Coastal Protection Project

for

Glen Isla Protection Society

Assessment of Coastal Processes

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1.0 Introduction

The Glen Isla Protection Society ("**GIPS"**) comprise a group of beachfront homeowners at 9, 11, 13, 15, 16, 14 and 12 Glen Isla Place, Waihi Beach. Their properties, located south of "Three Mile Creek", adjoin an approximately 200m stretch of unarmoured coastline, subject to coastal erosion.

Following a series of large erosion and storm events, including Cyclone Gabrielle, the GIPS propose to construct a buried revetment structure, supplemented with dune nourishment and replanting. The intent is to protect the backshore from further erosion, and future-proof this land for the effects of sea-level rise.

To support the necessary resource consent applications, GIPS have instructed Davis Coastal Consultants prepare a report on the effects of the proposed structure on the coastal process environment.

This report assesses the potential effect of the proposal on coastal processes, including in relation to future coastal erosion risk, in accordance with current best practice methodologies. It includes consideration of the effects of climate change over at least a 100-year timeframe.

A further report by Davis Coastal Consultants (Engineering Design Report – October 2024) sets out the design philosophy and assumptions and calculations undertaken as part of the wall and dune development for this project.

1.1 Definitions

Within this report terminology for the intertidal and tidal area is consistent with those defined in the Resource Management Act:

Coastal **M**arine **A**rea – CMA – *"means the foreshore, seabed, and coastal water, and the air space above the water -*

(a) of which the seaward boundary is the outer limits of the territorial sea:

(b) of which the landward boundary is the line of mean high water springs…"

Common **M**arine and **C**oastal **A**rea – CMCA – *“means the marine and coastal area other than –*
(a) specified freehold land located in that area; and
(b) any area that is owned by the Crown…”

Mean **H**igh **W**ater **S**prings – MHWS – “*the average of the heights of each pair of successive high waters during that period of about 24 hours in each semi-lunation (approximately every 14 days) when the range of tides is the greatest”*

Foreshore – *“means any land covered and uncovered by the flow and ebb of the tide at mean spring tides and, in relation to any such land that forms part of the bed of a river, does not include any area that is not part of the coastal marine area”*

Backshore – All land above Mean High Water Springs

2.0 Description of Existing Environment

2.1 Location

Waihi Beach is a coastal township located on the east coast of the North Island at the northern extent of the Bay of Plenty Region. It is an open coast beach, situated approximately 10km east of the inland town of Waihi. The site is directly south of Three Mile Creek (Figure 2.1a), and extends south from the creek along approximately 200m of coastline, seaward of properties 9, 11, 13, 15, 16, 14 and 12 Glen Isla Place.

The Reserve, located between the private properties and the adjacent CMA, is described as Reserve Lot 18 DPS 22035 and Esplanade Reserve Lot 19 22035. The wall structure is to be entirely located outside the CMA. The wall extents are shown below (Figure 2.1b).

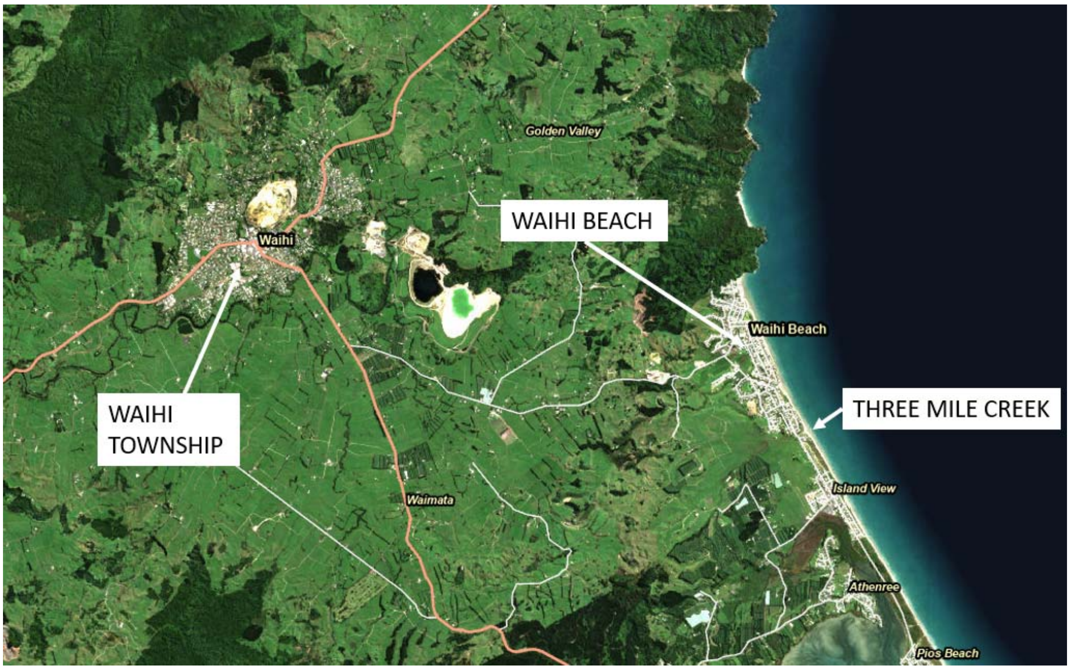


Figure 2.1a: Waihi Beach

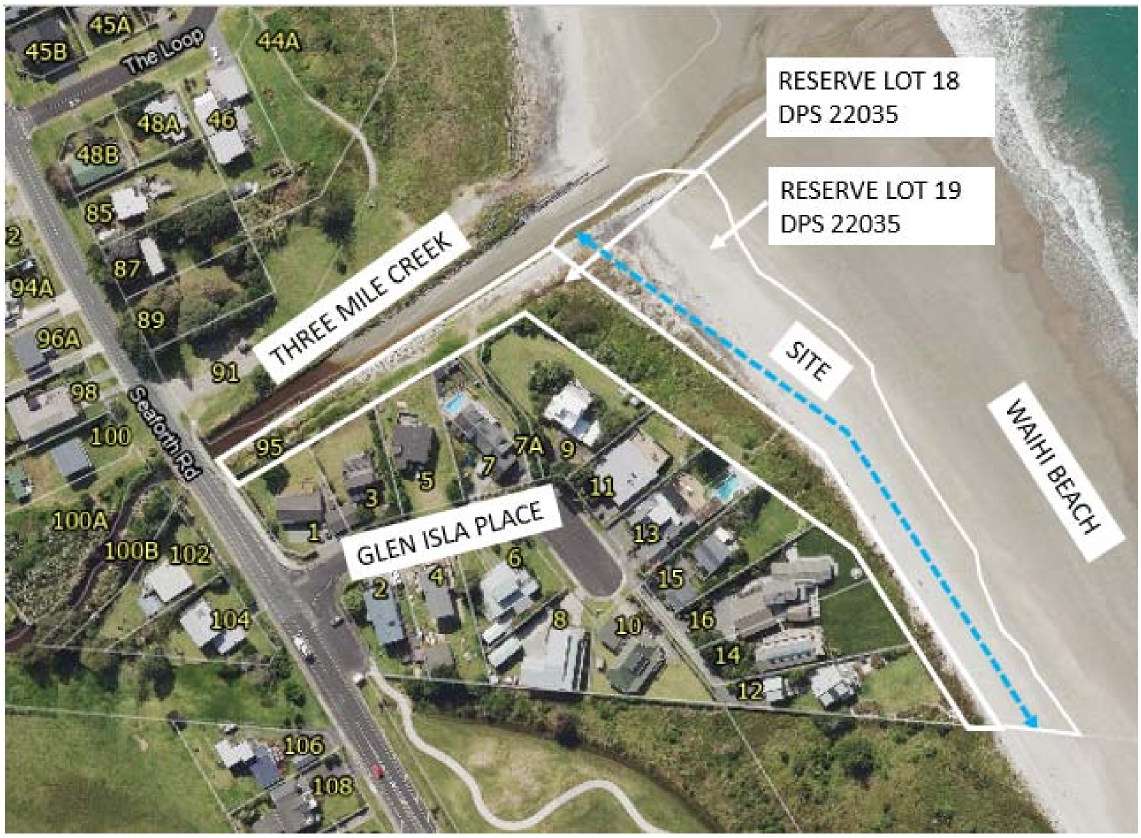


Figure 2.1b: Site adjacent to Three Mile Creek, Waihi Beach

2.2 Wider Morphology

Waihi Beach is a 10km long, open-coast barrier beach orientated north-east. Two creeks (Two Mile Creek and Three Mile Creek) discharge through the dune system onto the coast, and small dune systems characterise the foreshore where there is no development. Three Mile Creek is a man-made stormwater outlet through the dune system, which is discussed further in Section 3.4. Extensive residential development has resulted in properties in close proximity to the coastal margin for much of the central and northern beach. The coastline continues to the south and terminates at the Bowentown barrier spit. The spit is welded to outcropping rock structure that forms the northern headland to the Tauranga Harbour, an approximately 220km^2 large tidal estuary system (Figure 2.2a).

The deposition of the beach and dune sediments that make up this open coast beach began following stabilisation of sea-level to present level between 6500 – 7500 years ago, with an onshore movement of sediments from the adjacent continental shelf. This resulted in progradation of the beach face over time such that relic dune ridges are visible much landward of the existing coastline, evidence of a historic shoreline position. The natural dune system is clearly visible in aerial images, and is shown below on a historic aerial from 1942 prior to development of the central and southern coastline (Figure 2.2b). Holocene age paleo-frontal dunes sit approximately 50m-100m behind the present dune system which is intersected by older, more stabilised, transgressive, and parabolic dunes at central and south Waihi Beach. The dune ridge system has been modified through development on Waihi Beach. In most places, a strip of natural dune remains between development and the beach.

Figure 2.2a: Wider plan of Waihi Beach

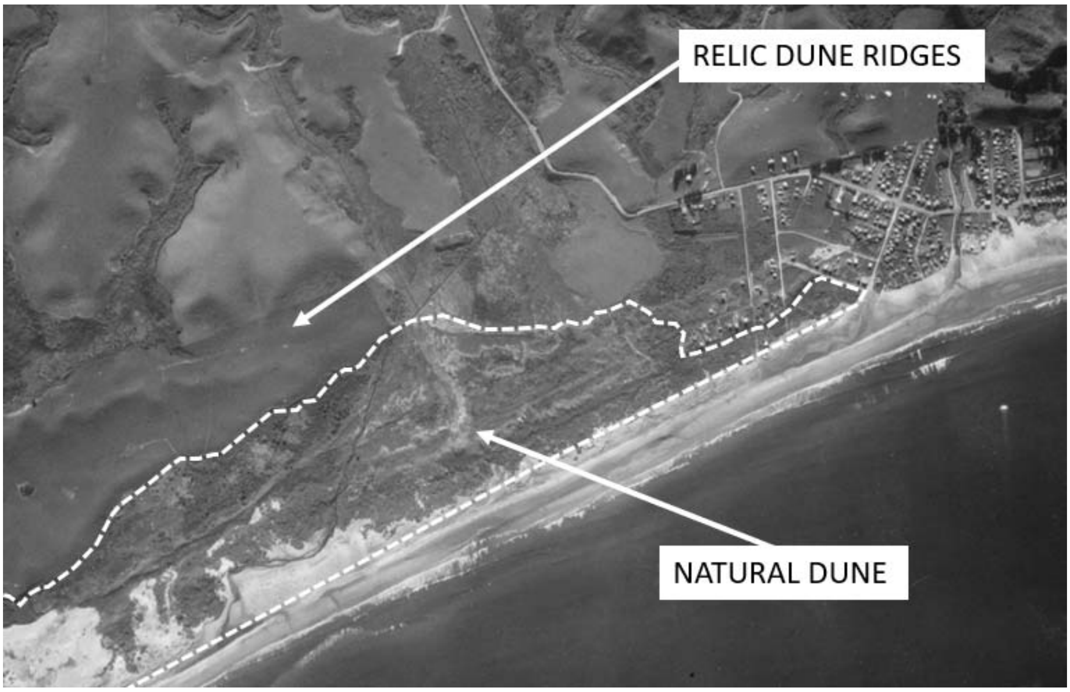


Figure 2.2b: 1942 Aerial of Waihi Beach – Retrolens.co.nz

2.3 Site Description

The site is located towards the centre of Waihi Beach, along a stretch of coastline characterised by a gently sloping intertidal area (approximately 1:17) which rises slowly to an unarmoured, narrow, vegetated bank. The site is part of a development on the seaward side of Seaforth Road, bound by Island View Reserve at its southern extent and a training groyne to the Three Mile Creek river channel and outlet at the northern extent (Figure 2.3). The GIPS properties are located landward of the narrow frontal dune, at an elevation of approximately Relative Level (**RL**) 4, and the original dwellings were all built between 1970-1990. Grassed lawn, comprising the modified back dune zone, typically separates the buildings from the frontal dune and such back dune as remains. However, the frontal dune is subject to episodic storm erosion and this was particularly evident during the series of large storm events including Cyclone Gabrielle in February 2023.

The current vegetated extent of the back dune system at the site is approximately 20m wide, closest to the channel outlet, and narrows to approximately 4-5m wide towards 12 and 14 Glen Isla Place. The remaining vegetated dune has been described in more detail in the Ecology Report but generally comprises a small number of isolated trees at the landward section with more ground cover species at the seaward extent. At the northern end of the site, the dune slopes from RL4.5 at the crest to the beach face at RL3 at approximately 1:16. At the southern extent of the site, the dune slopes more steeply at 1:4 from RL4.5 to RL3 towards a sandy beach, approximately 100m wide.

Figure 2.3: Features of the site

2.4 Geology

The underlying geology of the site is shown in the 1:50,000 Geological Map published by GNS (Figure 2.4). The Map describes the sediments of the Waihi Beach area as Holocene wind-blown dune deposits of the Kariotahi Group, that are *"loose to poorly consolidated, quartzofeldspathic and mafic-rich dune sands and associated facies"*. Directly inland of Waihi Beach are Late Pleistocene stable (windblown) dune deposits (light yellow), Late Miocene to Middle Pleistocene Rhyolitic River deposits (dark yellow), and Holocene River deposits (white). It is assumed the more recent Holocene River deposits have been deposited over the underlying Late Miocene to Middle Pleistocene Rhyolitic River deposits and Late Pleistocene windblown dune deposits.

The northern end of the barrier beach is bound by andesitic and dacitic material of the Coromandel Volcanic Zone and the southern end is bound by rhyolitic material of the Coromandel Volcanic Zone at the northern headland to the Tauranga Harbour.

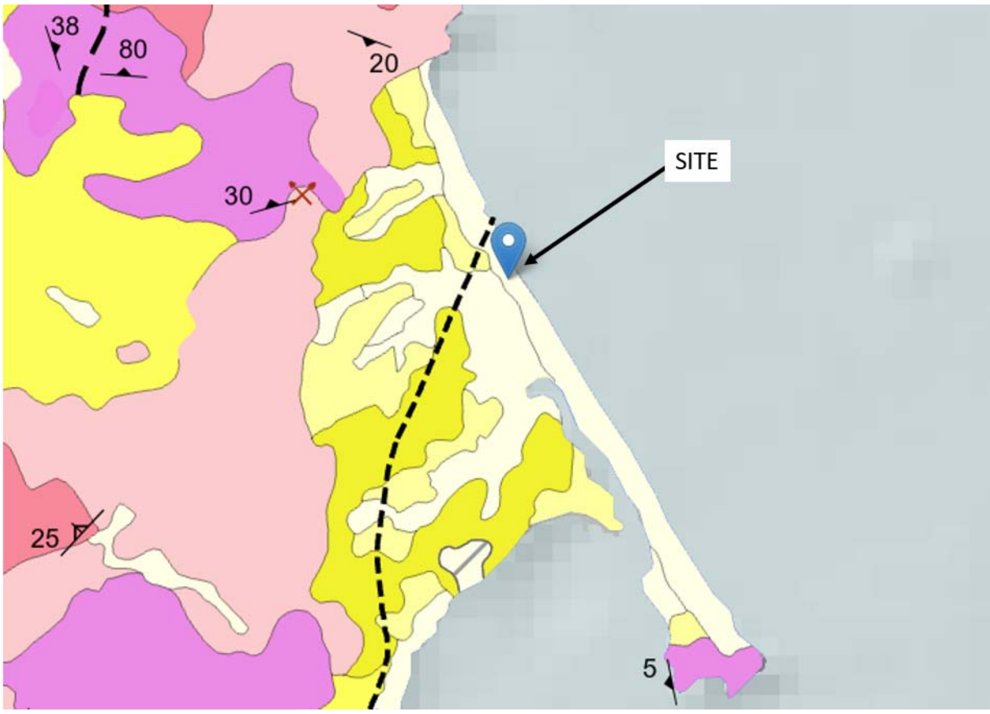


Figure 2.4: Excerpt from Geology Map by GNS showing site geology

3.0 Coastal Processes

3.1 Astronomical Tide

Tidal information is published online by LINZ, who provide Standard Port data for Tauranga. This is the best available data on the likely tidal range at the site. Data published online by LINZ is in terms of Chart Datum (**CD**). A topographic survey of the site is in terms of New Zealand Vertical Datum 2016 (**NZVD-2016**), and all existing beach monitoring data is in terms of Moturiki Vertical Datum 1953 (**MVD-53**). These two datum have been related to CD at Tauranga through a common relationship to LINZ BM BC84. This gives a conversion factor of NZVD = CD-1.16, and MVD = CD-0.97.

Accordingly, the tidal information has been expressed in terms of CD and RL to MVD-53 and NZVD-16 below (Table 3.1).

Existing work has been undertaken by Davis Coastal Consultants (Memorandum – Location of Mean High Water Springs, 28 March 2024, Appendix C) to determine MHWS for the purposes of the CMA boundary. This has been agreed with the Bay of Plenty Regional Council (**"BOPRC"**). RL 1.0 (**MVD-53**) was adopted in that reporting and is adopted here also.

Datum	HAT	MHWS	MHWN	MLWN	MLWS	MSL
Tauranga CD (m)	2.17	1.92	1.64	0.55	0.21	1.11
Tauranga NZVD-16 (RL)	1.0	0.8	0.5	-0.6	-1.0	0
Tauranga MVD-53 (RL)	1.2	1.0	0.7	-0.4	-0.8	0.2

Table 3.1: LINZ predicted tide levels at Tauranga

3.2 Storm Tide

During storm events water levels become higher due to lower atmospheric pressure and the effect of onshore wind energy "pushing" water towards the coast and up harbours in an effect called storm surge. Storm tides can be defined as tides that include the effects of storm surge and these represent the highest range of water levels experienced in coastal regions in decadal time scales. There are also other oceanic driven variations in the water level that affect extreme tidal levels that are captured in the tidal record.

The Bay of Plenty Regional Council commissioned NIWA in 2019 to develop a hydrodynamic model of the Tauranga Harbour, calibrated to tidal data and observations at numerous locations throughout the Harbour. The model outputs included some locations near the southern headland of the Bowentown Spit, at the Katikati Entrance to the Harbour (Figure 3.2). Whilst the exact location of model output site '92' is difficult to discern from the figures provided there are no other model outputs on the open coast, and it is assumed this is inside the upper estuary arm that runs behind the Bowentown Spit. Sites '95' or '96' are therefore considered most likely to represent open coast water levels, in the absence of wave effects, as they will have least additional amplification due to the shallow inner waters of the estuary.

Figure 3.2: Model Output sites – NIWA, 2019

The simulated 1% and 2% extreme storm tide levels modelled by NIWA for both sites are shown below (Table 3.2). The levels provided in the reporting are relative to MVD-53, and these have been converted to NZVD-16 (-0.2) for comparison with the local topographic survey. The modelled locations are approximately 7km southeast from the site. Additional modelling is also available for previous NIWA work (1997) which produced storm tide levels at Moturiki Island, approximately 30km to the south-east. These are also shown below. There is good agreement between Site 96 just inside the Harbour entrance and the open coast site. Accordingly, these are adopted.

	MVD-53	
Model Output Site	**1% AEP**	**2% AEP**
Site 95	2.12	1.91
Site 96 (adopted)	**1.98**	**1.78**
Moturiki Island (1997)	1.99	1.78

Table 3.2: Predicted Annual Exceedance Probability for Mount Maunganui (ex NIWA, 2017)

3.3 Wave Climate

The Waihi Beach coastline is an open coast beach, and as is typical on the east coast of the North Island, is affected by sub-tropical lows and by systems originating in the tropics moving south towards New Zealand as tropical or ex-tropical cyclones.

Information on the wave climate at the site has been obtained from MetOceanView, who have a publicly accessible website where data from their wave model (‘**MSL SWAN’**) is available. The nearest available model location to the site is located 600m offshore from the site. This data is shown below (Table 3.3a).

As expected, the northeasterly wave direction is shown to be the most frequent for the modelled location, comprising 97.5% of the wave record. The record shows waves of 0-1.0m 73% of the time. Waves larger than this are rarer, with waves at 1.0-2.0m comprising 27% of the record. Waves in the 2 – 2.5m range are highly infrequent, being 0.2%, and no counts of waves above 2.5m were recorded at this location.

