Coastal Geomorphological Change at Opunake Bay, Middleton Bay and in the Vicinity of the Patea Rivermouth

Based on a report to the South Taranaki District Council

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EXECUTIVE SUMMARY

This report was originally prepared for the South Taranaki District Council and entitled "Measurement-Based Monitoring and Compliance Reporting" – this being required as part of resource consenting by the Taranaki Regional Council. While the consents were existing, the measurement-based regime was being applied for the first time. Consequently, this report contains considerable background materials and analysis, including any previous surveys, to provide context and an initial indication of underlying geomorphological change. From a scientific perspective the renaming better describes the content; however, the report is otherwise unchanged.

The report summarises coastal monitoring carried out by the South Taranaki District Council between November 2021 to February 2022 using a new measurement-based programme. This programme is now required by the Taranaki Regional Council (the consenting agency) in the vicinity of structures considered to have the potential to cause environmental change. Structures subject to "measurement-based monitoring" are referred to as "major structures". Monitoring frequency varies depending on the structure involved, its environmental setting and whether shorter or longer-term change is bring assessed (see Table 1.2).

The following four specialist monitoring organisations were commissioned: Taylor Patrick Limited (TPL) for ground surveying (Appendix A); Landpro Ltd for aerial surveying (report Appendix B); Fugro Ltd for hydrographic surveying (report Appendix C), and BECA for structure-condition inspection (report Appendix D). The monitoring programme was designed, coordinated and reported by Coastal Systems Ltd (CSL).

As the present document is the first to report on this new system, it is compiled as a "base-line report" in that it also incorporates comparative historical data and discusses consequentially identified environmental change and process at the various sites.

At Middleton Bay, profile change shows the northwestern end of the bay is stable but the central area has experienced erosion, this could be related to recent structure (revetment) modifications.

In Ōpunakē Bay, profile analysis shows shoreline advance is now occurring at the southern end of the bay - this appears to be related to non-operation of the power station tail race. Should this behaviour persist, it will detrimentally affect drainage in the recreation area to the rear.

On the Patea open coast, profile analysis shows an extended period of foredune erosion along the northern beach (from 2010-11) appears to have ceased. Bathymetric change indicate that some of the eroded sediment may lie in a large shoal off the South Mole. This shoal may be temporarily reducing the sediment supply to the southern beach where profile analysis shows shoreline erosion is occurring.

Within the Patea inlet, bathymetric change (Figure 4.14) shows channel deepening (2 m) has occurred adjacent to the raised (2 m) river training wall, and also deepening has occurred along the adjacent South Mole. This appears to have resulted in greater wave penetration into the inlet which caused bank erosion immediately upstream of the raised training wall with bank protection subsequently being carried out. In addition, deposition has occurred along the village side of the channel from Manu Bay, along the wave guide wall and the Carlyle Bay frontage where infill and dune establishment and growth have occurred. This process may also result from the increase in wave penetration.

Change from ground, aerial and bathymetric surveys suggest that the Patea boat ramp extension, launching jetty and adjacent bank protection correspond with shoreline retreat immediately downstream; this has made the natural gas pipeline more vulnerable to erosion and also further reduced the river frontage of Carlyle Bay.

BECA's coastal structure condition survey stressed the urgent need for protection works on the mole ends and investigation of concrete block misorientation along the South Mole. We (CSL) provided photographic evidence (Figure 5.1) that the rotated blocks have been stable since at least 2005, but given the channel deepening in this area we recommend more frequent riverbed and mole surface monitoring be carried out along the raised training wall and the rotated block section.

In addition, BECA addressed the state of the wave guide wall and recommended that the landward rock section be raised to protect the public jetty (at its upstream end), and that the delipidated wooden pile section (at the downstream end) be removed. We (CSL) believe the fate of the training wall requires further consideration. Given the loss of what was a much-valued recreational beach in Carlyle Bay (Figure 4.2), at least in part due to the environmental effects of various structures within the inlet, maximising the recreational potential of Manu Bay would be desirable. Careful "reinstatement" of the wave guide wall could result in a safer bathing area and create a permanent mid to high tide beach compared with the present lower tide and somewhat hazardous beach. The Manu seawall (boulder revetment) would be buried becoming a "backstop seawall" operational only at times of severe sediment depletion. This initiative would also go some way to addressing possible impacts of climate change which could further degrade the present utility. CSL recommends structure design for recreational optimisation be carried out before any decision is made regarding the removal or raising of the existing wave guide wall.

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INTRODUCTION

This report summarises recent (November 2021 to February 2022) monitoring results for a new measurement-based programme for South Taranaki District Council (STDC) structures. This approach is now required by the consenting agency, the Taranaki Regional Council (TRC)) for structures considered have the potential to cause environmental change. Structures subject to “measurement-based monitoring” are referred to as “major structures”. In addition to consent compliance monitoring, additional environmental monitoring and asset monitoring by the STDC are also covered. The following four specialist monitoring organisations were commissioned; Taylor Patrick Limited (TPL) for ground surveying (Appendix A); Landpro Ltd for aerial surveying (report Appendix B); Fugro Ltd for hydrographic surveying (report Appendix C), and BECA for structure-condition inspection (report Appendix D). The monitoring programme was designed, coordinated and reported on (this document) by Coastal Systems Ltd (CSL). As the present document is the first to report on this new system, it is compiled as a “base-line report” in that it also incorporates comparative historical data and discusses environmental change and process at the various sites.

The following introductory section backgrounds types of coastal monitoring and notes the STDC’s past work in this regard, backgrounds the TRC’s new approach to monitoring consents, and describes monitoring types, frequencies and output by the different surveying organisations in South Taranaki.

1.1 Monitoring background

Territorial Authorities carry out coastal monitoring for a range of objectives such as:

- Acquiring baseline (or control) data for use in asset design, hazard assessment or environmental management (proactive environmental monitoring);
- Helping to understand and mitigate an unexpected problem situation that has arisen (reactive environmental monitoring). However, for best results baseline data is also required;
- Resource consent compliance, in particular to identify/define coastal structure/activity effects on the environment (adjacent shorelines in particular), or
- Asset management – to identify maintenance requirements.

Coastal monitoring methods typically involve visual inspection or measurement-based surveying (2D profiling, 3D topographic survey or bathymetric survey).

In the past, South Taranaki District Council’s (STDC) coastal structures have been subject to varying levels of baseline, reactive and asset management monitoring, usually when the need arose. The exception being the Patea sand dunes which have a long history of instability which at times has threatened the beach settlement, and regular measurement-based monitoring has occurred since the early 2000s.]

1.2 Revised consent compliance monitoring

In the past, coastal resource consent compliance was undertaken by TRC officers who carried out annual inspections and have produced monitoring reports since 2012.

More recently, the Taranaki Regional Council (TRC) has revised the monitoring requirements on the coastal resource consents it administers (listed in Table 1). In particular, consent holders are required to carry out annual visual inspections of all structures, STDC officers will include in their annual inspection/report any change in a coastal structure's physical condition, in the adjacent environment or associated potential hazards. In addition, a consultant is commissioned to carry out on-site inspection of the structures from time to time, or to further investigate/comment on change noted by officers.

The TRC also now required measurement-based monitoring on structures deemed more likely to affect the environment (see **emboldened** structures listed in Table 1.1). The STDC's measurement-based monitoring plan approved by the TRC was based on a 2021 review by Coastal Systems Ltd (CSL 2021a). Measurement-based monitoring (MBM) is typically carried out at 1-2 to 5-10 year intervals depending on the nature of a structure and its environmental setting, and a guide for STDC structures is summarized in Table 1.2.

Table 1.1 Summary of TRC coastal permits for STDC coastal structures from CSL (2021)

Location	Description	Consent number
Bayly Road	Boulder seawall	5512
Middleton Bay	**Boulder seawall**	**5504**
Opunake headland	**Breakwater and boat ramp**	**6791**
Opunake Beach	Retaining wall and accessway	4578
Kaupokonui	Boulder riverbank protection	5983
Denby Road	Accessway protection	6763
Patea	**Rivermouth structures[1]**	**4573**
Patea	**South Mole reinstatement[2]**	**6839**
Patea	**Boat ramp and jetty[3]**	**4566**
Patea	Wharf maintenance	4575
Waverly	Accessways	4579

1 Moles and training wall, Mana Bay seawall, wave guidewall, Carlyle Bay rock bank protection.
2 In 2007, 160 m of the existing (half tide) training wall adjoining the South Mole raised to the level of the mole.
3 Rock protection has been added to the adjacent riverbank.

Table 1.2 Summary of key monitoring attributes at each measurement-monitoring location for STDC consents issued by the TRC. Source CSL (2021a)

Location	Profiling N** freq (y)	Topographic* frequency (y)	Bathymetric frequency (y)	Further detail (in CSL 2021a)
Middleton	5 1(0.5)# Spring 2020	5 Spring 2019	10 2021-2022	Section 3.1 and Figure 1
Ōpunakē	5 1 (0.5) Spring 2020	5 Spring 2019	10 2021-2022	Section 3.2 and Figure 2
Patea north: **Dune- greenwaste**	4 (6) 2 (1) Spring 2021	5 Spring 2021	-	Section 3.3.1 and Figure 5
Patea north: **Structures**	4 2 (1) Spring 2021	5 2020-21 Sum	-	Section 3.3.1 and Figure 5
Patea south	2(3) 2(1) Spring 2021	-	-	Section 3.3.2 and Figure 5
Patea inlet	6 (8) 2 (1) Spring 2021	5 2020-21 Sum	10 (5) 2020-21 sum	Section 3.3.3 and Figure 5

* from drone photography or LIDAR ** N = number of transects to be profile surveyed

1 (0.5) First number is default (eg yearly sampling), Bracketed number if practicable or necessitated such as by an erosion episode (eg ½ yearly sampling)

Time/date is for commencement of monitoring regime. Bi-annual sampling in Spring and Autumn, annual and longer sampling intervals to be in the Spring to incorporate the effect of winter storms (wind and waves). Bathymetric sampling more suited to summer (Sum).

1.3 2021-22 measurement-based monitoring surveys and output

Inspection and output details for MBM structure monitoring by the 4 separate specialist survey organisations are outlined below and listed in Table 1.3.

All output are in NZTM 2000 positional co-ordinates and NZVD2016 elevation and summarised below

<u>TPL ground survey output</u> is predominantly along cross-shore transects (location plans in Sections 2 to 4). Data are provided in an Excel spreadsheet with separate sheets of xyz data points (cm accuracy) with chainage calculated from a permanent landward benchmark, graphs (charts) of superimposed profiles, time-series data and graphs, and datum and co-ordinate details.

Table 1.3 2021-22 monitoring organization and details

Organisation	Type of monitoring	Date(s) of survey
TPL	Ground surveys	7 & 8 December, 2021
BECA	Structure condition insp	25 & 26 November, 2021
Landpro Ltd	Aerial photography and LIDAR	14 January, 2022
Fugro[1]	Hydrographic surveys	18 January/1 Feb 2022

1.Patea incomplete, Opunaki and Middleton outstanding

To interpreting beach behaviour from the profile plots, an excursion analysis is performed which constructs time-series graphs of cross-shore distance from the first survey for a key (representative) elevation. As the beach moves seaward between surveys (or landward) the distance from the original data point increases (or decreases). Typically, such a representative elevation is higher on the beach, thus it is less affected by marine processes and more likely captures the underlying system behavioural signal

LandPro aerial and LIDAR output consists of an ortho photo at 5 cm resolution, LiDAR.LAS at 5 cm, DEM at 1m resolution, DSM at 1m resolution and contours spaced at 25 cm elevation. Note that an orthographic vertical aerial photo has had lens and other distortions removed including relief offsets. LiDAR refers to high density lazer detection of surface features, DSM refers to a digital surface model and the DEM locates the elevation of the actual ground (beneath vegetation). The DSM and DEM are obtained by filtering the high resolution LAS data.

Fugro multibeam sonar output consisted of high resolution georeferenced (tif format) imagery and a point cloud (LAS format) at 0.25 m spatial resolution, 1 sigma accuracy of 0.12 m vertical and 0.16 m horizontal.

BECA output tables describe structure condition using a colour coded rating and mapping, and outline required maintenance. The condition assessment rating was based the PIANC (2008) six category approach and is included below as Table 1.4.

All output data and survey/inspection reports are listed as Appendices A to D respectively and the PDF files are held by the STDC records office.

1.4 Additional inspection

On the weekends of 4-5 and 12-13 February, 2022, Taranaki was impacted by successive storm events. While significant wave effects were evident in North Taranaki, the Ōpunakē area was somewhat sheltered from the north swell. However, effects from particularly heavy rainfall and winds resulted in cliff destabilisation and flooding. On 17 February CSL

Table 1.4 Condition assessment ratings

Rating	Description
Good	No visible damage or only minor damage noted. Structural elements may show very minor deterioration, but no overstressing observed. No repairs required.
Satisfactory	Limited minor to moderate defects or deterioration observed, but no overstressing observed. No repairs are required.
Fair	All primary structural elements are sound; but minor to moderate defects or deterioration observed. Localised areas of moderate to advanced deterioration may be present, but do not significantly reduce the load bearing capacity of the structure. Repairs are recommended but the priority of the recommended repairs is low.
Poor	Advanced deterioration or overstressing observed on widespread portions of the structure but does not significantly reduce the load bearing capacity of the structure. Repairs may need to be carried out with moderate urgency.
Serious	Advanced deterioration, overstressing or breakage may have significantly affected the load bearing capacity of primary structural components. Local failures are possible and loading restrictions may be necessary. Repairs may need to be carried out on a high priority basis with urgency.
Critical	Very advanced deterioration, overstressing or breakage has resulted in localised failure(s) of primary structural components. More widespread failures are possible or likely to occur and load restrictions should be implemented as necessary. Repairs may need to be carried out on a very high priority basis with strong urgency.

inspected Middleton and Ōpunakē Bays, and on 3 and 4 of March the minor structures were inspected and reported (CSL, 2022a).

1.5 Historical data

Wherever possible the data collected during the summer of 2021-2022 is compared with equivalent historical data to enable an initial appreciation of change over more recent time. These previous data have been collected for a variety of purposes relevant to the time.

1.6 Report Layout

Sections 2 covers Middleton Bay, Section 3 covers Ōpunakē Bay, Section 4 covers Patea. Each section summarises the 4 types of specialist monitoring and addresses the associated consent compliance. The final section (5) provides conclusions and recommendations. STDC officer comment on remedial work underway, immanently underway or bring planned are provided in APPENDIX E.

2 MIDDLETON BAY

2.1 Background

Middleton Bay is a sandy pocket beach approximately 380 m wide backed by a 100 m long foredune at the NW end and a 110 m long boulder revetment, 16 m wide boat ramp and related infrastructure at the southeast end (Figure 2.1). Some modification was made to the revetment in 2020 which is further described in Section 2.5. Between the southeastern (developed) and northwestern (natural) sectors lies the Central Sector, a 90 m long transition zone comprising unstable dune sand, scattered vegetation, boulders and rubble which are backed by an unpaved accessway and a private building. A cliff extends around the bay and boulder reefs extend seaward of each headland.

The beach is composed of fine to medium grade sand overlying boulders. The shoreline in the NW sector has eroded at an average rate of 0.21 m/yr since 1953, the central sector has an average erosion rate of 0.14 m /yr and the SE sector has accreted at 0.18 m/yr. This environment is described in detail in the report entitled “Middleton Bay Long-term Management Strategy” (CSL, 2020).

Three cross-shore transects were selected to represent the three sectors (see T1, T2 and T5 in Figure 2.1). Two additional transects were required by the TRC to better define any response to seawall modifications.

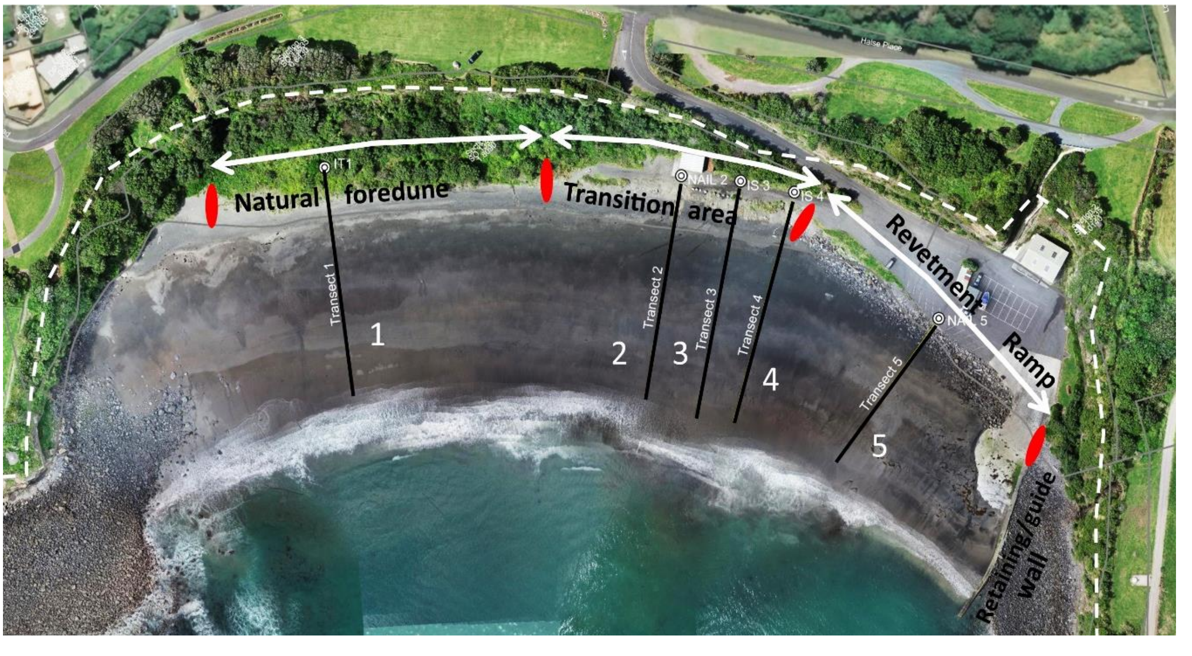

Figure 2.1 TPL profiling transects numbered 1 to 5 from northwest (left side) to southeast. (right side). Red ellipses mark boundaries between marked geomorphological units; on left the natural sand dune, on right the seawall and ramp, and the transition zone in between. The clifftop is defined by the dashed white line Base photo TPL, November 2019

2.2 Ground surveys

TPL most recently profile-surveyed Middleton Bay on 7 December 2021 with a previous ground survey in 2020 and ground and drone surveys in 2019. Superimposed profiles are plotted in Figure 2.2. In addition, the 2010 profiles are also plotted – these were generated from a contour survey by Bland and Howard Ltd for the STDC.

