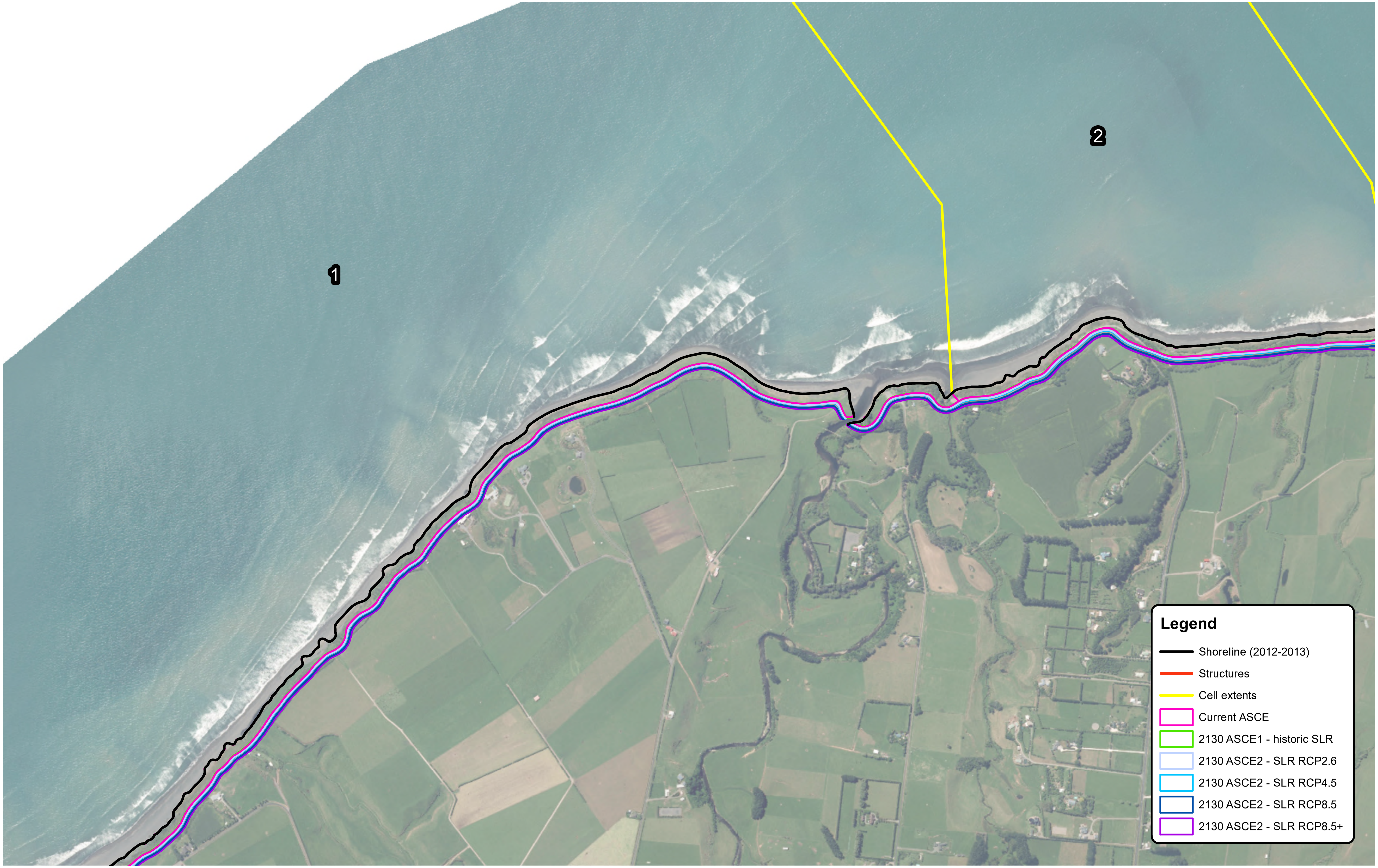


Notes:
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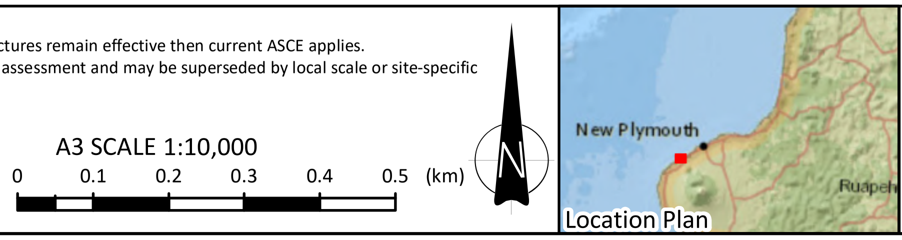


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FIGURE No. Figure 2.4
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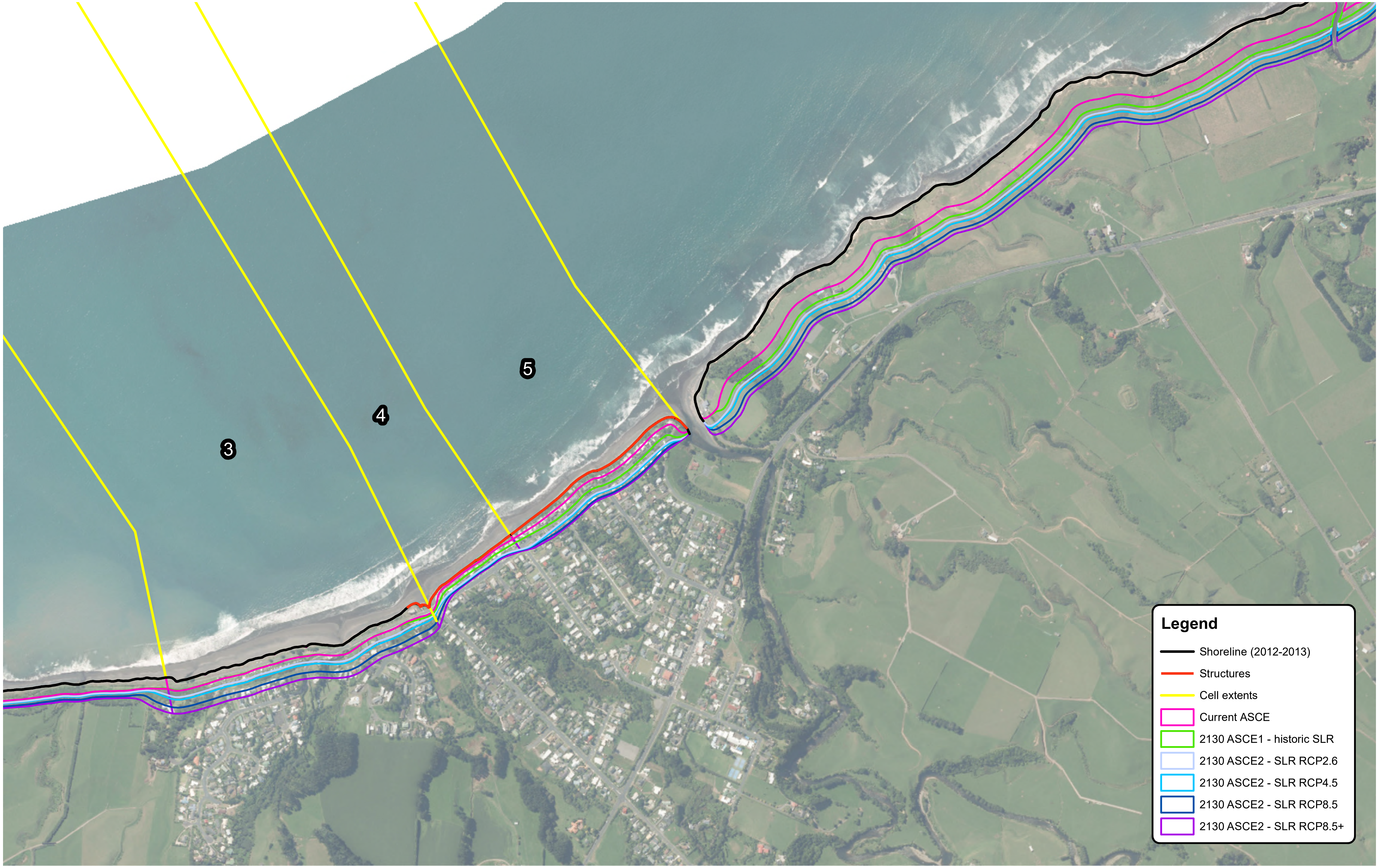


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.5

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A3 SCALE 1:10,000
0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.6
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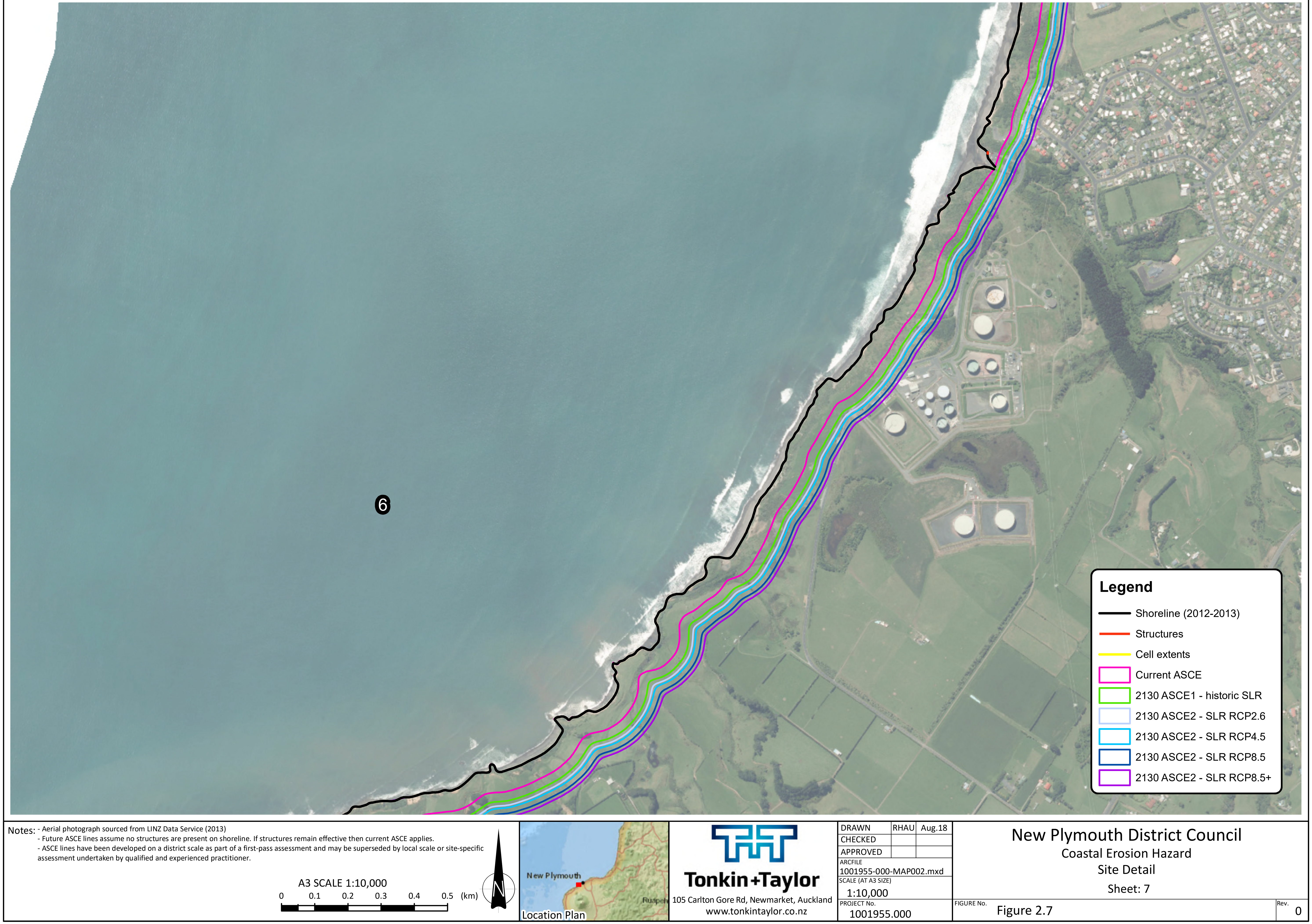