Direction	0 – 0.5m	0.5 – 1.0m	1.0 – 1.5m	1.5 – 2.0m	2.0-2.5m
N	<0.1%	<0.1%	0%	0%	0%
NE	26.8%	43.7%	18.7%	8.1%	0.2%
E	0.4%	0.9%	0.3%	<0.1%	0%
S	<0.1%	0%	0%	0%	0%

SW	<0.1%	<0.1%	0%	0%	0%
W	0.6%	<0.1%	0%	0%	0%
NW	<0.1%	<0.1%	0%	0%	0%

Table 3.3a: Wave data for Waihi Beach (cords: 175.9583, -37.4150, app.metoceanview.com)

Additional work has also been undertaken by NIWA (2013) in relation to extreme waves, which have been modelled for 10 year and 100 year Annual Return Interval (**ARI**) for Waihi Beach. These values are shown below (Table 3.3b). The extreme wave heights below have been used to determine the appropriate nearshore wave for design of the structure. Wave modelling was also undertaken by RoyalHaskoning DHV (**RHDHV**) as part of work further north on the Coromandel coastline for Thames Coromandel District Council. That work quotes a 1% Annual Exceedance Probability (**AEP**) for the offshore easterly wave per Table 3.3c below).

ARI	10year ARI	100year ARI
Extreme wave height (m)	4.6	5.3

Table 3.3b: Waihi Beach extreme wave heights (NIWA, 2013)

Wave height (H_{sig})	**Peak Period (T_p)**
5.37	11.3

Table 3.3c: East Coast (ERA5) output for 1% AEP water level – joint probability wave height and period (RHDHV, 2021)

3.4 Three Mile Creek and Groyne Morphology

One of the key morphological aspects of the site, that separate it from a typical open coast barrier beach, is the location of the outlet of Three Mile Creek immediately north of the site (Figure 3.4a). The creek runs through a culvert under Seaforth Road, and then within a rock-lined channel approximately 10m wide, for a length which varies but is approximately 85m to the southern bank and 115m to the northern bank. The armouring then transitions to geotextile sand containers forming training groynes at both sides of where the outlet pushes through the foredune. The north and south groynes, terminate approximately 160m and 170m, respectively from Seaforth Road, on the intertidal foreshore.

Figure 3.4a: Armouring to 3 Mile Creek

Typically, the location that a watercourse exits through a dune system is associated with greater dune fluctuation and, on average, a retreated shoreline. There is often significant loss of the adjacent dunes due to channel wander and beach lowering of the outlet channel. The wander is caused by wave driven beach sediment transport dominating the stream transport at most flow regimes. The wandering channel can directly erode the dunes on either side.

In addition, lowered beach level associated with the channel, allows larger waves closer to the dune line and less dissipation of swash, and these factors exacerbate dune erosion adjacent to the watercourse. The flowing watercourse then provides a ready mechanism to transport eroded material from the base of dune. At Three Mile Creek, this recess in the dune line is clear from direct observation but also readily observed from aerial photography and topographic survey.

Historical Cadastral and Survey plans, geomorphologic considerations and reported local history all indicate that the Three Mile Creek is an artificial man made and artificially maintained stormwater outlet through the dunes. One of the most obvious indicators of this, is that even with the increased piped flow to the outlet through the establishment of urban infrastructure, it still requires groynes and manual clearing (typically monthly and after storm events) to maintain flow. If the groynes and manual clearing of the channel did not occur the channel would block and become closed. It is reported (Tonkin and Taylor December 2012) that it was constructed "*circa 1930's to drain the backshore area, to provide for farming and residential development of the area*."

To summarise, a watercourse was created to discharge public storm water and wastewater at Three Mile Creek and that discharge results in a retreated dune line and additional risk of erosion to the adjacent properties; namely the Glen Isla Place properties. Since the installation of the groynes the retreat of dune toe at the outlet has become less pronounced but can still be readily identified (see Figure 3.4b). Similarly, the risk of further erosion around the outlet has been decreased by the installation of the groynes but it is still higher than the surrounding beach.

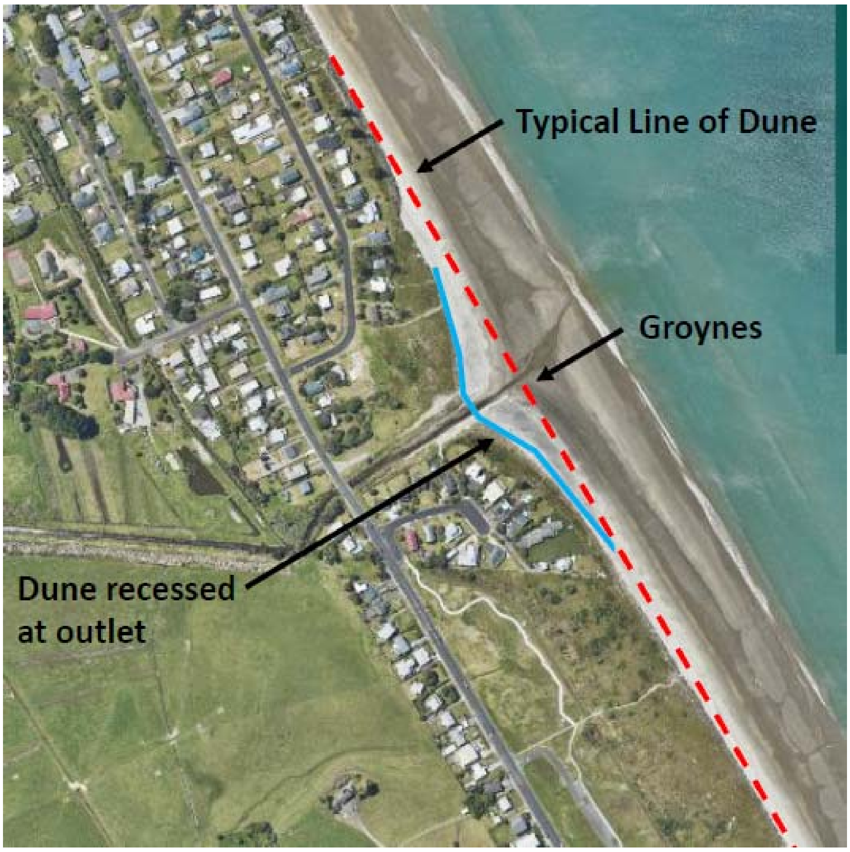


Figure 3.4b: Indicative dune line at TMC outlet

Since construction of the groynes, sand has tended to accumulate on the southern side of the southern groyne, indicative of a net northerly longshore transport of sediment (at least in the period since construction was undertaken in 2011). This is highlighted by the progradation of the dune line to the south side of the southern groyne. The first image below (Figure 3.4c) from 2024, has marked out the approximate edge of the existing dune vegetation. This same line is compared with an image from 2003, pre-groyne construction, and shows a much more retreated dune line, clearly affected both by migration of the river channel but also significantly lower sediment levels.

Figure 3.4c: Dune line post groyne construction

Figure 3.4d: Dune line pre-groyne construction

3.5 Historic Beach Changes – Historic Aerials

Inspection of historic aerials can provide a useful tool to make qualitative assessment of historic coastline changes. Historic images were obtained as far back as 1948, with common repeated features between images used to georectify and align the images. The geo-rectified images are attached as Appendix B, and delineations from 1948, 1963, 1975, 1982, 1986, 1999, and 2024 are overlaid on the 2024 aerial below (Figure 3.5a).

The most visible 'line of vegetation' has been mapped and trends in the coastline positions are described below for the 76 year period. In general, the coastline at the site, directly in front of Glen Isla Place, appears to be dominated by river mouth processes. As noted above the variation in the river mouth position can lead to a retreated dune line, however despite the periodic fluctuations of the river clearly influencing the dune vegetation, in general, the coastline has prograded significantly over the period since 1948. It is hypothesised that Three Mile Creek represents a reasonable sediment source to the beach system, which has assisted as in input to the sediment budget at the site.

The 1948 coastline is the most retreated on record, with accretion of 35-70m occurring between this and 1963, some 2-5m/yr. The shoreline has seen much less change since this point, with relatively constant accretion continuing to occur, at least in front of the site, through to 1999. The 2024 shoreline picks up the nearly unprecedented retreat that occurred in the extreme weather events in Jan-Feb 2023, and is approximately 3-5m landward of the 1999 coastline. Due to the length of time between these subsequent measurements there will be some fluctuation that is not captured by this record, but the accounts of the storm events indicate that Cyclone Gabrielle was likely responsible for a large part of the retreat that occurred.

Comparatively, the shoreline further south of the site has a less modified backdune and, being further from the river mouth, is dominated by open-coast processes. The 1963 shoreline was one of the more seaward positions in the record, and coastal erosion, although relatively slow at approximately 0.2m/yr, is present between 1963-1986.

Figure 3.5a: Historic coastlines overlaid on 2024 aerial

The most recent work by the WBOPDC (T&T, 2015) to define the coastal erosion hazard to Waihi and Pukehina, undertook analysis of the long-term shoreline trends from these historic shorelines. This calculated trends along the shoreline at 5m intervals using proprietary software. The data at the site is shown below (Figure 3.5b), which indicates accretion, as per the work above, with the colour key indicating this to be in the order of 0.25 – 1.5m/yr across the site.

Figure 3.5b: Long-term regression rate (T&T, 2015)

Another aspect of the beach changes that are evident in the historic aerial record, is the significant effect that dune restoration has had on the beach system. In the older aerials (see Figure 3.5c), access to the beach from the growing development was poorly controlled, and dune vegetation was disrupted as indicated by the presence of dune tracks. The dune system has been significantly altered by subdivision development. This is evident at Glen Isla Place which was developed on the dune system. The dune system further south has also been altered with the landward half appearing to have been grassed and more formally maintained for recreation and access between 1975 and 1982 (Figure 3.5d).

A coastal restoration programme, run by Coast Care, has been working on restoring and protecting dunes within the Bay of Plenty since 1994. Their work includes dune replanting and community education on access at Waihi Beach. The introduction of dune stabilisation species, such as Spinifex and Pīngao, helps mitigate erosion and natural dune repair is improved as sand is trapped and built up by these species during accretionary periods between storm / erosion events. The extent of healthy and relatively stable foredune systems present at Waihi Beach, are due in large part to the efforts of this community volunteer organisation.

Figure 3.5c: Historic aerial showing man-made dune tracks and subdivision development 1975

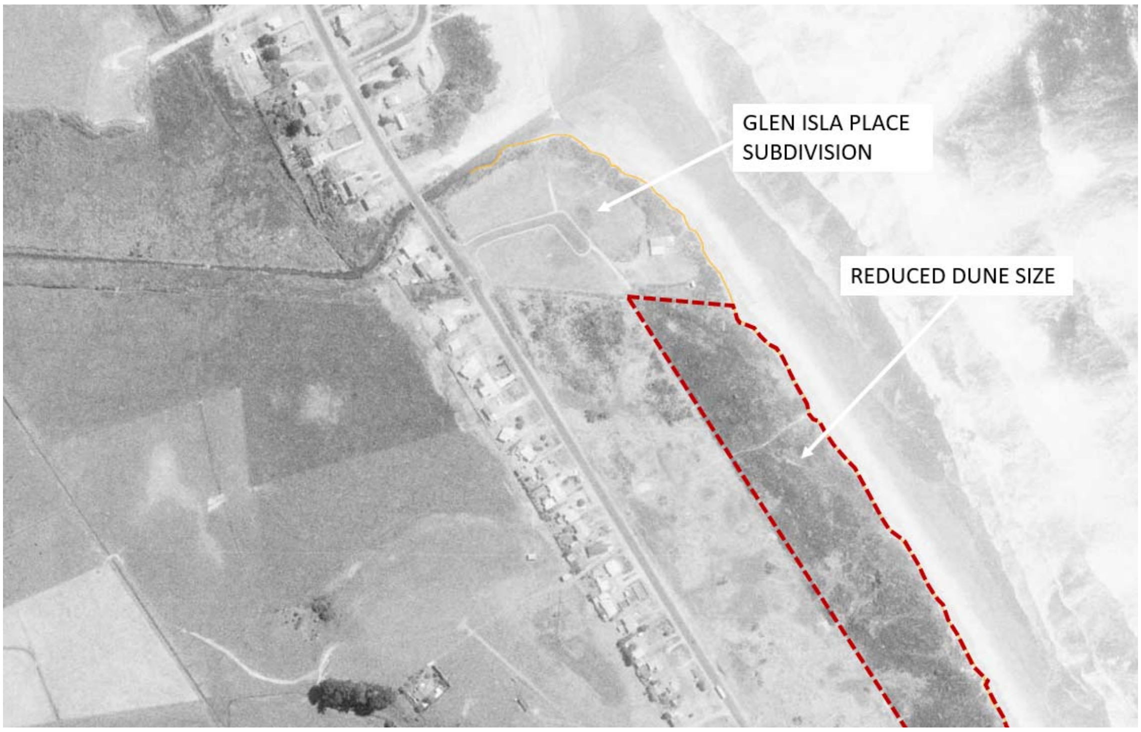


Figure 3.5d: Historic aerial showing reduced dune size and Glen Isla Place subdivision 1982

3.6 Beach Monitoring Data – MHWS Analysis

Waihi Beach has reasonable monitoring data for approximately 30 years (CCS49 and CCS50), and a limited amount of older data going back over 45 years (CCS49). The locations of monitoring data are shown below (Figure 3.6a). This data was obtained and analysed by Davis Coastal Consultants in a separate, appended, memorandum (Appendix C), which defines the envelope of MHWS fluctuation in the historic data, primarily to resolve the location of the CMA boundary with respect to the proposed structure.

The analysis of the two long term profiles (CCS49 and 50) and comparison of these with the three additional shorter term profile records (S1-S3) allowed the plotting of the width of the historic excursion of MHWS, onto the beach seaward of the site at Glen Isla Place, in order to demonstrate the position that MHWS has occupied over the last 30-35 years (Figure 3.6b).

Figure 3.6a: Monitoring profiles in relation to the site

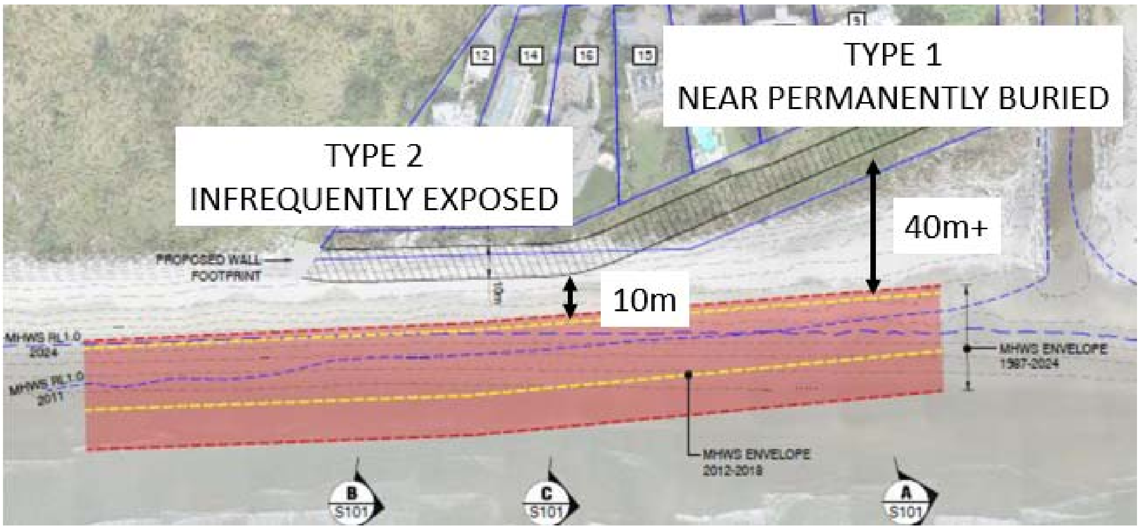


Figure 3.6b: Historic range of MHWS in relation to the site

3.7 Short Term Erosion / Shoreline Fluctuations

As an open ocean beach with predominately shore parallel wave approach, and a healthy dune system, erosion typically comprises storm cut of the dune and beach lowering for long lengths of coast. Eroded sand moves primarily across shore, to be deposited in intertidal and subtidal bars, before moving back onshore in periods of rebuilding associated with lower wave energy.

Erosion is (storm) event based and part of ongoing natural fluctuation. The fluctuations occur on various timescales from twice-daily tidal changes through seasonal variations to very long pan decadal cycles and extreme storm events. These various fluctuations are not cumulative and as long as there is adequate sediment, the shoreline will recover an equilibrium position.

The monitoring data captures the full extent of beach fluctuations over the monitoring period. The RL3.0 contour is well above the area of tidal interaction and changes at this level tend to represent the storm driven erosion and dune rebuilding. The excursion data for the RL 3.0 contour south of the site (CCS49) (Figure 3.7) clearly shows the extreme extent of the 2023 retreat, noting that the beach was monitored prior to the Cyclone Hale/Gabrielle sequence of cyclones. The RL 3.0 excursion north of the site (CCS50) also shows strong retreat though this period but interestingly shows greater retreat in 2011.

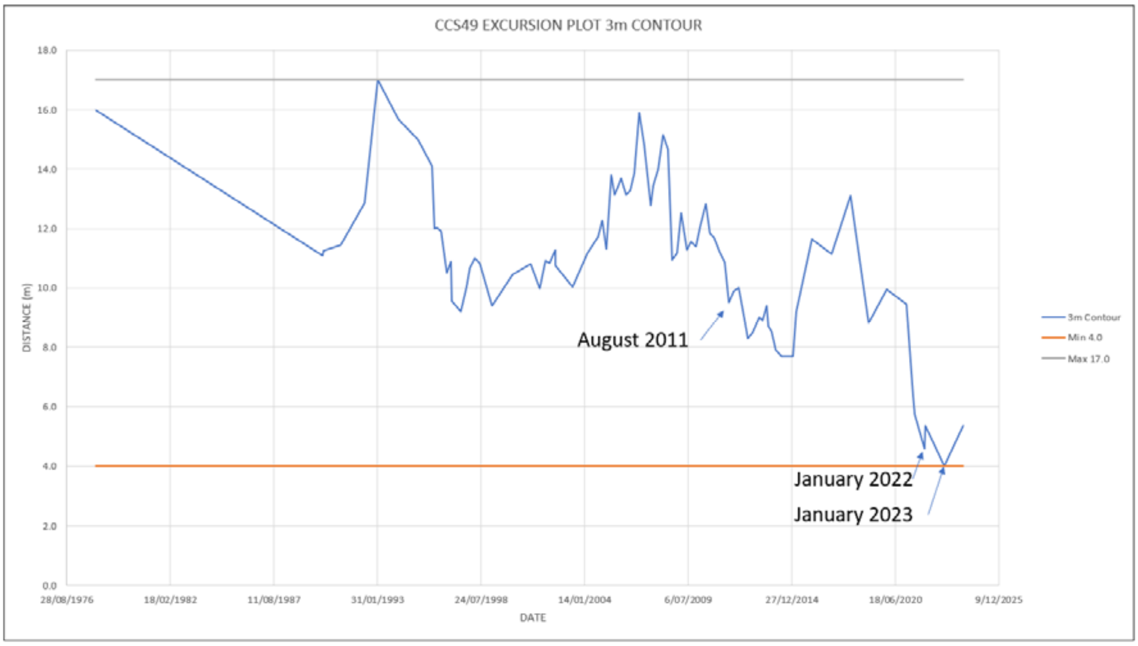


Figure 3.7: RL3.0 Excursion CCS49

3.8 Future Erosion Hazard – Probabilistic Analysis

Overlaying these short-term fluctuations can be slow, long-term trends associated with a slow net loss of sediment or net sea level rise creating a retreating shoreline position. At Glen Isla there has been long term accretion associated with changes in the Three Mile Creek Outfall. Either side of the Creek, small net retreats tend to dominate. These are predicted to increase with Climate Change driven sea level rise.

The WBOPDC report[1] uses both monitoring data from the beach monitoring profiles, and historic aerial analysis, to undertake a probabilistic analysis of the future shoreline retreat at each monitoring profile across Waihi and Pukehina. The underlying recession occurring at each profile location was reviewed, then future recession due to sea-level rise was determined using a Bruun analysis. An allowance for short-term retreat and regression of the dune to a stable angle of repose was also allowed for.

With reference to the profile locations above (Figure 3.6a), CCS50 is approximately 500m to the north of the site and displays no clear linear regression trend for the record (Table 4-2, TnT,

[1] Tonkin & Taylor, 2015, Coastal Protection Areas Re-assessment Stage Two

2015). CCS49 is approximately 650m to the south, and into the area where regression of the beach is indicated in the historic aerial analysis. This profile shows linear regression of -0.1m/yr.

The report, which was prepared in 2015, used the following values for sea-level rise (Table 3.8a).

