REPORT

Tonkin+Taylor

Kai Iwi Beach – Technical Assessment of Community Options

Prepared for
Whanganui District Council
Prepared by
Tonkin & Taylor Ltd
Date
November 2023
Job Number
1089724 v1.0

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Document control

Title: Kai Iwi Beach – Technical Assessment of Community Options					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
27/7/23	0.1	Preliminary draft	R. Haughey T. Shand	M. Paine	
21/8/23	0.2	Draft for client review	R. Haughey T. Shand	M. Paine	
15/11/23	1.0	Final report	R. Haughey T. Shand	M. Paine	G. Nicholson

Distribution:

Whanganui District Council 1 PDF copy

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Executive summary

Whanganui District Council (WDC) is developing a community-based Coastal Action Plan, focused particularly on the next 10 years but with a longer-term view to consider adaptation to coastal hazards over a longer timeframe. WDC have engaged Tonkin & Taylor Ltd. (T+T) to undertake a technical assessment of potential erosion mitigation options for Kai Iwi (Mowhanau) Beach that have been developed as part of a community engagement process.

Kai Iwi (Mowhanau) Beach is characterised by an approximately 400 m length of siltstone cliffs which are located between the Kai Iwi Stream mouth at the northwestern end and the Mowhanau Stream mouth at the southeastern end. The small sandy embayment of Mowhanau Beach is located on the southern side of the Mowhanau Stream mouth. To the north and south of Kai Iwi are high cliffs fronted by sand that is generally exposed only at low tide. These cliffs have been found to be eroding at rates of 0.3 to 0.5 m/year (Dahm, 2022). Between the Kai Iwi Stream to the north and the Mowhanau Stream to the south, a rock revetment has been progressively constructed along the cliff toe from the 1980s with semi-annual repairs and top ups. A rock groyne or breakwater has also been constructed to link the seaward end of Archer's Bridge, which crosses the Kai Iwi Stream, with the adjacent cliff headland to maintain access to the north and to avoid outflanking by the river or sea as the cliffs erode.

This report provides technical assessment of potential options to mitigate coastal erosion at Kai Iwi Beach including the likely effectiveness of each option in mitigating erosion hazard, future maintenance requirements, potential to adapt or upgrade the option in the future and assessment of the potential effects on the coastal environment. Additionally, a high-level indicative cost estimate is developed for these options including design, consenting costs, contingency and maintenance costs over the anticipated design life.

Four options, as provided by WDC, have been considered including:

1 Removal of existing 'shell rock' revetment.
2 Maintenance of the existing 'shell rock' revetment.
3 Replacement of the current structure with an engineered rock revetment.
4 Rock groyne(s) option with or without replenishment.

High level commentary is also provided on alternative options including: beach renourishment, offshore structures and a rock sill. A summary of the advantages and disadvantages of these options and high-level indicative cost estimates is set out below. It is expected that a detailed cost estimate would be undertaken for the preferred option during the consenting or detailed design phase.

Table E-1: Kai Iwi shoreline management options assessment

#	Description	Advantages	Disadvantages	Likely effective life	Indicative Cost ($M)		
					Capital	Total over 20 years	Total over 50 years
1	Removal of 'shell' rock wall	- Restores the coast to its' natural, unprotected state - no ongoing costs associated with protection	- Some health and safety risk following removal as the shoreline re-adjusts and cliffs slump - High ongoing risk of landslide/rock fall	N/A	0.5	0.5	0.5

#	Description	Advantages	Disadvantages	Likely effective life	Indicative Cost ($M)		
					Capital	Total over 20 years	Total over 50 years
		- more useable amenity area on beach	- Future costs associated with loss of assets on land (buildings, roads) - Low lying, public land (car park and playground) is likely to be affected by erosion				
2	Maintenance of 'shell' rock wall	- Lower cost option - Provides some level of erosion protection - Cost is spread over time - Uses local material	- Risk of structure damage during large event - Moderate risk of landslide/rock fall above structure - Displaced rock spread onto beach - Structure footprint occupies beach area reducing amenity - Loss of beach width over time as wider shoreline retreats landward	20 – 30 years	0	0.35	N/A
3	Engineered rock revetment	- More certainty of land protection - Higher levels of public safety - Access can be incorporated along and over the structure	- High cost (though opportunities exist for refinement) - Larger footprint occupies a wider beach area reducing amenity - Loss of beach width over time as wider shoreline retreats landward	50+ years	7.0	7.1	7.2
4	Groynes	- Potential for a wide, sandy beach at Kai Iwi - Improved amenity	- Very large structures + beach replenishment would likely be required - Very high cost - Unlikely to remain effective in long term	20 – 30 years	10.5	10.7	N/A

1 Introduction

Whanganui District Council (WDC) is developing a community-based Coastal Action Plan, focused particularly on the next 10 years but with a longer-term view to consider adaptation to coastal hazards over a longer timeframe. Castlecliff and Kai Iwi (Mowhanau) are the initial focus of the action plan. WDC have engaged Tonkin & Taylor Ltd. (T+T) to undertake a technical assessment of potential erosion mitigation options for Kai Iwi (Mowhanau) Beach (Photograph 1.1), which have been developed as part of a community engagement process. It is our understanding that the assessment results will be used as part of WDC's decision-making process on a preferred option for the Coastal Action Plan.

Photograph 1.1: Aerial view of the Kai Iwi shoreline (Source: WDC, 2022)

1.1 Scope of works

This report provides an assessment of the technical feasibility, likely effectiveness in mitigating erosion hazard and indicative cost for a range of proposed coastal adaptation options. These options, as provided by WDC, include:

1. Removal of existing 'shell rock' revetment.
2. Maintenance of the existing 'shell rock' revetment.
3. Replacement of the current structure with an engineered rock revetment.
4. Rock groyne(s) option with or without replenishment.

For each option we have undertaken

- Preliminary design to inform subsequent technical assessment including consideration of likely design life of the option.
- Assessment of the likely effectiveness of the option in mitigating erosion hazard including consideration of future maintenance requirements and potential to adapt or upgrade the option in the future.
- Assessment of the potential effects on the coastal environment.

- Indicative cost estimate including design, consenting costs and maintenance over the anticipated design life of the option.

High level commentary is also provided on alternative options including beach renourishment, offshore structures and a rock sill.

1.2 Datums and coordinates

All elevations (levels) within this report are presented in terms of New Zealand Vertical Datum 2016 (NZVD16) unless otherwise stated.

2 Environmental conditions

2.1 Physical setting

Kai Iwi (Mowhanau) Beach is located approximately 9.5 km northwest of Whanganui River mouth. The site is characterised by an approximately 400 m length of siltstone cliffs which are located between the Kai Iwi Stream mouth at the northwestern end and the Mowhanau Stream mouth at the southeastern end (Figure 2.1). The small sandy embayment of Mowhanau Beach is located on the southern side of the Mowhanau Stream mouth.

To both the north and south of Kai Iwi (Mowhanau) are high cliffs fronted by sand that is generally exposed only at low tide. This transitions to low dunes some 8 km to the south where the construction of the training walls (moles) at the Whanganui River mouth has resulted in accretion.

At the northern end of the site the current cliff crest is at the seaward edge of Sunset Parade near the Broadview Heights intersection. Properties on the landward side of Sunset Parade are less than 20 m from the cliff edge. Further south, there is some buffer between the edge of the road and the cliff crest, with a grassed area approximately 7 to 10 m wide. However, the loop road and lookout are located at the edge of the current cliff crest. The cliffs transition down to a lower banked area where the beach carpark is located at the edge of the current shoreline.

Figure 2.1: Overview of the site at Kai Iwi/Mowhanau Beach overlaid on the 2022 aerial photograph (sourced from LINZ)

2.2 Topography

Based on 2020-2021 LiDAR the cliff heights range from 20 to 25 m RL through the centre and northern extent of the site and are lower towards the southern extent, where the carpark is, ranging from 4 to 13 m RL (Figure 2.2 and Figure 2.3). The cliffs to the north and south of Kai Iwi are higher, at approximately 45 m RL. A UAV topographic survey has also been completed for the site in July 2020 by Atkin (2020).