Notes:
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FIGURE No. Figure 2.7
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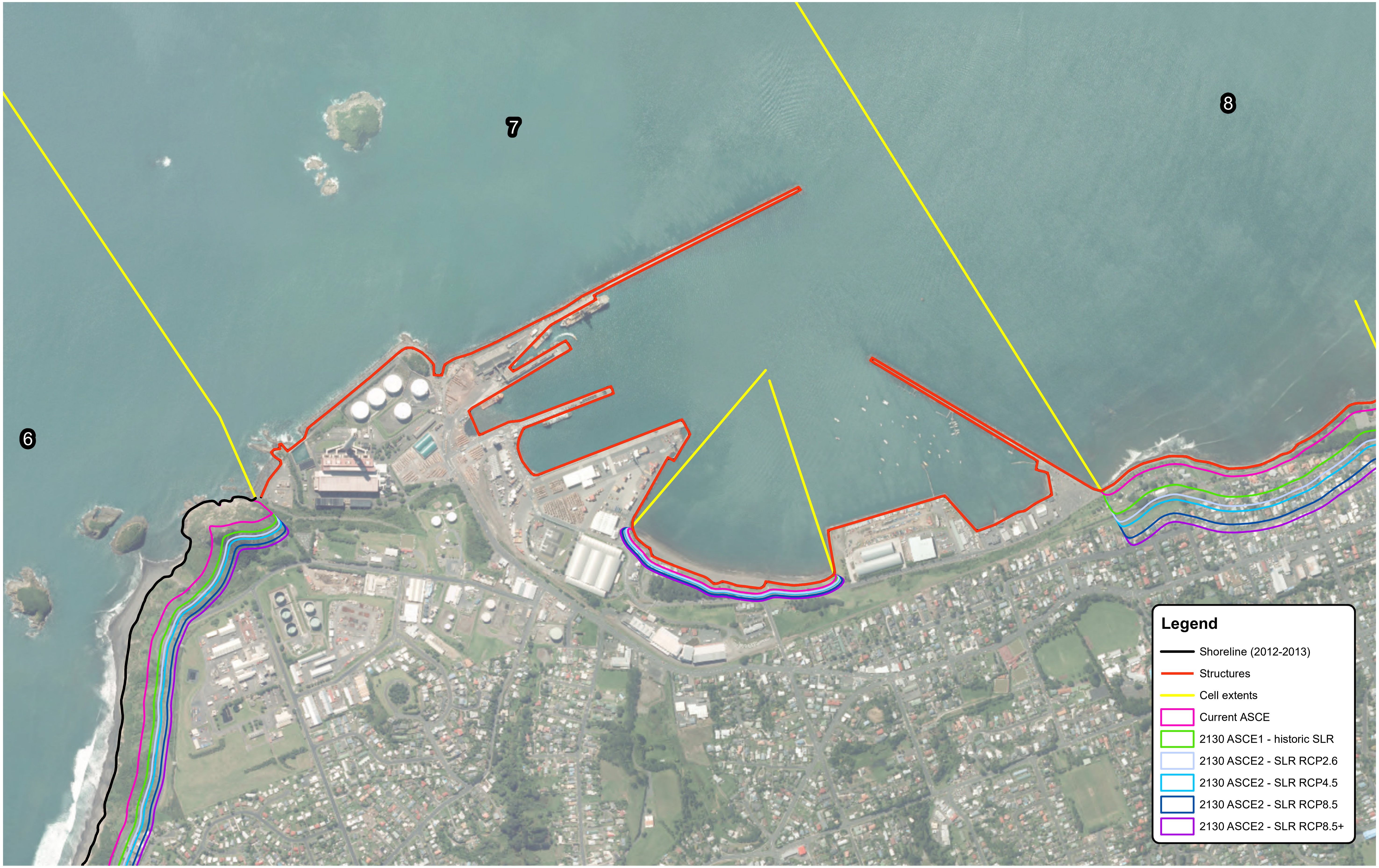


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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FIGURE No. Figure 2.8

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A3 SCALE 1:10,000
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Coastal Erosion Hazard
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FIGURE No. Figure 2.9
Rev. 0

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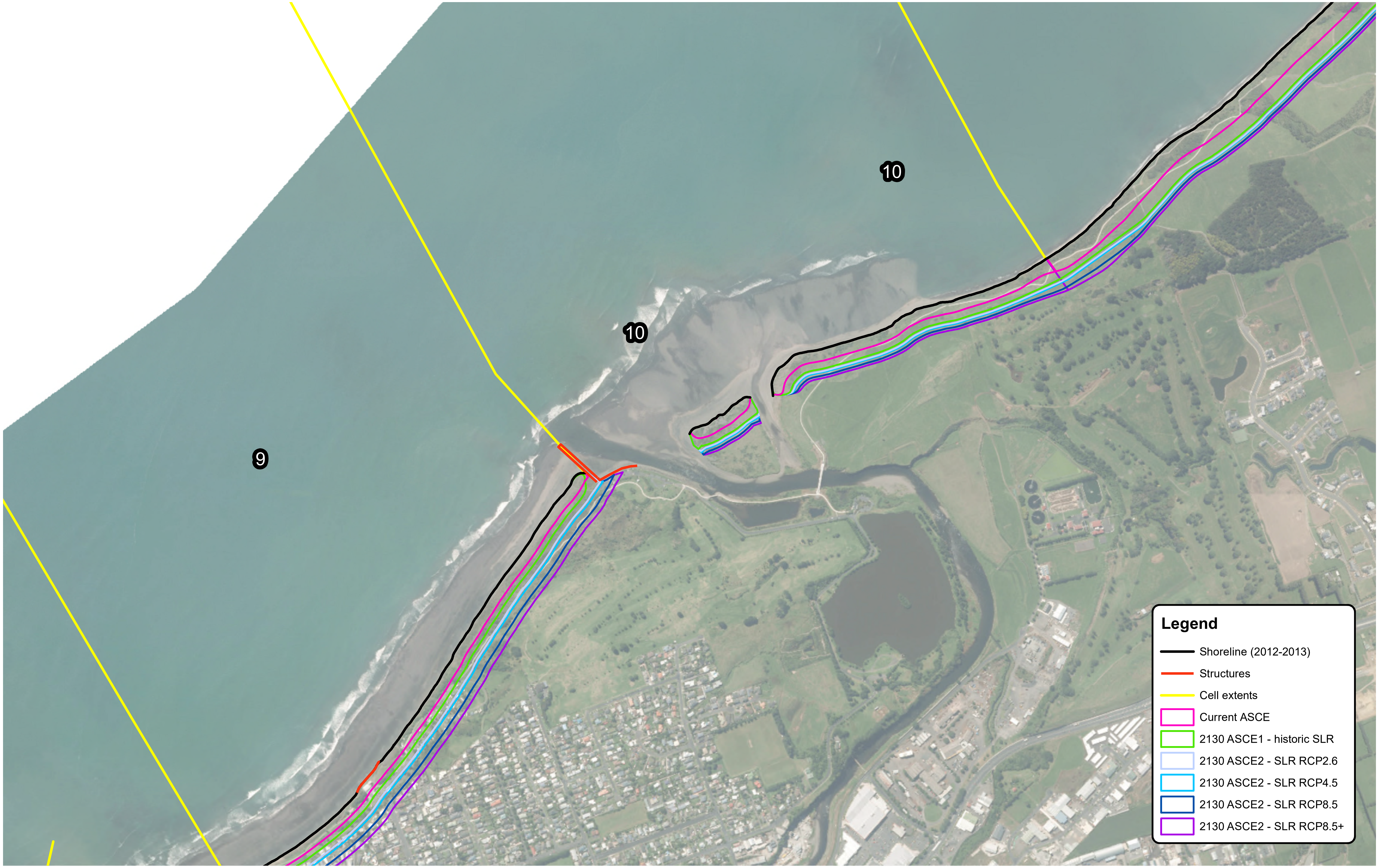


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.10

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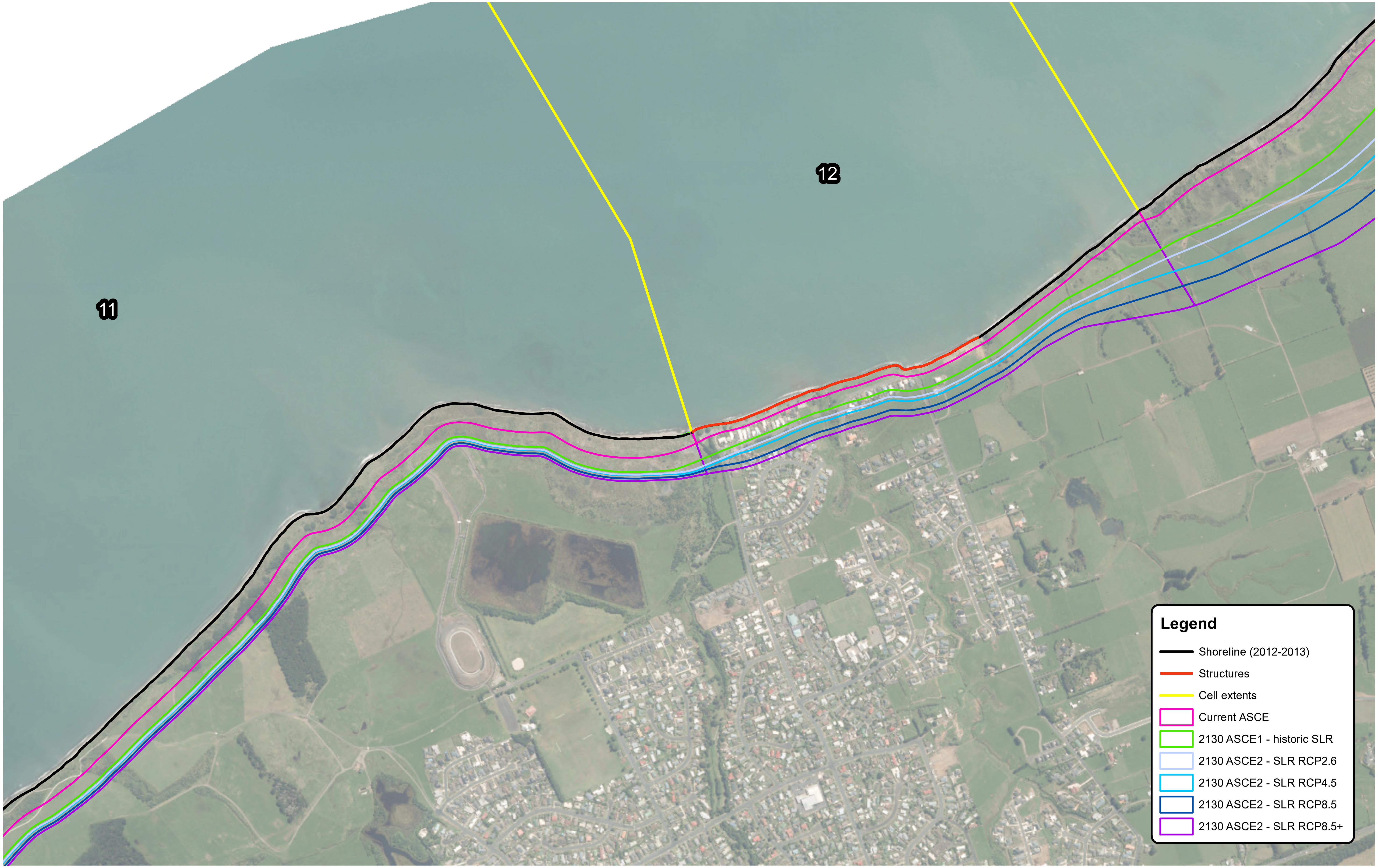


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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Coastal Erosion Hazard
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FIGURE No. Figure 2.11

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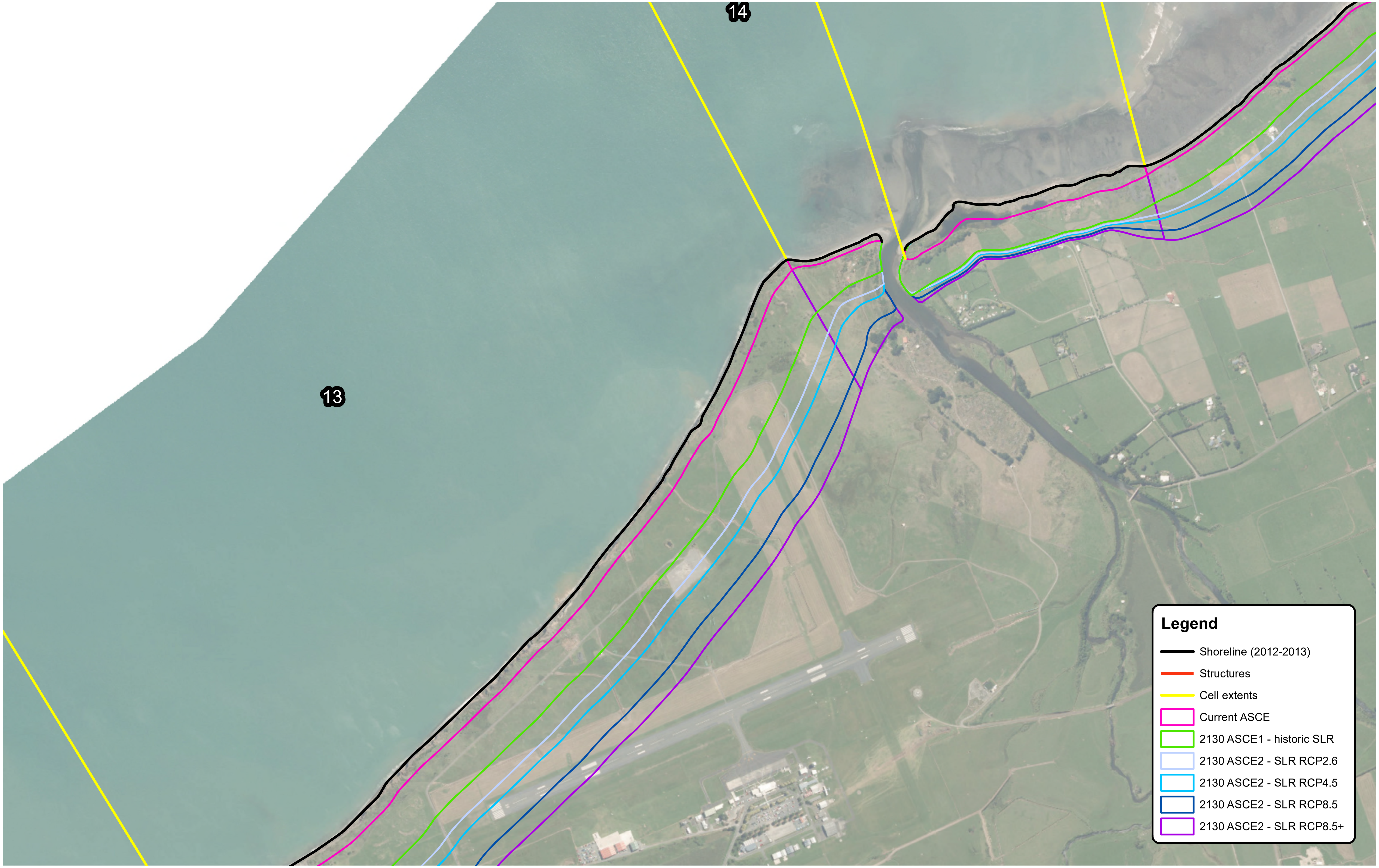