The time-series for representative elevations are shown in Figure 2.3. For Transect 1 the representative elevation is the dune toe, this being 5 m above MSL. For T2, T3, T4 the elevation is 4.0 m which is just below the scarp base which characterises this area. And for T5 the elevation is 2.5 m which lies on the beach sand fronting the boulder revetment. The results show relative stability for the northwestern fordune (T1). The three transects immediately beyond the revetment (T2 to 4) have undergone about a metre of erosion (0.8 to 1.5 m of shoreline retreat) since the November 2020 survey. Prior change (2019 to 2020) for this area was shoreline advance of 0.2 to 3.5 m. By comparison, T5 fronting the revetment had experienced retreat. Given the stability of the natural sector (T1), the observed recent erosion at T2-4 may be the result of storm-wave effects about the modified terminus of the revetment, with the eroded sediment subsequently accumulating in front of the revetment.

Inspecting the 2010 profiles in Figure 2.2 shows that the upper beach fronting the natural foredune at the NW end of the bay (T1) has remained relatively stable during the past 12 years. At the opposite end (T5), the structure appears to have subsided while the beach sand has accreted somewhat. The transition area shows some erosion of the upper beach/scarp. Overall, these results are somewhat consistent with the most recent change.

2.2. Aerial Surveys

Landpro flew Middleton Bay on 14 January, 2022. Coverage included both headlands and the backing cliff. The vertical aerial (orthographic) photo is reproduced as Figure 2.4. Contour lines derived from the corresponding LIDAR are also reproduced. The beach contours are essentially parallel through the dune and transition areas before bunching up in the vicinity of the structure. The contour lines show the selected transects adequately represent the wider area in which they occur. As LIDAR can detect the ground surface below vegetation, these data will be useful in future cliff hazard (re)assessment.

2.3. Hydrograhic Surveys

The planned survey by Fugro during the 2021-2022 summer has been delayed due to weather and other circumstances so this will be reported separately.

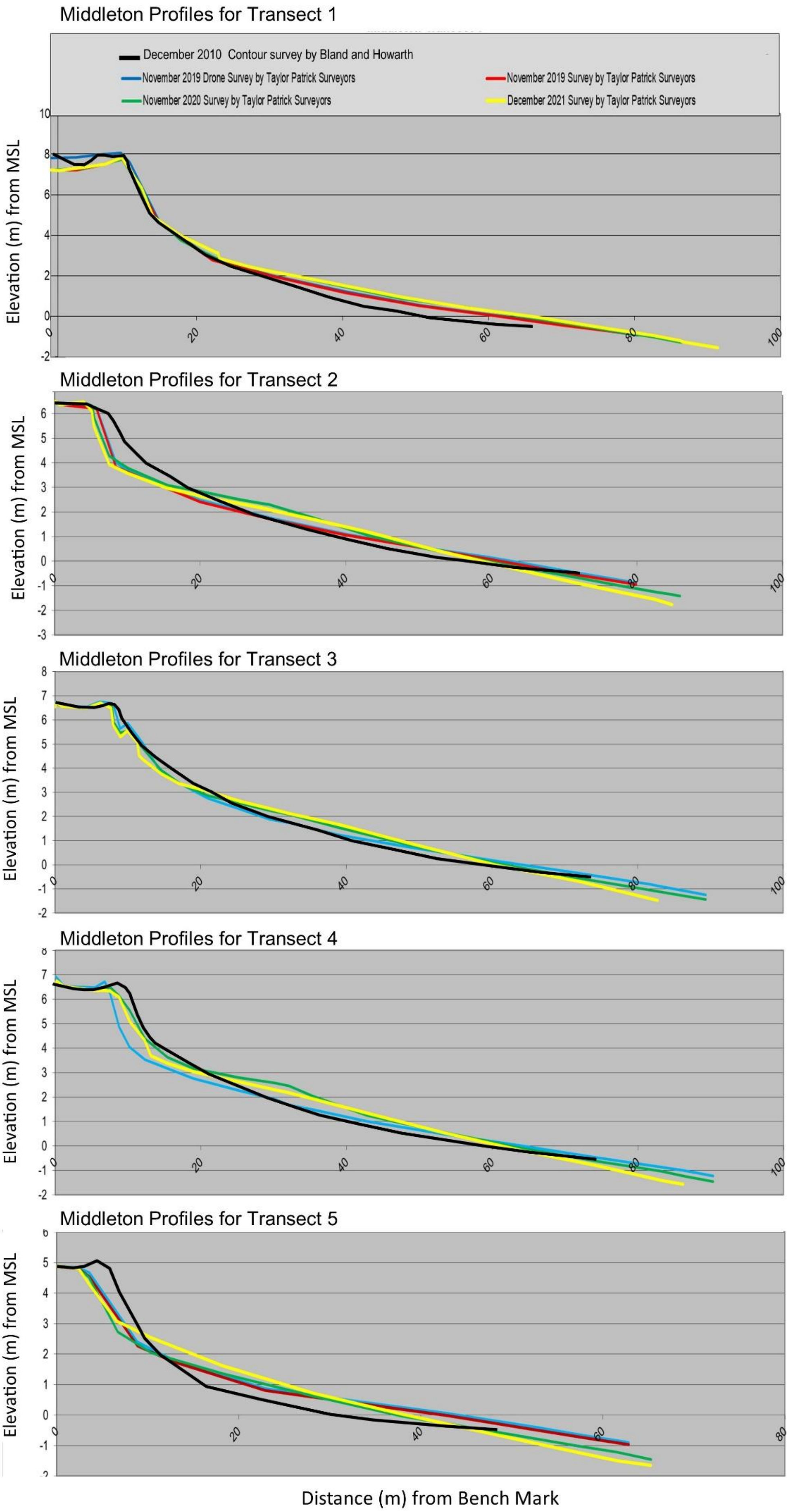

Figure 2.2 Superimposed profiles for the Middleton Bay's 5 transects surveyed in 2019, 2020 and 2021. The 2010 profiles were abstracted from a contour survey by Bland and Howarth.

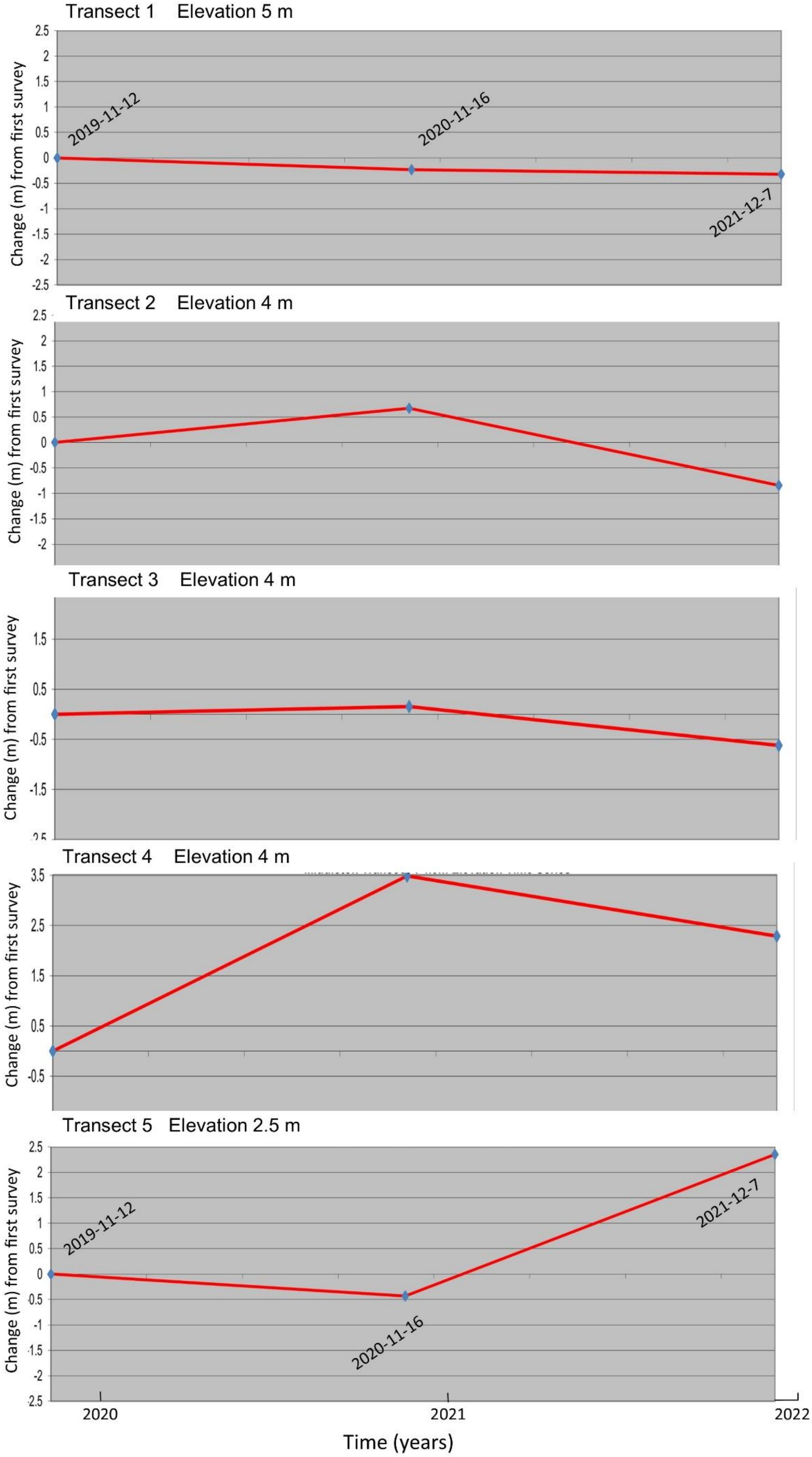

Figure 2.3 Time-series for Middleton Bay Transects 1 to 5 at stipulated elevations for 2019, 2020 and 2021 surveys.

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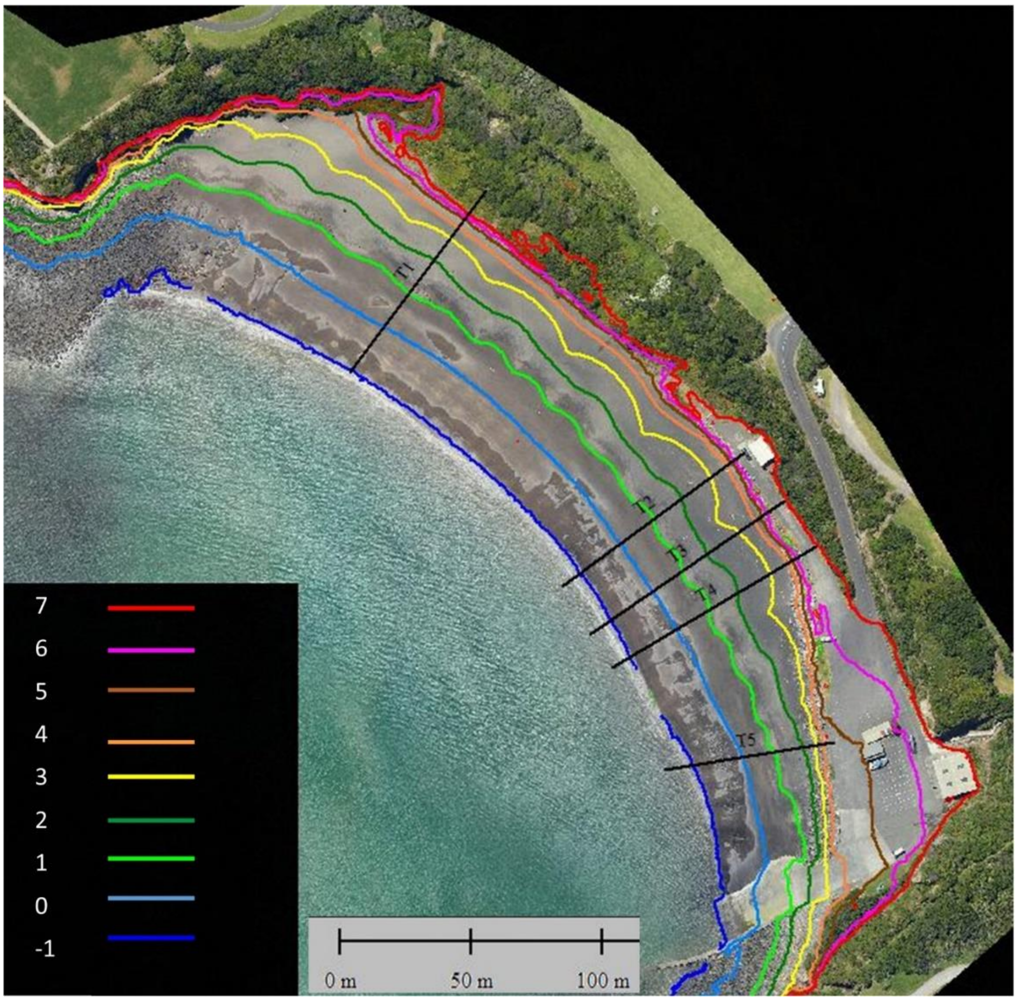

Figure 2.4 The Landpro aerial orthographic vertical photo with 1 m contours across the beach, foredune and revetment/carpark.

2.4. Inspections

BECA inspection

On 25 November, BECA inspected structural assets in Middleton Bay, assessed their condition and recommended any associated remedial maintenance.

<u>Boulder revetment</u>
Condition ranged between fair at the southeastern (boat ramp) end to critical at the northwestern end. Recommended high priority maintenance: additional armour rock required along the upper face and full (re) construction north of the stairway.

<u>Concrete boat ramp</u>
Condition rating was fair. No high priority maintenance.

<u>Concrete retaining/guide wall</u> (separating boat ramp from southeastern boulder beach)
Condition ranged between poor and fair. High priority maintenance: replace timber rubbing strips and fill any voids. Remediate significantly damaged concrete blocks.

Coastal Systems inspection

Following an intense storm in February 2022, Middleton Bay was inspected by CSL on 17 February 2022. The report to council officers read as follows:

The rock revetment at the eastern end and the natural foredune at the western end were in good condition. However, the central sector had some severe scouring in the vicinity of the private building – this appearing to result from the volume and concentration of local stormwater drainage. Of particular concern were boulders now precariously located at the top of the dune scarp. A recommendation for hazard fencing and relocation of some boulders was subsequently carried out.

2.5. Consent compliance assessment

Coastal Permit 5504

STDC holds coastal permit 5504-1 to occupy the coastal marine area of the Middleton Bay foreshore with an existing boulder riprap seawall for erosion protection purposes. The original permit was issued in 1999 with the present permit issued on 29 August, 2019.

There are five special conditions attached to the permit and the most significant are as follows:

1. The consent holder shall maintain the structure in a safe and sound state such that:

   a. it does not fall into a state of disrepair and continues to function effectively for the purpose it was designed;

   b. its structural integrity is maintained; and

   c. there is no settlement or loss of foundation material.

2. The structure shall not:

   a. cause erosion that is greater than that assessed when determining the application for this consent; or

   b. significantly increase the coastal hazard risk.

The AEE supporting the 2019 STDC consent reapplication stated that there would be no change in the nature or scale of the structure, but its degraded state would be restored and strengthened based on existing characteristics and standard seawall guidance criteria as set out in PRIF (2017), and other engineering guidance manuals. Design parameters were provided in the AEE.

-The restored seawall will curve (be "returned") landward at the northern end some 7 m to prevent outflanking and subsequent structure collapse onto the adjacent beach. Most of the return will be buried, only become exposed and active under extreme sea conditions.

-The margin between any hard structure and adjacent sand dune will always be susceptible to short-term erosion and as natural recovery can be protracted dune restoration may be carried out from time to time.

-To assist the public with safer access to the beach, steps can be built into the sheltered “return” part of the structure. As the steps will be flush with the revetment surface they will not affect the seawall’s performance or have any environmental impact.

-All works will be supervised by qualified and experienced personal.

CSL comment

In early 2020, concrete steps were constructed down the northwestern end of the revetment and additional stone placed on the revetment to each side of the stairway. The AEE states that the entire revetment requires maintenance to meet the design criteria and parameter values.

Since modification, the structure has undergone localized storm wave attack and erosion is evident in Figure 2.5 and in the 2019-2021 profile survey data. A structure effect/erosion enhancement is possible given that a wave turbulence-driven alongshore erosional beach response can extend up to 0.7 * seawall length (McDougal et al., 1987).

Figure 2.5 As-built photo taken 16-3-2020 (top) showing steps and newly place stone with battered bank (dune) in foreground. Lower photo taken 17 February 2022 showing stairs and area immediately northwest indicating past erosion. This area was identified by BECA as in urgent need of amour rock. It is also this area was designated to have a “return” build in to avoid future outflanking. Photos CSL

3 ŌPUNAKĒ BAY

3.1 Background

Ōpunakē Bay has a sandy (pocket) beach with a 300 m long high tide shoreline running northwest to southeast. The geomorphology and development histories are described in detail in the report entitled "Geomorphological assessment, hazard and risk assessments, and mitigation management options for Ōpunakē Bay" (CSL, 2019).

