REPORT

Coastal Protection Areas Re-assessment

Stage Two

Prepared for:

Western Bay of Plenty District Council

April 2015

Job No: 851833

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Executive summary

The Western Bay of Plenty District Council has commissioned Tonkin & Taylor Ltd to undertake a review of the Primary and Secondary Risk Coastal Protection Areas currently implemented in the Western Bay of Plenty District Plan for both Waihi Beach and Pukehina.

The Coastal Protection Areas represent properties susceptible to coastal hazard including both erosion and inundation. The Coastal Protection Areas were first introduced into the District Plan via the 1994 notification of the first Proposed District Plan which became Operative in 2002. The delineation of the Coastal Protection Areas was based on a technical report prepared for Council by Professor Terry Healy in 1993 (Healy, 1993). Council required the Coastal Protection Areas to be re-assessed in line with the current state of scientific knowledge, relevant legislation and best practice guidelines.

The New Zealand Coastal Policy Statement is a national policy statement under the Resource Management Act 1991. The New Zealand Coastal Policy Statement states policies in order to achieve the purpose of the Act in relation to the coastal environments of New Zealand. The Bay of Plenty Regional Council proposed Regional Coastal Environment Plan gives effect to the New Zealand Coastal Policy Statement. The re-assessment methodology used for this project has been developed in accordance with the Objectives and Policies of the New Zealand Coastal Policy Statement and the proposed Regional Coastal Environment Plan directly relevant to the assessment of coastal hazard.

This study has re-assessed the coastal hazard extent based on a similar method developed by Healy, where both the coastal erosion and inundation hazard have been assessed. Two planning timeframes were applied to identify the coastal hazard extent at sufficient time scales for planning and accommodating future development:

- 2065 (50 years)
- 2115 (100 years).

The methodology used in this study to assess the coastal erosion hazard combines standard and well-tested approaches for defining the coastal erosion hazard extent by addition of four erosion components. This method has been refined to include component bounds which are combined by stochastic simulation. The resulting distribution is a probabilistic forecast of potential hazard zone width, rather than including single values for each component and one overall factor for uncertainty. This probabilistic method produces a range of hazard zones corresponding to differing likelihoods which may be applied to risk-based assessments as advocated by the New Zealand Coastal Policy Statement and supported by best practice guidelines.

Waihi Beach and Pukehina were divided into coastal behavioural cells based on shoreline composition and morphology which can influence the resultant hazard. The full probability distribution range of coastal erosion hazard distances was calculated at a coastal cell level for both timeframes.

Following consultation with Council, the coastal erosion hazard value with a 66% likelihood of being exceeded within the timeframe was selected for 2065. The coastal erosion hazard value with a 5% likelihood of being exceeded by the timeframe was selected for 2115. These two scenarios are adopted as prudent *likely* and *potential* coastal erosion hazard values respectively. The likelihood terms of *likely* and *potential* are consistent with the NZCPS policies on coastal hazards. The values were mapped with respect to the adopted baseline to identify the extent of coastal erosion hazard over the two timeframes.

The coastal inundation hazard extent was identified as an elevation level based on the combination of the inundation components relevant to both the open coast and estuary coast environments. The estuary coast at Pukehina is located on the inner spit shoreline and is susceptible to coastal inundation. The low lying areas located at the north of Waihi Beach and the land adjacent to the mouth of Two and Three Mile Creek are also susceptible to coastal inundation hazard.

The final step of the review process involves Council right-aligning the re-assessed CEHZ and CIHZ delineation to the landward edge of current property boundaries to check where the existing CPA may need to be edited to either include or exclude properties as required.

We recommend continuing to regularly monitor the shoreline position across the region to provide data to track and verify shoreline position over time and its response to storms and climate change. This should include continuing beach profile monitoring and digitising shorelines from aerial imagery or by GPS survey. We also recommend the adopted CIHZ and CEHZ values are reassessed at least every 10 years or following significant changes in either legislation or best practice and technical guidance.

1 Introduction

The Western Bay of Plenty District Council (Council) has commissioned Tonkin & Taylor Ltd (T&T) to undertake a review of the Primary and Secondary Risk Coastal Protection Areas (CPA) currently implemented in the Operative Western Bay of Plenty District Plan First Review (Operative District Plan) for both Waihi Beach and Pukehina.

The CPA represent properties susceptible to coastal hazard including both erosion and inundation. The CPA were first introduced into the District Plan via the 1994 notification of the first Proposed District Plan which became Operative in 2002. The delineation of the CPA was based on a technical report prepared for Council by Professor Terry Healy in 1993 (Healy, 1993). The existing methodology developed by Healy (1993) is a building block approach that delineated a coastal hazard zone (CHZ) by summing the following four components:

- Long-term shoreline erosion or accretion trend
- Short-term duneline fluctuation, representing the maximum observed cyclical fluctuation of extreme storm cuts
- Dune line retreat response due to the projected sea level rise
- Dune stability factor.

The summation of these four components represent the coastal erosion hazard. Healy (1993) calculated the coastal inundation hazard based on a flood level along the open coast. The CHZ delineation was extended inland where the summation of the coastal erosion hazard components did not reach the inundation level contour. Therefore, the final CHZ produced by Healy (1993) accounted for both coastal erosion and inundation for a 100 year timeframe.

The delineation of the CHZ produced by Healy (1993) were right-aligned to the landward edge of the property boundaries by Council for District Plan mapping purposes and defined as the CPA. Figure 1-1 shows the relationship between the CHZ and the CPA.

The CPA was later split by Council into the two existing zones defined as Primary and Secondary Risk. This Secondary Risk CPA is directly based on the CHZ produced by Healy (1993) and represents the properties potentially susceptible to coastal erosion and inundation hazard over a 100 year planning period (i.e. up to 2093). The Primary Risk CPA represents properties currently susceptible to coastal erosion hazard only (i.e. inundation was not considered for this timeframe). The Primary Risk CPA was mapped by Council based on the combination of the components calculated by Healy (1993) for short-term fluctuation and dune stability only.

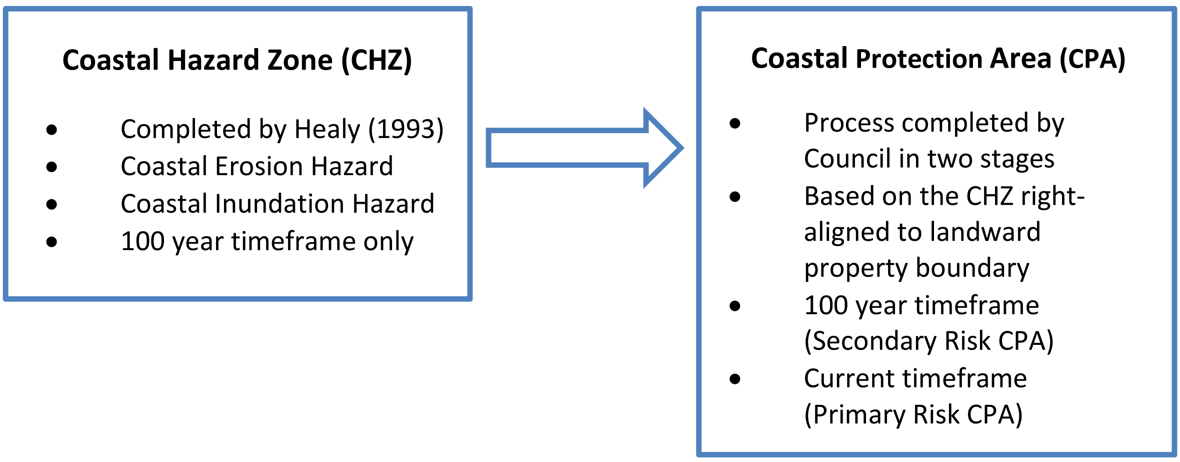

Figure 1-1 Relationship diagram for Coastal Hazard Zone completed by Healy (CHZ) and Coastal Protection Area completed by Council (CPA)

T&T have undertaken the review of the existing CPA in two stages. Stage One completed a technical review of the existing CPA to assess whether they are in accordance with the current state of scientific knowledge and best practice guidelines (T&T, 2015). The Stage One review recommended that the existing CPA are re-assessed based on the following developments:

- **Components** - Development of the current state of scientific knowledge and analysis techniques and the extended observations within datasets require the four components to be revised.
- **Methodology** - Best practice guidance (Envirolink, 2012) recommends adopting a probabilistic method that provides a more transparent way of capturing and presenting uncertainty and can be used for risk based assessments.
- **Mapping** – Healy (1993) divided Waihi Beach into five cells and Pukehina was assessed as one cell. Cells are used to define a length of shoreline within each site with similar morphological characteristics (e.g. dune height, historical shoreline movement trends). The two sites could be split into a greater number of cells based on the increased accuracy of the analysis techniques developed since the Healy assessment (1993). The origin[1] of the CPA delineation should also be re-surveyed as the current toe of foredune.

This report documents the method and results of the Stage Two CPA review, which includes re-assessing the existing CPA to incorporate the three key developments identified above. The main purpose of Stage Two is to develop a new delineation of both the coastal erosion and inundation hazard extents for both Waihi Beach and Pukehina. Two planning timeframes were applied to identify the coastal hazard extent at sufficient time scales for planning and accommodating future development:

- 2065 (50 years)
- 2115 (100 years).

[1] The origin is the starting point to which the CPA distance is measured inland.

2 Background information

2.1 Statutory legislation

2.1.1 New Zealand Coastal Policy Statement

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

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

- Policy 3 - requires a precautionary approach in the use and management of coastal resources potentially vulnerable to effects from climate change so that avoidable social and economic loss and harm to communities does not occur.
- Policy 24 - identify areas in the coastal environment that are ***potentially*** affected by coastal hazards (including tsunami) and giving priority to the identification of areas at high risk of being affected. These should take into account natural guidance and the best available information on the likely effects of climate change for each region.
- Policy 25 - promotes avoiding increasing the risk of social, environmental and economic values to erosion hazard in areas ***potentially*** affected by coastal hazards over at least the next 100 years.
- Policy 27 - promotes reducing hazard risk in areas of significant existing development ***likely*** to be affected by coastal hazards.

2.1.2 Regional Policy Statement

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

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

  (a) A 100 year timeframe;

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

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

2.1.3 Proposed Regional Coastal Environment Plan

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

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

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

2.2 Coastal processes

2.2.1 Water levels

Water levels play an important role in determining coastal erosion hazard both by controlling the amount of wave energy reaching the backshore causing erosion during storm events and by controlling the mean shoreline position on longer time scales.

Key components that determine water level are:

- Astronomical tides
- Barometric[2] set-up and wind effects, generally referred to as storm surge
- Medium term fluctuations, including El Nino-Southern Oscillation (ENSO) and Inter-decadal Pacific Oscillation (IPO) effects
- Long-term changes in sea level due to climate change
- Wave transformation processes through wave setup and run-up.

2.2.1.1 Astronomical tide

Tidal levels for primary and secondary ports of New Zealand are provided by Land Information New Zealand (LINZ) based on the average predicted values over the 18.6 year tidal cycle. Values for Port Tauranga in terms of Chart Datum and Moturiki Vertical Datum 1953 (MVD-53 RL) are presented within Table 2-1.

Table 2-1 Tidal levels given for Tauranga (LINZ, 2012)

Tide state	Chart Datum (m)	MVD53 (RL)
Highest Astronomical Tide (HAT)	2.11	1.15
Mean High Water Springs (MHWS)	1.94	0.98
Mean High Water Neaps (MHWN)	1.66	0.70
Mean Sea Level (MSL)	1.07	0.11
Mean Low Water Neaps (MLWN)	0.45	-0.51
Mean Low Water Springs (MLWS)	0.15	-0.81
Lowest Astronomical Tide (LAT)	-0.08	-1.04

Source: LINZ Nautical Almanac 2012 – 13

[2] Atmospheric pressure has an effect on water levels. Low atmospheric pressure results in higher water levels termed barometric set-up.

2.2.1.2 Storm surge

Storm surge results from the combination of barometric setup from low atmospheric pressure and wind stress from winds blowing along or onshore which elevates the water level above the predicted tide (Figure 2-1). Storm-surge applies to the general elevation of the sea above the predicted tide across a region but excludes nearshore effects of storm waves such as wave setup and wave run-up at the shoreline.

Previous studies of storm surge around New Zealand's coastline have concluded that storm surge appears to have an upper limit of approximately 1.0 m (Hay, 1991; Heath, 1979; Bell et. al, 2000). Given the perceived upper limit of storm surge for New Zealand, a standard storm surge of 0.9 m is considered representative of a return period of 80 to 100 years (MFE, 2004).

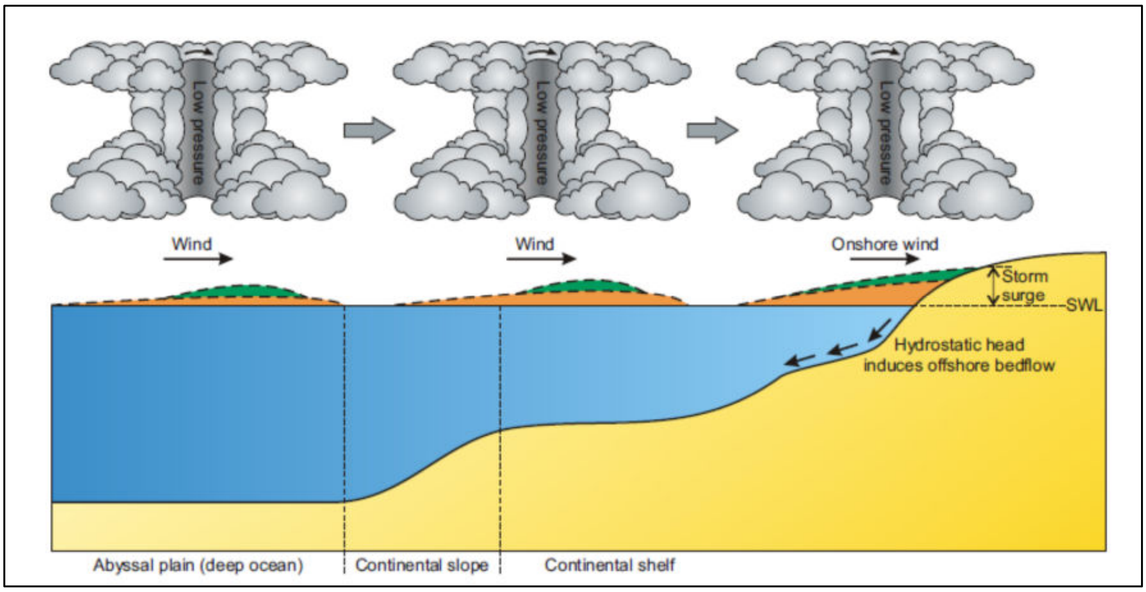

Figure 2-1 Processes causing storm surge (source: Shand, 2010)

2.2.1.3 Medium term fluctuations and cycles

Atmospheric factors such as season, El Nino-Southern Oscillation (ENSO)[3] and Inter-decadal Pacific Oscillation (IPO)[4] can all affect the mean level of the sea at a specific time (refer to Figure 2-2). The combined effect of these fluctuations may be up to 0.25 m according to the National Institute of Water and Atmospheric Research (NIWA, 2011).

[3] El Nino Southern Oscillation - natural climate fluctuation in relation to water temperature and surface pressure. El Nino conditions in New Zealand generally result in stronger and more frequent westerly winds. Conversely, La Nina conditions generally result in more north-easterly winds and higher water levels along the north east coast of New Zealand.

[4] Inter-decadal Pacific Oscillation - longer term recurring pattern of ocean-atmosphere climate variability detected as either warm or cool surface waters in the Pacific Ocean. During a "warm" or "positive" phase, the west Pacific becomes cooler and part of the eastern ocean warms. During a "cool" or "negative" phase, the opposite pattern occurs.

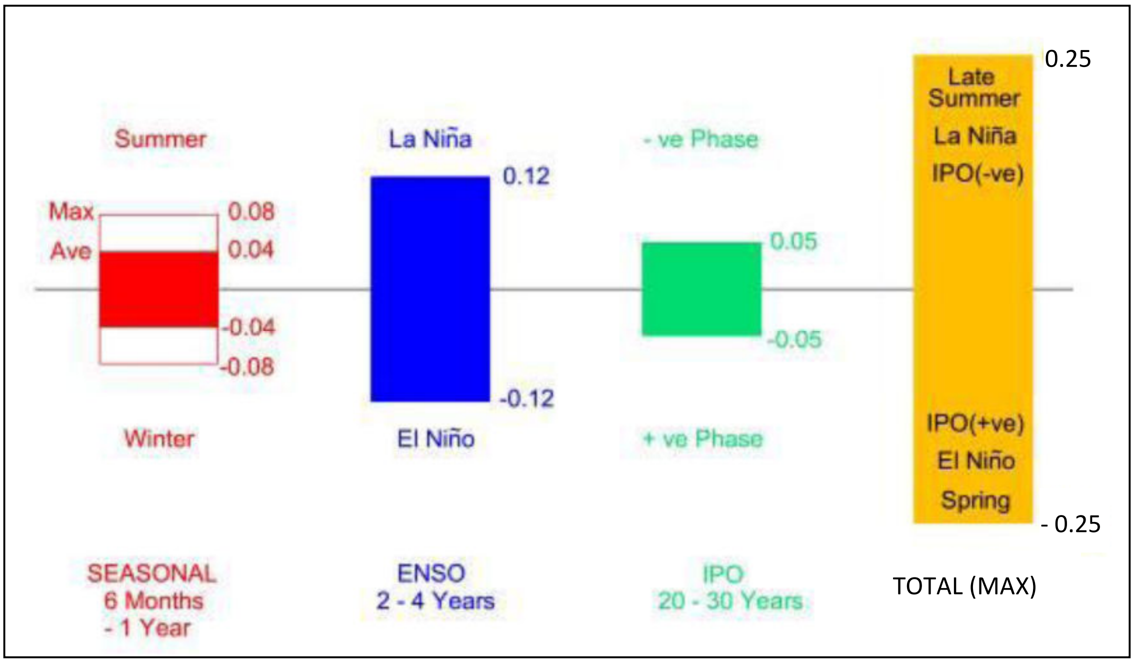

Figure 2-2 Components contributing to sea level variation over long term periods (source: Bell, 2012)

2.2.1.4 Storm tide levels

The combined elevation of the predicted tide, storm surge and medium term fluctuations is known as the storm tide. Extreme storm tide levels predicted for the open coast and the estuary coast are shown in Table 2-2. The storm tide levels are presented for both a 2% Annual Exceedance Probability (AEP) and 1% AEP events.

Table 2-2 Extreme storm tide

Site	Storm tide level (RL m)	
	2% AEP	1% AEP
Moturiki Island (open coast)[1]	1.78	1.99
Tauranga Port Tug Berth (estuary coast)[2]	1.51	1.57

[1]Based on NIWA (1997)

[2]Based on T&T (2008)

2.2.1.5 Long-term sea levels

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

The Ministry for the Environment (2008) guideline recommends a base value sea level rise of 0.5 m by 2100 (relative to the 1980-1999 average) with consideration of the consequences of sea level rise of at least 0.8 m by 2100 with an additional sea level rise of 10 mm per year beyond 2100. Bell (2013) recommends that for planning to 2115, these values are increased to 0.7 and 1.0 m respectively (relative to 2015). Bell (2013) also recommends that when planning for new activities or developments, that higher potential rises of 1.5 to 2 m above the present mean sea level should be considered to cover the foreseeable climate-change effects beyond a 100 year period.

Modelling presented within the most recent International Panel of Climate Change (IPCC) report (AR5; IPCC, 2014) show predicted global sea level rise values by 2100 (relative to the 1980-1999 average) to range from 0.27 m to 1 m. The IPCC sea level rise projections range depending on the emission scenario adopted, with the lower bound of 0.27m being slightly above the rate of rise over the previous 100 years. Extrapolating[5] the RCP8.5 scenario ("business as usual") to 2115 results in a sea level range from 0.27 to 0.47 m by 2065 and 0.62 to 1.27 m by 2115 (Figure 2-3). The RCP8.5 scenario assumes emissions continue to rise in the 21st century on a "business as usual" scenario. Adopting this scenario is considered prudent until evidence of emission stabilising justify use of a lower projection scenario.

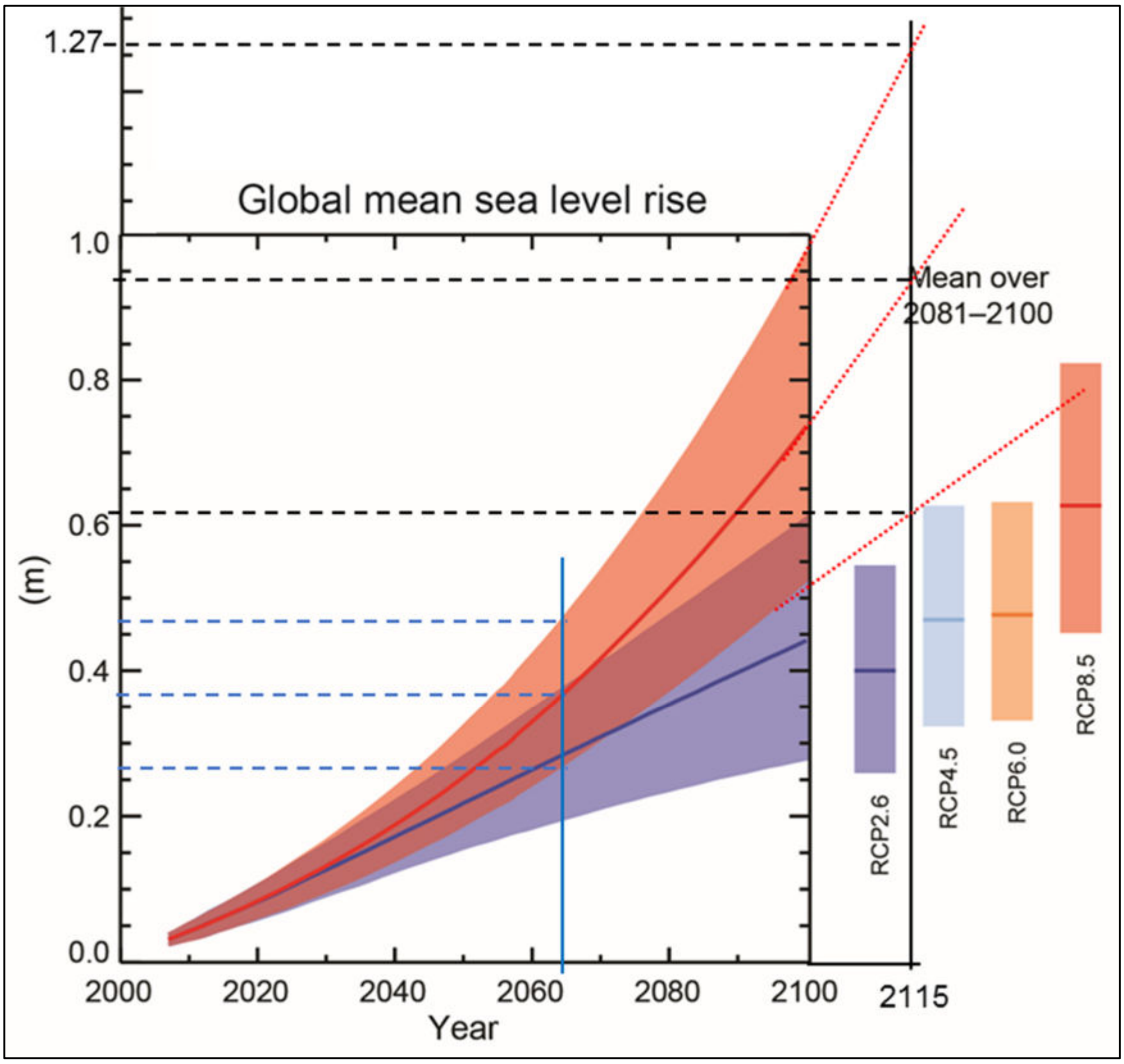

Figure 2-3 Projections of potential future sea level rise presented within IPCC AR5 (IPCC, 2014), with adopted values for this assessment at 2065 and extrapolated to 2115 for the RCP8.5 scenario

2.2.2 Waves

The east coast of the North Island is affected by sub-tropical lows and by systems of tropical origin descending towards the north of New Zealand as tropical or ex-tropical cyclones. Offshore wave

[5] Estimate a value outside the observed range by extending the trend line to the required timeframe.

data for both Waihi Beach and Pukehina have been modelled by NIWA (2013) as shown in Table 2-3. The 10 year and 100 year Annual Return Interval (ARI) for both Waihi Beach and Pukehina are used in this study for assessment storm cut erosion. The 10 year ARI represents a moderate storm event and a 100 year ARI represents a more extreme event.

Table 2-3 Significant wave height

Site	Extreme wave height (m)	
	10 year ARI	100 year ARI
Waihi Beach	4.6	5.3
Pukehina	6.0	7.0

2.3 New data collection

The coastal erosion hazard assessment required new data to be collected to re-assess shoreline change over both the short and long-term. The main data required includes historic shorelines, beach profiles and LiDAR[6].

2.3.1 Shorelines

The historical shoreline data was processed from aerial images using standard geo-referencing and digitising GIS methods using ArcGIS software. Available vertical aerial photographs were sourced from Council and additional photographs were supplied by New Zealand Aerial Mapping (NZAM). Refer to Table 2-4 for a summary of the historic aerial photographs sourced for this study.

Table 2-4 Summary of historic aerial photographs sourced to produce digital shoreline data

Site	Source	Date	Reference	Scale
Pukehina	NZAM	13/03/1943	670/10	1:16,000
Pukehina	NZAM	13/03/1943	670/08	1:16,000
Pukehina	NZAM	13/03/1943	670/06	1:16,000
Pukehina	NZAM	10/06/1948	503/142	1:16,000
Pukehina	Council	23/01/1964	106239	1:16,000
Pukehina	Council	23/01/1964	106240	1:16,000
Pukehina	Council	23/01/1964	106241	1:16,000
Pukehina	Council	5/08/1992	2382	1:20,000
Pukehina	Council	5/08/1992	2382	1:20,000
Pukehina	Council	5/08/1992	2382	1:20,000
Pukehina	Council	5/08/1992	2382	1:20,000
Waihi Beach	NZAM	16/11/1942	489/45	1:16,000
Waihi Beach	NZAM	16/11/1942	489/44	1:16,000

[6] Light Detection and Ranging (LiDAR) - laser based survey which provides elevation spot heights of the ground surface.

Site	Source	Date	Reference	Scale
Waihi Beach	NZAM	16/11/1942	488/42	1:16,000
Waihi Beach	NZAM	16/11/1942	487/39	1:16,000
Waihi Beach	Council	7/04/1960	121/1	1:16,000
Waihi Beach	Council	7/04/1960	121/3	1:16,000
Waihi Beach	Council	7/04/1960	121/5	1:16,000
Waihi Beach	Council	7/04/1960	121/6	1:16,000
Waihi Beach	Council	28/03/1964	108168	1:16,000
Waihi Beach	Council	12/04/1975	B135 SN3798 G/26	1:16,000
Waihi Beach	NZAM	1/03/1975	E/26	1:25,000
Waihi Beach	Council	31/08/1992	2381	1:20,000
Waihi Beach	Council	31/08/1992	2381	1:20,000
Waihi Beach	Council	31/08/1992	2381	1:20,000
Waihi Beach	Council	31/08/1992	2381	1:20,000

Although this data set of historical imagery existed prior to the Healy (1993) assessment, the digital alignment of the dune toe was not captured at that time and therefore all historical imagery has been re-assessed.

The seaward edge of the dune vegetation was digitised to represent the dune toe, which was taken as the shoreline proxy. This shoreline proxy was chosen because the change in contrast from dune vegetation to beach sand can more accurately be identified on the historic black and white aerial photographs rather than the water line. Verification and quality control focused on the accuracy of the shoreline representation including the position and frequency of the polyline nodes.

The Bay of Plenty Regional Council survey team surveyed the current 2014 dune toe (supervised by Mark Ivamy, T&T Senior Coastal Scientist). The survey was captured by RTK-GPS and included the full extent of both sites.

This set of shoreline information provides four time-periods spaced approximately every 20 years for analysing long-term trends over a 72-year period (1942 – 2014). The aerial imagery captured under the BOPLAS agreement in 2011 was not considered for this assessment because the dune toe surveyed in 2014 using RTK-GPS was considered more accurate.

2.3.2 Beach profiles

The Bay of Plenty Regional Council undertake cross-section surveys from the upper dune down to around the mean sea level contour. The cross-sections are termed beach profiles and are surveyed at a number of section locations along each site (refer to Appendix A maps for the beach profile locations). Waihi Beach has a total of nine beach profile sections and Pukehina has a total of four. Each of the beach profile sections are surveyed approximately four times a year to enable analysis of changes in beach levels over time. A summary of the beach profile dataset for both sites is provided in Table 2-5.

Table 2-5 Summary of beach profile data

Site	Section	Total number of profiles	Number of profiles used	Surveys		
				Start Date	End Date	Years
Waihi Beach	CCS54	60	57	25/08/1998	24/02/2014	15
	CCS53	58	58	10/12/1996	24/02/2014	17
	CCS52	60	60	10/12/1996	24/02/2014	17
	CCS51	75	73	23/01/1978	24/02/2014	36
	CCS50a	40	40	27/11/2003	24/02/2014	10
	CCS50	73	70	23/01/1978	24/02/2014	36
	CCS49	72	70	23/01/1978	24/02/2014	36
	CCS48	66	65	23/01/1978	24/02/2014	36
	CCS47	79	67	23/01/1978	24/02/2014	36
Pukehina	CCS29	91	88	31/10/1977	5/03/2014	36
	CCS28	89	88	3/02/1978	5/03/2014	36
	CCS27	120	108	2/02/1977	5/03/2014	37
	CCS26	79	79	9/03/1990	5/03/2014	24

The beach profiles were imported and processed in the Beach Morphology Analysis Package (BMAP) software. Figure 2-4 shows an example of the available (60 surveyed) beach profiles for Waihi Beach Surf Club section (CCS52). The figure shows the dune located at around the 0 m distance position with an elevation of around 4.5 m above mean sea level. The beach profiles were generally surveyed to a distance of approximately 200 m offshore.

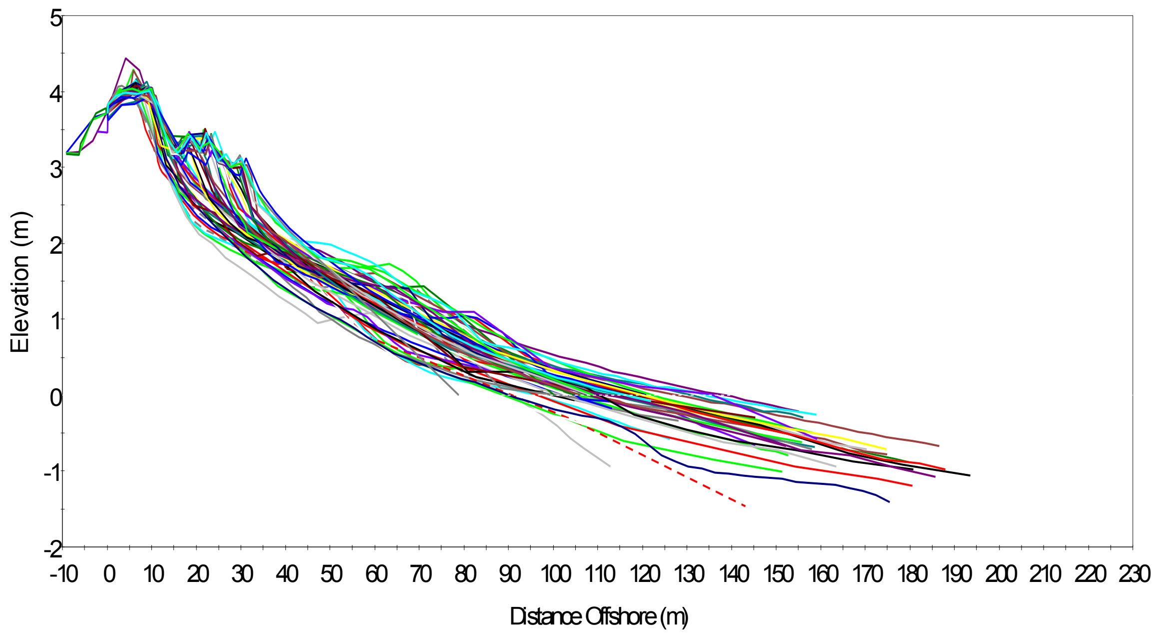

Figure 2-4 Example the beach profile dataset for Waihi Beach Surf Club

2.3.3 LiDAR

Council sourced LiDAR data was processed in GIS using ArcGIS software (Spatial Analyst Licence) to form a digital elevation model (DTM) for both sites. The LiDAR survey was undertaken in 2011. The generated DTM has a grid cell size of 1 m by 1 m. Dune crest elevations were extracted from the DTM as a 3D polyline along the dune crest alignment using standard transect methods with a node spacing of 1 m. LiDAR was also used to establish the elevation of the dune toe for both sites. This information is required for the shoreline change analysis of the beach profile datasets.

3 Previous assessment methodology (Healy, 1993)

The existing CPA are based on a deterministic coastal hazard zone (CHZ) approach developed by Healy (1993) outlined in Equation 2-1. The method first combines a number of components that estimate coastal erosion along the open coast.

$$CHZ = R + (2S_{max}) + X + D \quad (3\text{-}1)$$

Where:

CHZ = Linear distance measured inland from a reference point taken as the toe of the frontal dune

R = Long-term shoreline erosion or accretion rate trend

S_{max} = Decadal term duneline fluctuation, representing the maximum observed cyclical fluctuation of extreme storm cuts within the past 50 years

X = Dune line retreat response due to the projected sea level rise. The response is calculated using the modified Bruun Rule where the rate of sea level rise is multiplied by the slope from the dune crest to the closure depth

D = Dune stability factor.

A factor of safety of 2 was applied to the short-term erosion component to allow for uncertainty. A factor of safety of 2 results in the measurement of the short-term erosion component being doubled. No factor was applied to other components therefore the range of expected values and uncertainty for the other three components is unknown.

Equation 2-1 was used to delineate the extent of land potentially at risk from coastal erosion hazard over a 100 year planning timeframe. Healy (1993) calculated the coastal inundation hazard based on a flood level along the open coast. The CHZ delineation was extended inland where the total of the components did not reach the inundation level contour. Therefore the final CHZ produced by Healy (1993) accounted for both coastal erosion and inundation.

The delineation of the CHZ produced by Healy (1993) were right-aligned to the landward edge of the property boundaries by Council for District Plan mapping purposes and defined as the CPA (Figure 1-1). The CPA was later split by Council into the two existing zones defined as Primary and Secondary Risk. This Secondary Risk CPA is directly based on the CHZ produced by Healy (1993) and represents the properties potentially susceptible to coastal erosion and inundation hazard over a 100 year planning period from the date of the report (i.e. up to 2093). The Primary Risk CPA represents properties currently susceptible to coastal erosion hazard only (i.e. inundation was not considered for this timeframe). The Primary Risk CPA was mapped by Council based on the combination of the components calculated by Healy (1993) for short-term fluctuation (S_{max}) and dune stability (D) only. Note the Primary Risk CPA is also right-aligned to the landward property boundaries as mapped in the Operative District Plan.

Healy (1993) divided the Waihi Beach site into five different cells based primarily on dune morphology. The four CPA components were assessed individually for each of the five cells. Note the second cell from the north represented the section along Shaw Road which comprised a seawall shoreline. The S_{max} component was omitted from the CPA calculation for both the Primary and Secondary Risk CPA along this cell due to the assumption that the seawall would mitigate the short-term erosion component. Pukehina was treated as a single cell with the one set of components assessed for the entire extent.

Refer to the Stage One report for further review of the previous methodology (T&T, 2015).

4 Re-assessment methodology (T&T)

The existing CPA mapped in the Operate District Plan identifies properties potentially susceptible to coastal erosion and inundation hazard based on the Healy (1993) report. This study has re-assessed the coastal hazard extent based on a similar method developed by Healy, where both the coastal erosion and inundation hazard have been assessed.

For the purposes of this study, the coastal erosion hazard and coastal inundation extents are referred to as the coastal erosion hazard zone (CEHZ) and coastal inundation hazard zone (CIHZ) respectively. The method used in the re-assessment study to delineate the CEHZ is described in Section 4.1. The method used in the re-assessment to delineate the CIHZ is described in Section 4.8.

4.1 Coastal erosion hazard zone (CEHZ) delineation

The re-assessment method for delineating the CEHZ is established from the cumulative effect of four main parameters (plus timeframe) as defined in Equation 4-1 and illustrated in Figure 4-1. These components are further explained in Sections 4.3.1 to 4.3.5. T&T developed this method for use on unconsolidated sandy coastlines, such as Waihi Beach and Pukehina.

$$CEHZ = ST + DS + (LT \times T) + SL \qquad (4\text{-}1)$$

Where:

ST	=	Short-term changes in horizontal shoreline position related to storm erosion due to singular or a cluster of storms events or fluctuations in sediment supply and demand, beach rotation and cyclical changes in wave climate (m)
DS	=	Dune stability allowance. This is the horizontal distance from the base of the eroded dune to the dune crest at a stable angle of repose (m)
LT	=	Long term rate of horizontal coastline movement (m/yr)
T	=	Timeframe (years), for example 100 years from the present, projecting to 2115
SL	=	Horizontal coastline retreat due to the effects of increased mean sea level (m).

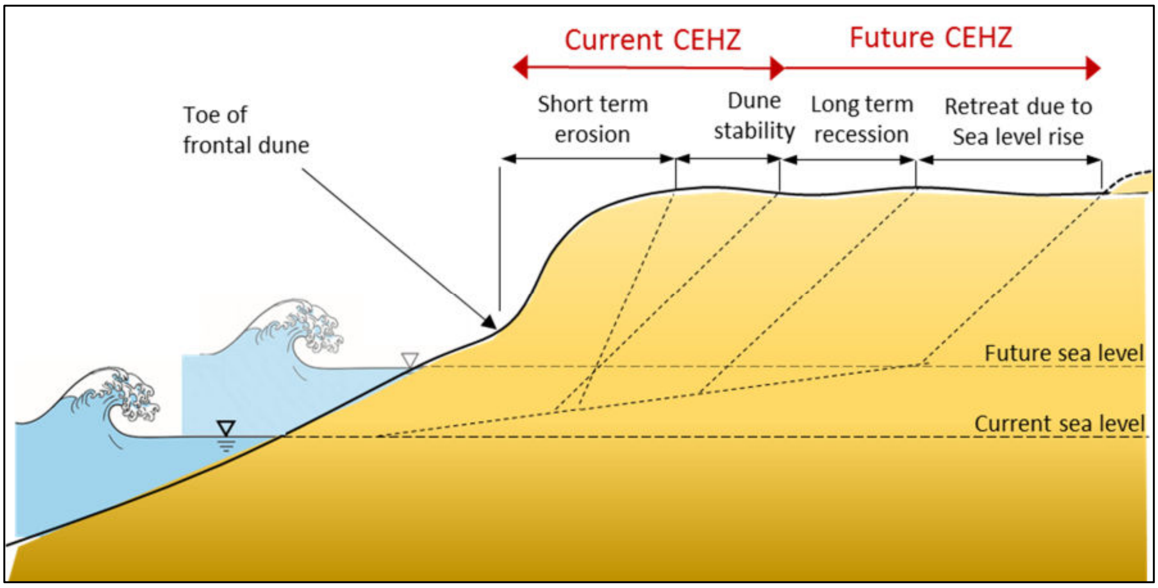

Figure 4-1 Definition sketch for open coast CEHZ

This method combines standard and well-tested approaches for defining coastal erosion hazard zones by addition of component parameters. However, rather than including single values for each component and a factor for uncertainty, component bounds are specified for each component and combined by stochastic[7] simulation. The resulting distribution is a probabilistic forecast of potential erosion hazard zone width at specified periods in time.

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

The probabilistic method is described in Cowell et al. (2006). The methods used to define probability distribution functions (pdfs) for each component are described within the component descriptions below. Where pdfs are not defined empirically (i.e. based on data or model results), simple triangular distributions have been assumed with bounding (minimum and maximum) and modal parameters (Figure 4-2). Figure 4-2 also shows the output displayed in cumulative distribution format (cdf).

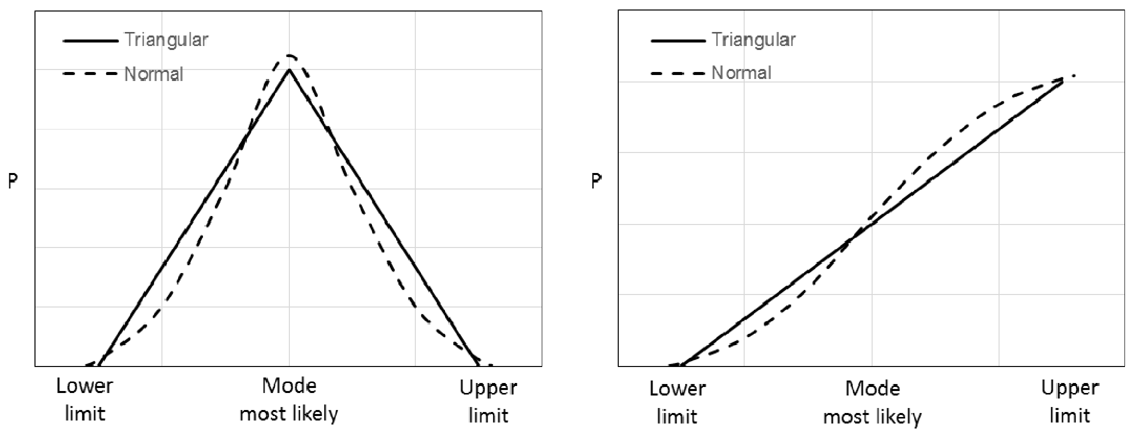

Figure 4-2 Example triangular and normal pdf (left) and cdf (right)

The CEHZ is measured horizontally inland from the 2014 dune toe and is mapped independently of the property boundaries. Council may decide to revise the existing CPA based on right aligning the re-assessed CEHZ delineation to the landward edge of property boundaries.