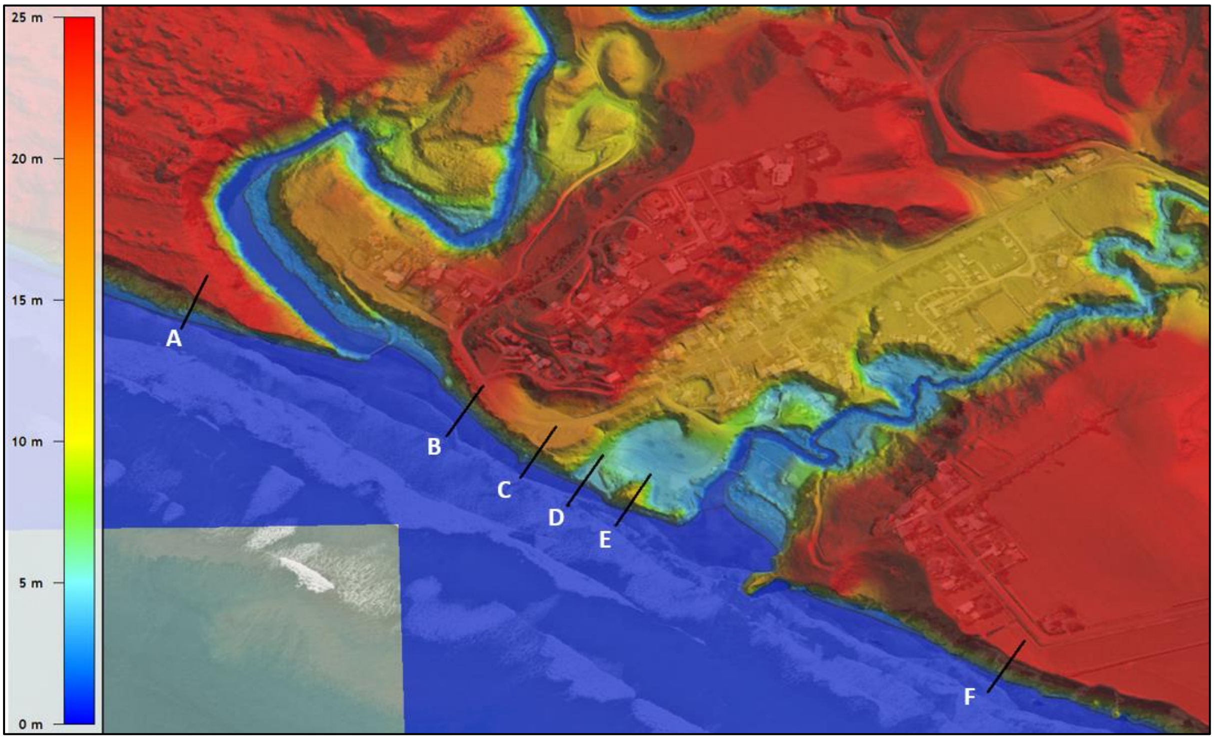

Figure 2.2: Digital Elevation Model for Kai Iwi shoreline, derived from 2020-2021 LiDAR (sourced from LINZ). Location of cross-sections presented in Figure 3.3

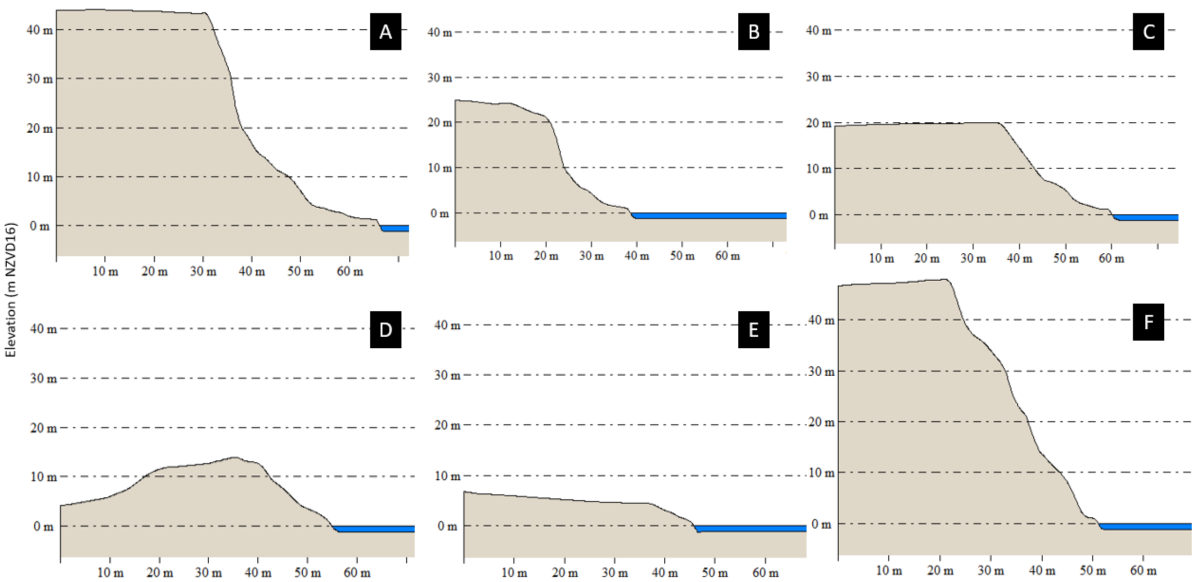

Figure 2.3: Example of cross-section along the Kai Iwi shoreline (locations shown on Figure 3.2)

2.3 Water levels

Water levels influence the amount of wave energy reaching the shoreline, causing erosion during storm events and by controlling the mean shoreline position on longer time scales. The key components that determine water levels at the coast are:

- Astronomical tides.
- Barometric and wind effects, generally referred to as storm surge.

- Long term changes in sea level.
- Wave transformation processes through wave setup and run-up.

2.3.1 Astronomical tide

Tide levels applicable to the Kai Iwi shoreline are summarised in Table 2.1.

Table 2.1: Tide levels for Kai Iwi (LINZ, 2021)

Tide state	Moturiki Vertical Datum (m MVD53)	New Zealand Vertical Datum 2016 (m NZVD16)
Mean High Water Springs (MHWS)	1.4	1.1
Mean Sea Level (MSL)	0.1	-0.2
Mean Low Water Springs (MLWS)	-1.2	-1.5

2.3.2 Storm tide

Storm surge results from the combination of barometric setup from low atmospheric pressure and wind stress from winds blowing along or onshore which elevates the water level above the astronomical tide.

Based on extreme value analysis of the mean sea level record, Sea Level Pressure data and Whanganui weather station data, Atkin et al. (2021) estimate the 1 % AEP storm surge value as 0.84 m. The 1 % AEP storm surge value combined with the MHWS results in a 1 % AEP storm tide level of approximately 1.94 m NZVD16.

2.3.3 Long-term sea levels

Historic sea level rise in New Zealand has averaged 1.7 ± 0.1 mm/year (Hannah and Bell, 2012). Climate change is predicted to accelerate the rate of SLR. The Ministry for the Environment interim SLR guidance recommends using a range of “medium confidence” SLR scenarios to cover a range of predicted future sea levels that reflect the inherent uncertainty. The scenarios are based on the most recent IPCC Assessment Report 6 (IPCC, 2022) (Figure 2.4).

- Low emission scenario (SSP2 - 2.6 median projection).
- Moderate emissions scenario (SSP2 - 4.5 median projection).
- High emissions scenario (SSP3 -7.0 median projection).
- Very high emissions scenario (SSP5 - 8.5 median projection).
- Very high emissions scenario (stress test), based on the (SSP5 -8.5 83rd percentile projection).