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

Table 3.8a: Adopted future sea-level rise values, TnT (2015)

The coastline was divided into cells, with the subject site being 'Site 1G'. For each cell, component bounds influencing the Coastal Erosion Hazard Zone (**CEHZ**) were defined and then adopted. Probability distributions for each parameter were generated, with the 2065 p66% (66% probability of exceedance) and the 2115 p5% adopted as the CEHZ for the coastline. The plotted CEHZ lines are shown below for the coastline in the vicinity of the site (Figure 3.8).

Figure 3.8: Plotted CEHA 2065 and 2115

The adopted values per that report for the subject Cell are set out below (Table 3.8b). The report notes that these lines have been offset from the '*most recent dune toe'* (2014 survey data) and represent the landward boundary of the coastal erosion hazard extent including storm cut and regression of the dune to a stable profile. It also notes in relation to the subject cell that:

> "*Inlet cells at Waihi Beach have man-made structures influencing the fluvial processes…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"*

CEHZ2065	-18
CEHZ2115	-54

Table 3.8b: Adopted CEHZ values

3.9 Sea-Level Rise – Updated Projections

There are two sources of guidance for sea-level rise allowances and the most up-to-date data. The MfE document "Coastal Hazards and Climate Change Guidance" released in 2024 provides precautionary relative sea-level rise allowances recommended for coastal planning and policy, before a Dynamic Adaptive Pathways Planning approach is implemented. For *'land-use planning controls for existing coastal uses and assets'* a timeframe to 2130 is specified, with the *'medium confidence SSP-8.5M based RSLR projection that includes the relevant VLM rate for the local and/or regional area'*.

In addition to projections of sea-level rise, a relatively recent addition to the future sea-level rise risk scenario is the potential for vertical land movement (**VLM**). This is where the land at the coast can be slowly changing in elevation (up or down), and in the case of sea-level rise risk, if the ground is sinking lower (due to subsidence) the rising sea-level can reach higher and further inland. With respect to the most recent data, the NZ Sea Rise programme has released location specific sea-level rise projections out to the year 2300 for every 2 kilometres of coastline, which is available in an online tool.

Estimates of local VLM rates (mm/year up or down) for the period of 2003 – 2011 are also available in the online tool. Despite the relatively short period of measurement, the potential for subsidence of the land to increase the effect of sea-level rise in the future needs to be considered.

The Intergovernmental Panel on Climate Change (**IPCC**) previously used Representative Concentration Pathways (**RCP**) to represent plausible climate futures. These potential future scenarios were focused on a radiative forcing of warming that could be reached by 2100, going from RCP 2.6 – 8.5. The latest (6th) IPCC Assessment Report (published 2021-2022) shifted to a new core set of future representative scenarios, based on Shared Socio-economic Pathways (**SSPs**). The new SSP's offer five different narratives of how the world may evolve in the future, that also combine the RCP's, related to increases in global mean temperature.

The closest mapped location on the NZ Sea Rise online tool to the subject site is located approximately 520m northwest of the site along the coastline (Site 1712) (Figure 3.9a). Being a project adjacent to the coastal margin, it is reasonable to use the most conservative SSP5-8.5 scenario (assuming ongoing fossil fuel development and negligible mitigation), and this is consistent with the most recent MfE (2024) guidance.

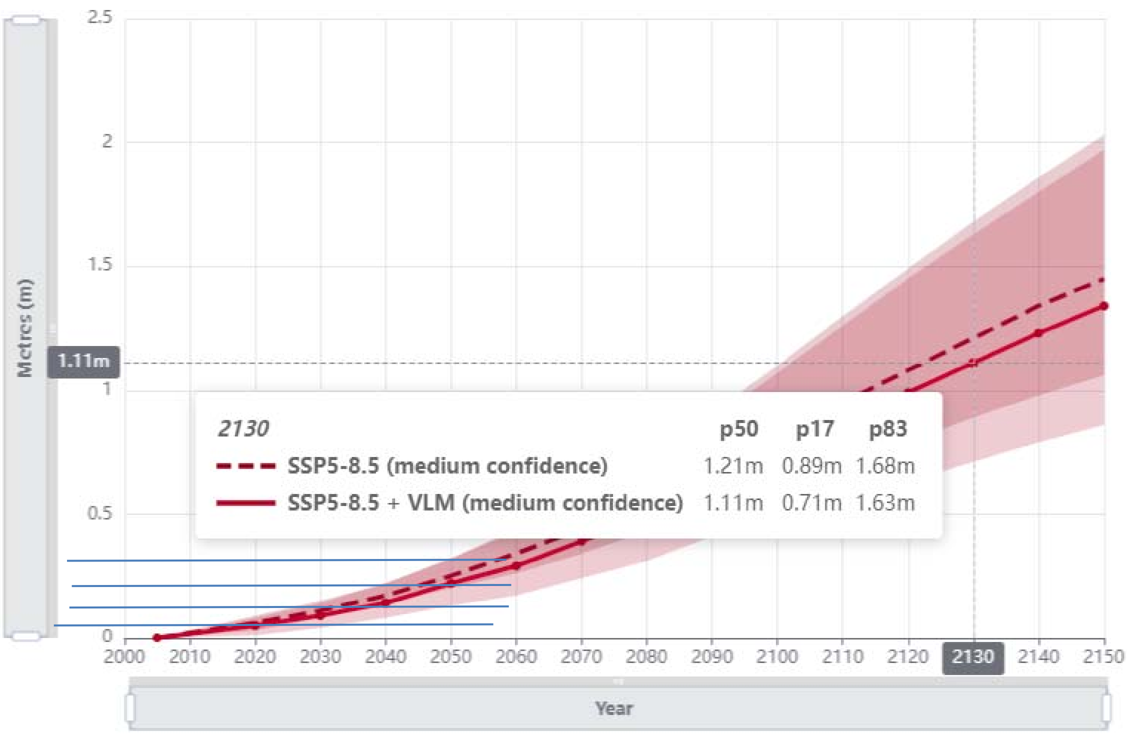


Figure 3.9a: Sea-level rise and VLM to 2130 – SSP5-8.5 scenario, Site 1712

The predicted effective sea-level rise depends both on the projected timeframe, the future scenario, and the probability within each scenario. The most probable value, i.e., the p50, is considered the most appropriate potential future rise to consider. The considered sea-level rise values over the 30-year, 50-year, and 100-year timeframes are summarised below (Table 3.9). Allowance for VLM actually reduces the sea-level rise allowance by 0.1m over the 100-year timeframe. This brings the future sea-level rise allowance to the same as that allowed for as the 'max' value in the region-wide work, for 2115 (see Table 3.8a above).

Sea Level Rise + Vertical Land Movement (30 – 100 years)			
Shared Socio-Economic Pathway	**30yrs (m)**	**50yrs (m)**	**100yrs (m)**
SSP5-8.5	0.34 (0.3)	0.55 (0.6)	1.21 (1.2)
SSP5-8.5 +VLM	0.29 (0.3)	0.49 (0.5)	1.11 (1.1)

Table 3.9: Sea-level rise and VLM to 2130 – Site 1712

3.10 Sea Level Data

A record of the mean sea level between 1974 – 2018 from NIWA for the Moturiki tide gauge, is shown below (Figure 3.10). The gauge is located at Moturiki Island, outside the Tauranga Harbour.

The total increase in sea level over the period measured at the gauge is approximately 170mm, giving an average increase of 3mm/yr. However, sea-level stayed relatively consistent for the period between 1974 – 1990, and only really started to increase in the period 1993 – 2023. The rate at which this more recent rise has occurred depends on where the 'start' point is taken for the calculation. Based on the graph below which takes the 'average' level (of 1.05) between 1974 – 1993 as the start point, this increase over the period of 30 years to 2023 is 5mm/yr. This period in which 5mm/yr sea-level rise has been observed matches the higher quality data in the monitoring period.

When considering a 30 - 50-year timeframe, irrespective of the SSP used, there is future sea-level rise of approximately 0.1m/decade or 10mm/yr, twice that captured in monitoring.

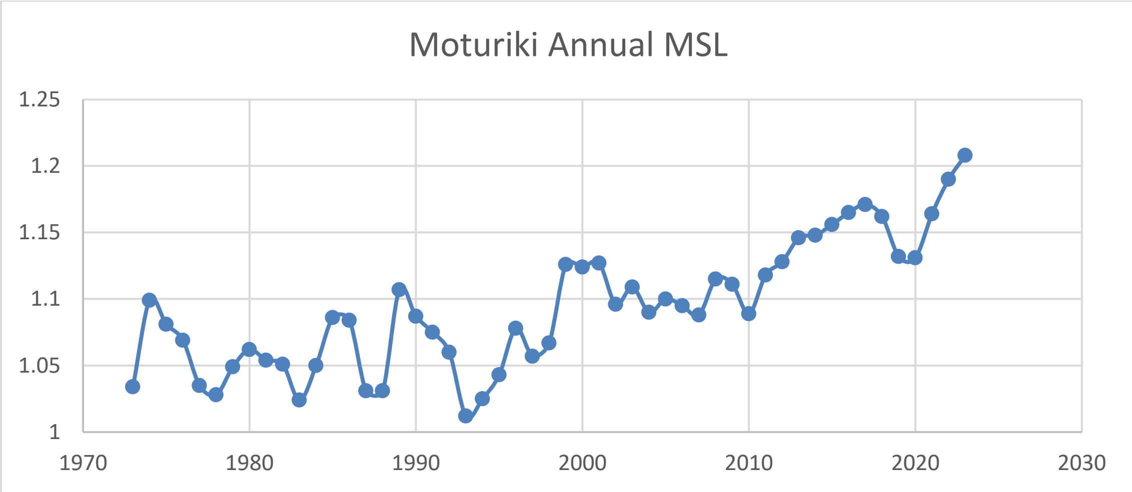


Figure 3.10: Moturiki annual mean sea level up to 2023

3.11 Future Beach Position in Relation to Structure

Long-term shoreline retreat as defined by the WBOPDC CEHZ line has been adopted as set out in Section 3.8 above. In order to assess how this may affect the buried wall and assess the extent of future exposure, the progress of the future retreat was modelled by translating the beach slope landward.

The beach profile, as defined by 2011 LIDAR survey, was assumed to retreat by translating horizontally to meet the erosion hazard predictions (Figure 3.11). The retreating beach profile results in a progressively lowering beach in front of the wall structure. The profiles will vary over time and retreat will tend to be episodic. However, the retreat model provides a "typical" section and will tend to show the trend and represent an "average" condition of the beach over time.

The beach profile was assumed to translate horizontally at a uniform rate between present day and the design CEHZ lines. The future beach positions have been modelled every decade, and these are then used in the Design Report to review the performance of the structure over time.

A uniform rate of retreat is used in design consideration. Given sea level rise is accelerating this will overpredict retreat in the first 20-30 years.

As set out in Section 3.10 during the monitoring observations over the last 30 years there has been sea level rise of 5mm per annum. This sea level rise does not appear to have resulted in the extent of shoreline retreat predicted by the probabilistic analysis. This is consistent with assumptions of uniform retreat overpredicting the wall exposure and effects in the next 20-30 years.

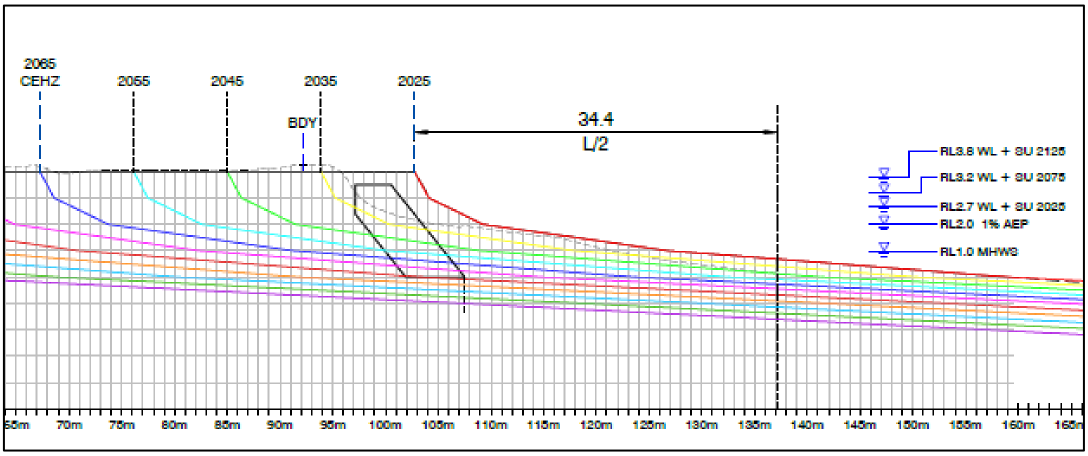


Figure 3.11: Beach Retreat

4.0 Proposal

The proposed solution is detailed more extensively in the standalone Design Report by Davis Coastal Consultants. Key aspects of the solution are summarised below. It is proposed that a buried rock revetment be constructed along approximately 200m of back and foredune area at the site, located immediately south of Three Mile Creek, Waihi Beach. Using sand excavated from the footprint of the revetment, a dune will be constructed over the wall face and planted with native dune binding species.

The revetment is continuous over the frontage of seven beach front properties from 12 Glen Isla Place to number 9 Glen Isla Place. It is proposed that the structure is located in the Three Mile Creek Reserve which is vested in the WBOPDC (Figure 4.0a). The southern end of the structure is seaward of 12 Glen Isla Place, with the landward side approximately 5m from the private property boundary. The structure continues to the north parallel to the boundary until a change of direction of the boundary midway through 16 Glen Isla Place. From this point, the structure is aligned such that it extends north to be 7.6m from the boundary at the existing large Norfolk Pine near the boundary of 11 and 13 Glen Isla Place. This 7.6m is the distance recommended by the Arborist to ensure the proposed construction would not damage the Norfolk Pine. From this point the wall extends further north angling closer into the property boundaries, such that the wall is approximately 6.5m from the boundary at the northern end of 9 Glen Isla Place.

Figure 4.0a: Layout Plan of rock revetment

The crest level is to be approximately RL 3.5 to ensure the structure is buried beneath approximately 0.5m of sand (Figure 4.0b). Footing depth will be at approximately RL 0.0, approximately mean sea level. Where the structure is more likely to interact with future coastal processes, for a length of 100m it has been termed a 'Type 1' and will have a face slope no steeper than 1:2, a double armour layer (D_{50}=1100) and a double underlayer (D_{50}=250), with a minimum three armour stone width crest. Where the wall returns further landward, for a length of 92m, it has been termed a 'Type 2', where the only differing design detail is a steeper face slope at 1:1.5.

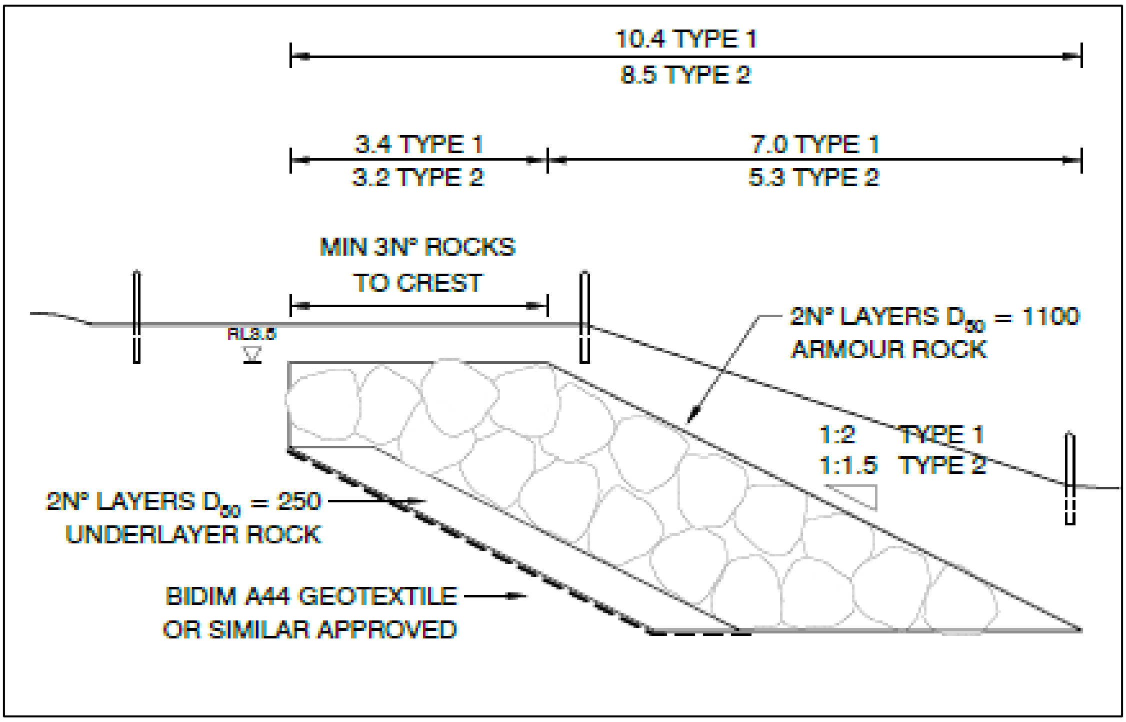


Figure 4.0b: Typical section

5.0 Potential Effects of Wall

5.1 Coastal Hazards

Coastal inundation occurs as a result of extreme high-water levels from a combined storm event characterised by a strong onshore wave climate, low barometric pressure and extreme tides. The 1%AEP extreme water level is RL 2.0, as set out in Section 3.2. Adopting the guidance provided by MfE for future sea-level rise, design inundation levels assume a 1.2m allowance for sea level rise over the next 100 years, giving a maximum water level of RL3.2. The sites are above RL4.0 and not considered at risk from inundation.

The structure has not been designed to prevent overtopping, and potential inundation of the backshore. The properties have not been inundated previously but may become affected by overtopping when the structure is more exposed. The relative elevation of the backshore, landward situation of the structure and planted foredune will help prevent overtopping and inundation in coming decades. The energy dissipation of the vegetation and sand loss at the foredune will work to prevent over topping until the structure is more fully exposed in 20 -30 years' time. Given the short duration of storm events leading to the potential overtopping events and the well recessed dwellings, overtopping will primarily lead to management issues of the land at the crest of the structure. Overtopping water will flow generally back through the permeable armour layers of the structure. A geotextile barrier beneath the structure will prevent the progressive loss of fines that would lead to structure failure.

Future coastal erosion, as set out in Section 3.8, will be limited by the backstop wall structure, and will therefore not affect the backshore area. However, there is potential for the wall to have effects on the surrounding coastline and this is addressed Sections 5.2 and 5.3 below

5.2 Review of Literature and Common Concerns

The effects of a seawall on the foreshore and sandy shorelines in particular have been the subject of much debate. A lot of claims have been made of the effects and these have sometimes been poorly informed. The long-term processes occurring at the location and the adequacy of wall design have sometimes been interpreted as indications of effects caused by the seawall. For example, a long-term loss in sediment supply may cause long term retreat of a coastline over many years, possibly decades. If in response to the initial "erosion" of the coastline a seawall is built, the seawall is likely:

- to be ineffective at preventing ongoing lowering of the beach
- to fail from being undermined or from being subject to increasing loading as water depth and wave height increase due to the loss of shore in front of the wall
- to be considered by some as the cause, or part of the cause, of the erosion.

A properly designed seawall that has been designed for the future foreshore level addresses these issues.

Pilkey and Wright (1988) use the terms passive and active erosion of the beach to distinguish between the perceived versus real natural and anthropogenic causes, respectively. The terms passive and active erosion can also be used to differentiate between effects of the wall being in place and potential effects of the wall interacting with incident coastal processes.

Passive effects:

- Loss of sediment to the system because it is trapped behind the seawall
- Occupying space on the beach profile preventing use of part of the beach

Active effects:

- Beach lowering in front of the wall, profile steepening
- End effects caused by rips, groyne effects swash deflection or concentration
- Over topping
- Increased sediment transport

Effects of seawalls have been relatively intensively investigated and the Coastal Engineering Manual (USACE 2008) provides a summary of literature reviews and findings as per the precis below.

Dean (1987) examined nine commonly expressed concerns about seawalls and adjacent beaches as summarised in Table 6.1 below. Using conservation of sediment mass, laboratory and field data and the theory of sediment transport the conclusions from the analysis were that:

a) Concerns that were probably **False** (or Unknown) were;

- profile steepening (6)

- delayed beach recovery after storms (5)
- increased longshore transport (8)
- sand transport far offshore (9)
- increase in long-term, average erosion rate (3)

b) Concerns that were probably **True** were;

- frontal effects (toe, scour, depth increase) (1)
- end-wall effects (flanking) (1)
- blockage of littoral drift when projecting into surf zone (groin effect) (4)
- beach width fronting armour likely to diminish (2)

Kraus (1988) reviewed over 100 references (laboratory, field, theory, and conceptual studies) to make a thorough examination of the literature. Kraus and McDougal (1996) examined 40 additional papers. In general, these extensive literature reviews agreed with Dean (1987) regarding which concerns were probably false and which many are true.

