Short-term concept design and costing - Clifton to Tangoio 2120 coastal strategy - Design workstream

Flood defences Pandora Unit

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Regional Assets

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Glossary of abbreviations and terms

AEP	Annual Exceedance Probability
MHWS	Mean High Water Spring tide level
MLWS	Mean Low Water Spring tide level
NCC	Napier City Council
NSC	Napier Sailing Club
$R_{u2\%}$	Run-up level exceeded 2% of the time during a sea state
TAG	Technical Advisory Group of the Clifton to Tangoio 2120 Coastal Strategy

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Executive summary

The Technical Advisory Group of the Clifton to Tangoio 2120 Coastal Strategy, commissioned the Hawke's Bay Regional Council to undertake the concept design and costing for the short-term preferred pathways selected by the community panels during the stage 3 of the strategy (Bendall, 2018).

A first report by Beya & Asmat (2021) provided the concept design and costing for most of the units requiring short-term action except for Pandora. The present report contains the design of 2,150 m of inundation protection from the railway embankment to West Quay as the selected pathway for the Pandora unit.

As part of the design process, modifications were introduced to the concept considered in stage 3, which short-term build costs were estimated at 2 million NZD. Changes in the layout and different typologies were introduced, including: stopbanks, a steel sheetpile wall, cantilever walls and revetments, road raising, the Napier Sailing Club upgrade and stormwater drainage. These changes originated significant additional costs:

- 204 m of steel sheetpile wall ($730,000 NZD construction cost).
- 240 m of cantilever wall and revetment ($930,000 NZD construction).
- Including a mobile flood barrier or raising of Pandora Rd in order to provide continuity to the flood defence (1.2 - 8.6 million NZD construction cost, Napier City Council estimate).
- Include a practical solution for the Napier Sailing Club inside the flood defences (23.8 million NZD construction cost, Napier City Council estimate).
- Include an additional drainage system to the existing for the stormwater produced behind the defences (7 million NZD construction cost, very rough order).

The design crest levels considered in the design vary from RL 12.9 m to RL 13.6 m, correspond to an extreme surge over a pessimistic mid-term sea level (RCP 8.5 H+, MFE, 2017), and include a 0.6 m freeboard.

The typologies above include a long-term resilience and adaptability strategy. Stopbanks can be raised relatively easily in the future if needed. Sheetpile walls have a short design life of 20 years after which they need to be replaced. Cantilever walls and revetment were designed so that the buried part of the wall does not need to be modified if the exposed part needs to be raised. Although, a less costly alternative where the buried part is designed for a lower crest level was also included. In order to keep the costs within reason, the design crest levels for Pandora Rd and the Sailing club allow for a long-term protection under a moderately optimistic long-term sea level rise scenario, but higher levels will need to be considered at a higher cost if a pessimistic scenario develops.

Stormwater drainage was included at a very rough order costing. The costing estimate was based on values provided by Napier City Council, which are currently in the early stages of the Ahuriri Masterplan Stormwater study.

Given that the level of expenditure required for the flood defences has been found to be of the order of tens of millions, the alternative of a storm surge barrier at the entrance of the Ahuriri Inner Harbour became more attractive and was also included as a preliminary concept idea.

In this way, five options were costed for the decision-making process and the following funding work required for the strategy. For the first two options, a sensitivity analysis on a ±0.5 m variation in the design crest level was included and shown below inside square brackets:

- Option 1a (20.11 [17.27, 21.66] million NZD construction cost): Flood defences (stopbanks, sheetpile wall and reinforced concrete cantilever wall with a revetment) along the coastal edge bypassing NSC and including the raising of Pandora Rd. The cantilever wall was designed to be easily raised in the future without having to modify its buried part.
- Option 1b (11.87 [8.61, 12.44] million NZD construction cost): Same as Option 1a but including a mobile flood barrier across Pandora Rd instead of raising it.
- Option 2a (43.57 [38.25, 47.57] million NZD construction cost): Same as Option 1a but upgrading NSC including raising its floor levels.
- Option 2b (35.33 [32.30, 38.36] million NZD construction cost): Same as Option 1b but upgrading NSC including raising its floor levels.
- Option 3 (~30 million NZD): A inflatable storm surge barrier. No flood defences or NSC upgrade.

For option 1a, the largest proportion of the cost is related to the raising of Pandora road and the additional stormwater drainage system (79 % of the total cost). For option 2a, the Napier Sailing Club upgrade is added to the latter raising the percentage to 92 % of the total cost.

These options are at least near 6 times more expensive than the estimated in Stage 3. However, given the importance and interest in developing the area, this result is unlikely to change the selected pathway (inundation protection for the short, mid and long terms).

A large area was identified as vulnerable to future flooding and further analysis has been recommended in order to assess the need for extending the flood defences beyond the present design.

For options 1a, 1b, 2a and 2b there is a high risk of consenting failure due to the ecological and environmental implications of altering the Ahuriri estuary and in particular the loss of intertidal area that would occur in the future with the projected sea level rise if flood defences are in place. For these options, environmental mitigation such as the creation of an artificial estuarine intertidal area in the present Ahuriri Lagoon farm may be required at an additional cost.

The Ahuriri Master Plan Stormwater study could provide better estimates for the additional stormwater systems required as a consequence of the coastal strategy works.

Finally, monitoring and investigations related to waves, water levels and corrosion were identified as critical to better define design crest levels and the design lifetime of the structures. It is recommended to start these soon in preparation for the future needs.

The peer review highlighted potential areas of improvement for this report, mainly for the inundation protection structures along the shoreline. However, the review was finalised after the results were presented to the community panels (Feb 2021) where it was decided to introduce the changes recommended by this report. These changes are:

- The short-term preferred pathway changes from inundation protection to status-quo.
- The preferred option from the inundation barriers along the Pandora shoreline to the storm surge barrier at the mouth of the estuary.

With these changes, many of the additional refinements to the concept design suggested by the peer reviewer are not justified. However, peer review comments have been noted and shall be considered for future designs in the area (Appendix E).

1 Introduction

The Technical Advisory Group (TAG) of the Clifton to Tangoio 2120 Coastal Strategy has commissioned the Hawke's Bay Regional Council (HBRC) to carry out the short-term preferred pathways concept design defined in Stage 3 (Bendall, 2018). A previous report (Beya & Asmat, 2021) covered most of the units requiring short-term action. The present report covers the short-term concept design for the remaining unit, Pandora. The preferred pathway selected in the Stage 3 of the strategy includes a coastal flood defence along the southern boundary of the Ahuriri estuary, between the Expressway and Pandora Rd and along the Napier Sailing Club (Figure 1-1, Table 1-1).

Figure 1-1: Layout of the preferred pathway for the Pandora Unit selected in the stage 3 of the strategy (Bendall, 2018).

Table 1-1: Preferred pathway Pandora Unit selected in the stage 3 of the strategy (Bendall, 2018).