Briefly, the beach is composed of fine sand with the shoreline consisting of boulders to the northwest including a 42 m long boulder revetment, a 150 length of sand dune in the centre with the shoreline protruding seaward, and two retaining walls (80 m and 40 m) separated by a 5 m wide vehicle ramp at the southeast end of the bay (see Figure 3.1). The retaining walls separate easily saturated Holiday Park grounds from a typically damp upper foreshore. The nonlinear plan form of the upper beach, illustrated by the typical spring HWM (dashed yellow line in Figure 3.1) appears to result from drainage outlets at both ends of the beach which facilitate localized beach-surface erosion
The bay is surrounded by a 15 to 20 m high cliff which extends seaward to a western headland some 700 m distant and the southern headland some 500 m distant. Boulder reefs extend seaward from each headland.

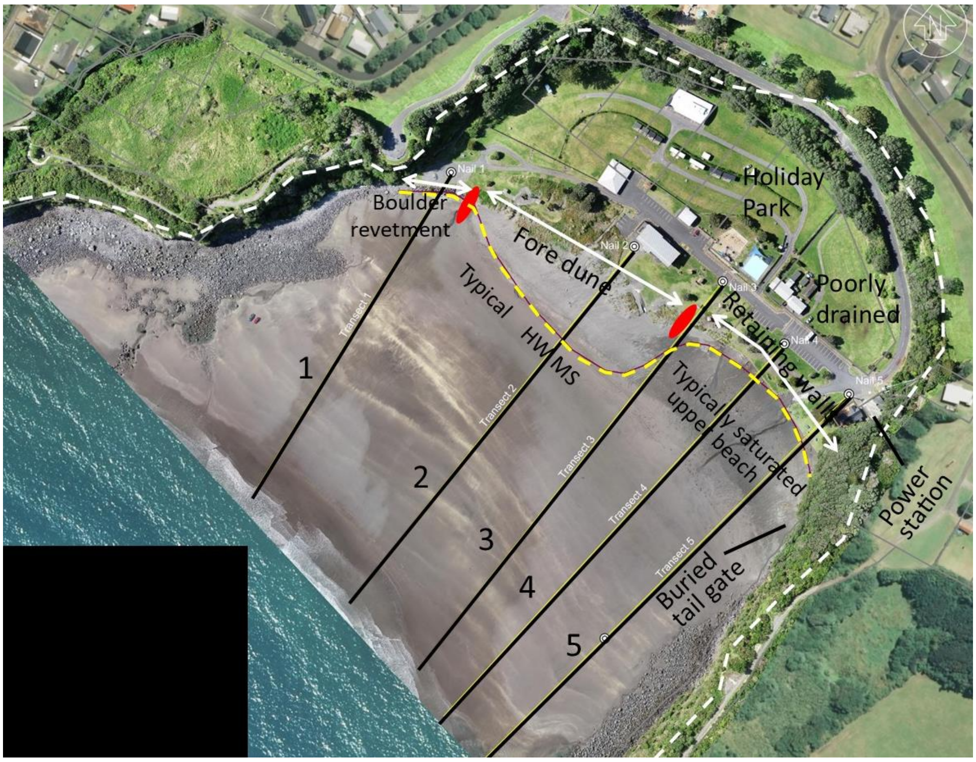

Figure 3.1 Red ellipses mark boundaries between marked geomorphological units; on left boulder revetment, on right the retaining walls with poor drainage to both landward and seaward. In the centre a foredune protrudes seaward. The clifftop is defined by the dashed white line and the typical HWMS by the dashed yellow line. Also marked are the 5 TPL profiling transects. Base photo was taken by TPL in November 2019.

Being important for settler transport, the bay (including cliffs and bathymetry) was first surveyed in the early 1880s. The 180 m long breakwater extending eastward into the Bay from the western headland was constructed in the late 1920s. The breakwater appears to have facilitated accretional processes to landward. Shoreline behaviour around the bay is characterized by long-term accretion at rates of 0.27 m/yr at the northwest end, 0.53 m/yr in the centre and 0.23 m/yr in the southeast.

Some maintenance to the breakwater and boat ramp appear to have been carried out in the early 2000s in preparation for constructing an artificial surf reef. TPL and Landpro aerial surveys in 2019 and 2022 respectively, found the breakwater's present crest elevation reduces from about 1.5 m above MSL at the landward end to about 1.0 m below MSL at the seaward end (Figure 3.7).

3.2 Ground surveys

TPL most recently profile-surveyed Middleton Bay on 7 December 2021 with previous ground surveys in 2020 and ground and drone surveys in 2019. These superimposed profiles are plotted in Figure 3.2. .

As described earlier in Section 1.3, to interpret profile change, time-series graphs of cross-shore distance from the first survey for a key (representative) elevation were constructed. For Transect 1 fronting the boulder revetment, the chosen elevation is 2.5 m above MSL, which is located on the beach fronting the structure. For Transect 2, the representative elevation is the dune toe which is 3.5 m above MSL. For T3, T4 and T5 the elevation is 3.0 m which is on the beach immediately seaward of the retaining wall. The resulting time-series are plotted in Figure 3.3 and show the December 2021 northwest and centre shorelines (T1 and T2) continuing to advance seaward (beach accretion) at 2 to 4 m per year. Such change indicates a steady sediment input from seaward along the north western side of the Bay – the dominant sediment transport route.

Beach behaviour fronting the retaining walls (T3-5) is more complex with T3 retreating slightly (0.5 m), T4 advancing about 4 m after previously undergoing a slight retreat, and T5 also showing a moderate and consistent advance of 2 m/year. The T5 deposition in particular may be being facilitated by outflow cessation from the power station tailrace which stopped operating in 2018 after several decades of flushing sediment seaward at the eastern end of the beach. The dramatic upper beach accretion at T4 following previous stability suggests localised beach behavour possibly related to the T5 accretion. The contrasting behaviour (slight erosion) at T3 is consistent with this area carrying the seaward return flow from storm-wave overwash from the more elevated central upper beach and possibly also from the recent T4 accretion.

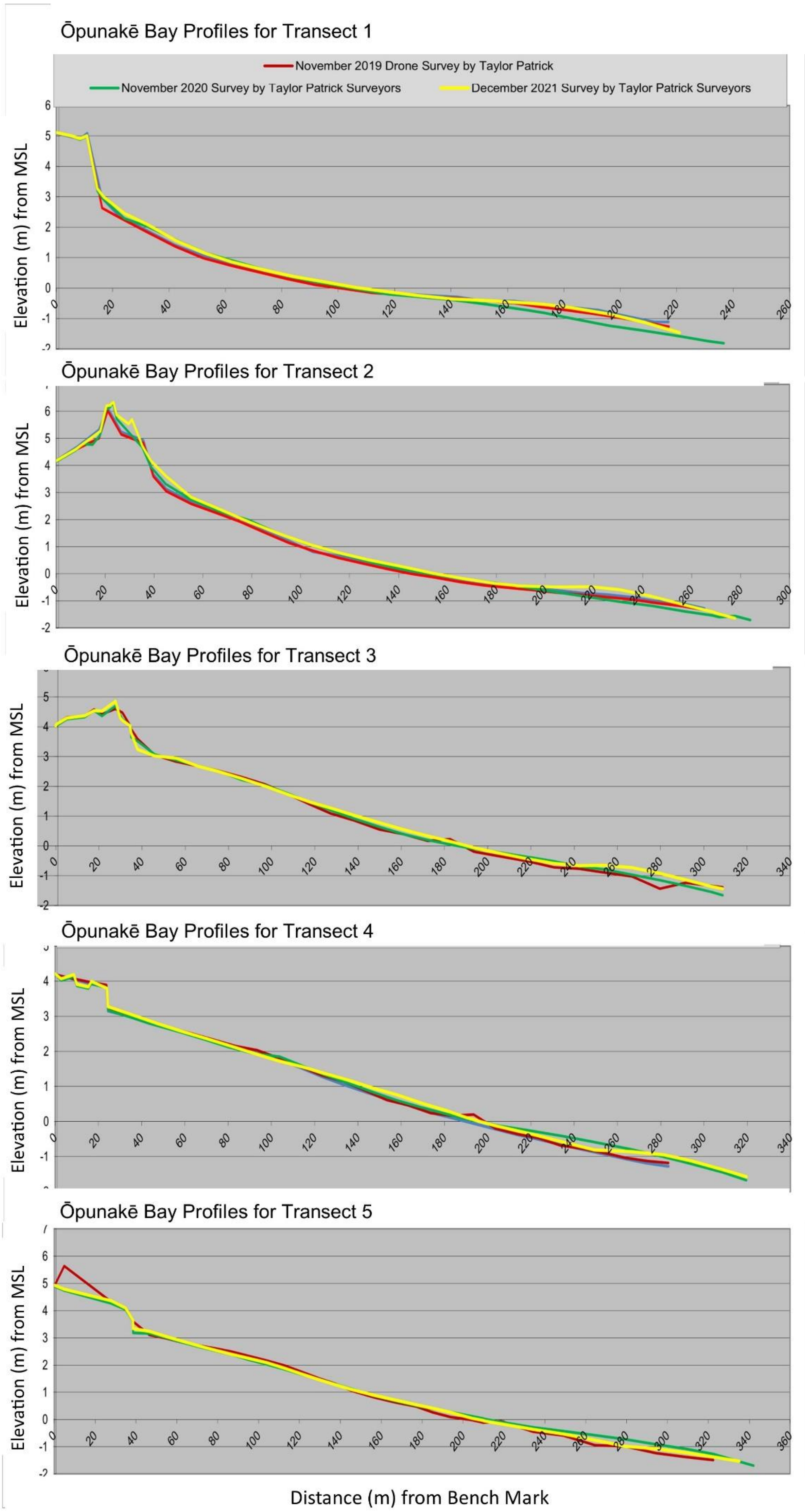

Figure 3.2 Superimposed profiles for the Ōpunakē Bay transects surveyed in 2019, 2020 and 2021

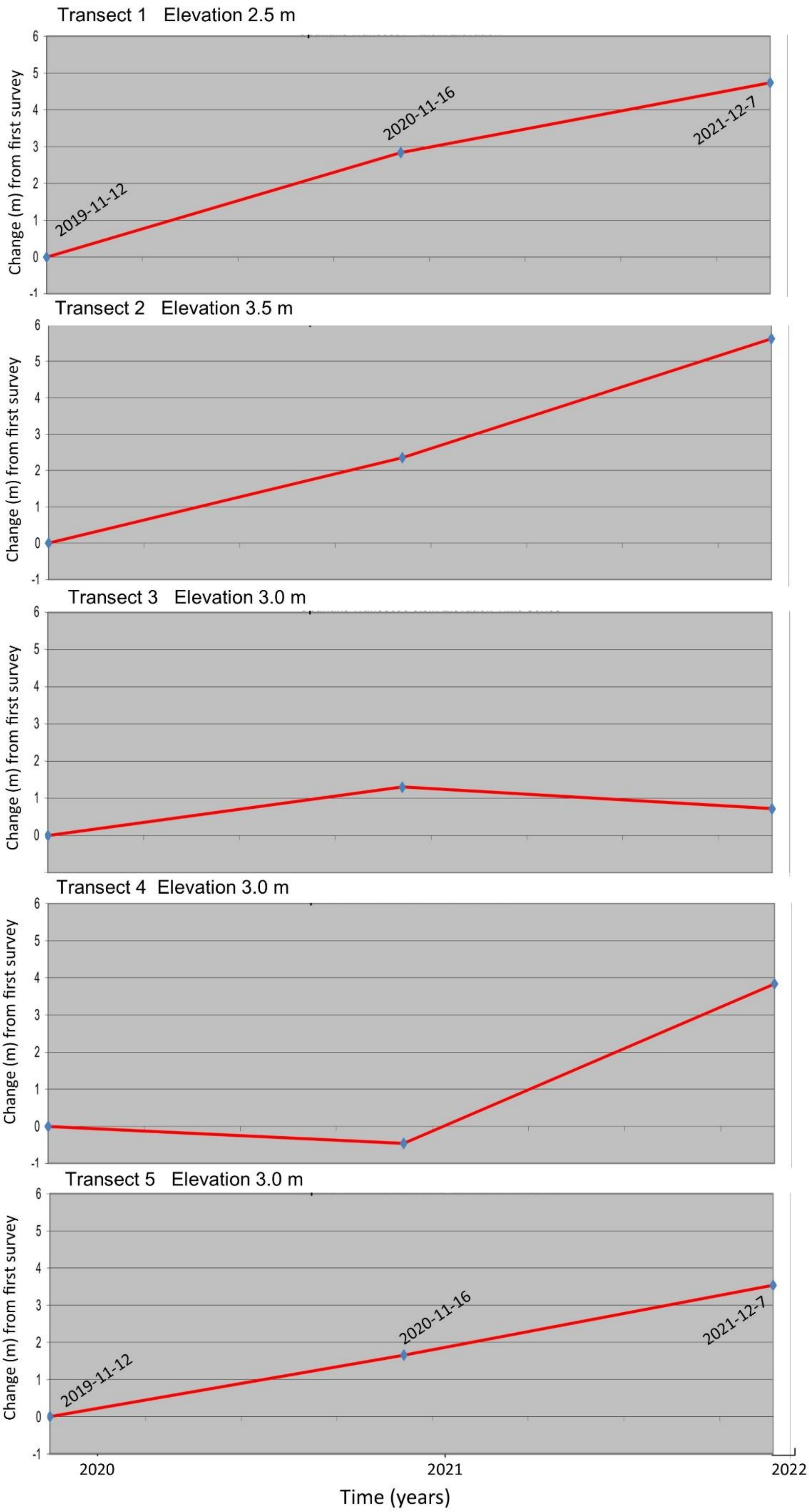

Figure 3.3 Time-series for Ōpunakē Bay Transects 1 to 5 at stipulated elevations for 2019, 2020 and 2021.

3.3 Aerial surveys

Landpro flew Ōpunakē Bay on 14 January, 2022. Coverage included both headlands and the backing cliff. The vertical aerial ortho photo is reproduced as Figure 3.4. Contour lines derived from the corresponding LIDAR are superimposed. The survey was completed before some substantial cliff collapse occurred during the intense rainstorm events in early February. As noted in Section 1, LIDAR can detect a ground signal (through cliffside vegetation) and hence the survey provides baseline data for future cliff hazard (re)assessment.

The contour lines show the selected transects adequately represent beach topography. The 5m contour defines the central sand dunes and the 3 m contour illustrates drainage outlets onto the beach. Of particular note is the seaward curvature in contour shape on the right (south eastern) side of the 2022 image. This contrasts with the 2016 aerial in Figure 3.5 where the strandlines[1] curve landward. This illustrates the southeastern sand buildup detected in TPL's T5 profile survey. The tailgate and tail race are evident and marked in the 2016 and the outflow appears to have previously been able to flush sand reaching this area. Ongoing sand accumulation will have environmental consequences including worsening drainage affecting the Holiday Park area.

Shoreline and bathymetric analyses in CSL (2019) strongly suggested that the breakwater had facilitated accretion within the bay upon which various assets stand, hence the long-term need for the breakwater to remain functional. However, monitoring such a structure in this particularly high energy environment is not realistic using conventional survey methods, but LIDAR and drone photogrammetry are promising. The 2022 ortho photo of the breakwater is shown in Figure 3.6 with the breakwater axis marked. LIDAR data captured along this axis are shown in Figure 3.7 and for comparison TPL's 2019 drone-based photogrammetric profile is superimposed. The spatial alignment of the two images was about 0.1 m. Such data show potential for detecting longer-term change in subsidence of the structure surface. The extent to which a multibeam hydrographic survey is able to define the subtidal breakwater is unknown until the forthcoming survey is carried out by Fugro Ltd.

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1. Intertidal strandlines are composed of materials with contrasting properties (density) left by wave runup during a lowering tide and are approximately horizontal.

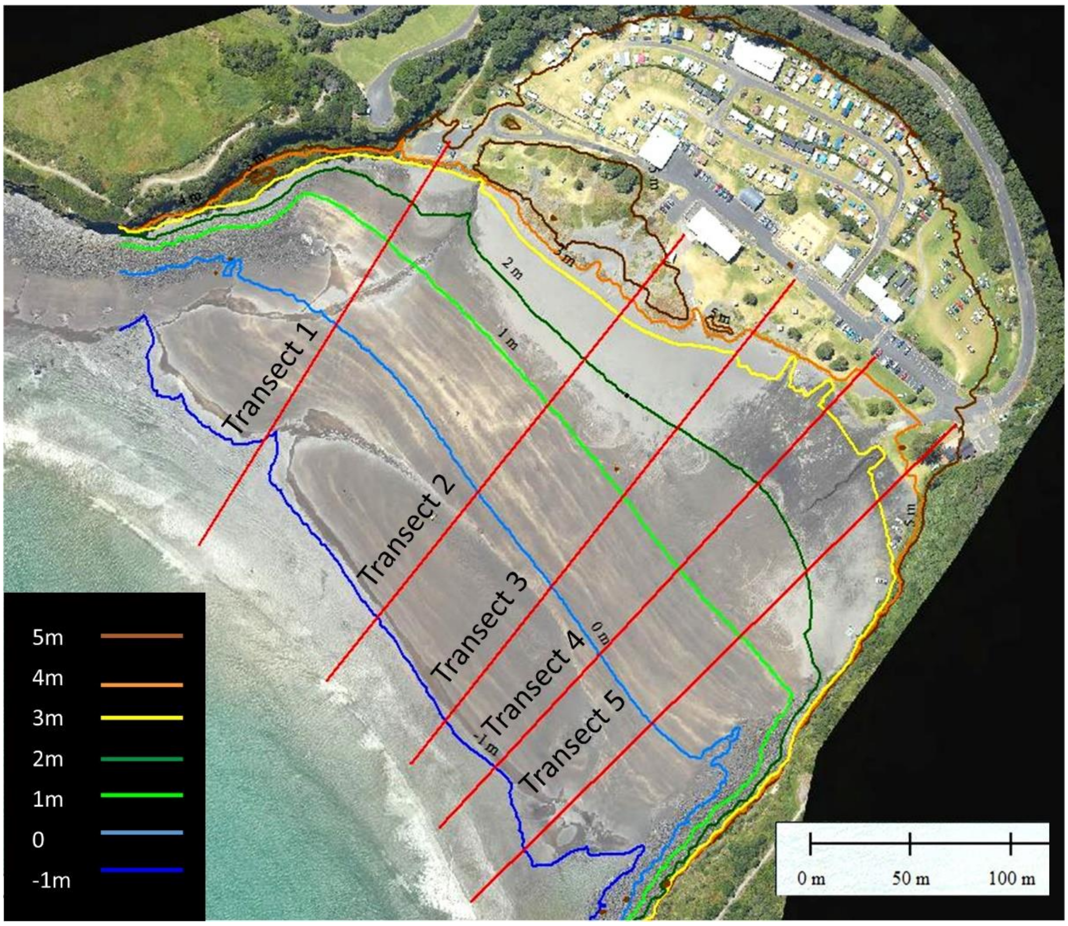


Figure 3.4 The Landpro aerial orthographic photo with contours marked at 1 m elevation increments across the beach, foredune and backshore. There is no evidence of the power station tail gate and tail race.