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.12

Rev. 0

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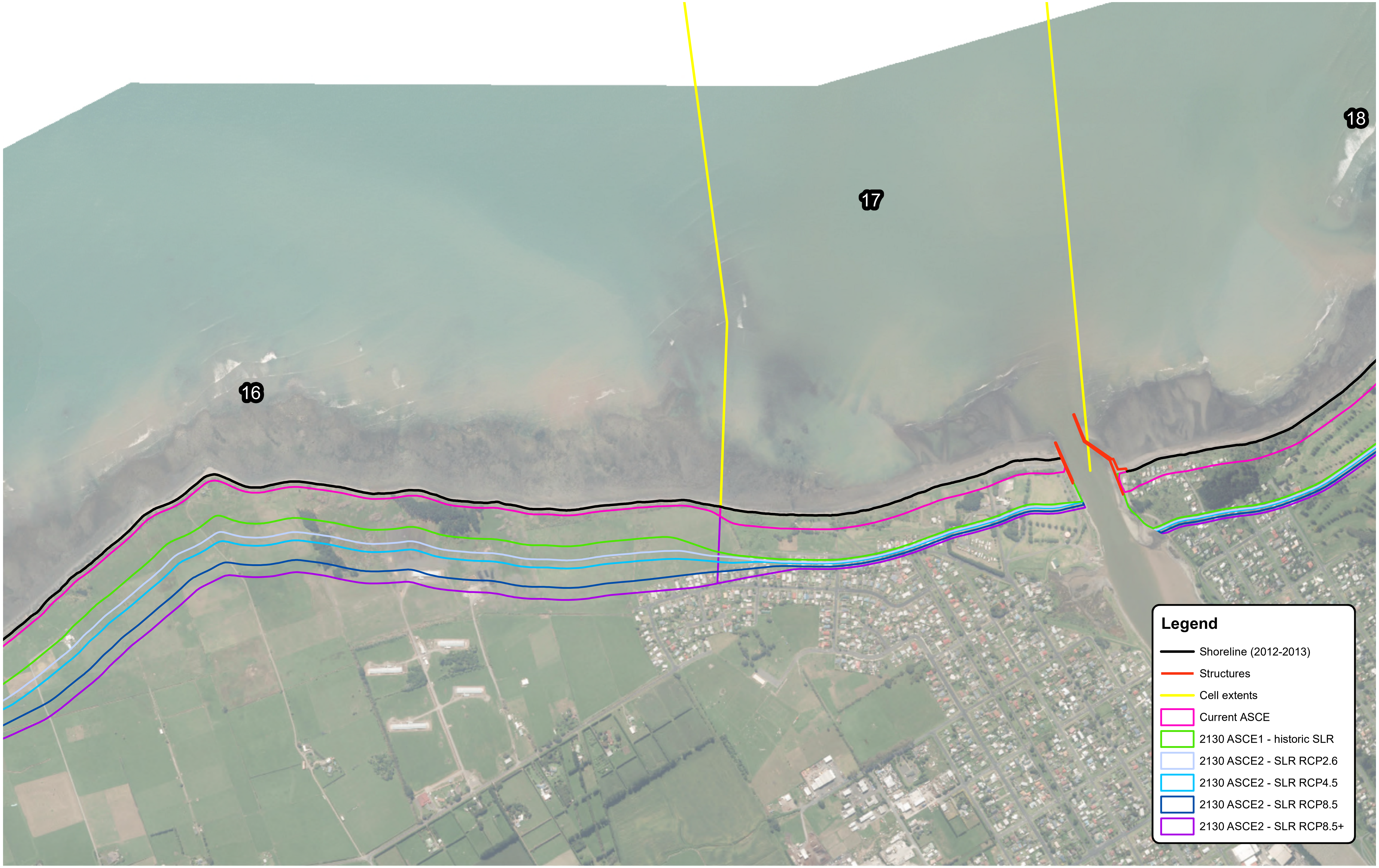


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000
0 0.1 0.2 0.3 0.4 0.5 (km)


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Sheet: 13

FIGURE No. Figure 2.13 Rev. 0

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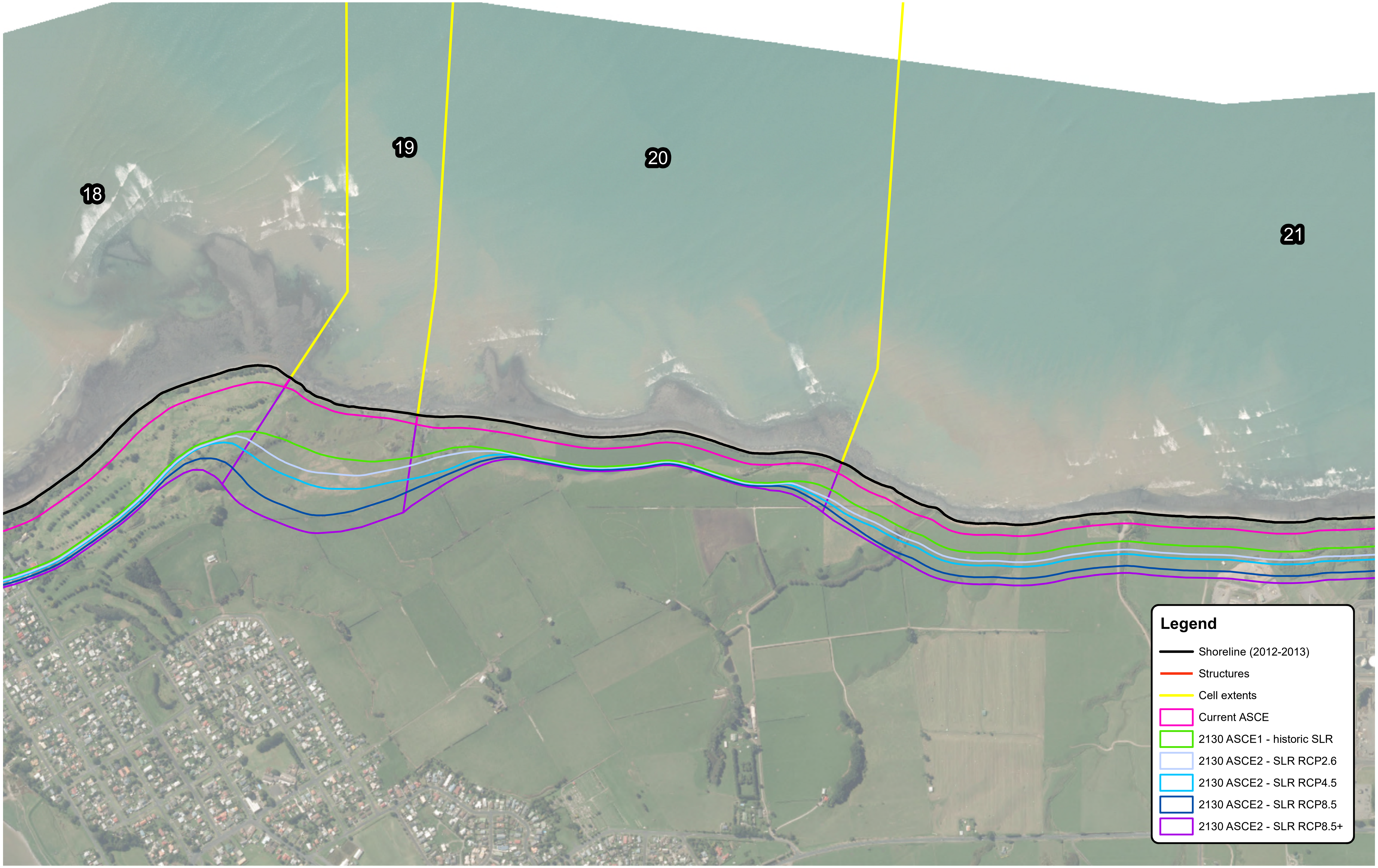


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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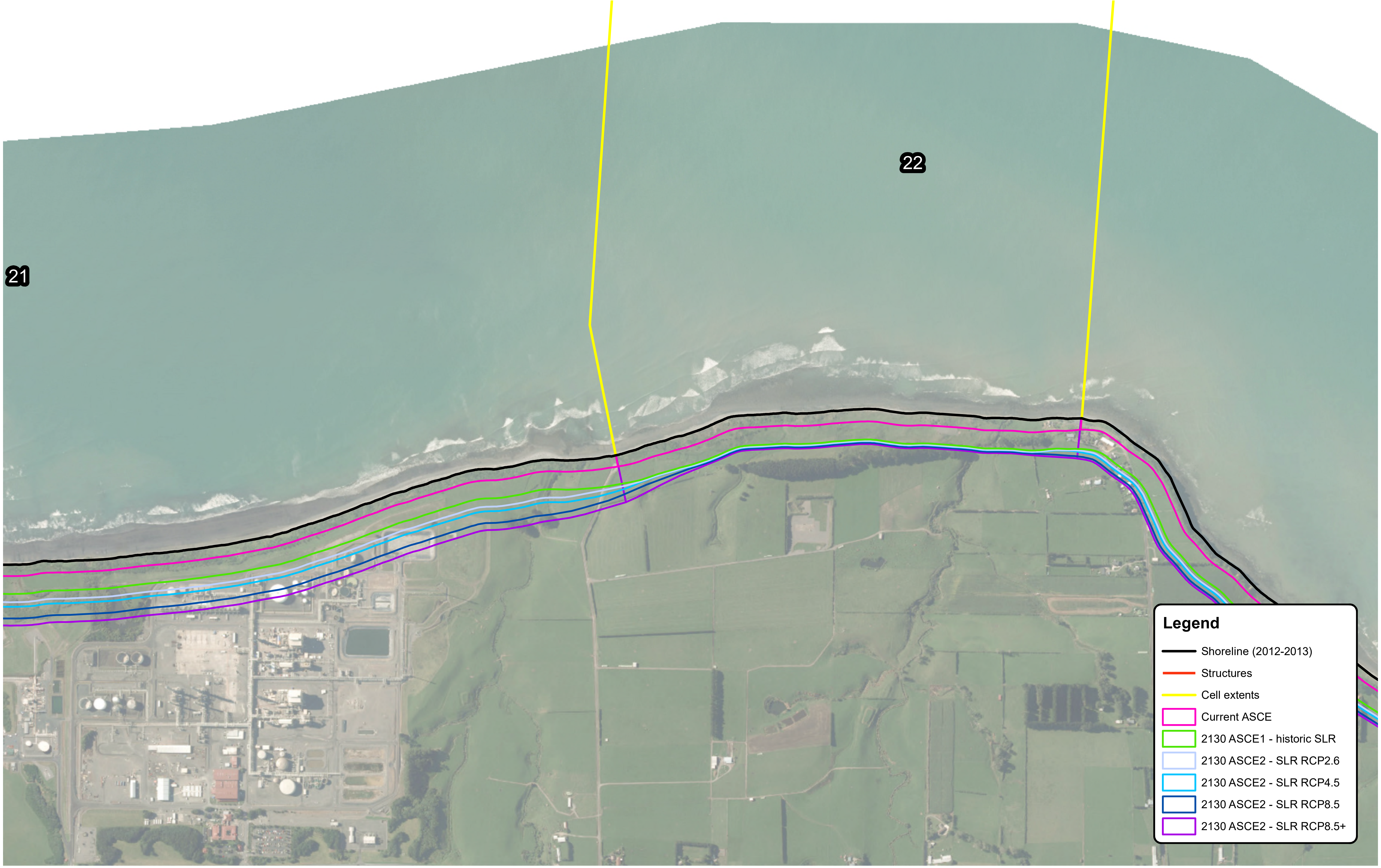
Sheet: 14

FIGURE No. Figure 2.14

Rev. 0

Path: T:\Auckland\Projects\1001955\WorkingMaterial\GIS\1001955-000-MAP002.mxd Date: 2/08/2018 Time: 9:54:13 AM




Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000
0 0.1 0.2 0.3 0.4 0.5 (km)

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Coastal Erosion Hazard
Site Detail
Sheet: 15