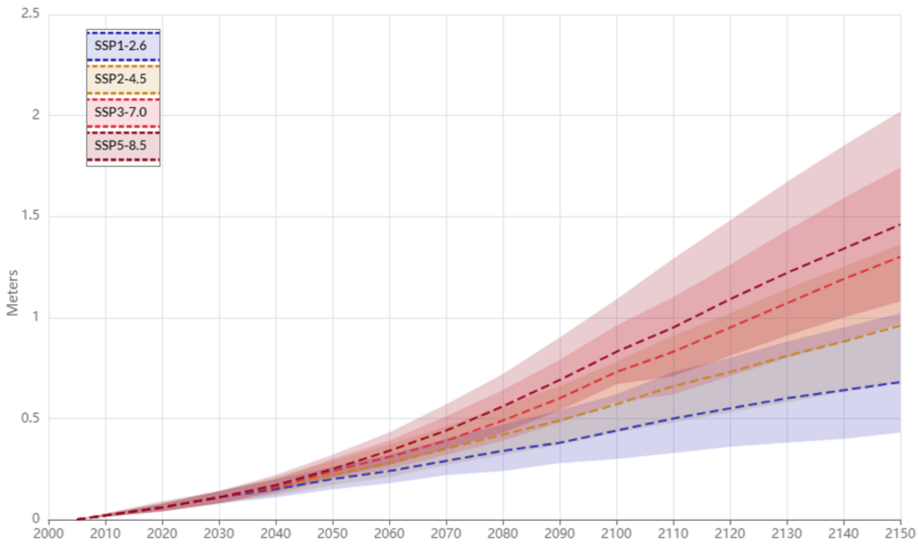

Figure 2.4: Four scenarios of sea-level rise projection for Kai Iwi coast as stipulated by the the MfE 2022 guidance (modified from NZ SeaRise 2023)

2.3.3.1 Effects of vertical land movement

MfE (2022) recommends consideration of vertical land movement (VLM), such as tectonic uplift or subsidence, as changes in land level can accelerate or decelerate the local effects of a rise in absolute sea level. The latest NZ SeaRise data indicates average subsidence rate of -0.63 mm/year for the Kai Iwi shoreline. Based on this average rate of subsidence the projected relative SLR for Kai Iwi is presented in Table 2.2.

Table 2.2: Projected SLR values for Kai Iwi

Timeframe	SSP scenario	Projected SLR values for New Zealand (m)[1]	Relative SLR accounting for local VLM (m)[2]
	SSP2 4.5 M	0.11	0.13
	SSP3 7.0 M	0.11	0.13
	SSP4 8.5 M	0.11	0.13
2030	SSP4 8.5H+	0.14	0.16
	SSP2 4.5 M	0.35	0.39
	SSP3 7.0 M	0.39	0.43
	SSP4 8.5 M	0.44	0.48
2070	SSP4 8.5H+	0.57	0.61
	SSP2 4.5 M	0.73	0.80
	SSP3 7.0 M	0.95	1.02
	SSP4 8.5 M	1.09	1.16
2120	SSP4 8.5H+	1.48	1.55

1 Projections of sea level rise (m above 1995-2014 baseline) for NZ (MfE, 2022)

2 Relative SLR accounting for -0.63 mm/year VLM

2.3.4 Future extreme water levels

Based on the storm tide estimates from Atkin et al. (2021) and the range of future SLR, the future 1 % AEP extreme water levels for Kai Iwi are presented in Table 2.3.

Table 2.3: Future extreme water levels for Kai Iwi

Timeframe	SSP scenario	Relative SLR	1 % AEP storm tide level
Present-day	N/A	0	1.94
2030	SSP2 4.5 M	0.13	2.07
	SSP4-8.5 M	0.13	2.07
2070	SSP2 4.5 M	0.39	2.33
	SSP4-8.5 M	0.48	2.42
2120	SSP2 4.5 M	0.80	2.74
	SSP4-8.5 M	1.16	3.10

2.4 Waves

The Kai Iwi shoreline faces southwest and is exposed to waves from the south to west directions. Based on wave modelling from Atkin et al. (2021) the wave climate at Kai Iwi is bimodal in nature with extreme wave heights from the south-southwest and west-southwest. The offshore mean significant wave height is approximately 1.5 m while the 1 % AEP offshore wave height is 5.28 m from the west-southwest and 5.57 m from the south-southwest (Table 2.4).

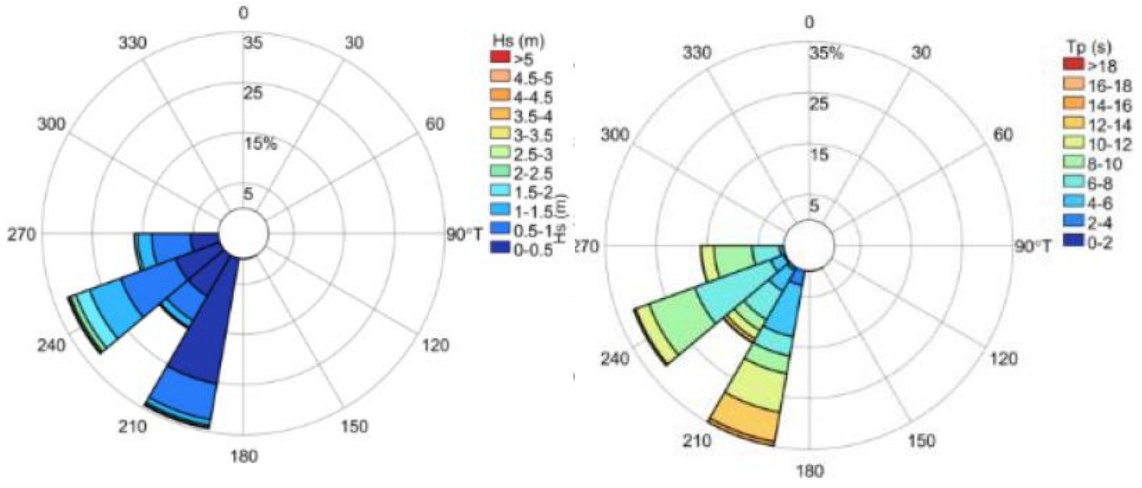

Figure 2.5: Historical offshore wave conditions for Kai Iwi Beach. (Left) significant wave height rose, (right) peak wave period rose (sourced from Atkin et al. 2021).

Table 2.4: 1 % AEP wave heights, periods and setup values from Atkin et al. (2021)

Annual Exceedance Probability (AEP)	Direction	Wave height (m)	Wave Period (s)	Wave setup (m)
1 % AEP	South-southwest (198.72°)	5.57	11.24	0.53
1 % AEP	West-southwest (237.38°)	5.28	12.31	0.57

Wave effects at the shore include wave set-up and wave run-up. Wave set-up is an increase in the mean water level elevation on the foreshore, caused by the dissipation of wave energy through the surf-zone. Wave run-up is the sum of the wave set-up and wave swash and is the maximum level that the waves reach on the shoreline relative to the still water level.

Both wave set-up and run-up are highly dependent on the local bathymetry and topography. Using empirical formula from Stockdon et al. (2006) and the foreshore beach slope, Atkin et al. (2021) calculate the wave setup as 0.53 m and 0.57 m for the 1 % AEP wave heights. The 1 % AEP extreme static water level is the combination of the storm tide, wave setup and sea level rise and is presented in Table 2.5

Waves reaching the toe of the cliff during high water levels, are likely to be depth-limited. Based on beach levels from the LiDAR data and the present-day 1 % AEP static water level, the depth-limited wave height at the shore is estimated to be 1.5 m (Table 2.5) and increased with future sea level rise. Note that lower beach levels may result in higher waves reaching the cliff/structure toe.