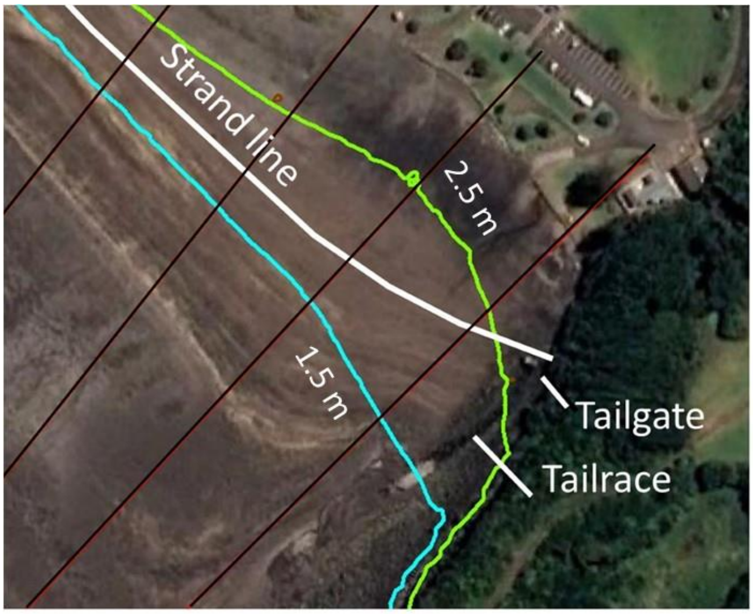


Figure 3.5 2016 Google Earth image with a strandline marked and 2022 contours superimposed for shape comparison. The power station tail gate and tail race are also evident.

Figure 3.6 The 2022 Landpro ortho photo of the Ōpunakē breakwater with the axis used for profile data capture (Figure 3.7) marked.

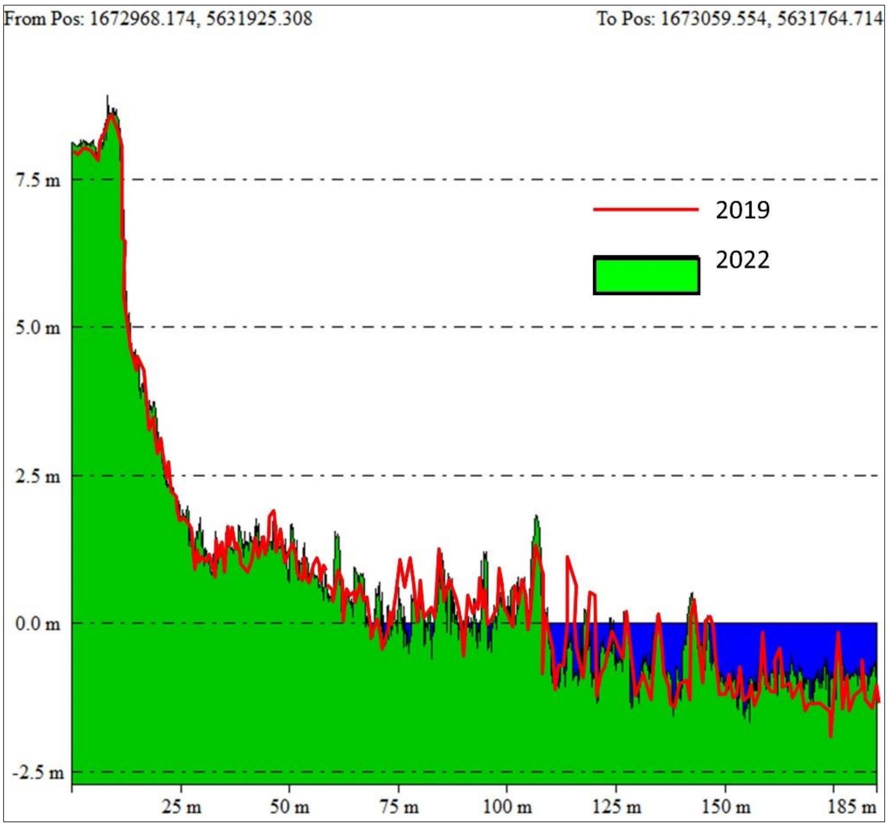


Figure 3.7 Longsection of the breakwater comparing 2019 TLP drone-based photogrammetric 3D data with 2022 Landpro LIDAR. Sampling occurred along the axis marked in Figure 3.6.

3.3 Hydrographic survey

The planned survey by Fugro during the 2021-2022 summer has been delayed due to weather and other circumstances. Once completed, the current seabed will be compared with a 2002 bathymetric survey by DML. The 2002 DML survey was compared with the 1880s survey in CSL (2019).

3.4. Inspections

BECA inspection

On 25 November, BECA inspected structural assets in Ōpunakē Bay, four along the shoreline and two on the western headland. The following summarises BECA's assessment of structure condition and associated remedial maintenance.

<u>Southeastern concrete block retaining wall</u>
The condition was satisfactory with the only high priority recommendation being to source discoloured drainage water discharging directly onto the beach and, if safe, have it rerouted.

<u>Southeastern lattice and pylon concrete retaining wall</u>
The condition rating was critical with disintegrating pylons and dysfunctional lattice, inadequate drainage outlets and public health and safety issues. High priority recommendations included structure replacement with a new engineering solution. Also to determine the safety of the drainage effluent then reroute.

<u>Beach boat ramp/accessway between the two retaining walls</u>
Overall condition rating was fair with a range of low priority minor repairs recommended.

<u>North western boulder seawall</u>
The condition of this structure was good and there were no high priority maintenance recommendations.

<u>Western headland boat ramp</u>
The boat ramp is in poor condition and inoperable. There were no high priority maintenance recommendations.

<u>Western headland boulder breakwater</u>
The overall condition is fair. However, there are displaced rock and the crest hight is low. There were no high priority maintenance recommendations.

Coastal Systems inspection

Following an intense storm in February 2022, Ōpunakē Bay was inspected by CSL on 17 February. The report to council officers noted that the concrete lattice and pylon retaining wall immediately westward of the beach vehicle ramp had become increasingly unstable with part of the structure now on the beach. Officers responded that consenting for a replacement structure was underway.

3.5. Consent compliance assessment

Coastal permit 4578

STDC holds coastal permit 4578-2 to occupy coastal space with retaining walls and associated accessway structures at Ōpunakē Beach. The original permit (4578-1) was issued on 28 June 1994. The present permit was issued on 29 October 2012 and expires on 1 June, 2030.

There are four special conditions attached to the permit with the most significant being that the consent holder shall maintain the structure in a safe and sound state so that they continue to function effectively as retaining walls and accessways.

Inspections found that the pylon and lattice retaining wall to be dysfunctional, hazardous and fails to meet compliance requirements.

The profile and aerial surveys identified morphological change (deposition) at the south eastern end of the beach which appears to result from recent non-operation of the power station tail race. As noted in Section 3.3, should this continue then there will be environmental consequences, in particular relating to drainage.

Coastal permit 6791

STDC holds coastal permit 6791-1 to erect, place and maintain a boat ramp and rock breakwater in the coastal marine area off the northern headland of Ōpunakē Bay. This permit was issued on 22 December, 2005 and is due to expire on 1 June 2024.

The BECA inspection found the boat ramp to be dysfunctional and hazardous.

The permit is, in part, to maintain the rock breakwater. As noted in Section 3.3 and considered further in CSL (2019), there is on ongoing need for the breakwater to remain functional as it appears to control sedimentation within in the bay to landward. Methods for monitoring the breakwater are being investigated with aerial-based approaches showing promise (Section 3.3). Repeat multi-beam hydrographic surveys may also be useful, and the first such survey has been commissioned.

4 PATEA

4.1 Background

The geomorphology and development history of the Patea Rivermouth area are described in some detail in CSL reports 2006, 2015 and 2021a and summarized in Figure 4.1. The moles were constructed in the late 19th /early 20th century with the North Mole extending some 325 m from the northern cliff and the South Mole reaching 450 m from the then southern riverbank. The South mole diverted the river mouth from its former southerly orientation into the sea (see the 1872 shoreline) to the present shore-normal alignment.

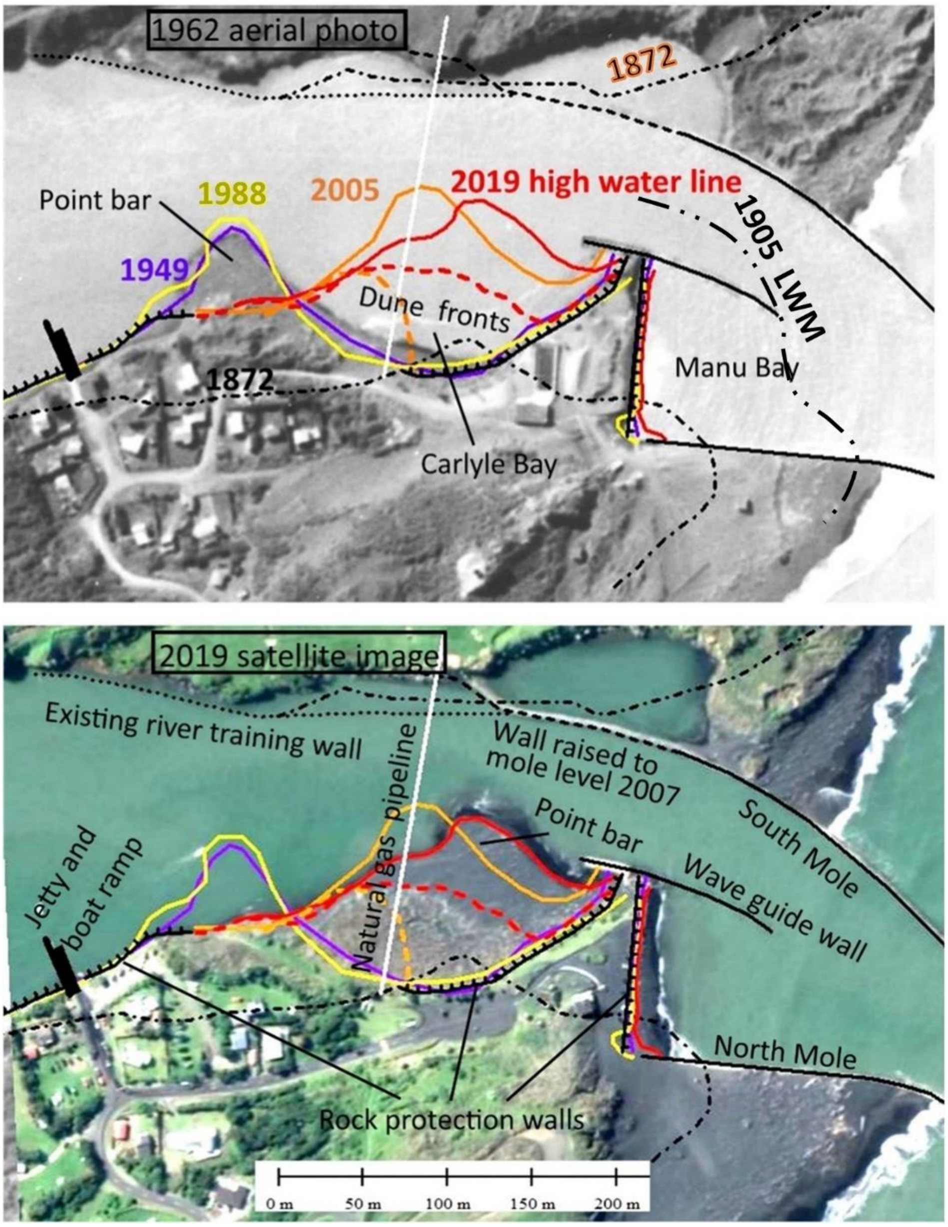


Figure 4.1 Patea Rivermouth historical shorelines marked on a 1962 aerial photograph (upper image) based on vegetation and textural change, and structures and shoreline response marked on a 2020 satellite (lower). Source: CSL (2021a)

Harbour development within the inlet began in the late 19th century with the 140 m long wave guide wall (pier), and a 60 m long seawall joining the guide wall to the western riverbank/North Mole (Figure 4.1). A half tide training wall extended upstream from the southern mole and several wharves were constructed a further 1 to 1.5 km upstream during the late 19th and early 20th centuries. From the 1990s to 2010 a boulder wall was constructed to halt wave erosion at the back of Carlyle Bay reaching the access road (Figure 4.2), and a boat ramp, jetty and adjacent boulder bank protection constructed at the upstream end of the beach settlement. A 160 m length of the half tide wall immediately upstream of the South Mole was raised to mole height to prevent outflanking – a threat considered highly likely to occur in the next 20 to 25 years due to ongoing retreat of the open coast shoreline (Duffill, Watts and King, 2003).

The historical structures have dramatically modified the open coast shorelines as illustrated in Figure 4.3. Both shorelines moved at least 100 m seaward closer to the moles, with the southern shoreline then undergoing systematic erosion while the northern shoreline remained relatively stable, although since 2010/11 a significant episode of erosion has occurred and the shoreline effects are defined by the ground and aerial monitoring data in the following sections (4.2 and 4.3).

Within the inlet, the early structures resulted in a stable "point bar" forming on the northern bank (Figure 4.1) which defined the upstream margin of Carlyle Bay. At this time the bay was sheltered, safe and popular for recreation. However, in the late 1980s wave erosion began affecting the back of Carlyle Bay (Figure 4.2) and also threatening the natural gas pipeline crossing. An investigation by the Water Water Quality Centre (Smith, 1987) noted the likelihood that the newly commissioned Patea hydro dam could be modifying the inlet hydrodynamics. Indeed, reduction in lower river flow duration would increase tidal flood flow and wave penetration. However, with time the bay began to infill with sediment, bury the rock wall, and sand dunes established (Figrue 4.2). Again this is potentially linked to the change in wave energy – in this case increasing littoral sediment transport into and up the inlet. By the early 2000s Carlyle Bay was also reducing in size as the point bar migrated downstream (Figrue 4.1) and this change is potentially linked to the more recent river structures and is discussed later in the report.

4.2 Ground surveys

Eighteen transects were surveyed on 7 and 8 December 2021 comprising 8 along the northern coast, 7 within the inlet, and 3 on the south coast. Their locations and sampling are shown in Figure 4.3. Fiver of the 18 transects were sampled in 2021 for the first time. As the data set increases, it may become evident that some transects are redundant, i.e. closely related to adjacent transect output. Historical profiles were derived from the BTW topographic survey carried out in 2003 after conversion to the current co-ordinate and elevation datum. BTW's contour map is reproduced later in Section 4.3 as Figure 4.13.

Figure 4.2 Carlyle Bay in 1990 (upper photo) with water, waves, a sandy beach and backed by an erosion scarp which was subsequently infilled with boulders. By 2020 (lower photo) the bay had filled with maturing sand dunes and vegetation. Red ellipses mark the upstream end of the wave guide wall. Photos CSL

4.2.1 North coast

Transects 1 to 9 were established in 2007 as part of the TRC Green Waste Discharge consent (6088). For sites closer to the river, BTW's 2003 data was incorporated. When planning the revised survey programme in 2021 for the Green Waste Consent renewal, it was agreed that Transects 3A, 6 and 9 be discontinued, but reactivated if a significant episode of erosion occurred. However, during the recent 2021 survey all transects were surveyed. For the Patea Rivermouth Structures consent 4573, the TRC require the shoreline to be monitoring for 500 m to the north (and south) of the rivermouth – this reach includes transects T1, T2, T3 and T4, so there is an overlap with the green waste consent monitoring surveys.

The full set of profile overlay and time-series graphs for the northern sites are included in the TPL output (Appendix A) with a representative selection of transects (2,4 and 8) shown in Figures 4.5 and associated time-series of change in Figure 4.6.

Time-series line graphs for the dune toe (MSL +4 m) and mid dune face (MSL +10 m) clearly define the erosion episode at T4 and T8, but it is not apparent closer to the mouth. However, it could be that the shoreline impact here was masked by the arrival substantial quantities of eroded sediment from further updrift (T4 and T8), a possibility supported by the more recent deposition which is evident in the T2 time-series graph.