UNIT E2: PANDORA – PATHWAY 3				
Short term (0 – 20 years)	→	Medium term (20 – 50 years)	→	Long term (50 – 100 years)
Inundation Protection	→	**Inundation Protection**	→	**Inundation Protection**

2 Background information

A previous design report by Beya & Asmat (2021) developed the concept design and costing for the short-term preferred pathways for most of the units in the coastal strategy except for Pandora. The report contains base information on water levels, wave data, structural design and costing.

The survey data used in the present study corresponds to the HBRC digital elevation model created with Lidar survey data from year 2003. The default vertical datum used in this report is the HBRC vertical datum which was set at RL 10 m at the sea level at the time (1960's).

Geotechnical information of the area has been obtained from Tonkin & Taylor (2017a, 2017b), who undertook geotechnical investigations for a toilets block in the Humber Street reserve (10 Humber St, Pandora) and the Port of Napier Storage area in 73-75 Thames St, Pandora. Both studies indicate that the surficial soils at 1 m depth are loose to medium dense sands and gravels, and provide an indicative geotechnical ultimate bearing capacity of 300 kPa. Deeper soil composition is mostly non-cohesive.

Goodier (2007) carried out a 2D flood modelling study in the Ahuriri estuary considering storm surge, astronomical tides and sea level rise, which identified areas at future risk. The maximum water level considered as a sea level boundary condition was RL 12.6 m. Goodier (2007) found that this maximum level attenuated from 10 cm up to 40 cm as the water flooded the inner harbour and estuary during the astronomical tide cycle. Goodier (2019, *pers. comms.*) also indicated that flooding from inland run-off and streams causes negligible effects in the estuary and inner harbour.

Tonkin & Taylor (2016) carried out a coastal hazards risk assessment based on sea level rise scenarios of 0.5 m and 1.0 m for the 2065 and 2120 time horizons. Extreme water levels for 10% AEP, 1% AEP and 0.5% AEP based on a frequency analysis of the Port of Napier tide gauge records were estimated. Extreme levels ranged from RL 11.4 to RL 11.54 m for the present day, from RL 11.9 m to RL 12.04 m for year 2065, and from RL 12.1 m to 12.54 for year 2120. Mapping based on this study and unpublished modelling work by Goodier (2016) is included in the current coastal hazards maps (www.hbhazards.co.nz).

As-built, design and upgrades information for the existing stopbanks in the Ahuriri estuary is scattered and scarce. However, the Lidar survey indicates that the design crest level must be RL 12.5 m. Graham Edmonson (HBRC senior engineer officer, 2019, *pers. comms.*) who was the engineer in charge of the stopbank construction, indicated that the stopbank composition is of poorly graded clean fill but that intensive compaction of the existing ground and fill material was undertaken. He also indicated that the crest width and slopes were originally those typical of river stopbanks (4 m; grassed 2: 1, H:V), but that in 2015 the water side slope was decreased to 2.5:1 (H:V) and protected with a rock rip-rap with a geotextile filter.

3 Layout design

Different typologies were selected for the flood defences depending on local conditions such as space availability, existing and future infrastructure, land use and aesthetics. Meetings with TAG members and planners from Napier City Council (NCC) and Napier Sailing Club (NSC) were held. The Ahuriri Estuary & Coastal Edge Masterplan (NCC, 2018) was considered in the design.

In this process, it was identified that the original layout (Figure 1-1) needed to be altered and that Pandora Road and NSC needed to be raised (Figure 3-1). The main changes recognized are:

- Need to Raise Pandora Road to provide continuity to the flood defence.
- Impracticality to build a seawall along the NSC waterfront. This was anticipated to be an awkward solution, which would make providing the services required by the marina costly and cumbersome. Meetings with NCC and NSC have confirmed this view. NSC indicated that their preferred option is to raise the land. As a first option, a flood defence that bypasses NSC (Stopbank 3 in Figure 3-1) has been considered. As a second option, NCC has provided rough order costing for an upgrade of NSC which consists of raising ground levels, building a revetment and a sea wall, and demolishing and reconstructing buildings. The estimated construction cost of this upgrade was 18.3 million NZD (Robin Malley, NCC, *pers. comms,* 2019). A different option could be a combination of the latter by building a flood defence that bypasses NSC, while undertaking adaptability measures for NSC and accepting higher flooding occurrence.
- Change of the location of the flood defence from the railway to Tyne drain (Stopbank 1 in Figure 3-1) to include the storm water treatment wetland proposed in the master plan.

Additionally, it was identified that in the future, depending on the magnitude of the sea level rise, extended protection may be required beyond that identified in the Stage 3 of the strategy (Figure 1-1, Figure 3-2).

Figure 3-1: Layout design for the flood defences in the Pandora unit.