Table 2.5: Present-day and future nearshore, depth-limited wave heights at Kai Iwi Beach

Timeframe/scenario	1 % AEP static water level (m NZVD16)	Depth-limited wave height (m)
Present-day	2.51	1.5
2030 (SSP5-8.5)	2.64	1.6
2070 (SSP5-8.5)	2.99	1.8
2120 (SSP5-8.5)	3.67	2.2

2.5 Sediments and littoral drift

Beach sediments along this section of coast likely originate from a combination of local streams and rivers which discharge onto the coast, erosion from the Pleistocene sedimentary cliffs and heavy minerals such as augite and opaques (mainly titanomagnetite) which originate from the Egmont Volcanic Region. Gibb's (1979) minerology results are presented in Figure 2.6 and indicate that to the west of the Whanganui River mouth, sediments are dominated (60 to 80 %) by heavy minerals.

The net regional sediment transport along the Whanganui coast is from the northwest to the southeast (Shand, 2016). Estimate of net sediment transport for Whanganui range from around 180,000 to 320,000 m^3/year. Rates at Kai Iwi are likely to be slightly lower smaller owing to the slightly reduced wave climate but in the same general direction.

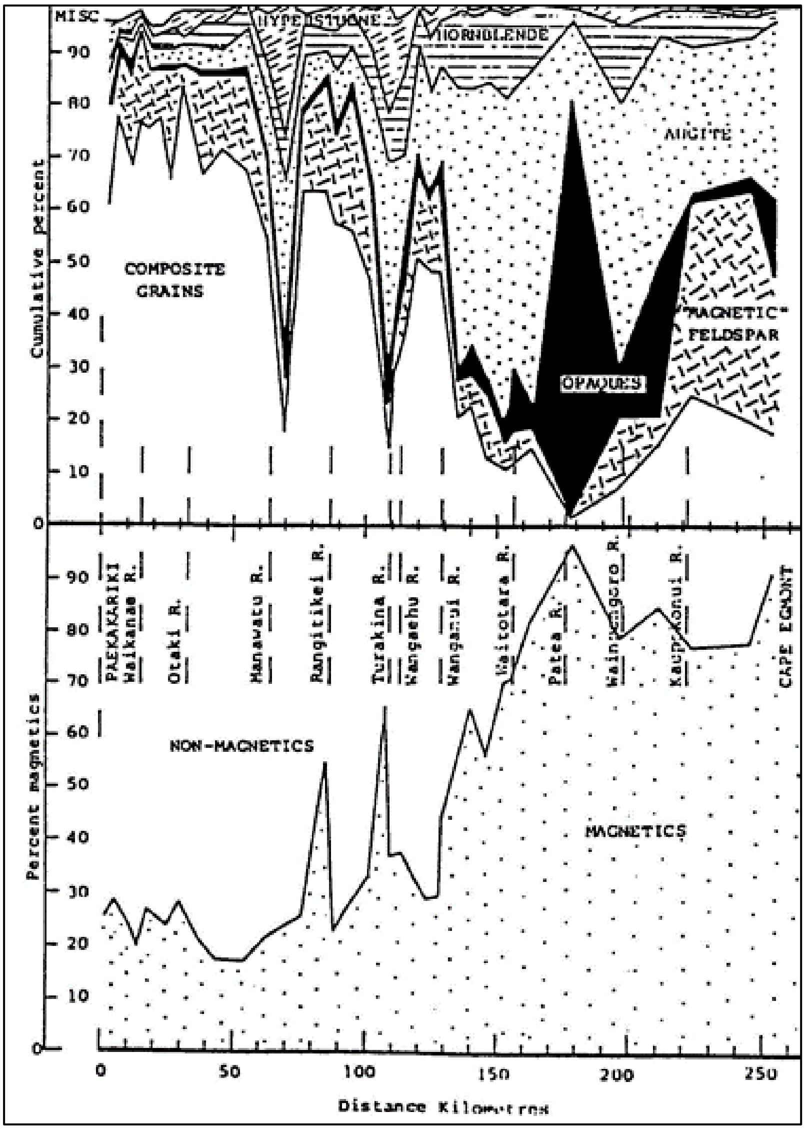

Figure 2.6: Longshore dispersal pattern of minerals in beach sand between Cape Egmont and Paekakariki (Source: Gibb, 1979)

2.6 Geomorphology and shoreline trends

As described in Atkin et al. (2021), the cliffs at Kai Iwi beach are relatively weak sedimentary cliffs comprising Kaimatira Pumice Sand, overlain by Lower Kai Iwi Siltstone, Lower and Upper Westmere Siltstone, inter dispersed with thin sand and shellbed layers; then the Rapanui Formation, followed by modern sand dunes (Photograph 2.2).

The cliffs along majority of the Whanganui coast, including the Kai Iwi cliffs, tend to be oversteepend with minimal high tide beaches. Local observations indicate sand levels along the beach can fluctuate significantly (Atkin et al. 2021). Gibb (1999) estimated the stable equilibrium slope of the cliffs to be 40^{o}. Most recent LiDAR shows most of the cliffs are sitting at steeper angles (50^{o} to 90^{o}) and are subsequently vulnerable to failure.

Photograph 2.2: Cliffs to the north (top), and south (middle and bottom) of Kai Iwi/Mowhanau beach (sourced from NZJane.com and WDC, 2022)

Previous studies indicate that the entire Kai Iwi coastline is retreating landward and has shown long-term erosion for at least the last 7500 years (Dahm, 2022). Dahm (2022) estimate historical erosion rates of 0.3 to 0.5 m/year. Based on analysis of historic aerial photographs from 1942 to 2020, Atkin et al. (2021) found that between 1982 and 2003, several metres of erosion occurred along the site, with the northern headland at Kai Iwi Stream eroding at a faster rate than the other parts of that formation. The study also states erosion rates have been accelerating along the cliff section at the southeastern end of the bay, particularly around the peninsula.

With consideration of future SLR, Atkin et al. (2021) predicted cliff retreat of 7 m to 22 m by 2030 and 37 to 79 m by 2100 for different sections of the Kai Iwi shoreline (Table 2.6).

Table 2.6: Future erosion distances along the Kai Iwi shoreline calculated by Atkin et al. (2021)

Location	2030 (RCP8.5 H+)	2070 (RCP8.5 H+)	2100 (RCP8.5H+)
Northern headland	7 m	22 m	42 m
Sunset Parade	12 m	25 m	37 m
Southern headland	22 m	54 m	79 m

2.7 Existing structures

Archer's Bridge crosses the Kai Iwi Stream mouth at the northern end of the site (Photograph 2.3). The bridge has been damaged in the past during storm events. In 2016 rock was placed along the seaward side forming a training wall or breakwater to link the bridge to the eroding headland and avoid outflanking by the river or sea. The intent of this appears to have been to enable pedestrians to reach the beach north of the Kai Iwi Stream.

Photograph 2.3: Archers Brdiget crossing the Kai Iwi Stream mouth with a small rock abutment on the landward side and a low rock breakwater linking the seaward end of the bridge with the cliff (source: Top - WDC, 2022, Lower – Whanganui Chronicle Dec 2021)

Between the Kai Iwi Stream to the north and the Mowhanau Stream to the south, a rock revetment has been constructed along the cliff toe (Photograph 2.4). The initial construction date of this wall was reportedly in the 1980s with semi-annual repairs and top ups (Atkin et al., 2021). The revetment protects the toe of the cliff and lower backshore fronting the car park and surf club from coastal erosion but also from both the Kai Iwi and Mowhanau Streams when they flow along the base of the cliff. A small groyne is located some 220m south of Archer's Bridge, reportedly to divert flows from the Kai Iwi Stream (Atkin et al., 2021). The revetment wraps around towards the Mowhanau Stream with a slipway that ran from the road to the sand reportedly collapsing in 2017/18 with an emergency repair now covered in sand (Atkin et al., 2021). A bridge crosses Mowhanau Stream some 50 m upstream linking the carpark to the playground.