4.2 Defining coastal behaviour cells

Both the Waihi Beach and Pukehina sites have been divided into coastal behaviour cells (cells) based on shoreline composition and behaviour which can influence the resultant hazard. The four components defined in Equation 4-1 are calculated separately for each cell. This is similar to Healy's (1993) method, however a greater number of cells have been created based on the collection of the new data (refer to Section 2.3). The factors which influence the behaviour of a cell and which are the basis for the cell division include:

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[7] When stochastic modelling is used, the outcome is not deterministic anymore, but instead is a forecast with a certain probability of occurrence.

- cell morphology and lithology
- exposure
- profile geometry
- backshore elevation
- historic shoreline trends.

Waihi Beach is now separated into 11 cells (A to K) and Pukehina has been separated into 3 cells (refer to Table 4-1 and Appendix A for a spatial representation). Table 4-1 shows the chainage for each individual cell as a spatial reference point. Chainage is a distance measurement from a fixed point taken as the north west end of each site.

The cell type has also been identified as either dune or inlet. The dune cell type represents the majority of the length of both sites which are typically characterised by a foredune and flat sandy beach.

There are four cells identified as the inlet cell type which include the streams that exit out on to Waihi Beach. The inlet cells represent shorelines that typically fluctuate more over time due to fluvial processes. The inlet cells were assessed using the same methodology to delineate the CEHZ, except the baseline was taken as the inlet migration curve (IMC) rather than the 2014 dune toe. The IMC is the maximum inland extent of shoreline fluctuation (envelope) over the extent of the cell (refer to Section 4.4).

Table 4-1 Cell division for both sites

Site				
Name	**No.**	**Cell**	**Cell type**	**Chainage (m from NW end)**
Waihi Beach	1	A	Inlet	0-300
Waihi Beach	1	B	Inlet	300-900
Waihi Beach	1	C	Dune	900-1300
Waihi Beach	1	D	Dune	1300-1800
Waihi Beach	1	E	Inlet	1800-2300
Waihi Beach	1	F	Dune	2300-2700
Waihi Beach	1	G	inlet	2700-3100
Waihi Beach	1	H	Dune	3100-5000
Waihi Beach	1	I	Dune	5000-7000
Waihi Beach	1	J	Dune	7000-8000
Waihi Beach	1	K	Dune	8000-9000
Pukehina	2	A	Dune	0-900
Pukehina	2	B	Dune	900-1800
Pukehina	2	C	Dune	1800-6000

We note cell 1I is the area of Council reserve land located between Waihi Beach settlement and Bowentown and has not been assessed.

4.3 Component derivation

The five components defined in Equation 4-1 have been derived separately for each of the cells within the two sites. A full description of the methods used to derive the individual components is outlined in the Sections below.

4.3.1 Short-term (ST)

Short-term effects apply to non-consolidated sandy beach systems where rebuilding follows periods of erosion. These effects include changes in horizontal shoreline position due to storm erosion caused by singular or clusters of storms events, or seasonal fluctuations in wave climate or sediment supply and demand.

The short-term coastline movements have been assessed from analysis of:

- existing information sources such as previous reports and anecdotal evidence
- statistical analysis of shoreline position obtained from aerial photographs or beach profile analysis
- numerical model assessment of storm erosion potential.

4.3.1.1 Anecdotal or experience-based

Existing information presented within previous studies has often been derived based on anecdotal or field evidence or experience. Maximum erosion excursions of up to 18-20 m have been reported (Healy, 1993) at Bowentown, although these are generally considered at the upper end of potential storm cut. Therefore, these existing values were retained as the upper bound for short term erosion at the Bowentown end of Waihi Beach and also for Pukehina.

4.3.1.2 Statistical methods

The horizontal position of shorelines derived from aerial photographs or contours (typically the dune toe elevation) extracted from profile analysis can be used where available to assess short-term fluctuation.

The Beach Morphology Analysis Package (BMAP) has been used to calculate the change in horizontal shoreline position per surveyed beach profile. BMAP is an integrated set of computer analysis routines compiled at the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center (CERC) for analysing beach profile morphology and its change (Larson and Kraus 1992).

Figure 4-3 shows an example of the available (60 surveyed) beach profiles for Waihi Beach Surf Club (CCS52 – refer to Table 2-5). Each of the beach profiles are surveyed from a benchmark offshore to around the low tide line. The surveyed distance offshore is shown on the x-axis and the survey elevation is plotted in the y-axis. Figure 4-3 shows the fluctuation of the beach profile elevation, which has a vertical envelope of movement of approximately 1 m. The excursion of the RL 2m contour, which is approximately the dune toe, has been assessed in BMAP to provide a plot of contour position over time (Figure 4-4). For assessing short-term erosion cut, the data is de-trended to remove any long-term effects leaving residual excursion distances (Figure 4-5).

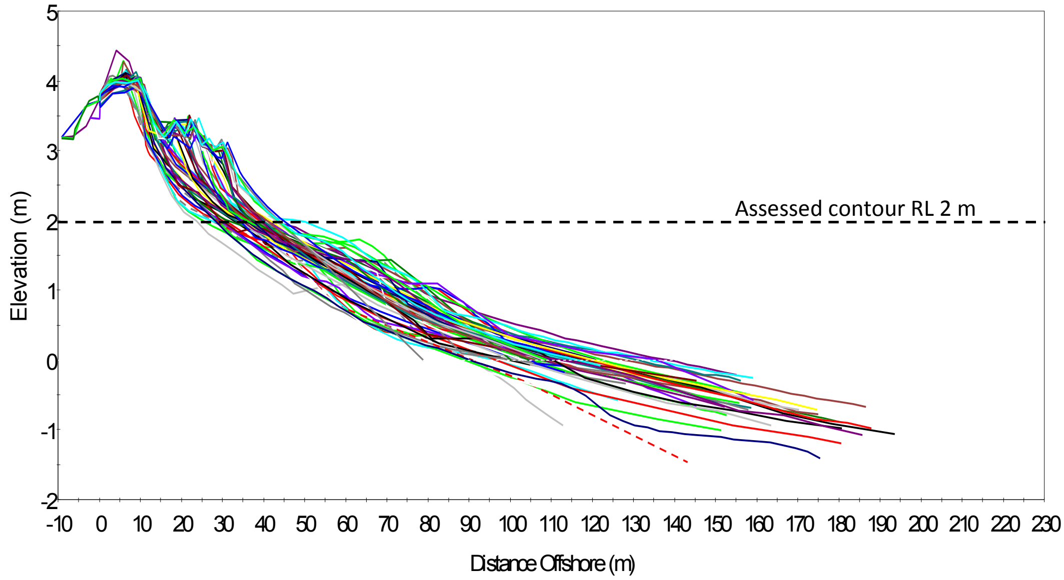


Figure 4-3 Example beach profiles for Waihi Beach Surf Club (each colour line represents a beach profile survey within the 1993-2014 dataset)

A negative residual represents an erosion event measured landward from the de-trended (projected) shoreline position. The maximum negative residual is -4.6 m for the CCS52 beach profile site (Figure 4-5). The maximum landward extent within the residual analysis was interpreted as the lower bound value for the short-term erosion component. A check was also made against the SBEACH results, which were used as a minimum value for the lower bound.

The standard deviation of residual describes the spread of the de-trended excursion distances. Previous work by Tonkin & Taylor (T&T, 2004; T&T 2006) found that the distribution of annual residual shoreline movement could be considered to be approximately normally distributed. The values at 1 standard deviation (SD), 2 x SD and 3 x SD from the mean will have corresponding annual probabilities of occurrence of 16%, 2.5%, and 0.5% respectively. The Waihi Beach and Pukehina beach profile datasets also display normally distributed residual values.

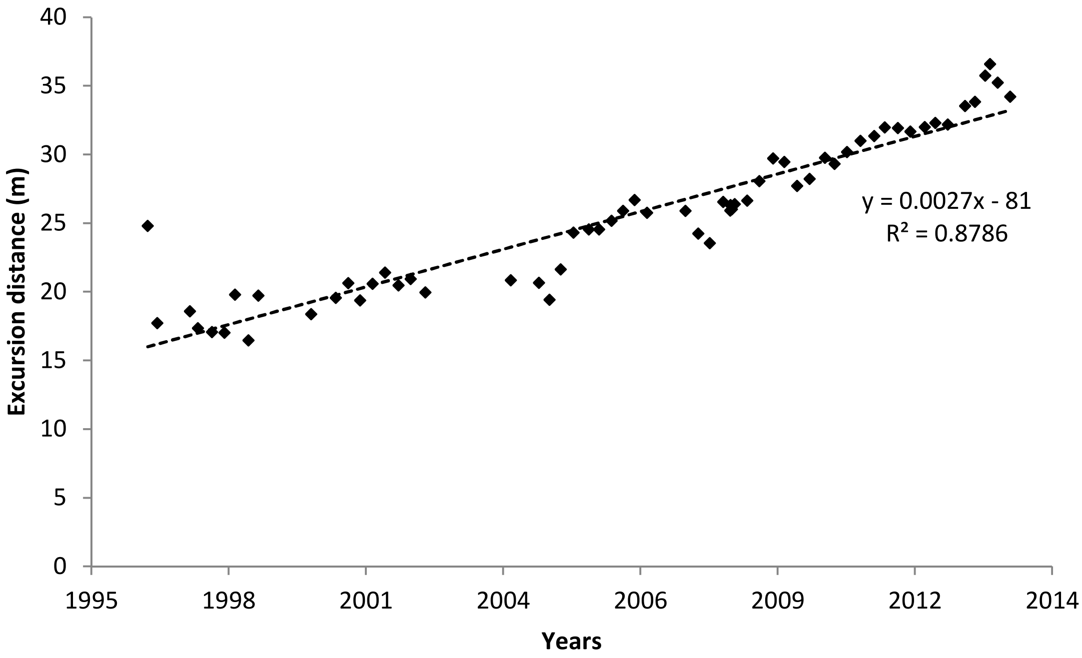


Figure 4-4 Example Linear Regression for Waihi Beach Surf Club (CCS52)

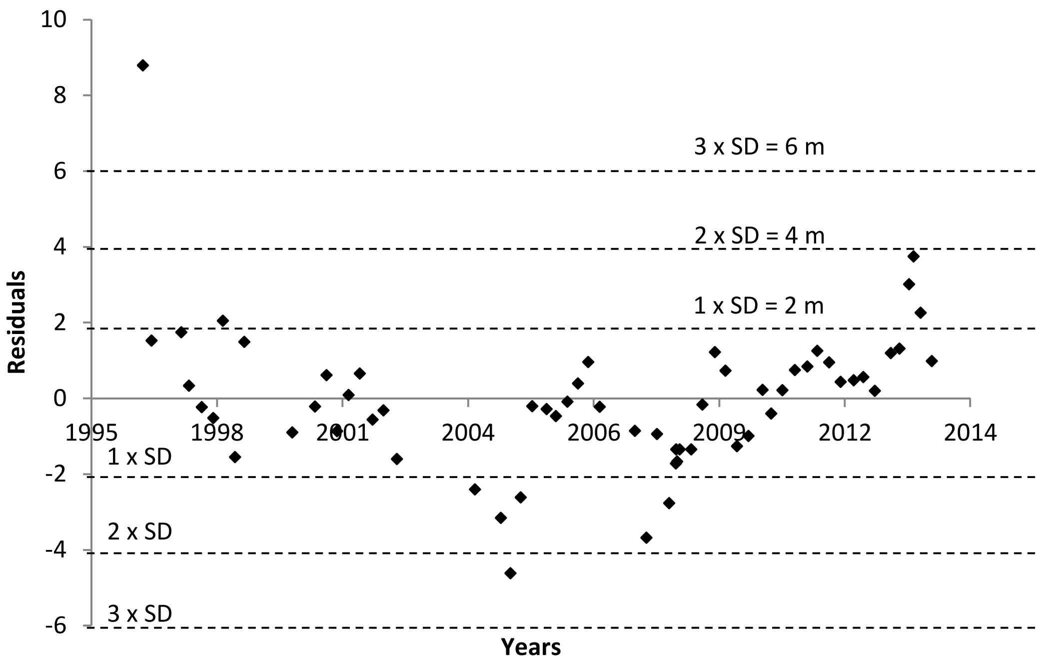


Figure 4-5 Example contour excursion residuals (de-trended) for Waihi Beach Surf Club (CCS52)

The 3 x SD was interpreted as the modal value of the short-term fluctuation component. However, without frequent survey data, particularly immediately following storm events, it is likely that the maximum impact of storms is omitted from the physical survey data set as some beach recovery will occur before the next regular survey record. Therefore, we have also considered the maximum cumulative erosion distance to analyses the short-term modal value (Table 4-2). The maximum cumulative erosion distance at CCS52 was -7.1 m (Figure 4-4 and Table 4-5).

Table 4-2 Statistical measures of shoreline excursion

Site	Number	Regression (m/yr)	Residual (m)			Excursion Distance (m)
		Linear regression rate	Standard Deviation (SD)	3 x SD	Max landward extent (erosion)	Max cumulative distance (erosion)
Waihi Beach	CCS54	1.0	2.1	6.3	-4.6	-4.7
	CCS53	0.5	2	6	-4.9	-5.2
	CCS52	1.0	2	6	-4.6	-7.1
	CCS51	0.3	2.1	6.3	-6.6	-6.4
	CCS50a	0.2	1.8	5.4	-3.7	-5.9
	CCS50	0.0	5	15	-4.5	-11.7
	CCS49	-0.1	2.6	7.8	-4.7	-6.8
	CCS48	-0.3	3.1	9.3	-5.4	-9.9
	CCS47	-0.4	4.7	14.1	-8.6	-15.1
Pukehina	CCS29	-0.4	3	9	-9.1	-12.7
	CCS28	0.1	2.1	6.3	-5.3	-8.1
	CCS27	-0.3	3.5	10.5	-8	-8.8
	CCS26	0.0	2.2	6.6	-6.2	-7.3

Table 4-2 also shows the linear regression rate for each beach profile site over the time period of the dataset. Over the last 20 to 30 years the shoreline has been accreting at the northern end of Waihi Beach and eroding at the southern end. Pukehina observes a mixed trend with the shorelines generally fluctuating.

4.3.1.3 Numerical model assessment of storm erosion potential

Erosion of the upper beach is dependent on the energy able to reach the backshore, the duration of exposure to that energy and the erodibility of the upper beach material. The energy able to reach the backshore is dependent on water level and the offshore profile which controls wave breaking and energy dissipation. Both of these parameters change over the duration of a storm event.

Semi-process based model description

The numerical cross-shore sediment transport and profile change model SBEACH (Storm Induced BEAch CHange) (Larson and Kraus, 1989) has been used to define storm cut volumes and horizontal movement of the dune toe. SBEACH considers sand grain size, the pre-storm beach profile and dune height, plus time series of wave height, wave period, water level in calculating a post-storm beach profile. Model development involved extensive calibration against both large scale wave tank laboratory data and field data. SBEACH has been verified for measured storm erosion on the Australian east coast (Carley, 1992; Carley et al. 1998). Pukehina and Waihi Beach are subject to similar wave climate and storm events as the Australian east coast and the model is therefore considered applicable for these environments.

Model input

A representative cross-shore profile from the dune crest to the RL -10 m contour was assessed for each site (Waihi Beach and Pukehina) based on average profile surveys information. Design storm nearshore time series including wave height, period and water level are applied at the outer profile boundary (i.e. Figure 4-6 for Waihi Beach). Design storms for 10 yr, 100 yr and 2x100 yr events are simulated with the later allowing for potential clustering of storms. Such clustering may result in greater erosion as the first event lowers the beach height and relatively greater wave energy may reach the backshore in subsequent events.

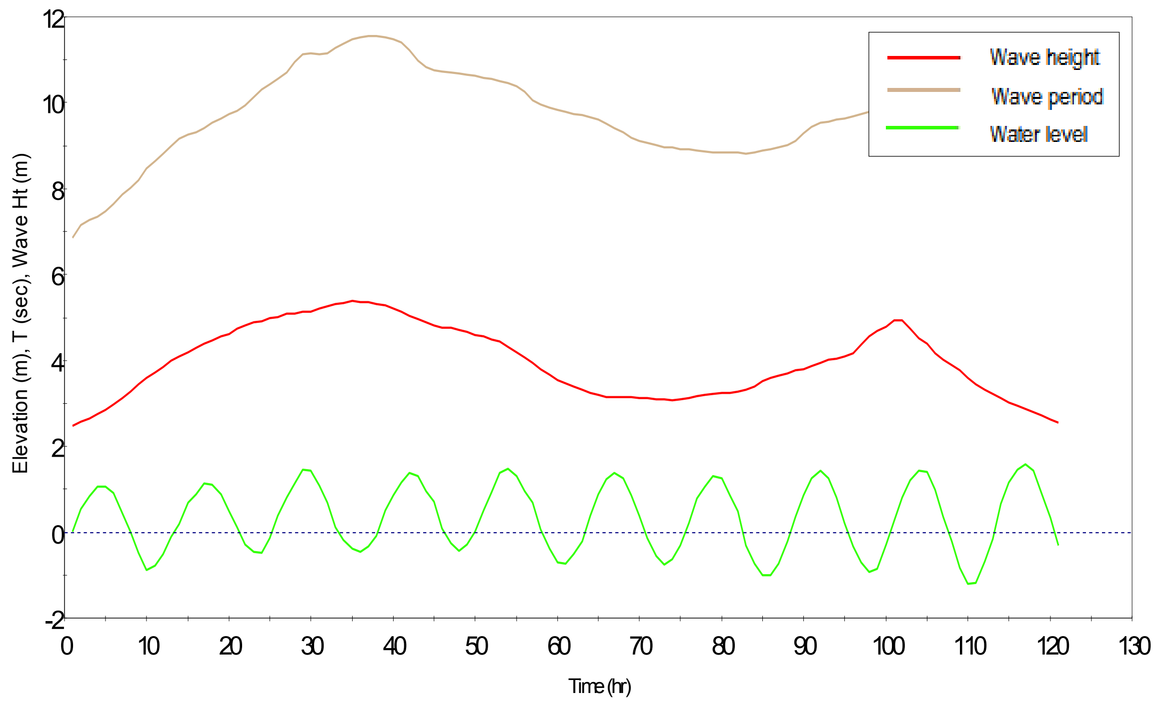


Figure 4-6 Synthetic 100yr design storm input for Waihi Beach

Model results

SBEACH assumes an equilibrium profile concept which instantly responds to the present wave forcing conditions and calculates an equilibrium profile based on that forcing. Changes in horizontal shoreline position at a predefined contour (i.e. the dune toe) provide information on short-term erosion distances.

For Waihi Beach the maximum storm cut was modelled in SBEACH as 5 m erosion. The range of shoreline excursion distances calculated by SBEACH for Waihi Beach and Pukehina is shown in Table 4-3.

Table 4-3 Storm excursion distances calculated by SBEACH for both Waihi Beach and Pukehina

Storm	**10 year**	**100 year**	**2 x 100 year**
Waihi Beach	4 m	4 m	5 m
Pukehina	2 m	2 m	3 m

Numerical storm cut distances of 2 to 5 m were found for Waihi Beach and Pukehina. However, we consider that this model likely underestimates storm cut on relatively flat dissipative beaches as it does not include the effects of infra-gravity waves which dominate swash motions and sediment transport on dissipative beaches. Therefore, the SBEACH results were considered a minimum value for the short-term component lower bound. Figure 4-7 shows the results of the SBEACH modelling including the initial and equilibrium profiles formed due to 10, 100 and 2x100 year storms for Waihi Beach. The Figure shows the modelled beach profiles retreating landward of the initial profile at around the RL 2 to 3 m elevation. This retreat indicates the storm cut distance at the dune toe position.

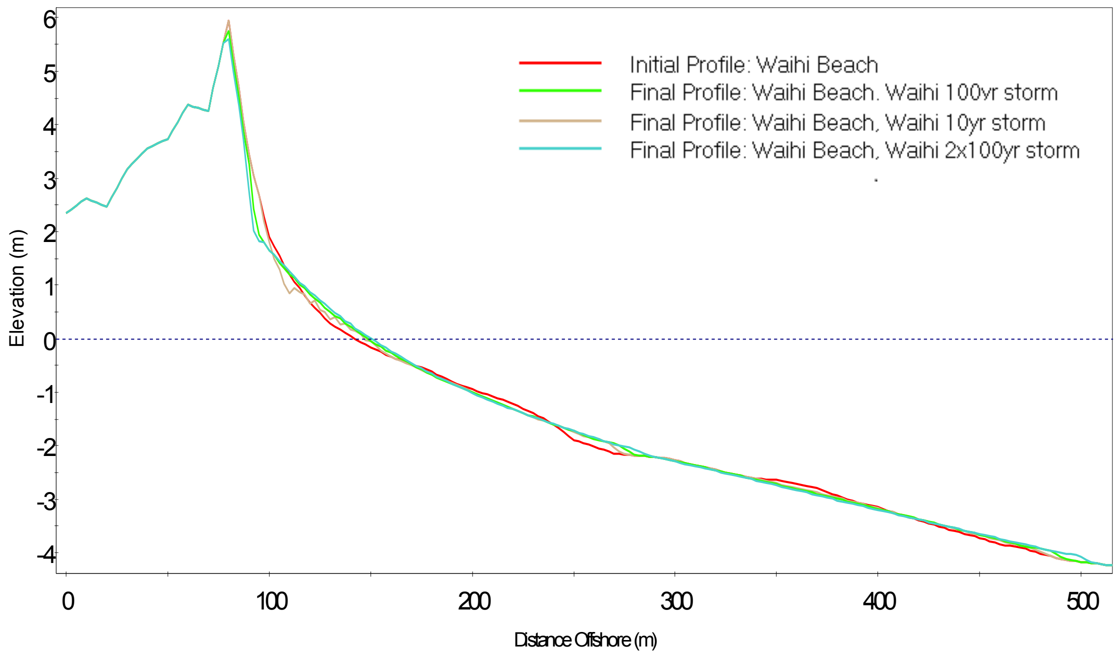


Figure 4-7 SBEACH results for Waihi Beach

4.3.1.4 Adopted values

The re-assessment used both anecdotal, statistical and numerical methods to derive the short-term component. The results from the numerical SBEACH model were used to set the lower bounds. With the extended new beach profile datasets, statistical analysis provides adequate information to derive the modal bounds for the short-term component. The anecdotal values were used to set the upper bounds for the Bowentown end of Waihi Beach and Pukehina. The full construction of the component value distribution is outlined in Table 4-4.

Table 4-4 Short-term erosion component values

		Short-term component value bounds		
Site	**Cell**	**Lower (m)**	**Mode (m)**	**Upper (m)**
Waihi Beach	A-B	4	6	8
	C-D	5	10	15
	E-K	10	15	20
Pukehina	A-C	10	15	20

4.3.2 Dune stability (DS)

The dune stability factor delineates the area of potential risk landward of the short-term erosion scarp to buildings and their foundations. The component assumes that storm erosion results in an over-steepened scarp which must adjust to a stable angle of repose for loose dune sand. The dune stability width is dependent on the height of the existing backshore dune and the angle of repose for loose dune sand. This has been obtained from an examination of historic reports and a review of the beach profile data. The dune stability factor is outlined below:

$$DS = \frac{H_{dune}}{2(\tan\alpha_{sand})} \quad (4\text{-}2)$$

Where H_{dune} is the dune height from the mean sea level (RL 0.1 m) to the crest and α_{sand} is the stable angle of repose for beach sand (ranging from 30 to 34 degrees). In reality, dune scarps will stand at steeper slopes due to the presence of binding vegetation and formation of talus slope at the toe, however, these have been ignored for the present assessment as any development immediately landward of the scarp and within the area defined by the formula may still be vulnerable due to foundation loads. The component bounds are defined based on the variation in dune height along the coastal behaviour cell and potential range in stable angle of repose.

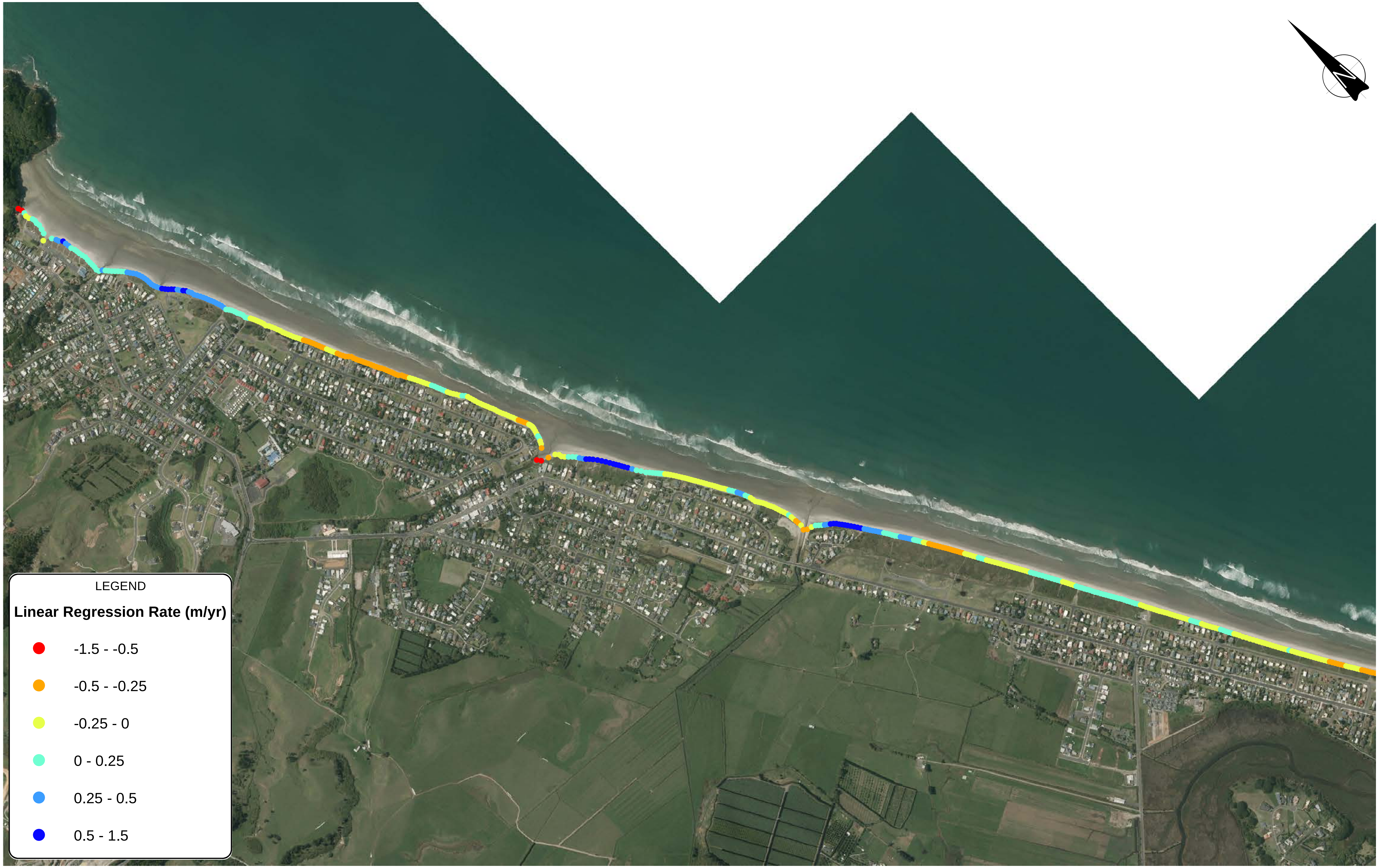
4.3.3 Long-term trends (LT)

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

Long-term trends have been evaluated by the analysis of the historic shoreline positions. These have been derived from geo-referenced historic aerial photographs, augmented with GPS surveys of the dune toe.   The shoreline data has be analysed using the GIS-based Digital Shoreline Shoreline Analysis System (DSAS) model. DSAS processes the shoreline data and calculates linear regression shoreline change statistics at 5 m intervals along the entire extent of each site. Figure 4-8 illustrates the DSAS results, where the rate of shoreline movement is plotted along Waihi Beach at 5 m intervals.

By calculating trends along the entire shoreline, rather than at a low number of discrete points, alongshore variation in trends can be determined and either used to inform component bounds or separated into separate coastal behaviour cells (refer to Figure 4-9 for Waihi Beach and Figure 4-10 for Pukehina). The range of linear regression rates (LRR) of long-term shoreline movement within each cell provide the bounding values for the component distribution.   The positive rate indicates accretion and the negative rate indicates erosion.

Figure 4-9 and Figure 4-10 present both the LRR and the end point rate (EPR). The EPR has been included for comparison purposes and displays the rate of shoreline change between the oldest and latest shoreline date and does not include the other shoreline dates. Table 4-5 outlines the long-term component values used for each cell at both Waihi Beach and Pukehina.



Notes: Imagery: Bay of Plenty Local Authority Shared Services
Linear regression is a measurement of shoreline movement based on historic aerial photographs and GPS survey between 1943 and 2014.

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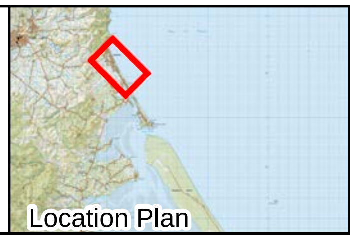

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WESTERN BAY OF PLENTY
Coastal Hazard Assessment
DSAS results for Waihi Beach

FIGURE No. Figure 4.8

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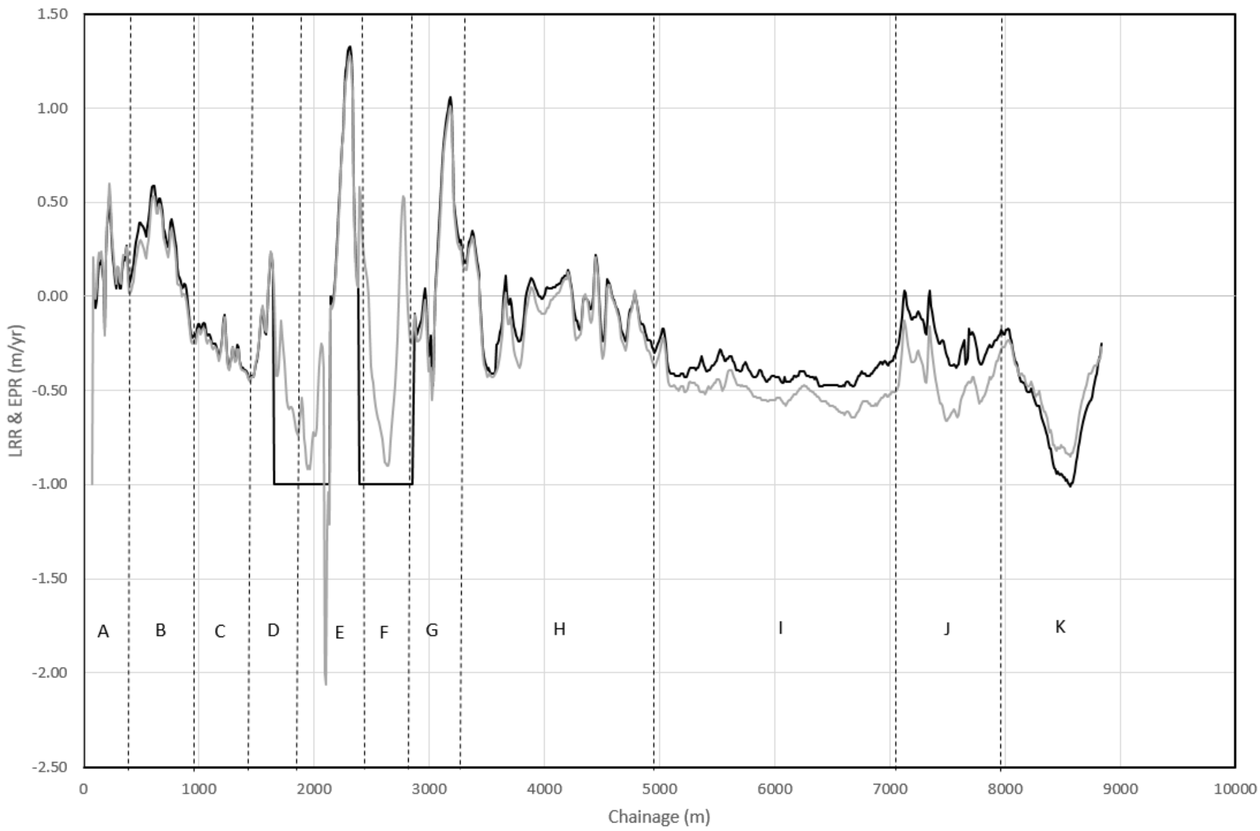

Figure 4-9 Long-term DSAS results for each cell for Waihi Beach showing both the linear regression rate (LRR as the dark line) and the end point rate (EPR as the light line). Positive value indicates accretion and negative value indicates erosion.

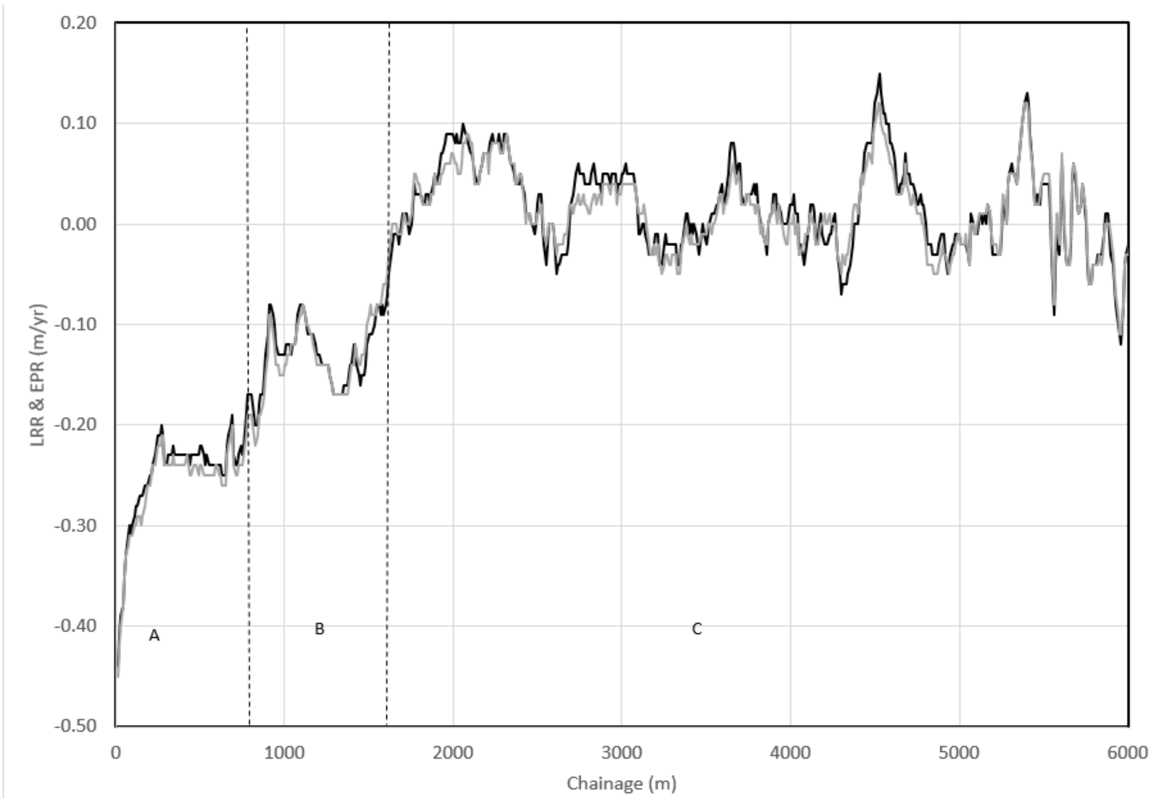

Figure 4-10 Long-term DSAS results for each cell for Pukehina showing both LLR as the dark line and EPR as the light line. Positive value indicates accretion and negative value indicates erosion.

Table 4-5 Long-term component values

Site	Cell	Long-term component value bounds		
		Lower (m/yr)	Mode (m/yr)	Upper (m/yr)
Waihi Beach	A	0.3	0.15	0
	B	0.5	0.1	-0.1
	C	-0.2	-0.3	-0.4
	D	0	-0.25	-0.5
	E	1	0	-1
	F	0.1	-0.25	-0.6
	G	0.6	0.3	0
	H	0.1	-0.15	-0.3
	I	n/a	n/a	n/a
	J	-0.1	-0.2	-0.3
	K	-0.3	-0.5	-0.8
Pukehina	A	-0.2	-0.21	-0.25
	B	-0.05	-0.1	-0.15
	C	0.1	0	-0.05

4.3.4 Planning timeframe (T)

Two planning timeframes were applied to provide information on coastal erosion hazards over the medium and long term time scales for planning and accommodating future development:

- 2065 Coastal Erosion Hazard Zone (50 years): 2065 CEHZ
- 2115 Coastal Erosion Hazard Zone (100 years): 2115 CEHZ.

4.3.5 Effects of sea level rise (SL)

4.3.5.1 Adopted SL values

We have adopted a range of sea level rise values over the two required timeframes (i.e. 2065 and 2115) which conform to guidance provided within MfE (2008) but also take into account new model results presented in the IPCC 5th Assessment Report (IPCC, 2014 DRAFT).

Utilising the most recent projections (IPCC, 2014 DRAFT) and adopting a precautionary approach required by NZCPS (2010) and in keeping with recommendations in MfE (2008), this assessment has adopted sea level rise values projected for the *RCP8.5 scenario - emissions continue to rise in the 21st century*. This is considered prudent until evidence of emission stabilising justify use of a lower projection scenario. These sea levels range from 0.27 to 0.47 m by 2065 and 0.62 to 1.27 m by 2115 (refer to Section 2.2.1.5).

An average historic rate of sea level rise of 1.7 mm/year has been deducted from the adopted 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. Table 4-6 presents the sea level rise values used in this present assessment.

Table 4-6 Sea level rise values utilised in assessment

Timeframe	Min (m)	Mode (m)	Max (m)
2065	0.19	0.29	0.39
2115	0.45	0.77	1.1

Note these values include a discount of 1.7 mm/year based on average historical trends as presented in Section 3.3.5

4.3.5.2 Beach response

Geometric response models propose that as sea level is raised, the equilibrium profile is moved upward and landward conserving mass and original shape (Figure 4-11). The most well-known of these geometric response models is that of Bruun (Bruun, 1962, 1988) which proposes that with increased sea level, material is eroded from the upper beach and deposited offshore to a maximum depth, termed closure depth. The increase in 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 the following equation:

$$SL = \frac{L_*}{B + d_*} S \tag{4-3}$$

Where SL is the landward retreat, d_* defines the maximum depth of sediment exchange, L_* is the horizontal distance from the shoreline to the offshore position of d_*, B is the height of the berm/dune crest within the eroded backshore and S is the sea level rise.

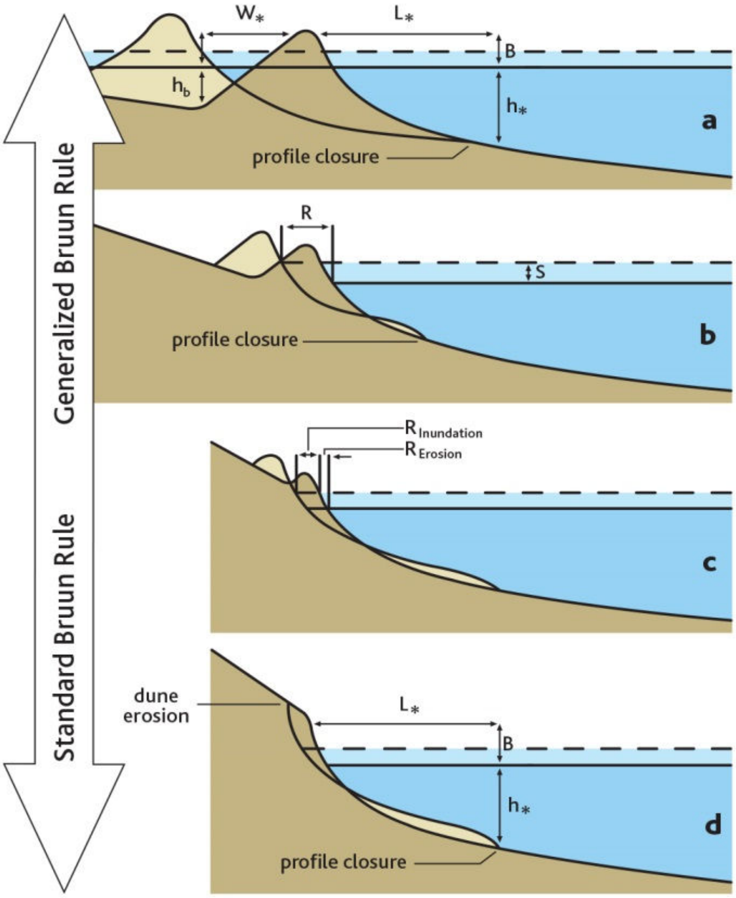

Figure 4-11 Schematic diagrams of the Bruun model modes of shoreline response (after Cowell and Kench, 2001)

The rule is governed by simple, two-dimensional conservation of mass principles and assumes no offshore or onshore losses or gains and an instantaneous profile response following sea-level change. The rule assumes an equilibrium beach profile where the beach may fluctuate under seasonal and storm-influences but returns to a statistically average profile (i.e. the profile is not undergoing long-term steepening or flattening). Losses or gains to the system and changes to the equilibrium profile are likely accounted for within the long-term change parameter and therefore are not likely to introduce additional uncertainty. The definition of a closure depth (maximum seaward extent of sediment exchange) and the lag in response of natural systems have been cited as significant limitations in the method (Hands, 1983).