FIGURE No. Figure 2.15

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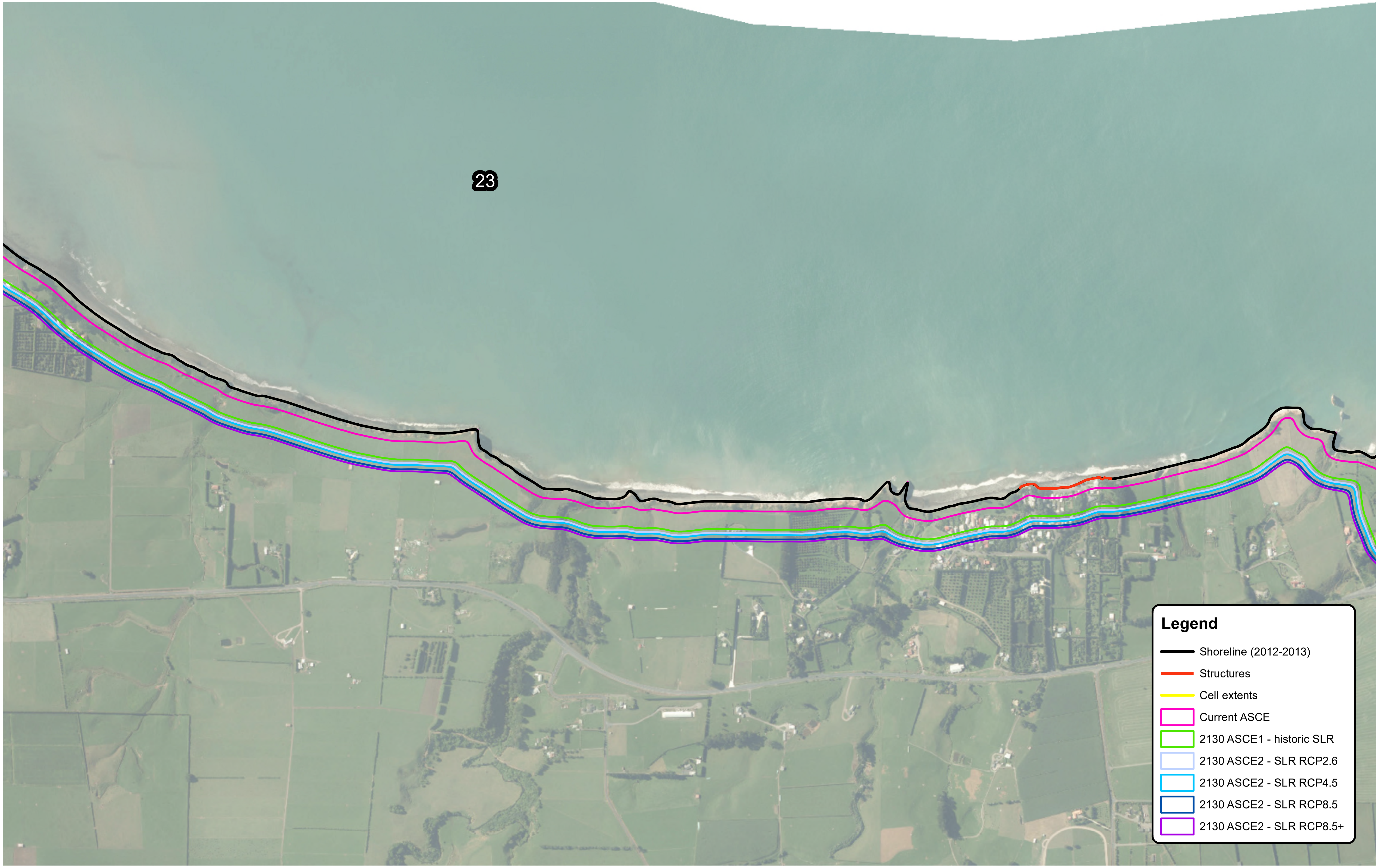


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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Sheet: 16

FIGURE No. Figure 2.16

Rev. 0

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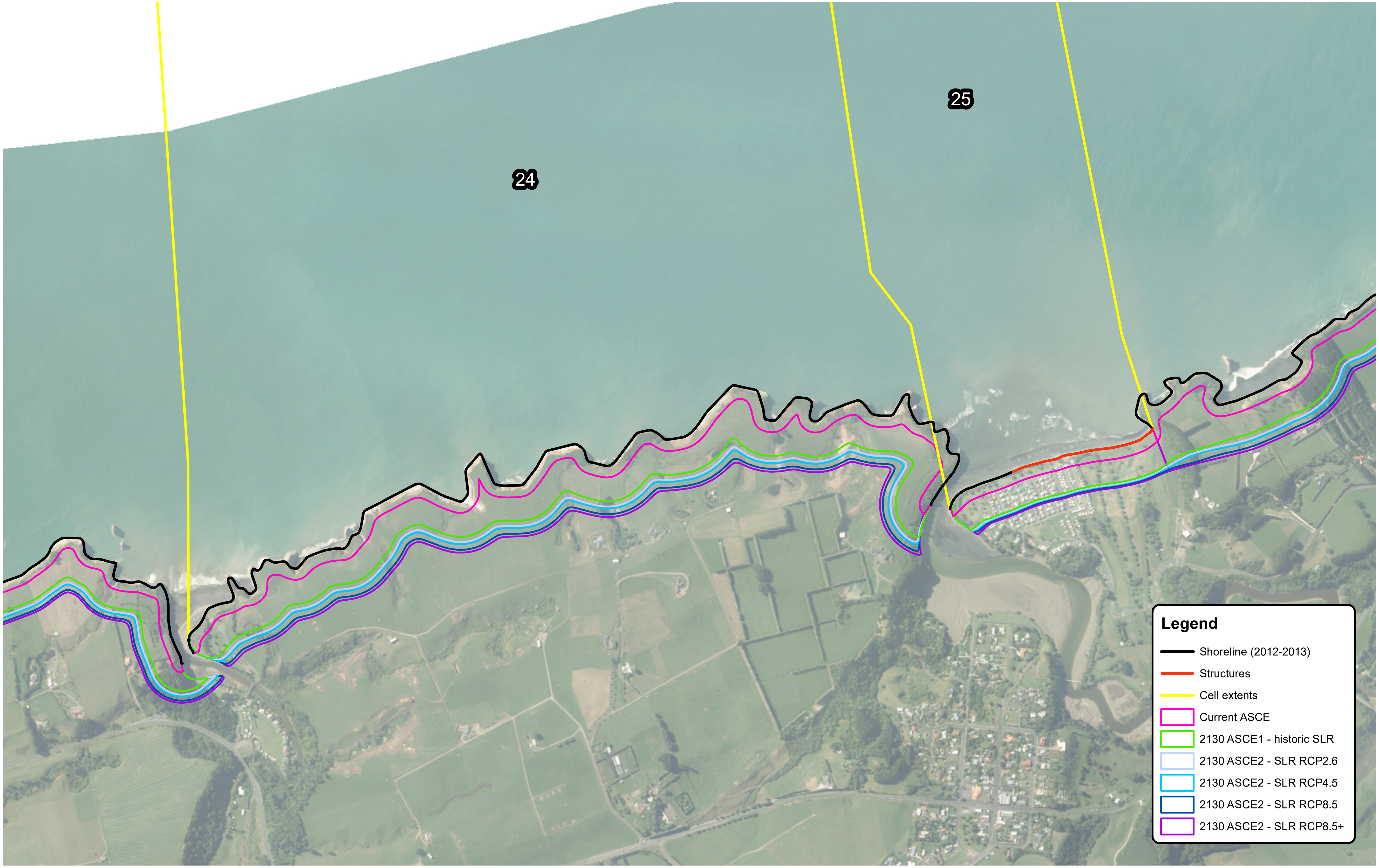


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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Sheet: 17

FIGURE No. Figure 2.17
Rev. 0

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Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

Location Plan: New Plymouth

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Coastal Erosion Hazard
Site Detail
Sheet: 18

FIGURE No. Figure 2.18

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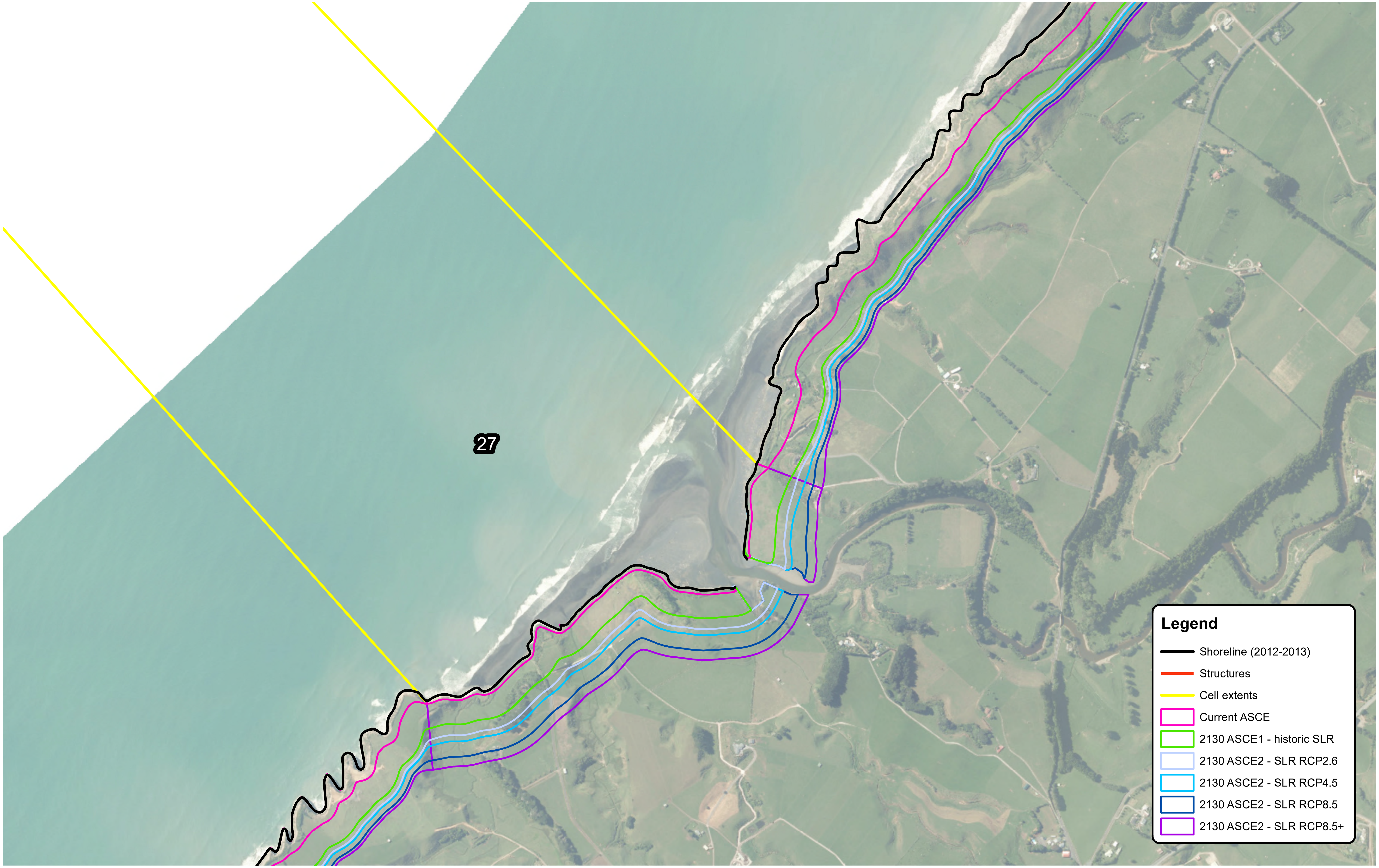


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000
0 0.1 0.2 0.3 0.4 0.5 (km)


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Sheet: 19

FIGURE No. Figure 2.19
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Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000
0 0.1 0.2 0.3 0.4 0.5 (km)


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Coastal Erosion Hazard
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FIGURE No. Figure 2.20
Rev. 0