Photograph 2.4: Existing 'shellrock' revetment running along the toe of the cliff at Kai Iwi Beach and smaller groyne within the revetment (source: Top – WDC, 2022, Middle and Lower – eCoast, 2020)

The revetments have been constructed using local ‘shellrock’. This sedimentary rock is formed by consolidation of shells and finer sediments and is well distributed around the Whanganui District, particularly in the Nukumaru and Kaiwhaiki regions. The rock varies in hardness and density depending on its source, but is generally lighter (2.4 - 2.5 t/m^3) than volcanic rock that is typically used in coastal armouring (i.e. andesite or basalt at 2.6 to 2.8 t/m^3) with higher water absorption and weathering characteristics. However, better shellrock can be resilient in the coastal environment with both the north and south Whanganui Moles being originally constructed of shellrock between 100 and 130 years ago.

The revetments do not show evidence of a geotextile layer, generally incorporated to prevent fine materials from migrating through the armour rock, or smaller underlayer materials used as a filter. It must therefore be concluded that the revetment is an informal structure placed and repaired as required using available rock. No information on toe depth is available with the LiDAR showing the beach level at the toe of the revetment to be around 1.2m RL (approximately MHWS). The beach level is reported to fluctuate so the toe likely extends 1-2m below this level. The crest level appears to be at around 4.5m RL based on LiDAR (around 3.5m above MHWS), though like varies along the structure. The slope of the structure is steep, around 1(H):1(V) based on LiDAR which likely contributes to instability and overtopping. Some damage to the backshore and loss of vegetation is apparently along the top of the revetment, particularly at its southern end indicating wave overtopping may occur reasonably frequently.

3 Technical assessment

This section provides a technical assessment of potential options to mitigate coastal erosion at Kai Iwi including:

- Preliminary design to inform subsequent technical assessment including consideration of likely design life of the option.
- Assessment of the likely effectiveness of the option in mitigating erosion hazard including consideration of future maintenance requirements and potential to adapt or upgrade the option in the future.
- Assessment of the potential effects on the coastal environment.

3.1 Removal of existing 'shell rock' revetment

Option description

This option would remove part or all of the existing 'shell rock' revetment which extends along the cliff toe between the Kai Iwi Stream mouth and the Mowhanau Stream mouth. This would require mechanical plant to access the beach (likely from the Mowhanau Stream end) to remove rock and any other construction debris located beneath the rock from the coastal environment. This rock could be re-used elsewhere or disposed of at a clean fill site.

Figure 3.1: Extent of existing 'shell rock' revetment wall between the Kai Iwi and Mowhanau stream mouths

Option effectiveness and adaptation

Removing the existing 'shell rock' revetment would restore the shoreline to an unprotected state. While the existing structure is essentially non-engineered and has undergone repair and upgrade over time, it has provided some mitigation against cliff and backshore erosion. In doing so, this section of coast is likely to be slightly 'out of alignment' from its' natural position if unprotected and/or the beach levels may be slightly lower than they would have been if this section of coast has been allowed to erode. Therefore, following removal of the existing wall, some rapid re-adjustment of the backshore may occur (i.e., erosion of softer areas and re-activation and slumping of cliffs. Following this adjustment, erosion would continue at historic rates.

Based on the future erosion distances projected by Atkin et al. (2021) Sunset Parade near the Broadview Heights intersection and the adjacent properties are most vulnerable. Removal of the erosion protection structure will most likely require relocation of the access road and properties along the northern end of Sunset Parade. The road may become compromised by 2030 which will limit access to the properties and the properties themselves may be exposed to erosion by 2070.

Erosion predictions from Atkin et al. (2021) also indicate that the southern end of the loop road at the cliff top lookout will be compromised beyond 2045 in the absence of armour protection. Additionally, the beach carpark will require relocating to mitigate the high erosion hazard. The edge of the carpark will be immediately at risk if the structure is removed and based on Atkin et al. (2021) the entire carpark will be lost by 2070.

Potential effects on the environment

Effects on the environment may include:

- Construction activities to remove the existing revetment including tracking and excavating the beach.
- Exposure of potentially dangerous substances (composition of revetment sub-layers or contained within the backshore is unknown).
- Rapid adjustment of the backshore and cliff following removal including rockfall and landslide.
- Ongoing erosion of the backshore.

3.2 Maintenance of 'shell rock' revetment

Option description

Maintenance of the existing 'shell rock' revetment would involve leaving the existing structure in place and adding rock as it is lost or abraded during wave events. There is also potential to increase the height of the rock wall over time, particularly if the cliff and backshore begin to be damaged by wave overtopping and to extend the length if the wall starts to become outflanked or increase rock sizing to limit damage. Note that placing rock on top of the existing structure will only be feasible for some locations where the existing profile accommodates this.

Photograph 3.5: Existing 'shell rock' revetment between the Kai Iwi and Mowhanau stream mouths

Option effectiveness and adaptation

The existing rock wall appears to moderately effective in mitigating erosion of the cliffs behind with only some areas of active erosion apparent, likely due to wave overtopping or migration of material through the structure. As the rock wall does not appear to be a formally engineered structure with an impermeable filter, waves are still able to erode material from within and behind the structure and therefore this option is only likely to *slow* the rate of erosion rather than preventing the erosion completely.

The existing 'shell' rock is relatively light and more susceptible to weathering and abrasion compared to commonly used armour rock materials (i.e., basalt, andesite or dolomite) and therefore is likely to be more easily moved and damaged by waves. Maintenance works replace these displaced rocks, though erosion can occur between when damage occurs, and maintenance is undertaken. Subsequently, this option is likely to only be effective for 15 – 30 years before water levels and wave climate increase to a point of causing damage to the structure more frequently than is feasible to repair. It must be acknowledged with this option, however, that major damage requiring a substantial re-build could occur at any time.

At the end of this period (or before if substantial damage occurs in the interim), either a more formal engineered revetment would likely be required (refer Option 3), or the revetment could be removed (as per Option 1) with a similar shoreline response as it returns to equilibrium.

Potential effects on the environment

Maintaining the existing wall is likely to result in a gradual reduction in dry beach width and time during which the beach is accessible in front of the structure. This is because the cliffs either side of Kai Iwi are gradually eroding and as this occurs the wider beach system is also migrating landward. If the wall prevents this landward migration, then the beach level in front of the wall will gradually reduce. Note that because the beach slope is relatively gentle, this reduction is beach level will likewise be relatively small (differing for example from a steep high tide beach that is migrating landward).

Effects on the environment may therefore include:

- Construction activities to maintain the existing revetment including tracking on and excavating the beach.
- Continual displacement of rock onto the beach fronting the structure.
- Ongoing occupation of the beach by a rock structure.
- Reduction in beach level and width in front of the structure reducing access and space for amenity over time.

3.3 Engineered rock revetment

Option description

The existing structure could be removed and replaced with an engineered rock revetment. Rock revetments typically comprise a geotextile fabric to prevent the loss of finer sediments through the structure, an underlayer or secondary armour layer of smaller rock and a double layer of primary armour rock sized to withstand the local wave climate. The toe should be designed by below potential scour levels or able to accommodate scour and the crest should be sufficiently high to reduce overtopping to tolerable levels.

Key design parameters include the design life, design event, tolerable damage during the design event and tolerable wave overtopping. Additional design considerations include structure slope, rock density and shape, toe detail, crest detail and access across the structure. Preliminary design has been undertaken using the following parameters.

- Design life: 50 years.
- Design event: 1 % AEP (or 1 % likelihood of being exceeded in any one year).
- Sea level rise scenario: RCP8.5 (high end scenario).
- Damage: S = 2 (start of damage).
- Tolerable overtopping (10 l/s/m – start of damage of unprotected slopes).
- Slope: 1(V):1.5(H).
- Rock density: 2700kg/m^3 (assuming andesite or similar rock).

Design based on these parameters and using methods set out in CIRIA (2007) and Eurotop (2018) results in a median primary armour rock size of 3T (range 1.2 – 7T), with a total structure height of 6 m and width of 12 m (Figure 3.2). These are relatively conservative design parameters resulting in a structure that is significantly larger (higher and wider) than currently existing. The design parameters and resultant structure geometry and sizing may be further refined during future design stages along with consideration of crest and toe detail to ensure damage due to wave overtopping and toe scour is managed.