Trapped Sand

It has been suggested (Dean 1987) that a reason for both erosion in front of a seawall and erosion of adjacent unarmoured beachfront is that the sand trapped behind the wall removes active sediment from the beach system. The volume of sediment trapped behind a seawall depends upon its position on the beach, crest elevation and length. Weggel (1988) defined six types of seawalls depending on their location on the beach and water depth at the toe. At one extreme (Type 1) the wall is located landward of the limit of storm wave runup to have zero impact. At the other extreme (Type 6) walls are located seaward of the normal breaker line. Types 2-5 lie in between and are said to have increasing effects on coastal sediment processes as the type number increases. The type of a wall may change during beach erosion as the beach profile alters. A wall well back in the envelope of beach profile positions will remain a Type 1 or 2 where further forward in the profile may become a Type 3-4 during periods of low beach level and high tide during a storm surge.

A Wall Trap Ratio WTR has been defined (Equation 1 below) comparing the volume of sand behind the wall with the total volume of sand in the active profile at the wall location. Especially in a Type 1 or 2 wall, the fraction of sand behind the wall is insignificant when compared to the larger active volume suggesting the passive effect will be negligible.

$$WTR = \frac{\text{Volume of Sand trapped behind the wall}}{\text{Total Volume of Sand in the profile}} \quad (1)$$

Groyne Effect

If the seawall extends seaward into a zone of the beach where waves are causing littoral transport of sediment along the beach, sediment can be trapped "upstream" of the wall. In effect the wall becomes a groyne and by trapping sand causes downstream effects. The effect has been reported (Tait and Griggs (1991), Toue and Wang (1990)) and can be readily observed on seawalls seaward of surrounding areas. Typically, unless associated with large reclamations, the groyne effect is limited by the upstream sink being small and rapidly filled allowing transport to recommence. With well retreated, shore parallel walls such as that proposed, this groyne effect is not relevant to the Glen Isla situation.

Beach lowering in front of wall

Beach profile change, toe scour during storms and nearshore bar differences have been attributed to seawalls. Conventional wisdom has been that these impacts were due to wave reflection. Substantial study in both the field and laboratory (Kraus and McDougal (1996), Barnett and Wang (1998) and Moody and Madsen et al (1995) concluded that reflection is not a significant factor in profile change or toe scour. In the field, toe scour is more dependent on local, sediment transport gradients and the return of overtopping water (through permeable revetments or beneath walls) than a result of direct, cross-section wave action. Their conclusions also negate the common perception that sloping and permeable surfaces produce less effects than vertical, impermeable walls.

Plant (1990), Plant and Griggs (1992), McDougal, Sturtevant, and Komar (1987) observed rip currents at interior sections and at the ends of armoured sections. These rip currents were attributed to wave overtopping, return flows and elevated beach water tables during storms. It was concluded that this mechanism may be more responsible for end-of-wall, flanking effects than the sand trapping theory of Dean (1987).

A number of studies (Griggs et al. (1997) Basco et al. (1997) (Everts, Battley, and Gibson 1983) et al) have concluded that no significant long-term effects were revealed or that there was never evidence of flanking effects after storms on adjacent beaches.

In general, Basco et al. (1997) have confirmed all the conclusions of Dean (1987), Kraus (1988) and Kraus and McDougal (1996) except the end-wall flanking effect.

5.3 Assessment of Effects of Glen Isla Coastal Seawall

5.3.1 Potential Effects at Glen Isla

Given a 30-year envelope of beach position it is possible to locate any armouring at the landward extent of the defined envelope of historical beach change. The structure will provide a backstop position, where it will protect the backshore from erosion in storm events. It will then only be rarely exposed as a result of extreme events. Between such events, sand on the profile will establish to historic equilibrium levels and the structure will become buried again. When exposed, Type 1 or 2 (ref Weggel 1988 above) "frontal effects" and beach lowering etc will only occur to a limited extent, for a short time during the storm event.

Similarly, given a lack of protrusion onto the surf zone and shore parallel alignment, and the far larger adjacent shore-perpendicular structures of the Three Mile Creek Groynes, the proposed wall will not act as a groyne trapping sand, and will not affect longshore sediment movement on Waihi Beach.

Even in the advent of shoreline retreat the beach lowering and groyne effects will be less than minor. The potential for end effects remains the largest potential effect of the wall and this is discussed below.

5.3.2 Potential End of Wall Effects

While during storm events only the upper wall may be exposed, due to limited interaction of the structure with coastal processes, end effects will be negligible. However, during a very large storm event or following beach retreat due to sea level rise when the wall is providing coastal protection as designed, consideration of potential end effects is warranted.

The primary mechanisms by which this would be likely to occur would be through either

a) Rip currents and differential head
b) Deflection of Swash

c) Sediment lock-up

Rip currents / Differential head

The cause of rip currents within surf beaches is the subject of much study and some conjecture. The case of rip currents high on the beach face, where the actions are primarily of swash not wave action, is atypical of most rip currents. Swash moving up the beach impacting on a wall face will gain elevation when compared to swash moving up the unarmoured adjacent beach face. The figure below is based on a sloping structure (Figure 5.3.2a) but the effect is similar for a vertical structure.

For example, if the beach is at 1:10 and the wall at 1:2 when the water has flowed 1m past the toe of the wall the water elevation of swash on the wall will be 500mm, while the water elevation on the beach will be 100mm. This is a simplified illustration of the actions for explanation. Greater turbulence and potentially permeability of the wall will change the parameters, but the principle holds and the situation creates a differential of head. The net differential in head will create a component of flow in a shore parallel direction towards the end of the wall. The accelerated greater volume of flow preferentially scours the adjacent unprotected bank causing additional scour at the end of the wall. Similarly, a greater return current is created, scouring the foreshore in a rip current type action.

Similarly, if overtopping of the wall were to occur and concentrate returning flows these could create a scouring "rip" current. Overtopping flows will tend to percolate back through the very permeable upper armour layers and so this will not occur.

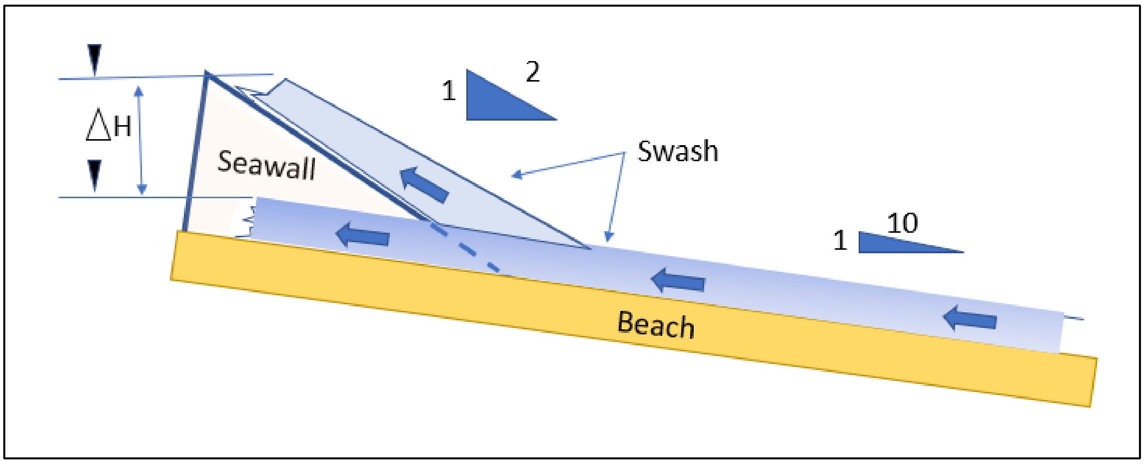


Figure 5.3.2a: Head differential at wall end

The creation of differential head would require the swash to be passing well past the wall ends. This will only occur when the general dune line has retreated landward of the wall. This would represent a more severe storm than so far recorded in the monitoring record or a large long-term retreat due to sea level rise. In either event the extent of additional scour is likely to be very limited in extent of affected coast and severity of erosion. The effects would only endure for the particular storm and then the adjacent beach recover with the surrounding dunes.

South of the wall is an Esplanade Reserve where the temporary retreat of a dune in a natural, if slightly exacerbated, manner is unlikely to cause effects beyond a slightly more eroded area, in the order of 2-5m for a length of coastline of 5-15m. The dune replanting work proposed within the proposal would tend to help the adjacent dune recover and mitigate the effects. To the north of the proposed wall is Three Mile Creek and the groyne structure which would not be affected at all. The lowering of the Creek channel causes preferential wave action acting within the channel and no end appreciable effects of the northern end of the wall would be created.

Any adverse effects of the proposed wall on adjacent areas due to rip currents/differential head are expected to be negligible.

<u>Deflection of swash and wave energy by end of wall</u>

This is a special or localised case of a wall being at an angle to the beach face. Where swash acts on the face of the wall it is deflected and channelled along the wall face to the adjoining bank. The return current then also tends to scour more as described above. The alignment of the structure as landward as possible, and dune building proposed, will limit the potential for the wall to interact with wave processes and generate these effects.

The subject wall will deflect some incoming wave energy along its length where it is angled away from the beach to the north will. However, due to the length of this return, and the distance the wall returns significantly landwards into the Reserve, any deflected swash and wave energy will have ample room to dissipate on the progressively rising foreshore. There will be a gap between the two built structures that could notionally be breached by erosion to threaten the structure end. However, the end of the structure is so far landward this is extremely unlikely and impossible without very significant beach retreat. If in coming decades this became a real risk, the gap could be readily bridged. At that time, the groyne heads will have been lost and significant rework of the groynes would be required. The Three Mile creek channel would remain with intact armour, even after the loss of the groynes, as there are still minimal wave effects on the upper channel structures due to sea level rise. It is therefore anticipated that the northern flank will be protected. On balance, it is highly unlikely, even under conditions of future sea-level rise, there will be appreciable issues between the wall end and the river training structure at this location.

The southern wall end, as the seaward-most portion of the structure, is most likely to interact with incoming wave energy. Waihi Beach is orientated more or less directly towards the north-east, and waves would need to have more of a northerly component to deflect swash to the southern end of the structure. The MetOcean wave climate data (Section 3.3) shows that waves from the north are negligible in the record, with waves from the north-east comprising almost the entirety of the record (98%), and these waves will tend to approach the structure shore perpendicular.

In this location the offshore contours tend to be relatively even, regular and shore parallel (Figure 5.3.2b). Waves approaching at an angle will tend to refract towards shore normal, which is also normal to the wall alignment at the southern end. If some storm scour does occur at the southern wall end (Figure 5.3.2c), it will be localised and small scale due to the position of the wall high on the beach profile, and shore parallel angle of the wall. Any potential effect would be temporary and not cumulative. The area to the south is vegetated dune, without potentially damaging pedestrian access. This, in combination with the dune planting proposed, will ensure that the dune recovers relatively quicky between storms.   There are not any assets or structure within the relevant area of Island View Reserve that would be at potential risk from end effects.

Figure 5.3.2b: Bathymetry contours offshore from Waihi

Figure 5.3.2c: Potential scour at southern wall end

Sediment lock-up

A potential cause of end effects of a seawall on sandy beaches is that sand behind the wall is "unavailable" or separated from beach processes. This decreases the sand volume available for natural variation in the shoreline. In this case, with a retreated structure line over a very short length of beach relative to the beach length, and very large volumes of sand available in the dunes and foreshore, the "unavailable" sand in this case is negligible and will have no discernible effect on the beach.

Conclusion

The structure is outside the area of typical interaction with coastal processes. This reduces the likelihood of occurrence of much of the potential negative effects associated with seawall structures. Potential short-term lowering of the beach level during storm events and minor additional storm scour at the southern end cannot be totally discounted. The wall has been designed to address this. There are not any structures within Island View Reserve potentially affected and any scour is likely to be transient. There will not be end effects on Three Mile Creek at the northern end.

5.3.3 Potential Exposure of Buried Structure

The proposed location of the southern end of the structure is such that over the 30-year period of monitoring records the upper layer (1-1.5m) of structure would have only been exposed once over that time. This would have been during the recent Gabrielle/Hale set of storms. It is predicted at current sea level, that the structure is likely to be exposed no more than once every 5-10 years. Such exposure would only be the top 1.0-1.5m of the wall which is expected to be quickly re-buried by natural processes. The recovering of the structure will be assisted through the replanting of a healthy dune system, as part of the proposal.

Given the minimal retreat evidenced by monitoring over the last 30 years and that sea level rise over the last 20-30 years (100mm) is of a similar order to that expected over the next 30 years (200mm), we would expect relatively slow retreat over that time frame. This will result in the rare exposure of the wall and natural re-establishment of the dune in front of the wall. Additional storminess associated with climate change may tend to expose the wall more often.

However, as set out in Section 3.11 above, it has been assumed the beach will progressively retreat due to Climate Change driven sea level rise. This analysis has been undertaken in more detail in the Design Report however, the conclusions are set out below (Table 5.3.3).

Time	**Wall Exposure**
0-10 years	Wall buried, 1-2 possible exposures of upper 1-1.5m
10-20 years	Top of 1m wall exposed for long periods. During storms upper 1.5-2.0m exposed during storm events greater than any that have occurred in the last 20 years.. Wall covers back up but upper meeting exposed
20-30 years	Upper 2-3m of face of wall exposed at all times. High tide may reach structure in large storm events.
30-40 years	MHWS at base of wall. Access in front may become limited for 1-2hr around high tide
40-50 years	High tide at wall. Scouring during storm events may threaten toe and remedial to toe may be required. Over topping may require raising wall crest.
50 -100 years	With beach retreat and sea level rise as predicted, significant upgrade may be required on the wall including increase in outer armour size which could be overlayed on the outer face. Foundation would need to be lowered or improved. Over topping may require raising wall crest.

Table 5.3.3 – Wall Exposure

5.3.4 Potential Effects on Public Access

In addition to access along the sandy foreshore as tide levels allow, there is also an existing public access arrangement through a pedestrian walkway off Glen Isla Place, and beach access both sides of Three Mile Creek to access the foreshore (Figure 5.3.4a).

At current sea level, public access along the high tide beach will be unaffected by construction of the wall, except for very short-term effects following a 1%AEP storm or similar. During and within days of the extreme storm event, within two hours of high tide, public access may be limited. High tide beach will rapidly return by natural processes.

Figure 5.3.4a: Public access to foreshore from Glen Isla Place and Seaforth Road

Over time, the MHWS envelope will move landward with rising sea-level, and potentially recession of the backshore. As a consequence, there will be times in the future, over the lifetime of the structure, that it is located within the MHWS envelope and water will be at the face of the wall, limiting access along the shoreline at high tide. Based on the predicted long term retreat rate MHWS will be at the face of the wall in 30 years.

However, there are numerous examples of extensive sections of seawall already present on Waihi Beach, for example approximately 500m of wall at Shaw Road (Figure 5.3.4b), where water levels are present at the seawall face already. Ongoing sea-level rise and profile lowering at these locations will result in deeper waters at the wall face.

Given these existing limitations on access at high tide on Waihi Beach, and that the Glen Isla Dune proposal is set back in the dune environment to the extent possible such that it does not restrict access at current sea-level, the proposed location of the structure is considered the best practicable option and will not contribute significant public access issues on the wider beach.

Figure 5.3.4b: Seawall at Shaw Road – water at wall

5.3.5 Effect of Retreating Beach Profile on Proposed Wall

Shoreline retreat due to sea level rise is poorly understood and accordingly conservative assumptions are made using standardised procedures to predict potential retreat. The existing studies at Waihi Beach, indicate significant retreat, in the order of 50m landward, over the 100-year time frame.

Assuming shoreline retreat due to Sea Level rise occurs in line with predictions, the lowering of the beach profile in front of the wall will increase wave height and loading on the wall. Rock armour is designed by assuming that there will be a level of damage during the design storm event. Typically, the acceptable damage level is set at 2 which is the start of damage. Complete wall failure is level 8. In 40-50 years, some slightly higher damage, level 3, may occur in the design storm. The level of damage would require simple maintenance following the 100%AEP Event.

In the 50–100-year period increased storm damage may require further work at the wall toe and an increase in outer armour size which could be overlayed on the outer face. The design of the wall is readily adaptable to any future requirements.

6.0 Conclusion

The properties of the Glen Isla Protection Society, adjacent to the coastal margin, are at risk from coastal erosion and a buried backstop wall with dune nourishment and planting is proposed. This report analysed the coastal process environment of Waihi Beach, and discusses the potential effect of the wall on the coastal process environment.

The solution proposed has consistent materiality with other armouring present extensively at Waihi Beach. However, by situating the proposed structure markedly landward and enhancing the natural dune the proposal will have markedly less impact.

At current sea levels the proposed wall would only be exposed by a storm event greater than any that has occurred in the last 20-30 years. During this period the effects of the sea wall on the surrounding dune environment will be negligible, with positive benefits provided due to the dune enhancement.

The analysis indicates that over a 30-50 year period, assuming beach retreat associated with sea level rise, the wall will become progressively more exposed. If the wall is to become exposed it will be crucial to protect the backshore and adjacent residential development. During this time the effects will comprise temporary lowering of the beach during and immediately after storm events and temporary minor additional erosion of the dune adjacent to the southern wall end. This erosion is likely to be in the order of 2-5m on a 5-15m length of shoreline and will not put any structure or infrastructure at risk. It may be no worse than, and difficult to discern from, dune erosion elsewhere on the natural coastline.

Based on the assessment undertaken the structure is considered to have less than minor potential effects on the coastal process environment of Waihi Beach, and the proposal will provide positive benefits through dune enhancement.

Appendix A

Design Drawings – Buried Backstop Wall

COASTAL PROTECTION PROJECT

GLEN ISLA DUNE

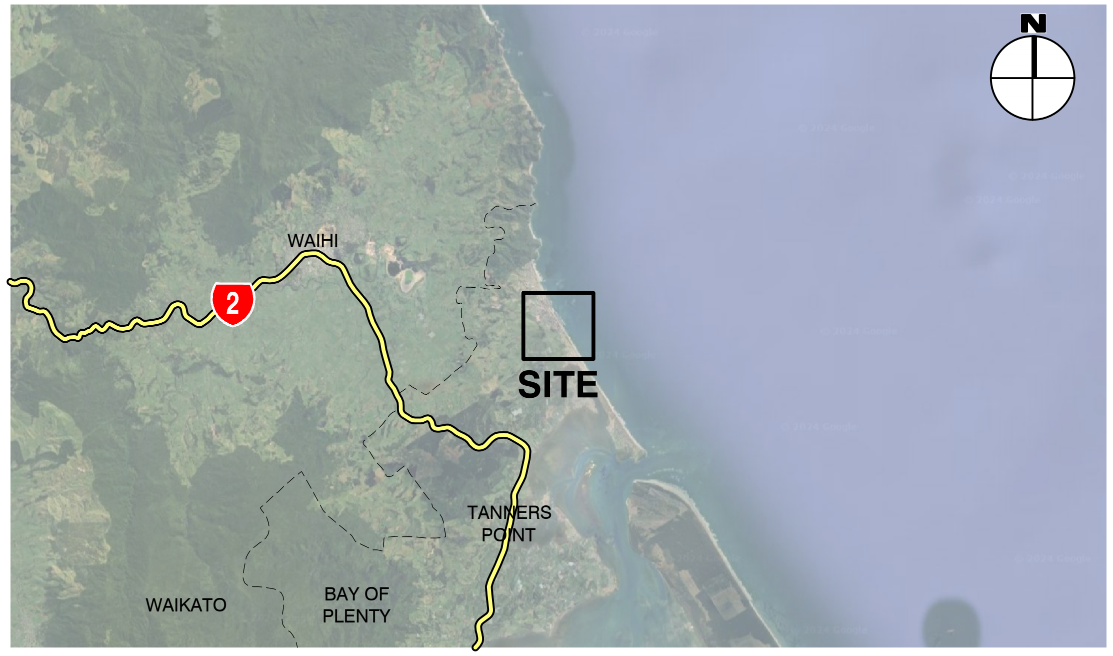
FOR

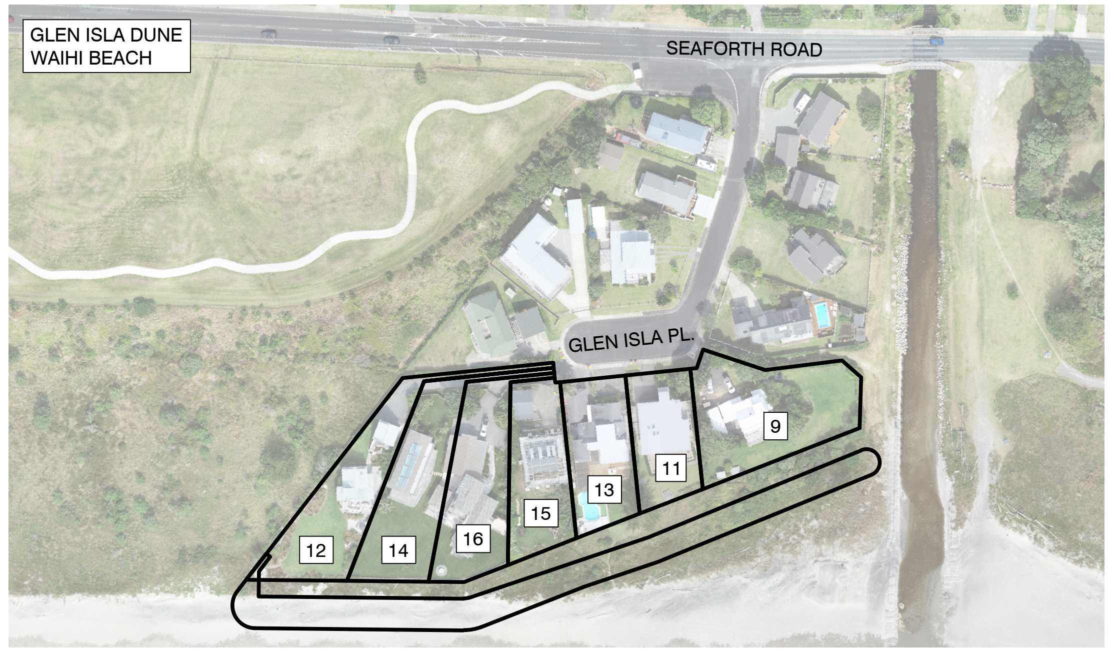
GLEN ISLA PROTECTION SOCIETY

PREPARED BY

DAVIS COASTAL CONSULTANTS

RESOURCE CONSENT





DRAWING SCHEDULE			
NO	TITLE	REV	DATE
01	DRAWING SCHEDULE AND LOCATION PLAN	A	10.10.24
02	PROPOSED LAYOUT	-	23.08.24
03	PROPOSED SECTIONS	-	23.08.24