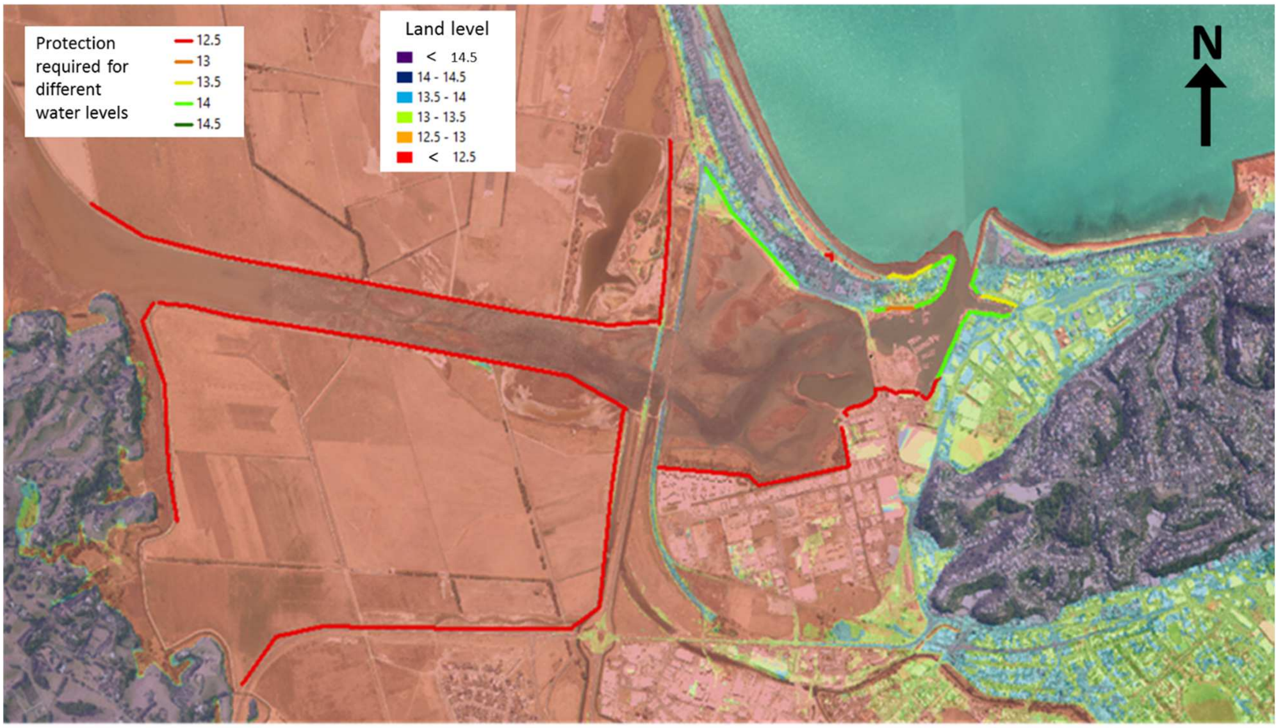


Figure 3-2: Potential extent of the flood protection defences for different water levels (coloured lines) and land levels (coloured areas) in the surroundings of Pandora.

4 Design Water Levels

The design water levels were calculated using as a base, the levels in the concept design from the previous design work (Beya & Asmat, 2021). In addition to those levels, local considerations such as seiches, wind-setup, waves and run-up had to be included.

For Pandora, the long-term effects had to be considered in more detail as the design of the foundations need to account for possible future upgrades of the flood defences.

The following components were considered for the design water level:

4.1 Sea level rise

The future sea level rise was obtained from MFE (2017; See Beya & Asmat, 2021) and IPCC (2019, SROCC report, Figure 4-1). Values for the short, medium and long-term for different RCP scenarios were considered.

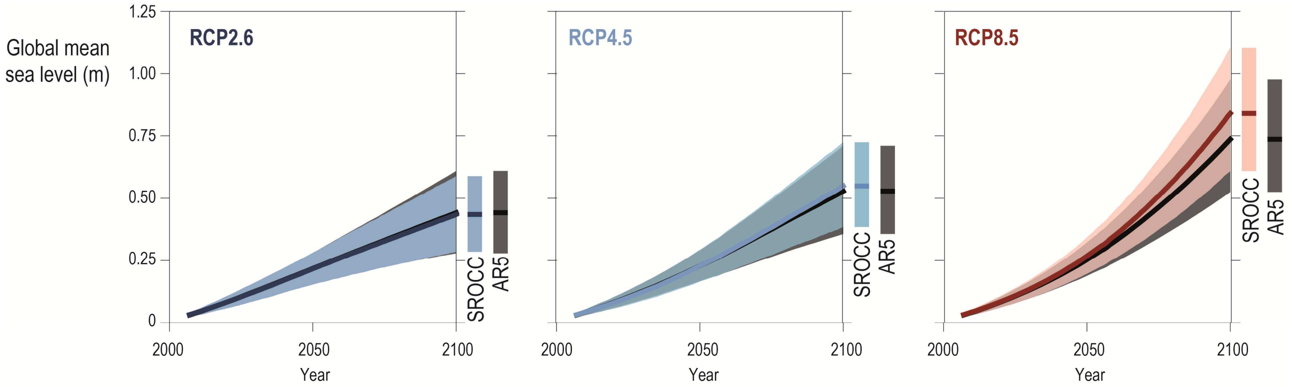


Figure 4-1: Updated sea level rise projections IPCC (2019).

4.2 Land Subsidence

A 2 mm/y subsidence rate was considered (Beavan & Litchfield, 2012; Rob Bell, NIWA*, pers. comms*., 2019).

4.3 Astronomical tides

A value of 1.89 m above the Chart Datum equivalent to the MHWS was considered as by Beya & Asmat (2021).

4.4 Hydrodynamic reduction

Hydrodynamic modelling by Goodier (2007) showed that the full coastal tidal amplitudes are not able to penetrate through the estuary. As a consequence, a reduction of 10 cm in the Inner Harbour area and 30 cm in the Pandora basin was considered.

4.5 Sea level anomaly

A 7.4 cm value was considered corresponding to the 95% non-exceedance value as by Beya & Asmat (2021).

4.6 Combined storm surge and wave run-up

A 21 year long time series was available for atmospheric pressure and wind velocity using the data from the Port of Napier and Hawke's Bay Airport stations. The coastal wind set-up and inverse barometer pressure effect were calculated as by Beya & Asmat (2021) from this timeseries.

The wind set-up, wave height and period inside the estuary were calculated using CIRIA (2007, eq. 4.12) and Kamphuis (2000, section 5.2.1 - Jonswap method). The $R_{u2\%}$ (Run-up level exceeded 2% of the time during a sea state) was calculated for the wind waves generated inside the estuary following EurOtop (2018, eq. 5.4, eq. 5.5, eq. 5.6, table 6.2) for the different design slopes, roughnesses and locations.

A frequency analysis was carried out for the combined water level including coastal storm surge, wind set-up and wave run-up, for the different batter slopes and roughnesses, in order to determine the super elevations for a range of Annual Exceedance Probabilities (AEP). The 2% AEP value plus a 5% increase due to potential future changes was selected for design.

4.7 Seiches

Values between 0.2 m and 0.3 m were considered based on an educated guess confirmed by qualitative knowledge by senior NSC members during noticeable events. A harbour resonance study may be required to quantify better this parameter.

4.8 Run-up from ocean waves

Values between 0.2 m and 0.3 m were considered based on qualitative information for the area with direct exposure to the ocean (i.e. Napier Sailing Club, West Quay). A wave penetration study may be required to better quantify this parameter.

4.9 Inland flooding effects

The super elevations produced by inland flooding were studied by Goodier (2019, *pers. comms.*), who found that those effects were negligible in the estuary.

4.10 Freeboard

A 0.6 m freeboard was considered following recommendations by CIRIA (2013) and the present day freeboard in the Hawke's Bay rivers and estuaries stopbank network.

The design crest levels were calculated as the superposition of the components outlined above for different locations, time horizons and carbon emissions scenarios (Table 4-1). The values obtained range from RL 12.40 m to RL 14.72 m.

Table 4-1: Total Design water and crest level.