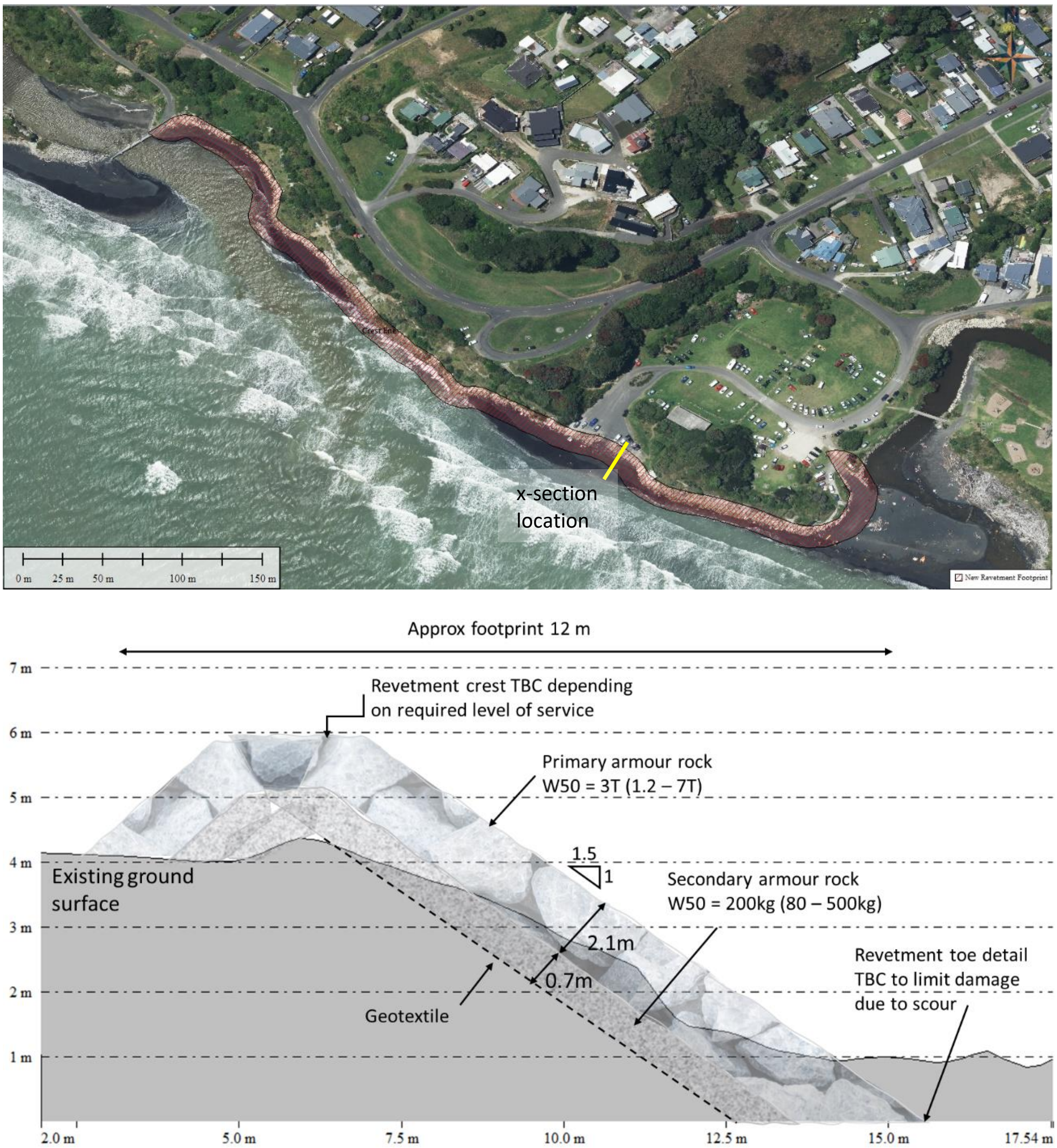

Figure 3.2: Indicative plan and cross section for new rock revetment

<u>Option effectiveness and adaptation</u>

An engineered rock revetment is likely to be an effective option for limiting erosion of the cliff and the low backshore areas. As the rock surface is irregular and the rock armour layer is permeable the slope face of the revetment dissipates wave energy and protects the materials behind from being removed by hydraulic forces.

A similar example occurs at Onaero, in North Taranaki where a revetment has been constructed in front of a soft siltstone cliff (Photograph 3.6). The revetment has prevented further erosion of the cliff and backshore, with access provided along the crest of the revetment. However, erosion of the adjacent cliff has continued, and the revetment requires periodic extension.

The effective design life of a rock revetment will depend on the adopted design conditions (i.e., design storm and sea level rise values), but if suitably constructed, maintained and adapted as required, could achieve design life of 50 to 100 years. Maintenance could be required if an 'over-design' storm occurs, or if scour of the fronting beach is particularly severe and causes displacement of the toe. Beyond 50 years, the revetment could be raised to accommodate higher levels of overtopping and either higher levels of damage to the rock during design events accepted or an additional layer of rock placed over the revetment increasing the porosity. Alternatively, at a point in the future, the revetment could be removed (as per Option 1). This would be followed by a similar, although more extreme, shoreline response as it returns to equilibrium from an artificially seaward position.

Photograph 3.6: Example of a rock revetment along the cliff shoreline at Onaero, Taranaki protecting a low backshore and carpark in the foreground and cliff headland in the middle of the beach while the cliff adjacent to the wall (top of photo) continues to retreat

Potential effects on the environment

The potential effects on the environment are similar to those associated with maintaining the existing structure. The adjacent cliff and beach will continue to migrate landward while the revetment will remain static. Due to the likely longer effective life of the rock revetment, there is more chance that the adjacent cliffs retreat landward of the revetment section leaving it as an 'artificial headland'. The example at Onaero (Photograph 3.6) shows similar trends.

A similar reduction in beach width and level as for the existing revetment would occur, though to a greater degree due to the wider footprint and longer effective design life of the replacement structure. It is likely that over time, access in front of the revetment would not be possible, even at low tides, similar to the headland immediately south of Mowhanau beach.

Effects on the environment may therefore include:

- Construction activities to remove the existing and construct a new revetment including tracking on and excavating the beach.
- Occupation of the beach by a rock structure (~5000-6000 m^2 along the entire length).
- Reduction in beach level and width in front of the structure, to a greater extent than the existing revetment, reducing access and space for amenity over time.

3.4 Groynes

Option description

Groynes are structures (typically constructed of rock) placed perpendicular to the shoreline with the intent of trapping sediment as it is moved alongshore by waves (Figure 3.3). The effectiveness of groynes is dependent on the quantity of sediment being moved in the upper part of the beach, and the ability of the structure to retain this sand. Groynes can be combined with beach replenishment to limit adverse effects down-drift of the trapped sediment.