No.	REVISION DETAILS	DATE
A	RESOURCE CONSENT ISSUE	10.10.2024
-	RESOURCE CONSENT ISSUE	23.08.2024

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SURVEY: SEAM SPATIAL
DRAWN: JMA
CHECKED: -
DATE: OCTOBER 2024
SCALE NTS
CAD FILE: 23028-02 Glen Isla Place Waihi

NOT FOR CONSTRUCTION

JOB TITLE:

COASTAL PROTECTION PROJECT
GLEN ISLA DUNE
WAIHI BEACH

DAVIS COASTAL CONSULTANTS
COASTAL MANAGEMENT AND ENGINEERING
P.O. Box 185
Orewa
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Email: coastal@daviscoastal.co.nz

DRAWING TITLE: **DRAWING SCHEDULE AND LOCATION PLAN**

FILE NO: 23028
SHT NO: 01
REV: A

SERIES: RESOURCE CONSENT

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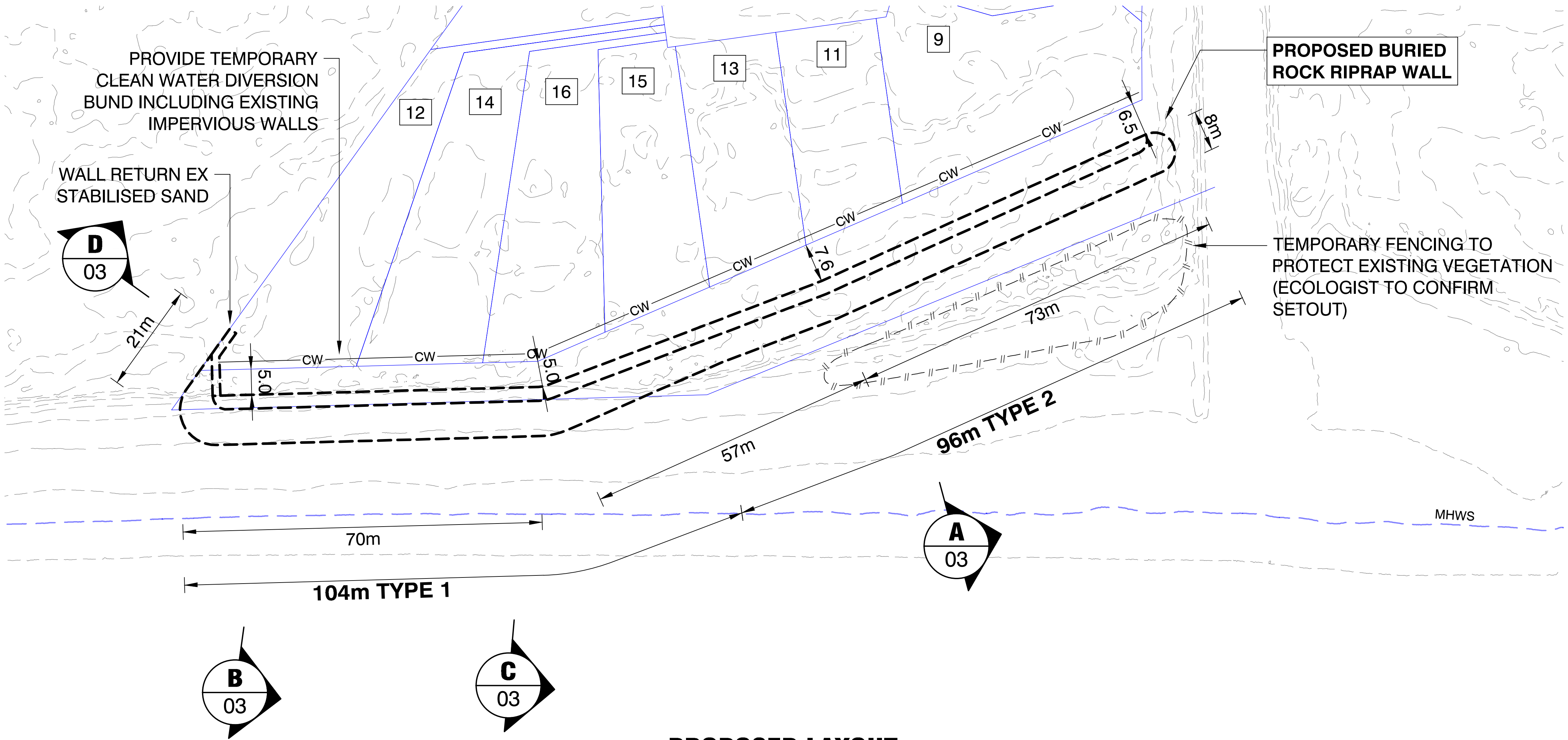

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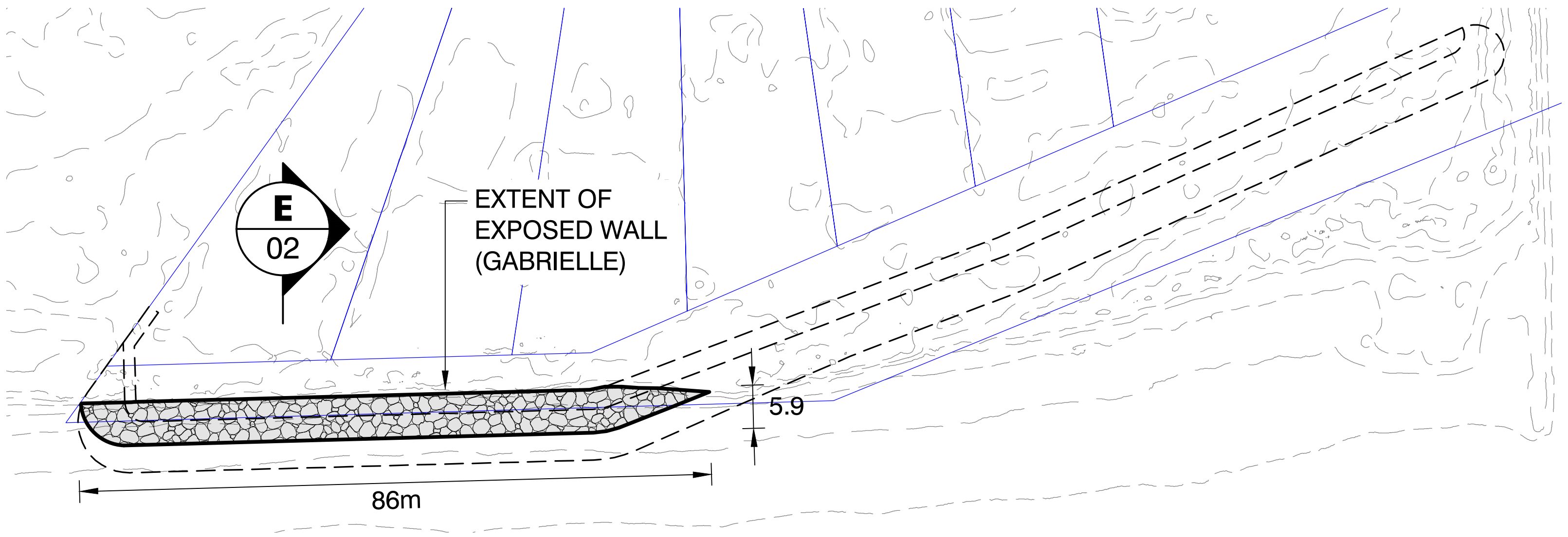

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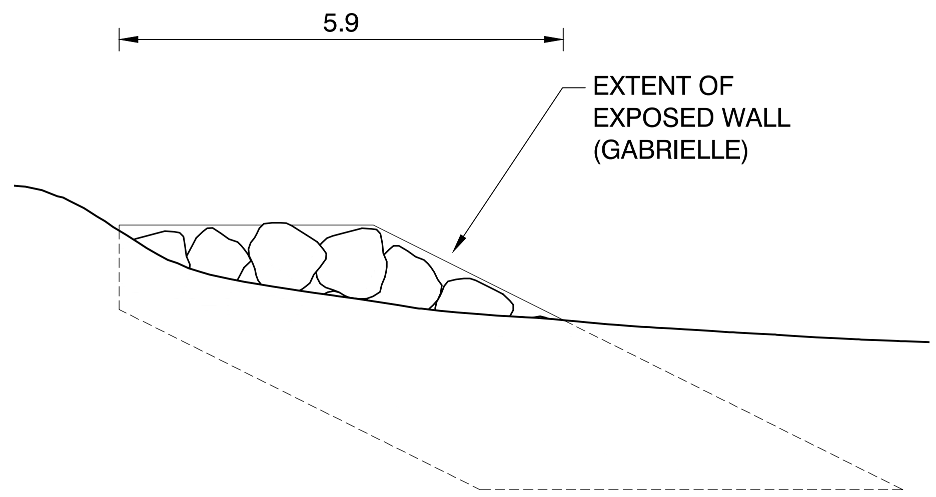

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No.	REVISION DETAILS	DATE
-	RESOURCE CONSENT ISSUE	23.08.2024

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SURVEY: SEAM SPATIAL
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CHECKED: -
DATE: AUGUST 2024
SCALE: VARIES @ A3
CAD FILE: 23028-02 Glen Isla Place Waihi

NOT FOR CONSTRUCTION

JOB TITLE:

COASTAL PROTECTION PROJECT
GLEN ISLA DUNE
WAIHI BEACH

DAVIS COASTAL CONSULTANTS
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P.O. Box 185
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Phone: 09 428 0040
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DRAWING TITLE: PROPOSED LAYOUT

FILE NO: 23028
SHT NO: 02
REV: -

SERIES: RESOURCE CONSENT

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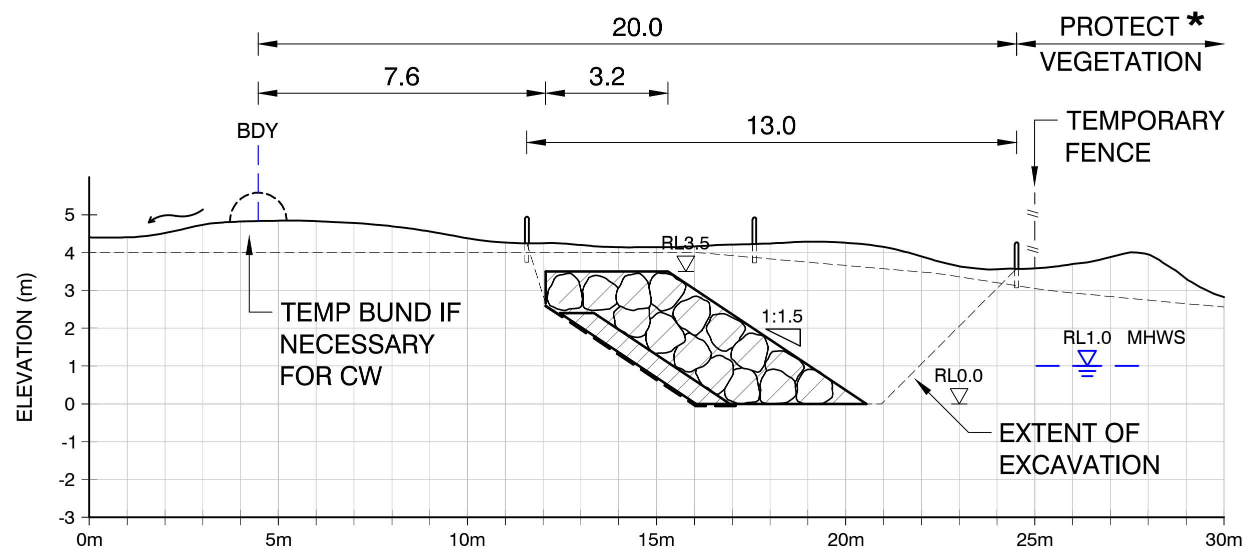

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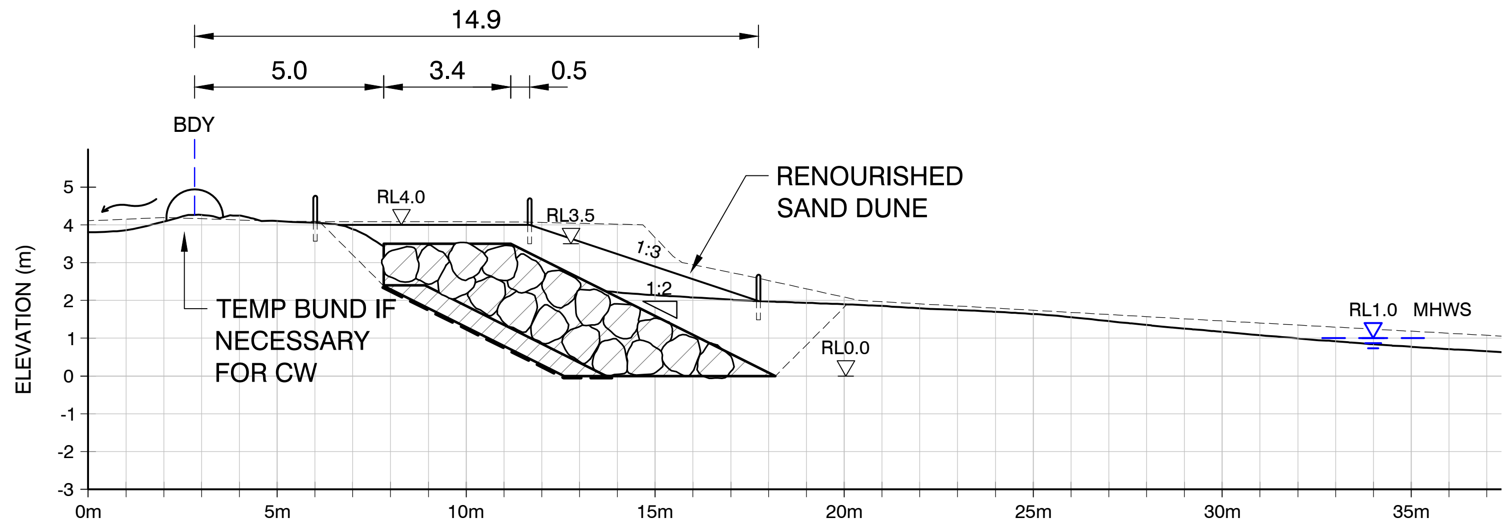

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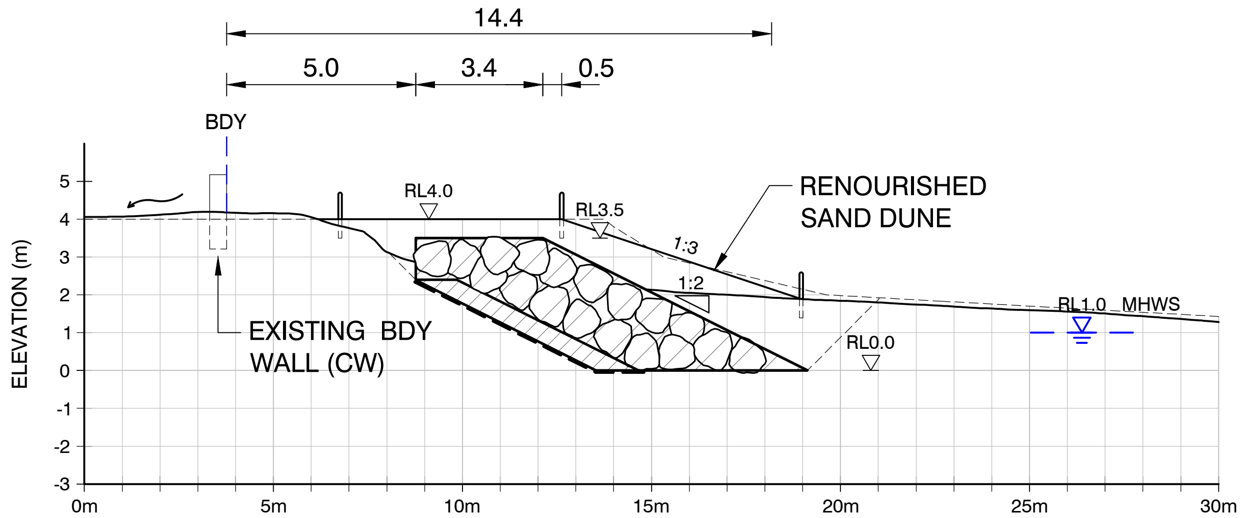

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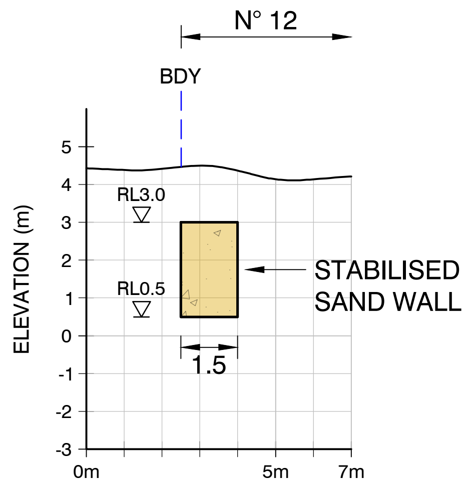

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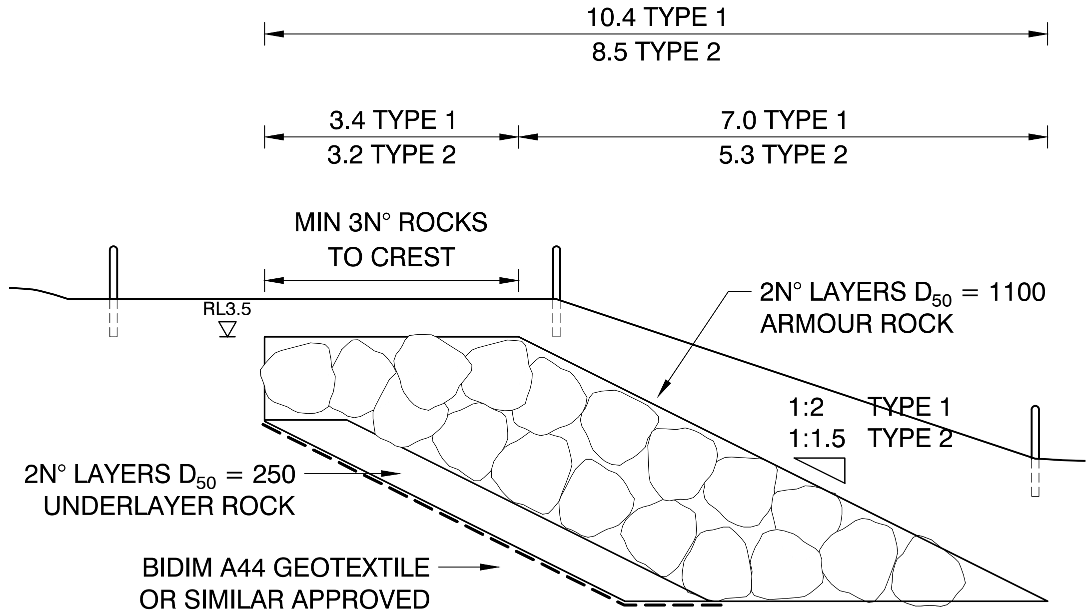

TYPICAL RIPRAP SECTION
SCALE 1:100

NOTES

* AREA OF EXISTING HIGH QUALITY DUNE VEGETATION TO BE DEFINED ON SITE BY ECOLOGIST AND PROTECTED BY TEMPORARY FENCE FOR DURATION OF WORKS

KEY

———	EXISTING SURFACE - 2024
- - - -	HISTORIC SURFACE - 2011

No.	REVISION DETAILS	DATE
-	RESOURCE CONSENT ISSUE	23.08.2024

DESIGN: DAVIS COASTAL CONSULTANTS
SURVEY: SEAM SPATIAL
DRAWN: JMA
CHECKED: -
DATE: AUGUST 2024
SCALE: VARIES @ A3
CAD FILE: 23028-02 Glen Isla Place Waihi

NOT FOR CONSTRUCTION

JOB TITLE:
COASTAL PROTECTION PROJECT
GLEN ISLA DUNE
WAIHI BEACH

DAVIS COASTAL CONSULTANTS
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DRAWING TITLE: PROPOSED SECTIONS
FILE NO: 23028
SHT NO: 03
REV: -
SERIES: RESOURCE CONSENT

Z:\Projects\23028 Glen Isla Place Waihi\Drawings\Dwg\23028-02 Resource Consent\23028-02 Glen Isla Place Waihi

Appendix B
Historic Aerial Analysis

SHORELINE COMPARISON

23028 SHORELINE DETECTION GLEN ISLA PLACE WAIHI

SCALE 1:2000

DATE: 00.00.20

REV: REV

DAVIS COASTAL CONSULTANTS

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2024 SHORELINE

23028 SHOREL[illegible]TECTION GLEN ISLA PLACE WAIHI

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DAVIS COASTAL CONSULTANTS

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1999 SHORELINE

23028 SHORELINE DETECTION GLEN ISLA PLACE WAIHI

SCALE 1:

DATE: 00.00.20

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DAVIS COASTAL CONSULTANTS

1986 SHORELINE

23028 SHORELINE DETECTION GLEN ISLA PLACE WAIHI

SCALE 1:

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DAVIS COASTAL CONSULTANTS

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1982 SHORELINE

23028 SHORELINE DETECTION GLEN ISLA PLACE WAIHI

SCALE 1:

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DAVIS COASTAL CONSULTANTS

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1975 SHORELINE

23028 SHORELINE DETECTION GLEN ISLA PLACE WAIHI

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1963 SHORELINE

23028 SHORELINE DETECTION GLEN ISLA PLACE WAIHI

SCALE 1:

DATE: 00.00.20

REV: REV

DAVIS COASTAL CONSULTANTS

1948 SHORELINE

23028 SHORELINE DETECTION GLEN ISLA PLACE WAIHI

SCALE 1:

DATE: 00.00.20

REV: REV

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Appendix C
MHWS Analysis

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Orewa
Phone 09 428 0040
021 627 193
Email coastal@daviscoastal.co.nz

Our Ref: 23028
Rev. B

28 March 2024

Mr Allan Fraser
Glen Isla Place
Waihi Beach

Dear Mr Fraser,

Memorandum – Location of Mean Highwater Springs
Glen Isla Place, Waihi Beach

1.0 Introduction

In the context of investigating the provision of erosion control measures at Glen Isla Place, Waihi Beach, we have undertaken an analysis of the position of Mean High Water Springs (MHWS) at the site.