	Revetment 1 (Pandora)					Stopbanks 1 and 2					Stopbank 3 and Revetment 2 (West Quay)					Sheetpile wall				
Design Water levels	**ST 8.5H+**	**MT 8.5 H+**	**LT 4.5**	**LT 8.5**	**LT 8.5 H+**	**ST 8.5H+**	**MT 8.5 H+**	**LT 4.5**	**LT 8.5**	**LT 8.5 H+**	**ST 8.5H+**	**MT 8.5 H+**	**LT 4.5**	**LT 8.5**	**LT 8.5 H+**	**ST 8.5H+**	**MT 8.5 H+**	**LT 4.5**	**LT 8.5**	**LT 8.5 H+**
Sea level rise (m)	0.24	0.58	0.65	1.03	1.33	0.24	0.58	0.65	1.03	1.33	0.24	0.58	0.65	1.03	1.33	0.24	0.58	0.65	1.03	1.33
Astronomical tide MHWS (Chart datum)	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89
Hydrodynamic reduction (m)	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1	-0.1	-0.3	-0.3	-0.3	-0.3	-0.3
Storm surge (m)*																				
Sea level anomaly (m)	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
Set-up from ocean waves (m)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Run-up ocean waves (m)	0	0	0	0	0	0	0	0	0	0	0.2	0.25	0.3	0.3	0.3	0	0	0	0	0
Seiches (m)	0.2	0.25	0.3	0.3	0.3	0.2	0.25	0.3	0.3	0.3	0.2	0.25	0.3	0.3	0.3	0.2	0.25	0.3	0.3	0.3
Local wave run-up (m)*																				
Combined Storm surge and Local wave runup (m)**	0.57	0.60	0.60	0.60	0.60	0.68	0.70	0.70	0.70	0.70	0.82	0.84	0.84	0.84	0.84	0.59	0.61	0.61	0.61	0.61
Land subsidance 2mm/y	0.04	0.10	0.20	0.20	0.20	0.04	0.10	0.20	0.20	0.20	0.04	0.10	0.20	0.20	0.20	0.04	0.10	0.20	0.20	0.20
Increase IPCC SROOC report 2019	0.01	0.05	0.00	0.15	0.20	0.01	0.05	0.00	0.15	0.20	0.01	0.05	0.00	0.15	0.20	0.01	0.05	0.00	0.15	0.20
Inland flooding (m)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (m) Chart datum	2.72	3.24	3.41	3.94	4.29	2.84	3.35	3.52	4.05	4.40	3.38	3.94	4.16	4.69	5.04	2.74	3.25	3.42	3.95	4.31
Total (m) HBRC Datum	11.80	12.32	12.49	13.02	13.37	11.92	12.43	12.60	13.13	13.48	12.46	13.02	13.24	13.77	14.12	11.82	12.33	12.50	13.03	13.39
Freeboard - Settlement (m)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Total (m) Chart datum	3.32	3.84	4.01	4.54	4.89	3.44	3.95	4.12	4.65	5.00	3.98	4.54	4.76	5.29	5.64	3.34	3.85	4.02	4.55	4.91
Design Level (m) HBRC Datum	12.40	12.92	13.09	13.62	13.97	12.52	13.03	13.20	13.73	14.08	13.06	13.62	13.84	14.37	14.72	12.42	12.93	13.10	13.63	13.99

5 Stopbanks design

A 1070 m stopbank (**Stopbank 1**) has been proposed for the reach between the railway and Tyne drain, crossing a DOC reserve area (Figure 3-1). The Ahuriri Master Plan (NCC, 2018) was taken into consideration and the initial layout (Figure 1-1) was changed to include inside the flood protection a wetland for storm water treatment located adjacent to the railway.

A second 190 m long stopbank (**Stopbank 2**) has been proposed across the Humber St reserve. A third 180 m long (**Stopbank 3**) is proposed through the Napier Sailing Club (NSC). Presently, along these stopbanks, there are accesses to the estuary and Sailing Club. However, a recent discussion with NCC Senior Roading Engineer, Tony Mills indicated that access provision through these stopbanks may not be required in the future. For Stopbank 2, an access solution for the *wakas* may be achieved at a similar cost as for the stopbank in the location. For Stopbank 3, access to the Sailing Club is planned to be shifted directly from Pandora St next to the bridge.

5.1 Design crest elevation

The design crest elevations were defined as in Table 5-1 for the three stopbanks based on the mid-term design levels in Table 4-1.

Table 5-1: Design crest level for the stopbanks.

Stopbank	Short-term Design Crest Level (m HBRC vertical datum)
Stopbank 1	RL 13.0 m
Stopbank 2	RL 13.0 m
Stopbank 3	RL 13.6 m
Existing stopbanks	RL 12.5 m

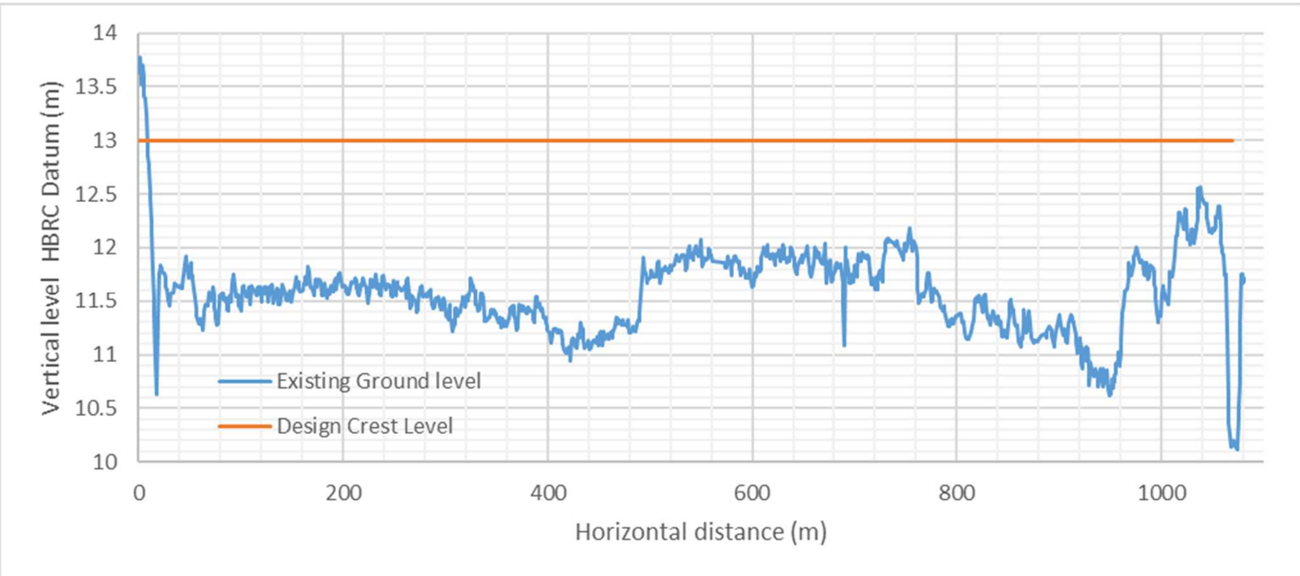


Figure 5-1: Stopbank 1 ground level and design crest level long elevations.