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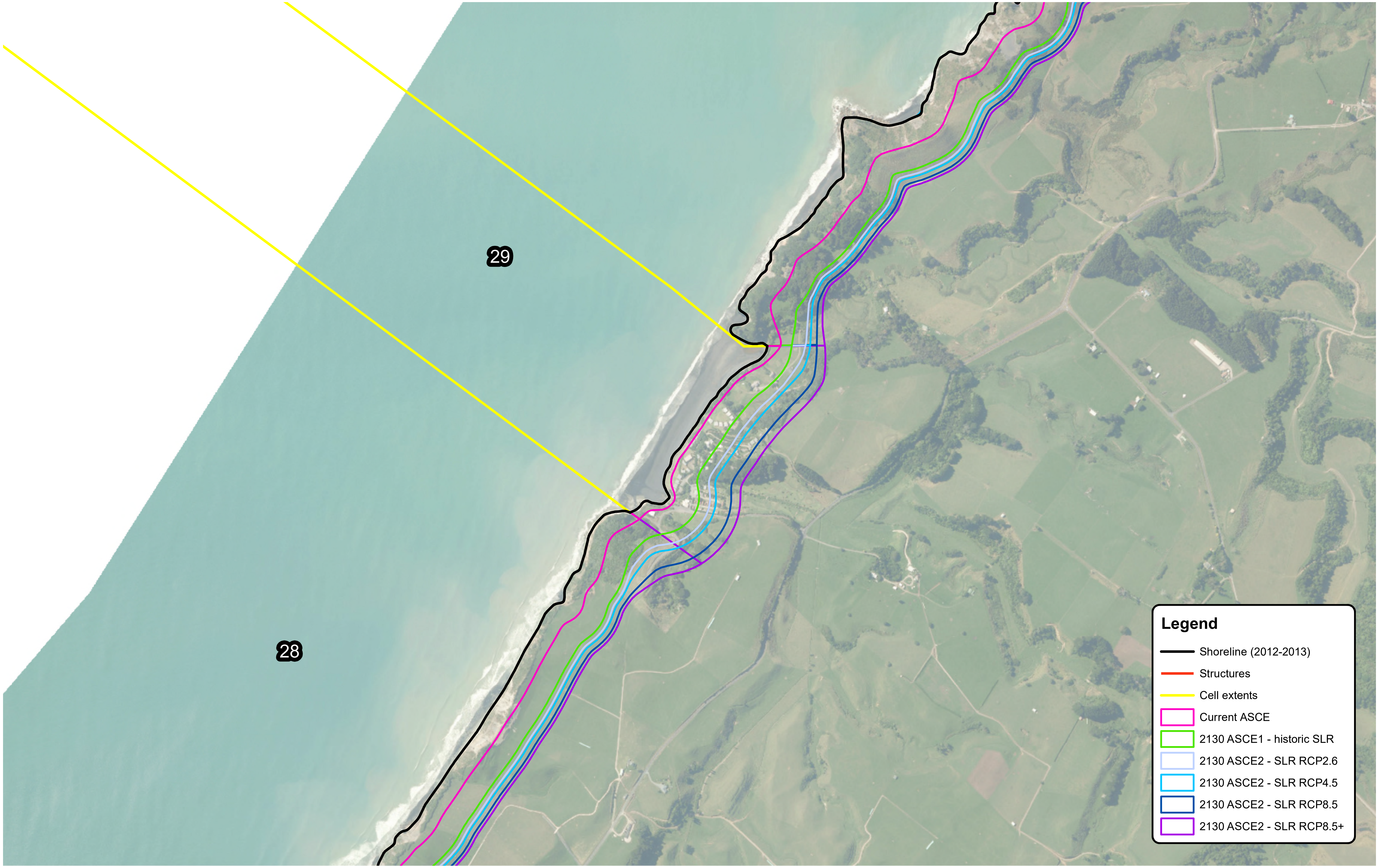


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.21

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Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.22

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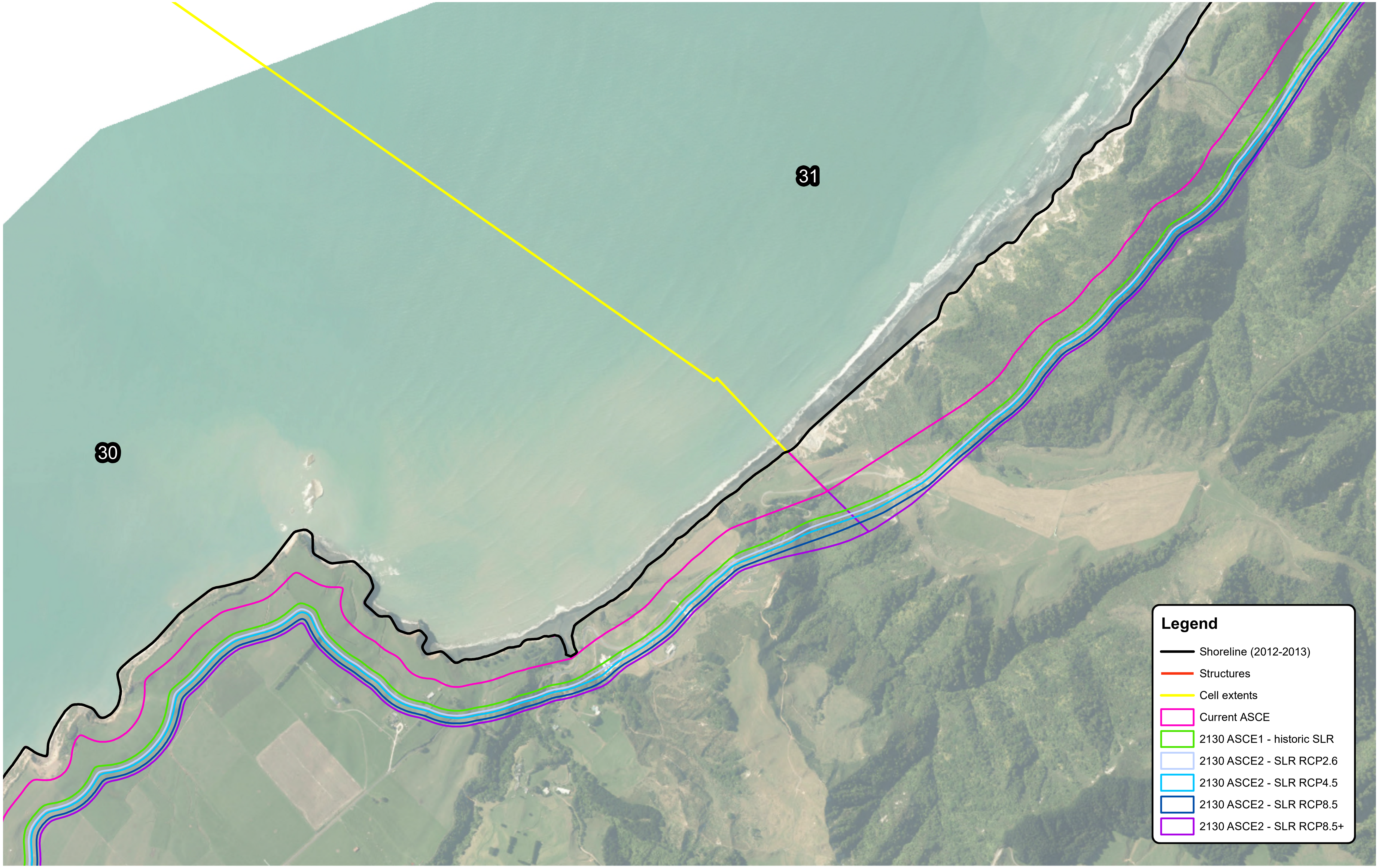


Notes:
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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FIGURE No. Figure 2.23

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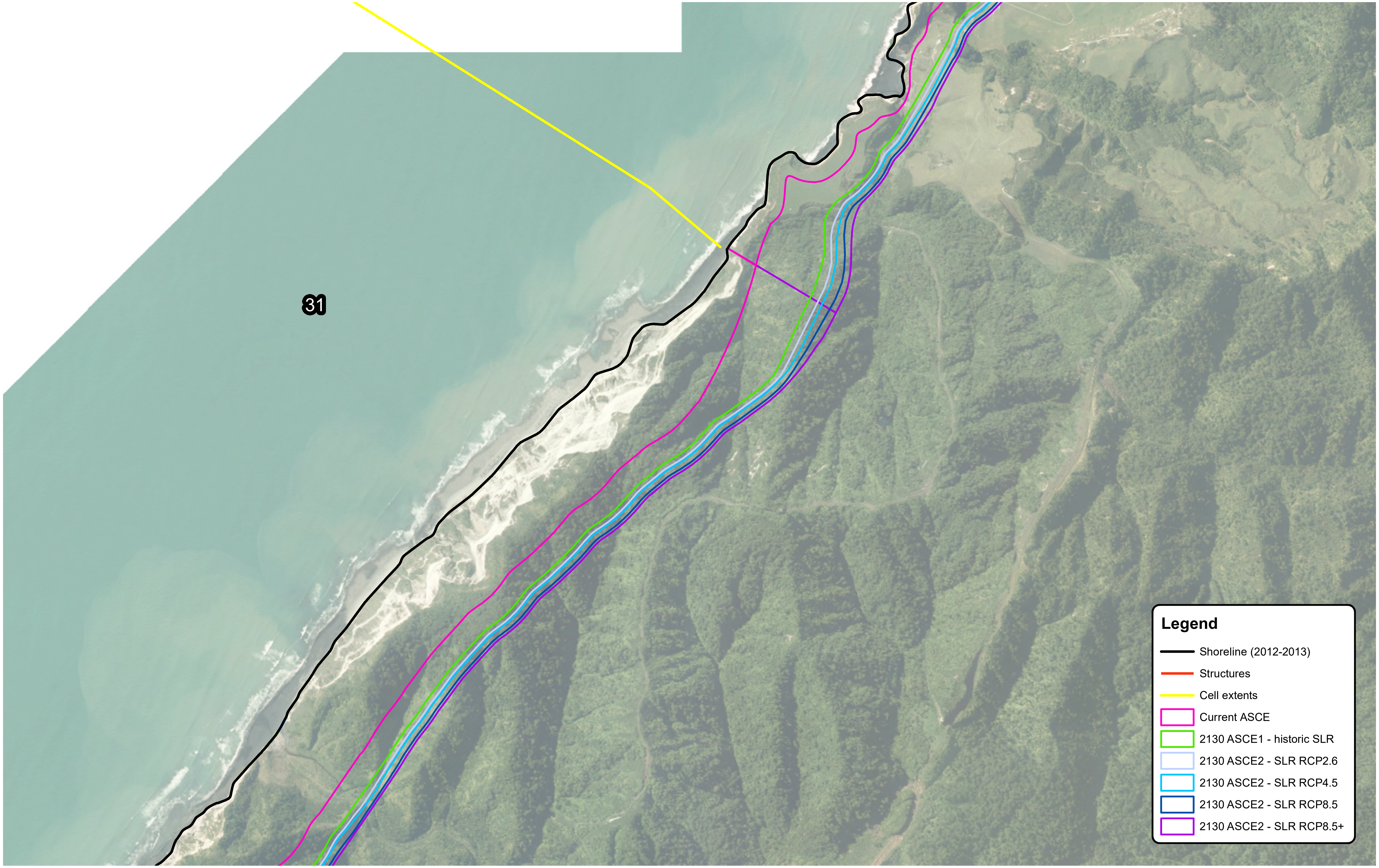


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000
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FIGURE No. Figure 2.24

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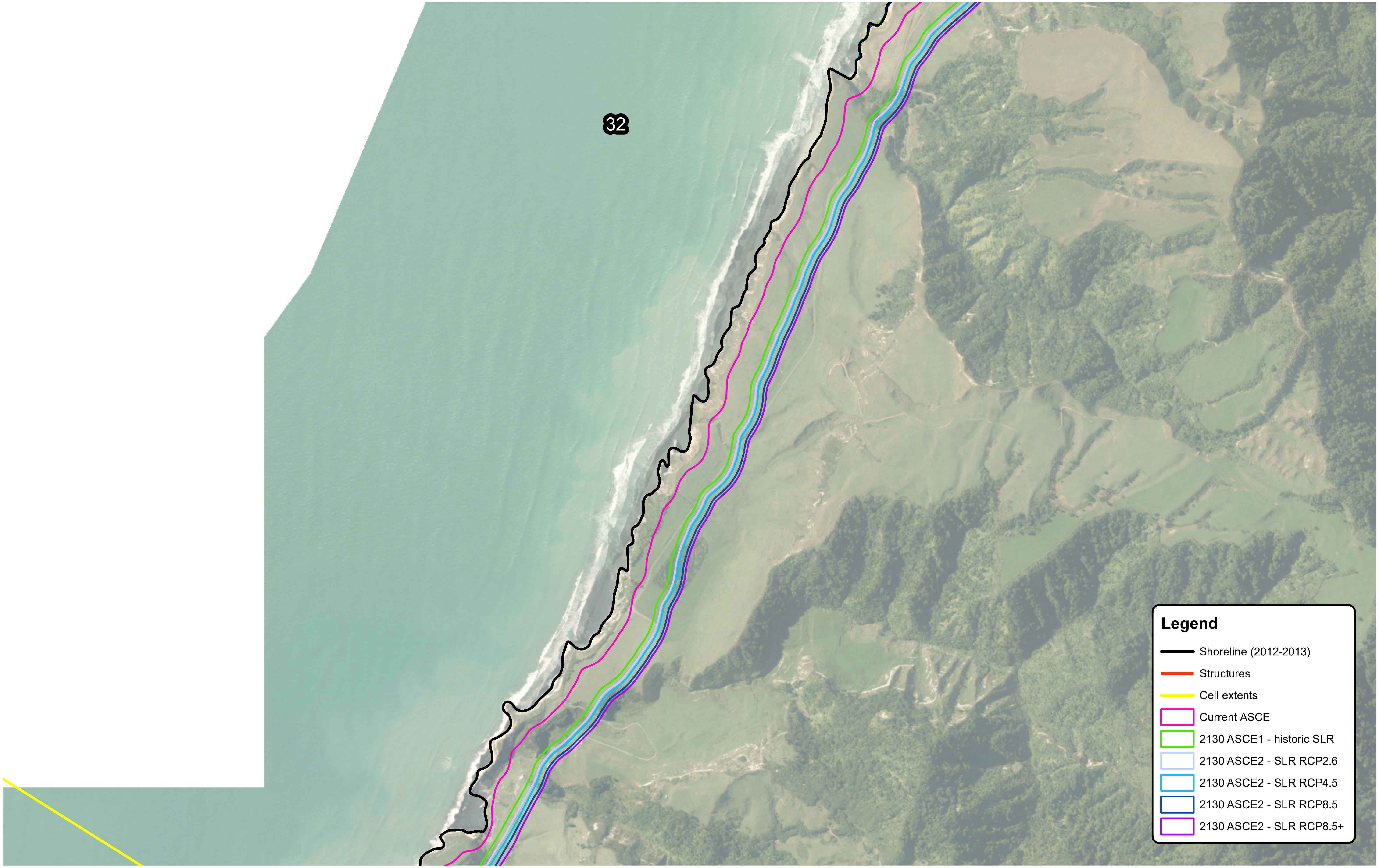