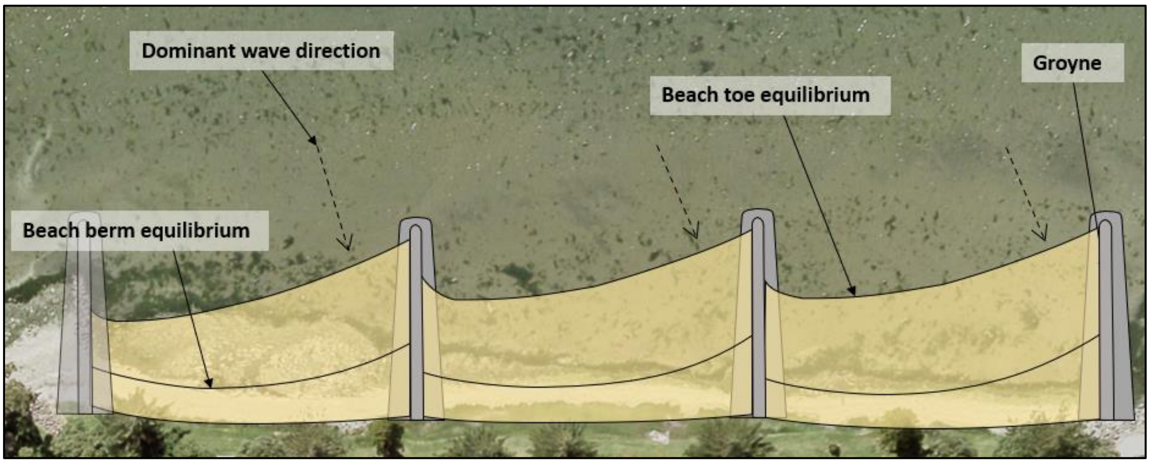

*Figure 3.3: Plan view s*chematic *of groynes with beach replenishment*

Option effectiveness and adaptation

For groynes to be effective in reducing erosion, they need to retain sufficient sand to dissipate wave energy before it reaches the backshore. The only example of this in the area is Mowhanau Beach which reaches an elevation of around 3m RL at the backshore. However, this is essentially a pocket beach, confined by 'headlands' on either side which allow room to develop a dry above-tide beach.

Short, upper beach groynes are not likely to be effective in trapping sand in this environment due to the very low beach slope with most alongshore sediment transport occurring in the nearshore bar and channel system rather than the upper beach (which essentially does not exist in this environment). This is evidenced by the existing groyne located in the middle of the existing revetment which shows no evidence of sediment accumulation on the updrift (northern) side (though it is noted that the intent of this groyne was to divert flows from the Kai Iwi Stream, Atkin et al., 2021).

The training walls (moles) at Whanganui and Patea river mouths have trapped sediment on their updrift side, with the Whanganui training walls resulting in progradation of the shoreline by some 600m and accumulation extending some 6 km north. However, these very large structures with the Whanganui north and south mole extending some 850 m offshore of the original shoreline position. These structures extended to the outer edge of the surf zone transport and therefore trapped most, if not all, sediment moving along the coast.

Photograph 3.7: Examples of an existing manmade (left) groyne at Kai Iwi with no appreciable sand accumulation on the updrift (north) side evident and a pocket beach (Mowhanau Beach) adjacent to a natural headland (right)

For the groynes to be effective at Kai Iwi they would need to be very large structures extending well into the surf zone and allowing a high tide beach to accumulate in their lee (similar to the difference between the southern headland and Mowhanau Beach). While a detailed assessment has not been undertaken, two to three structures in the order of 150 m long may be required to retain significant sediment to have any notable effect on erosion. Even at this size, it is likely that sea level rise will reduce the effectiveness of the structures and ability to hold sand and therefore further upgrades may be required beyond 20-30 years.

<u>Potential effects on the environment</u>

Groyne structures are intended to trap longshore sediment, and if successful, they can result in a sediment deficit downdrift of the groynes which can lead to accelerated erosion in these downdrift areas. This is often mitigated by importing sands to 'pre-fill' the beach. This provides an immediately wider beach while not starving the downdrift coast. While the processes operating along Kai Iwi differ from a typically beach scenario, if groynes of sufficient size to trap sediment were constructed, they may result in lower beach levels against the cliffs immediately south of the groynes. This would allow larger waves to reach the cliffs more frequently, potentially increasing erosion rates.

Effects on the environment may therefore include:

- Construction activities to construct groyne structures including tracking on and excavating the beach and nearshore.
- Occupation of the beach by a rock structure (~5000-6000 m^2 between three groynes).
- Trapping of sediment potentially reducing beach levels downdrift.

3.5 Alternative options

3.5.1 Beach renourishment

Beach renourishment involves placement of sediment on the foreshore to create a wider and more elevated beach profile. However, without sediment control structures (of sufficient size), sand placed at Kai Iwi is not likely to be retained (except potentially within the Mowhanau Beach pocket) and will not make a long-term difference to sand levels in front of the cliffs or long-term erosion along the Kai Iwi shoreline. This option would only be considered with control structures such as (large) groynes or offshore structures.

3.5.2 Offshore structures

Offshore breakwaters act by reducing the wave energy reaching the shoreline. This can result in accumulation of sediments in their sheltered lee, increasing the natural buffering capacity against erosion. Offshore breakwaters can be constructed of a range of materials, but rock is generally the most cost effective. Breakwaters may be either emerged or submerged, with emerged structures being more effective, particularly in large tidal range environments.

Due to the large tidal range and flat offshore profile at Kai Iwi offshore breakwaters would need to be relatively large to be effective in trapping sufficient sand to mitigate erosion. At least two structures may be needed in the order of 150 to 200 m long, placed 150 to 200 m offshore. Similar to groynes, it would be advisable to place sand in their lee to mitigate potential for trapped sand to cause a deficit downdrift.

3.5.3 Rock sill

A rock sill typically comprises a low-crested rock structure located along the foreshore with the intent of trapping sediment behind. It often is combined with vegetation to help bind the trapped sediment. Rock sills can be effective in sheltered estuarine or reef-top environments or where sediment volumes are high, and structures can be located high on the beach. However, it is unlikely to be effective along the Kai Iwi shoreline where the tidal range is large, there is moderate wave energy and sand levels are low. The rock sill would easily be overtopped by waves during high tides and sediment would likely to be washed out from behind the structure. A rock sill may potentially slow the rate of erosion through reducing the rate at which debris is lost after a landslip, however, it is not likely to make a notable difference to erosion in the long-term.

Photograph 3.8: Example of a rock still on an open coast beach at Port Fairy, Vic (source: T+T)

4 Option costs

Indicative high level cost estimates including design, consenting costs and maintenance over the anticipated design life of the option are presented in this section.

Indicative high level cost estimates have been derived for each option based on recent costs of similar projects and costs supplied by Council for local projects. A 30 % contingency has been added but cost estimates should be considered accurate to within +/-50 %. Key elements and assumptions used to develop costs are set out in Table 4.1.

Table 4.1: Key elements and assumptions used in cost estimates:

Item	Unit	Rate	Notes
Sand excavation and placement	m^3	$20	Assume excavated and moved locally on beach (i.e., <200m)
Sand importation and placement	m^3	$70	Assume imported from local, land-based source
Rock removal and disposal rate	m^3	$80	Assume removal and disposal offsite to clean fill site (i.e., no contaminated materials)
Rock (Shell rock) import and placement	m^3	$200	Supply and place based on local quarry source
Rock (Andesite) import and placement	m^3	$280	Supply and place based on South Taranaki quarry source
Geotextile supply and placement rate	m^2	$15	Assume Texcel 900R or similar
P&G (site establishment, traffic, travel, disestablishment)	%	25	Generally 15-30 % But assume upper end for small works, difficult site, working around tides
Professional fees (survey, design, consenting, site supervision)	%	20	Generally 10-25 % depending on scale of works and complexity of consenting.
Contingency	%	30	30 % for concept level, will reduce at future design stages

It is expected that a detailed cost estimate would be undertaken for the preferred option during the consenting or detailed design phase.

4.1 Removal of existing 'shell rock' revetment

The construction detail of the existing rock wall is unknown and therefore the exact composition of the wall, or depth of the toe is unknown at this stage. Likewise, the total volume requiring remove is unknown but may be in the order of 4000 m^3 over entire 450 m length (assuming average height of 4 m, slope of 1(V):1.5(H) and thickness of 1.5 m). Costs have assumed low-end professional fees of 10 % with less investigation, consenting and supervision likely required compared to construction. Costs could be reduced substantially if a nearby, lower cost disposal site or site for re-use is identified. Partial removal of a portion of the revetment would similarly result in lower costs.

It should be noted that costs associated with removal of roads, buildings or utilities as a result of ongoing erosion of the reserve or other public or private land has not been included.