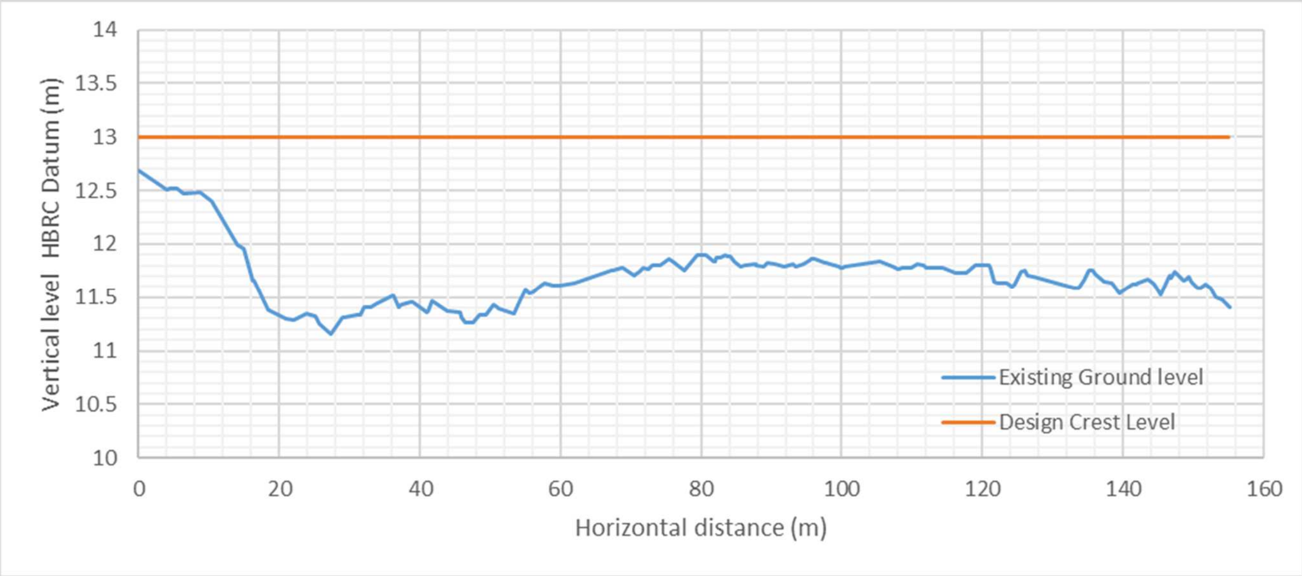


Figure 5-2: Stopbank 2 ground level and design crest level long elevations.

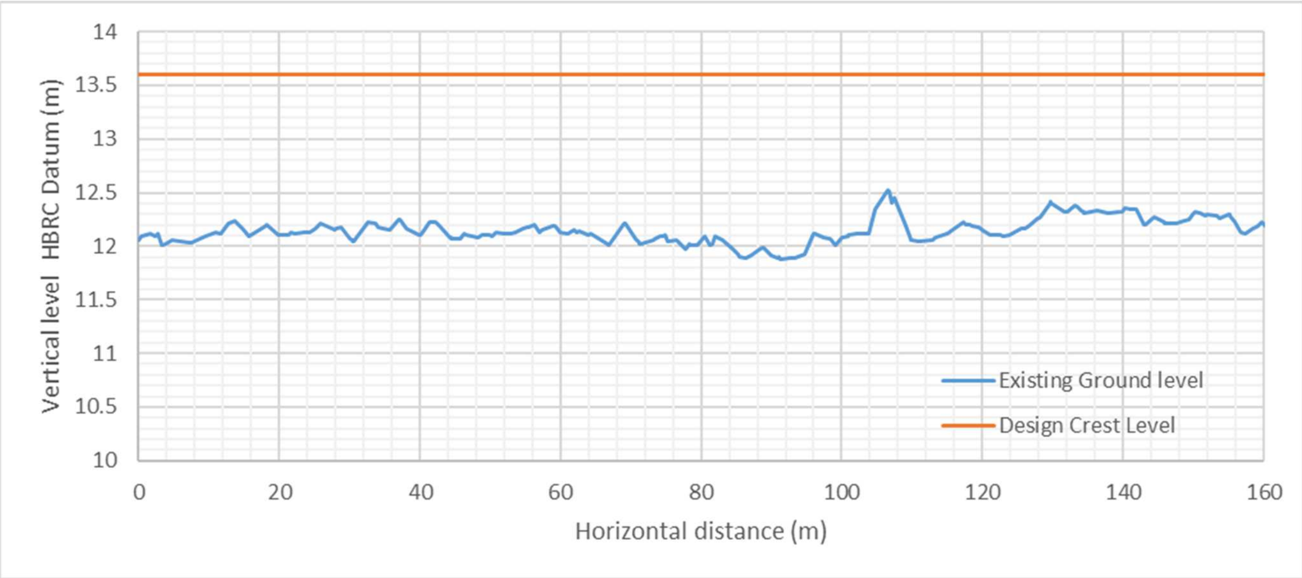


Figure 5-3: Stopbank 3 ground level and design crest level long elevations.

5.2 Geometry

A typical design cross section following CIRIA (2007) has been considered (Figure 5-6). This geometry is consistent with the existing stopbanks upstream the Ahuriri estuary. The ground level is assumed to be approximately flat across the stopbank for the quantity calculations.

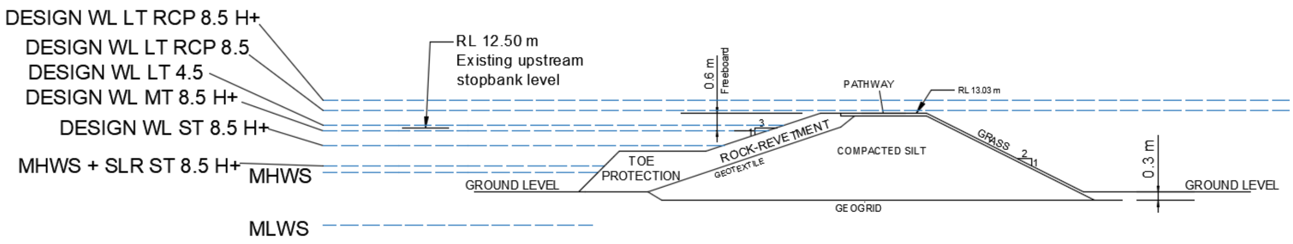


Figure 5-4: Typical stopbank cross section.

5.3 Embankment composition

Compacted silt of adequate grading has been considered as the embankment fill material. Detail material specifications must consider piping, seepage, geotechnical stability, and rapid drawdown failure modes.

5.4 Foundations

The soils in the area are composed of loose to medium density gravelly sands with a geotechnical ultimate bearing capacity of 300 kPa (Tonkin & Taylor, 2007a, 2007b). Therefore, soil improvement such as deep compaction and geogrid at the base have been considered. Global and local stability analysis should be carried out in the detail design stage.