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A3 SCALE 1:10,000
0 0.1 0.2 0.3 0.4 0.5 (km)

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FIGURE No. Figure 2.25
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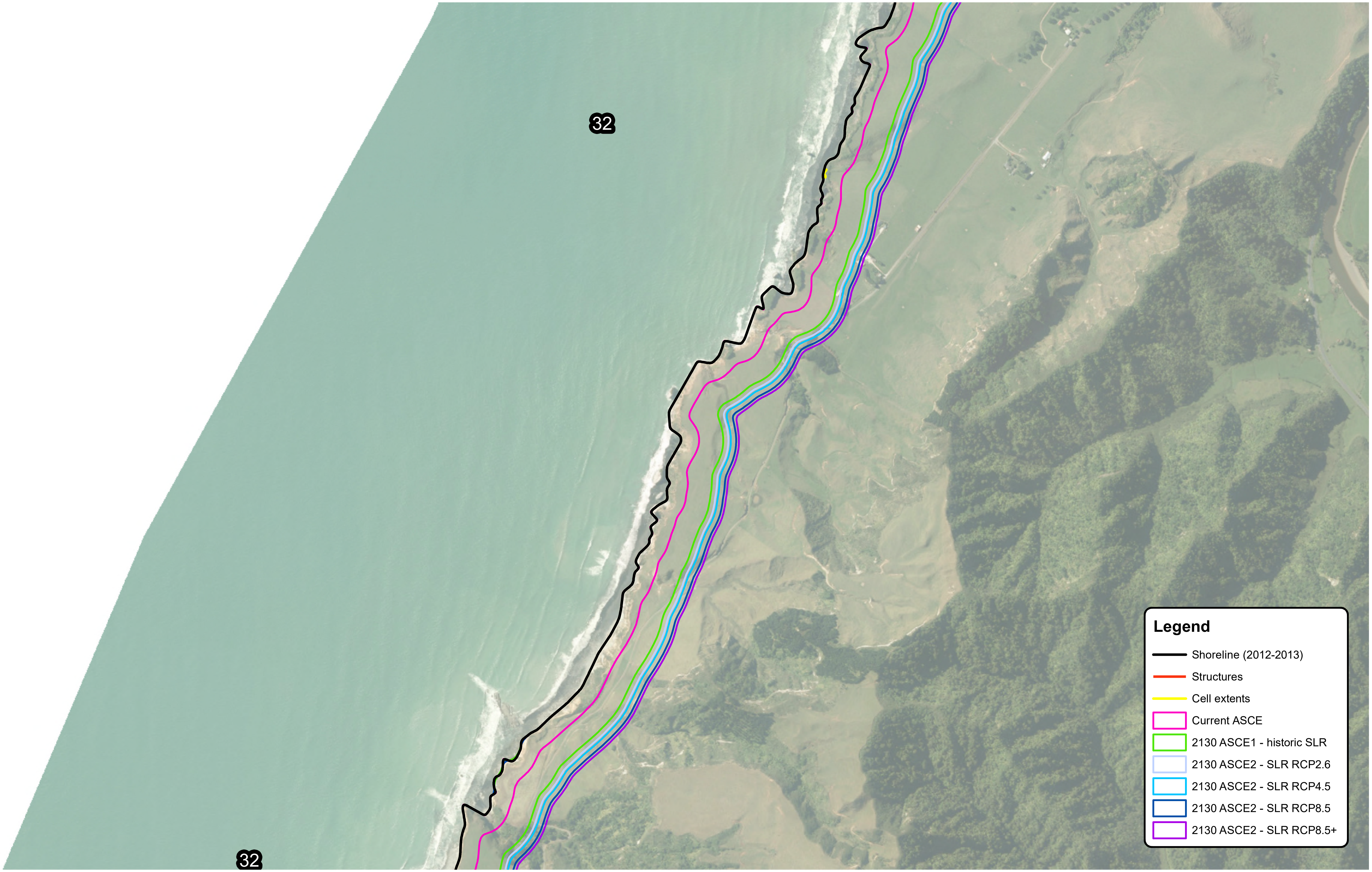


Notes:
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A3 SCALE 1:10,000
0 0.1 0.2 0.3 0.4 0.5 (km)

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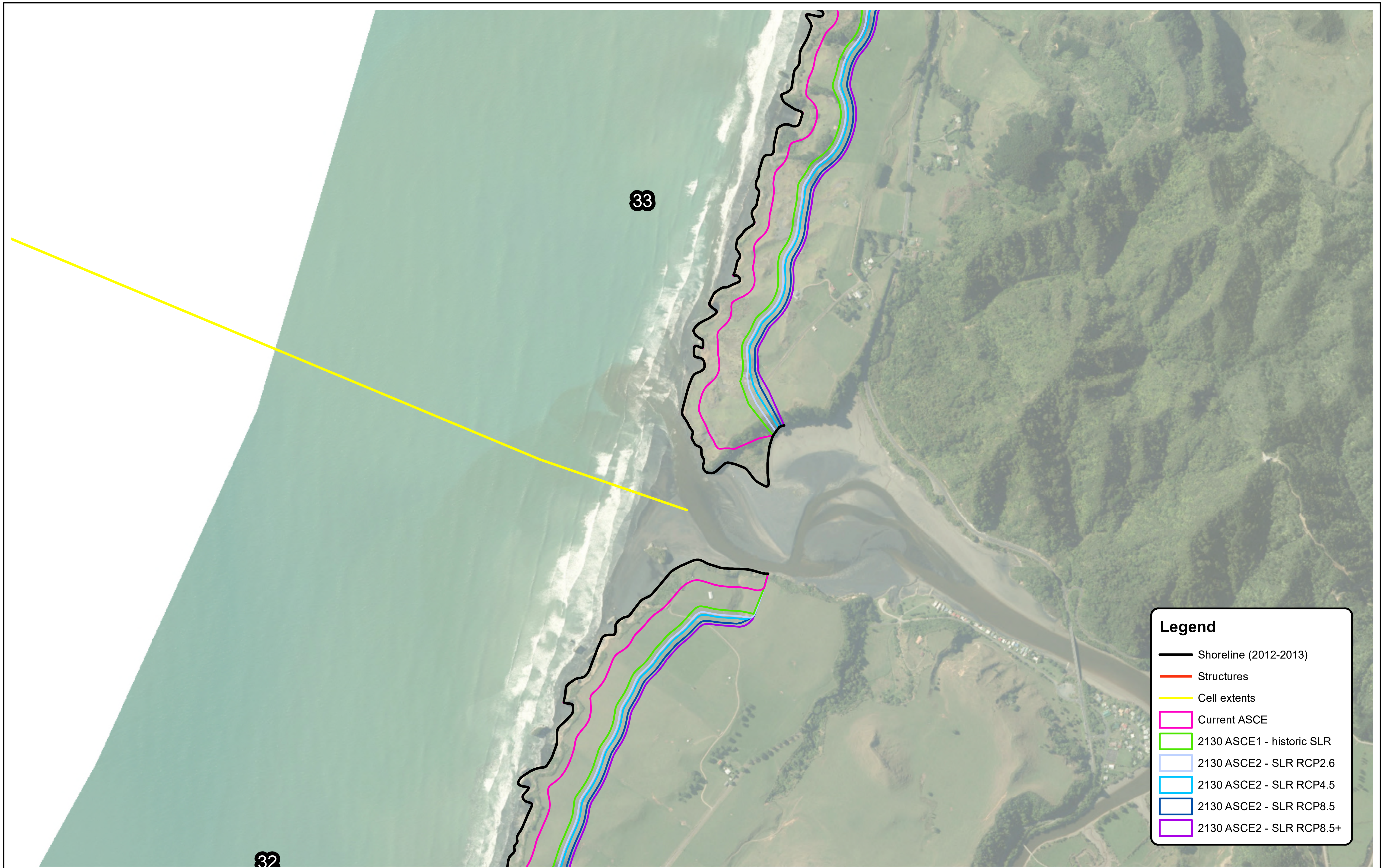
Coastal Erosion Hazard
Site Detail
Sheet: 26

FIGURE No. Figure 2.26
Rev. 0

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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.27

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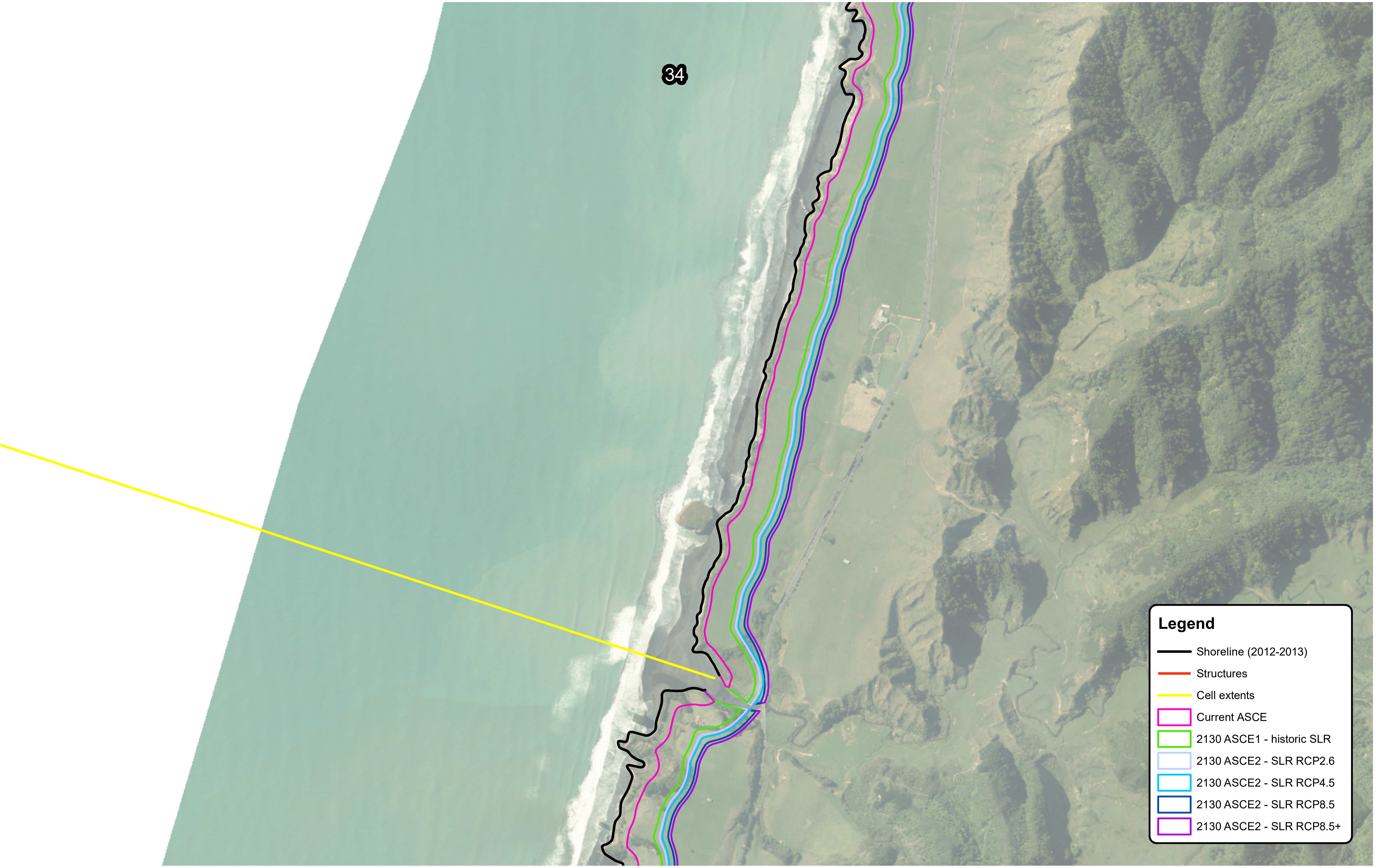


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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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FIGURE No. Figure 2.28