Mean High Water Springs (MHWS) is specified as the jurisdictional boundary between "Land" and the "Coastal Marine Area" (sea) in the Resource Management Act (RMA). The District Plan defines the Planning Rules and Consent requirements for Activities landward of this line. The Regional Coastal Plan has the same function seaward of this line.

Definition of this boundary was usefully explained by Professor J. Hannah of University of Otago to the Planning Tribunal (Falkner v Gisborne District Council Decision A82/94) as "*a two-stage process: determining the vertical height of the mean high water springs level, and then projecting that height on to the shore profile to determine the horizontal location of the mean high water springs contour."*

The boundary can be envisaged as a flat plane at the level of MHWS intersecting with the sloping shoreline (Figure1). We have used this two-stage process to determine MHWS at the site.

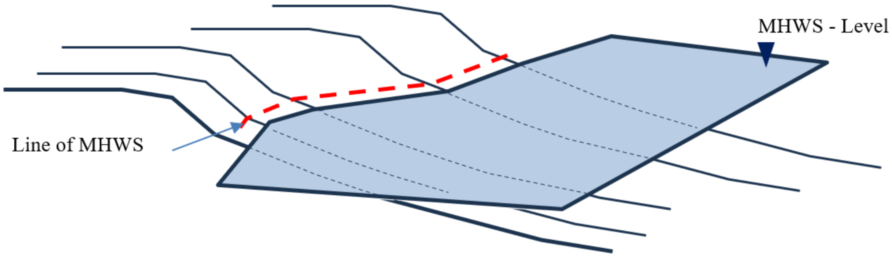


Figure 1 – Depiction of MHWS Calculation

2.0 Vertical Height of MHWS

MHWS is a statistic of the variable level of the high tide. It is typically interpreted as an average water level of spring tide.

There are multiple definitions of MHWS. A traditional maritime definition of MHWS (and MLWS) is provided by LINZ as *"The average of the levels of each pair of successive high waters, and of each pair of low waters, during that period of about 24 hours in each semi-lunation (approximately every 14 days), when the range of the tide is greatest (spring range)."* This definition was expected to be exceeded by approximately the 12% highest tides.

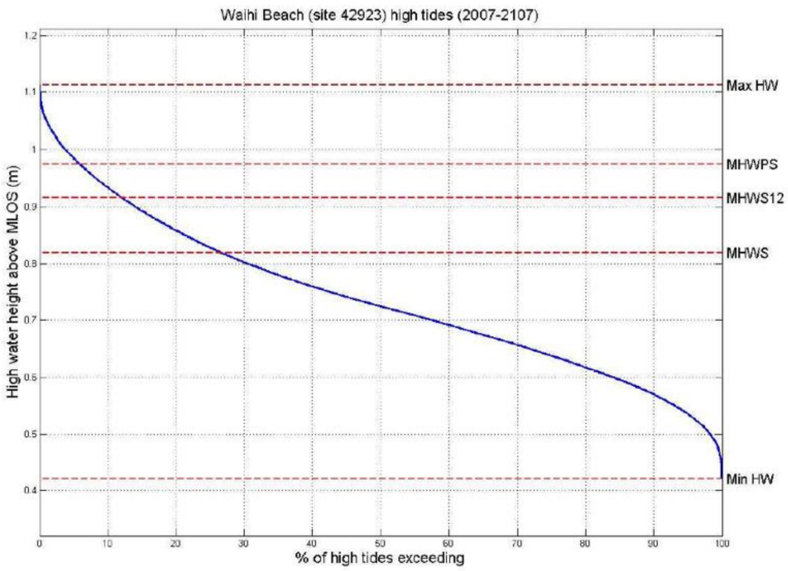
A mathematical algorithm (Equation 1) has often been used to calculate MHWS. It takes the primary harmonic Sun and Moon components of tide and combines the maxima of these to define high tide. In recent years, issues with this producing a representative MHWS in New Zealand, particularly in the upper South Island, led to inclusion of a third (N_2) harmonic component (Equation2). The N_2 component accounts for changes in tidal height due to the variation in distance between the moon and earth resulting from the elliptical lunar orbit. The component is at its maximum when the moon is at its closest point or perigee and the resulting tidal statistic often defined as the Perigean Mean High Water Spring (MHWSP).

$$MHWS = MLOS + A(M_2) + A(S_2) \quad (1)$$

$$MHWSP = MLOS + A(M_2) + A(S_2) + A(N_2) \quad (2)$$

With the advent of more sophisticated computer modelling and longer-term tidal monitoring to provide calibration, tidal exceedance curves have been developed. These curves show the frequency that all high tide levels occur. A figure for MHWS is then defined as level that only a given percentage of tides exceed. Typically, because of the traditional expectation that 12% of tides were greater than MHWS the height exceeded by 12% of tides is provided from the exceedance curve (MHWS12). The height exceeded by only 10% of high tides (MHWS10) is also another relatively common measure. NIWA have been at the forefront of this work in New Zealand and in 2006 provided a report for the Bay of Plenty Regional Council (BOPRC) detailing tidal calculation methods and modelling tidal levels in the Region. They produced an exceedance curve for Waihi Beach (Figure 2).

The exceedance curve for Waihi, reproduced from the 2006 report, shows the maximum tide is RL1.1 and all high tides are between RL 0.4 and RL1.1 The level of the traditionally defined MHWS is approximately RL 0.8 and the MHWSP is approximately RL1.2. (Table 1) These levels are all given relative to the "*Mean Level of the Sea (MLOS)*". They are set out in Table 1 below along with conversion to levels in respect to the Moturiki Vertical Datum 1953 (MVD1953). The Moturiki Datum is typically used in topographical survey data for the area.



High-tide exceedance curve for **Waihi Beach** relative to MLOS (which will vary). Annotation descriptors are given in the text abov

Figure 2 – High Tide Exceedance for Waihi Beach ex NIWA 2006

Statistic	**Level (m)** Relative to MLOS	**Level (m)** Relative to MVD1953
Maximum High tide	1.1	1.2
MHWS10	0.9 *(0.93)*	1.0
MHWS12	0.9 *(0.916)*	1.0
MHWS	0.8	0.9
Minimum High tide	0.4	0.5

Table 1 – Summary of High tide Statistics ex NIWA 2006

Both Case law and published reporting on tidal determination, highlight the need for pragmatism in determining MHWS. There is no correct or definitive value that can be specified. However, there is only a 300mm difference between a traditional value of MHWS and the maximum highest tide expected (excluding sea level rise). Between all the MHWS statistics quoted in the NIWA report there is less than a 200mm difference. This difference is largely theoretical and relevant primarily to the mathematical model.

On an open coast such as Waihi, tidal height is overlain by an active wave environment and the tide acts on a dynamic changing beach. In this context, the difference in level between the various definitions becomes less significant.

For the purposes of defining MHWS for this matter we have adopted the value adopted by NIWA in their specialist report to BOPRC on this matter, which is exceeded by only approximately 10 % of tides. The adopted value by the NIWA report to one decimal place is RL1.0 MVD1953.

MHWS = RL1.0 MVD1953

This value has the benefit of being a contour that is readily and often plotted in a number of historic and contemporary studies and plans. It therefore provides a practicable and useable value. The contours on some topographical mapping, including the GIS mapping used by the BOPRC website, expresses contours and height in NZVD2016. Table 2 shows the offset of 0.3 between the data. Where the GIS shows a RL1.0 contour based on NZVD2016, the line of MHWS will be 0.3m above this.

	MVD1953	NZVD2016
MHWS	1.0	1.3
1.0 Contour on WBOPRC GIS	0.7	1.0

Table 2 – Comparison of RL1.0 in MVD and NZVD

3.0 Location of MHWS Line at Glen Isla Place

In order to locate the line of MHWS on site we must determine where the beach is at the level of RL1.0 or the location of the RL1.0 contour. This RL1.0 contour is the line MHWS.

However, the level of the beach varies due to many drivers on differing times scales. This includes diurnal tidal changes, seasonal and storm event changes as well as longer term changes from longer weather patterns. Changing weather patterns can be associated with El Nino/ La Nina cycles over many years and pan-decadal patterns have also been defined. In combination with these fluctuations, changes in the beach drivers such as a change in sediment supply, change in local control points (river outlets, headlands), sea level rise or man-made effects can also create changes in the beach profile.

As previously mentioned, there is an accepted need for pragmatism in determining MHWS. The location chosen may depend on the accuracy required for the task at hand and practicable measures such as site features which provide some consistency in determining the jurisdictional boundary.

For the purposes of determining the jurisdictional planning boundary at this site, we have investigated the range of locations that the line of MHWS has been in over time and related this to the proposed location of any potential works. The over-arching philosophy is to maintain our works landward of any reasonable depiction of MHWS so that the work is firmly on Land and not within the Coastal Marine Area.

Waihi Beach has reasonable monitoring data for approximately 20 years, and a limited amount of older data going back over 30 years. This monitoring tends to show a generally stable beach, but this may be influenced by human interventions.

There are long term monitoring sites (Figure 3), CS49 and CS50, 400-600m each side of the site, that have 37-year and 34-year records, respectively. A set of three profiles at the Glen Isla site were monitored for 6 years between 2012 and 2018. This is understood to have been some short-term monitoring in relation to the drainage outlet of Three Mile Creek.

The data is mapped as beach cross sections or profiles, as Figure 4 and Attachment 1. From this record of profiles an envelope of profiles can be determined. This envelope provides a cross-section area of within which the beach profile has fluctuated.

Figure 3: Monitoring Locations

A useful tool in determining the location of MHWS over time is to map the "excursion" of the RL1.0m contour over time. This maps the horizontal distance from a fixed monitoring point to the RL1.0 contour. As more sand builds up on the beach and the beach builds seaward, the RL1.0 contour moves seaward. In times of storm erosion and beach retreat the beach lowers and the RL1.0 contour moves closer to the shore, landward.

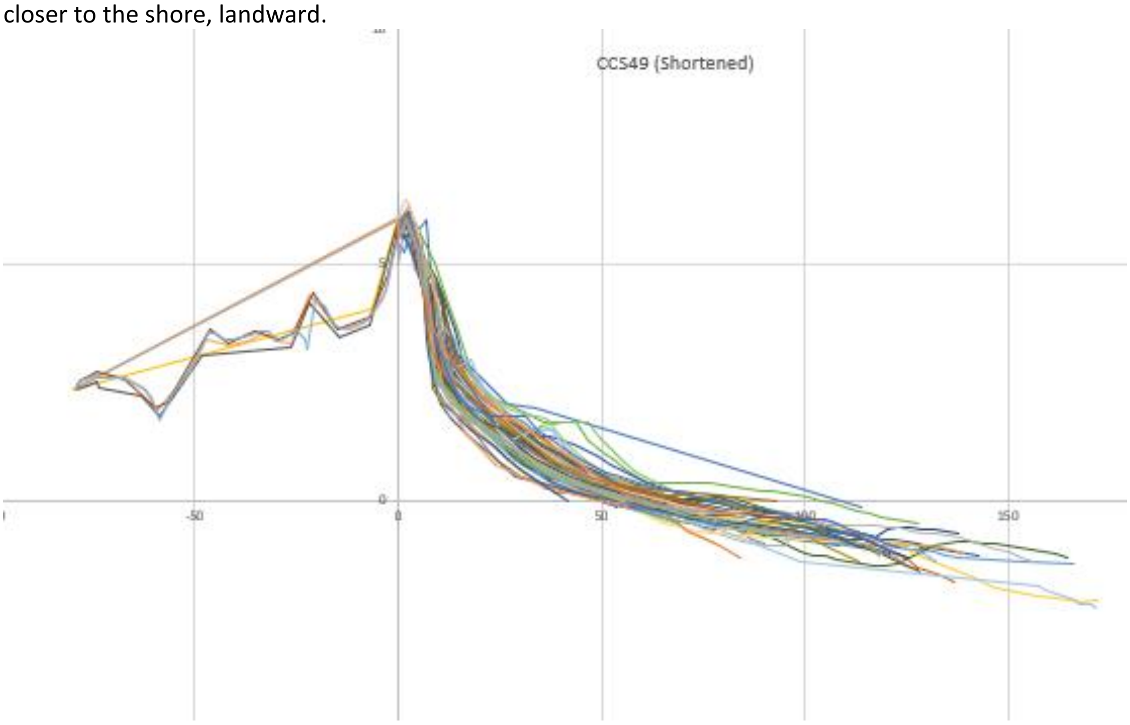


Figure 4: CS49 Profile Data

We mapped Excursions for all five profiles (Figures 5 and 6 and Attachment 1). As would be expected, there was greater variability and a greater range of excursion of the MHWS mark on the profiles that had been monitored over a longer time frame when compared to the profiles monitored for only six years. In order to determine the applicability of the wider range of movement to our site, which was adjacent to profiles only monitored over a short timeframe, all profiles were compared over similar 6-year timeframe to compare fluctuations at the sites.

Over the similar six-year period (2012-2018) the long-term monitoring sites (CS49 and CS50) behaved similarly to S1, S2 and S3. The range of excursion was 17m +/-1m at all profiles. Table 3 provides the maximum and minimum excursion information for the MHWS contour. Over the 6-year time period the minimum excursion was within 1m of that monitored over the 30year timeframe. The majority of the larger range of excursion in the longer record depicts a higher level of sand on the beach and a more seaward line of MHWS.

It was therefore extrapolated that S1-S3 would behave similarly to CS49 and CS50 over longer time frames and it was reasonable to assume the range of excursion documented at CS49 and CS50 would have been present at the site over that time. As the minimum excursion represents the" most eroded" of landward location of the beach although the 30-year period minimum was within 1m of the 6-year minimum, it was assumed that the long-term excursion was 2m further landward than the six-year figures.

This width of excursion was then mapped in Plan onto the beach seaward of Glen Isla as the area in which MHWS has been located over the last 30-35 years. (Figure 7 Attachment 2)

It is assumed that work landward of this area, and so landward of MHWS for the last 30 years is therefore outside the Coastal Marine Area and under the Jurisdiction of the District Plan and Terrestrial Consent Authority, Western BOPDC.

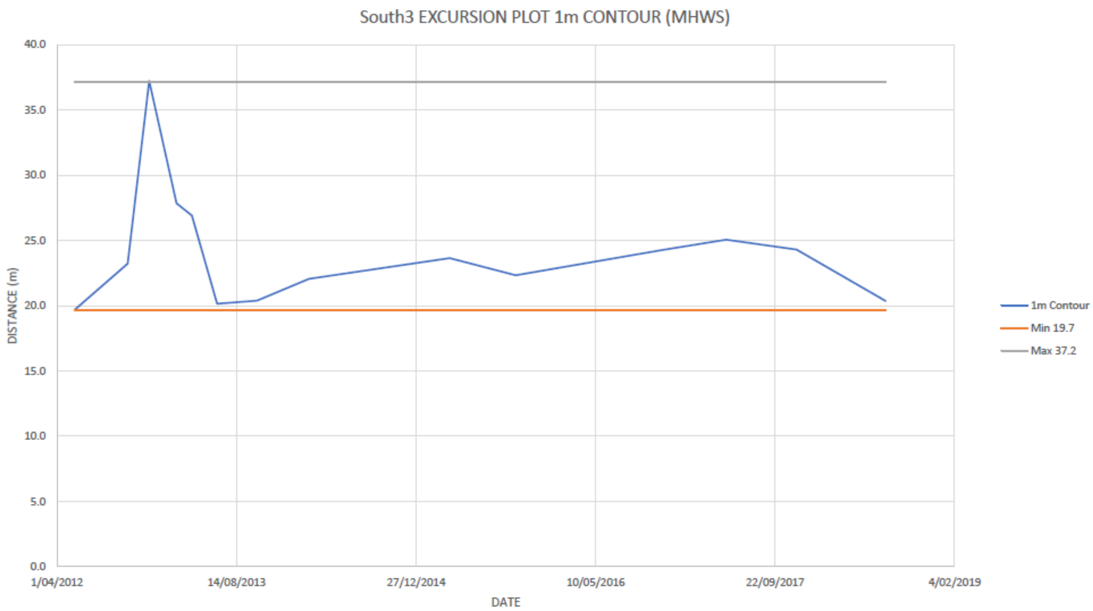


Figure 5 – Excursion of RL1.0m contour (MHWS) 2012-2019 Glen Isla Place

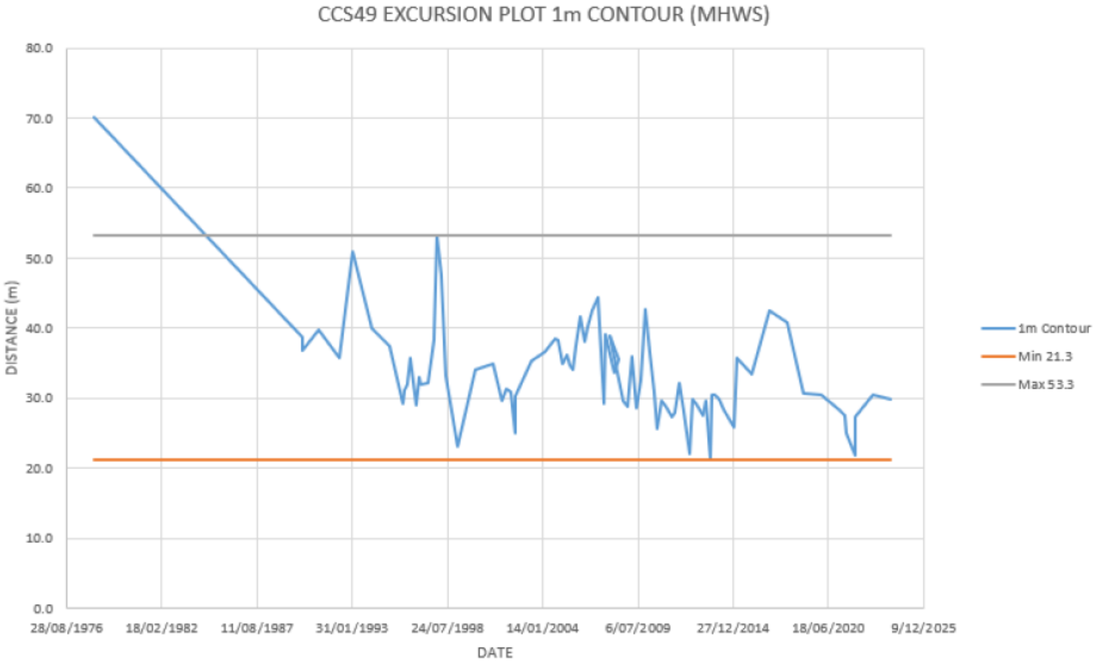


Figure 6 – Excursion of RL1.0m contour (MHWS) 1987-2024 CS49

MONITORING PROFILE EXCURSION RANGE - FULL PERIOD							
Profile	**Duration**			**Excursion**		**Range**
			years	min	max	m
CS49	1987 -	2024	37	21	53	32
CS50	1990 -	2024	34	47	71	24
N	2012 -	2018	6	15	33	17
S1	2012 -	2018	6	46	62	16
S2	2012 -	2018	6	25	43	18
S3	2012 -	2018	6	20	37	17