5.5 Piping, seepage and internal erosion control

Under-seepage risk through the existing ground has been analysed at a concept level (USACE, 2000, Appendix B). The analysis indicated that the risk of piping is small given the maximum height of the stopbank. Therefore, no counteracting measures such as cut-off walls, pressure relief wells and landside berms were considered. Further analysis is required for the detail design phase.

Seepage through the embankment is controlled by the type of material used for the embankment (compacted silt of adequate grading). Further design and specifications will be required for the detail design stage.

5.6 External erosion

On the waterside slope, a two layers, 100 kg median mass, limestone rock revetment with a geotextile filter and a Dutch toe (Figure 5-5) has been considered as erosion protection against locally generated wind waves, small amplitude ocean waves, currents and animal burrowing. Rock size is over dimensioned for the purposes of stability against wave attack, in order to make difficult the manual movement of the rocks by people. This issue has been occurring on the existing stopbanks, where smaller size rocks have been displaced possibly by people looking for access to launch their vessels.

Wave conditions were estimated as per section 4.6. Rock size and layer thickness were calculated following USACE (2006, Part VI-5). Local scour was considered to be of the order of the design significant wave height (0.33 m). General scour was considered to reach the MLWS.

In places where the stopbank height is small due to higher existing ground levels, the toe is placed below ground level assuming a scour depth equal to the local scour. In places where the excavation of the toe would reach the present day MSL, a surface toe is considered assuming a scour depth equal to the local scour plus 0.5 m of general scour.

On the crest and landside slope, the stopbank is designed to not overtop for water levels below the design condition. The pathway on the crest and grassed landside slope will provide protection for external erosion in case of minor overtopping. Large overtopping will likely cause severe erosion and timely emergency management actions such as sandbagging, which may help in preventing a catastrophic failure in this extreme case.

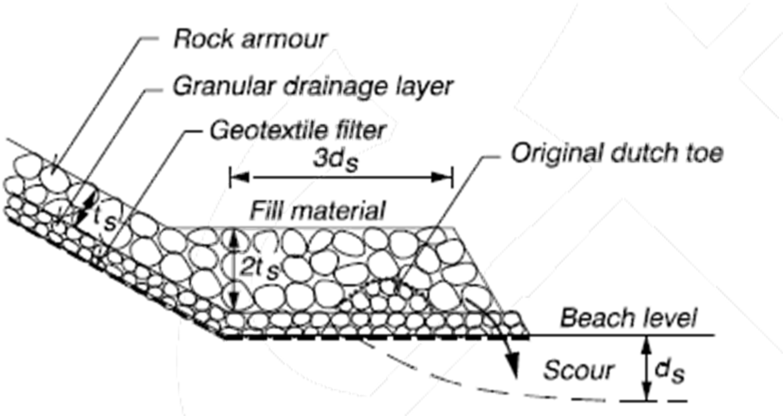


Figure 5-5: Toe designs where scour is foreseen (USACE, 2006, Fig VI-5-50)

5.7 Long-term resilience and adaptability

Future need to increase the crest height can be achieved incrementally by rising the stopbanks as shown in Figure 5-6, provided the foundations have sufficient bearing capacity. A preliminary analysis based on existing soil data showed that the soil may have sufficient capacity for a long-term design upgrade. In any case, soil improvement has been specified in case the results of the soil parameters differ from those by Tonkin & Taylor (2017a, 2017b). Further geotechnical investigations and design are required.

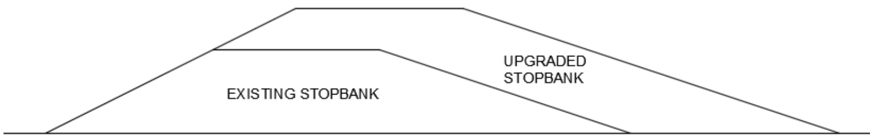


Figure 5-6: Stopbank future upgrade configuration.

5.8 Costing

Costing for the stopbanks has been estimated from projects undertaken by HBRC. A 10% increase in future prices and a 20% provision for contingency costs has been included. Operations supervision has been estimated as 5% the maintenance cost.

For the total costs in Section 9, carbon emission offsetting has been estimated based on coarse figures obtained for the Clifton revetment, considering 1% the construction cost as a capital cost and 0.07% of the maintenance cost for the operational cost (Beya & Asmat, 2021). A 5% allowance has been considered for design and a 10% allowance for consenting. A provision for structural repairs due to erosion or settlement has been included as 10% of the construction cost every 10 years.

Table 5-2: Construction costing for Stopbank 1.

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base stopbank and stockpile	m2	17,505	$ 1.50	$ 26,257
3	Excavate, load cart unsuitable material	m3	500	$ 6.00	$ 3,000
4	Soil improvement (Dynamic Compaction)	m2	15,365	$ 30.31	$ 465,677
5	Geogrid	m2	11,879	$ 5.00	$ 59,396
6	Excavate,load,cart,place,compact Stopbank	m3	11,059	$ 8.40	$ 92,895
7	Supply, place geotextile	m2	9,473	$ 5.00	$ 47,365
8	Supply Rock (limestone or greywacke)	m3	7,329	$ 70.00	$ 513,027
9	Place Rock	m3	7,329	$ 10.00	$ 73,290
10	Topsoil, grass and harrow	m2	3,448	$ 0.20	$ 690
11	Construct, maintain haul roads	LS	100%	$ 5,000	$ 5,000
12	Watercart	hr	100	$ 85.00	$ 8,500
13	Erosion control	LS	100%	$ 5,000	$ 5,000
14	Construct limesand pathway	m	1,070	$ 35.00	$ 37,450
15	Supervision	week	4	$ 2,000	$ 8,000
16	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 1,355,547**
17	Contingency	LS	10%	$ 1,355,547	$ 135,555
18	Future increase	LS	10%	$ 1,355,547	$ 135,555
Total Construction Cost					**$ 1,626,656**

Table 5-3: Construction costing for Stopbank 2.

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	50%	$ 5,000	$ 2,500
2	Stripping base stopbank and stockpile	m2	2,440	$ 1.50	$ 3,660
3	Excavate, load cart unsuitable material	m3	125	$ 6.00	$ 750
4	Soil improvement (Dynamic Compaction)	m2	2,130	$ 30.31	$ 64,560
5	Geogrid	m2	1,654	$ 5.00	$ 8,270
6	Excavate,load,cart,place,compact Stopbank	m3	1,374	$ 8.40	$ 11,538
7	Supply, place geotextile	m2	1,322	$ 5.00	$ 6,610
8	Supply Rock (limestone or greywacke)	m3	1,018	$ 70.00	$ 71,281
9	Place Rock	m3	1,018	$ 10.00	$ 10,183
10	Topsoil, grass and harrow	m2	449	$ 0.20	$ 90
11	Construct, maintain haul roads	LS	20%	$ 5,000	$ 1,000
12	Watercart	hr	20	$ 85.00	$ 1,700
13	Erosion control	LS	20%	$ 5,000	$ 1,000
14	Construct limesand pathway	m	155	$ 35.00	$ 5,425
15	Supervision	week	1.5	$ 2,000	$ 3,000
16	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 196,567**
17	Contingency	LS	10%	$ 196,567	$ 19,657
18	Future increase	LS	10%	$ 196,567	$ 19,657
Total Construction Cost					**$ 235,881**

Table 5-4: Construction costing for Stopbank 3.