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

Examination of the beach profile datasets identifies a “pinch point” depth where the profile stops fluctuating over time (zero flux depth). The average zero flux depth for the Waihi Beach and Pukehina sites was calculated as RL 6 and 6.5 m respectively. The zero flux depths are similar to those from previous studies referred to in the Healy (1993) report, which analyse limits of offshore sediment exchange based on sediment characteristics and profile adjustments. The results of these local studies documented a range of zero flux depths from 5.5 to 6 m (Foster, 1991; Harray and Healy, 1978; Gibb and Aburn, 1986; Lange and Healy, 1993).

To define component distributions, the Bruun rule estimates using the inner Hallermeier closure depth definition (d_l) have been adopted as upper bound values, estimates using the zero flux depth provides the modal (most likely) values and results using the beach face slope (Komar, 1999) provide the lower (almost certain) bounds. The beach face is defined by average mean low water spring position and average beach crest height. The Hallermeier closure definition is defined as follows (Nicholls et al., 1998):

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

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.

A summary of the distribution of depths used to define the offshore limit of sediment exchange are outlined in Table 4-7. The depths are used to derive a slope for each cell from the dune crest to the defined depth.

Table 4-7 Offshore limit of sediment exchange

Site	Lower (RL m)	Mode (RL m)	Upper (Rl m)
	Beach face	**Zero flux depth**	**Inner Hallermeier Closure Depth (d_l)**
Waihi Beach	-1	-6	-10.1
Pukehina	-1	-6.5	-10.1

4.4 Combination of components to derive CEHZ

For each coastal cell, the relevant component bounds influencing the CEHZ have been defined according to the methods described above as summarised in Table 4-7. The actual input values used for each site are presented in Appendix D.

Table 4-8 Theoretical erosion hazard parameter bounds

Component	Lower bound	Mode	Upper Bound
ST (m)	2 x 1% AEP SBEACH cut or Maximum landward residual	3 x standard deviation (SD) or Maximum cumulative distance (erosion)	Anecdotal evidence
DS (m)	H_{max} & α_{min}	H_{mean} & α_{mean}	H_{min} & α_{max}
LT (m/yr)	Min regression trend	Mean regression trend	Max regression trend
SLR (m)[1]	Lower 95% SLR value for RCP8.5 scenario minus historic trend	50% SLR value for RCP8.5 scenario minus historic trend	Upper 95% SLR value for RCP8.5 scenario minus historic trend
Closure slope[1]	Slope across active beach face to typical swash excursion	Slope from dune crest to zero flux depth	Slope from dune crest to inner Hallermeier closure depth

[1]SL component is a function of SLR and active beach slope parameters

Probability distributions constructed for each parameter are randomly sampled and the extracted values used to define a potential CEHZ distance. This process is repeated 10,000 times using a Monte Carlo technique[8] and the probability distribution of the resultant CEHZ width is forecast. Figure 4-12 presents an example of both the component and CEHZ histograms for Waihi Beach at 2065. Results show the possible CEHZ to range from -4 to -43 m, with a $P_{50\%}$ (50% probability of exceedance) value of -18 m. The $P_{5\%}$ is -28 m, which is substantially below the maximum extent of -43 m.

The CEHZ distances are mapped as offsets to the existing baseline of the 2014 dune toe. The inlet cells at Waihi Beach (Cell A, B, E and G) were offset from the Inlet Migration Curve (IMC) baseline due to the shoreline fluctuation in this area. The IMC is defined as the most inland shoreline position over the fluctuating spit area (i.e. Shand, 2012).

Where the hazard values differ between adjacent coastal cells, the mapped CEHZ is merged over a distance of at least 10 x the difference between values providing smooth transitions or along contours or material discontinuities where these are present.

[8] Monte Carlo technique is a computational algorithm that enables repeated random sampling to obtain numerical results.

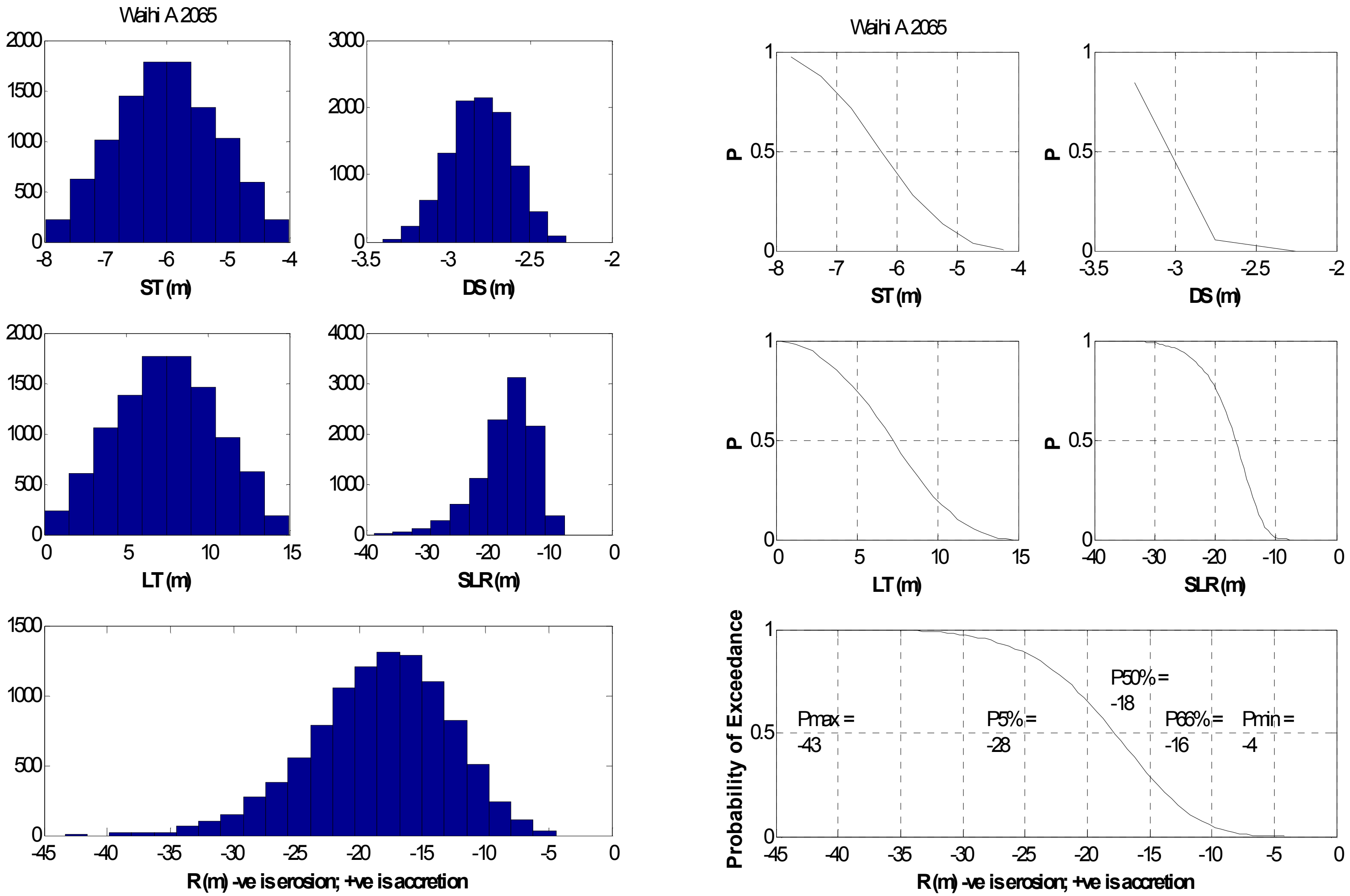

Figure 4-12 Example histogram (A) and cumulative distribution functions (B) of parameter samples and the resultant CEHZ distances for Waihi Beach cell AB 2065.

4.5 Risk-based approach

A risk-based approach to managing coastal hazard is advocated by the NZCPS (2010) with both the likelihood and consequence of hazard occurrence requiring consideration. For example, the NZCPS (2010) suggests consideration of areas both 'likely' to be affected by hazard and areas 'potentially' affected by hazard (refer to Section 2.1.1). While the term 'likely' may be related to a likelihood over a defined timeframe based on guidance provided by MfE (2008), i.e. a probability greater than 66% as shown in Table 4-9, the term potential is less well defined. This assessment therefore aims to derive a range of hazard zones corresponding to differing likelihoods which may be applied to risk assessment.

Table 4-9 Likelihood of scenario occurring within the selected planning horizon

Designation	Frequency	Description	IPCC definition
			Virtually certain (> 99% chance that a result is true)
A	Almost certain	Is expected to happen, perhaps more than once	Very likely (90–99%)
B	Likely	Will probably happen	Likely (66–90%)
C	Possible	Might occur; 50/50 chance	Medium (33–66%)
D	Unlikely	Unlikely to occur, but possible	Unlikely (10–33%)
E	Rare	Highly unlikely, but conceivable	Very unlikely (1–10%)
			Exceptionally unlikely (< 1%)

4.6 Uncertainties and limitations

Uncertainty may be introduced to the assessment by:

- an incomplete understanding of the components influencing the coastal erosion hazard zone
- an imprecise description of the natural processes affecting, and the subsequent quantification of each individual parameter
- errors introduced in the collection and processing of data
- variance in the processes occurring within individual coastal cells.

Uncertainty in the individual components are incorporated into the present assessment within the individual parameter bounds. This allows independent uncertainty terms to be combined within the probabilistic framework rather than utilising a single factor or adding uncertainty to each term as has been done previously.

Uncertainties in individual components will reduce as better and longer local data is acquired, particularly around rates of short- and long-term shoreline movement and shoreline response to SLR. Data collection programmes such as beach profiling are essential to reducing this uncertainty and should be continued. Our approach can also allow for uncertainties and data limitations by the user defined selection of the P value output. We recommend that conservative, lower probability CEHZ values are selected for implementation.

Of these uncertainties, the alongshore variance of individual coastal cells may be reduced by splitting the coast into continually smaller cells. However, data such as beach profiles are often available only at discrete intervals, meaning increasing cell resolution may not necessarily increase data resolution and subsequent accuracy. We believe we have refined the cells as far as practical based on factors which could significantly affect results. Residual uncertainty may be allowed for by selecting a lower probability CEHZ value.

Numerical models are beginning to better resolve the physical processes responsible for coastal erosion. However, complex coupled models are computationally expensive and heavily reliant on quality, long-term data. Without such data, complex model results are largely meaningless. We have attempted to balance the use of numerical modelling where useful (wave and beach response) with analytical and empirical[9] assessment to ensure results are robust and sensible.

4.7 Anthropogenic effects

Human influences can affect the coastal erosion hazard. For example, a rock revetment has been constructed at Waihi Beach designed to prevent landward retreat for a period of time.

While properly designed coastal protection works along beach can reduce erosion rates while in place, the shoreline position is generally returned to its long-term equilibrium position rapidly once the structure fails or is removed. We have therefore evaluated the erosion hazard (CEHZ) extent excluding the effects of any structures. This identifies the potential land area that could be affected, or the area that is benefitting with the structure. Informed decision around the future maintenance or re-consenting of structures can then be made.

Dune planting and fencing has been undertaken at the northern end of Waihi Beach. Analysis of both the long-term and short-term datasets suggest this erosion mitigation strategy has been successful in that location. If this strategy is not maintained over the timeframe of the CEHZ period, then we could expect a greater area of land to be susceptible to coastal erosion hazard in this area.

Inlet cells at Waihi Beach have man-made structures influencing the fluvial processes (e.g. timber and geosynthetic sand container training groynes). The shoreline adjacent to the inlets/streams have been stabilised by groyne structures. We have largely ignored the structures in these two locations and taken into account the historical shoreline fluctuations when setting the CEHZ baseline.

4.8 Coastal inundation hazard zone (CIHZ) delineation

The CIHZ was assessed over a 2065 (50 year) and 2115 (100 year) planning timeframe for both Waihi Beach and Pukehina. The CIHZ was based on an inundation level derived from the combination of the following components (refer to Section 2.2 for further description of coastal processes):

- Storm tide (refer to Section 2.2.1.4)
- Wave set-up
- Wind set-up
- Sea level rise (refer to Section 2.2.1.5).

The inundation components were calculated separately for the open coast environments that exist at Waihi Beach and the estuary coast environment that exists at Pukehina (inner spit shoreline). The foredune heights at Pukehina are sufficient to mitigate any inundation hazard from the open coast.

Wave set-up has been calculated for both the open coast and estuary coast based on the Coastal Engineering Manual method (CEM, ll-4-3). Additional wind set-up was calculated for the estuary coast based on the CIRIA (Construction Industry Research and Information Association) method.

[9] Gaining knowledge through observations such as beach profile surveys.

Table 4-9 outlines the inundation component values used to calculate the CIHZ levels. The CIHZ levels for Waihi Beach for the 2065 and 2115 timeframes are RL 2.9 m and 3.7 m respectively. The CIHZ levels for the estuary coast for the 2065 and 2115 timeframe are RL 2.1 m and 2.8 m respectively.

Table 4-10 Coastal Inundation Hazard Zone component values

Site	Timeframe	Storm Tide (m)[1]	Wave set-up (m)[2]	Wind set-up (m)	Sea level rise (m)	Total CIHZ level (RL m)[3]
Waihi Beach (Open Coast)	2065	1.78	0.7	n/a	0.4	2.9
	2115	1.99	0.7	n/a	1.0	3.7
Pukehina (Estuary Coast)	2065	1.51	0.15	0.07	0.4	2.1
	2115	1.57	0.15	0.07	1.0	2.8

Notes: [1]Storm tide elevations are based on 2% AEP and 1% AEP levels for the 2065 and 2115 timeframe respectively.
[2]Wave event is based on a 1%AEP for both the 2065 and 2115 timeframes.
[3]All levels reduced to Moturiki Datum 1953 (RL m).

The CIHZ levels were mapped based on the LiDAR derived DTM for both Waihi Beach and Pukehina. The 2065 and 2115 CIHZ identify land susceptible to coastal inundation hazard over a 50 and 100 year planning timeframe respectively.

Council may decide to revise the existing Primary and Secondary Risk CPA based on right aligning the re-assessed CIHZ mapping to the landward edge of property boundaries.

5 Coastal erosion and inundation hazard assessment results

5.1 CEHZ values

For each coastal cell a range of CEHZ probabilistic values are calculated and presented within the individual site assessments within Appendix D. Following consultation with Council, the $P_{66\%}$ value for 2065 (value with a 66% likelihood of being exceeded by 2065) and the $P_{5\%}$ value for 2115 (5% likelihood of being exceeded by 2115) were adopted as prudent *likely* and *potential* coastal erosion hazard zones values termed the Primary Risk CPA and Secondary Risk CPA respectively.

A summary of the CEHZ values are presented in Table 5-1. The CEHZ values have been mapped with respect to the adopted baseline. The CEHZ baseline to which values are referenced is the most recent dune toe derived from site survey data captured in 2014, except in some cases of dynamic inlets where the maximum inland extent of fluctuation (envelope) may be adopted (i.e. Shand, 2012). This has been considered for Waihi Beach cells E and G. Where the hazard values differ between adjacent coastal cells, the mapped CEHZ is merged over a distance of at least 10 x the difference between values providing smooth transitions.

These CEHZ lines represent the landward boundary of the coastal erosion hazard extent and are presented in individual site assessments within Appendix A (and are also provided to Council in digital form). The methodology used to calculate the CEHZ distances is described in Section 4.1 and Equation 4-1.

Table 5-1 Coastal erosion hazard zone values

Site		**CEHZ 2065**	**CEHZ 2115**
Name	**Cell**	**$P_{66\%}$**	**$P_{5\%}$**
Waihi Beach	A	20	70
Waihi Beach	B	20	70
Waihi Beach	C	40	120
Waihi Beach	D	40	120
Waihi Beach	E	20	130
Waihi Beach	F	40	110
Waihi Beach	G	20	50
Waihi Beach	H	40	90
Waihi Beach	I	n/a	n/a
Waihi Beach	J	40	100
Waihi Beach	K	60	150
Pukehina	A	40	80
Pukehina	B	30	60
Pukehina	C	30	50
Notes: values rounded to the nearest multiple of 10			

The CEHZ 2115 values for Waihi Beach range from 70 to 150 m. The equivalent CHZ values produced by Healy (1993) for Waihi Beach range from 127 to 137 m, which are the basis of the existing Secondary Risk CPA. The CEHZ 2115 values for Pukehina range from 50 to 80 m. The equivalent CHZ value produced by Healy (1993) for Pukehina was 90 m.

We note mapping of the final CPA is a separate process where the CEHZ may be right-aligned to the property boundaries located within them. Council is responsible for undertaking this process, which may result in some of the existing properties within the CPA now being excluded or alternatively new properties now being included in the CPA.

5.2 CIHZ values

The results of the CIHZ mapping are displayed within the site maps included in Appendix B. The Pukehina cell A is susceptible to inundation along the inner spit shoreline to a level of RL 2.1 m and 2.8 m for the 2065 and 2115 timeframes respectively. The Waihi Beach site is susceptible to inundation hazard at the low lying areas in the north (Cell A) and around both Two Mile and Three Mile Creeks (Cell E and G respectively). The CIHZ levels for the open coast Waihi Beach site for the 2065 and 2115 timeframes is RL 2.8 m and 3.6 m respectively.

5.3 Discussion

Coastal processes and future shoreline positions are difficult to forecast over a 100 year timeframe due to the potential for morphological feedbacks to slow or increase the rates of historic trends. These forecasts become more uncertain when considering the effect of potential sea level rise and interrelationships with other systems (i.e. rivers or streams).

The distal ends of spits are also very dynamic areas where accurately forecasting future shoreline positions is problematic. We have represented the shoreline movement as a result of sea level rise as a fairly linear retreat along the spit. However, we are aware that a number of alternative morphological responses may occur due to a variety of drivers. For example, at Pukehina where the distal end of the spit is relatively narrow (i.e. less than 100 m in some locations), the inlet may breach the spit where the spit width is reduced over time.

Due to the level of development at the sites, most areas have a relatively narrow area of dune vegetation. Some sites have areas with no dune vegetation where backshore areas comprise revetment, grass reserve or private development. We expect dune recovery to be negatively affected where native dune vegetation has been removed, which could result in a greater erosion response in both the long-term and short-term than historically experienced.

The coastal erosion (CEHZ) and inundation (CIHZ) hazard for both a 2065 and 2115 timeframe have been identified and mapped accordingly. The existing CHZ assessed by Healy (1993) were right aligned to the property boundaries at the time for the purposes of mapping for inclusion in the District Plan. Council will undertake a similar process to revise the existing CPA based on as right aligning the CEHZ and CIHZ to the current property boundaries. Council can then make an assessment if additional properties are required to be included in the CPA, or alternatively some properties may now be excluded from the CPA. These differences occur due to either the change in the coastal erosion hazard delineation and/or a change in property boundaries that may have been sub-divided since 1993 (when the CPA were first introduced).

We recommend continuing to monitor the shoreline position at both sites by mapping shoreline positions from aerial photographs or GPS surveys along with continuing the traditional beach profile dataset. The shoreline monitoring will provide background data to help resolve these uncertainties for future re-assessments.

There are several low lying communities within harbours and estuaries that are at risk to coastal inundation hazard and may experience passive shoreline erosion due to sea level rise as the high tide elevation exceeds the crest of the dune of the backshore bank over a 100 year timeframe.

At sites with relatively flat backshore areas, the high tide line could move significantly inland over a 100 year timeframe. We recommend undertaking a coastal inundation assessment in these areas to identify the coastal inundation hazard as required by the NZCPS and the PRCP under policy CH 14 and 15. Appropriate minimum building floor levels could then be set within the identified areas to mitigate coastal inundation hazard over a 100 year timeframe.

6 Summary and conclusions

Council have previously assessed the coastal hazard for both Pukehina and Waihi Beach through introduction of the CPA (Healy, 1993). Council required the CPA to be re-assessed in line with the current state of scientific knowledge, relevant legislation and best practice guidelines.

The NZCPS is a national policy statement under the Resource Management Act 1991. The NZCPS states policies in order to achieve the purpose of the Act in relation to the coastal environments of New Zealand and the Bay of Plenty Regional Council PRCEP gives effect to the NZCPS. The re-assessment methodology used for this project has been developed in accordance with the Objectives and Policies of the NZCPS and the proposed RCEP directly relevant to the assessment of coastal hazard.

This study has re-assessed the coastal hazard extent based on a similar method developed by Healy, where both the coastal erosion hazard zone (CEHZ) and the coastal inundation hazard zone (CIHZ) were assessed. Two planning timeframes were applied to identify the coastal hazard extent at sufficient time scales for planning and accommodating future development:

- 2065 (50 years)
- 2115 (100 years).

The CEHZ methodology used in this study combines standard and well-tested approaches for defining coastal erosion hazard zones by addition of four components. This method has been refined to include parameter bounds which are combined by stochastic simulation. The resulting distribution is a probabilistic forecast of potential hazard zone width, rather than including single values for each component and one overall factor for uncertainty. This probabilistic method produces a range of hazard zones corresponding to differing likelihoods which may be applied to risk-based assessments as advocated by the NZCPS and supported by best practice guidelines.

Each site has been divided into coastal behavioural cells based on shoreline composition and morphology which can influence in the resultant hazard. The full probability distribution range of CEHZ distances was calculated at a coastal cell level for both timeframes.

Following consultation with Council, the $P_{66\%}$ CEHZ value at 2065 (value with a 66% likelihood of being exceeded by 2065) and the $P_{5\%}$ CEHZ value at 2115 (5% likelihood of being exceeded by 2115) are adopted as prudent *likely* and *potential* CEHZ values. The likelihood terms of *likely and potential* are consistent with the NZCPS policies on coastal hazards. The values were mapped with respect to the adopted baseline to identify the extent of coastal erosion hazard over the two timeframes.

The CIHZ was calculated as an inundation level based on the combination of the inundation components relevant to both the open coast and estuary coast environments. The estuary coast at Pukehina located on the inner spit shoreline is susceptible to inundation. The low lying areas located at the north of Waihi Beach and the land adjacent to the mouth of Two and Three Mile Creek are susceptible to inundation hazard.

The final step of the review process involves Council right-aligning the re-assessed CEHZ and CIHZ delineation to the current landward edge of the property boundaries to check where the existing CPA may need to be edited to either include or exclude properties as required.

We recommend continuing to regularly monitor the shoreline position across the region to provide background data, including continuing beach profile monitoring and digitising shorelines from aerial imagery or by GPS survey. We also recommend the adopted CIHZ and CEHZ values are reassessed at least every 10 years or following significant changes in either legislation or best practice and technical guidance.

7 Applicability

This report has been prepared for the benefit of Western Bay of Plenty District Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor LTD

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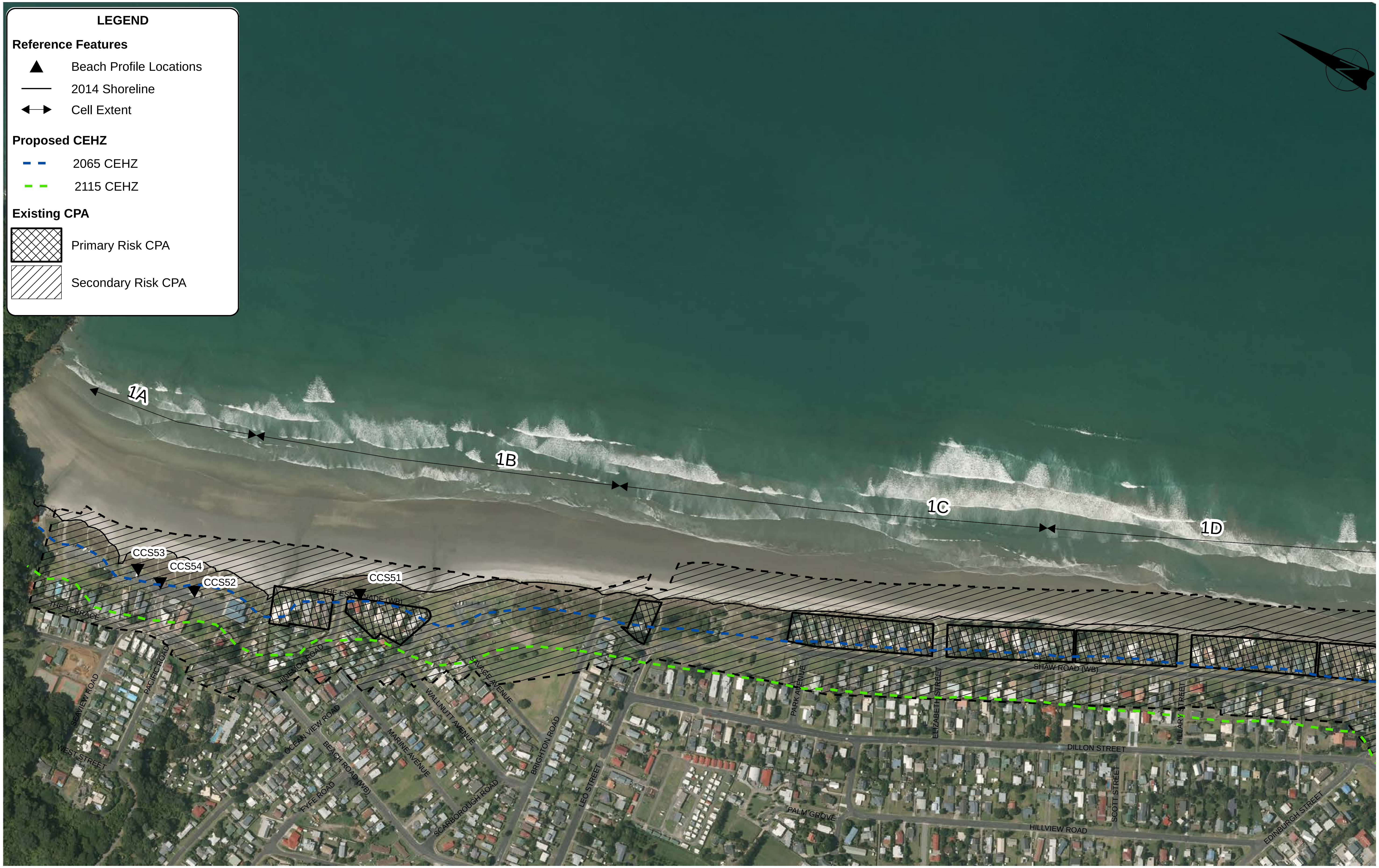
Appendix A: Coastal Erosion Hazard Zones



Notes: Imagery: Bay of Plenty Local Authority Shared Services

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WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CEHZ Mapping
Waihi North

FIGURE No. A1

Rev. 2

Notes: Imagery: Bay of Plenty Local Authority Shared Services

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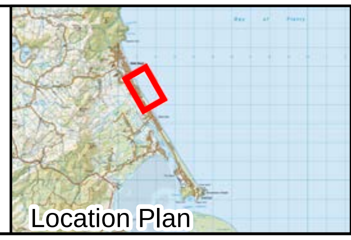

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WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CEHZ Mapping
Waihi Central

FIGURE No. A2
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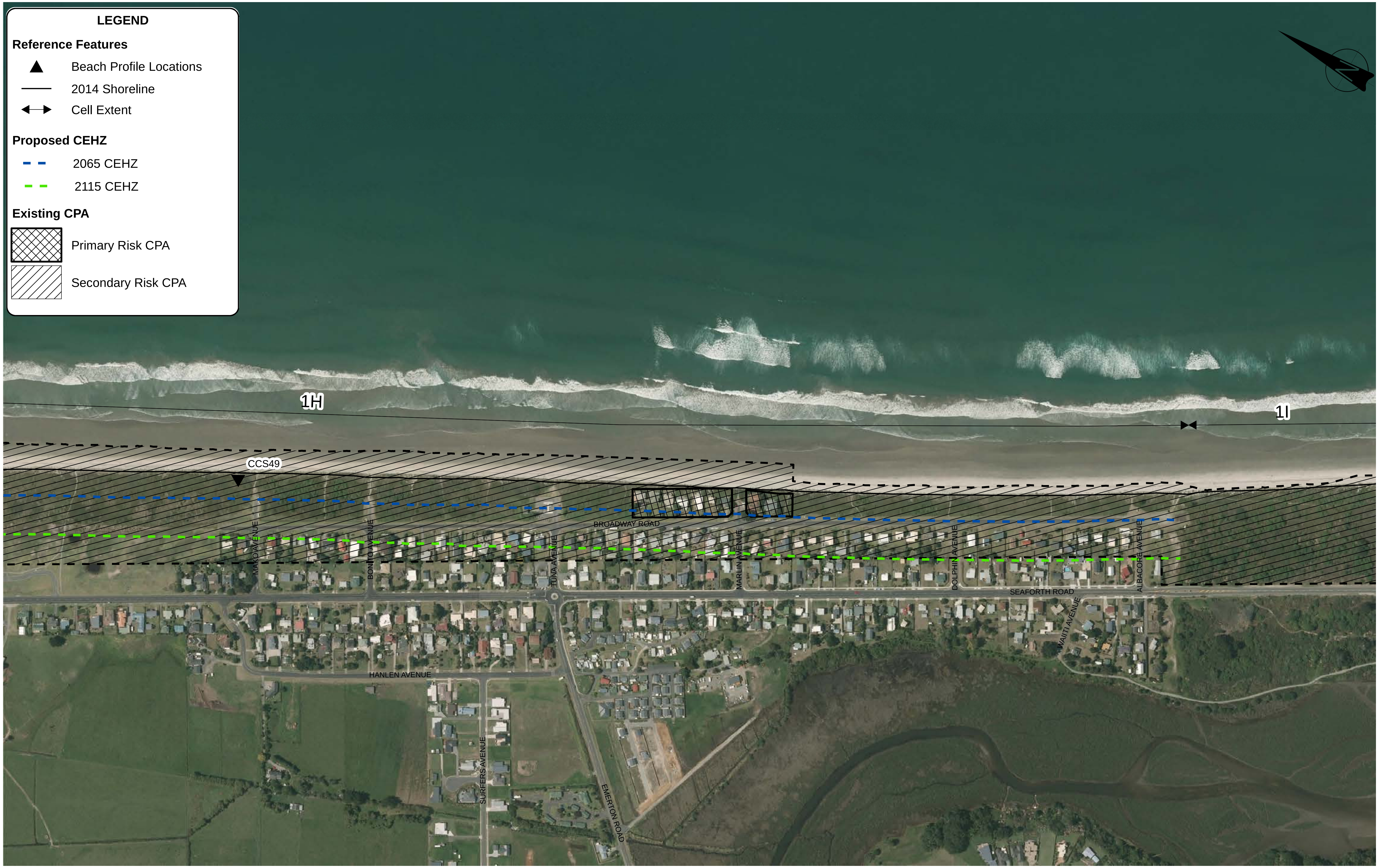

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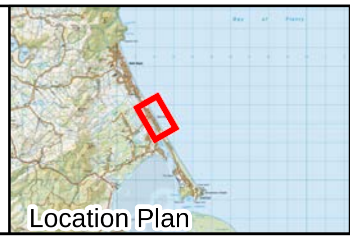

Location Plan

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WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CEHZ Mapping
Waihi South

FIGURE No. A3

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Location Plan

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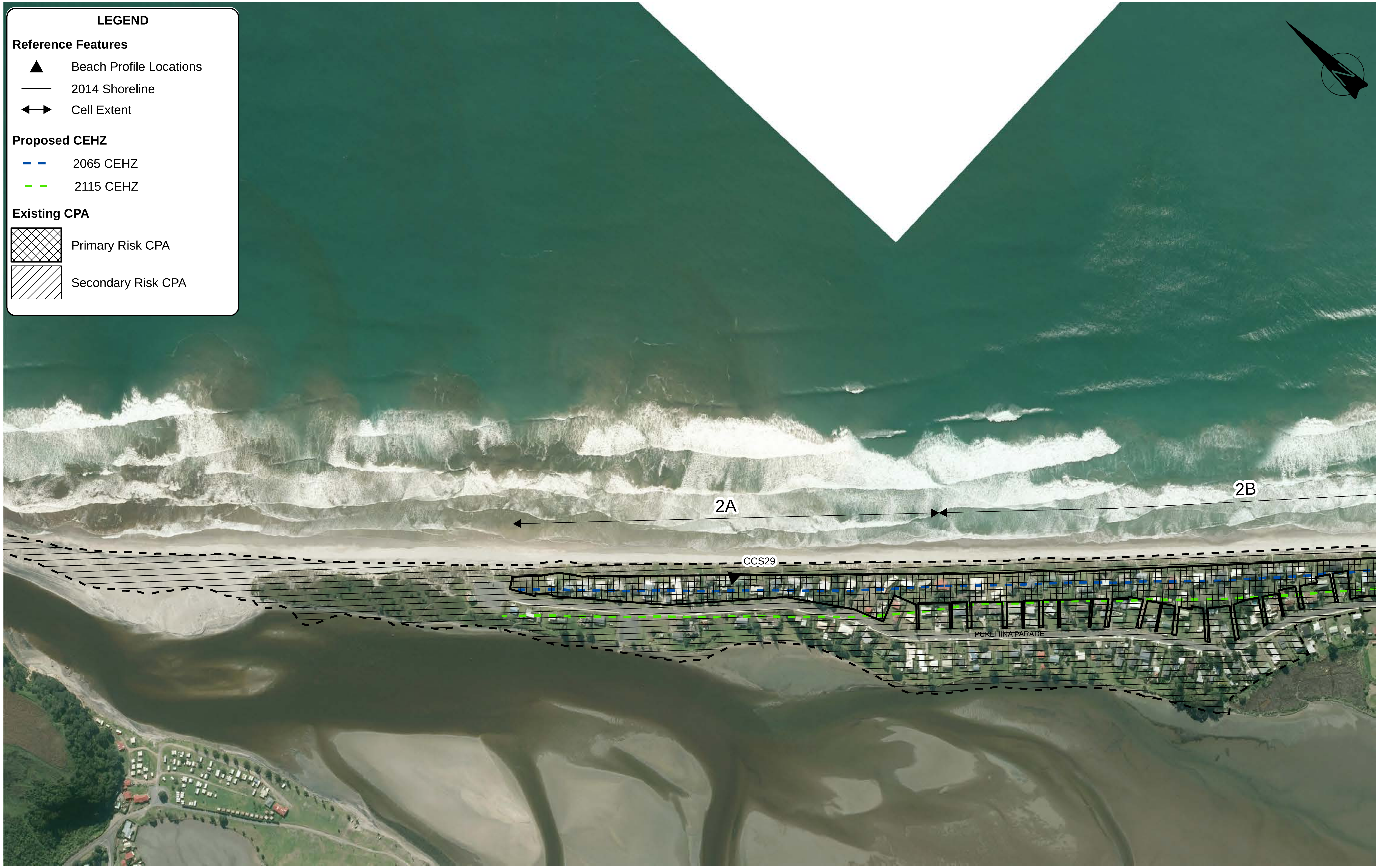
WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CEHZ Mapping
Bowentown

FIGURE No. A4

Rev. 2



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A3 SCALE 1:5,000

0 100 200 Meters

Location Plan

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WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CEHZ Mapping
Pukehina West

FIGURE No. A5

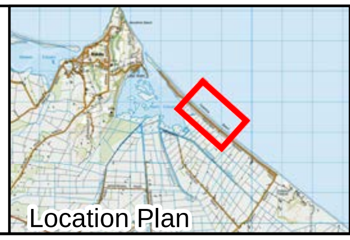
Rev. 2

Path: T:\Tauranga\Projects\851833\WorkingMaterial\GIS\MapDocuments\150429.Revision\851833.AA1_7.mxd Date: 29/04/2015 Time: 10:10:40 p.m.

Notes: Imagery: Bay of Plenty Local Authority Shared Services

A3 SCALE 1:5,000

0 100 200 Meters



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DRAWN	PPK	Apr.15
CHECKED		
APPROVED		
ARCFILE 851833.AA1_7.mxd		
SCALE (AT A3 SIZE) 1:5,000		
PROJECT No. 851833		

WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CEHZ Mapping
Pukehina Central

FIGURE No. A6

Rev. 2

Path: T:\Tauranga\Projects\851833\WorkingMaterial\GIS\MapDocuments\150429.Revision\851833.AA1_7.mxd Date: 29/04/2015 Time: 10:11:27 p.m.

Path: T:\Tauranga\Projects\851833\WorkingMaterial\GIS\MapDocuments\150429.Revision\851833.AA1_7.mxd Date: 29/04/2015 Time: 10:12:16 p.m.

Notes: Imagery: Bay of Plenty Local Authority Shared Services

A3 SCALE 1:5,000

0 100 200 Meters

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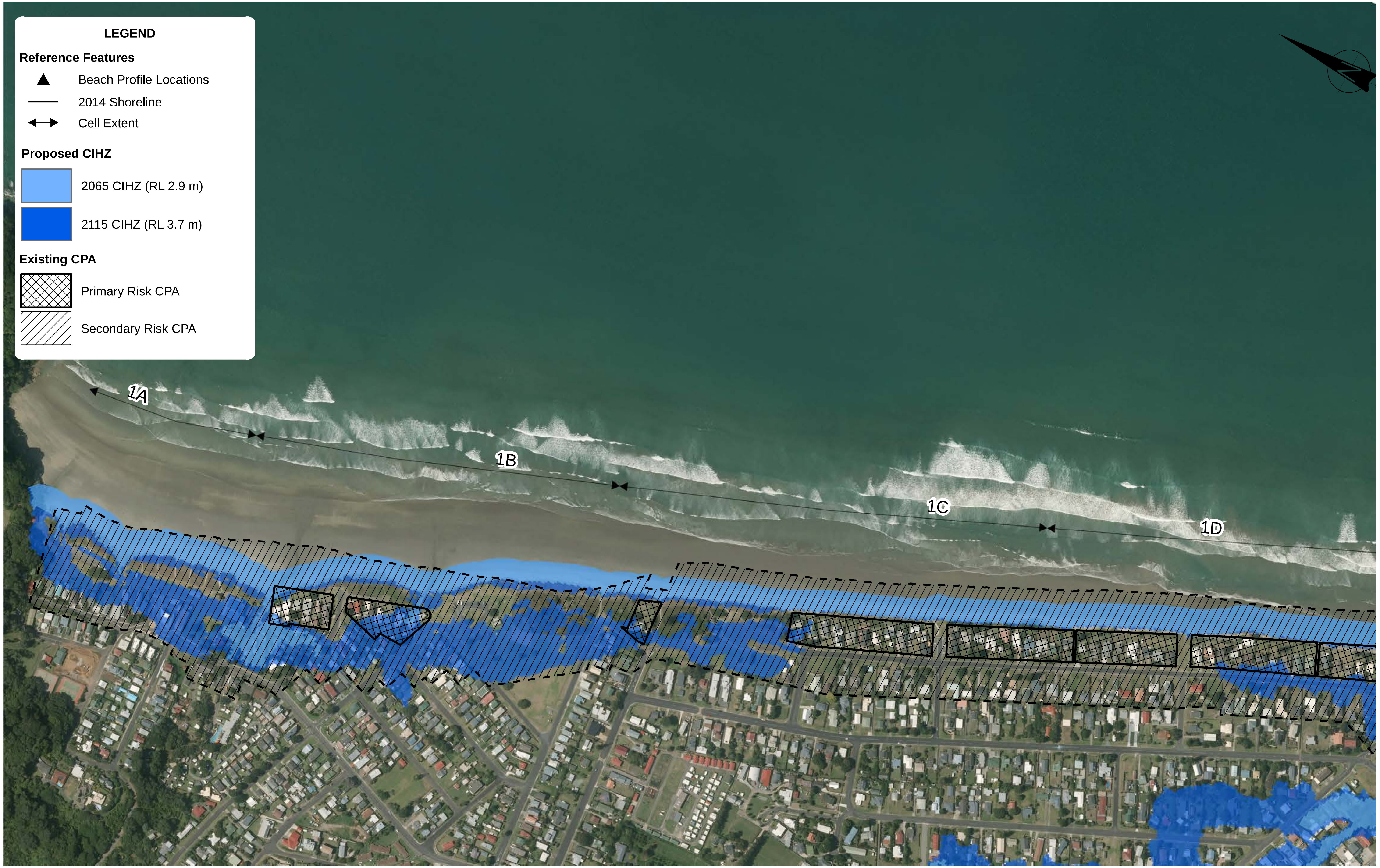
DRAWN	PPK	Apr.15
CHECKED		
APPROVED		
ARCFILE 851833.AA1_7.mxd		
SCALE (AT A3 SIZE) 1:5,000		
PROJECT No. 851833		

WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CEHZ Mapping
Pukehina East

FIGURE No. A7

Rev. 2

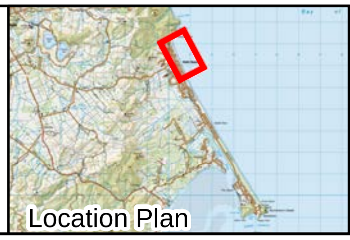
Appendix B: Coastal Inundation Hazard Zones



Notes: Imagery: Bay of Plenty Local Authority Shared Services

A3 SCALE 1:5,000

0 100 200 Meters



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DRAWN	PPK	Apr.15
CHECKED		
APPROVED		
ARCFILE 851833.AB1.mxd		
SCALE (AT A3 SIZE) 1:5,000		
PROJECT No. 851833		

WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CIHZ Mapping
Waihi Beach

FIGURE No. B1

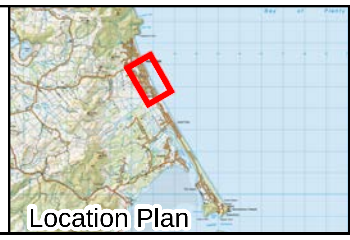
Rev. 0

Path: T:\Tauranga\Projects\851833\WorkingMaterial\GIS\MapDocuments\150429.Revision\851833.AB1.mxd Date: 29/04/2015 Time: 10:57:24 p.m.