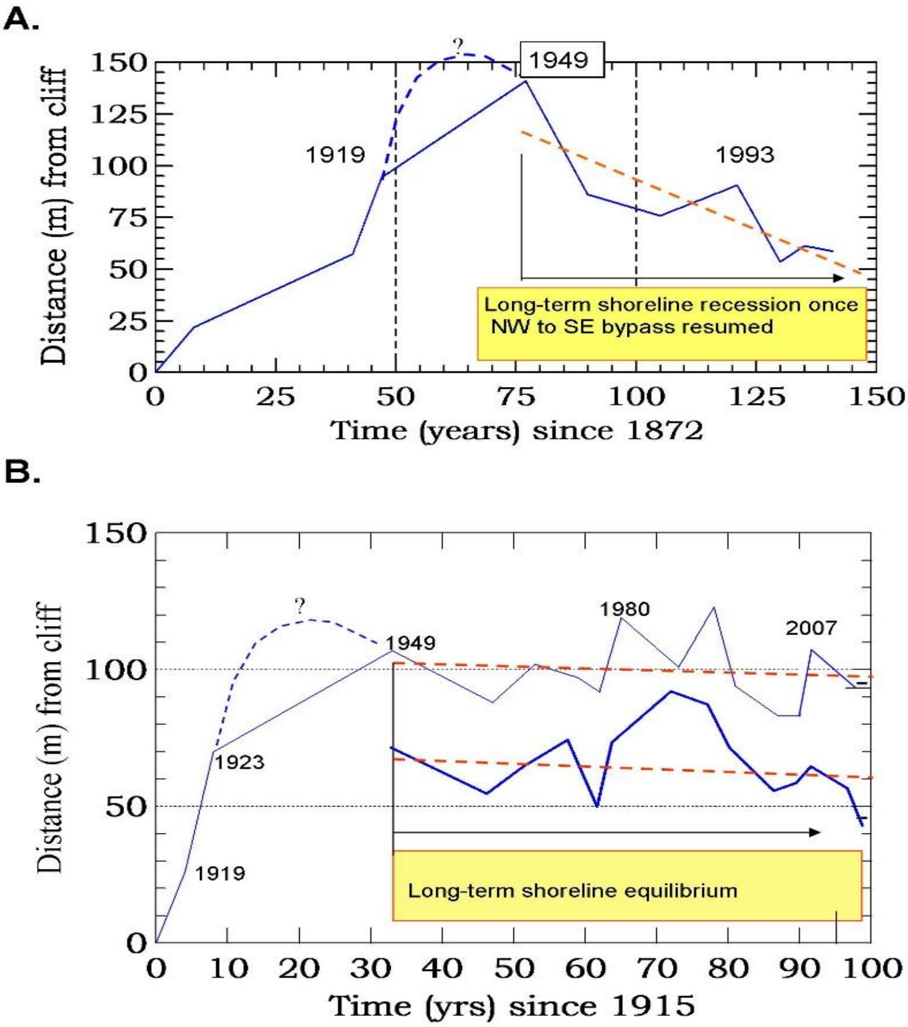
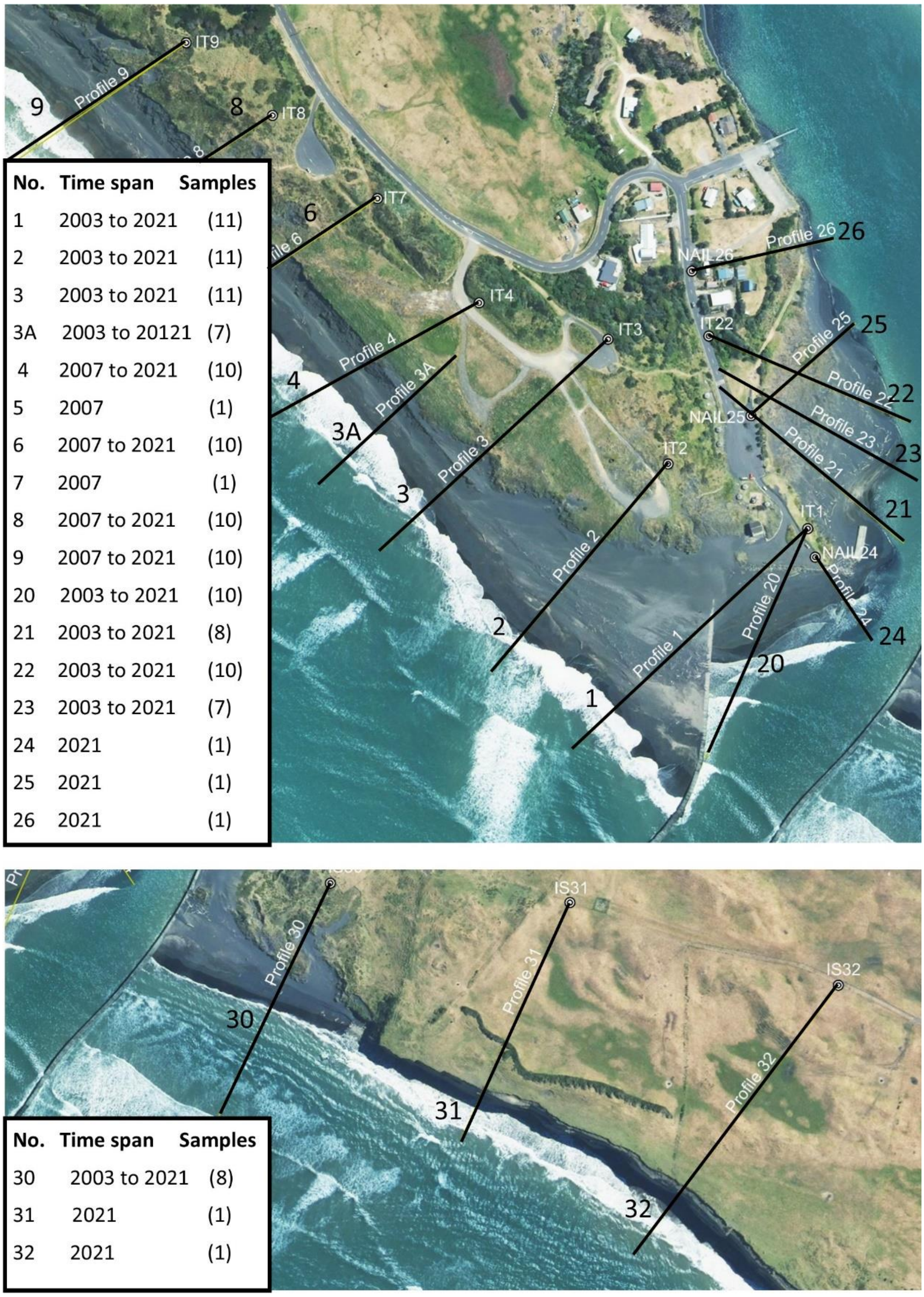


Figure 4.3 Shoreline responses to the rivermouth moles. The upper graph depicts the South Beach transect 100 m SE of the South Mole (approximating Transect 30 in Figure 4.4). The lower graph shows North Beach transects 250 m northwest of the North Mole (thin line) which is mid Transect 2 and 3, and 700 m to the northwest (bold line) which is mid Transect 8 and 9. From CSL (2015)



No.	Time span	Samples
1	2003 to 2021	(11)
2	2003 to 2021	(11)
3	2003 to 2021	(11)
3A	2003 to 20121	(7)
4	2007 to 2021	(10)
5	2007	(1)
6	2007 to 2021	(10)
7	2007	(1)
8	2007 to 2021	(10)
9	2007 to 2021	(10)
20	2003 to 2021	(10)
21	2003 to 2021	(8)
22	2003 to 2021	(10)
23	2003 to 2021	(7)
24	2021	(1)
25	2021	(1)
26	2021	(1)

No.	Time span	Samples
30	2003 to 2021	(8)
31	2021	(1)
32	2021	(1)

Figure 4.4 Transect locations for TPL profile surveys. Sampling histories also provided

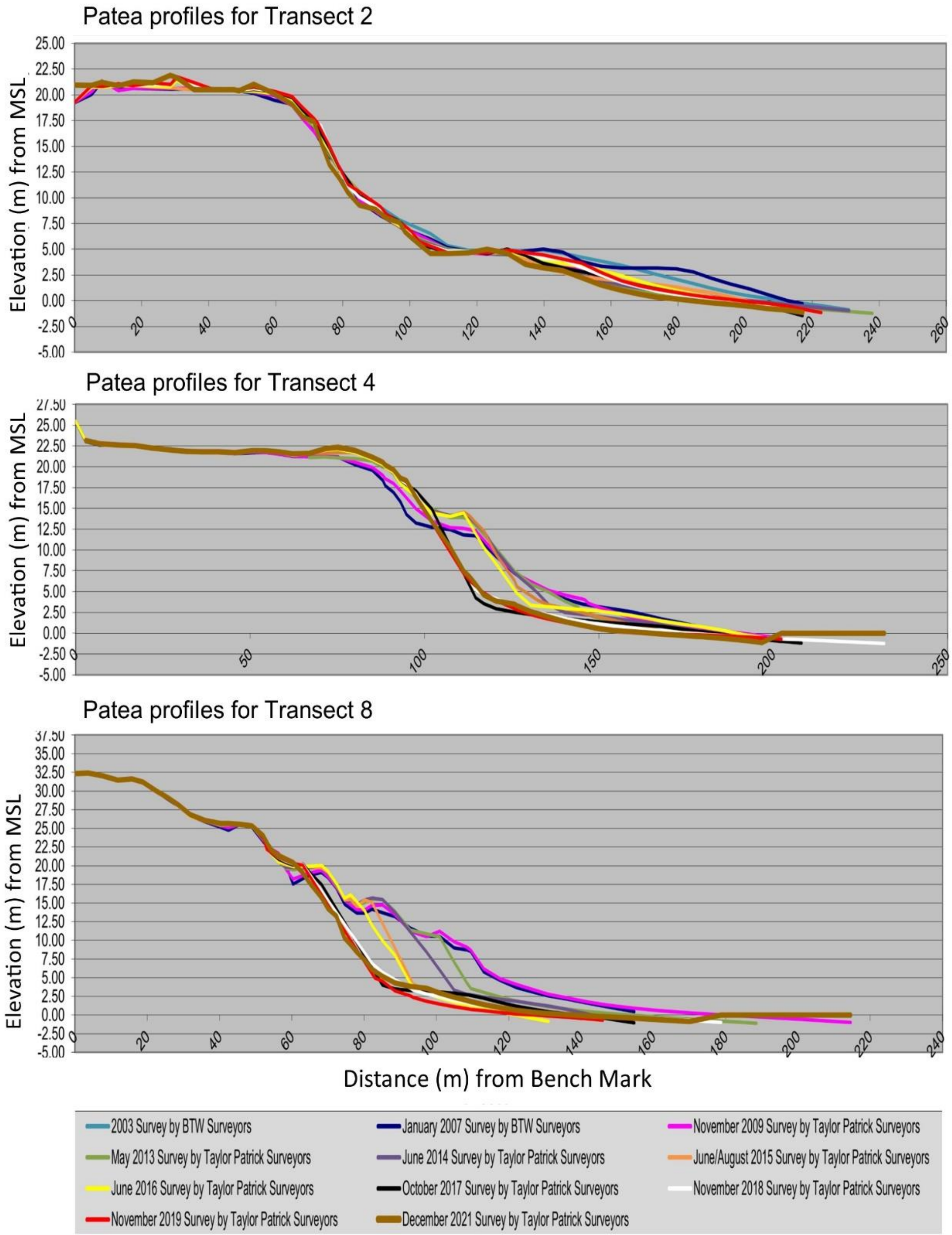


Figure 4.5 Superimposed profiles for transects 2, 4 and 8 along the northern coast.

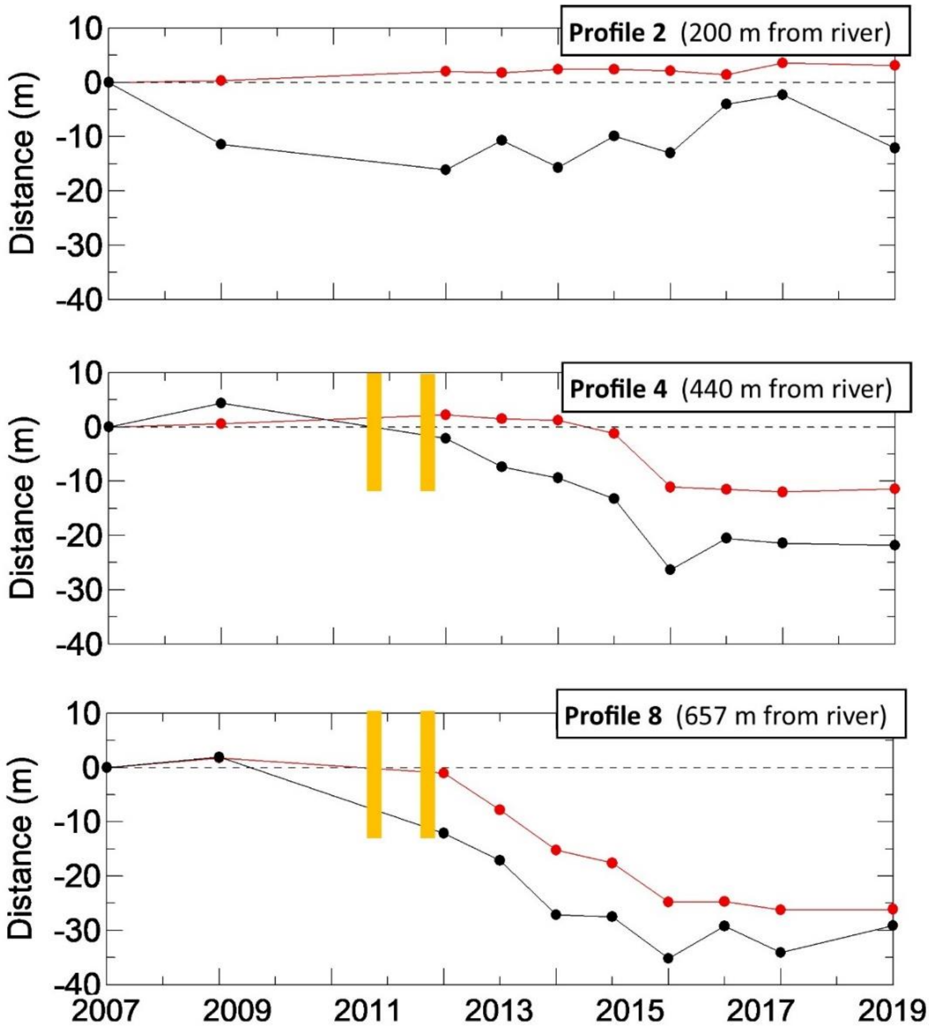


Figure 4.6 Time-series for Transects 2, 4 and 8 along the northern coast. **Positive values=accretion, Negative values=erosion** The dune toe (MSL +4m) is represented by **black line** and mid/upper foredune face (MSL +10 m) by the **red line.** The vertical **orange bars** mark initial observations of foredune erosion in October 2010 and June 2011. Source: CSL (2022)

4.2.2 Inlet

Previously established transects within the estuary (T20 and 22) were to track potential consequences of the shoreline/dune erosion episode on the north coast, this being for the Patea Sand Management Programme. Transect 21 and 23 were subsequently added as the Carlyle Bay transect (T22) was under threat of river erosion – however, it has survived. The three additional transects (24, 25 and 26) are to provide additional coverage required by the new measurement-based monitoring regime for coastal structures. All profiles are displayed/superimposed in Figure 4.7. Of particular note is the erosive effect of a severe flood in 2015 which lowered the bed some 1.5 m at T20 in Manu Bay and 2 m upstream at T22.

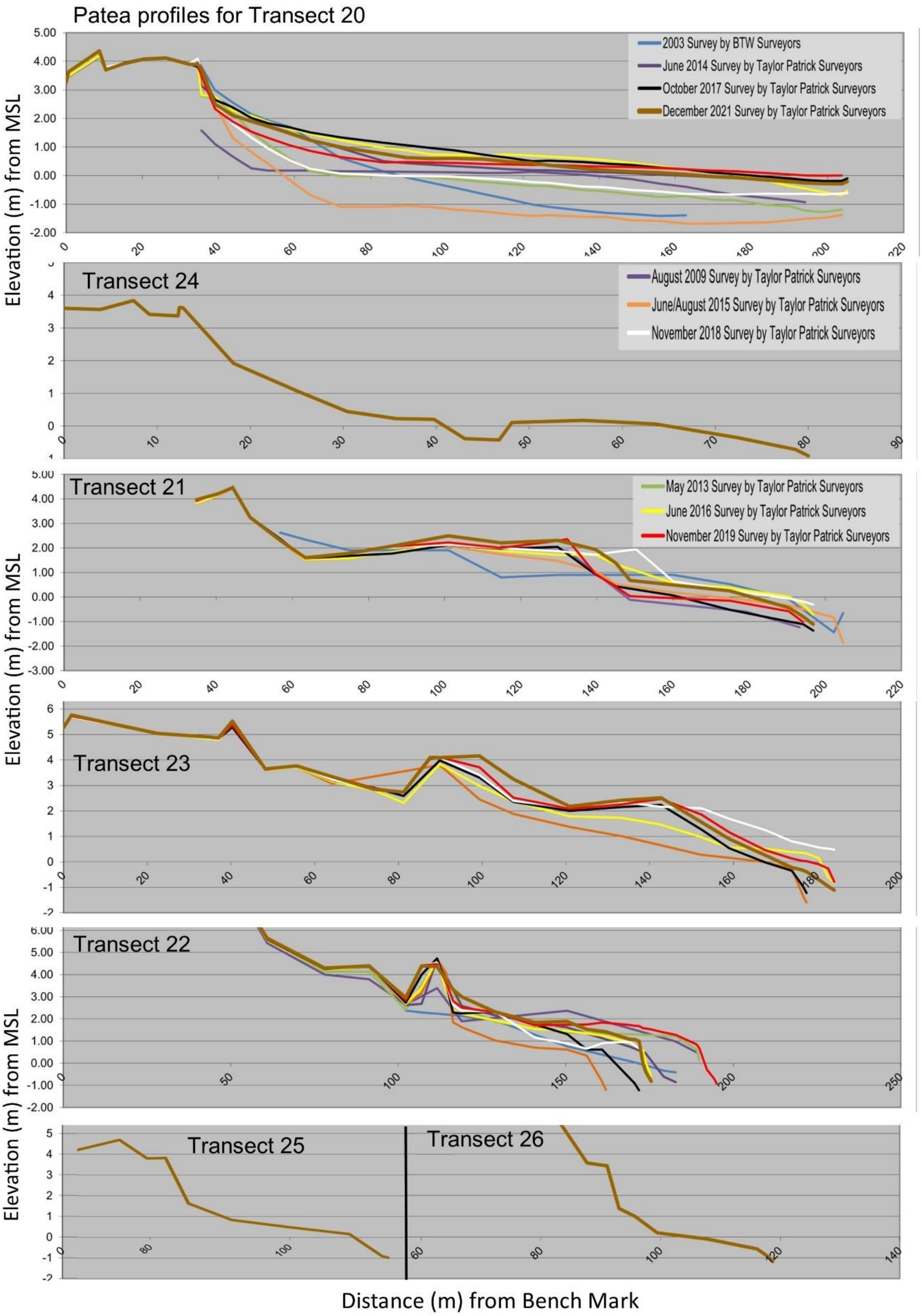


Figure 4.7 Superimposed profiles for inlet Transects 20 at top of figure to 26 at base). Note (irregular) transect numbering follows order of establishment.