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base stopbank and stockpile	m2	2,960	$ 1.50	$ 4,441
3	Excavate, load cart unsuitable material	m3	500	$ 6.00	$ 3,000
4	Soil improvement (Dynamic Compaction)	m2	2,590	$ 30.31	$ 78,510
5	Geogrid	m2	2,086	$ 5.00	$ 10,431
6	Excavate,load,cart,place,compact Stopbank	m3	1,880	$ 8.40	$ 15,796
7	Supply, place geotextile	m2	1,563	$ 5.00	$ 7,813
8	Supply Rock (limestone or greywacke)	m3	1,235	$ 70.00	$ 86,456
9	Place Rock	m3	1,235	$ 10.00	$ 12,351
10	Topsoil, grass and harrow	m2	602	$ 0.20	$ 120
11	Construct, maintain haul roads	LS	25%	$ 5,000	$ 1,250
12	Watercart	hr	25	$ 85.00	$ 2,125
13	Erosion control	LS	25%	$ 5,000	$ 1,250
14	Construct limesand pathway	m	185	$ 35.00	$ 6,475
15	Supervision	week	2	$ 2,000	$ 4,000
16	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 244,018**
17	Contingency	LS	10%	$ 244,018	$ 24,402
18	Future increase	LS	10%	$ 244,018	$ 24,402
Total Construction Cost					**$ 292,821**

6 Steel sheetpile design

A 204 m long steel sheetpile wall is proposed for the industrial area in Pandora (Figure 3-1), because currently there is no space for a stopbank.

6.1 Design crest elevation

Given that a 20 year design life was defined for the proposed sheetpile wall (see Section 6.3). A design crest level of RL 12.9 m corresponding to the midterm RCP 8.5 H+ scenario in Table 4-1 was considered. This in the realisation that the construction of this project may be many years ahead as the triggers have not yet been defined.

The long profile ground levels from a Lidar survey and design crest elevation are shown in Figure 6-1.

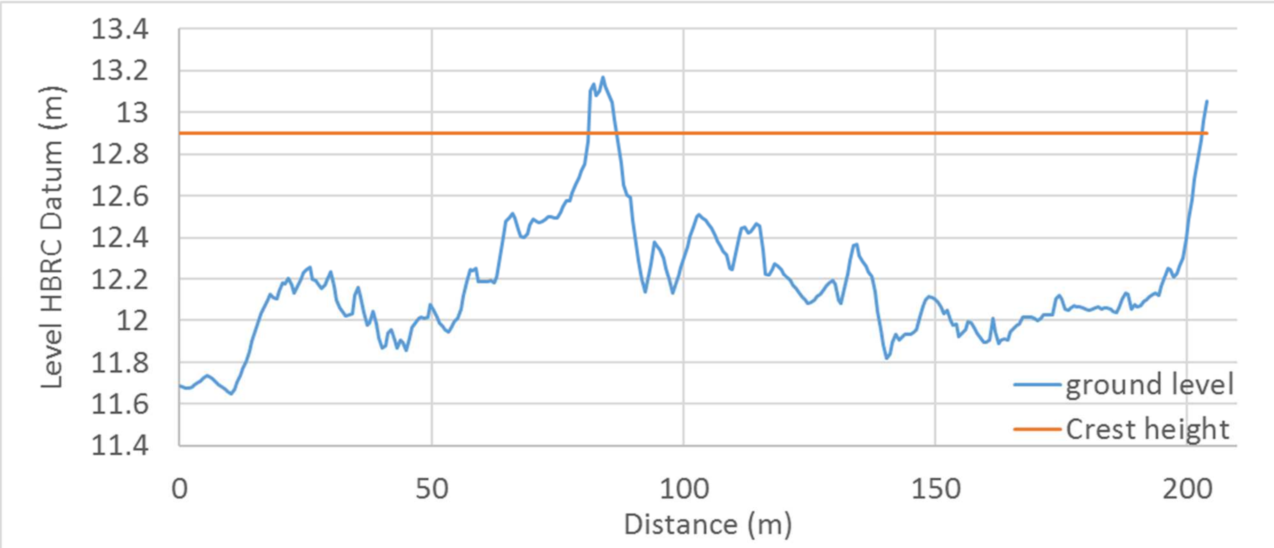


Figure 6-1: Steel sheetpile ground levels and crest elevation.

6.2 Geotechnical and structural design

The geotechnical and structural design was carried out using the Acelormittal software Prosheet v2.2 for different water depths. The parameters used in the software are listed below and the results shown in Table 6-1:

- Wall type: Cantilever
- Water level in front =0
- Water level behind = wall height
- Soil parameters:
  - Homogeneous sand layer
  - Dry density= 15.6 kN/m^3
  - Moist density= 19.6 kN/m^3
  - Submerged density= 9.55 kN/m^3
  - Passive pressure coefficient, K_p=3
  - Active pressure coefficient, K_a=0.33
- Loads:

- Hydrostatic and soil loads
- Wave impact force 2.8 KN/m at the top of the wall obtained for a H = 0.3 m T_p = 2 s design wave using Goda (1974) formula (USACE,2006, part VI).
- Debris impact force 20 KN/m at the top of the wall.

Table 6-1: Sheetpile geotechnical and structural design results.

Sheetpile height above ground (m)	Sheetpile depth below ground (m)	Sheetpile Length (m)	Max moment (kNm/m)
0.0	0.00	0.00	0
0.5	2.90	3.48	34.6
1.0	3.57	4.57	58.5
1.5	4.20	5.72	93.1
2.0	3.14	5.14	47.6
3.0	4.55	7.55	142.6

6.3 Durability design

The design life and sheetpile section design was defined using the Acelormittal software Durability 3.5.2.145 and the assistance from Acelormittal Australia. The software also provides with an estimate for the steel quantities which were used in the costings in section 6.6.

The corrosion rate used in the design was 0.15 mm/y corresponding to a very severe exposure condition according to the SNZ 3404 (2018, Tables 10 and 13). However, the Eurocode used by the software indicates a maximum corrosion rate of 0.075 mm/y.

The most sensitive area for corrosion control is the buried part of the sheetpile subject to tidal groundwater fluctuations because it is where inspection and maintenance will be difficult, the bending moments are maximum, and any coating protection may suffer abrasion during the driving process. Nonetheless, the corrosion rates may be lesser than those in the exposed areas as the ground will decrease the oxygen exchange with the atmosphere. On the other hand, corrosion exposure may also be larger with rates over 0.2 mm/y according to SNZ 3404:2018.