Notes: Imagery: Bay of Plenty Local Authority Shared Services

A3 SCALE 1:5,000

0 100 200 Meters



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APPROVED		

ARCFILE 851833.AB2.mxd
SCALE (AT A3 SIZE) 1:5,000
PROJECT No. 851833

WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CIHZ Mapping
Waihi Beach

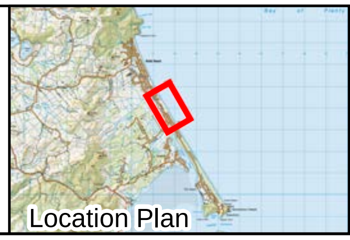
FIGURE No. B 2
Rev. 2

Path: T:\Tauranga\Projects\851833\WorkingMaterial\GIS\MapDocuments\150429.Revision\851833.AB2.mxd Date: 29/04/2015 Time: 10:45:38 p.m.

Notes: Imagery: Bay of Plenty Local Authority Shared Services

A3 SCALE 1:5,000

0 100 200 Meters



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DRAWN	PPK	Apr.15
CHECKED		
APPROVED		
ARCFILE 851833.AB3.mxd		
SCALE (AT A3 SIZE) 1:5,000		
PROJECT No. 851833		

WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CIHZ Mapping
Waihi Beach

FIGURE No. B 3

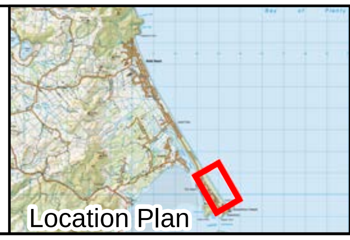
Rev. 2

Path: T:\Tauranga\Projects\851833\WorkingMaterial\GIS\MapDocuments\150429.Revision\851833.AB3.mxd Date: 29/04/2015 Time: 10:47:40 p.m.

Notes: Imagery: Bay of Plenty Local Authority Shared Services.
No CIHZ are present at Bowentown due to the high dune elevation.

A3 SCALE 1:5,000

0 100 200 Meters



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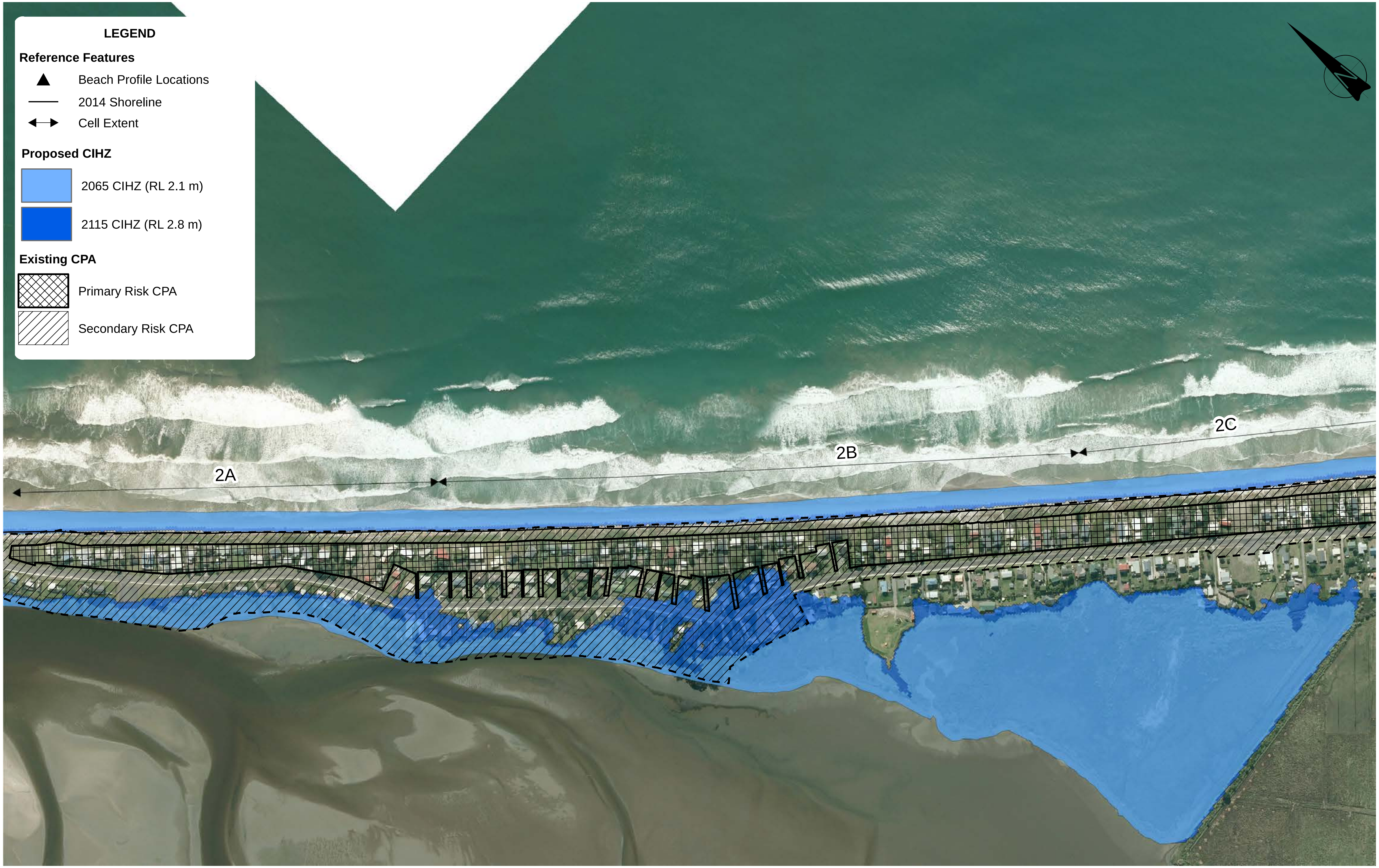
DRAWN	PPK	Apr.15
CHECKED		
APPROVED		
ARCFILE 851833.AB4.mxd		
SCALE (AT A3 SIZE) 1:5,000		
PROJECT No. 851833		

WESTERN BAY OF PLENTY
Coastal Hazard Assessment
CIHZ Mapping
Waihi Beach

FIGURE No. B 4

Rev. 2



Notes: Imagery: Bay of Plenty Local Authority Shared Services

A3 SCALE 1:5,000

0 100 200 Meters

Location Plan

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CHECKED		
APPROVED		
ARCFILE 851833.AB5.mxd		
SCALE (AT A3 SIZE) 1:5,000		
PROJECT No. 851833		

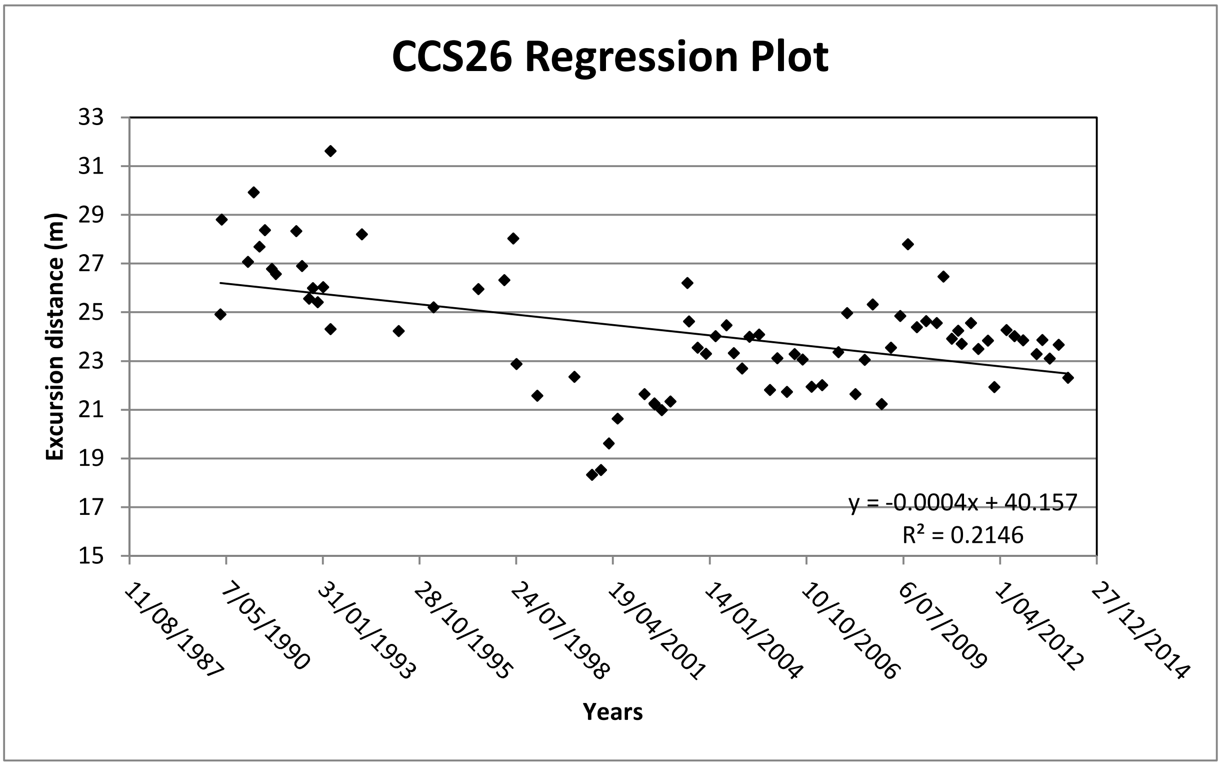
WESTERN BAY OF PLENTY
CIHZ Assessment
Pukehina West
Sheet: 5

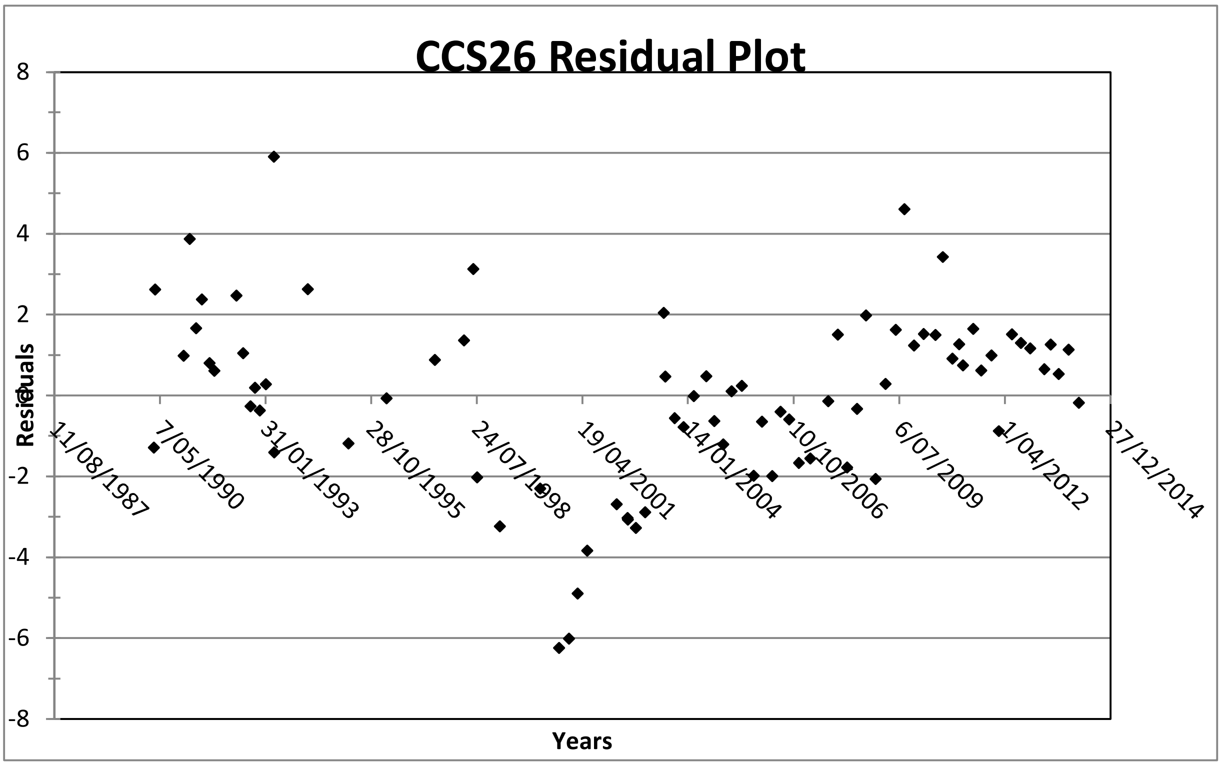
FIGURE No. B 5

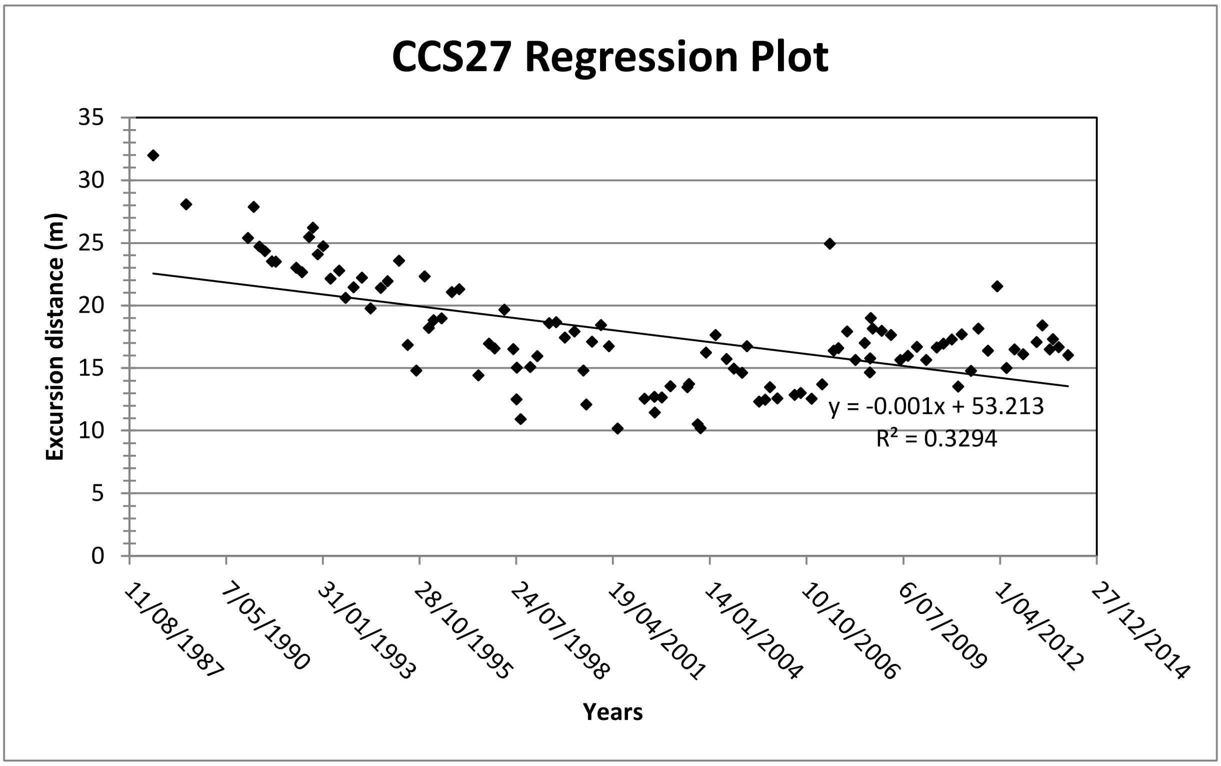
Rev. 2

Path: T:\Tauranga\Projects\851833\WorkingMaterial\GIS\MapDocuments\150429.Revision\851833.AB5.mxd Date: 29/04/2015 Time: 9:44:45 p.m.

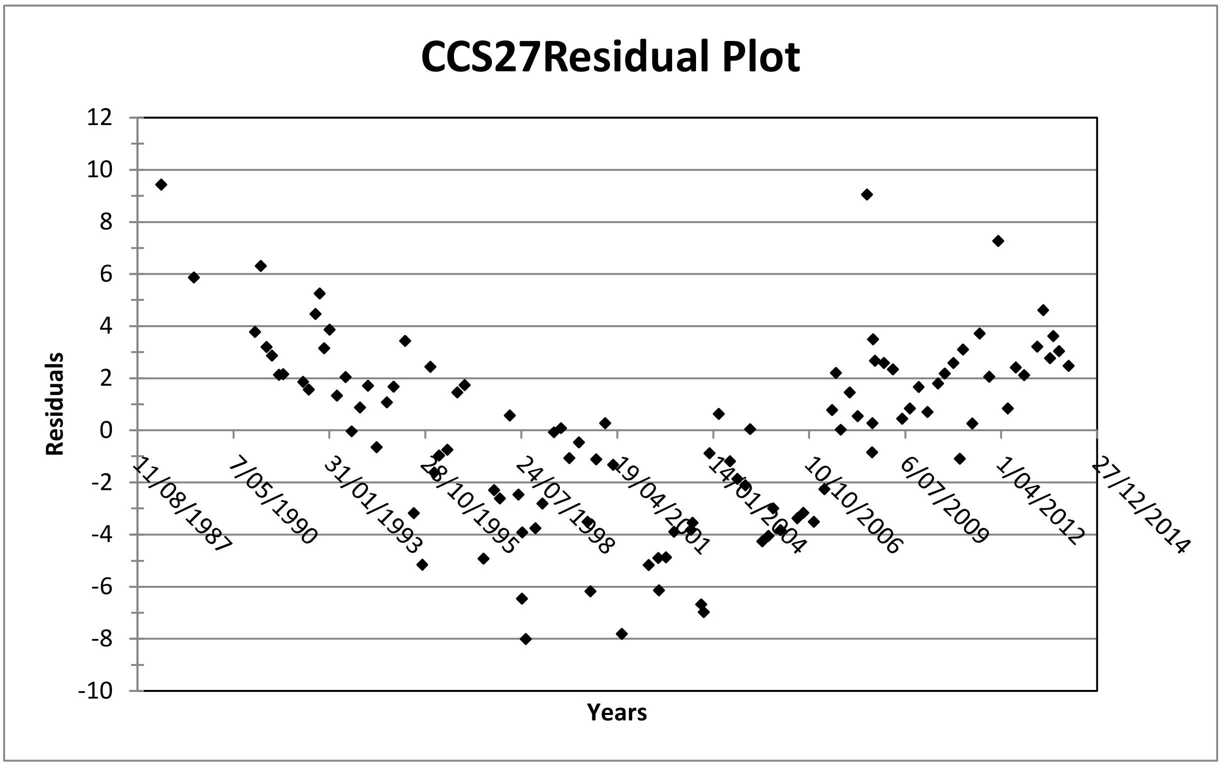
Appendix C: Beach Profile Analysis Plots


CCS26 Regression Plot
33
31
29
27
25
23
21
19
17
15
Excursion distance (m)
y = -0.0004x + 40.157
R² = 0.2146
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

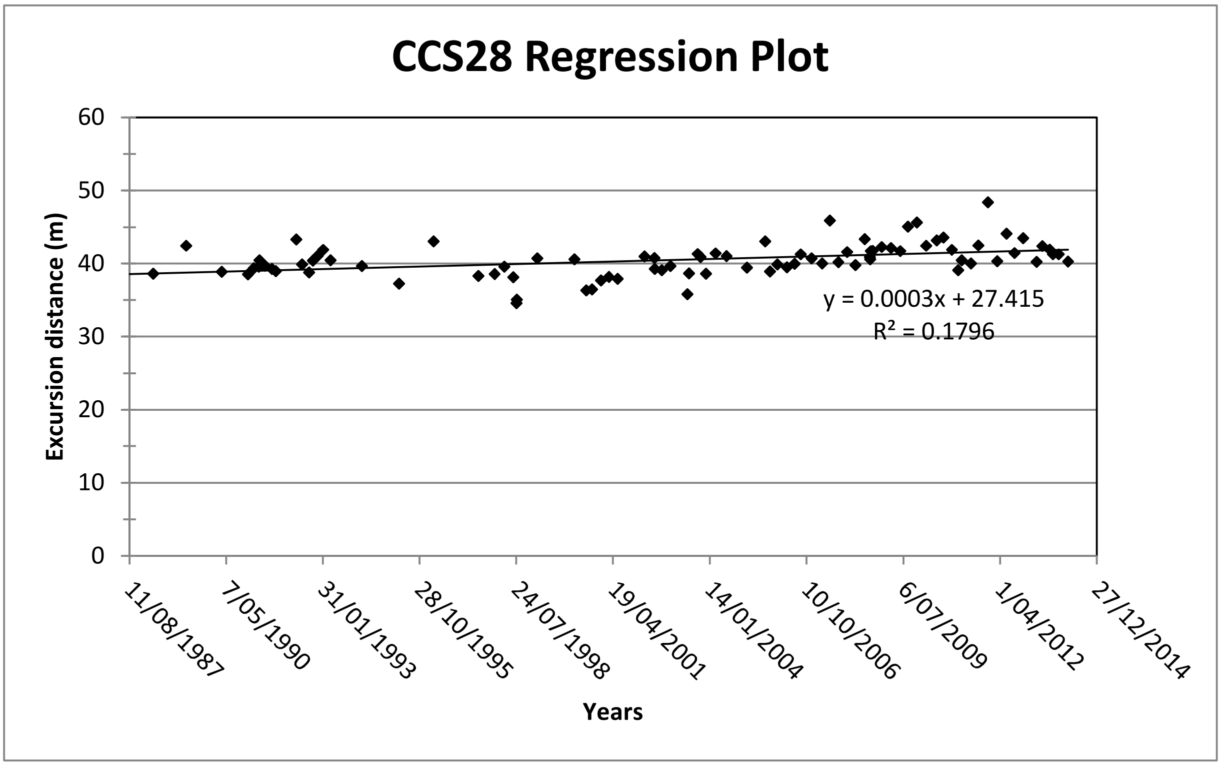

CCS26 Residual Plot
8
6
4
2
0
-2
-4
-6
-8
Residuals
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

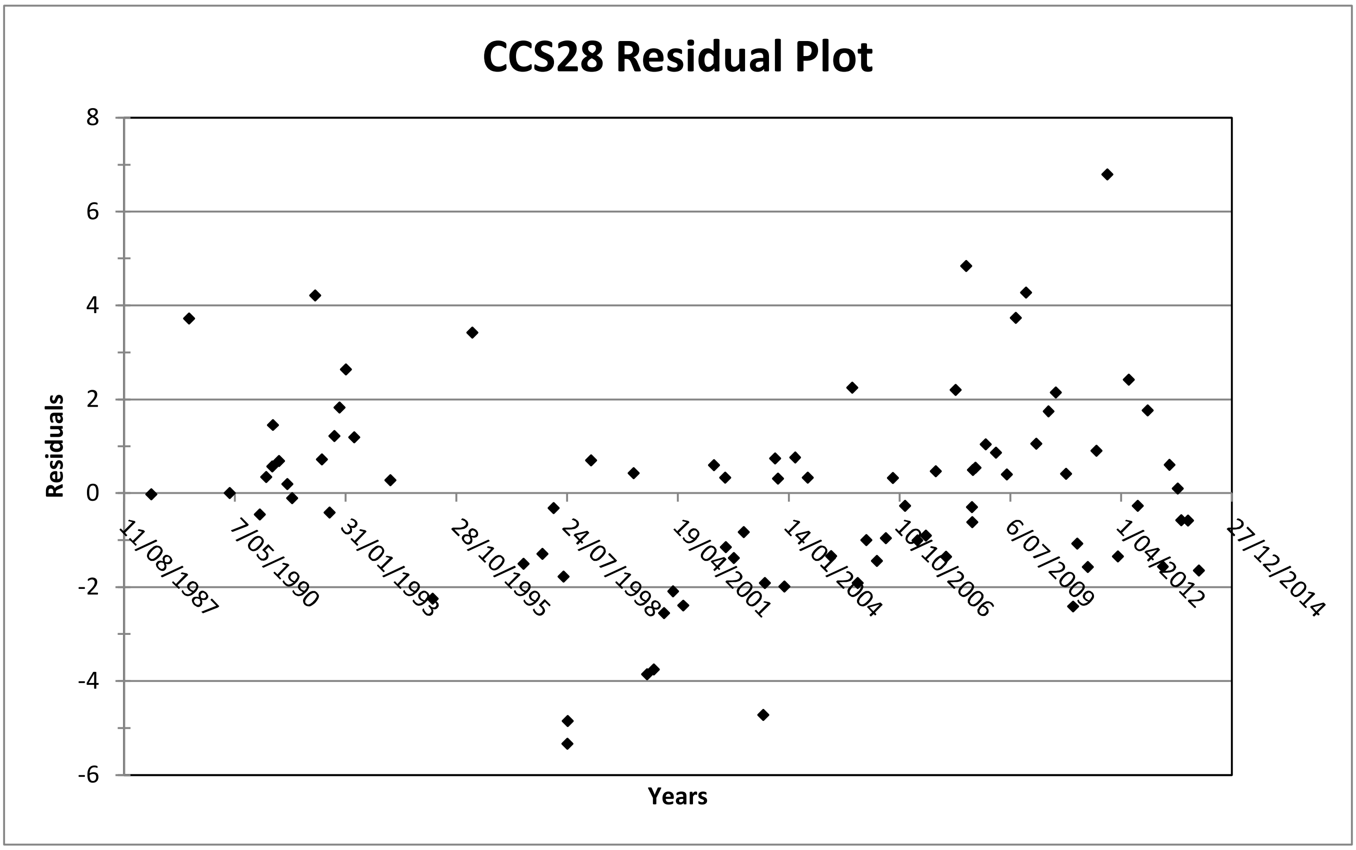


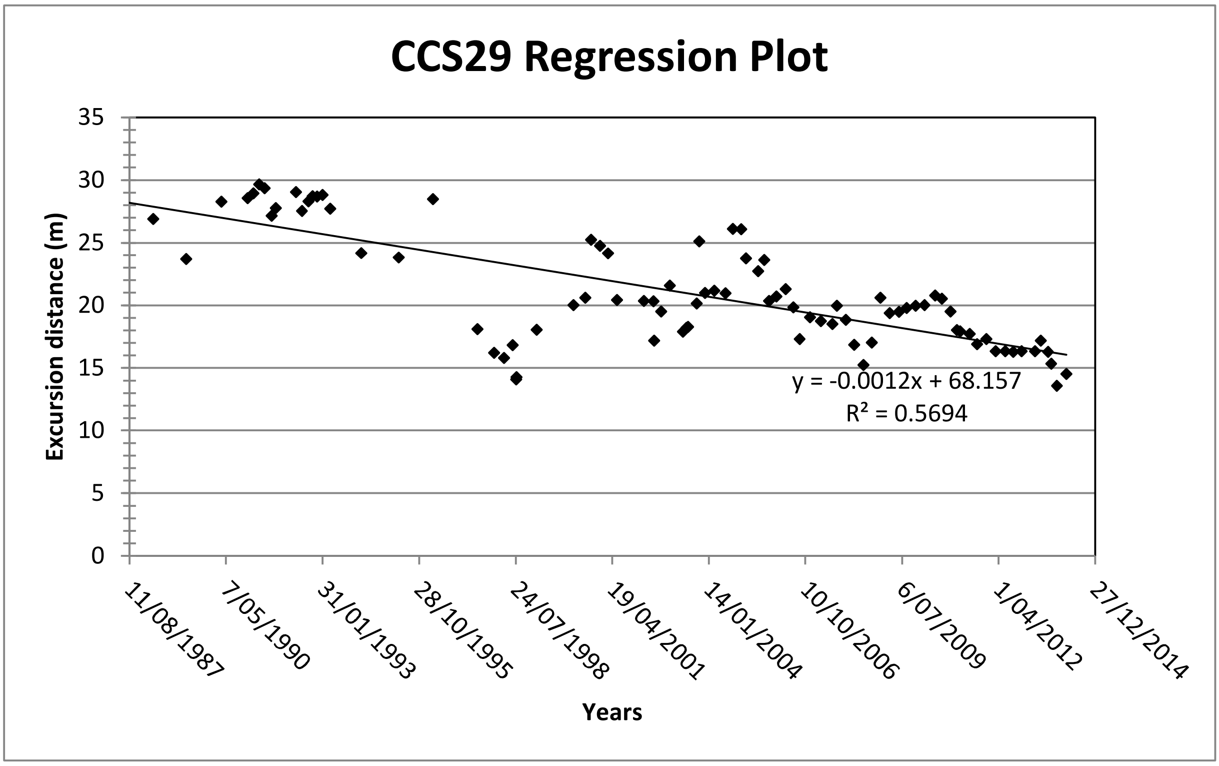
CCS27 Regression Plot
Excursion distance (m)
35
30
25
20
15
10
5
0
y = -0.001x + 53.213
R² = 0.3294
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

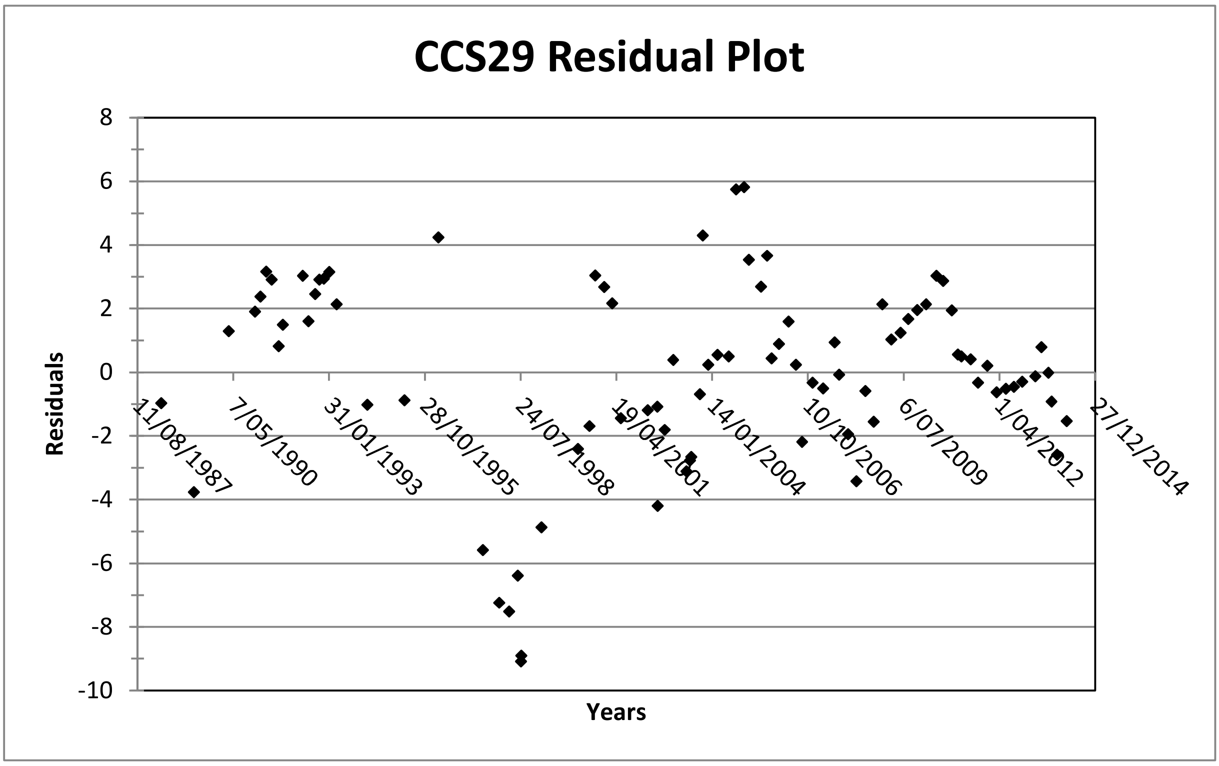


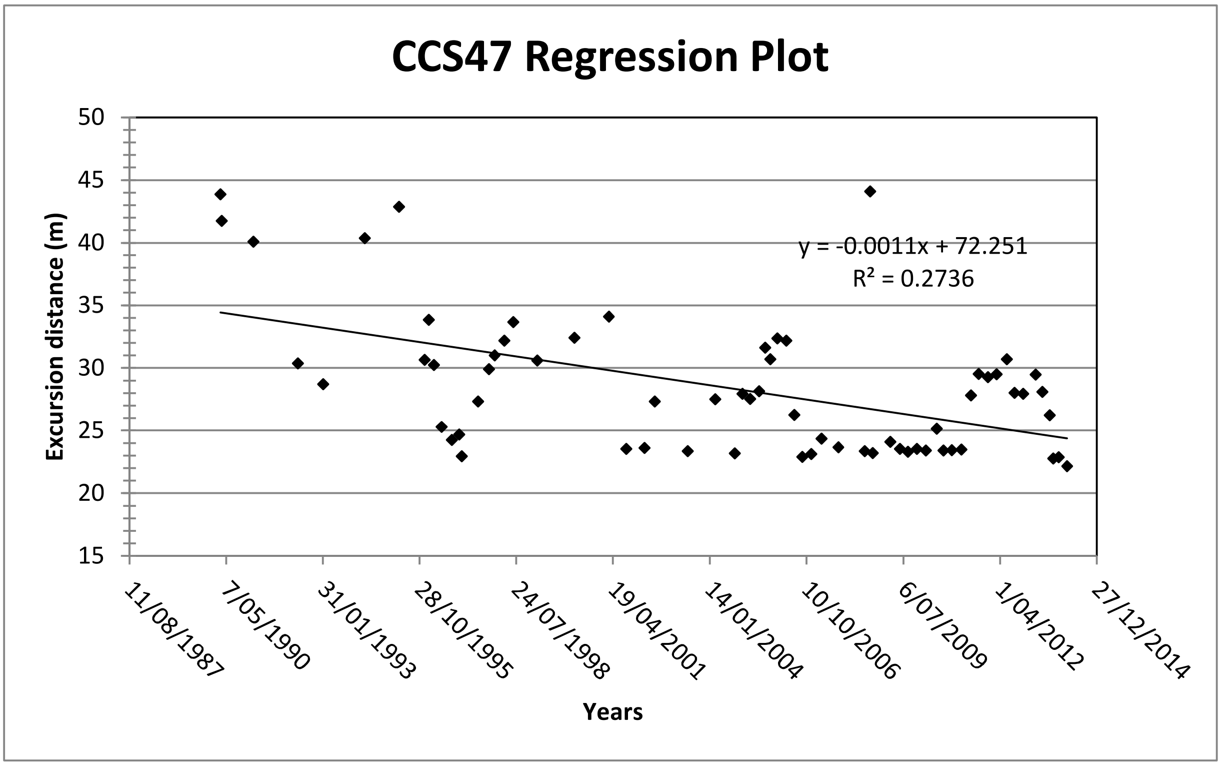
CCS27Residual Plot
Residuals
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

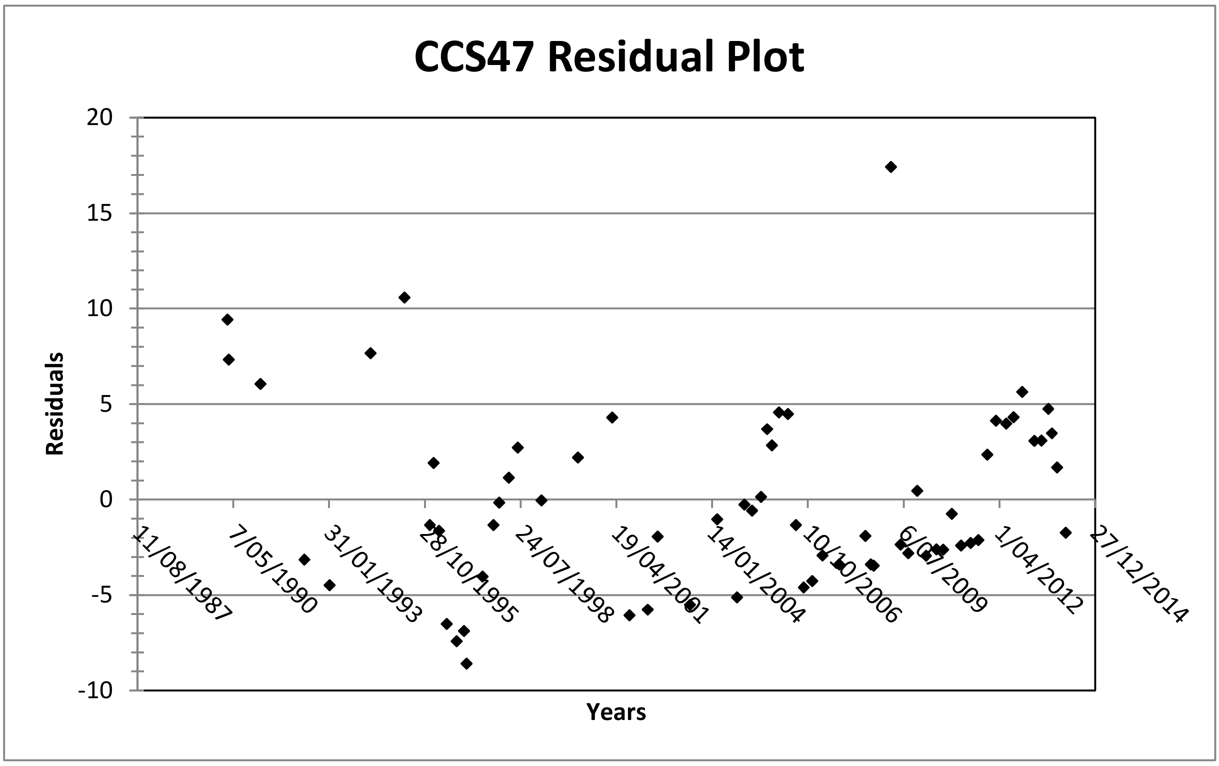

CCS28 Regression Plot
Excursion distance (m)
60
50
40
30
20
10
0
y = 0.0003x + 27.415
R² = 0.1796
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

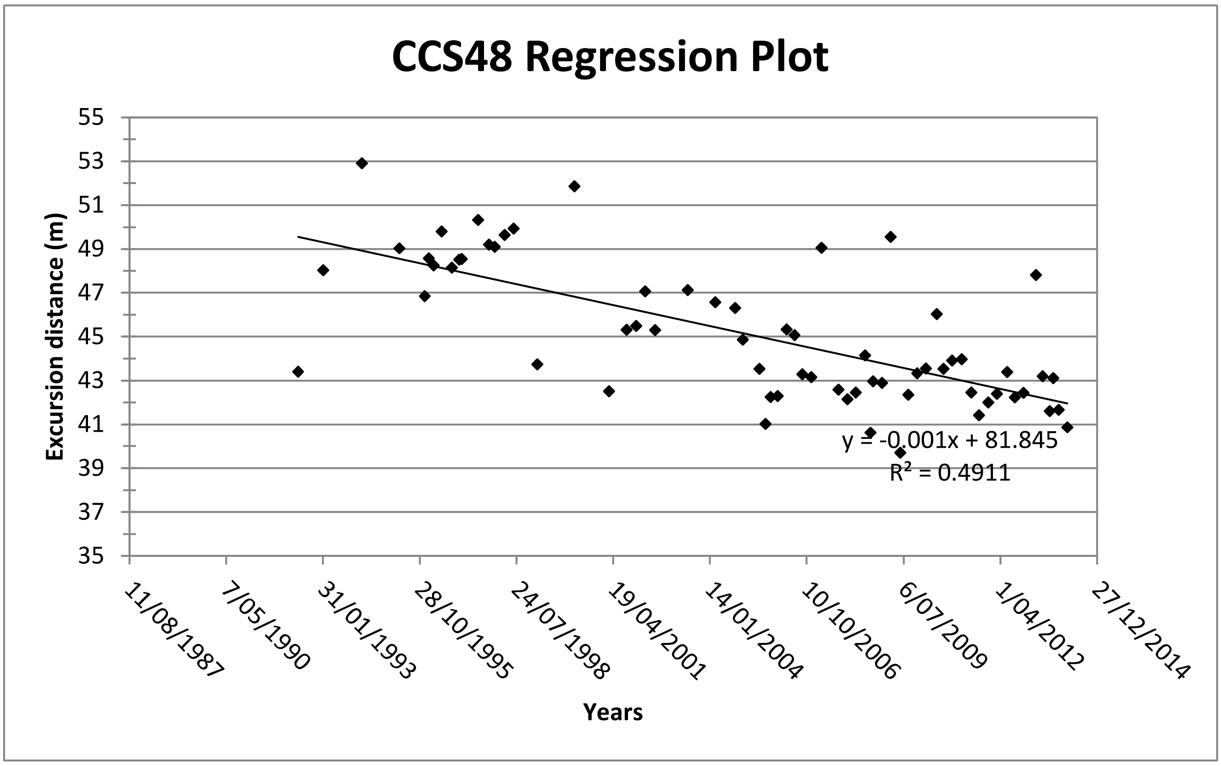

CCS28 Residual Plot
Residuals
8
6
4
2
0
-2
-4
-6
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