MONITORING PROFILE EXCURSION RANGE- 2012-2018						
Profile	**Duration**			**Excursion**		**Range**
			years	min	max	m
CS49	2012 -	2018	6	21	33	17
CS50	2012 -	2018	6	48	67	19
N	2012 -	2018	6	15	33	17
S1	2012 -	2018	6	46	62	16
S2	2012 -	2018	6	25	43	18
S3	2012 -	2018	6	20	37	17

Table 3 – Excursion Range of MHWS

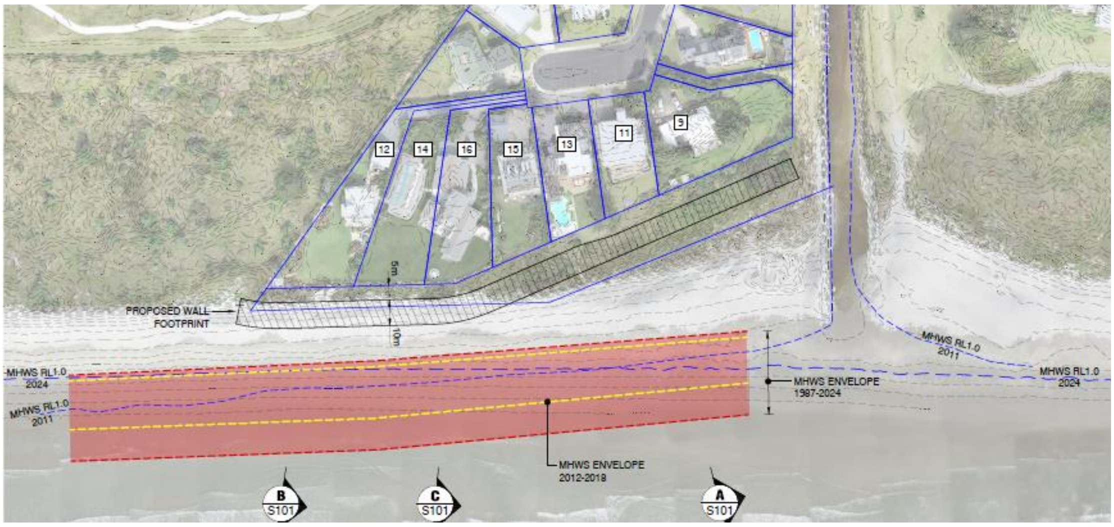


Figure 7 – Plan Showing Historic Range of MHWS 30+ years

4.0 Sea Level Rise

The location of MHWS is likely to migrate landward with rising levels due to Climate Change. Accepted theory is that as the water level increases the average location of the shoreline is likely to also migrate shoreward.

This is at odds with the longer-term processes such that estuaries tend to infill and barrier bar beaches tend to migrate seaward over long-term sea-level rise. Again, the quantum of sea level rise is relevant. Within a typical design time frame (50Y) sea-level rise is likely to be in the order of 0.5m and shoreward translation of 5m for a 1:10 Beach. This will be insufficient to make the proposed works within the CMA. We therefore consider that the structure is within an area of District Council Jurisdiction for construction of any erosion protection.

5.0 Conclusion

The location of MHWS has been considered on the site in order to determine Consent requirements of any proposal to address erosion issues for the properties on Glen Ilsa Place, Waihi. A level of pragmatism and judgement is required when determining the location of MHWS.

In this case, a detailed study and modelling of the height of MHWS has been undertaken by NIWA in 2006 and adopted by the Regional Council. The height of MHWS at Waihi Beach provided by that report and adopted for this exercise is RL1.0 (MVD53).

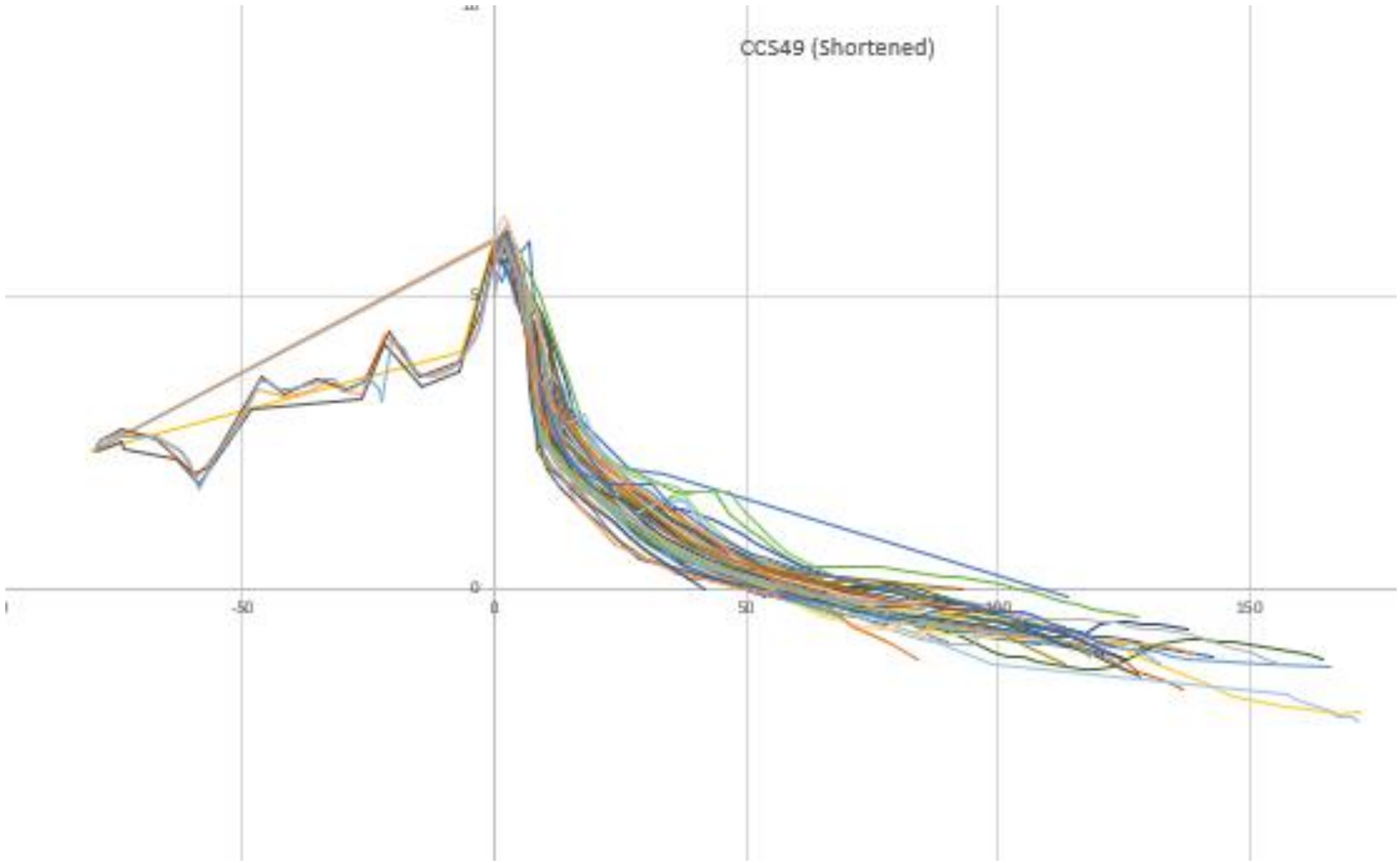
We have utilised the monitoring data of beach level over a period of over 30 years and plotted where this line of MHWS would have been due to beach fluctuation over that time. A median or mean location would seem a reasonable representation of MHWS at the site. However, we have adopted the most landward position that MHWS has been within that 30 year+ period and ensured all proposed work is outside this line.