Table 4.2: Summary of costs associated with removal of existing shell rock revetment

Item	Full removal
Capital cost[1]	$500,000
Maintenance cost (/year)[2]	$0
Total cost (20 years)[3]	$500,000
Total cost (50 years) [3]	$500,000

[1]Costs have assumed lower-end professional fees of 10% with less investigations, consenting and supervision likely required compared to construction.

[2]Note that no allowance has been made for removal of roads, buildings or utilities as a result of ongoing future erosion.

[3]No discount rate has been applied to future costs.

4.2 Maintenance of 'shell' rock wall

As above, the construction detail of the existing rock revetment including rock sizing, crest height or toe depth is unknown. The current condition or performance of the existing revetment is therefore unknown, and it is difficult to predict the amount of maintenance that will be required. Using a base assumption of $12,000 per year maintenance based on reported council spend (WDC, pers. comm. Aug 2023) for 0 to 5 years, $15,000 per year for 5 to 10 years and $20,000 per year for 10 to 20 years seems reasonable allowing for an increase in damage and required rock size over time as the beach level reduces in front of the structure, sea level rise and depth-limited waves reaching the structure increase. Beyond 20 years it is likely that a more substantial re-build would be required, although it must be acknowledged with this option that major damage requiring a substantial re-build could occur at any time. Costs associated with this rebuild have not been estimated as the preference would be to revert to option 1 (removal) or 3 (engineered revetment) at this point.

Table 4.3: Summary of costs associated with removal of existing shell rock revetment

Item	Maintenance
Capital cost	$0
Maintenance cost (/year)[1]	$12,000 (1 – 5 years) $15,000 (6 – 10 years) $20,000 (11 – 20 years)
Total cost (20 years)[2]	$335,000
Total cost (50 years) [2]	N/A

[1]Costs have assumed lower professional fees of 10 % with less consenting and supervision likely required compared to construction.

[2]No discount rate has been applied to future costs.

4.3 Engineered rock revetment

As set out in Section 3.3, a conservative set of design parameters has been assumed resulting in a structure with a height of 6 m, thickness of 2.8 m and total width of ~9-12 m (depending on crest and toe detail). It has been assumed that the existing rock revetment would be removed from site and disposed to clean fill, although there may be opportunity to reuse some of part of this structure as fill material.

Maintenance costs have been assumed at 5 % of the capital cost of the structure if an over-design event were to occur and cause 'intermediate' level damage (i.e., displacement of ~5-10 % of the structure). While some repair of the structure may be required, the displaced rock will generally remain available reducing the requirement for importing additional materials. An over-design event has a likelihood of 1 % of occurring in any one year and therefore an equivalent maintenance cost including this likelihood has been allowed.

Opportunities for cost refinement include:

- Refining the wave height reaching the toe along the structure allowing potentially smaller rock and a lower crest height to be used in more sheltered locations.
- Adopting a lower level of service – a lower design event or accepting more damage during a design event. This will increase the maintenance cost while decreasing the capital cost.
- Replacement of only a section of the existing revetment, such as the 300 m along the more exposed central area.
- Reuse of the existing shell rock within the revetment such as within the secondary armour layer (although noting that this rock does not generally meet standard rock specifications for coastal armouring).
- Use of (large) local shell rock rather than imported rock (although noting that this rock does not generally meet standard rock specifications for coastal armouring).

Table 4.4: Summary of costs associated with construction of an engineered rock revetment

Item	Full replacement
Capital cost	$7,000,000
Maintenance cost (/year)[1,2]	$3,500
Total cost (20 years)[3]	$7,100,000
Total cost (50 years)[3]	$7,200,000

[1]Costs associated with professional fees have been excluded from maintenance (assuming permitted activity).

[2]Maintenance costs are assumed at 5 % of capital cost of the structure with a 1 % likelihood of happening in any one year.

[2]No discount rate has been applied to future costs.

Additional features that have not been costed but could be considered include:

- Incorporation of a walkway along the crest of the structure.
- Access across the structure to the foreshore (concrete access ramp or timber stairs).
- Incorporation of ecological features such as tidal pools within the rock structure.

4.4 Groyne options

A groyne option has been costed based on three structures, extending some 150 m offshore. While the exact seabed levels are unknown, it is assumed that the structure has a toe elevation ranging from 0 m RL at the shoreline to -2 m RL at it’s offshore terminus with a crest height of 3 m RL. These structures would be partially overtopped during large events. Similar rock sizing as for the rock revetment has been assumed with similar maintenance considerations.

Sand importation has been allowed for to ‘pre-fill’ the groynes and limit downdrift effects. These have been based on an assumed 5 m wide berm at 3 m RL, with a 1:20 slope along 400 m to provide sufficient buffer to limit erosion of the cliff toe behind. Maintenance assumes two days’ work per year for an excavator and loader moving sand.

Table 4.5: Summary of costs associated with construction of groynes and replenishment

Item	Full replacement
Capital cost (groynes + sand)	$8,500,000 (Groynes) $2,000,000 (Sand) $10,500,000 (Total)
Maintenance cost (/year)[1,2]	$4,250 (groynes) $4,000 (sand)
Total cost (20 years)[3]	$10,700,000
Total cost (50 years) [3]	N/A

[1]Costs associated with professional fees have been excluded from maintenance (assuming permitted activity).

[2]Maintenance costs are assumed at 5 % of the structure capital costs with a 1 % likelihood of happening in any one year and 2 x days beach maintenance per year.

[2]No discount rate has been applied to future costs.

5 Summary

Table 5.1: Kai Iwi shoreline management options assessment

#	Description	Advantages	Disadvantages	Likely effective life	Indicative Cost ($M)		
					Capital	Total over 20 years	Total over 50 years
1	Removal of 'shell' rock wall	- Restores the coast to its' natural, unprotected state - no ongoing costs associated with protection - more useable amenity area on beach	- Some health and safety risk following removal as the shoreline re-adjusts and cliffs slump - High ongoing risk of landslide/rock fall - Future costs associated with loss of assets on land (buildings, roads) - Low lying, public land (car park and playground) is likely to be affected by erosion	N/A	0.5	0.5	0.5
2	Maintenance of 'shell' rock wall	- Lower cost option - Provides some level of erosion protection - Cost is spread over time - Uses local material	- Risk of structure damage during large event - Moderate risk of landslide/rock fall above structure - Displaced rock spread onto beach - Structure footprint occupies beach area reducing amenity - Loss of beach width over time as wider shoreline retreats landward	20 – 30 years	0	0.35	N/A
3	Engineered rock revetment	- More certainty of land protection - Higher levels of public safety - Access can be incorporated along and over the structure	- High cost (though opportunities exist for refinement) - Larger footprint occupies a wider beach area reducing amenity - Loss of beach width over time as wider shoreline retreats landward	50+ years	7.0	7.1	7.2
4	Groynes	- Potential for a wide, sandy beach at Kai Iwi - Improved amenity	- Very large structures + beach replenishment would likely be required - Very high cost - Unlikely to remain effective in long term	20 – 30 years	10.5	10.7	N/A

6 Applicability

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

The construction rates utilised for this high-level cost estimate are based on assumed design concepts, estimated quantities and a combination of recently submitted tender rates for similar projects within the regional area along with the latest available rates from QV Cost Builder database (formerly Rawlinsons). These rates are based on historic information and data and do not include allowance for any cost escalation since the date of the data other than where/as specifically stated.

Consequently, a significant margin of uncertainty exists on the cost estimate and the contingency we have allowed should be considered as part of the cost rather than a potential add on.

In particular, we have not made any attempt to allow for the potential impact of COVID-19 in this estimate. Also, supply chain disruptions are currently having quickly-changing effects on construction costs and schedules. We recommend you seek up-to-date specialist economic advice on what budgetary allowances you should make for escalation, including for any potential changes in construction costs and timing in relation to both COVID-19 and supply-chain issues.

Tonkin & Taylor Ltd
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