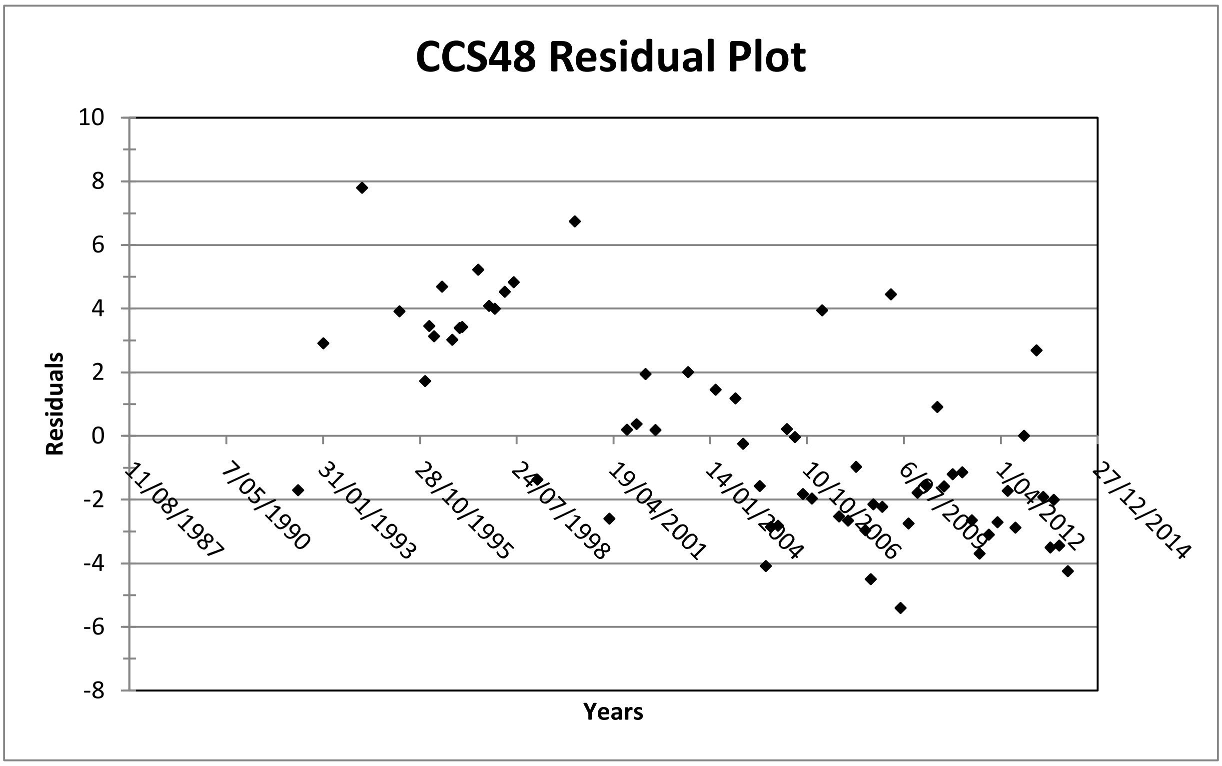

CCS29 Regression Plot
Excursion distance (m)
35
30
25
20
15
10
5
0
y = -0.0012x + 68.157
R² = 0.5694
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

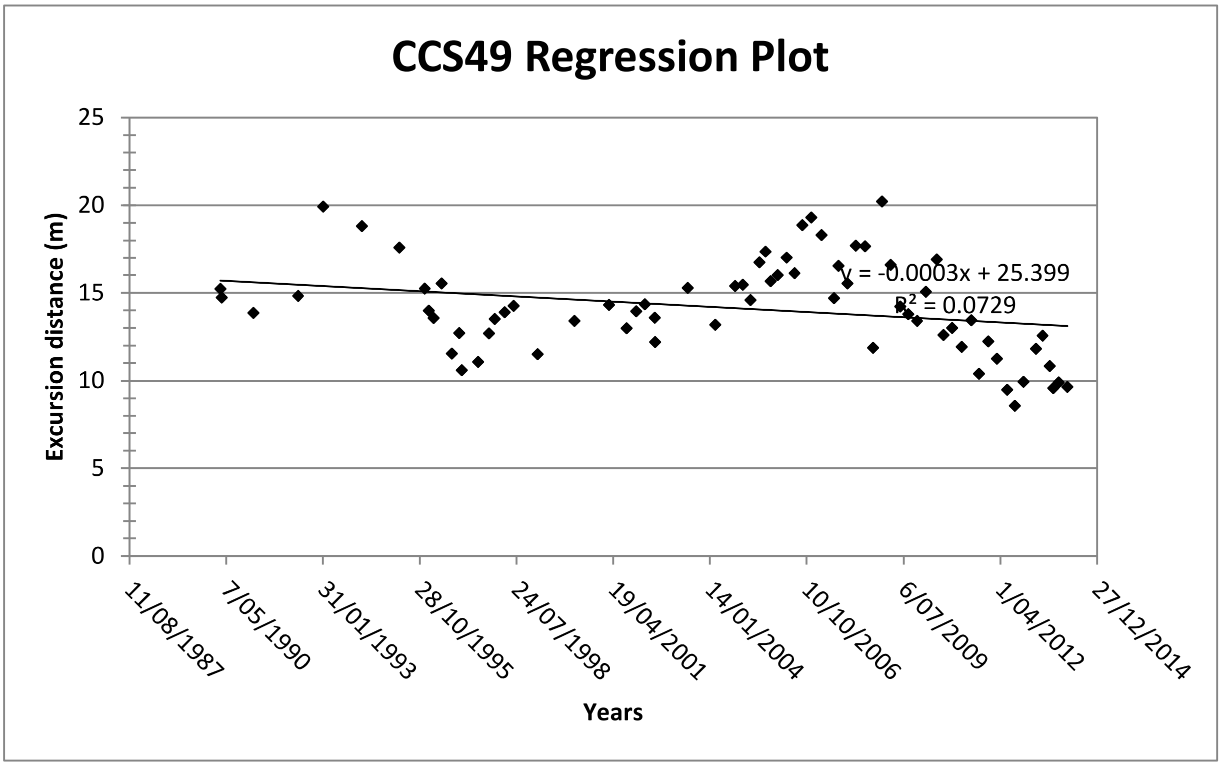

CCS29 Residual Plot
Residuals
8
6
4
2
0
-2
-4
-6
-8
-10
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

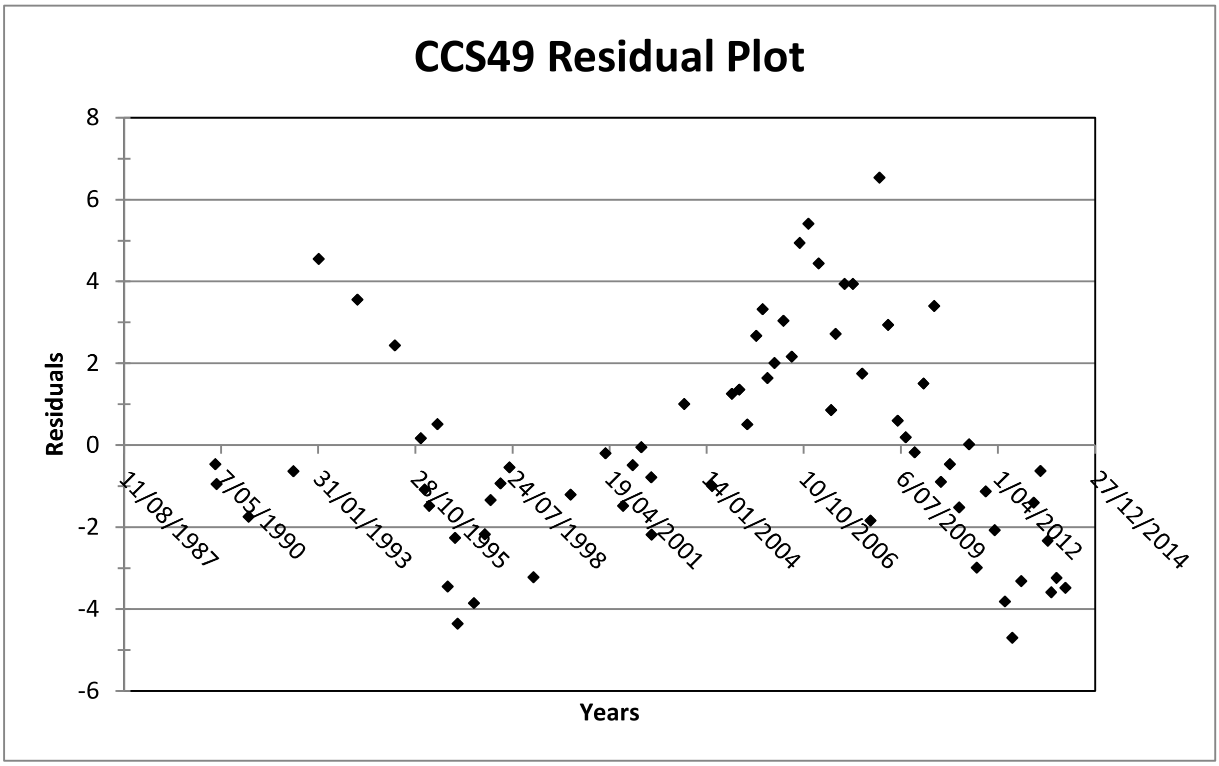

CCS47 Regression Plot
Excursion distance (m)
50
45
40
35
30
25
20
15
y = -0.0011x + 72.251
R² = 0.2736
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

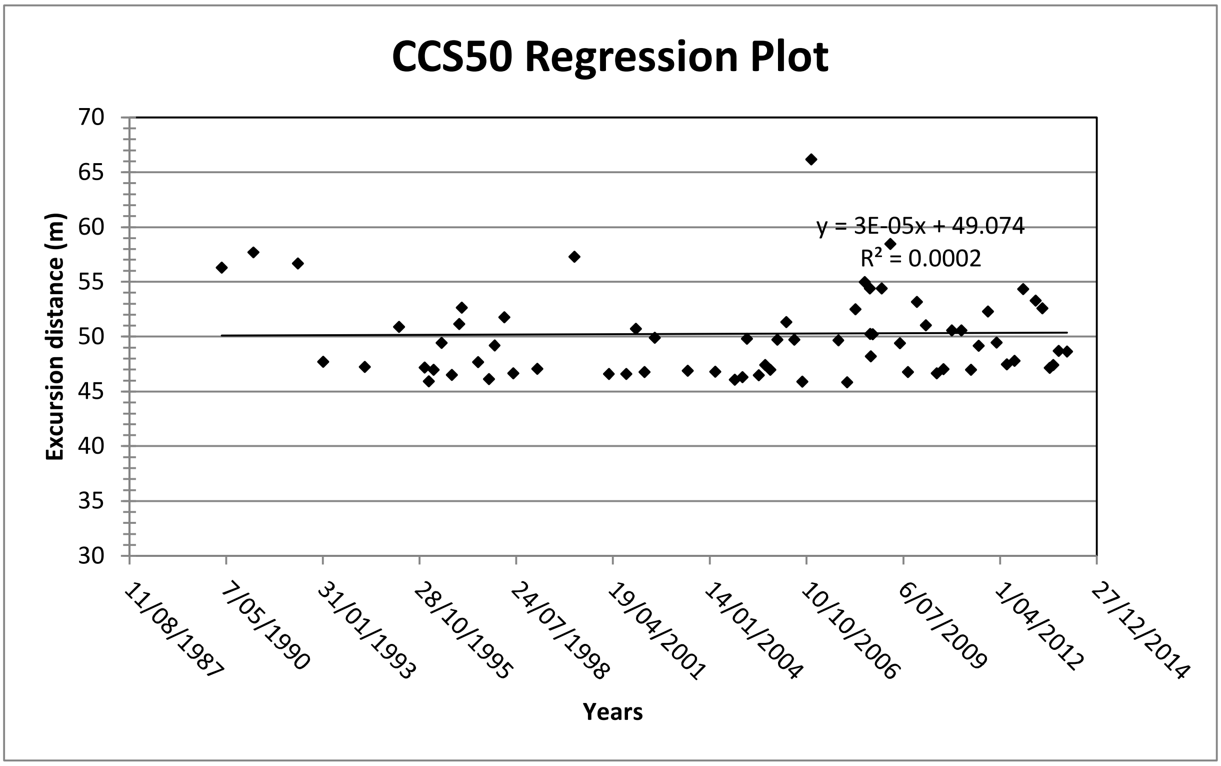

CCS47 Residual Plot
Residuals
20
15
10
5
0
-5
-10
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

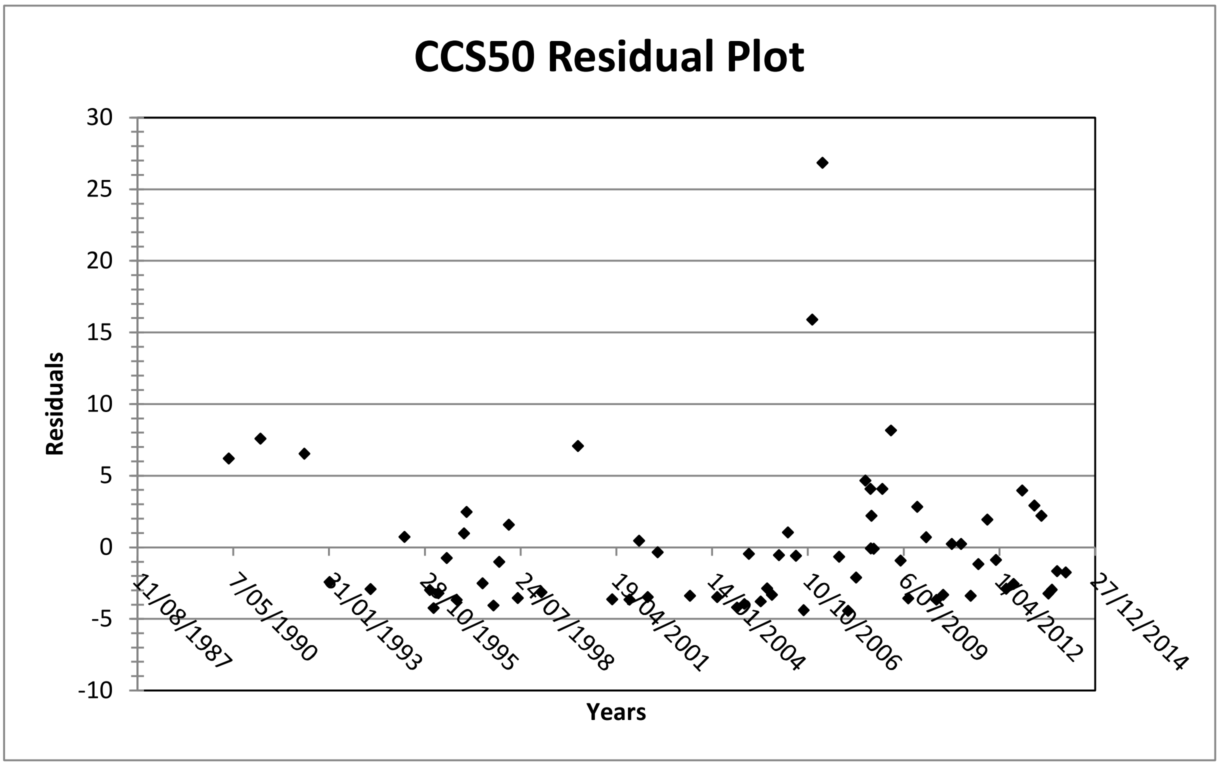

CCS48 Regression Plot
Excursion distance (m)
55
53
51
49
47
45
43
41
39
37
35
y = -0.001x + 81.845
R² = 0.4911
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

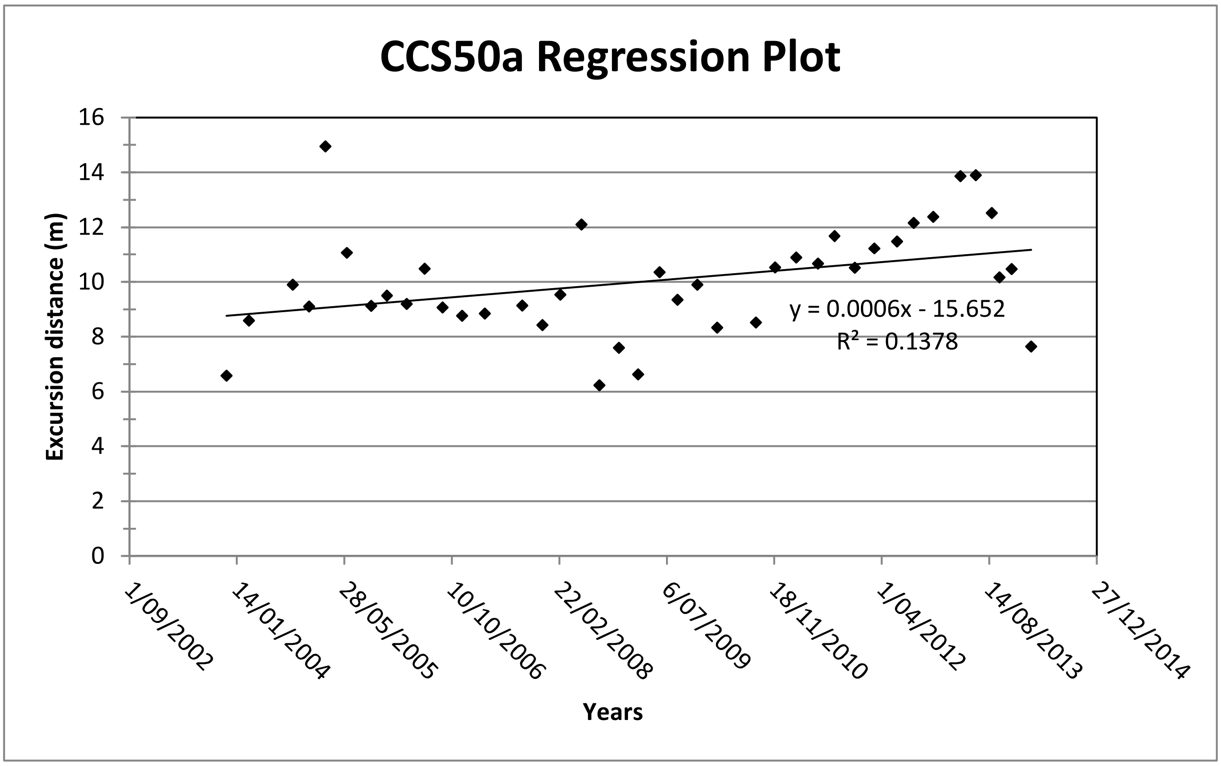

CCS48 Residual Plot
Residuals
10
8
6
4
2
0
-2
-4
-6
-8
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

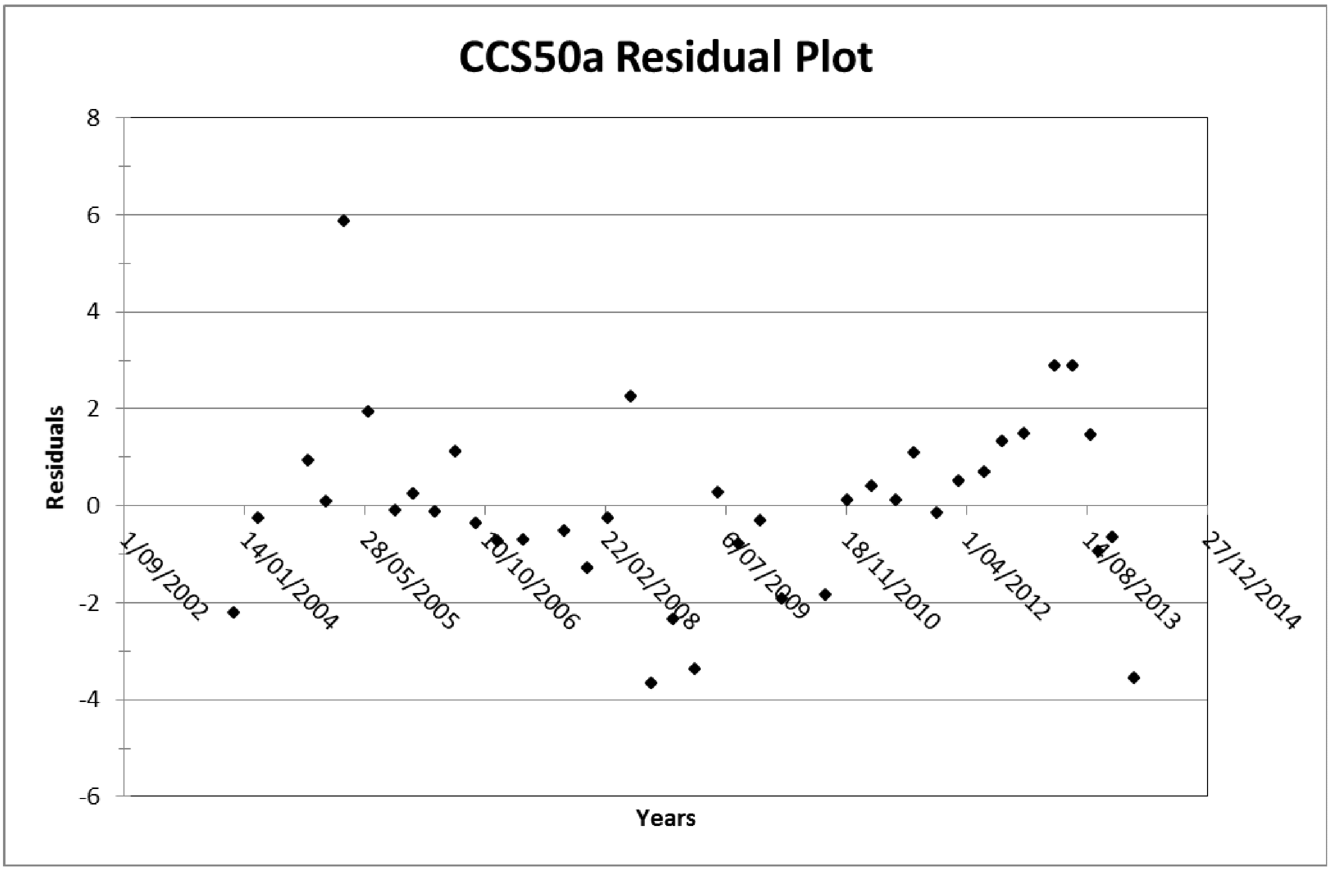

CCS49 Regression Plot
25
20
15
10
5
0
Excursion distance (m)
y = -0.0003x + 25.399
R² = 0.0729
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

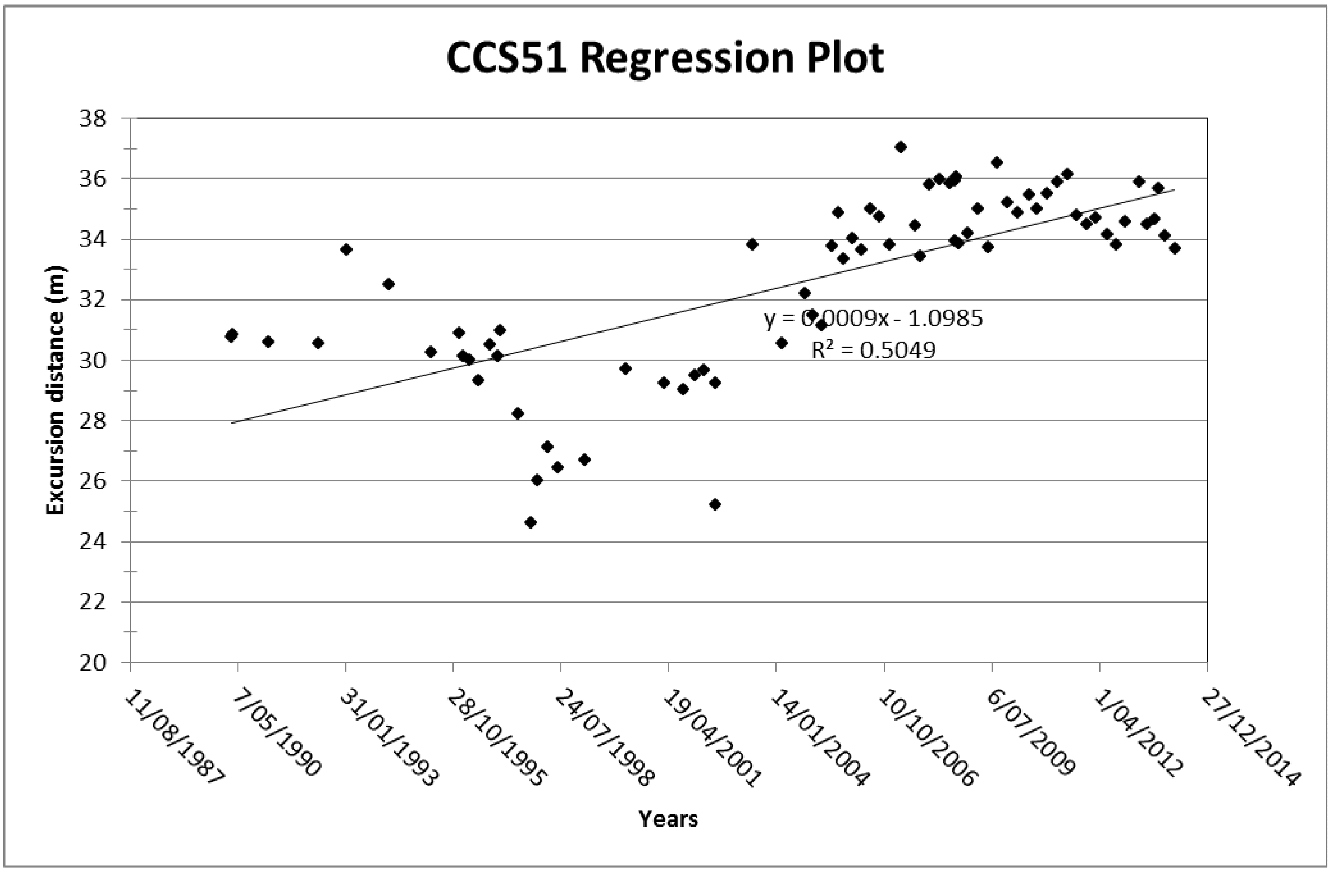

CCS49 Residual Plot
8
6
4
2
0
-2
-4
-6
Residuals
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

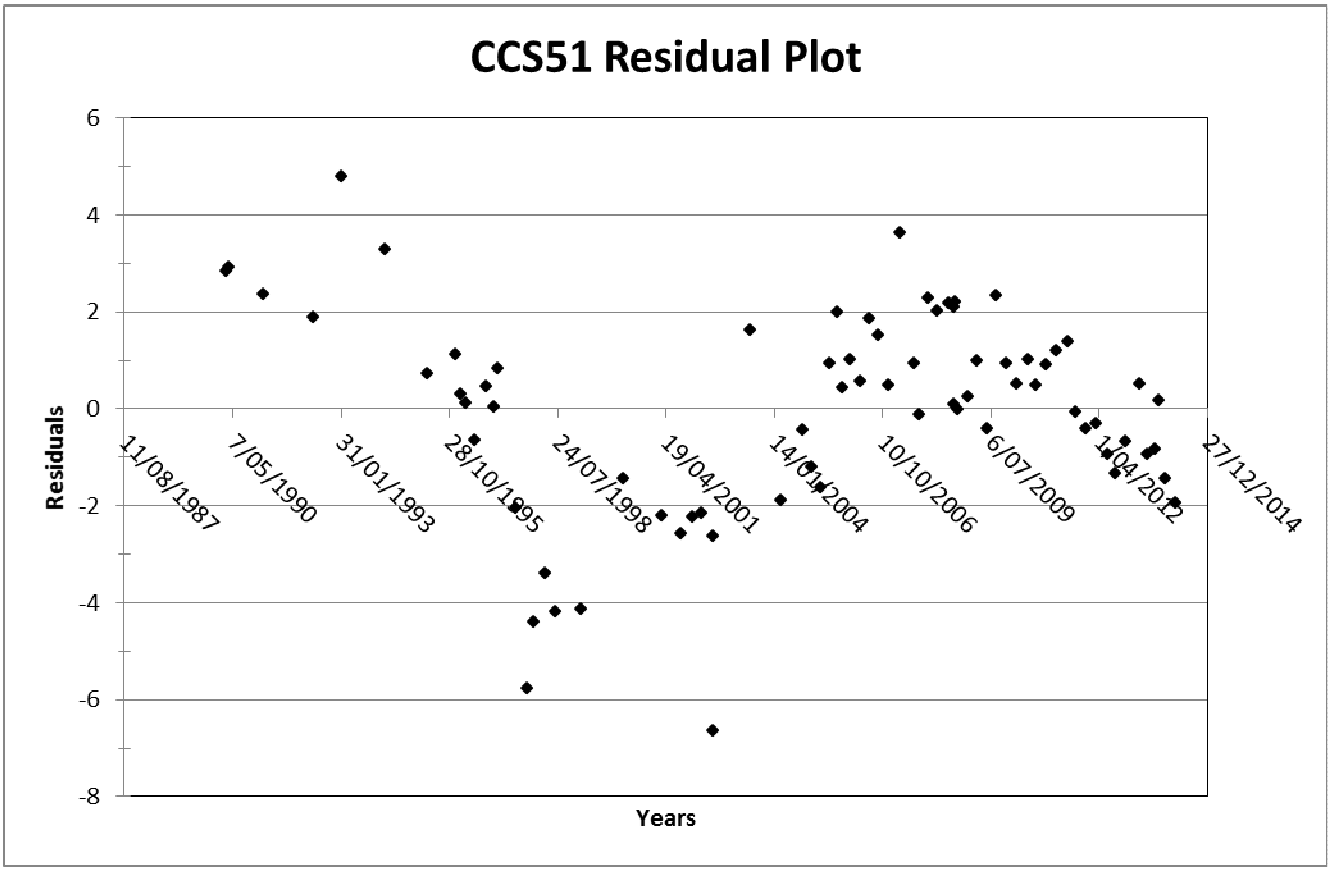

CCS50 Regression Plot
Excursion distance (m)
70
65
60
55
50
45
40
35
30
y = 3E-05x + 49.074
R² = 0.0002
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

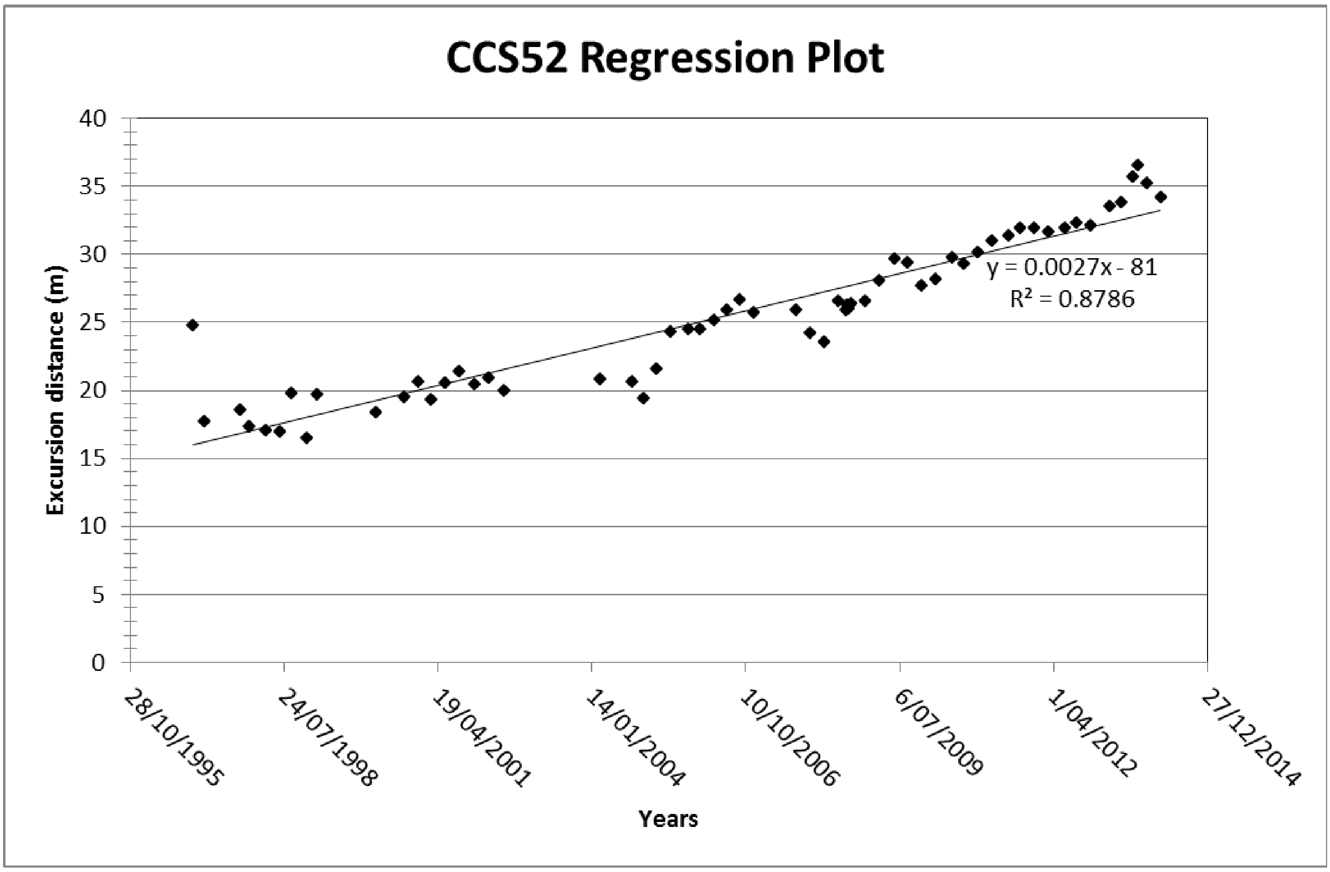

CCS50 Residual Plot
Residuals
30
25
20
15
10
5
0
-5
-10
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

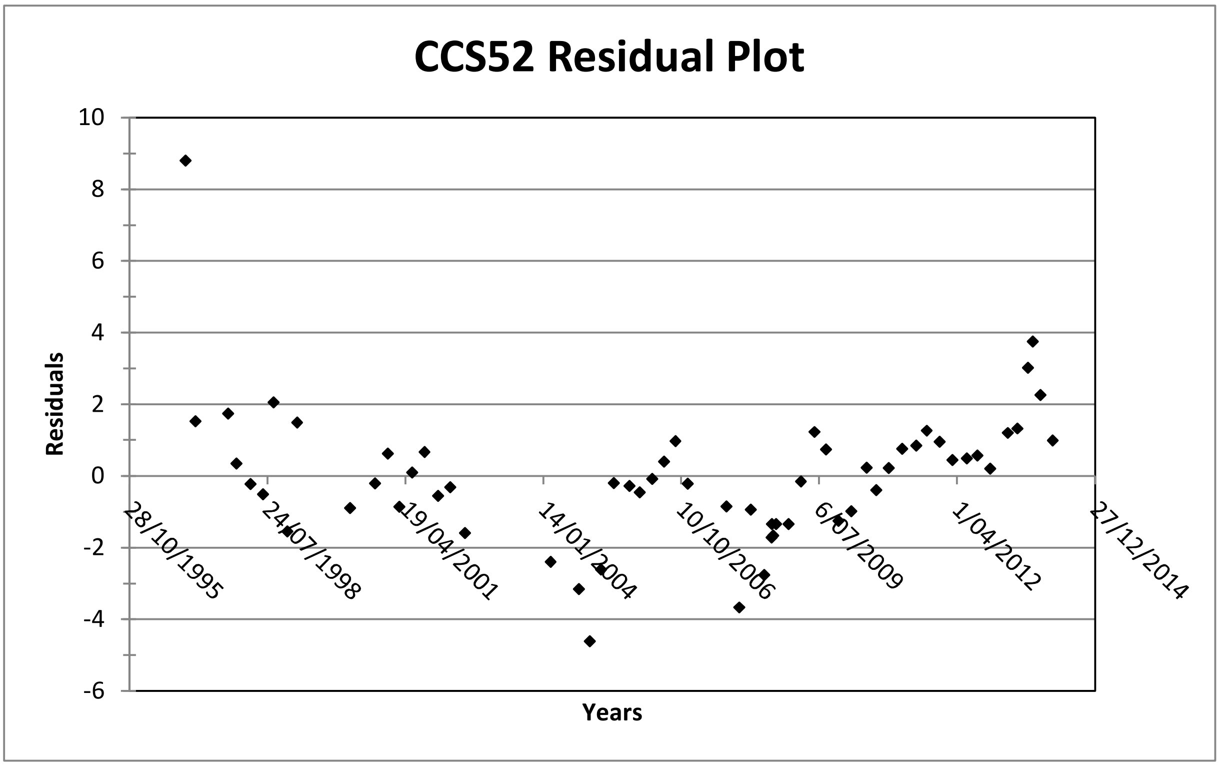

CCS50a Regression Plot
Excursion distance (m)
16
14
12
10
8
6
4
2
0
y = 0.0006x - 15.652
R² = 0.1378
1/09/2002
14/01/2004
28/05/2005
10/10/2006
22/02/2008
6/07/2009
18/11/2010
1/04/2012
14/08/2013
27/12/2014
Years

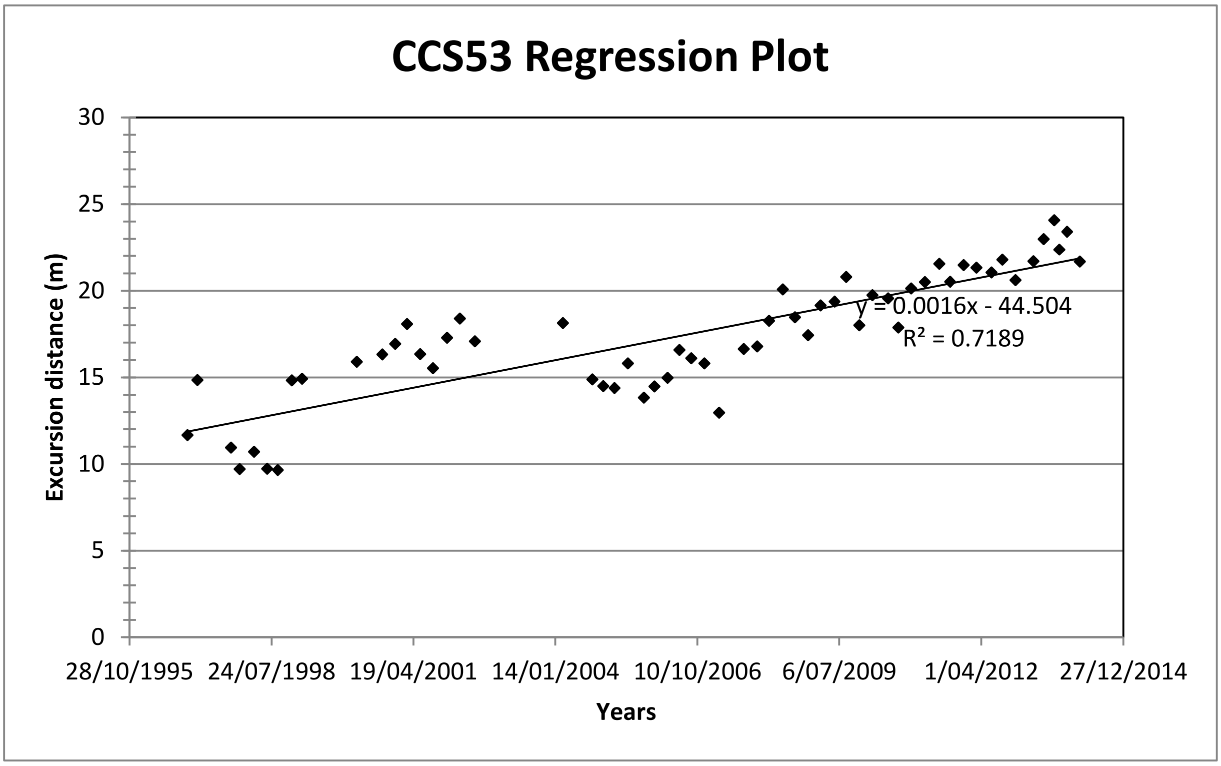

CCS50a Residual Plot
Residuals
8
6
4
2
0
-2
-4
-6
1/09/2002
14/01/2004
28/05/2005
10/10/2006
22/02/2008
6/07/2009
18/11/2010
1/04/2012
14/08/2013
27/12/2014
Years