Time-series for the MSL +1 m elevation for T20, 21 23 and 22 (in order moving upstream) are shown in Figure 4.8. All sites contain samples from 2015 to the present and the associated regression models are shown in the graphs by the bold red lines. The average rate of change is also marked and shows shoreline accretion at all sites with the rate increasing systematically upstream from 0.52 m/y at T20 up to 7.5 m/y at T22.

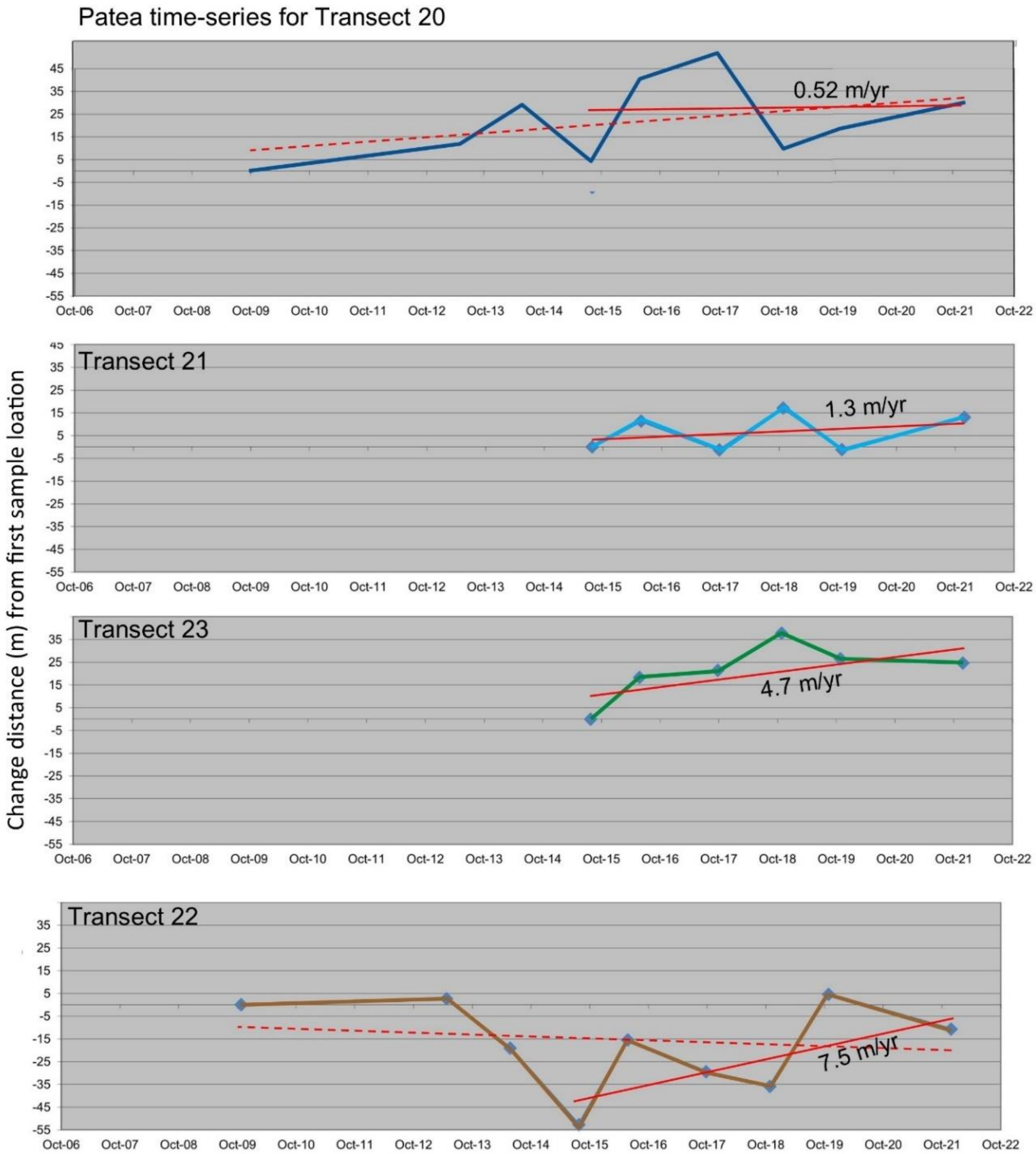


Figure 4.8 Time-series for inlet Transects 20 to 23. Top graph (T20) is nearest mouth and T22 at base is furthermost upstream (NB transect locations shown in Figure 4.4). Regression models have been fitted to the 2015 to 2021 data common to all sites (bold red line), and to the 2009 to 2021 data available for T2 and T22 (red dashed line).

The T20 and T22 records extend back to 2009 and each contains the impact of the 2015 flood event. The effect of that flood on regression modelling at T22 is particularly notable and illustrate the need for long data sets to remove the distorting effect of shorter-term responses contaminating underlying morphological (signal) change. However, making allowance for the 2015 flood, the T20 time series shows a sustained sediment build-up between 2013 and 2017 which corresponds to the north coast shoreline erosion episode. The upriver sites provide an indication that some of this sediment has been transported upstream, this is discussed further in Section 4.4 and illustrate the dynamic nature of the shoreline on the seaward side of point bar.

4.2.3 South coast

Transect 30 (~100 m beyond the South Mole) was established in 2014 as part of the Patea Sand Management monitoring programme to track potential down-drift consequences of the erosion episode affecting the north coast. In addition, the TRC required two additional transects to satisfy measurement-based monitoring requirements, i.e. to cover 500 m of coast from the South Mole. Transect 31 at approximately 290 m from the South Mole, and T32 at approximates 470 m, were surveyed in December 2021 for the first time. The full set of profiles for T30 along with the 2021 profiles for T31 and T32 are shown in Figure 4.9, and the time-series elevations for MSL+1 m, 4.5m and 10 m for T30 are shown in Figure 4.10.

The upper tidal data (MSL +1m) in the T30 time-series graph continues to show a deficit of sediment relative to the 2015 start point with some possible recovery marked with the asterisk in Figure 4.10). The T30 time-series sediment wave in 2018/19 is very similar in form to the inlet time-series wave for T20 albeit lagging by about 2 years. This suggests (some) north to south travelling littoral sediment is diverted into the inlet before (some) being flushed seaward under higher river flow and ebb tidal flow – a process referred to as “inlet bypassing”. Littoral sediment is also likely to cross the rivermouth directly – a process referred to as “bar bypassing”. South Beach shoreline behaviour, and the ongoing deficit is discussed further in conjunction with the bathymetric monitoring output (Section 4.4).

The dune toe (MSL +4 m) change correlates with the upper beach (MSL+1m curve), albeit being considerably subdued as the 4 m level is affected by the less energetic aeolian processes c.f. wave processes. These MSL+4m data depict an erosive trend of 0.61 m/yr (using a linear regression model). The upper dune (MSL +10 m) is essentially stable reflecting a lack of available sand for dune development.

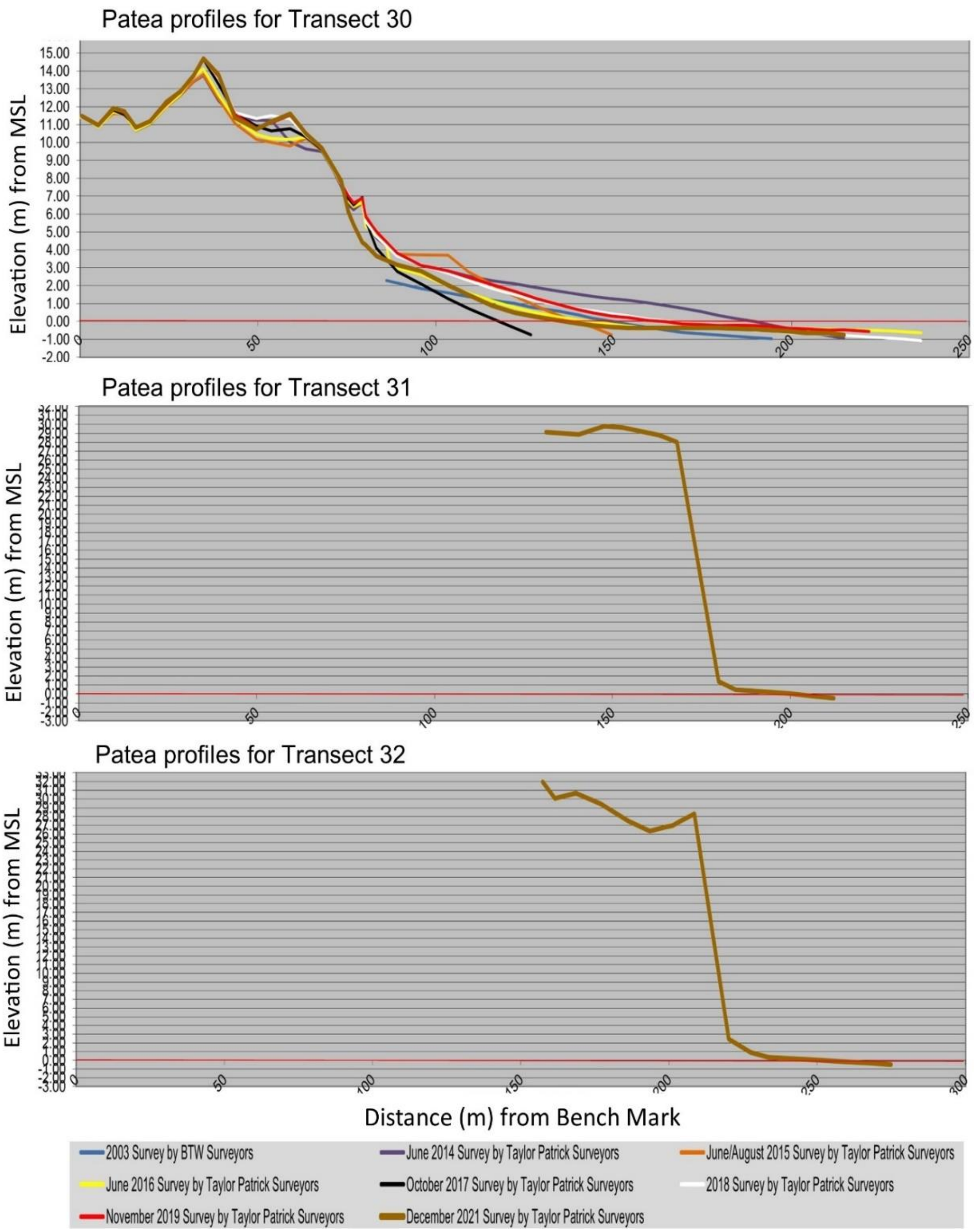


Figure 4.9 South coast superimposed profiles for Transect 30 (top) and the 2021 profiles for new Transects 31 and 32 below.

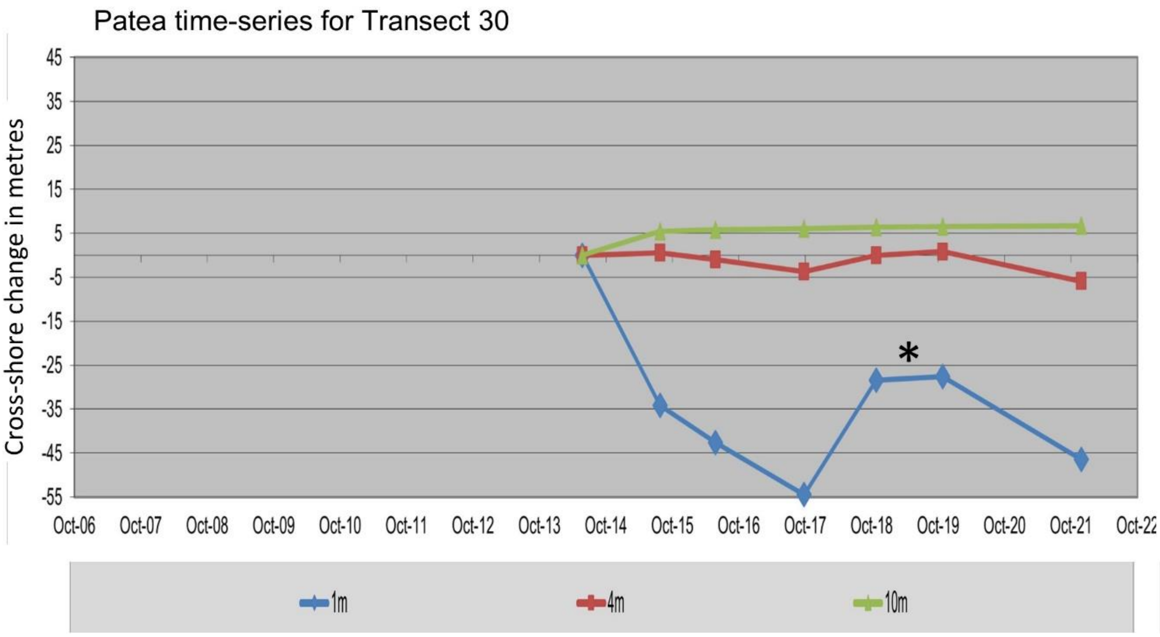


Figure 4.10 Time-series for Transect 30 on the southern coast. Positive values=accretion, Negative values=erosion. MSL+1m represents the upper tidal beach, 4 m the dune toe and 10 m the upper dune. The asterisk marks sediment wave discussed in test.

4.3 Aerial surveys

Landpro flew the Patea rivermouth area on 14 January, 2022 under optimal tidal (spring low) and light (clear sky and high sun) conditions, and captured high resolution vertical photographs and LIDAR. Coverage extended 2 km along the northwestern coast from the rivermouth, 1.5 km up the river and (generously) 3.4 km along the southern coast which included the Whenuakura Rivermouth. Sections of the vertical aerial ortho photo are reproduced in Figure 4.11. The ground survey transects are marked along with the 1 m contour line (derived from the LIDAR) within the inlet, as well as the vegetation line fronting sand dunes along the open coast, and the base of the cliff to the southeast. The following comparative historical data are also shown in Figure 4.11: the 2003 BTW 1 m contour within the inlet and the vegetation line and cliff base derived from 2007 aerial ortho photography by New Zealand Aerial Mapping Ltd.

The uppermost photo in Figure 4.11 shows how cross-shore erosion (based on the vegetation-front) along the northern coast stops closer to the rivermouth where the foredune is set back from the beach and hence unaffected by storm waves. The 2022 vegetation line also shows substantial alongshore variation; in the centre/northwest this is associated with slope adjustment processes affecting the erosion scarp. Closer to the river the variation results from wind processes – funnelling through low areas of the dune crest to create a gut (blowout) with sand then burying vegetation as it drifts inland. These processes are described in the CSL annual Patea Beach sand management reports along with associated sand stabilisation works.