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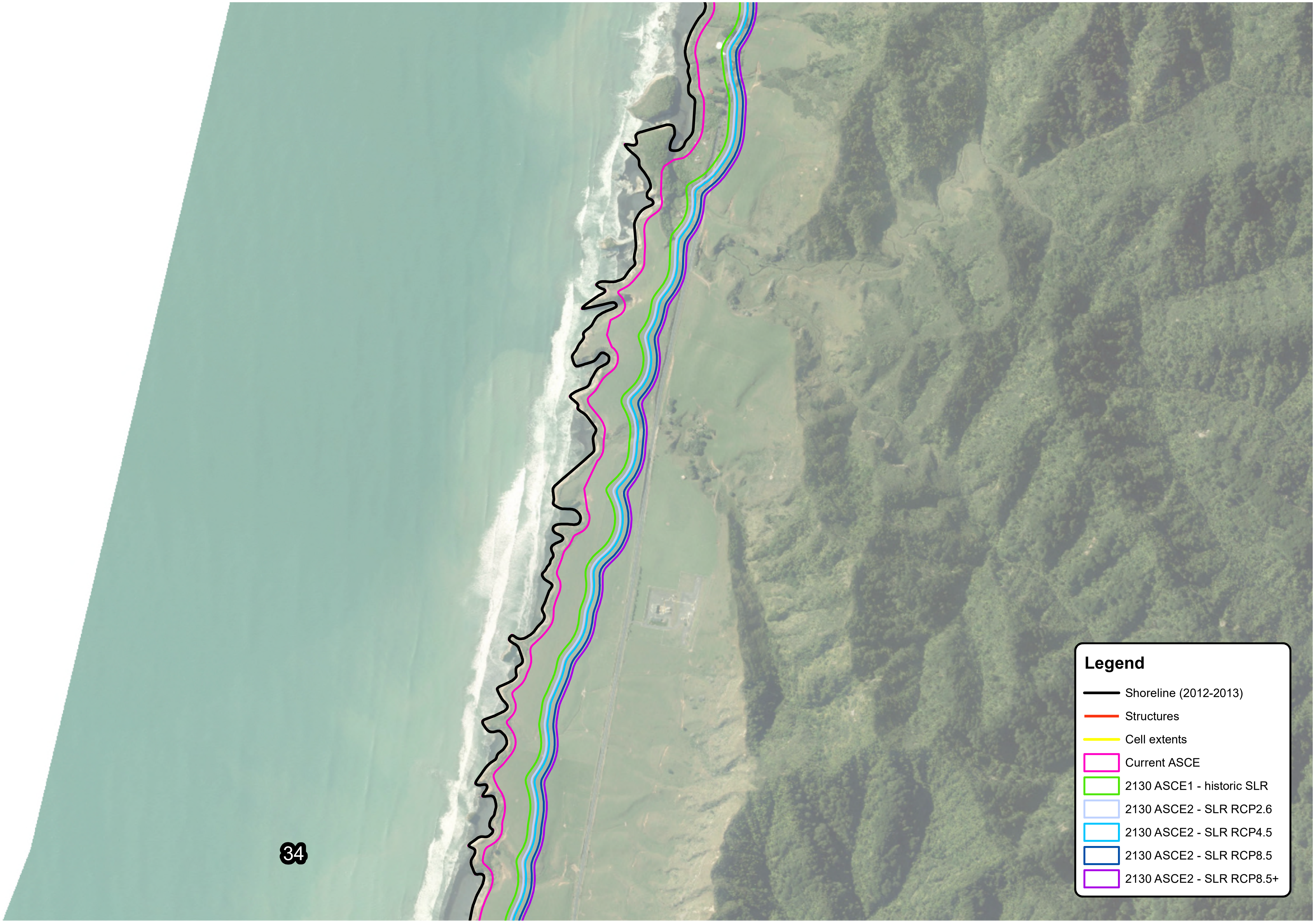


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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)

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| ARCFILE | 1001955-000-MAP002.mxd | |
| SCALE (AT A3 SIZE) | 1:10,000 | |
| PROJECT No. | 1001955.000 | |

New Plymouth District Council
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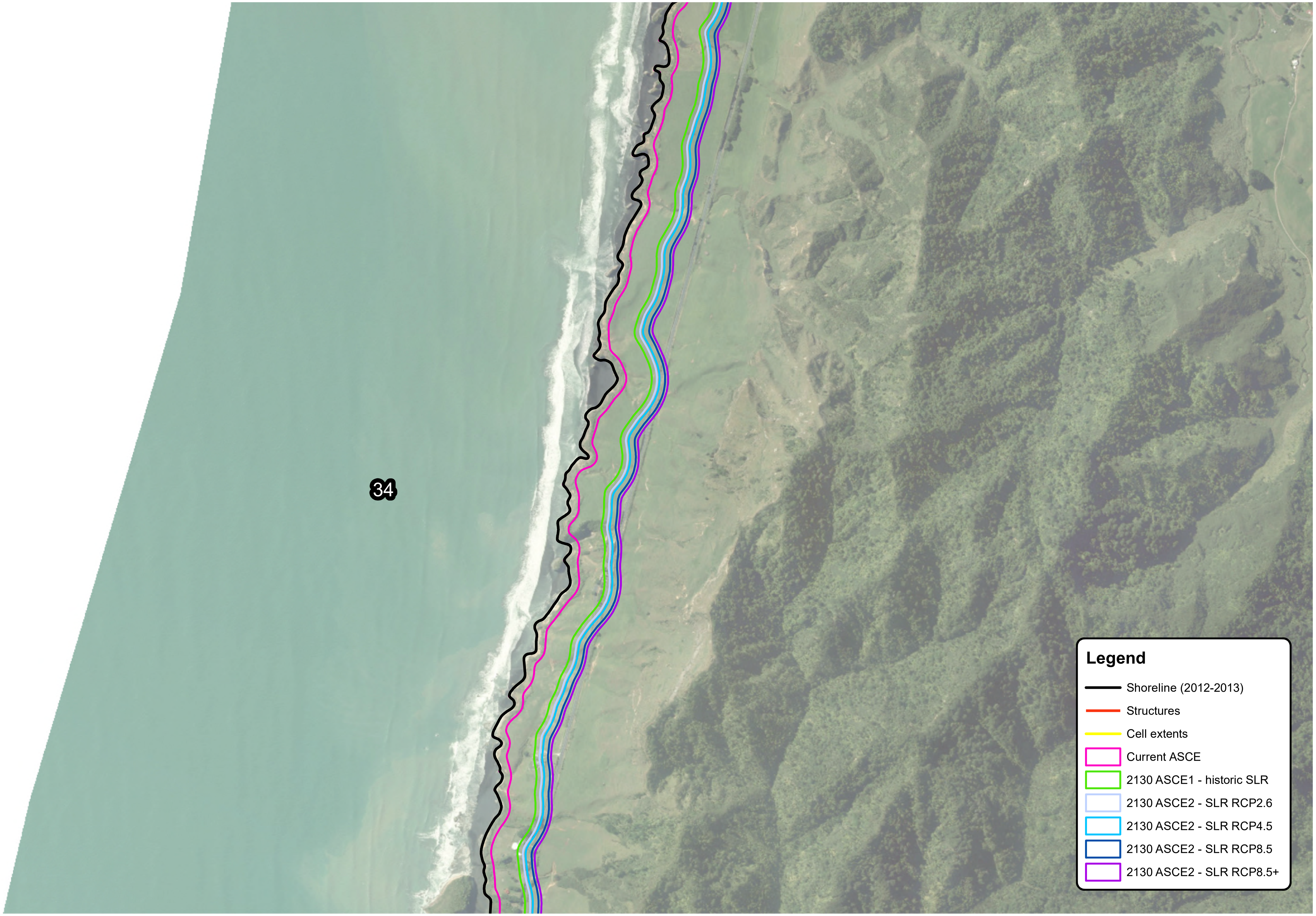
FIGURE No. Figure 2.29

Rev. 0

Path: T:\Auckland\Projects\1001955\WorkingMaterial\GIS\1001955-000-MAP002.mxd Date: 2/08/2018 Time: 9:57:15 AM




Notes: - Aerial photograph sourced from LINZ Data Service (2013)
- Future ASCE lines assume no structures are present on shoreline. If structures remain effective then current ASCE applies.
- ASCE lines have been developed on a district scale as part of a first-pass assessment and may be superseded by local scale or site-specific assessment undertaken by qualified and experienced practitioner.

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)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|---|---|---|
| DRAWN | RHAU | Aug.18 |
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| ARCFILE 1001955-000-MAP002.mxd | | |
| SCALE (AT A3 SIZE) 1:10,000 | | |
| PROJECT No. 1001955.000 | | |

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FIGURE No. Figure 2.30

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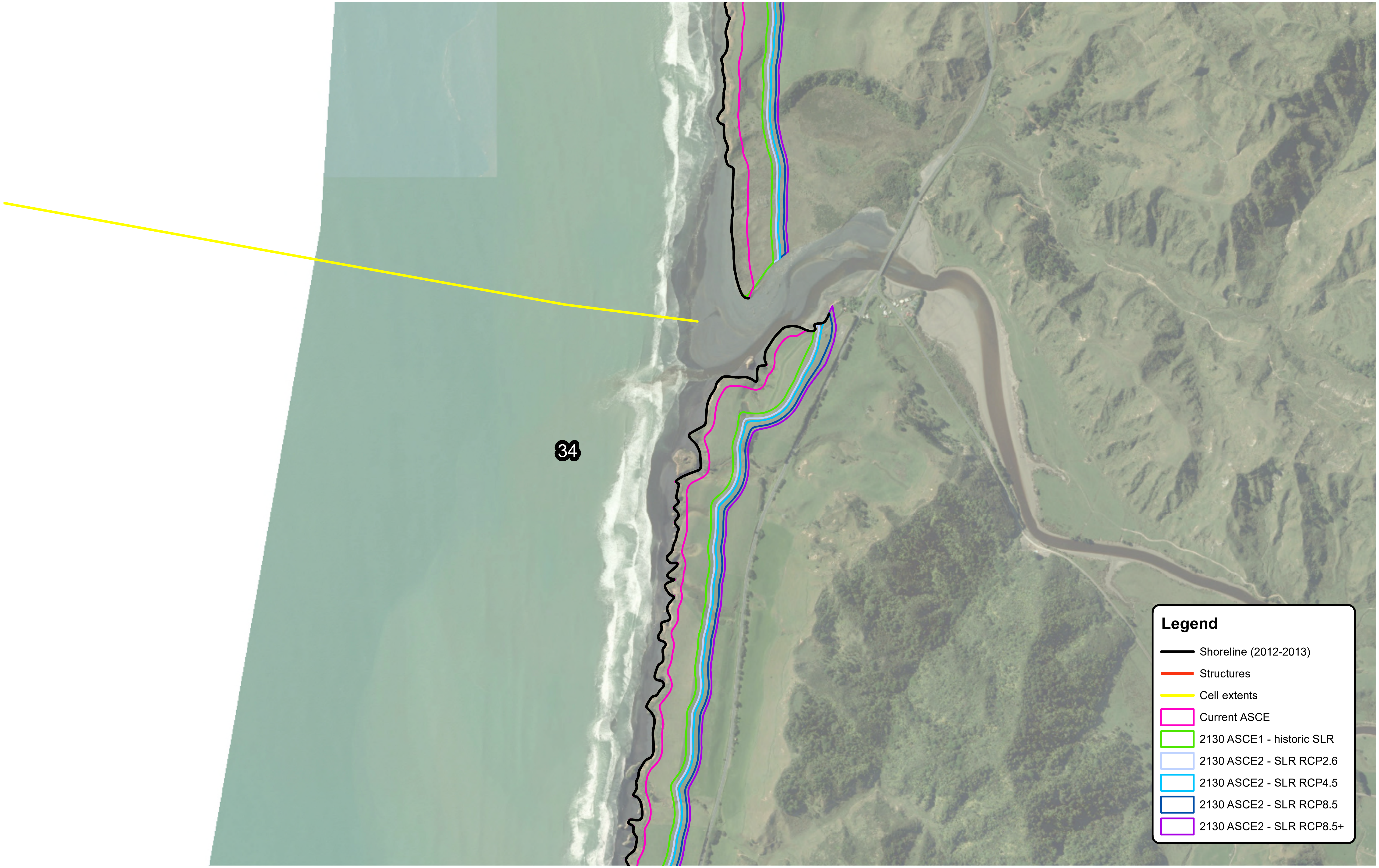


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
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A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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| SCALE (AT A3 SIZE) 1:10,000 | | |
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FIGURE No. Figure 2.31