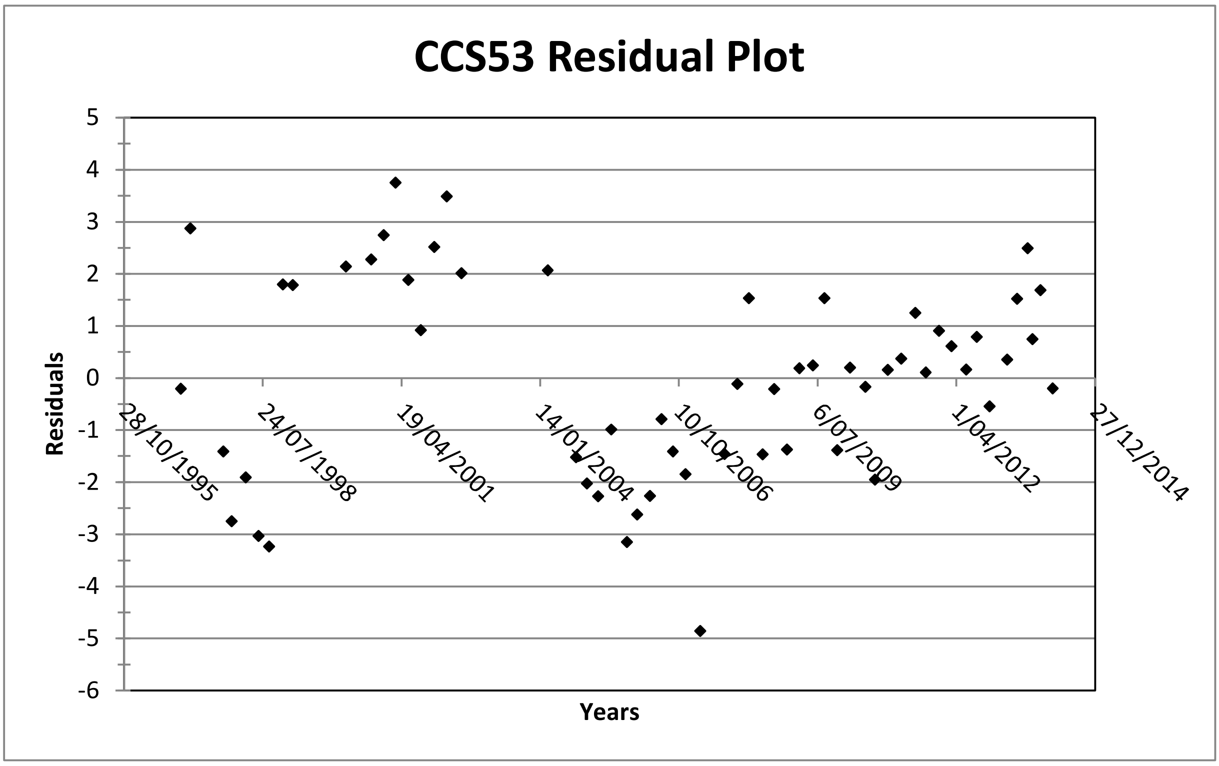

CCS51 Regression Plot
Excursion distance (m)
38
36
34
32
30
28
26
24
22
20
y = 0.0009x - 1.0985
R² = 0.5049
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

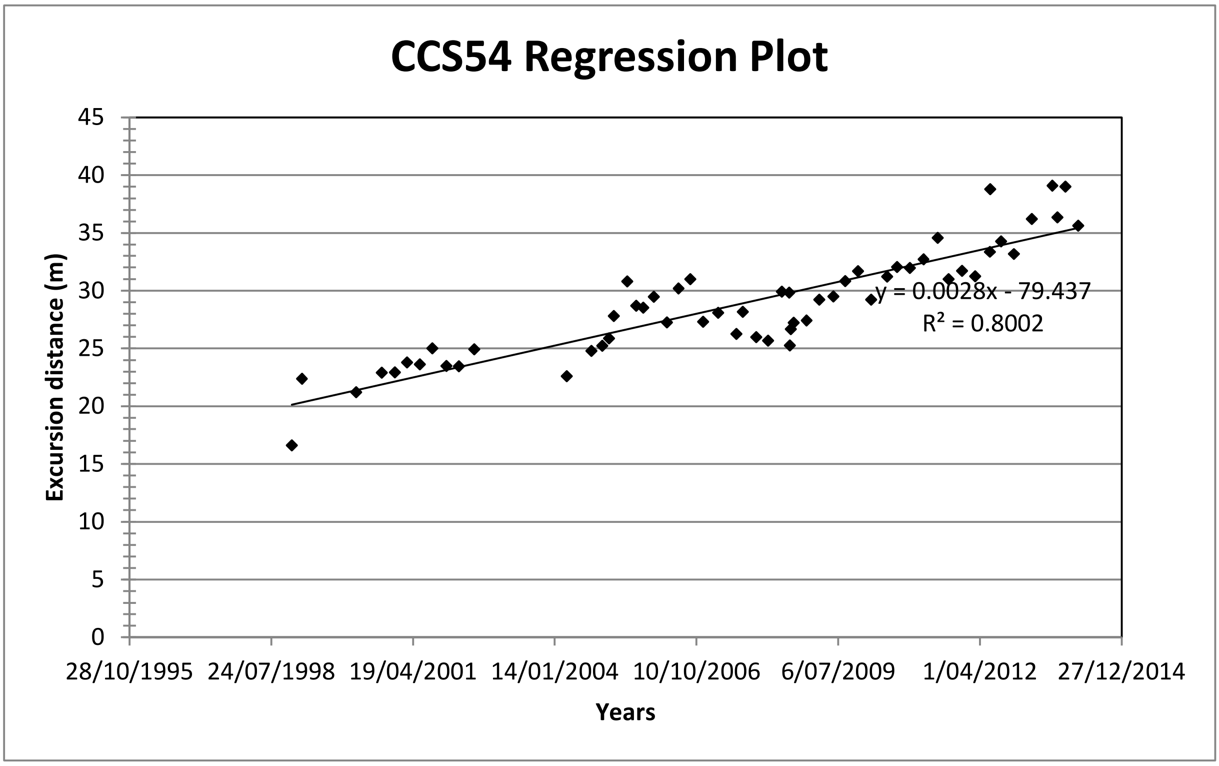

CCS51 Residual Plot
Residuals
6
4
2
0
-2
-4
-6
-8
11/08/1987
7/05/1990
31/01/1993
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

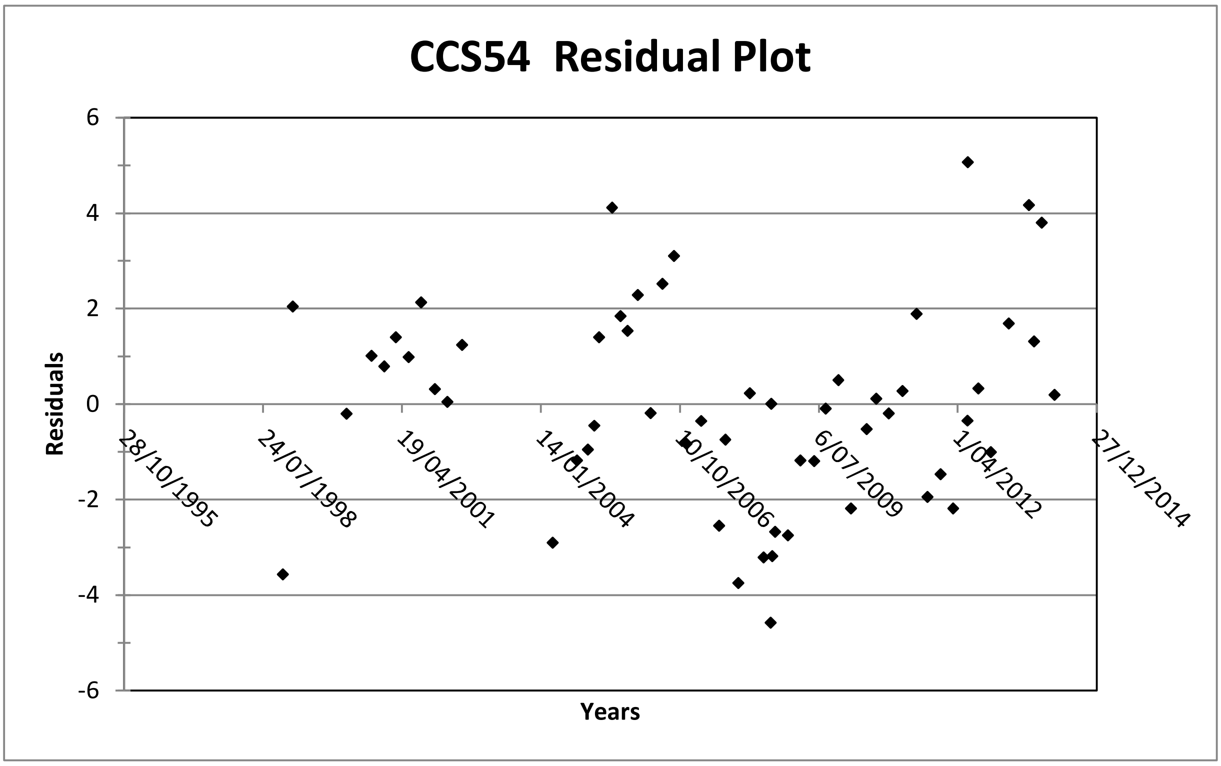

CCS52 Regression Plot
y = 0.0027x - 81
R² = 0.8786
Excursion distance (m)
40
35
30
25
20
15
10
5
0
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years


CCS52 Residual Plot
Residuals
10
8
6
4
2
0
-2
-4
-6
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years


CCS53 Regression Plot
Excursion distance (m)
30
25
20
15
10
5
0
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years
y = 0.0016x - 44.504
R² = 0.7189


CCS53 Residual Plot
Residuals
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years


CCS54 Regression Plot
Excursion distance (m)
45
40
35
30
25
20
15
10
5
0
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years
y = 0.0028x - 79.437
R² = 0.8002


CCS54 Residual Plot
Residuals
6
4
2
0
-2
-4
-6
28/10/1995
24/07/1998
19/04/2001
14/01/2004
10/10/2006
6/07/2009
1/04/2012
27/12/2014
Years

Appendix D: CEHZ probabilistic model inputs

Site 1: Waihi Beach

Table 1-1 Component values for CEHZ Assessment

Site		1. Waihi Beach										
Cell		1A	1B	1C	1D	1E	1F	1G	1H	1I	1J	1K
Chainage, m (from N/W)		0-300	300-900	900-1300	1300-1800	1800-2300	2300-2700	2700-3100	3100-5000	5000-7000	7000-8000	8000-9000
Morphology		Inlet	Inlet	Dune	Dune	Inlet	Dune	Inlet	Dune	Dune	Dune	Dune
Short-term (m)	Min	4	4	5	5	10	10	10	10	0	10	10
	Mode	6	6	10	10	15	15	15	15	0	15	15
	Max	8	8	15	15	20	20	20	20	0	20	20
Dune elevation (m above toe)	Min	3.0	3.0	3.0	3.5	3.5	4.0	3.5	3.5	0	4.5	4.5
	Mode	3.5	4.0	4.0	4.0	4.5	5.5	4.5	5.5	0	6.0	6.5
	Max	4.0	5.0	5.0	5.0	5.5	6.5	6.0	7.5	0	9.5	9.0
Stable angle (deg)	Min	30	30	30	30	30	30	30	30	0	30	30
	Mode	32	32	32	32	32	32	32	32	0	32	32
	Max	34	34	34	34	34	34	34	34	0	34	34
Long-term (m) -ve erosion +ve accretion	Min	0.3	0.5	-0.2	0	1	0.1	0.6	0.1	0	-0.1	-0.3
	Mode	0.15	0.1	-0.3	-0.25	0	-0.25	0.3	-0.15	0	-0.2	-0.5
	Max	0	-0.1	-0.4	-0.5	-1	-0.6	0	-0.3	0	-0.3	-0.8
Closure slope	Min	0.026	0.025	0.025	0.025	0.036	0.036	0.036	0.035	0	0.041	0.044

Site		**1. Waihi Beach**										
Cell		1A	1B	1C	1D	1E	1F	1G	1H	1I	1J	1K
	Mode	0.018	0.018	0.018	0.018	0.022	0.022	0.022	0.02	0	0.016	0.012
	Max	0.009	0.009	0.009	0.009	0.01	0.01	0.01	0.011	0	0.01	0.009
SLR 2065 (m)	Min	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0	0.19	0.19
	Mode	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0	0.29	0.29
	Max	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0	0.39	0.39
SLR 2115(m)	Min	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0	0.45	0.45
	Mode	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0	0.77	0.77
	Max	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0	1.1	1.1

Table 1-2 Waihi Beach CEHZ Widths

Cell		**1A**			**1B**			**1C**			**1D**			**1E**			**1F**		
Time		2015	2065	2115	2015	2065	2115	2015	2065	2115	2015	2065	2115	2015	2065	2115	2015	2065	2115
Probability of CEHZ (m) Exceedance	Min	-6	-4	-4	-7	5	18	-8	-29	-54	-8	-21	-38	-13	21	61	-14	-21	-28
	99%	-7	-8	-13	-7	-1	-1	-9	-35	-65	-9	-28	-51	-14	13	36	-15	-27	-42
	95%	-7	-10	-19	-8	-5	-10	-10	-38	-70	-10	-32	-60	-15	2	14	-16	-31	-51
	90%	-8	-12	-23	-8	-8	-16	-10	-39	-74	-11	-34	-65	-16	-4	1	-16	-34	-57
	80%	-8	-14	-28	-8	-11	-24	-11	-41	-78	-11	-37	-71	-17	-14	-17	-17	-38	-65
	70%	-8	-15	-31	-9	-14	-30	-12	-43	-82	-12	-39	-75	-17	-21	-31	-18	-41	-70
	66%	-8	-16	-33	-9	-15	-31	-12	-43	-83	-12	-40	-77	-18	-23	-36	-18	-41	-72
	60%	-9	-17	-35	-9	-16	-34	-13	-44	-85	-13	-41	-80	-18	-26	-44	-19	-43	-75
	50%	-9	-18	-38	-9	-18	-39	-13	-45	-88	-13	-43	-84	-19	-32	-55	-19	-45	-80
	40%	-9	-19	-41	-9	-20	-43	-14	-46	-91	-14	-45	-88	-19	-37	-66	-20	-47	-84
	33%	-9	-20	-44	-10	-22	-46	-14	-47	-94	-14	-46	-91	-20	-41	-74	-20	-49	-88
	30%	-9	-21	-45	-10	-22	-48	-14	-48	-95	-14	-47	-92	-20	-43	-78	-20	-50	-89
	20%	-10	-23	-51	-10	-25	-54	-15	-50	-100	-15	-49	-98	-20	-50	-93	-21	-53	-95
	10%	-10	-26	-58	-10	-28	-62	-16	-52	-108	-16	-53	-106	-21	-60	-111	-22	-56	-104
	5%	-10	-28	-66	-11	-31	-69	-17	-55	-115	-17	-56	-114	-22	-67	-126	-23	-59	-111
	1%	-11	-33	-80	-11	-36	-83	-18	-60	-129	-18	-61	-129	-23	-78	-147	-24	-65	-128
	Max	-11	-43	-105	-12	-52	-116	-19	-72	-153	-19	-73	-160	-24	-92	-210	-25	-76	-172
	CEHZ2065	-16			-15			-43			-40			-23			-41		
	CEHZ2115	-66			-69			-115			-114			-126			-111		

1G			1H			1J			1K		
2065	2115	2115	2065	2115	2115	2065	2115	2115	2065	2115	2115
-13	5	20	-13	-21	-28	-14	-28	-42	-14	-39	-63
-14	-1	9	-15	-26	-39	-16	-33	-53	-16	-46	-77
-15	-5	1	-16	-29	-46	-17	-36	-59	-17	-50	-85
-16	-7	-4	-16	-31	-51	-17	-38	-62	-17	-52	-90
-17	-11	-11	-17	-34	-56	-18	-40	-66	-18	-55	-97
-18	-13	-16	-18	-36	-60	-19	-41	-70	-19	-58	-102
-18	-14	-17	-18	-37	-62	-19	-42	-71	-19	-58	-104
-18	-15	-20	-19	-38	-64	-20	-43	-73	-20	-60	-107
-19	-17	-24	-19	-39	-68	-20	-44	-76	-20	-62	-112
-19	-19	-29	-20	-41	-71	-21	-45	-80	-21	-64	-118
-20	-21	-32	-20	-42	-73	-21	-46	-83	-21	-66	-121
-20	-21	-33	-21	-42	-75	-22	-47	-85	-22	-67	-123
-21	-24	-39	-21	-44	-80	-22	-49	-90	-22	-69	-131
-22	-27	-47	-22	-47	-87	-23	-52	-97	-23	-74	-141
-22	-30	-54	-23	-49	-92	-24	-54	-104	-24	-77	-151
-23	-36	-68	-24	-54	-104	-25	-59	-118	-25	-83	-166
-24	-46	-103	-25	-65	-129	-27	-71	-144	-27	-93	-199
-18			-37			-42			-58		
-54			-92			-104			-151		

Site 2: Pukehina

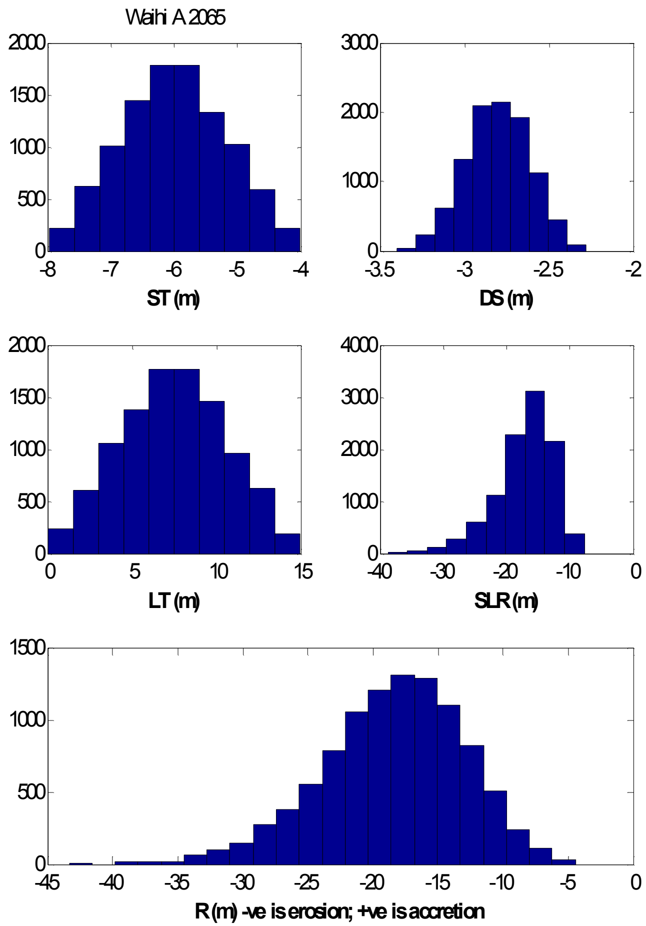
Table 2-1 Component values for CEHZ Assessment

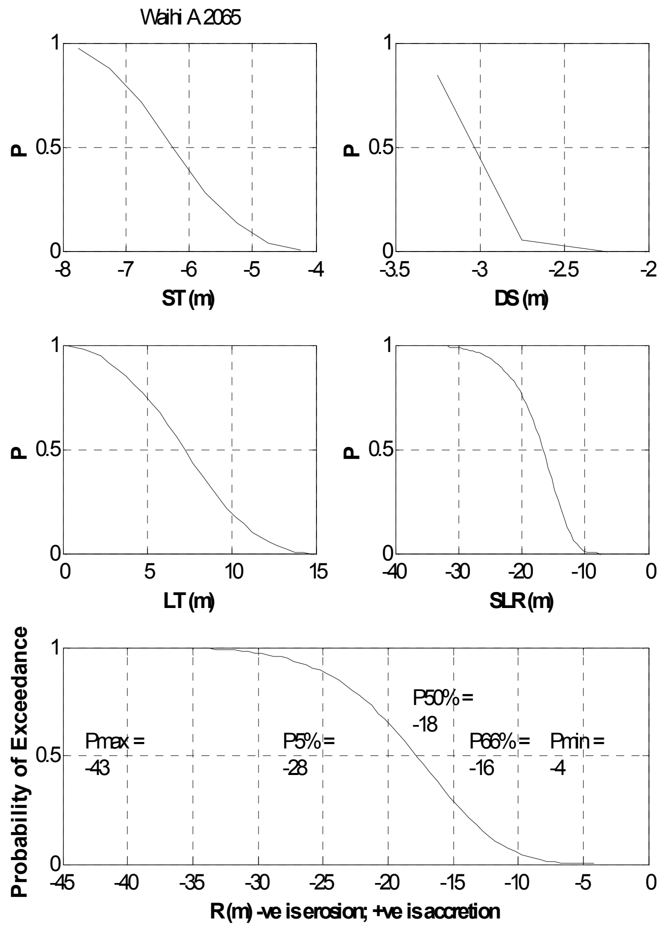
Site		**2. Pukehina**		
Cell		2A	2B	2C
Chainage, m (from N/W)		0-900	900-1800	1800-6000
Morphology		Dune	Dune	Dune
Short-term (m)	Min	10	10	10
	Mode	15	15	15
	Max	20	20	20
Dune elevation (m above toe or scarp)	Min	6.0	6.0	6.0
	Mode	7.5	7.5	8.0
	Max	9.0	10.0	11.0
Stable angle (deg)	Min	24	24	24
	Mode	29	29	29
	Max	34	34	34
Long-term (m) -ve erosion +ve accretion	Min	-0.2	-0.05	0.1
	Mode	-0.21	-0.1	0
	Max	-0.25	-0.15	-0.05
Closure slope	Min	0.058	0.058	0.064
	Mode	0.031	0.042	0.039
	Max	0.023	0.029	0.023
SLR 2065 (m)	Min	0.19	0.19	0.19
	Mode	0.29	0.29	0.29
	Max	0.39	0.39	0.39
SLR 2115 (m)	Min	0.45	0.45	0.45
	Mode	0.77	0.77	0.77
	Max	1.1	1.1	1.1

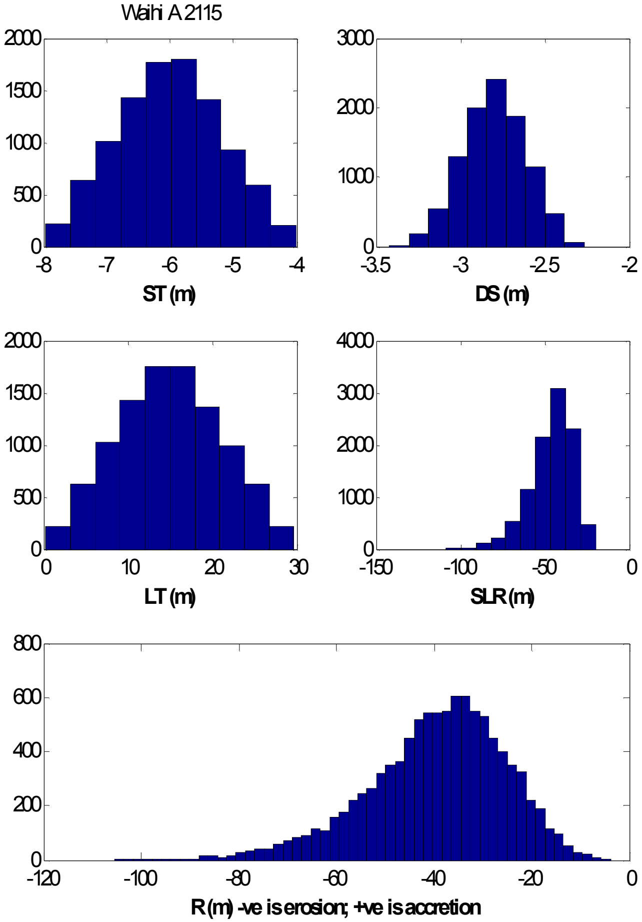
Table 2-2 Pukehina CEHZ Widths

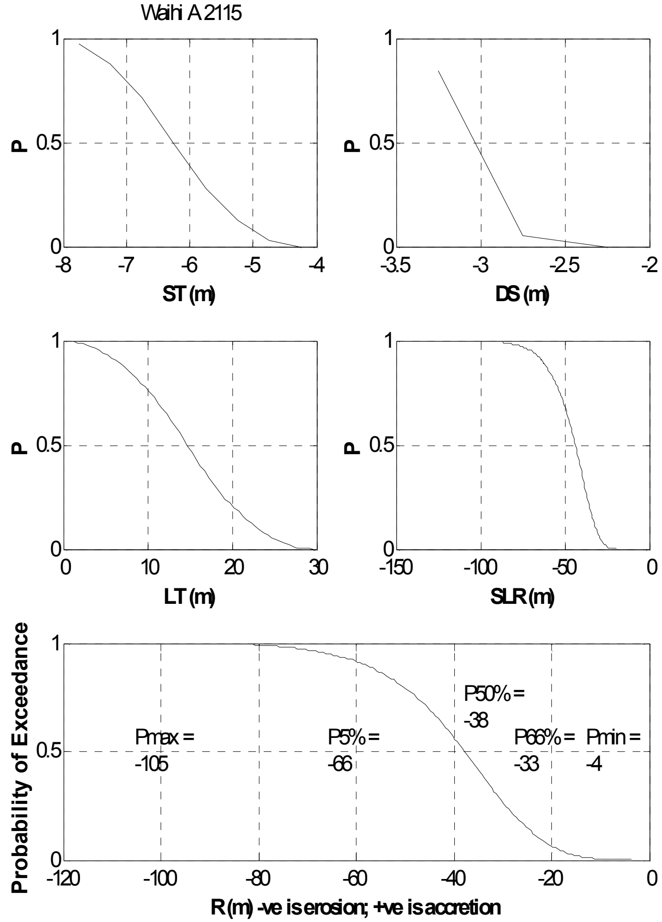
Site		2. Pukehina Beach								
Cell		2A			2B			2C		
Time		2015	2065	2115	2015	2065	2115	2015	2065	2115
Probability of CEHZ (m) Exceedance	Min	-16	-29	-46	-16	-25	-34	-16	-18	-19
	99%	-17	-33	-51	-17	-28	-40	-17	-22	-27
	95%	-18	-35	-54	-18	-29	-42	-19	-24	-31
	90%	-19	-36	-55	-19	-30	-44	-19	-25	-33
	80%	-20	-37	-58	-20	-32	-46	-21	-27	-36
	70%	-21	-38	-60	-21	-32	-48	-21	-28	-38
	66%	-21	-38	-60	-21	-33	-48	-21	-28	-38
	60%	-21	-39	-61	-21	-33	-49	-22	-29	-40
	50%	-22	-40	-63	-22	-34	-50	-23	-30	-41
	40%	-22	-41	-65	-23	-35	-52	-23	-31	-43
	33%	-23	-41	-66	-23	-35	-52	-24	-31	-44
	30%	-23	-41	-67	-23	-35	-53	-24	-32	-45
	20%	-24	-42	-69	-24	-36	-55	-25	-33	-48
	10%	-25	-44	-72	-25	-38	-57	-26	-34	-51
	5%	-25	-45	-75	-26	-39	-59	-26	-36	-54
	1%	-27	-47	-80	-27	-40	-63	-28	-38	-60
	Max	-28	-51	-89	-29	-44	-70	-30	-43	-77
	CEHZ2065	-38			-33			-28		
	CEHZ2115	-75			-59			-54		

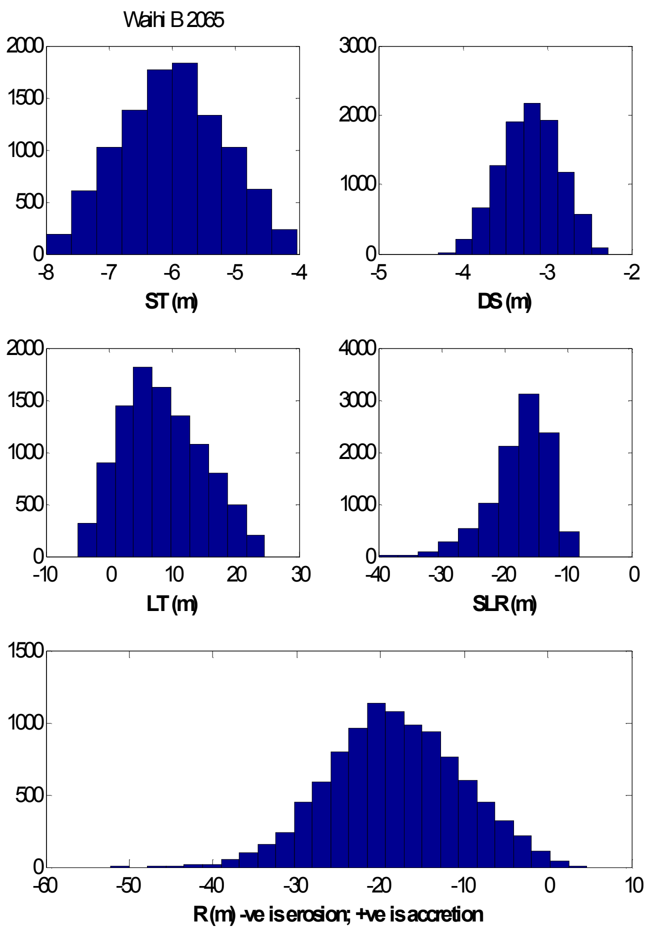
Appendix E: CEHZ probabilistic model outputs

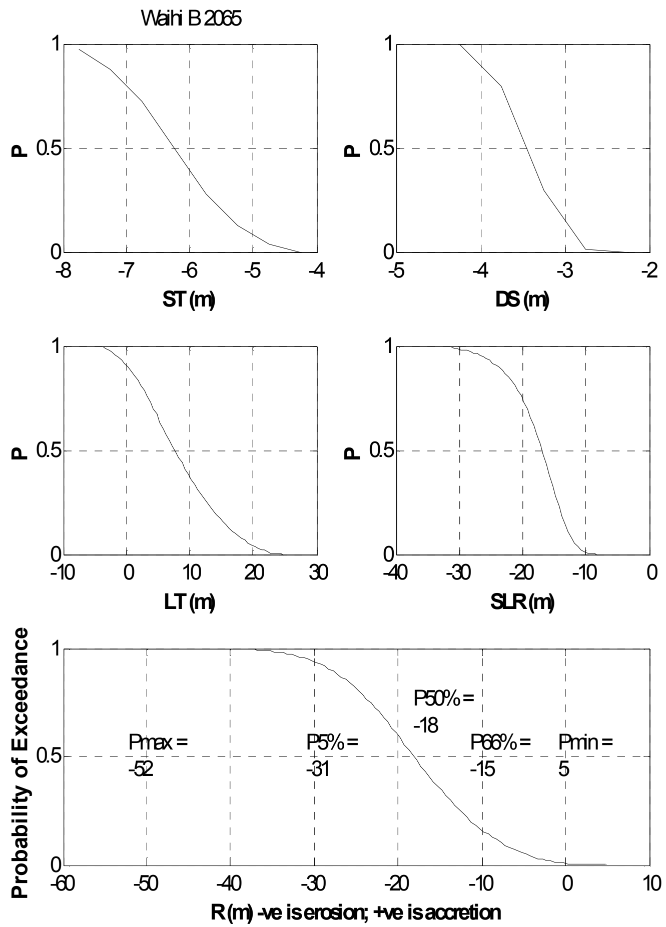

Waihi A 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

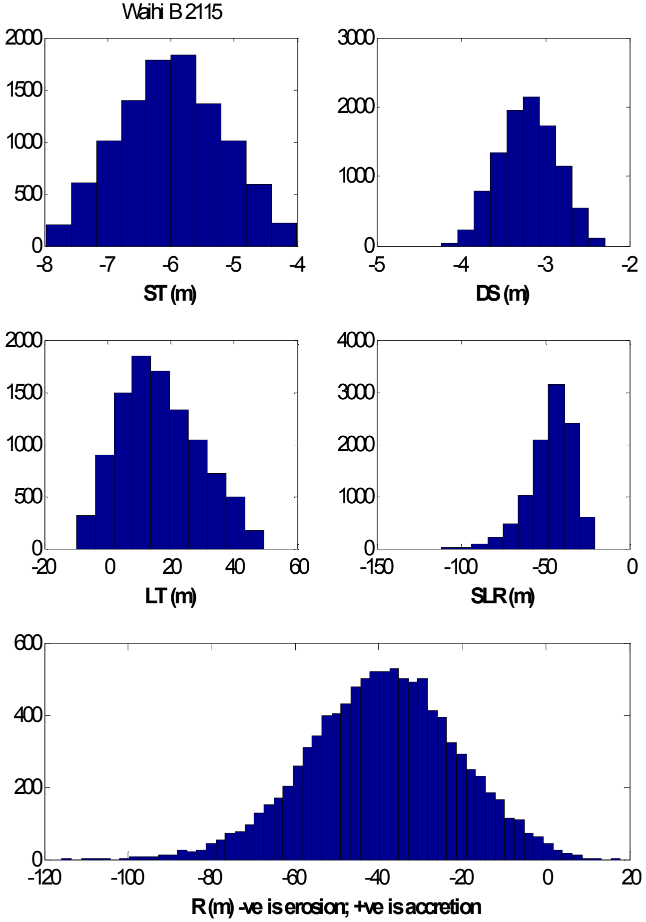

Waihi A 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-43
P5% =
-28
P50% =
-18
P66% =
-16
Pmin =
-4
R (m) -ve is erosion; +ve is accretion

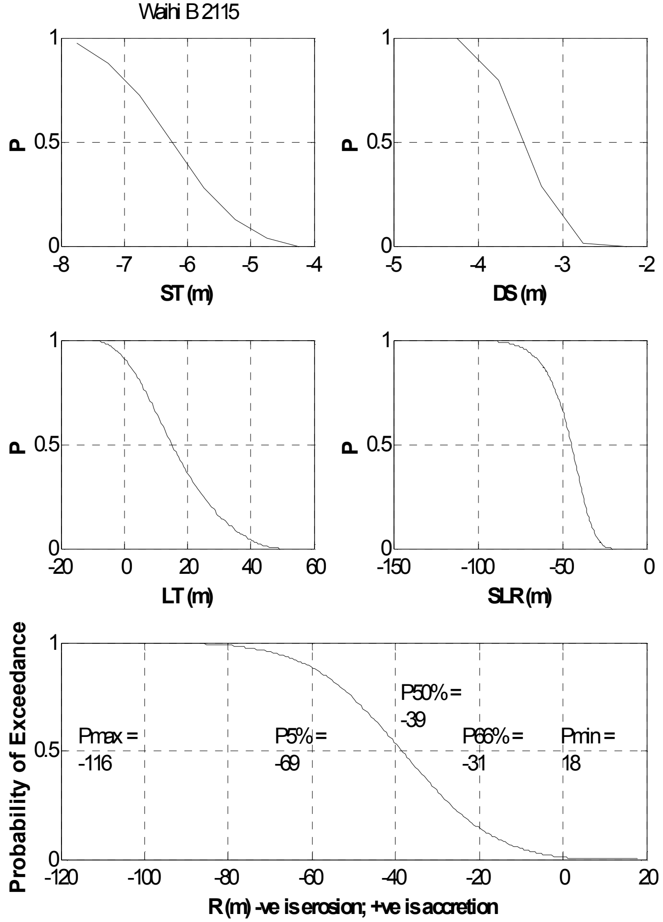

Waihi A 2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

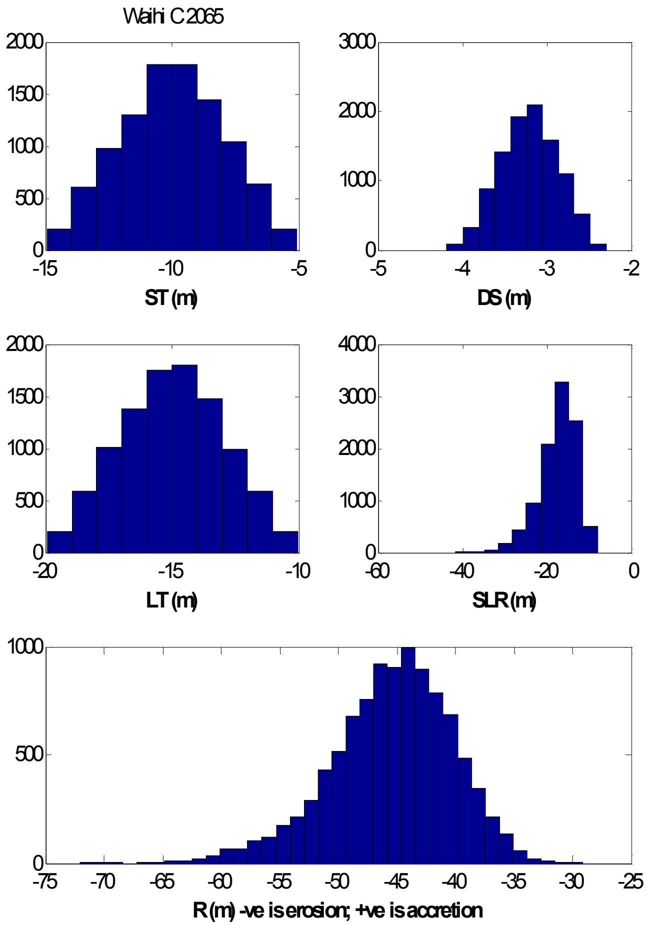

Waihi A 2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -105
P5% = -66
P50% = -38
P66% = -33
Pmin = -4
R (m) -ve is erosion; +ve is accretion

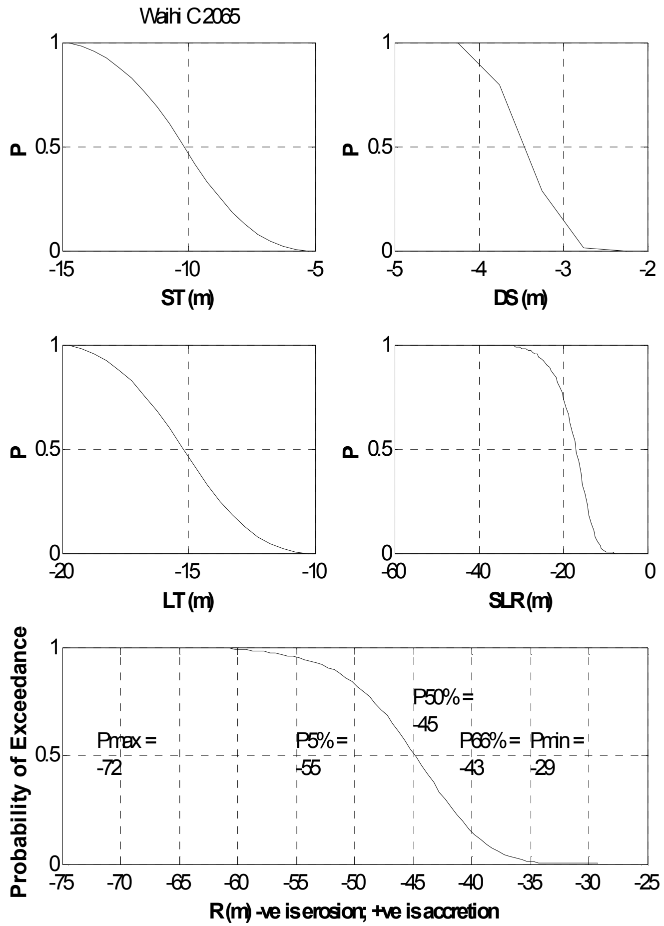

Waihi B 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

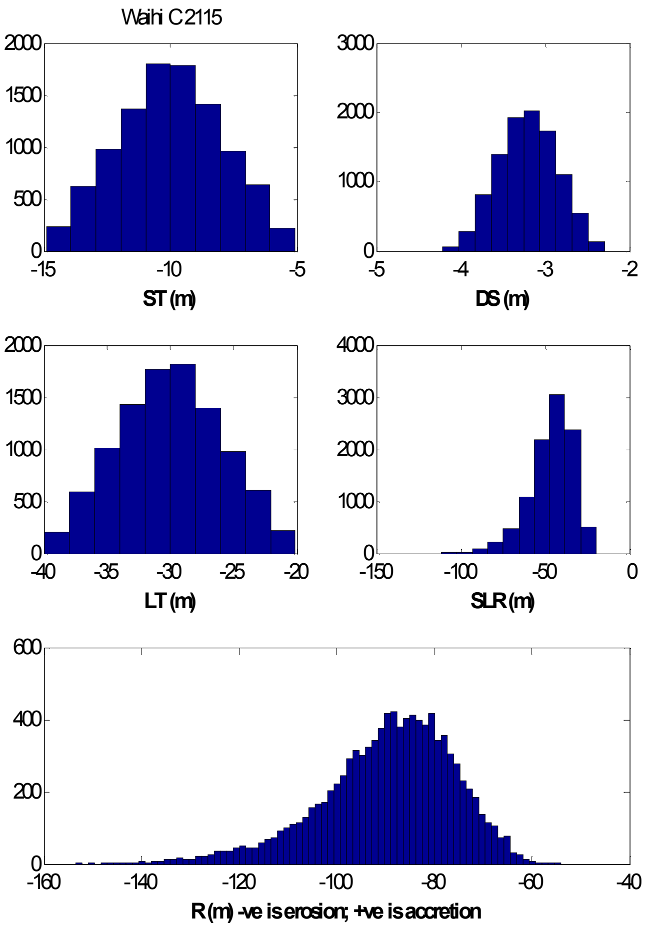

Waihi B 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-52
P5% =
-31
P50% =
-18
P66% =
-15
Pmin =
5
R (m) -ve is erosion; +ve is accretion