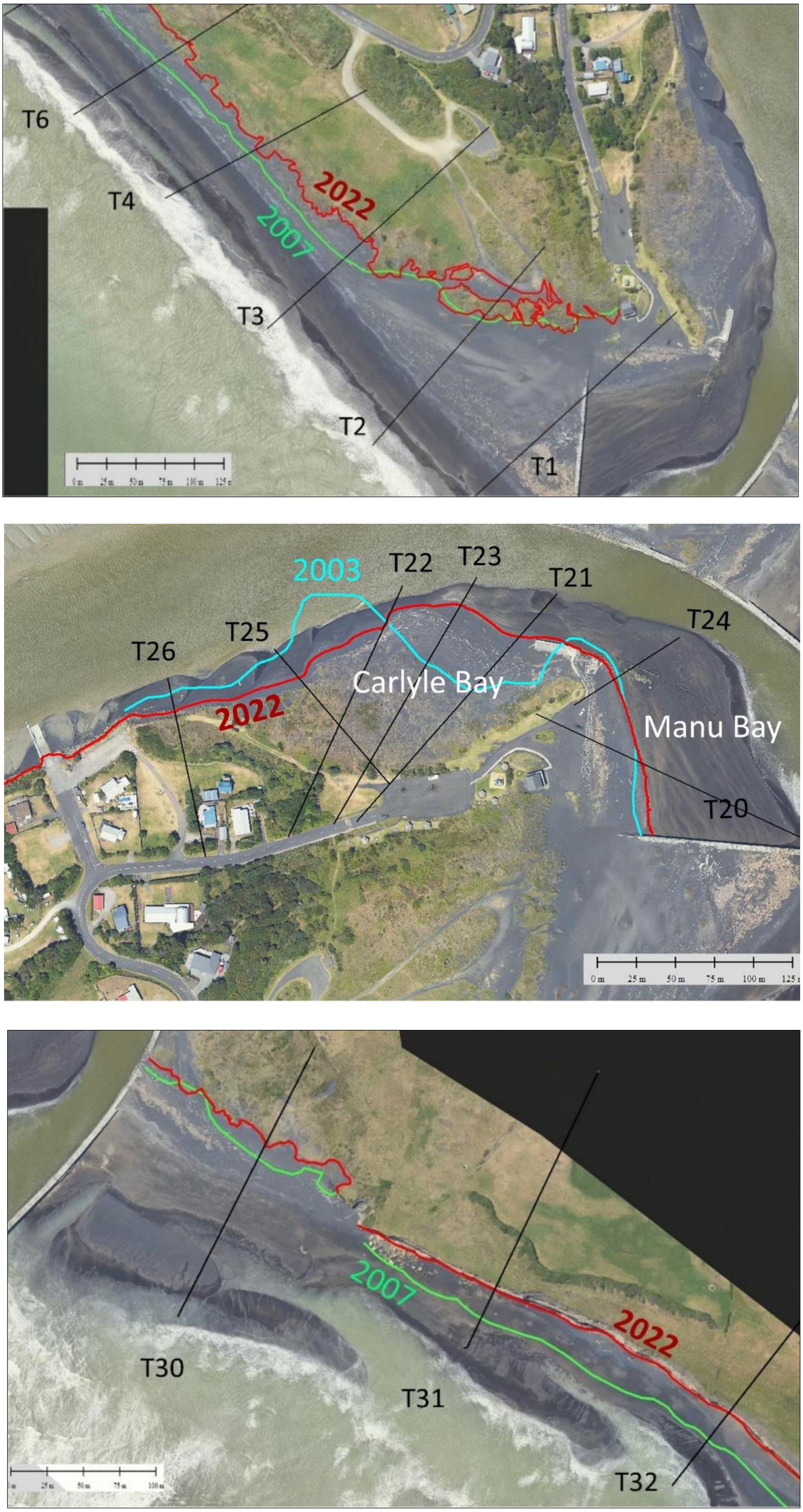


Figure 4.11 Sections of the Landpro 2022 aerial orthographic vertical photography with north beach at top, inlet in centre and south beach at the bottom. Open coast shorelines are marked based on the sand dune vegetation-front and cliff base. Within the inlet the 1 m (LIDAR-based) contour is marked. In addition, the vegetation-front and cliff base from the 2007 ortho photo and the 1m contour from the 2003 BTW survey are shown. Patea profile transects are also marked for reference.

Within the inlet (central photo) the 2003 MSL+1m contour shows a well-defined indentation marking Carlyle Bay and the protruding point bar upstream. By comparison, the current 1 m contour shows the shoreline south of the boat ramp structures to have receded, the point bar to have shifted some 60 m downstream, and the Carlyle Bay indentation has all but disappeared.   These contour data more accurately define the changes noted earlier in Figure 4.1. The transect locations for T20 to T26 can be seen to adequately capture the shoreline behaviour within the inlet.

A foredune extends from the South Mole southward for some 155m where it adjoins the 30 m high cliff which then extends for several hundred metres downcoast. The 2007 and 2022 vegetation lines show the sand dune is relatively stable closer to the mole but has eroded up to 20 m thereafter. The cliff is characterised by erosion along its entire length – in places having retreated up to 30 m since 2007. The three transect locations can be seen to well-represent the shoreline behaviour.

4.4 Hydrographic survey

Fugro Ltd carried out a multibeam sonar survey of the inlet and rivermouth on 18 January and 1 February 2022. The offshore area was not completed.   The mole ends are particularly difficult to survey due to wave surge even on relatively calm days. Daily river flow fluctuation from the Patea hydro dam limit surveying to January-March when minimal operation occurs. Nonetheless, high-resolution bathymetric output was obtained (Figure 4.12). Of particular note is the relative increase in depth along the south side of the channel opposite Carlyle Bay (marked A), the shallows fronting Manu Bay (marked B), and the channel's southerly offset seaward from the mouth as it cuts through the coastal sand bar (marked C).

The 2003, BTW contoured bathymetry is reproduced as Figure 4.13 and the difference surface between 2003 and 2022 is shown in Figure 4.14. Because the 2003 survey used single side beam sonar and coarse spacing, a raster image was first generated by interpolating over 5 square metres. While the resulting difference-surface has coarse resolution and limited coverage on the settlement side of the river, it none-the-less enables broad change of the riverbed and seabed over this 19 year period to be identified.

The following assessment focuses on vertical bed-level change greater then +/- 0.5 m as this is more likely to contain a signal rather than responses to shorter-term energy and/or sediment variation.   Indicated processes and structure interactions are incorporated with the following description.

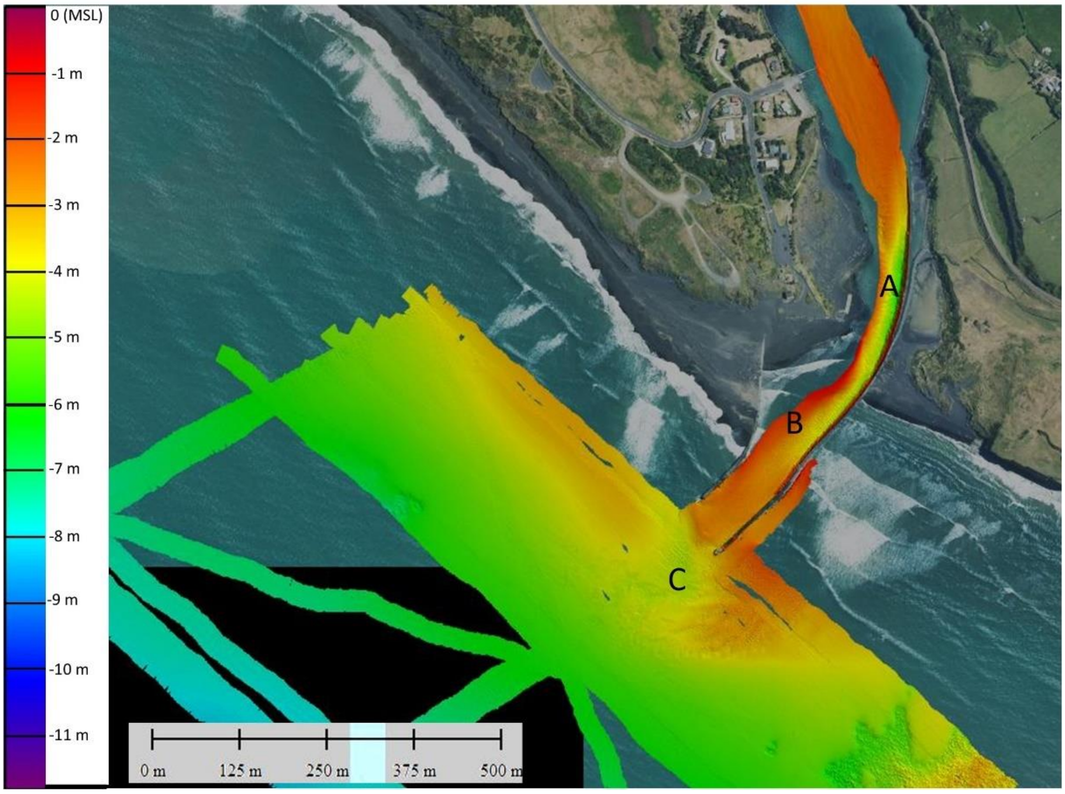


Figure 4.12 Fugro's January 2022 multibeam sonar survey extent and output. A B and C locate features described in the text.

Deepening

Beginning at the upstream end of the difference output (upper image) in Figure 4.14, riverbed deepening is indicated (marked) on the northwest (beach village) side of the channel beginning from the boat ramp and launching jetty. The large wave-like bedforms along the intertidal area immediately downstream of the jetty/bank-protection in the Landpro aerial photo underlying the bathymetric change, are a product of very high flow which is consistent with the deepening indicated by the bathymetric change. Such deepening along the northwestern side of the channel to the point bar is also consistent with shoreline retreat depicted by the 1 m contour in Figure 4.11 and this erosion would explain the observed seaward movement of the point bar.

Given that these structures were placed following the initial 2003 survey (boat ramp extension 2002 to 2005 and jetty 2009), given also that adjacent bank erosion appears to have been exacerbated by the structure effects and the bank was then protected with boulders, and furthermore, given that such bank erosion and channel deepening conceptually/theoretically occur down-stream of such structures, the possibility of this environmental change being a response to the structures is certainly plausible.

Channel deepening then appears on the opposite side of the river, adjacent to the raised training wall where a sustained excavation depth of 2 m occurs (marked). Deepening continues along the South Mole, with a local 2 m maximum some 170 in from the mole

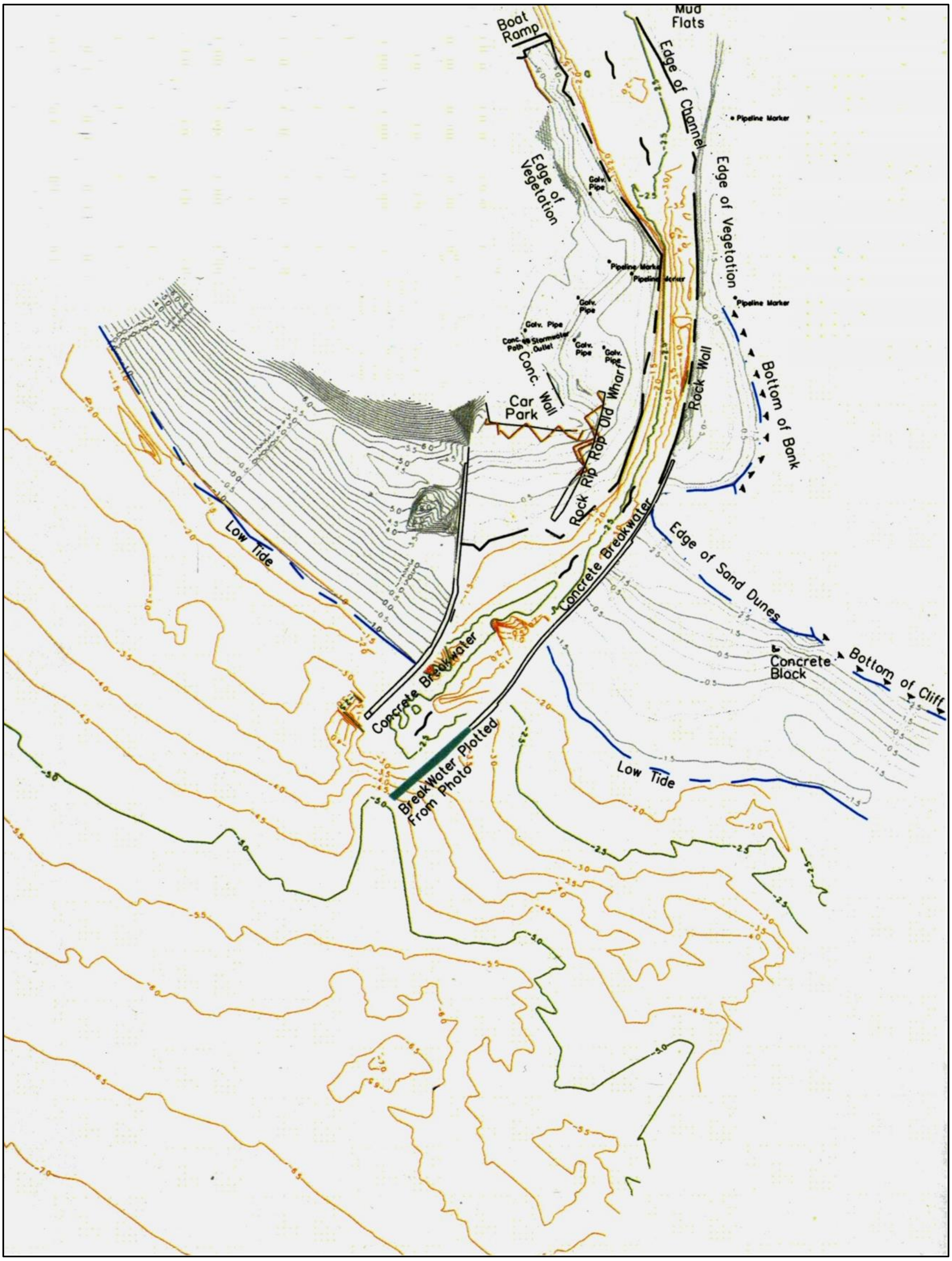


Figure 4.13 Contoured output of BTW's March 2003 survey. Source Duffill, Watts and King (2003).

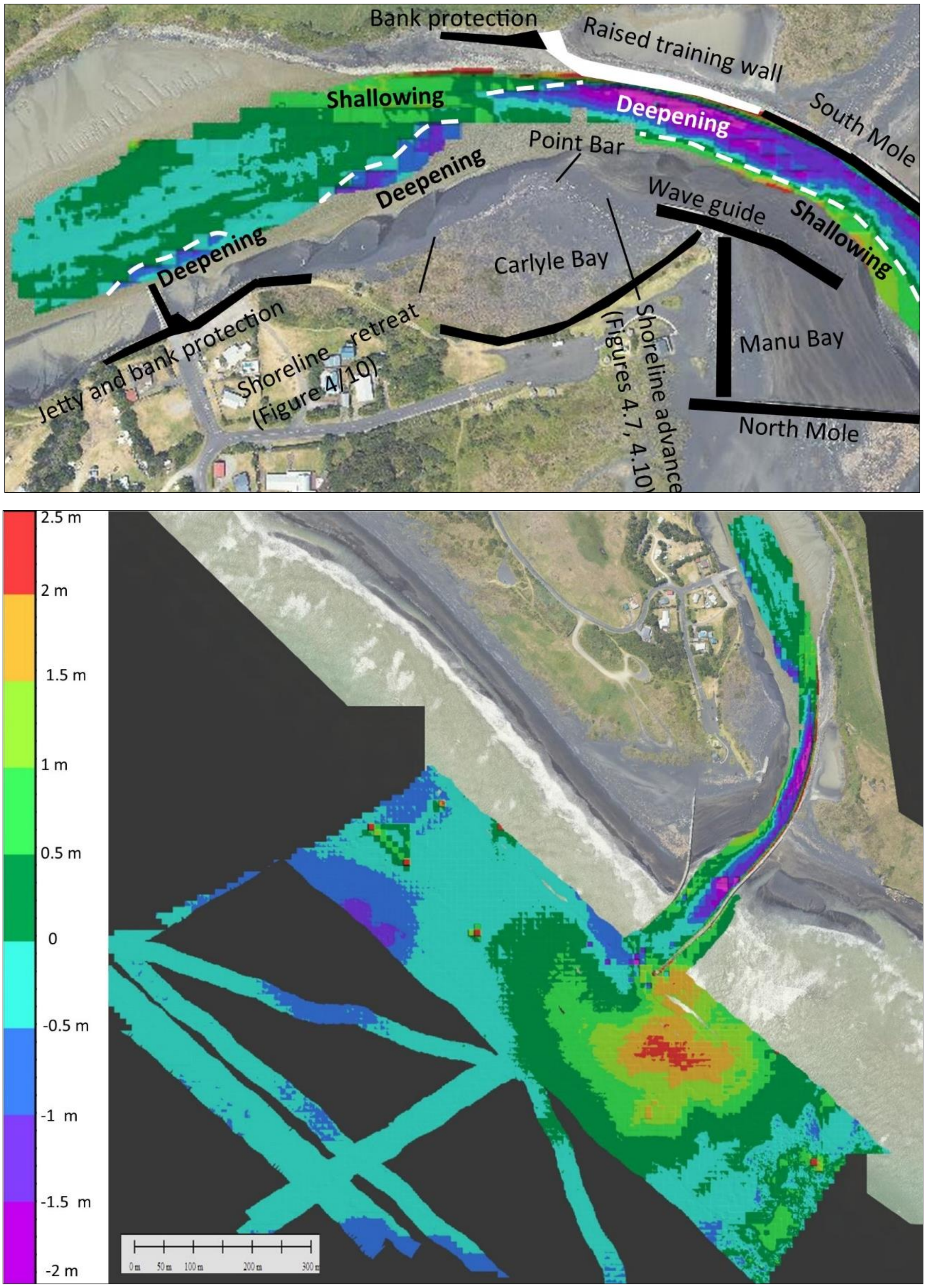


Figure 4.14 Bathymetric difference surface between the 2003 and 2022 surveys. Negative values (cyan to magenta) indicate deepening while positive values (green to red) indicate shallowing.

end (Figure 4.14 lower image) before trailing off closer to the mole ends. Such intense deepening along the raised training wall (constructed in 2006/7) and its continuance (albeit less intense) along the South Mole supports a cause and effect process. In particular, the heightened training wall concentrates flood flows which had previously been able to dissipate energy across mudflats beyond the original half tide wall. Such bed lowering adjacent to these structures could impact structural integrity and should be a focus of future monitoring.

Shallowing

Again beginning upstream in Figure 4.13 (upper image), shallowing is evident on the left (east) side of the river (marked), possibly a result of channel realignment into the adjacent deepened locations up and downstream .