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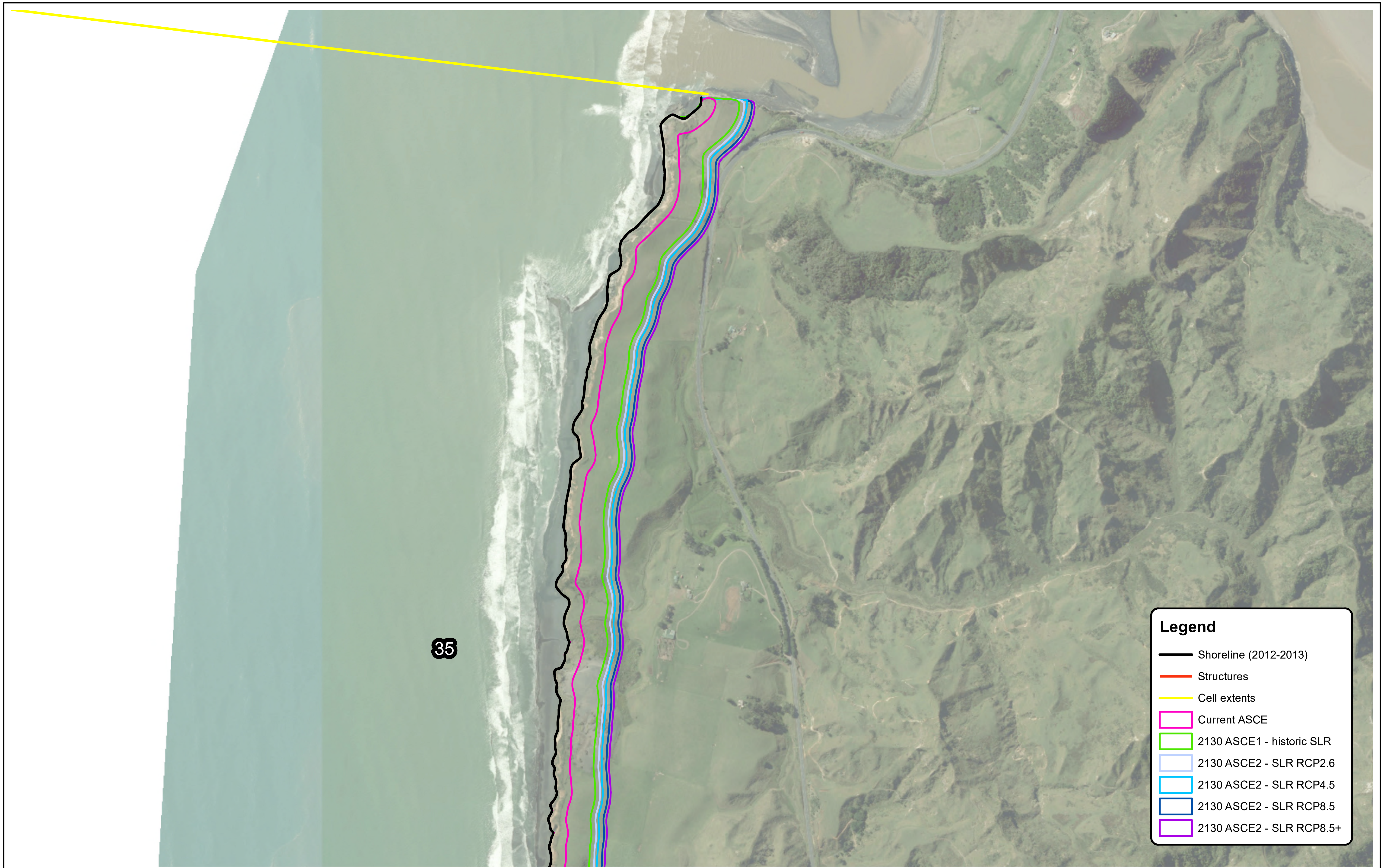


Notes: - Aerial photograph sourced from LINZ Data Service (2013)
- Future ASCE lines assume no structures are present on shoreline. If structures remain effective then current ASCE applies.
- ASCE lines have been developed on a district scale as part of a first-pass assessment and may be superseded by local scale or site-specific assessment undertaken by qualified and experienced practitioner.

A3 SCALE 1:10,000

0 0.1 0.2 0.3 0.4 0.5 (km)


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| DRAWN | RHAU | Aug.18 |
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| SCALE (AT A3 SIZE) | 1:10,000 | |
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New Plymouth District Council

Coastal Erosion Hazard

Site Detail

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FIGURE No. Figure 2.32

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# Appendix E Qualitative risk assessment

| Risk | Description |
|---|---|
| High | High value or quantity of indicator within area susceptible to coastal erosion |
| Moderate | Moderate value or quantity of indicator within area susceptible to coastal erosion |
| Low | Low value or quantity of indicator within area susceptible to coastal erosion |
| Zero | Indicator not within area susceptible to coastal erosion |

| | | Economic | | | | Social | | | | | Cultural | | | | Environmental | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cell ID | Name | Transport Infrastructure | Water + energy infrastructure | Tourism facilities | Business/Industry | Resident Dwellings | Recreational facilities/parks | Schools | Community Centres | Medical centre/hospitals | Archaeological sites | Heritage sites | Churches | Marae | Marine biodiversity inventory | National/Regional Park | Conservation Area | Natural coastal defences | Outstanding natural landscapes & features | Outstanding coastal natural character |
| 1 | Stony - Weld | Greenwood Road, Coast Rd | Water supply pipes | | Farm | 1 house (Perth Rd), 1 house (Kaihihi Rd) + the edge of several residential properties | Coastal Rd Esplanade, Lower Pitone Rd reserve, Lower Greenwood reserve, Timaru Esplanade, Weld Rd and Ahu Ahu Rd Reserves | | | | 2 Waahi Tapu site | Bach | | | | | | | Komene Lagoon | |
| 2 | Ahu Ahu - Camp | Ahu Ahu Rd (Lower) | Water supply pipes | | | | Weld Rd and Ahu Ahu Rd Reserves, Oakura Beach (part of Corbett Park Domain) | | | | | | | | | | | | | |
| 3 | Camp to Surf Club | Tasman Parade, Shearer Dr | Storm water, waste water & water supply pipes | Oakura Beach Holiday Park | | 5+ houses | Shearers Reserve (skatepark) | | Oakura Board Riders Club | | 1 Waahi Tapu site | Oakura Board Riders Club | | | | | | | | |
| 4 | Sth Mess Tce | Messenger Terrace | Storm water, waste water & water supply pipes | | | All houses on the seaward side of Messenger Terrace | | | | | | | | | | | | | | |
| 5 | Nth Mess Tce | Messenger Terrace, McFarlane St, Dixon St | Storm water, waste water & water supply pipes | | | All houses on the seaward side of Messenger Terrace + many houses on the landward | | | | | | | | | | | | | | |
| 6 | Oakura-Paritutu | Centennial Dr | Storm water & waste water pipes | | Farm | 5+ houses (Centennial Dr, South Rd) | Corbett Park + Paritutu Centennial Park | | Club | | 5+ Waahi Tapu sites | | | | | | | | Natural value polygon | |
| 7a | Port - West | | | | | | | | | | | | | | | | | | | |
| 7b | Ngamotu Beach | Ocean View Parade | Water supply & storm water pipes | | | | Ngamotu beach reserve | | New Plymouth Yacht Club | | | Beam oil pump + NP Yacht Club | | | | | | | | |
| 7c | Port-East | | | | | | | | | | | | | | | | | | | |
| 8a | Belt Rd | Belt Rd, Kawaroa Ln, Kawaroa Cl, Bulkeley Trc, Tisch av | Storm water, waste water & water supply pipes | Belt Rd Seaside Holiday Park | | 20+ houses | Kawaroa Park , Tennis/Squash Club, NP Coastal Walkway | | | | | 4 heritage houses | | | | | | | | |
| 8b | Kawaroa Park | Bulkeley Trc, Hine St, Dawson St, Regina Pl, St Aubyn St | Storm water, waste water & water supply pipes | | Businesses on Dawson St & St Aubyn St | 10+ houses | Kawaroa Park, Todd Energy Aquatic Centre, NP Coastal Walkway | | | | | Kawaroa Park Howitzer, Kawaroa Pool and Mosaic Wall, Honeyfield Drinking Foundation, Richmond Estate, Taranaki Club building, Cenotaph, Stone wall + seats | | | | | | | | |
| 8c | Puke Ariki | Molesworth St, Egmont St, Liardet St | Storm water, waste water & water supply pipes | iSITE visitor centre | Businesses on Molesworth St | | NP Coastal Walkway | | | | 1 Waahi Tapu site | | | | | | | | | |
| 8d | Woolcombe Tce | Pari St, Molesworth St, Buller St, Woolcombe Terrace, Octavius Pl | Storm water, waste water & water supply pipes | | Several businesses | 20+ houses | Mount Bryan Reserve, NP Coastal Walkway | | RSA | | | Heritage house | | | | | | | | |
| 8e | East End | Buller St, Nobs Line | Storm water, waste water & water supply pipes | | | 5 houses (Buller St) | East End Reserve, NP Coastal Walkway | | Surf Club | | 1 Waahi Tapu site | Te Henui Railway Bridge, East End Reserve Gates | | | | | | | | |
| 9 | Fitzroy | Nobs Line, Beach St | Storm water, waste water & water supply pipes | Fitzroy Beach Holiday Park | | 10+ houses | NP Coastal Walkway, Reserve | | Fitzroy Surf Life Saving Club + NP Surfriders Club | | | | | | | | | Dune | | |
| 10 | Waiwhakao Golfcourse | | Waste water pipe | | | | NP Coastal Walkway + Reserve | | | | | | | | | | | | | |
| 11 | West Bell Block | | | | | | NP Coastal Walkway + Reserve (Hickford Park) + Taranaki Cycle Park | | | | | | | | | | | | | |
| 12 | Bell Block | Wanaka Terrace, Tiromoana Cres, Mangati Rd | Storm water, waste water & water supply pipes | | Farm paddocks east of Bell Block | 20+ houses | Bell Block Beach reserve | | | | 2 Waahi Tapu site | | | | | | | Dune | | |
| 13 | Airport Cliffs | End of the airport runwa | Waste water pipe | | | | | | | | 3 Waahi Tapu site | | | | | | | | | |
| 14 | Waiongona West | | | | | 1 house | Waitangirua Esplanade Reserve | | | | | | | | | | | | Waiongana Stream inlet | |
| 15 | Waiongona East | | | | | 1 house | | | | | | | | | | | | | Waiongana Stream inlet | |
| 16 | Brown Road | | | | | 1 house | Reserve (Waitara West) | | | | 1 Waahi Tapu site | | | | | | | | | |
| 17 | Waitara West | Battiscombe Trc, West Beach, Browne St Extn, | Storm water, waste water & water supply pipes | | | 10+ houses | Marine Park Reserve | | Boating club | | 1 Waahi Tapu site | Waitara Boating Club + Rock wall/groyne | | | | | | | | |
| 18 | Waitara East | East Beach Rd, Howard St, Mouatt St | Storm water, waste water & water supply pipes | | | 10+ houses | Waitara Golf Course | | | | 1 Waahi Tapu site | | | | | | | Dune | | |
| 19 | Waitara Golfcourse | | | | | | Waitara Golf Course | | | | | | | | | | | Dune | | |
| 20 | Motunui West | | | | Farm | | | | | | | | | | | | | | | |
| 21 | Motunui Cliffs | Otaraoa Rd + Epiha Rd | | | Methanex NZ | | Otaraua Road Esplanade Reserve | | | | 5+ Waahi Tapu sites | | | | | | | | | |
| 22 | Motunui East | Turangi Rd | | | | 4 houses | Turangi Rd Beach Reserve | | | | 3 Waahi Tapu Site | | | | | | | | | |
| 23 | Onaero West | Turangi Rd + Ongaero Beach Rd, Sutton Rd | Water supply and storm water pipes | | Farm | 20+ houses | Onaero Coastal Esplanade Reserve + Motukari Place + Onaero Beach Rd Reserve + Onaero Headland Esplanade Reserve | | | | 5+ Waahi Tapu sites | | | | | | | | | |
| 24 | Onaero R to Urenui R | | Water supply and waste water pipes | | Farm | | Onaero Domain Recreation Reserve + Kaipikari Esplanade Reserve | | | | | | | | | | | | Onaero River mouth + Urenui River mouth | |
| 25 | Urenui Bay | 1st, 2nd, 3rd, 4th,5th, 6th, 7th and 8th Ave, Urenui Domain | Water supply and waste water pipes | Urenui Beach Camp | | | Urenui Domain Recreation Reserve | | | | | | | | | | | | Urenui River mouth | |
| 26 | Urenui to Mimi | | | | Farm | 1 house | Beach Rd Reserve Urenui | | | | 4 Waahi Tapu sites | | | | | | | | | |
| 27 | Mimi River | Waitoetoe Road | | | Farm | 1 house | | | | | 4 Waahi Tapu sites | | | | | | | | Mimi estuary | |
| 28 | Mimi to Waiiti | | | | Farm | 5+ houses | Wai-iti Beach Reserves | | | | 5+ Waahi Tapu sites | | | | | | | | Mimi estuary | |
| 29 | Waiiti Stream | Beach Rd | | Waiiti Beach Retreat | Waiiti Café | 5+ houses | Wai-iti Beach Reserves | | | | 1 waahi Tapu site | | | | | | | | | |
| 30 | Waiiti to Whitecliffs | Gilbert Rd | Energy pipeline | | Farm | 3 houses | Pukearuhe Domain + White Cliffs Walkway | | | | 5+ Waahi Tapu sites | Wilkinson's Castle + Whiteley Memorial | | | | | | | | |
| 31 | Whitecliffs | | Energy pipeline | | | | | | | | | | | | | | | | White Cliffs + dune system | |
| 32 | Whitecliffs to Tongaporutu | Clifton Rd | Water supply + waste water pipes + energy pipeline | | Farm | 1 house | | | | | 5+ Waahi Tapu sites | | | | | | | | The Three Sisters + beach | |
| 33 | Tongaporutu to Rapanui | | Energy pipeline | | Farm | 2 houses | | | | | 2 Waahi Tapu sites | | | | | | | | | |
| 34 | Rapanui to Mohakatino | Mokau Rd (SH3) | Energy pipeline | | Farm | 4 houses | | | | | 5+ Waahi Tapu sites | | | | | | | | | |
| 35 | Mohakatino to Mokau | | Energy pipeline | | Farm | | | | | | 2 Waahi Tapu sites | | | | | | | | | |

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