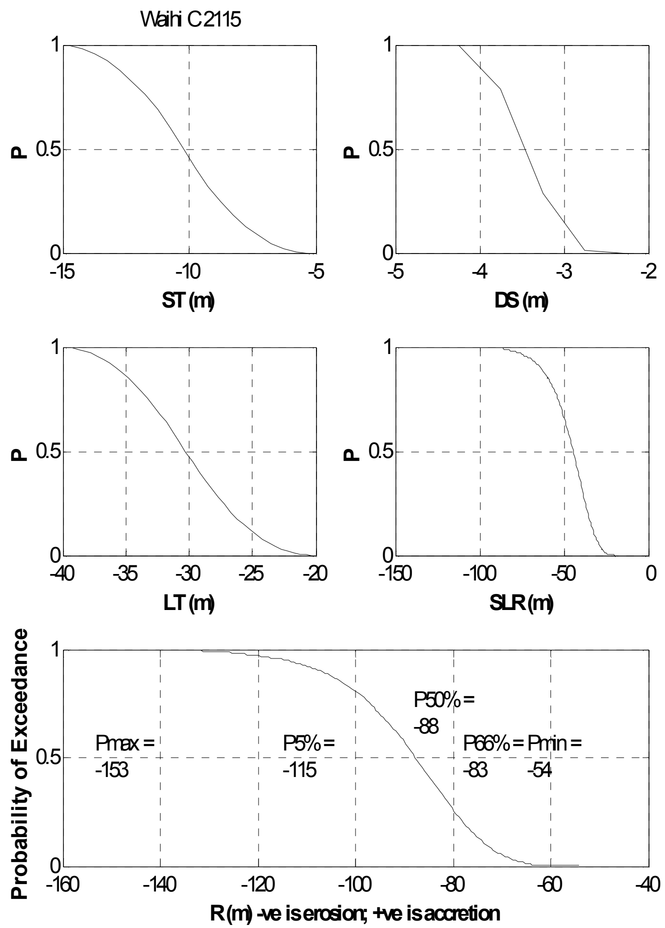

Waihi B 2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

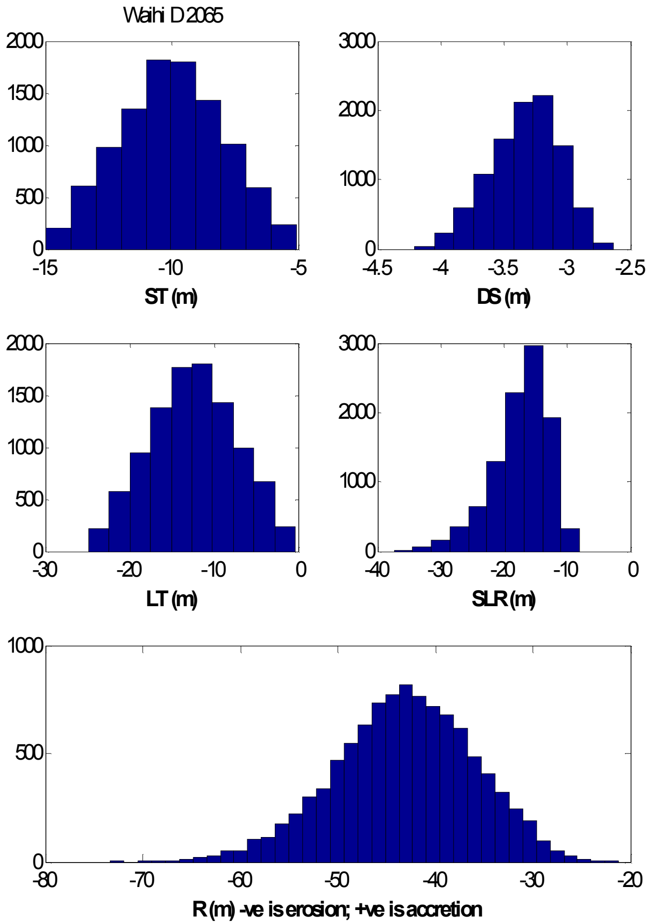

Waihi B 2115
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-116
P5% =
-69
P50% =
-39
P66% =
-31
Pmin =
18
R (m) -ve is erosion; +ve is accretion

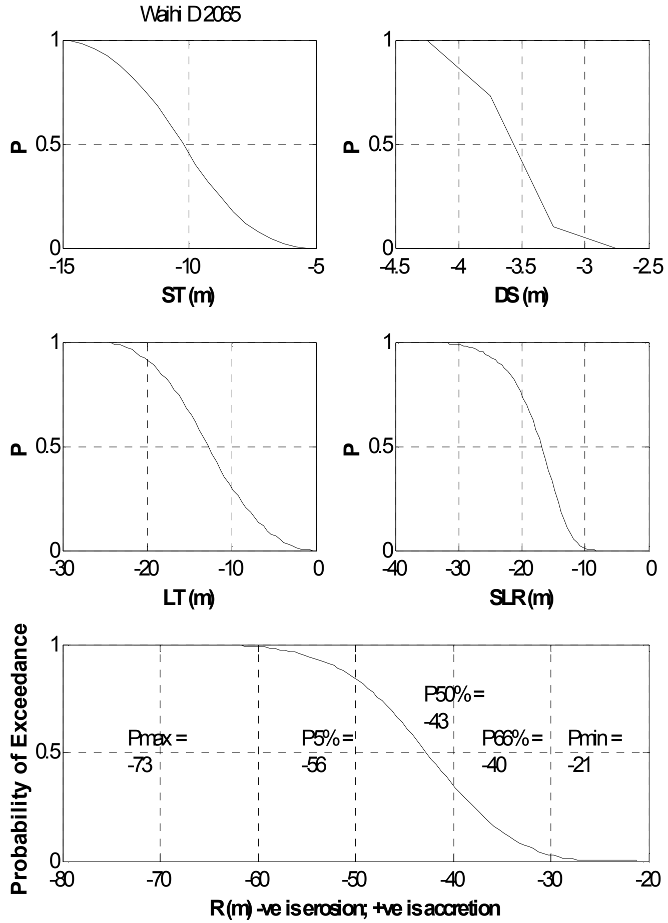

Waihi C 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

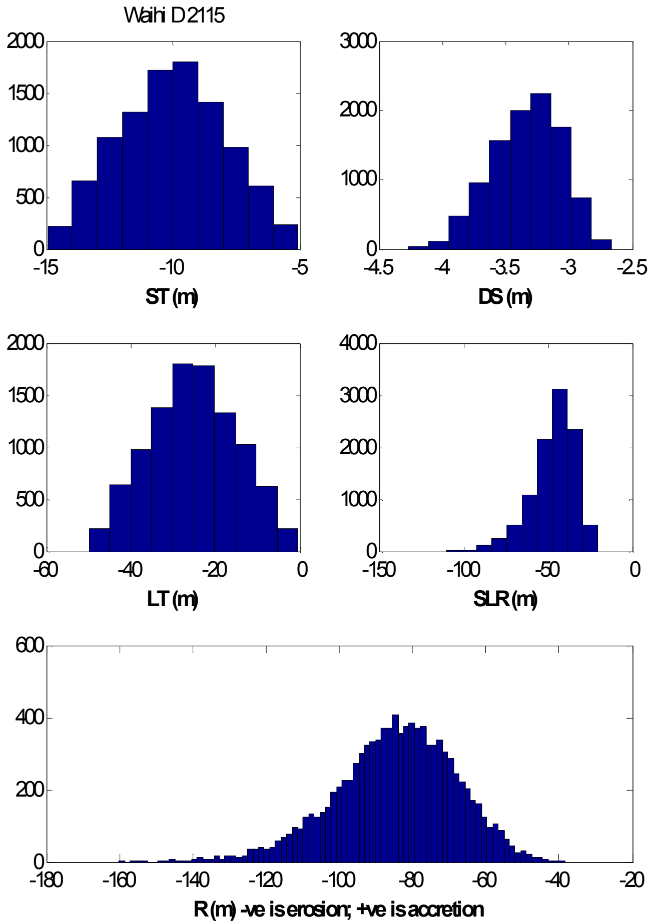

Waihi C 2065
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -72
P5% = -55
P50% = -45
P66% = -43
Pmin = -29
R (m) -ve is erosion; +ve is accretion

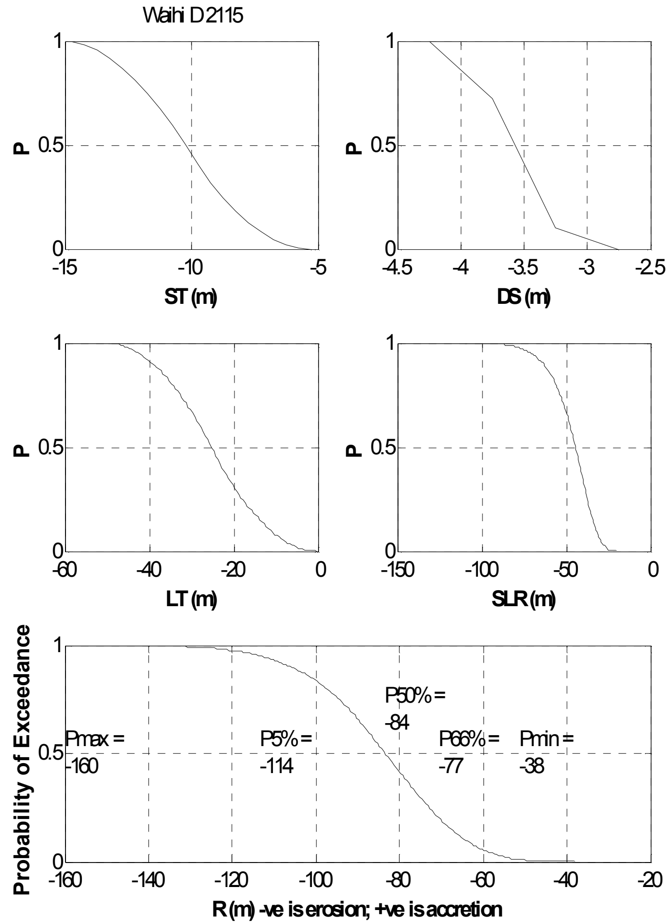

Waihi C2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

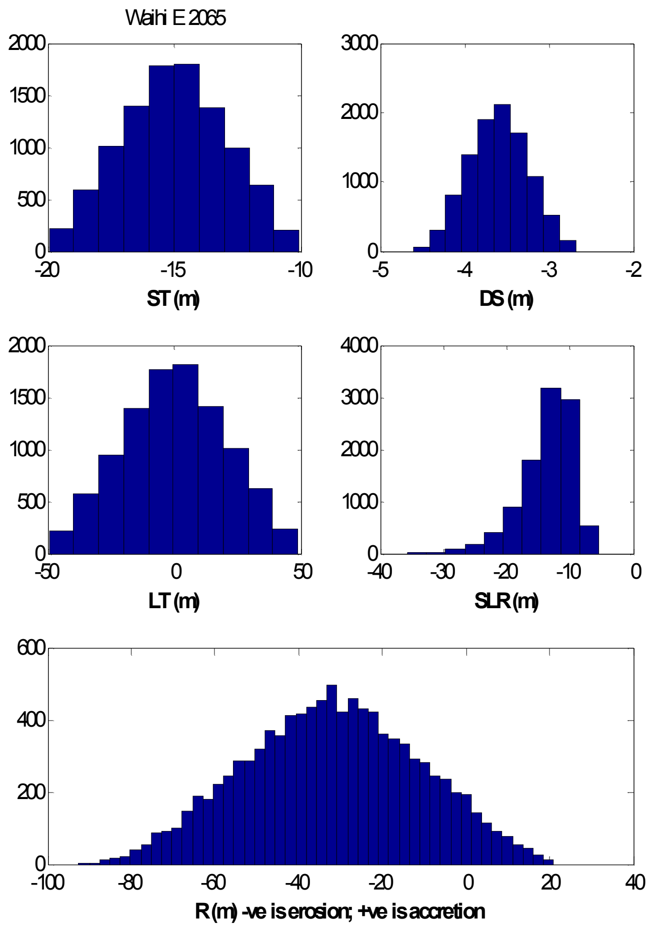

Waihi C2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -153
P5% = -115
P50% = -88
P66% = -83
Pmin = -54
R (m) -ve is erosion; +ve is accretion

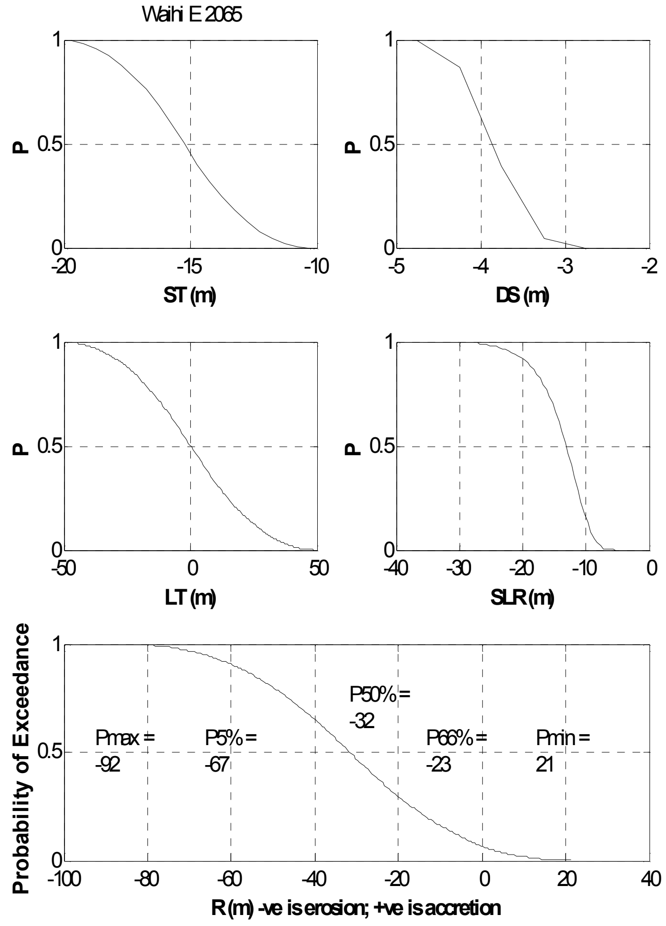

Waihi D2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

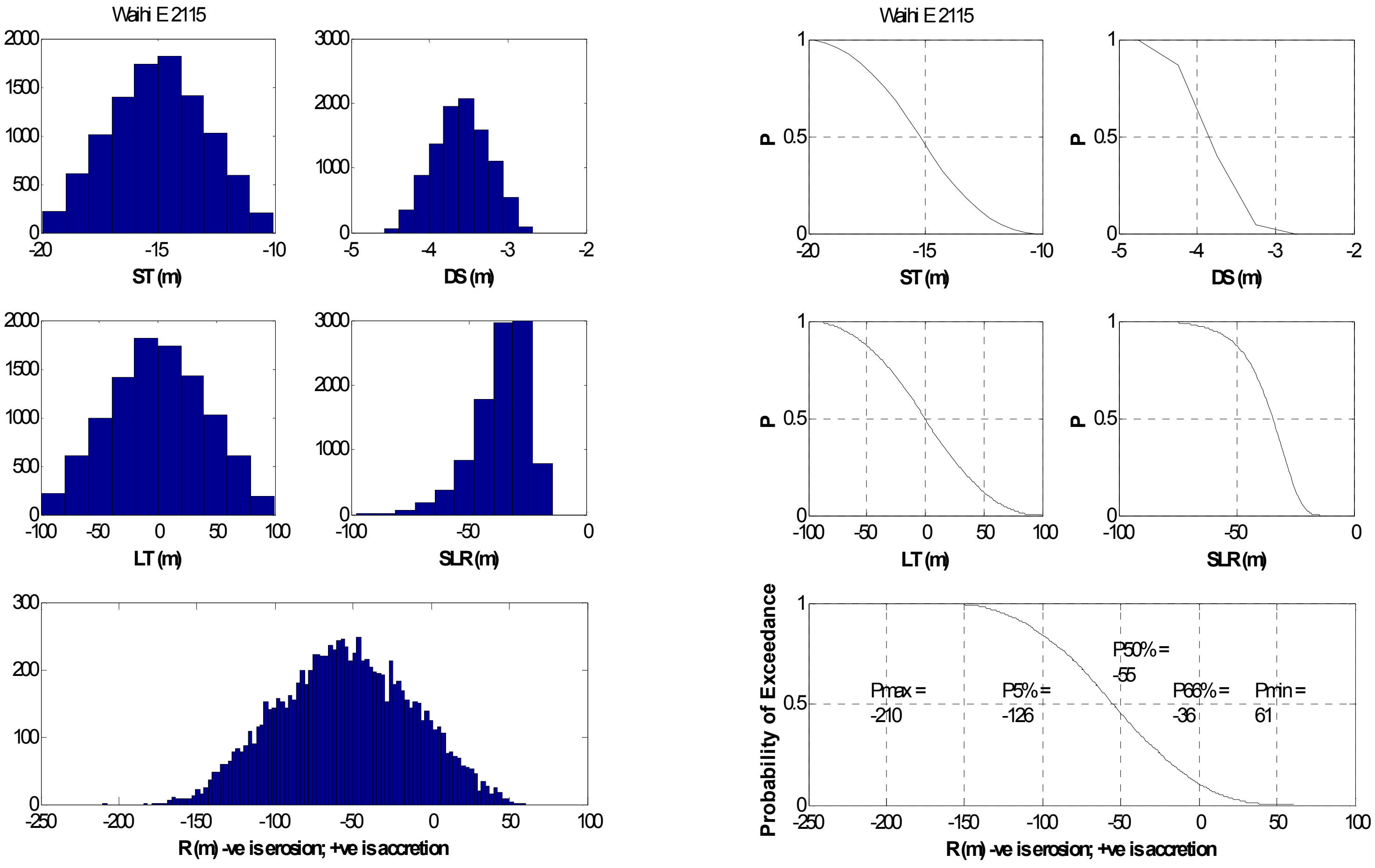

Waihi D2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-73
P5% =
-56
P50% =
-43
P66% =
-40
Pmin =
-21
R (m) -ve is erosion; +ve is accretion

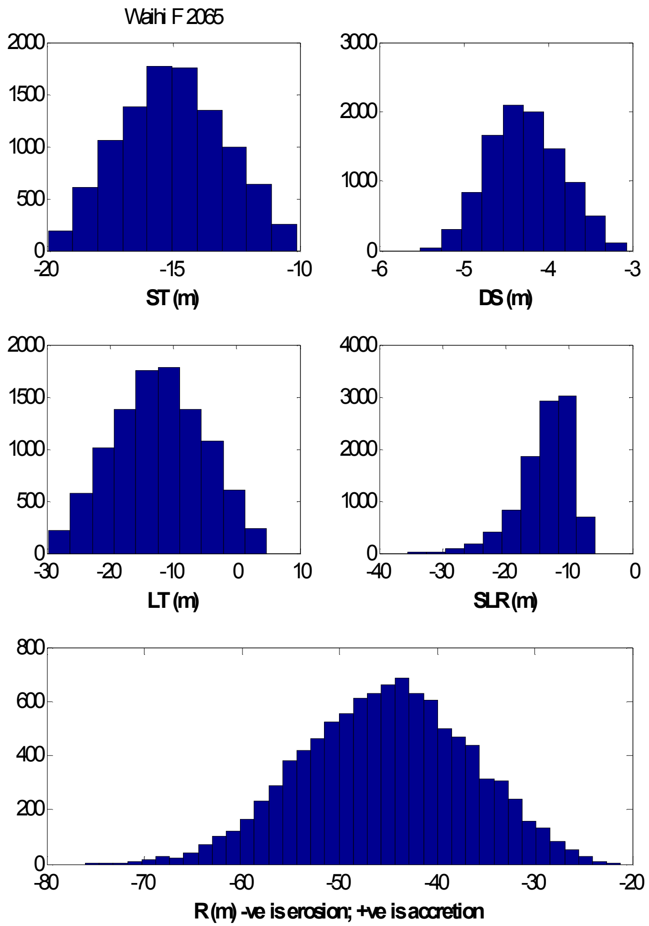

Waihi D2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

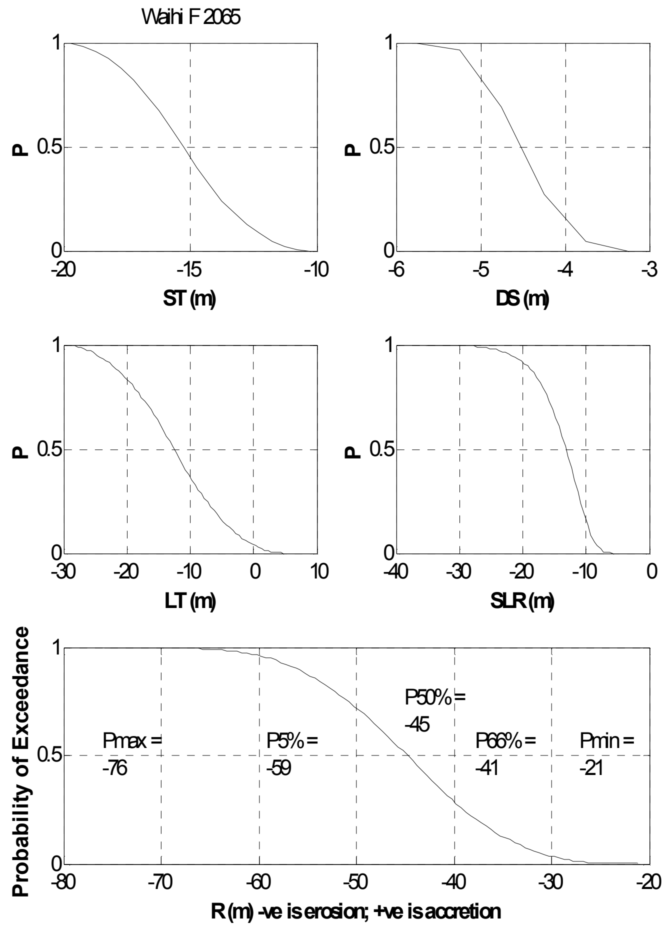

Waihi D2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -160
P5% = -114
P50% = -84
P66% = -77
Pmin = -38
R (m) -ve is erosion; +ve is accretion

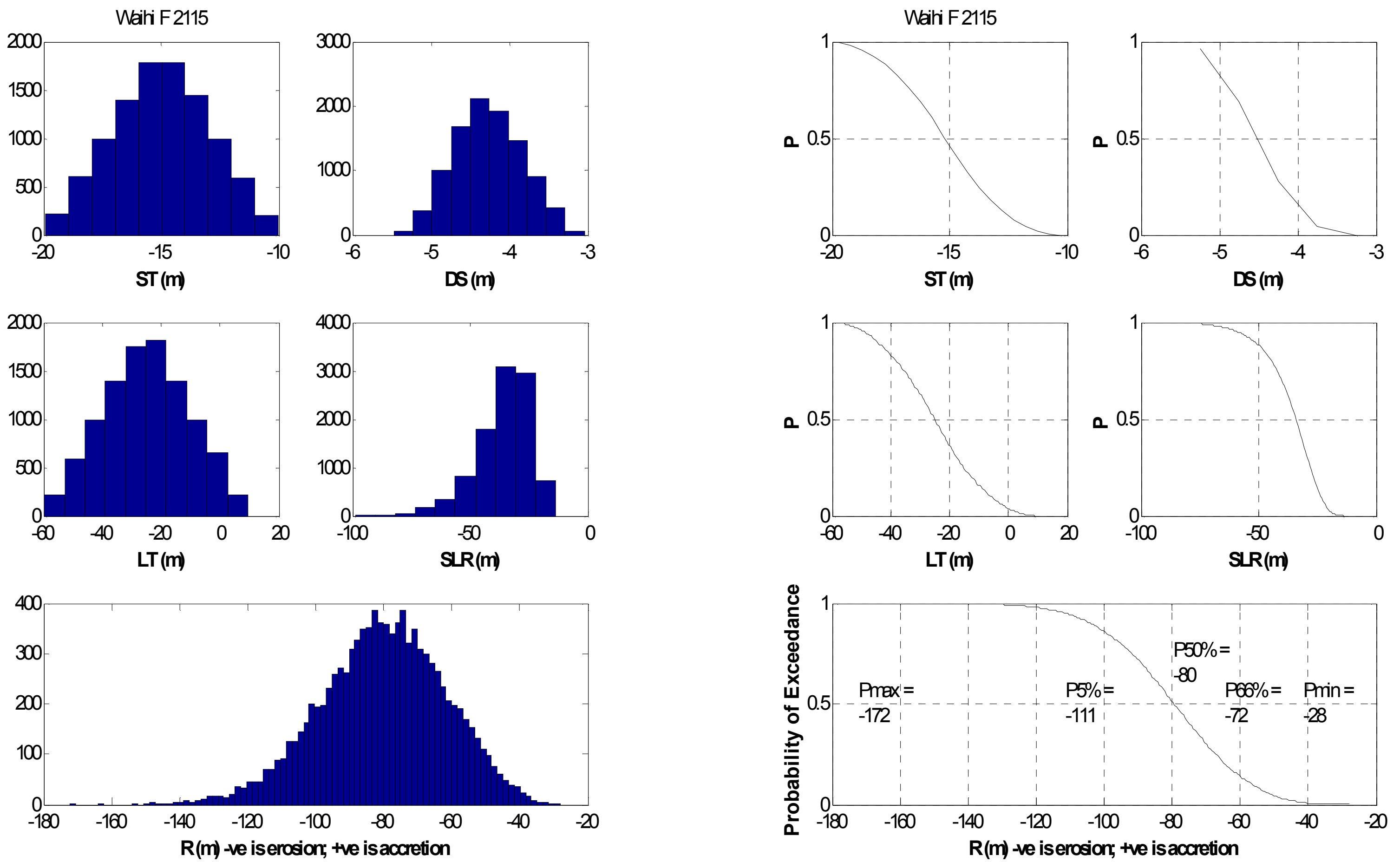

Waihi E 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

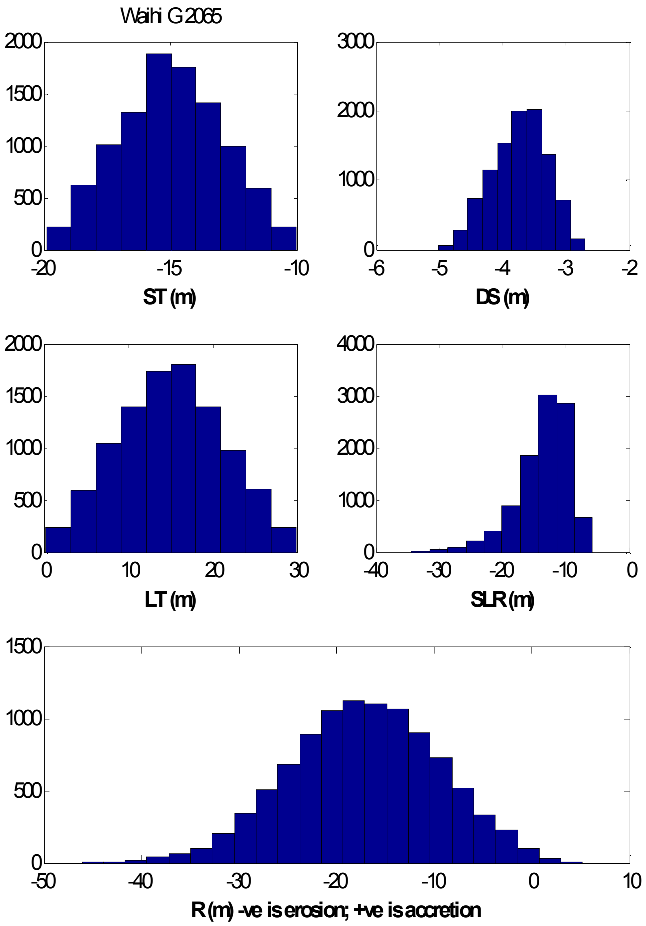

Waihi E 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -92
P5% = -67
P50% = -32
P66% = -23
Pmin = 21
R (m) -ve is erosion; +ve is accretion

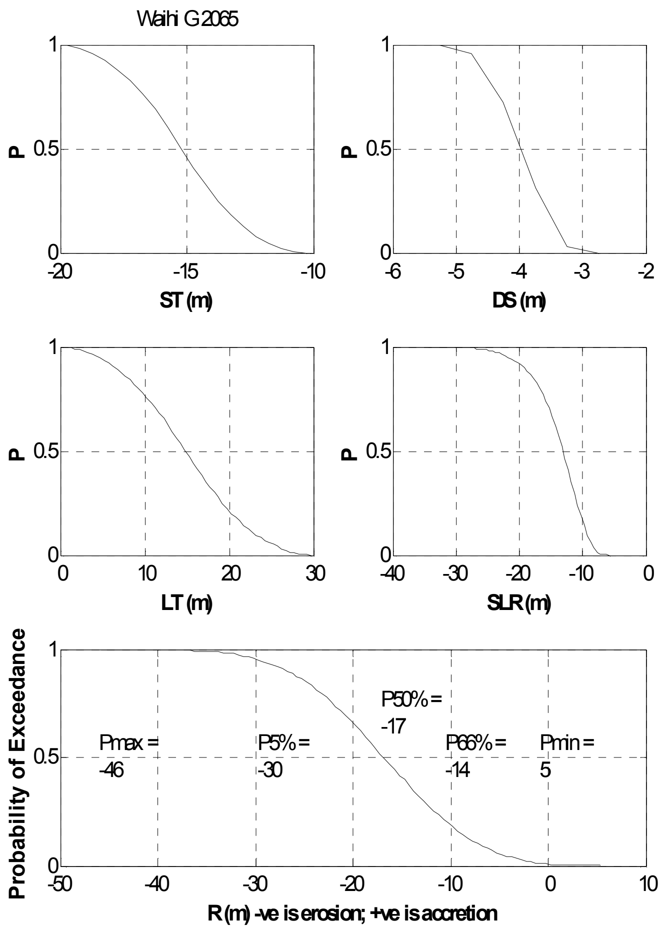

Waihi E 2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion
Waihi E 2115
P
Probability of Exceedance
Pmax =
-210
P5% =
-126
P50% =
-55
P66% =
-36
Pmin =
61
R (m) -ve is erosion; +ve is accretion

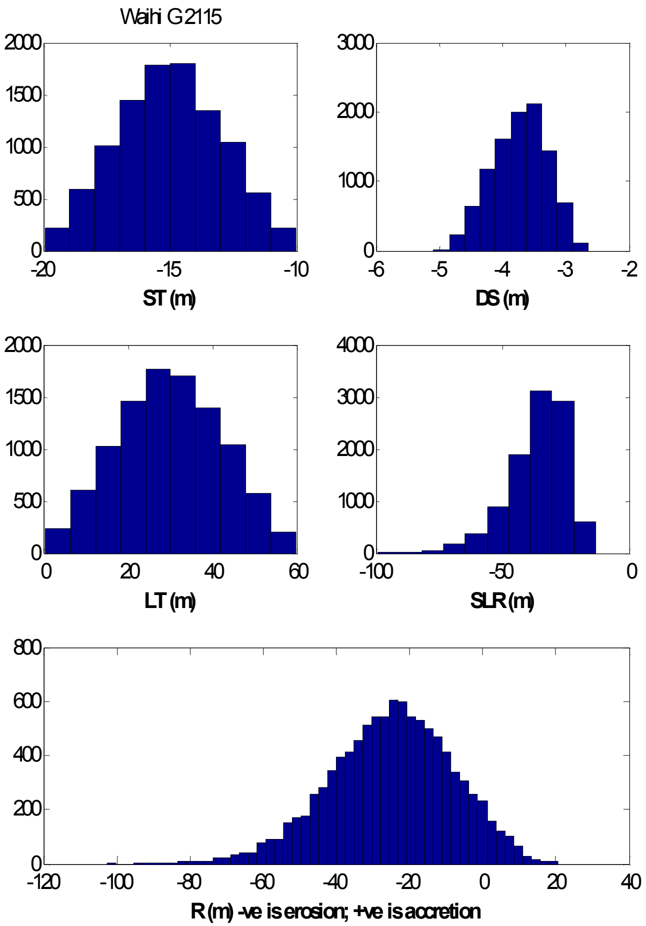

Waihi F 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

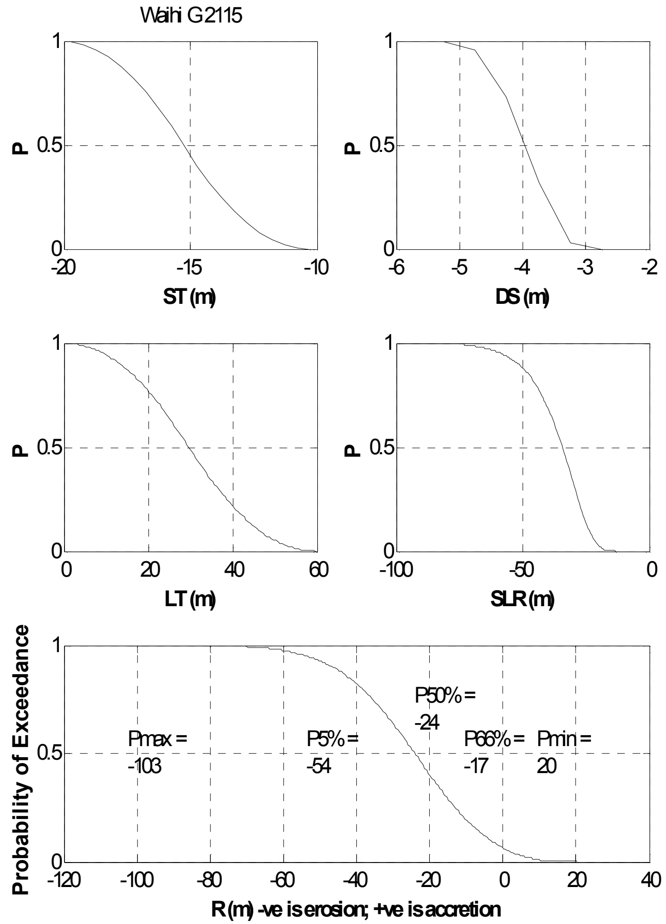

Waihi F 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -76
P5% = -59
P50% = -45
P66% = -41
Pmin = -21
R (m) -ve is erosion; +ve is accretion

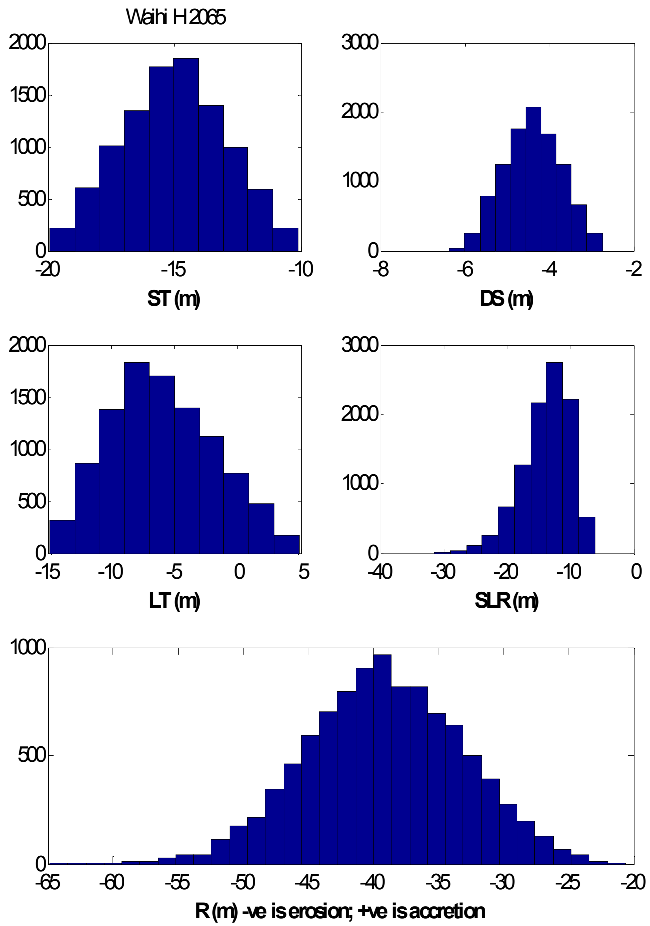

Waihi F 2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion
Waihi F 2115
P
Probability of Exceedance
Pmax = -172
P5% = -111
P50% = -80
P66% = -72
Pmin = -28

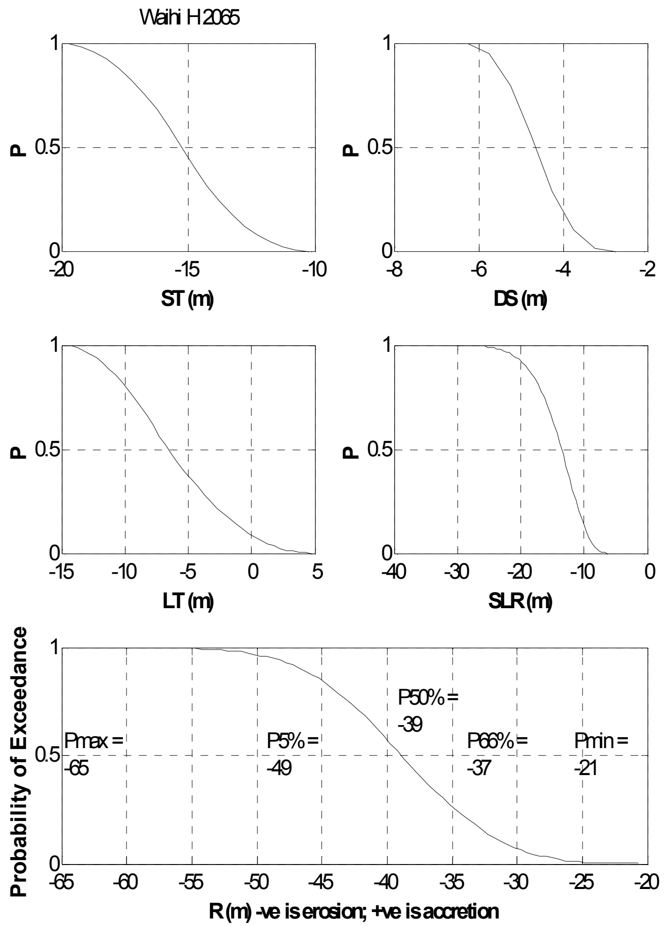

Waihi G 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

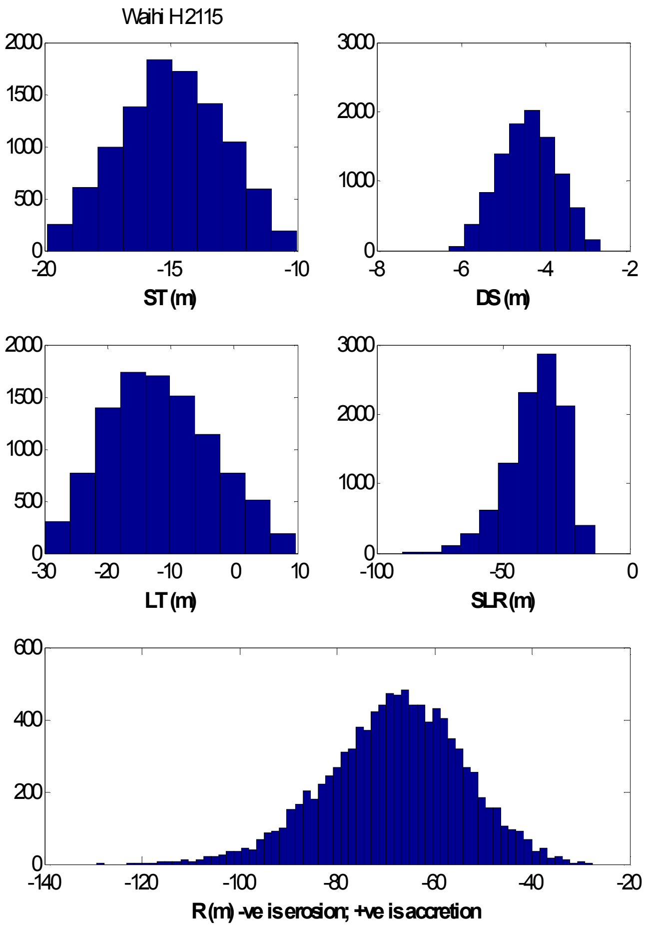

Waihi G 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -46
P5% = -30
P50% = -17
P66% = -14
Pmin = 5
R (m) -ve is erosion; +ve is accretion