Shallowing is also evident along the northwestern side of the channel at Manu Bay and the wave guide wall (marked). The available intertidal profile record (Figure 4.8) has a deposition trend consistent with the bathymetric change. The deepened channel along the raised training wall and South Mole could facilitate such sedimentation by focusing river and tidal flows away from the northwestern side of the river which then encourages sedimentation in the more sheltered bays. The increase in depth along the southeastern side of the river would also allow for an increase in wave penetration, as evidenced by the subsequent bank protection (marked) along the riverbank immediately upstream of the raised training wall. Such an increase in wave energy assists the transport of littoral sediment into and within the inlet – transport that appears to extend as far as the point bar. The increase in wave transport potential would have enabled more of the sediment released by the episode of northern dune erosion to be carried into the inlet.

While the offshore hydrographic survey is incomplete, the difference surface does show substantial deposition south of the mole ends (Figure 4.14 lower image). The southern offset is consistent with the net currents controlling the entrance channel configuration; this same situation occurs at the nearby Whanganui Rivermouth which has been investigated using extensive Harbour Board bathymetric data (Shand, 1990).

The shoal itself could incorporate natural fluctuations and/or be a product of the sustained episode of north beach dune erosion reaching this area by bar bypass, inlet bypass, and/or sediment sourced from scour fronting the raised training wall/South Mole. Such an offshore accumulation is unlikely to affect north coast or inlet processes, but could modify wave processes and the increase in erosion along the south beach as defined by the profile data in Figure 4.10. However, once sediment reaches the beach under wave transport processes, as the wave and bar pattern in Figures 4.12 and 4.14 indicate is underway, shoreline erosion should lessen.

4.5. BECA structure inspections

On the 24 and 25 November, BECA inspected the engineering structures about the Patea Inlet, assessed their condition and recommending remedial maintenance. The various structures are marked above in Figures 4.1 and/or 4.14.

North Mole
Condition ranged from fair at the landward end, poor along the central section to critical at the seaward end. High priority maintenance consisted of filling voids, repairing broken concrete and replacing missing concrete blocks at the end of the mole.

South Mole
Condition ranged from serious at the landward end where blocks were observed to be rotating into the river, poor in the central section, to serious at the seaward end with block damage and erosion. High priority maintenance consisted of filling of voids with concrete and investigating the below-water condition of the rotating blocks. The Fugro bathymetry did not help the underwater condition assessment.

We (CSL) note that comparing photographs taken in 2005 and 2022 (Figure 5.1), indicate the blocks have maintained their positions and orientations during this time period suggesting the structure is stable despite the bed lowering as described earlier in Section 4.4 and Figure 4.14. However, the bed-level change spans 17 years and there is no intermediate data on how the change occurred (systematic or episodic), or the extent of shorter-term process-response (bed-level fluctuations). The monitoring regime needs to be intensified in this area with more regular riverbed surveying and structure stability surveying – perhaps using “pins” coupled with drone surveys.

Wave guide wall
Condition of the upstream rock armour section of wall is rated as poor, while the down stream timber pile section is dilapidated, not fit for purpose, and rated critical. BECA recommend removing the timber piles and, at lower priority, increase the crest height of the rock wall section.

Mana Bay rock revetment
Condition is rated as fair. High priority recommendation is to place additional rock at the northern end which has a low profile and erosion appeared to be occurring.

Carlyle Bay rock protection wall
Much of the structure is buried preventing condition assessment.

Raised stone training wall
Condition is satisfactory with no maintenance requirement.

Boat ramp
Condition is fair with no high priority maintenance requirement

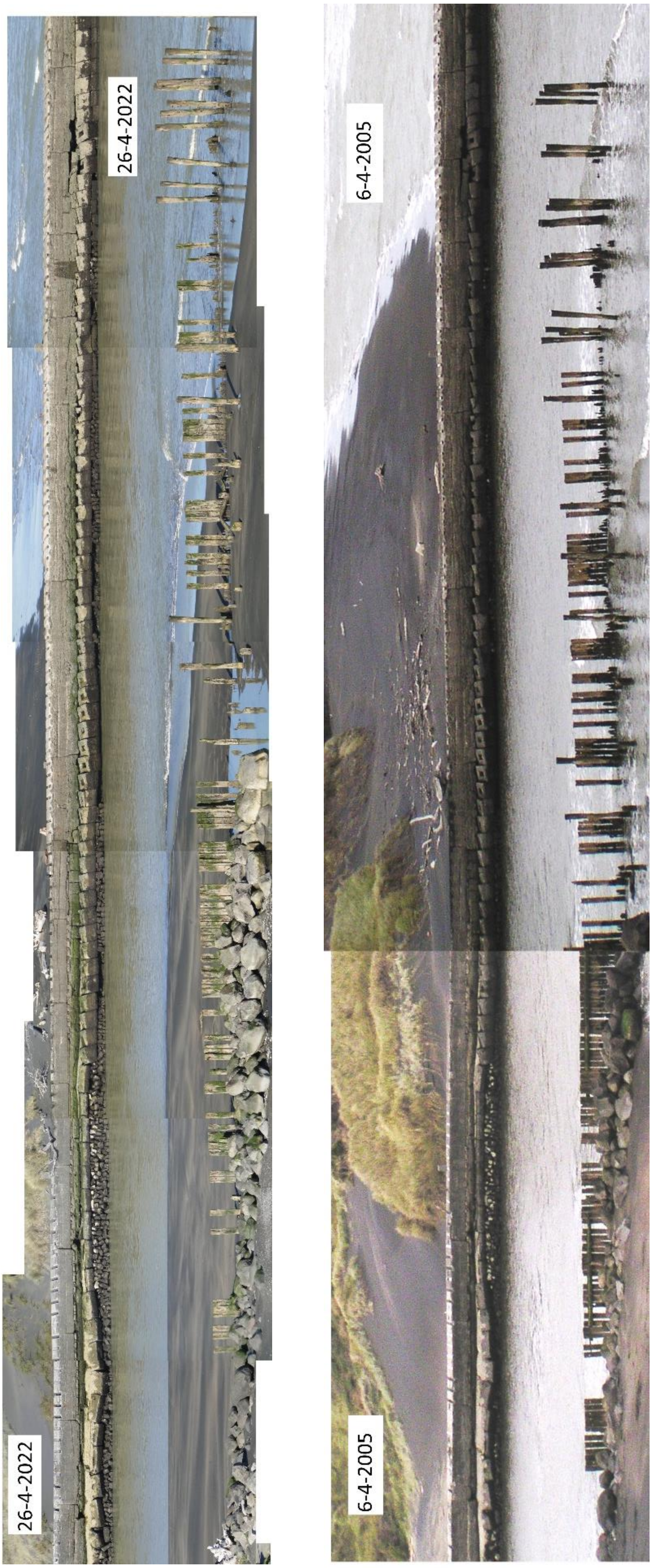


Figure 5.1 Patea South Mole rotating block comparison 2005 cf 2022. Photos from CSL

<u>Boulder bank protection wall upstream of boat ramp</u>
Condition rating as fair with no maintenance required

<u>Boulder protection wall downstream boat ramp</u>
Overall condition is fair, but coverage is inadequate in places enabling bank erosion and remedial work is recommended but at a lower priority.

4.5. Consent compliance assessment

Coastal permit 4566

STDC holds coastal permit 4566-2 to occupy coastal space with a boat ramp and jetty. This consent also covers bank protection to each side of this structure. It is unclear when the first consent was issued, but it expired on 1 June 2010. The current consent was issued thereafter with lessened special conditions as "the existing boat ramp and jetty did not restrict the flow of the Patea River". There are now three special conditions with the most significant being that the consent holder shall maintain the structure in a safe and sound condition so that it continues to function effectively

The BECA inspection found that the structures in fair condition other than the bank protection being somewhat ineffective at the southern end.

Measurement-based monitoring described earlier in the present report (Section 4.3 and 4.4) demonstrated that the riverbed had deepened at, and downstream of, the jetty/boat ramp/bank protection structures, and that the shoreline between these structures and the point bar had receded significantly. Indeed, the natural gas pipeline is more vulnerable as it is no longer protected by the point bar. It is noted that when the pipeline was laid it was within Carlyle embayment, and in some earlier reports Carlyle Bay is referred to as Pipeline Bay. Section 4.4 concludes that "the possibility of such environmental change being a response to the structures is certainly plausible".

Coastal permit 4573

STDC holds coastal permit 4573-2 to occupy the coastal marine area of the Patea River mouth with the following existing structures:
• West and South Moles;
• Mana Bay Seawall;
• Wave Guide Wall;
• Carlyle Beach Rock Protection Works, and
• Rock Training Wall.

This consent was first issued in 1996 and reissued in June 2016 with an expiry date of 2034. There are three special conditions the most significant is Condition 2 which requires the consent holder to maintain the structure in a safe and sound state so that it continues to function effectively for its intended purpose.

The moles are the major control on the inlet and beaches and Figures 4.1 and $.3 suggest that the shoreline response was essentially complete by the 1950s (Figures 4.1 and 4.2); however, sand dune formation continued for many years. The Mana seawall and adjacent wave guide wall were designed to provide a wave energy spending beach. The profile analysis (Figure 4.8) suggests the beach is approximately in equilibrium with the accretional trend possibly a result of the episode of dune erosion on the north beach providing a sediment influx. Lack of historical data mean that the sedimentation response to the wave guide wall falling into disrepair is uncertain; however, the 1905 low tide line marked in Figure 4.1 indicates the guide wall's length controlled the seaward extent of the beach. The loss of the sheltered and popular Carlyle Bay and its infill with sand dunes appears to be related to hydrodynamic process and sedimentation changes from structures within and upstream of the inlet.

Coastal permit 6839

STDC holds coastal permit 6839-1 to reinstate approximately 160 metres of the Patea River training wall for river protection purposes on the true left bank of the Patea River mouth. This consent was issued in 2006 and the structure completed soon after.

While the consent allowed for reinstating the existing structure, the protection works consisted of raising the half tide training wall by over 2 m to the same height of the South Mole. This is a modification that goes beyond reinstatement and had the potential to influence the river hydrodynamics and sedimentation regime.

Analysis of existing data in Sections 4.2 to 4.4 indicate a range of environmental effectssuch as deepening fo the adjacent river channel by 2 m and the deepening extending along the South Mole. Increased wave penetration required rock protection along the bank immediately upstream of the structure. It is also likely the increase in wave penetration caused an increase in littoral sediment entering the inlet and reaching the remnant of Carlyle Bay where it provides a sediment source for dune growth. It is noted that continual sand dune growth within such a confined setting can lead to future values and management issues.

Channel deepening may also be associated with supplying sediment to the extensive offshore shoal, which, as noted in Section 4.2, may (temporarily) deprive the South beach of sediment and enhance shoreline erosion.

5 CONCLUSIONS

This report summarises the initial round of measurement-based monitoring for major coastal structures on the South Taranaki Coast now required by the resource consent issuing body, the Taranaki Regional Council. Four types of monitoring have been used: ground surveys, aerial/LIDAR surveys, hydrographic surveys and visual inspections. The frequency of each type of monitoring depends on the structure involved, its environmental setting and whether it for defining shorter or longer-term change (see Table 1.2).

Profile (ground) surveys are the most frequently used approach and the aerial and bathymetric output show the transect (the line of surveying to produce the profile) spacing adequately detects morphological/change. Future results will show whether some transects are redundant. The possibility of using 3D output from drone photography to abstract the profile data will also need to be considered given improvements in accuracy, potential cost savings and the increased information available in 3D surface output.

Incorporation of equivalent historical data has enabled some background change to be identified. In particular, profiling had been carried out in Middleton and Opunaki Bays from 2019 (as part of the STDC environmental monitoring programme) and also the Howard and Bland Ltd contour survey of Middleton in 2010. At Patea, the BTW survey from 2003 provides base data for terrestrial, intertidal and subtidal change. Repeat profile surveys are also available at Patea for some sites on both the open coast and within the inlet – these data have been collected since 2007 as part of the Green Waste Discharge consent and the Patea Sand Management Programme. Some historical aerial photography has also been utilised. In addition, CSL reports from 2019, 2020, and 2021a investigated the processes operating at Ōpunakē, Middleton and Patea respectively and these are useful in interpreting monitoring results.

At Middleton Bay, profile change shows instability close to the northwestern terminus of the boulder revetment; this could be related to recent structure modifications. The programmed Fugro bathymetric survey has not yet been carried out.

In Ōpunakē Bay, profile analysis shows shoreline advance is now occurring at the southern end of the Bay which appears to be related to non-operation of the power station tail race. This is a new behaviour which will detrimentally affect drainage in the recreation area to the rear if not corrected. The programmed Fugro bathymetric survey has not yet been carried out.

On the Patea open coast, profile analysis shows the episode of foredune erosion along the northern beach (beginning in 2010-11) appears to have ceased. Bathymetric change indicate that some of the eroded sediment may lie in a large shoal off the South Mole.

This shoal may be temporarily reducing the sediment supply to the southern beach where shoreline erosion is evident in recent profile data and aerial photo analysis.

Within the Patea inlet, bathymetric change (Figure 4.14), shows deepening (2 m) along the raised (2 m) river training wall and deepening extending along the South Mole. A causal relationship between wall height and scour is likely. The deepened channel appears to have resulted in greater wave penetration which caused bank erosion immediately upstream of the training wall. In addition, profile and bathymetric change show deposition has occurred along the village side of the channel from Manu Bay, along the wave guide wall and to Carlyle Bay frontage where sediment has infilled the bay and is available for dune growth. This process may also result from the increase in wave penetration.

Change evident in profile, aerial and bathymetric surveys is strongly suggestive that the boat ramp extension, launching jetty and associated bank protection have caused shoreline retreat immediately downstream; this has made the natural gas pipeline more vulnerable to erosion and also further reduced the river frontage of Carlyle Bay.

BECA's coastal structure condition survey stressed the urgent need for protection works on the mole ends and investigation of concrete block misorientation along the South Mole. We (CSL) provided photographic evidence (Figure 5.1) that the structure has been stable since at least 2005, but given the channel deepening in this area we recommend more frequent riverbed and mole surface monitoring be carried out along the raised training wall and the rotated block section.

In addition, BECA addressed the state of the wave guide wall and recommended that the landward rock section be raised to protect the public jetty (at its upstream end), and that the delipidated wooden pile section (at the downstream end) be removed. We (CSL) believe the fate of the training wall requires further consideration. Given the loss of what was a much-valued recreational beach in Carlyle Bay (Figure 4.2), at least in part due to the environmental effects of various structures within the inlet, maximising the recreational potential of Manu Bay would be desirable. Careful "reinstatement" of the wave guide wall could result in a safer bathing area and create a permanent mid to high tide beach compared with the present lower tide and somewhat hazardous beach. The Manu seawall (boulder revetment) would be buried becoming a "backstop seawall" operational only at times of severe sediment depletion. This initiative would also go some way to addressing possible impacts of climate change which could further degrade the present utility. CSL recommends structure design for recreational optimisation be carried out before any decision is made regarding the removal or raising of the existing wave guide wall.

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APPENDICES

APPENDIX A TPL ground surveys (separate file)

APPENDIX B Landpro Ltd aerial surveys (separate file)

APPENDIX C Hydrographic surveys (separate file)

APPENDIX D BECA structure inspections (separate file)

APPENDIX E STDC Officer comment on actions/planned responses

Middleton Bay

The Middleton Bay rockwall is on council and protects the car park and boating club buildings. A private building is currently located on council land nearby. This is currently at threat of erosion and the deconstruction process is being planned.

Recent storm damage stripped sand from the beach and partially exposed the staircase. Remedial action has been completed in conjunction with TRC.

Collaboration is required to determine renewals required for the northern end of the rockwall and any increased extents or planting required in response to the storm damage. Planting and angling of the bank have been recommended along the mid section to minimise erosion. Due to the high costs of physical works such as physical rockwall modifications, the management strategy will need to be considered as part of the next council Long Term Plan (2024-2034). Precarious boulders have been moved away.

The concrete boat ramp and guide wall are not covered in STDC consents, it is believed the boat club holds these consents.

Council land is purple, roading reserve is shaded grey, coastal protection zone is blue line.

Opunake Beach

Opunake Beach contains a number of structures. These are largely on council land, Department of Conservation land and roading reserve. Several buildings are located in the beach area, on roading, DoC and council land parcels. inside the coastal protection zone. Much of the cliffs and roadway are roading reserve.

The Opunake Beach retaining wall is located on beach reserve. The structure was a failed structure and has been rebuilt in the minimum footprint possible to provide with an engineered block-wall retaining wall that is safer and better suited to withstanding wave action.

The Opunake beach boat ramp has some low priority repairs planned.

The western headland boat ramp is beside advancing cliffs and boat launching is discouraged.

The breakwater is difficult to access and we hoping that the hydrographic survey by Fugro may be able to provide further information.

Further condition-based assessment can be considered for future monitoring programmes.

Department of Conservation land is red, Council land is purple, roading reserve is shaded grey, coastal protection zone is blue line.

Patea

Patea contains a number of structures with various functions.

The Patea training wall protect the land adjacent to the rail corridor and the natural gas pipelines. This land is owned by the Department of Conservation and a private owner. The absence of the training walls are expected to have compromised these land parcels and further land owned by the council.

Renewals are planned for the moles, beginning with the northern moles which are deemed most critical from a functional and safety point of view. At the time of writing, the works are being prepared for public tender.

Renewal of the southern moles is planned for 2024-2025, in accordance with the condition survey by Beca.

A management plan and consultation with the community are expected to be required with regards to the future of the wave guide wall.

The Mana Bay revetment works will be considered as part of the next Long-Term Plan.

No works are planned for the Carlyle Bay rock protection wall or the raised stone training wall.

The Patea boat ramp is in the planning phase for widening, to accommodate additional safety measures for the boating community. The works are expected to include minor renewals to the boulder protection walls which are located upstream and downstream of the boat ramp.

Coastal permit 6839 is expected to be relinquished, as the rockwall has been reinstated and is covered by coastal permit 4573.