Yours sincerely,

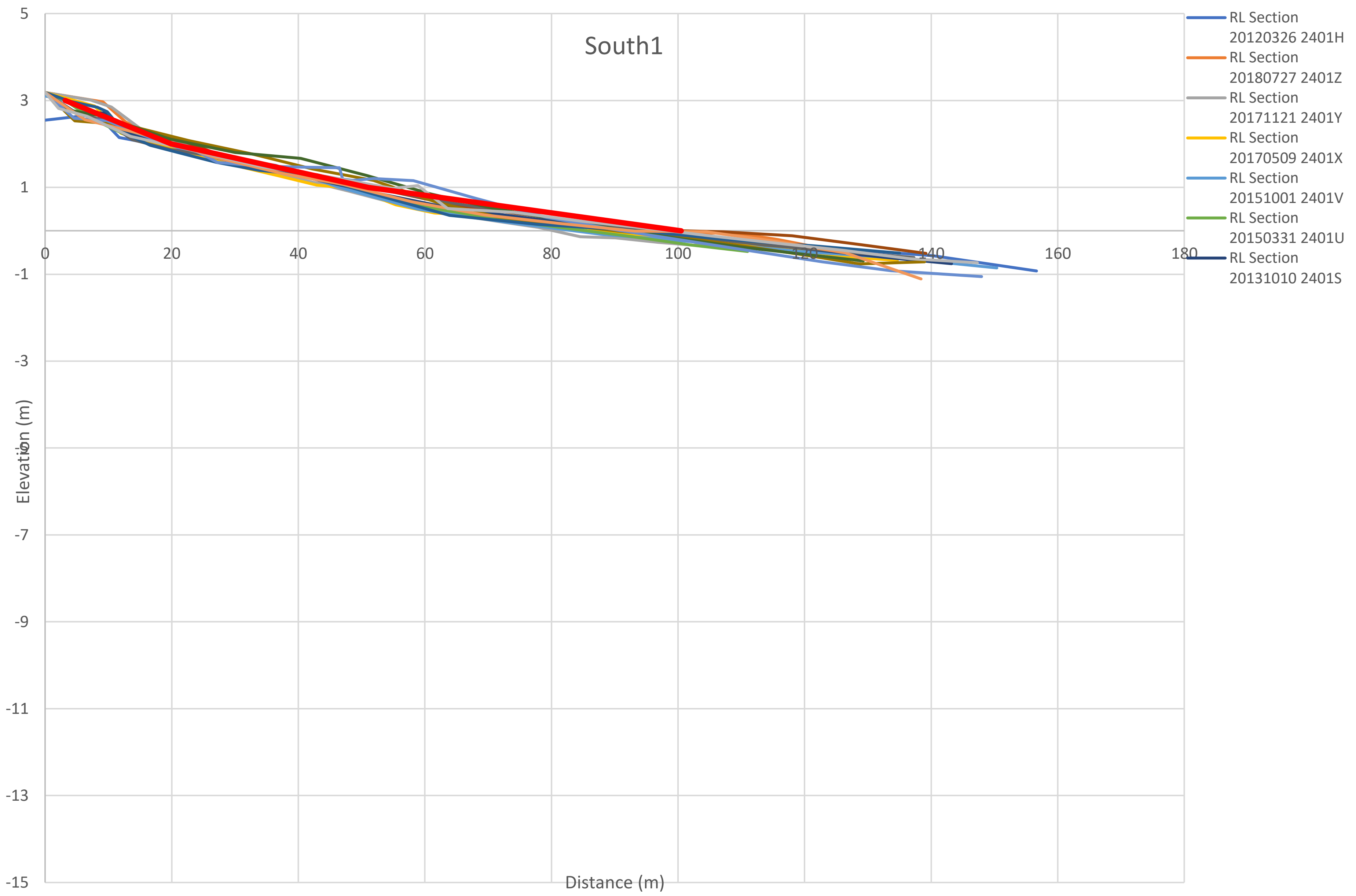
Craig Davis
BE, CPEng, IntPE(NZ), CMENZ

ATTACHMENT A

Monitoring Profiles and Excursion Data Plots



OCS49 (Shortened)
10
5
0
-50
0
50
100
150


South1
Elevation (m)
Distance (m)
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3
1
-1
-3
-7
-9
-11
-13
-15
0
20
40
60
80
100
120
140
160
180
RL Section 20120326 2401H
RL Section 20180727 2401Z
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RL Section 20170509 2401X
RL Section 20151001 2401V
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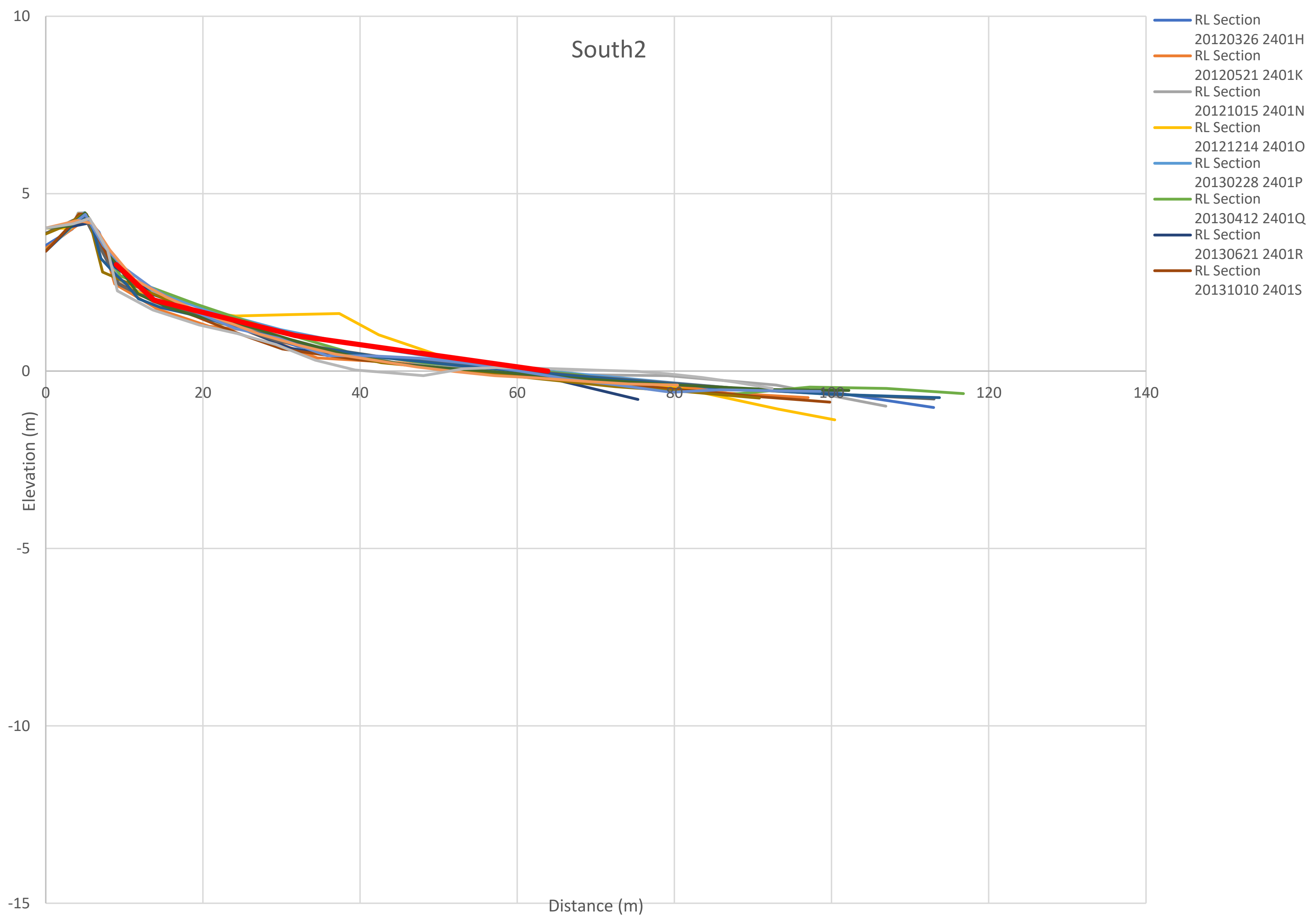
South2
Elevation (m)
Distance (m)
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5
0
-5
-10
-15
0
20
40
60
80
100
120
140
RL Section 20120326 2401H
RL Section 20120521 2401K
RL Section 20121015 2401N
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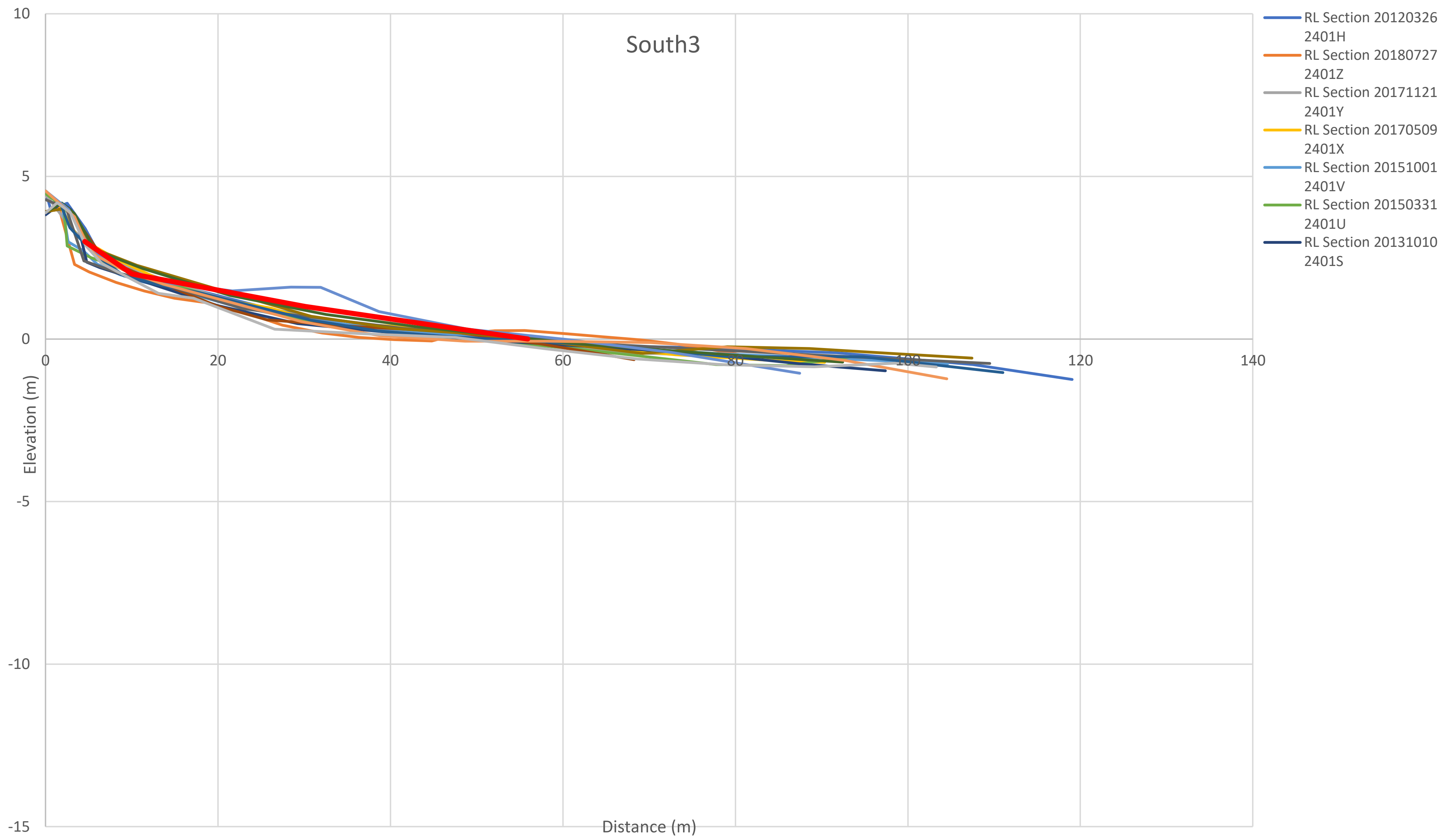
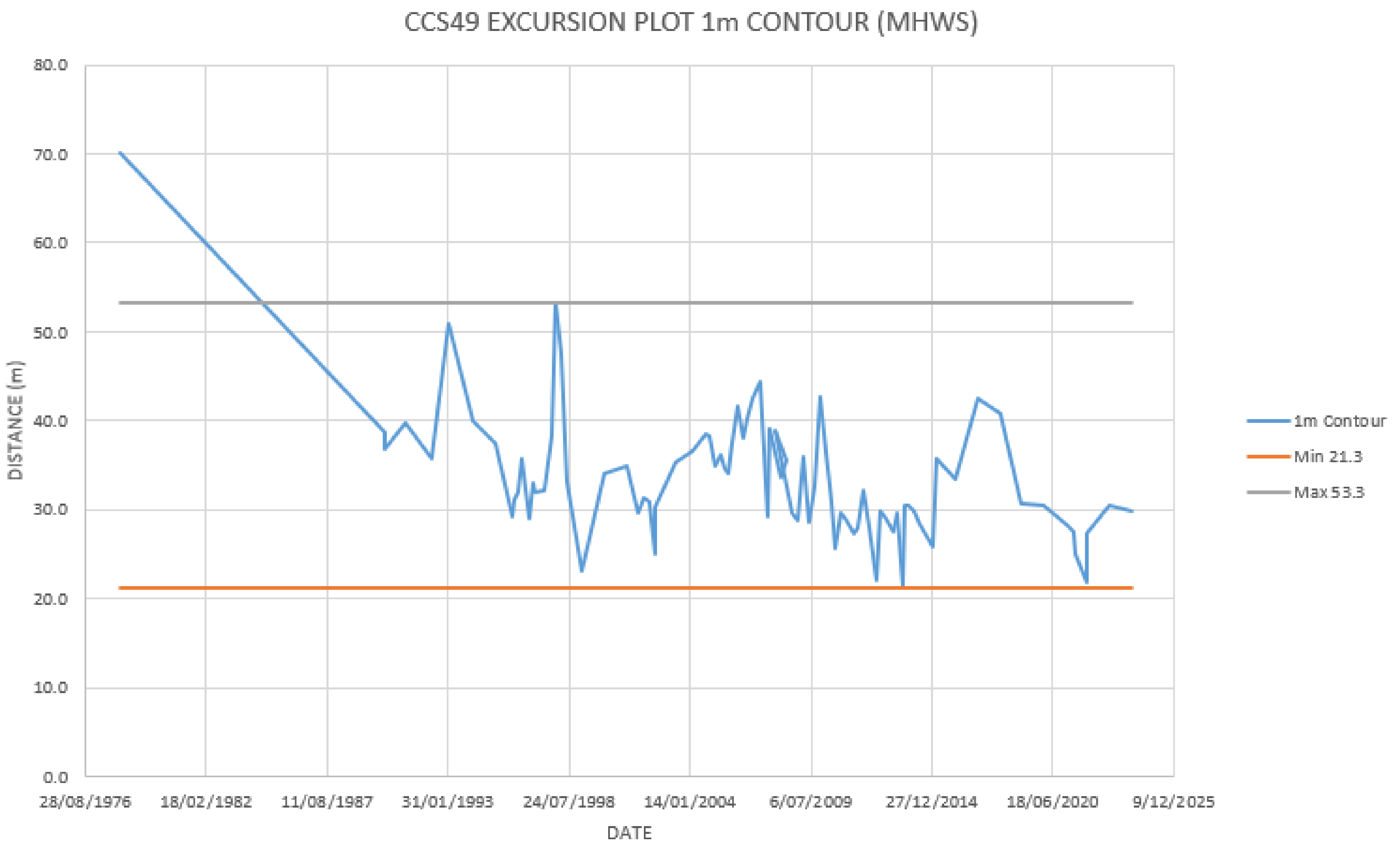
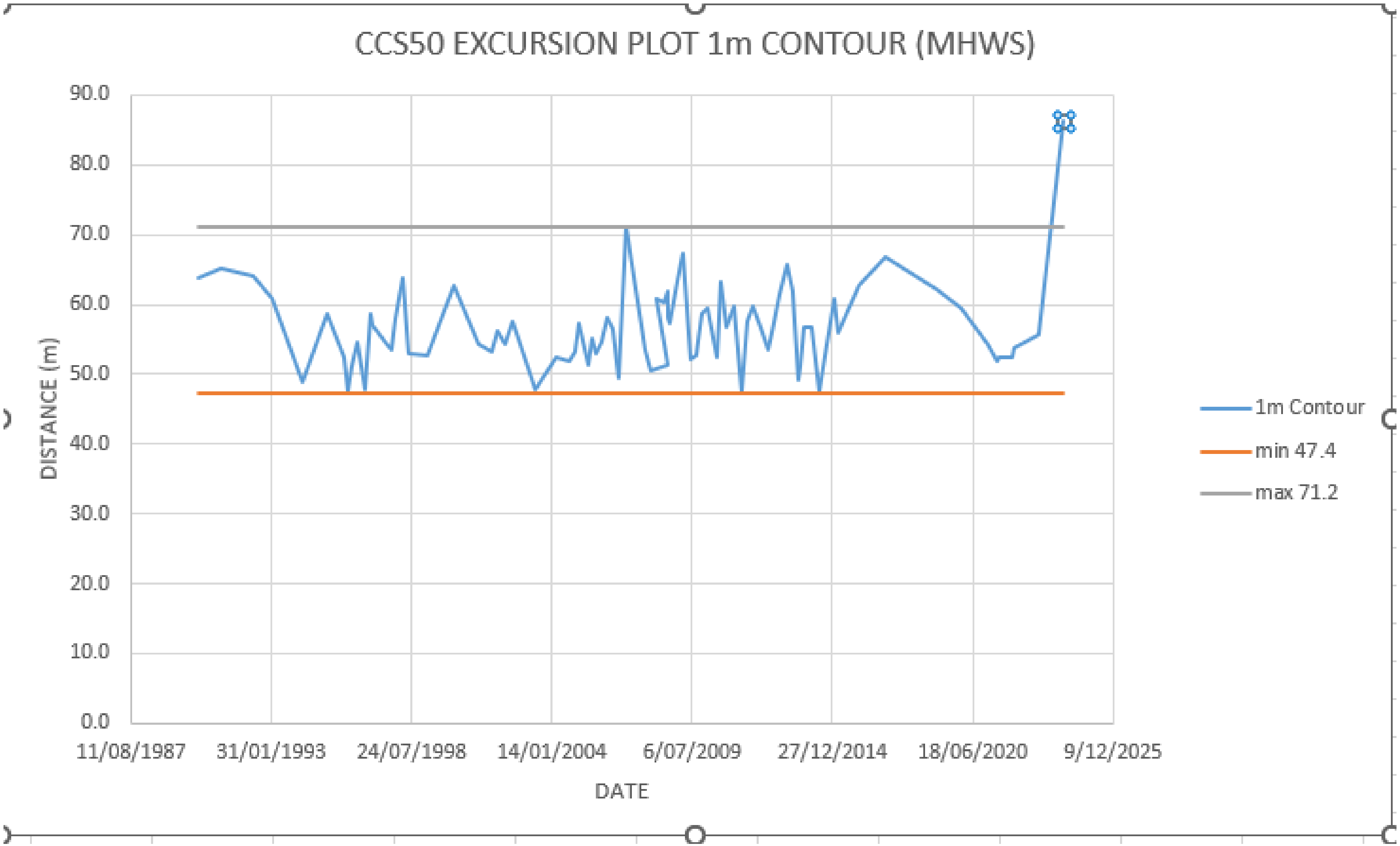
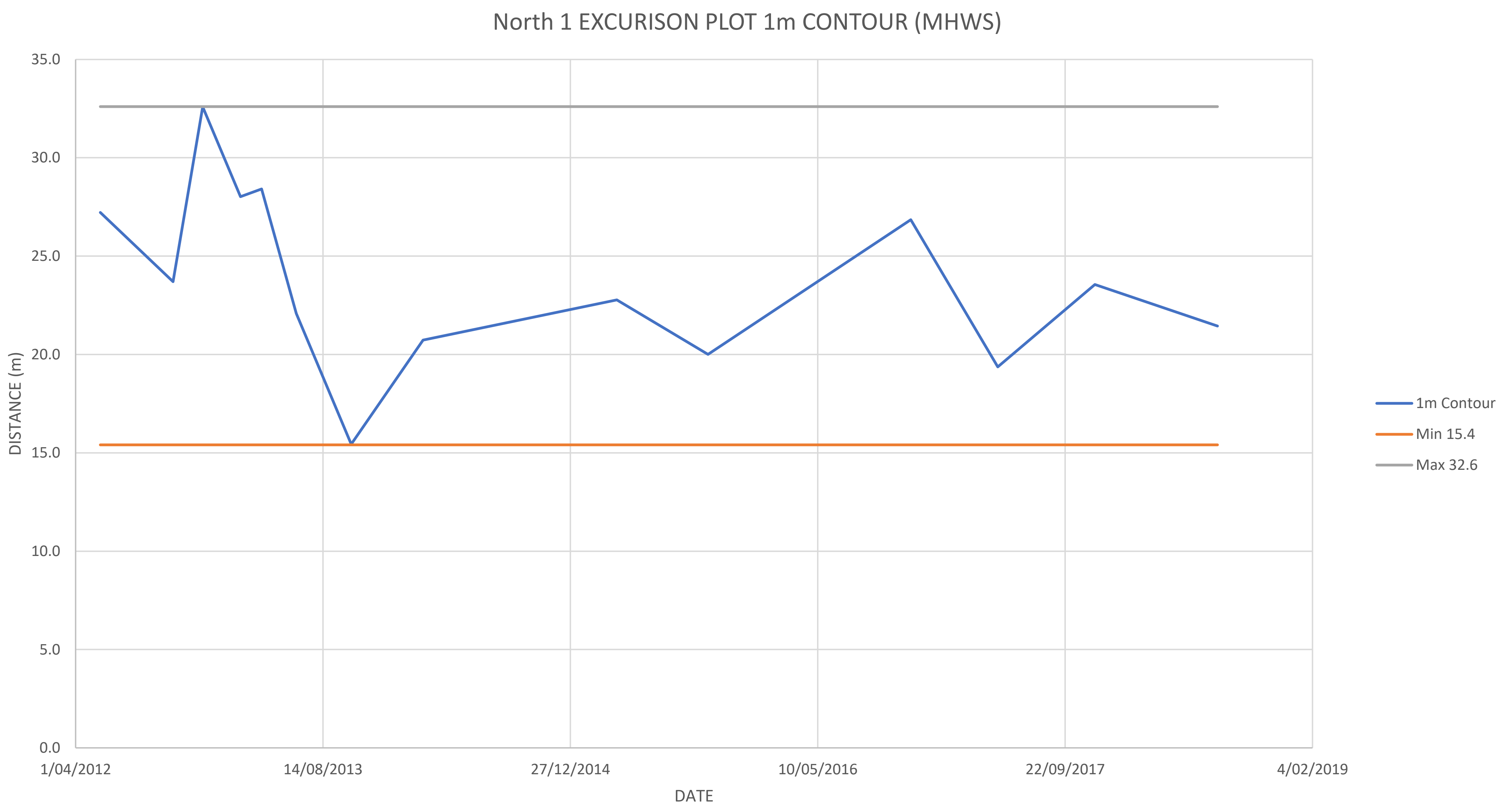
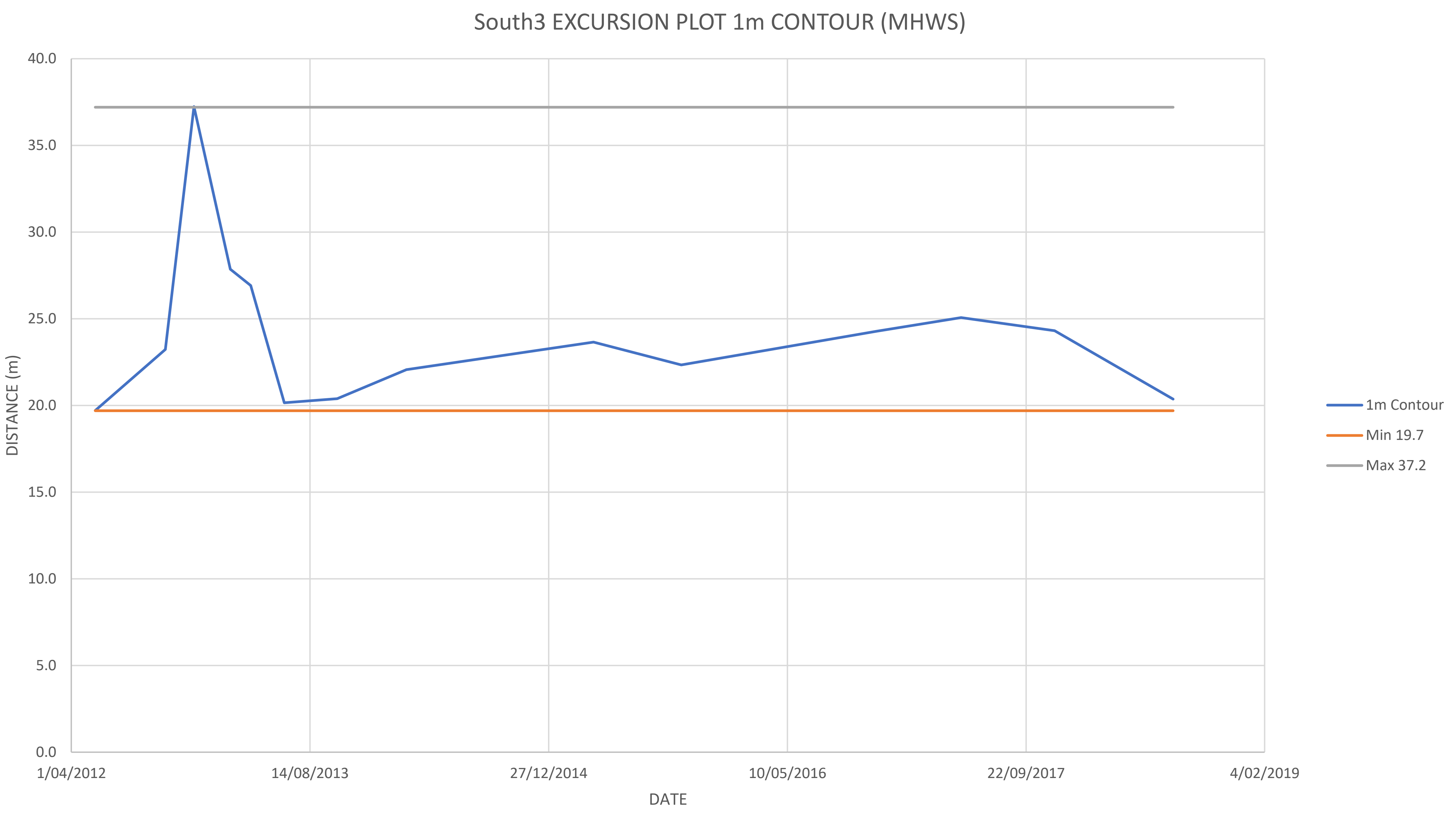

South3
10
5
0
-5
-10
-15
Elevation (m)
0
20
40
60
80
100
120
140
Distance (m)
RL Section 20120326 2401H
RL Section 20180727 2401Z
RL Section 20171121 2401Y
RL Section 20170509 2401X
RL Section 20151001 2401V
RL Section 20150331 2401U
RL Section 20131010 2401S


CCS49 EXCURSION PLOT 1m CONTOUR (MHWS)
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
DISTANCE (m)
28/08/1976
18/02/1982
11/08/1987
31/01/1993
24/07/1998
14/01/2004
6/07/2009
27/12/2014
18/06/2020
9/12/2025
DATE
1m Contour
Min 21.3
Max 53.3



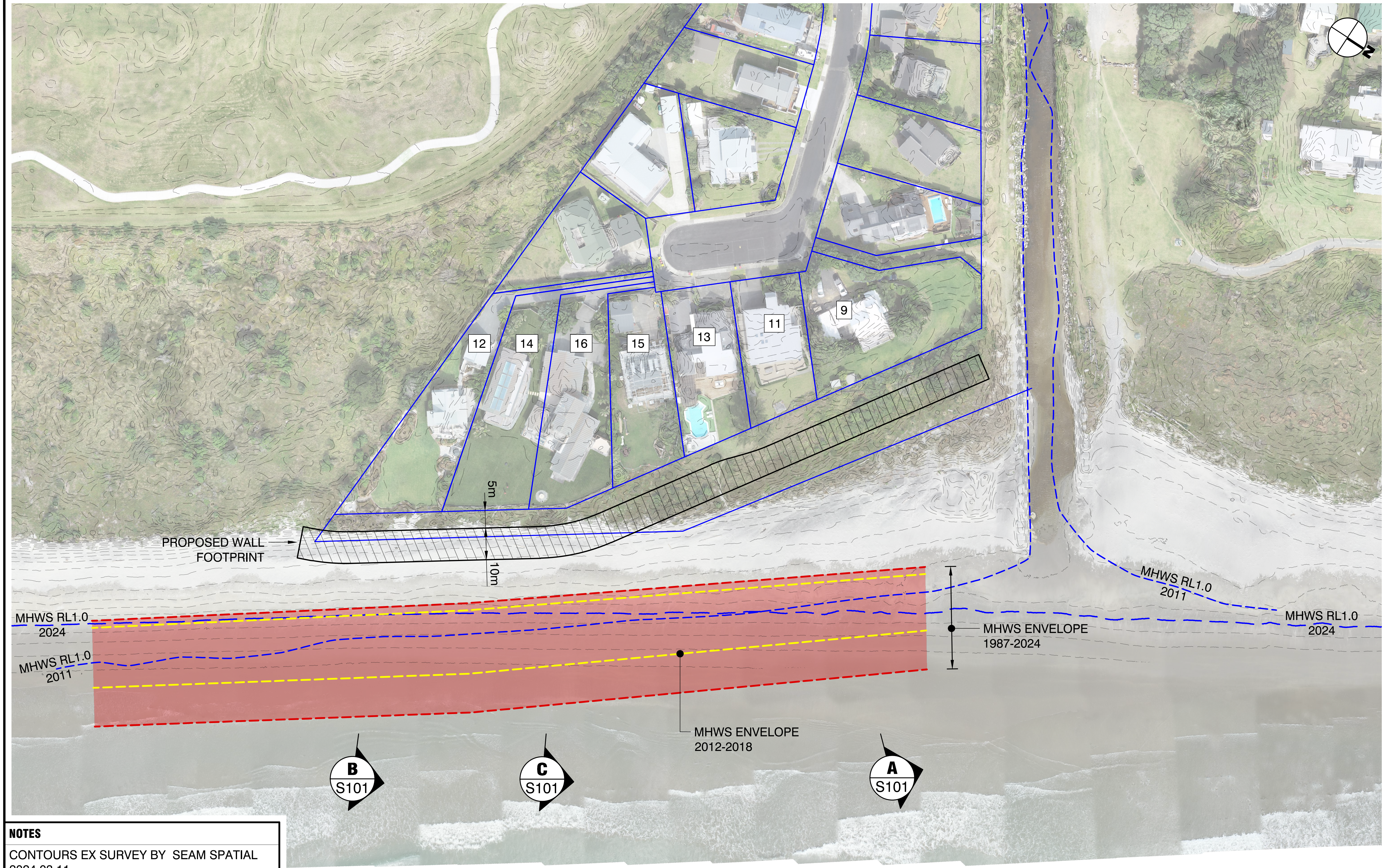
CCS50 EXCURSION PLOT 1m CONTOUR (MHWS)
DISTANCE (m)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
11/08/1987
31/01/1993
24/07/1998
14/01/2004
6/07/2009
27/12/2014
18/06/2020
9/12/2025
DATE
1m Contour
min 47.4
max 71.2


North 1 EXCURISON PLOT 1m CONTOUR (MHWS)
DISTANCE (m)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
4/02/2019
DATE
1m Contour
Min 15.4
Max 32.6


South3 EXCURSION PLOT 1m CONTOUR (MHWS)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
DISTANCE (m)
1/04/2012
14/08/2013
27/12/2014
10/05/2016
22/09/2017
4/02/2019
DATE
1m Contour
Min 19.7
Max 37.2

ATTACHMENT B

Site Plan Showing Historic Extent of MHWS over 30+ years



NOTES

CONTOURS EX SURVEY BY SEAM SPATIAL 2024.03.11

No.	REVISION DETAILS	DATE
-	PRELIMINARY ISSUE	03.04.2024

DESIGN: DAVIS COASTAL CONSULTANTS
SURVEY: SEAM SPATIAL
DRAWN: JMA
CHECKED: -
DATE: APRIL 2024
SCALE 1:1000 @ A3
CAD FILE: 23028-01 Glen Isla Place Waihi

NOT FOR CONSTRUCTION

JOB TITLE:

GLEN ISLA EROSION PROTECTION OPTIONS

DAVIS COASTAL CONSULTANTS

COASTAL MANAGEMENT AND ENGINEERING
P.O. Box 185
Orewa

Phone: 09 428 0040
Mobile: 021 627 193
Email: coastal@daviscoastal.co.nz

DRAWING TITLE:
PROPOSED WALL LAYOUT

FILE NO: 23028
SHT NO: S100
REV: -

SERIES:
PRELIMINARY

Z:\Projects\23028 Glen Isla Place Waihi\Drawings\Dwg\23028-01 Preliminary\23028-01 Glen Isla Place Waihi