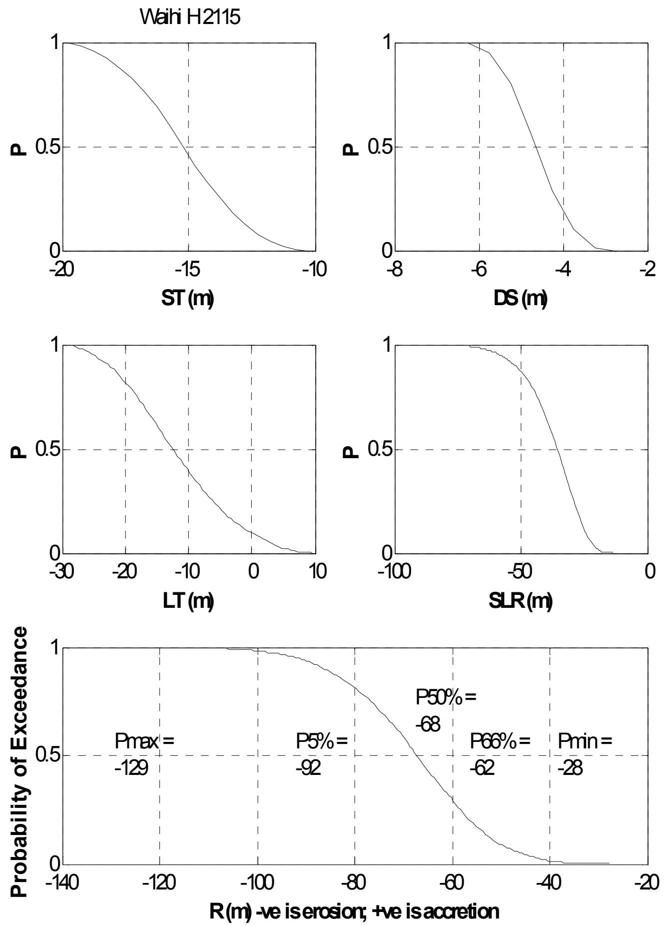

Waihi G2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

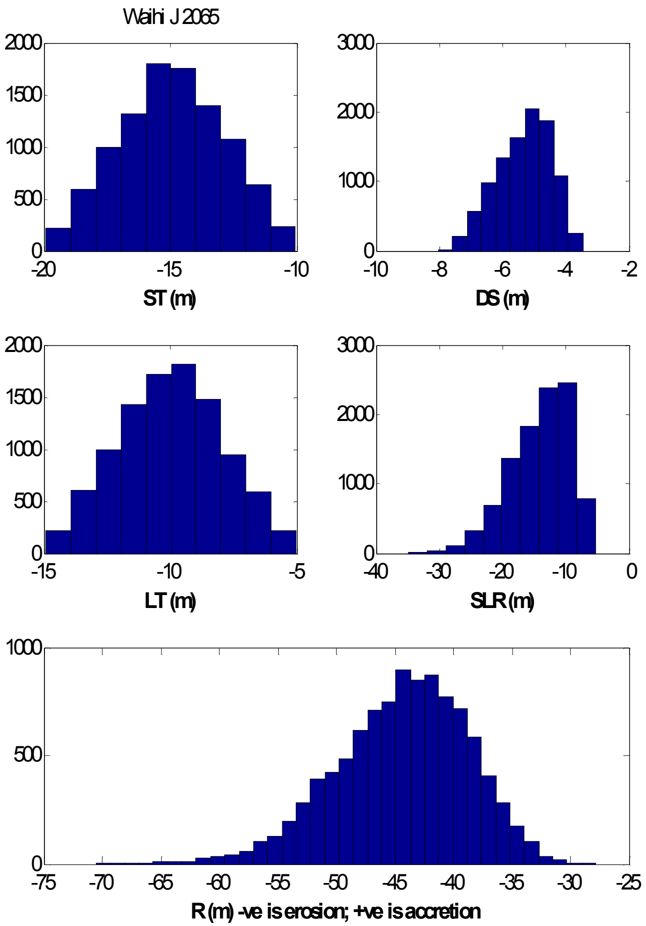

Waihi G2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-103
P5% =
-54
P50% =
-24
P66% =
-17
Pmin =
20
R (m) -ve is erosion; +ve is accretion

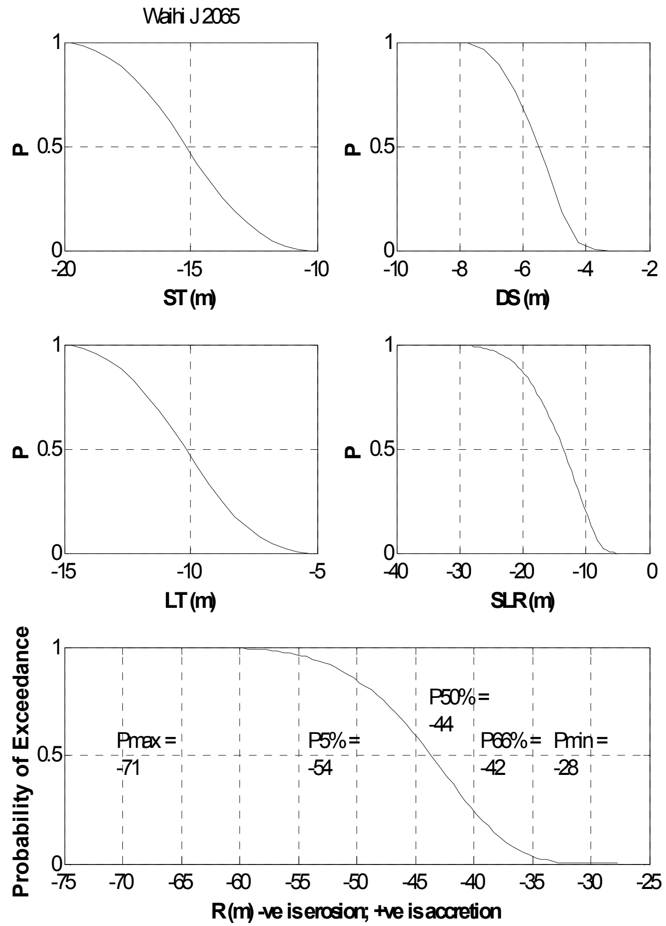

Waihi H2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

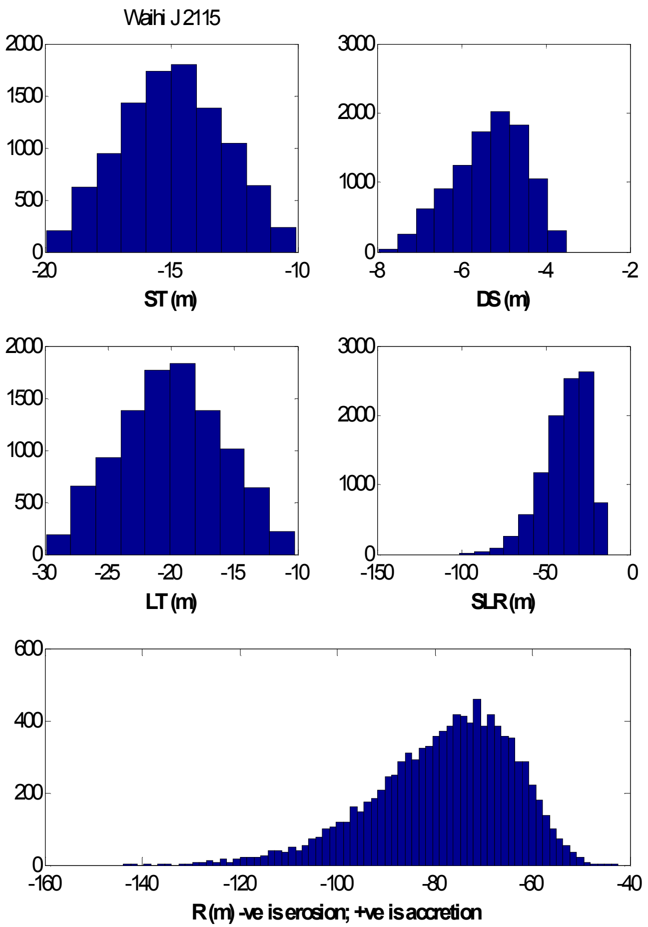

Waihi H2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-65
P5% =
-49
P50% =
-39
P66% =
-37
Pmin =
-21
R (m) -ve is erosion; +ve is accretion

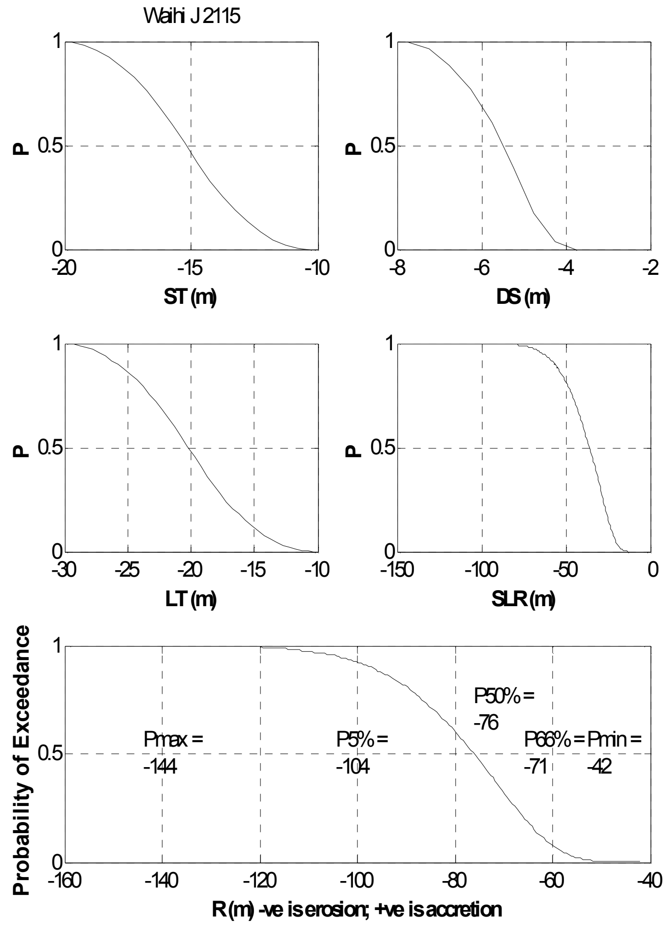

Waihi H2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

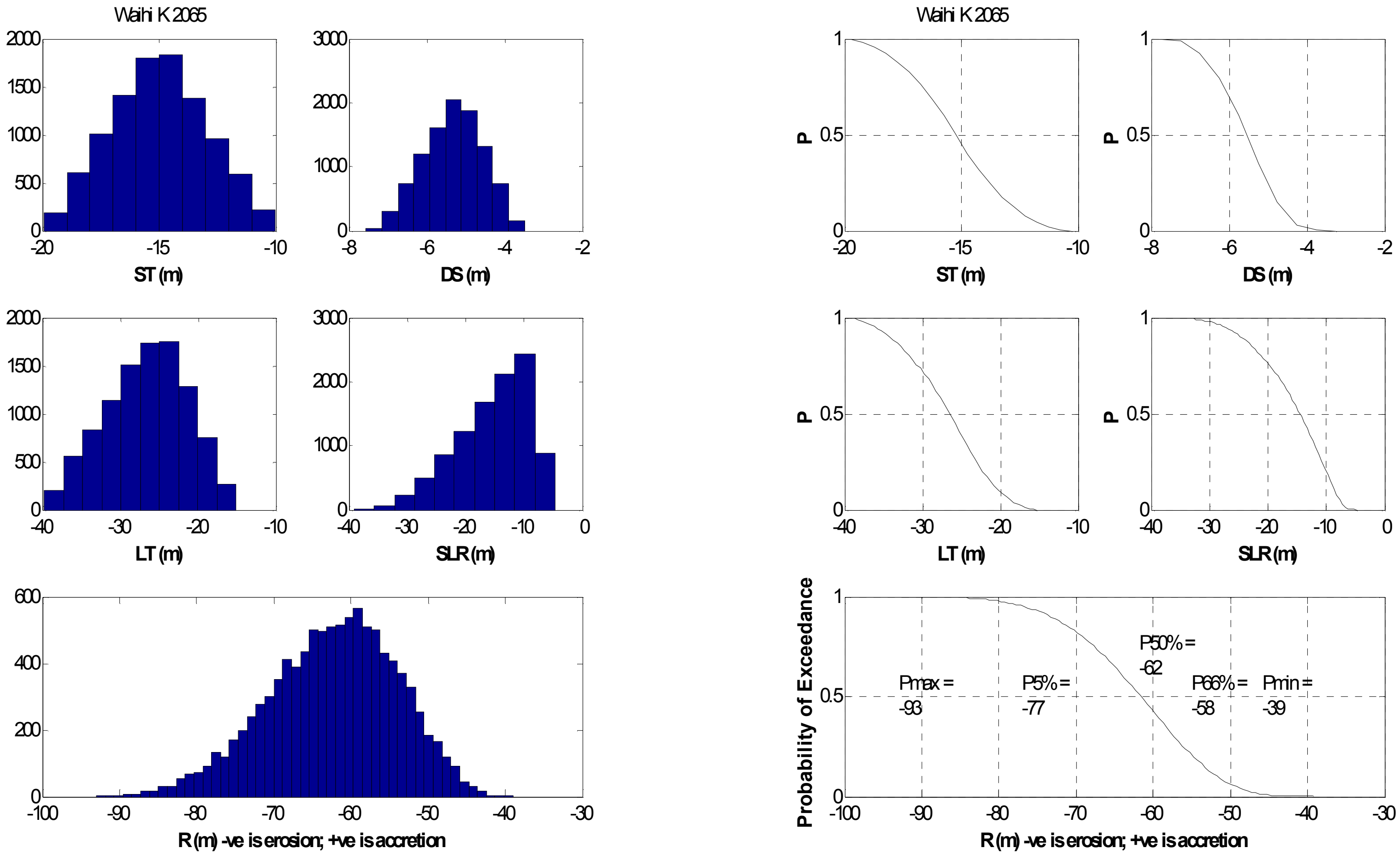

Waihi H2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-129
P5% =
-92
P50% =
-68
P66% =
-62
Pmin =
-28
R (m) -ve is erosion; +ve is accretion

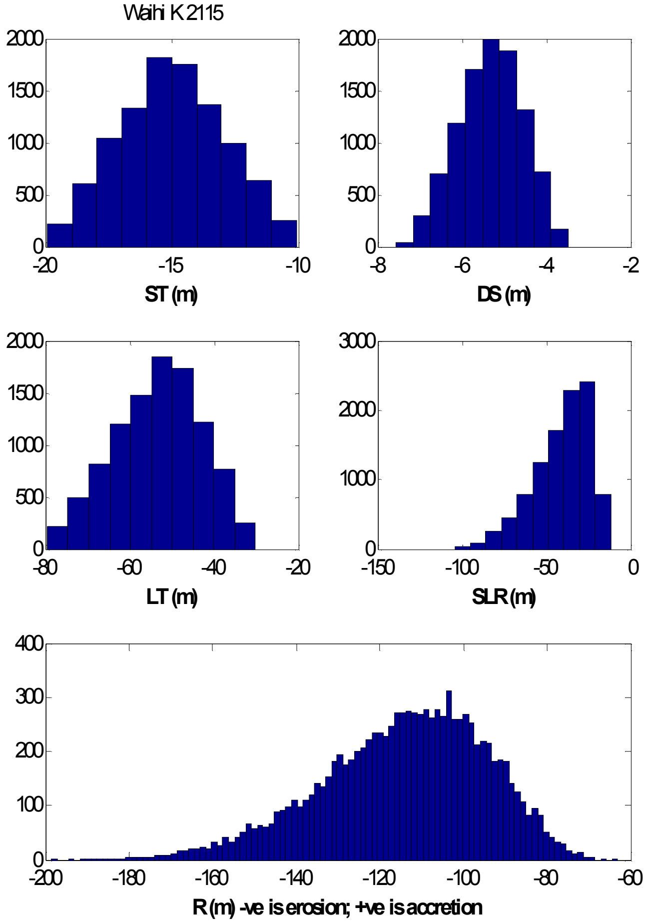

Waihi J 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

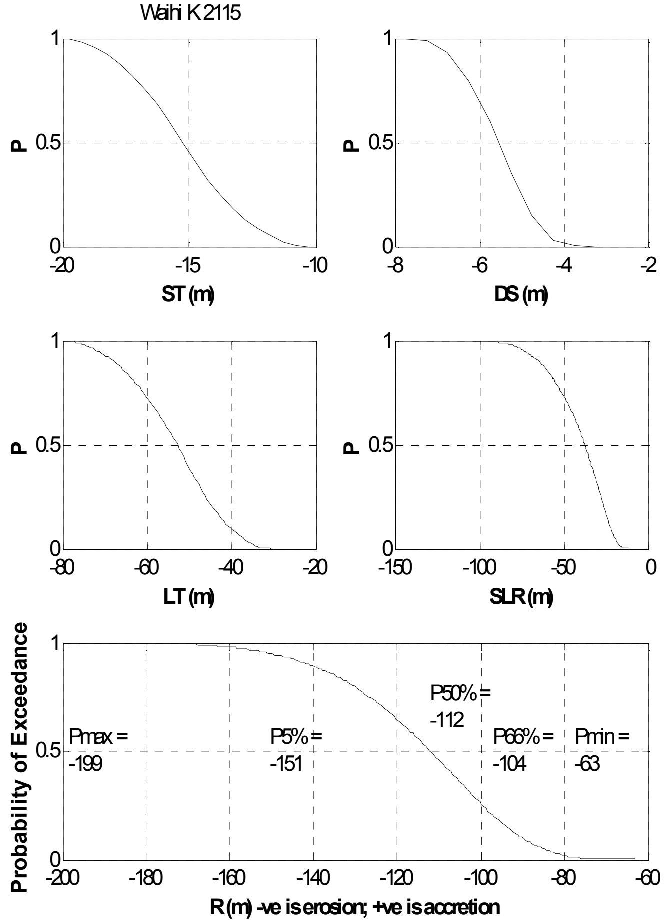

Waihi J 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -71
P5% = -54
P50% = -44
P66% = -42
Pmin = -28
R (m) -ve is erosion; +ve is accretion

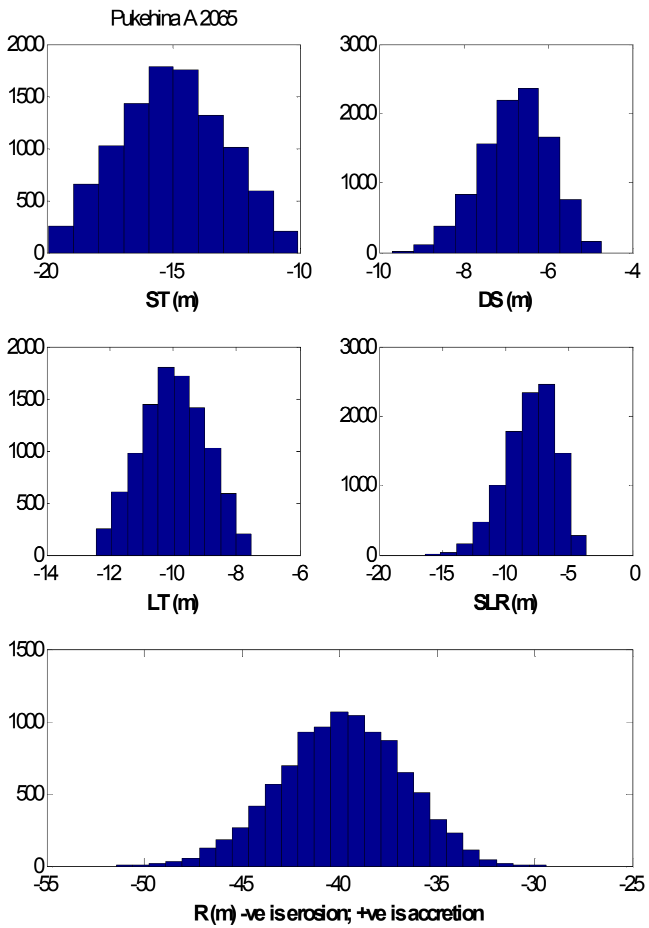

Waihi J2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

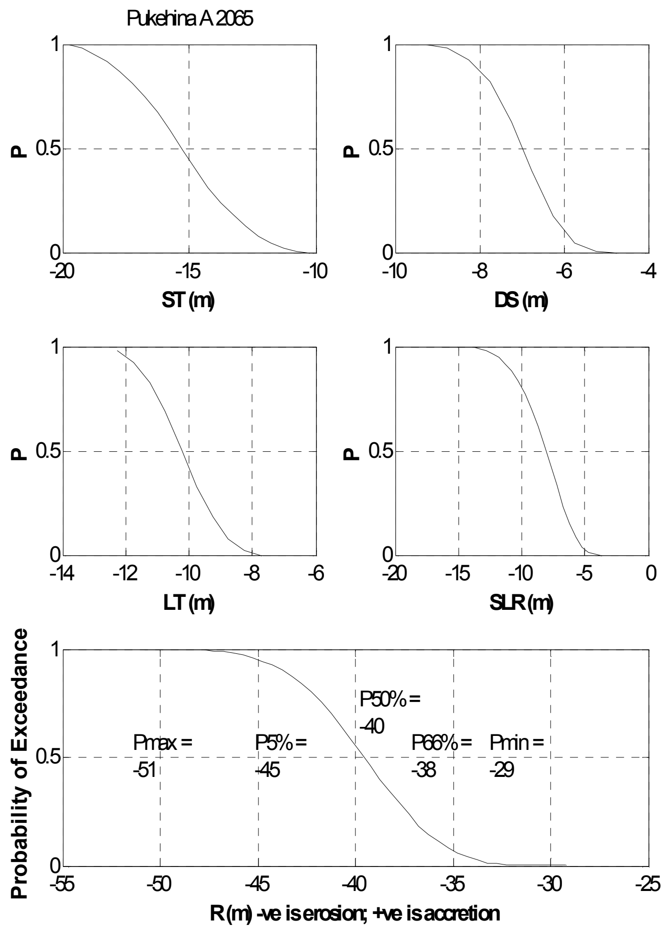

Waihi J2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax =
-144
P5% =
-104
P50% =
-76
P66% =
-71
Pmin =
-42
R (m) -ve is erosion; +ve is accretion

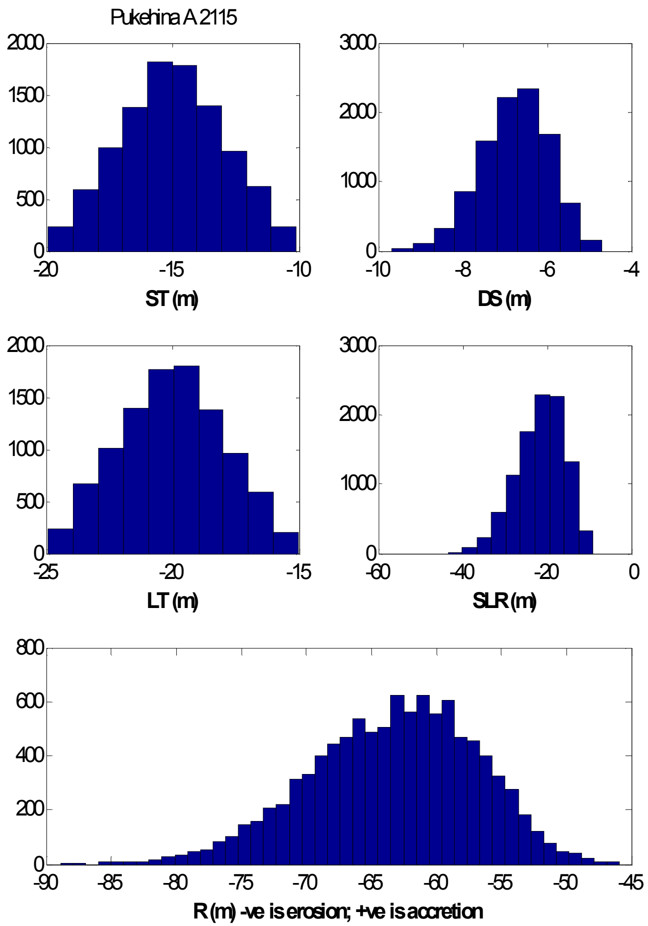

Waihi K 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion
Waihi K 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -93
P5% = -77
P50% = -62
P66% = -58
Pmin = -39
R (m) -ve is erosion; +ve is accretion

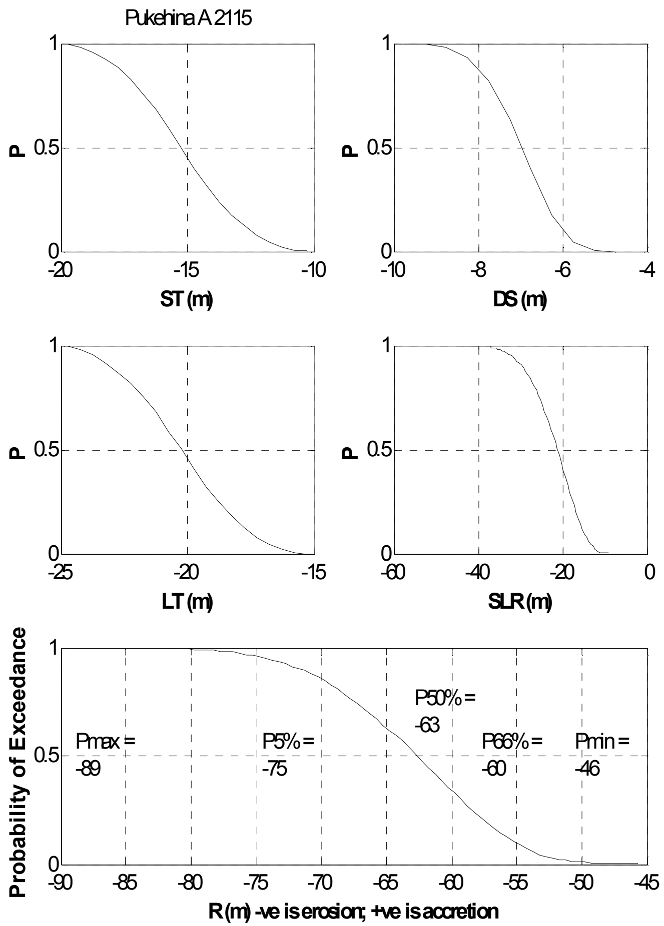

Waihi K2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

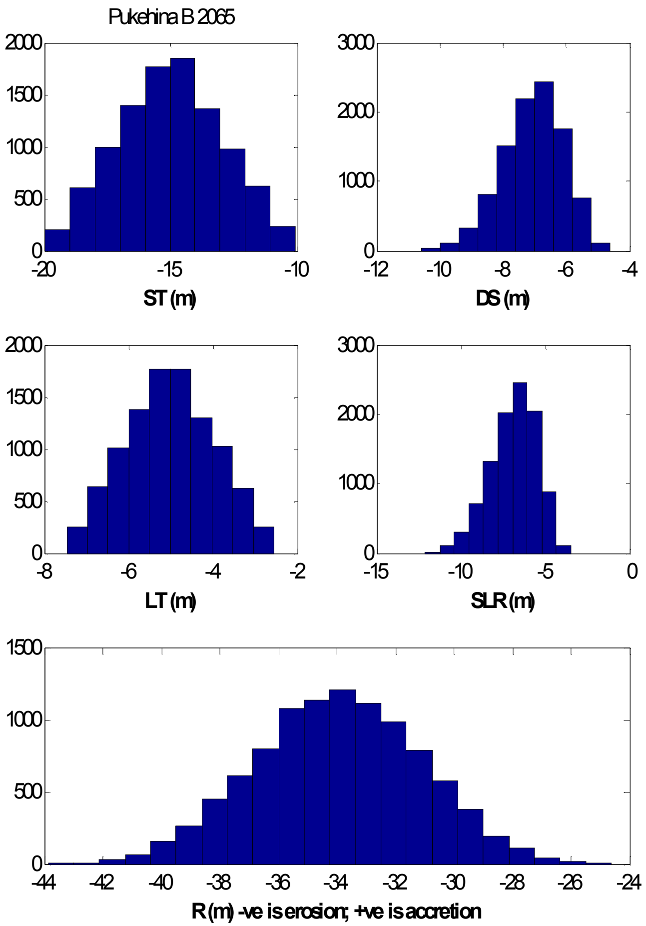

Waihi K2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -199
P5% = -151
P50% = -112
P66% = -104
Pmin = -63
R (m) -ve is erosion; +ve is accretion

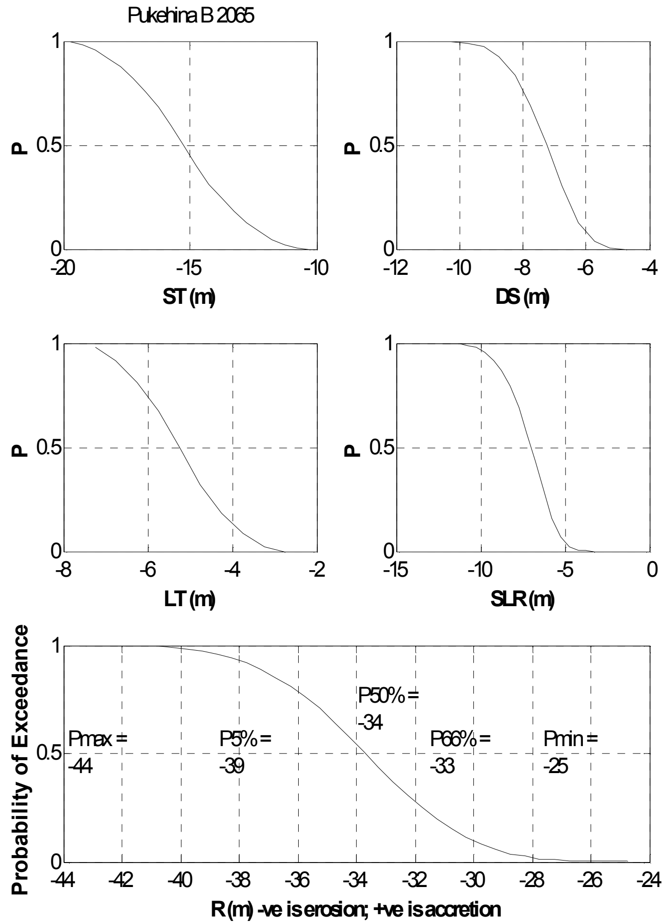

Pukehina A 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

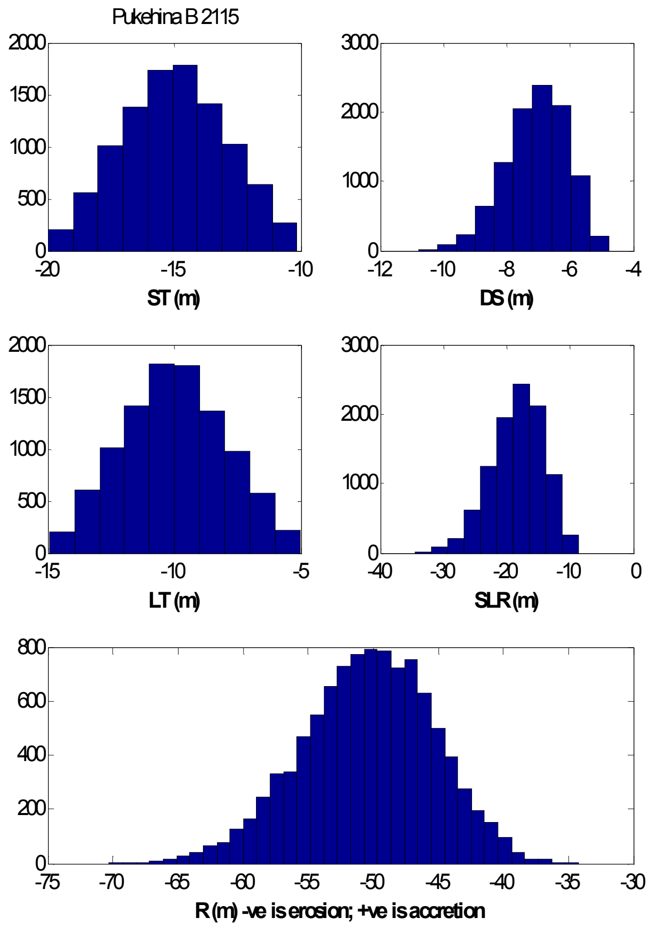

Pukehina A 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -51
P5% = -45
P50% = -40
P66% = -38
Pmin = -29
R (m) -ve is erosion; +ve is accretion

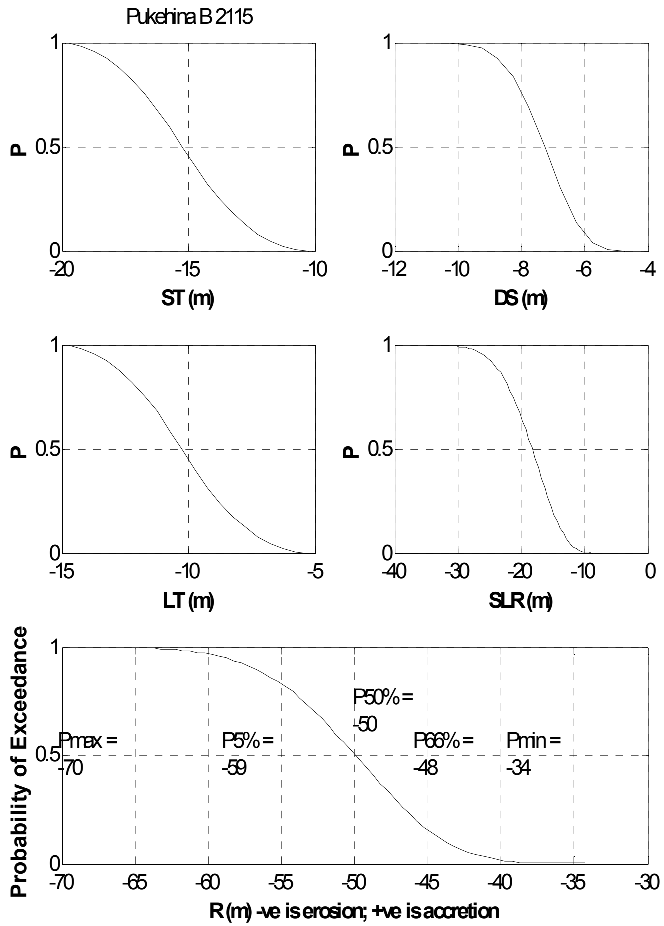

Pukehina A 2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

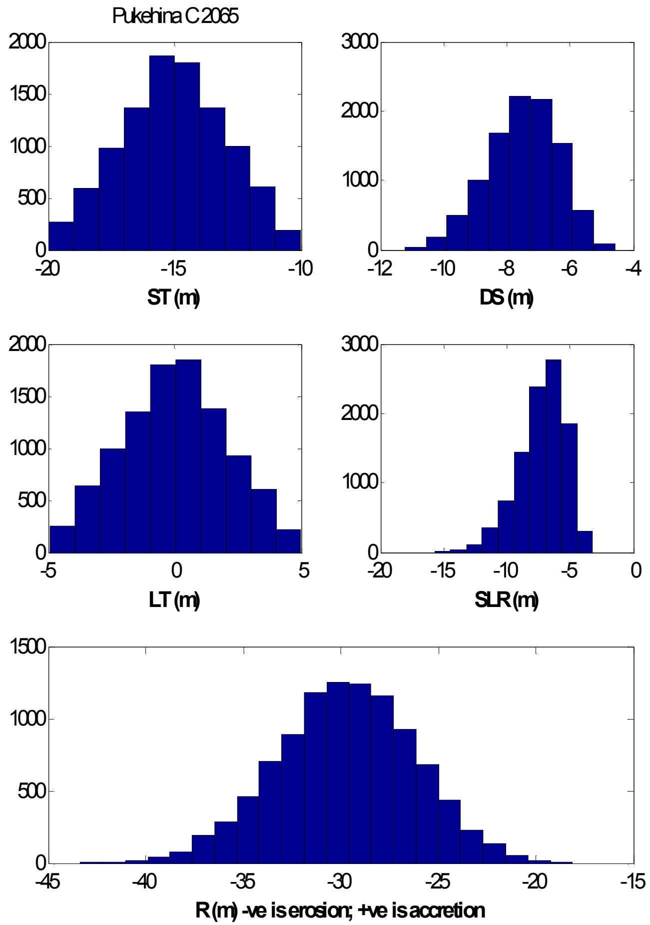

Pukehina A 2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -89
P5% = -75
P50% = -63
P66% = -60
Pmin = -46
R (m) -ve is erosion; +ve is accretion

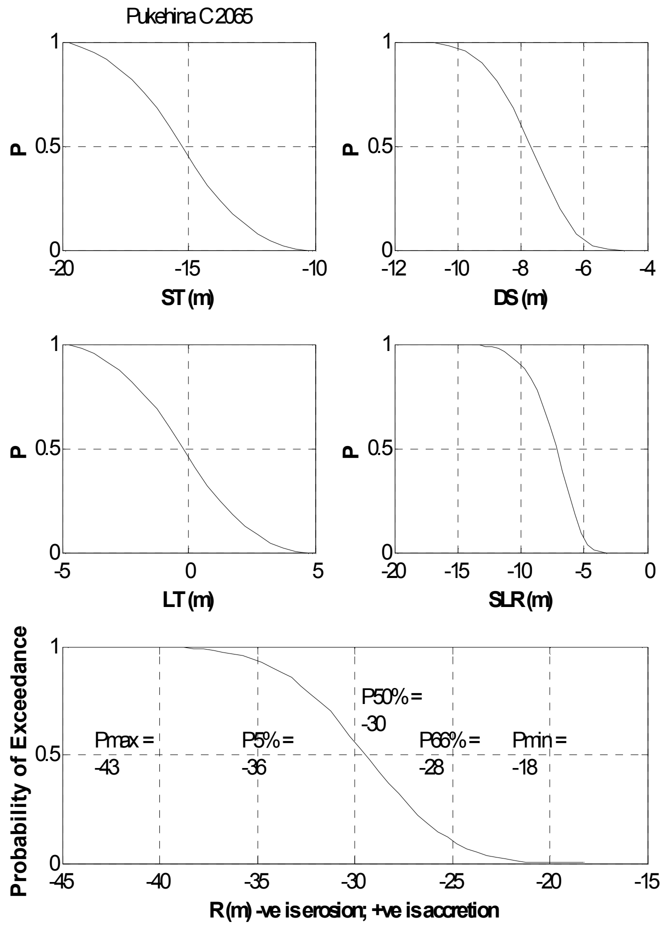

Pukehina B 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

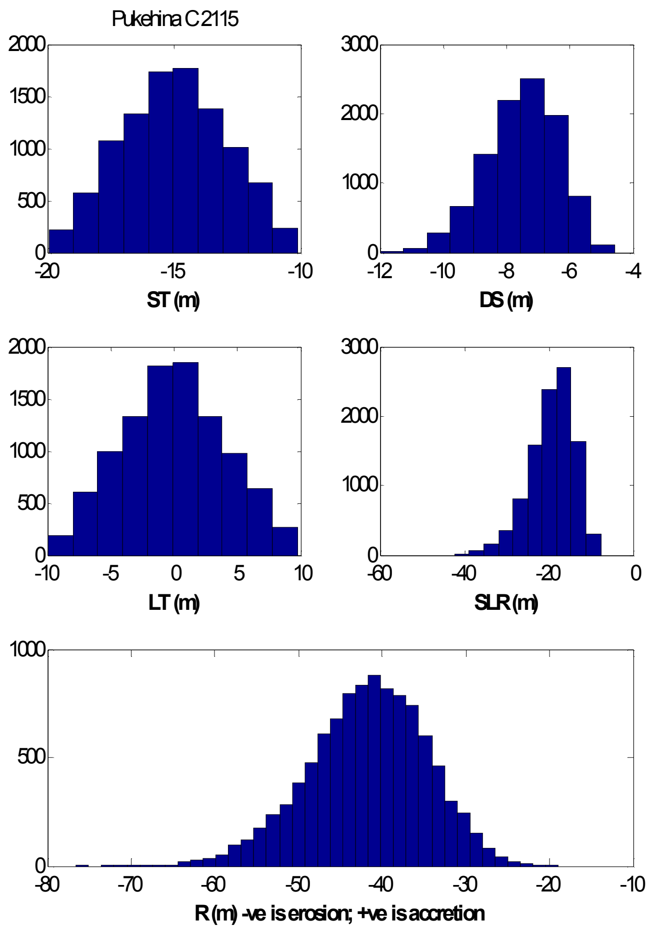

Pukehina B 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -44
P5% = -39
P50% = -34
P66% = -33
Pmin = -25
R (m) -ve is erosion; +ve is accretion


Pukehina B 2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion

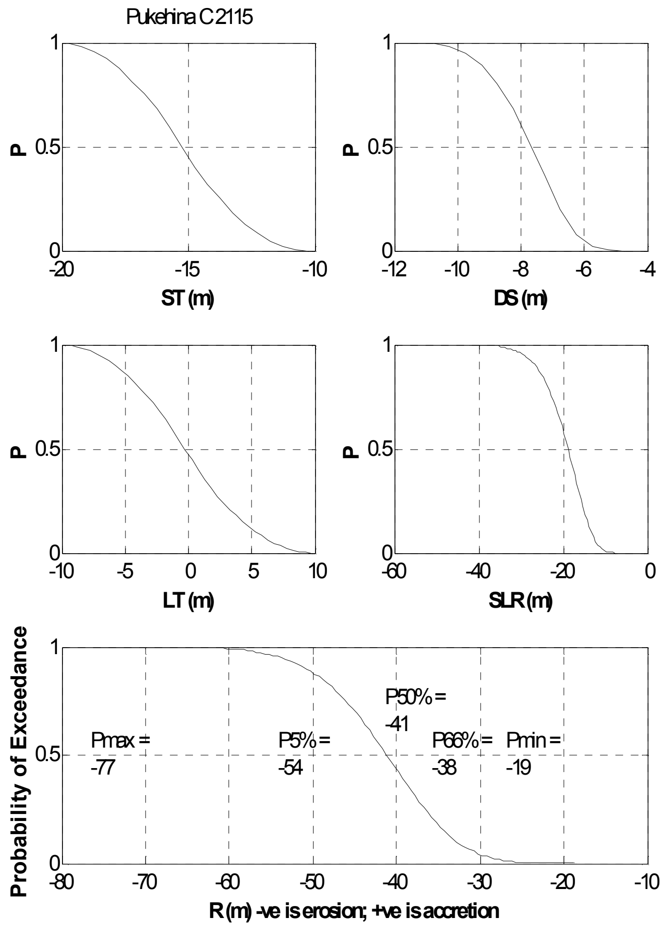

Pukehina B 2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -70
P5% = -59
P50% = -50
P66% = -48
Pmin = -34
R (m) -ve is erosion; +ve is accretion


Pukehina C 2065
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion


Pukehina C 2065
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -43
P5% = -36
P50% = -30
P66% = -28
Pmin = -18
R (m) -ve is erosion; +ve is accretion



Pukehina C2115
ST (m)
DS (m)
LT (m)
SLR (m)
R (m) -ve is erosion; +ve is accretion



Pukehina C2115
P
ST (m)
DS (m)
LT (m)
SLR (m)
Probability of Exceedance
Pmax = -77
P5% = -54
P50% = -41
P66% = -38
Pmin = -19
R (m) -ve is erosion; +ve is accretion