Corrosion protection measures such as galvanising, epoxy coating and cathodic protection were considered but they resulted costly and of uncertain effectiveness for the project (protection in the most sensitive area cannot be ensured). Rough order factory coating of sheetpiles (~ $200.000) and cathodic protection (~$100.000, only effective for the permanently submerged part) where investigated.

Results indicate that an uncoated 10.2 mm carbon steel thickness Acelormittal GU 16N sheetpile wall should provide a 20 years design life at a cost of ~ $630.000 (Figure 6-2). Note that since the design lifetime is 20 years, the maximum height of the wall is 1.5 m with the corresponding maximum bending moment of 93 kNm/m. If a longer design life is considered, greater heights will be required and the structural stability of the wall should be revised for higher design bending moments.

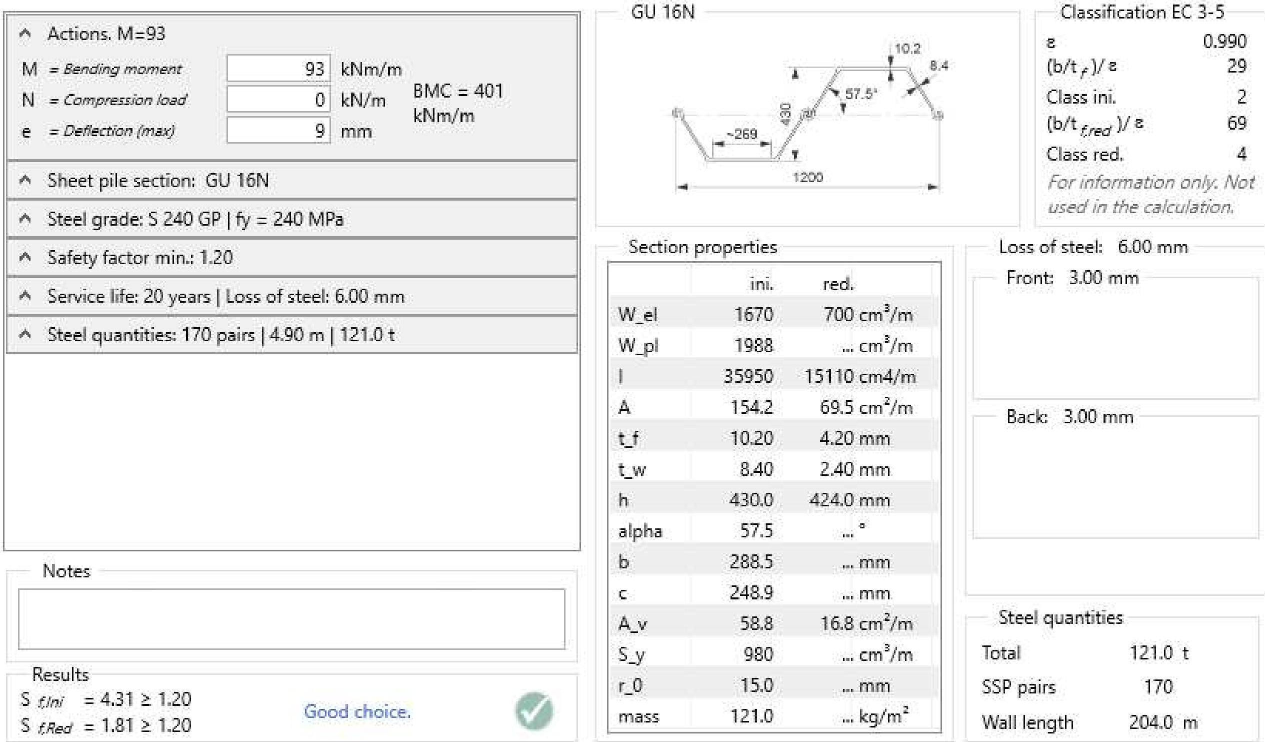


Figure 6-2: Input parameters and results from the durability design (Acelormittal Durability software).

6.4 Water tightness

Factory applied sealant in the sheetpile clutches was considered for the area of the wall above ground. This in order to minimise inundation from leakage through the wall.

6.5 Capping beam

An uncoated double 150 mm x 900 mm x 10 mm unequal angle bolted through the top of the sheetpile wall was considered as a capping beam.

6.6 Long-term resilience and adaptability

Given the design life of this structure, the wall may need to be replaced after 20 years when a new solution will need to be designed (possibly another sheetpile wall). The long-term adaptation plan for this structure is reconstruct every 20 years if needed.

6.7 Costing

The construction cost for the sheetpile was estimated from information provided by Lattey, Acelormittal Australia and ANZOR (Table 6-2). Protective coating may be included for the part exposed to the atmosphere at a cost of $190/m^2, in an attempt to extend the life of the structure. However, since the design life is 20 years for an uncoated wall, the operational cost has been limited to an inspection cost of $2,000/y.

A 10% increase in future prices and a 15% allowance for contingency costs has been included in the construction cost.

For the total costs in Section 9, the carbon emissions offsetting cost has been estimated in 130 tonne of CO_2 at a price of 30 NZD/Tonne CO_2 using the Carbon Calculator from the UK Environment Agency (Environment

Agency, 2007). Operations supervision has been estimated as 5% the maintenance cost. A 5% allowance has been considered for design and a 10% allowance for consenting.

Table 6-2: Construction costing for steel sheetpile.

Item	Quantity	Unit quantity	Unit cost	Cost (NZD)
Supply of sheetpile	121.0	tonne of steel GU 16N	$1,400	$139,497
Transportation of sheetpile to site	121.0	tonne of steel GU 16N	$300	$29,892
Sealant	1666	Sheetpiles length	$32	$43,919
Pile driving cost	340	N of piles	$909	$309,091
Top beam unequal angle	7058	Kg of steel 150x90x10mm angle	$3.53	$24,933
Bolts for top beam	680	for M12 X 50 GALV 8.8 HSFG STRUCTURAL BOLT & NUT & WASHER	$1.733	$1,178
Top beam installation	5	days	$610	$3,050
Gravel foundation for plant	1		$20,000	$20,000
Plant mobilization/demobilization	1		$15,000	$15,000
Subtotal				**$586,561**
Contingency	15%	subtotal	$632,198	$87,984
Future increase	10%	subtotal	$632,198	$58,656
Total				**$733,201**

Note: Contractor overheads and profit are included in the rates

7 Cantilever wall with revetment

A revetment backed with a cantilever reinforced concrete wall has been considered for two stretches along the flood defence. Revetment 1 is 110 m long along the Pandora pond, where an existing car-tyre revetment is located. Revetment 2 is 130 m long at the location of the existing rock revetment at West Quay (Figure 3-1).

7.1 Design crest elevation

The defined design crest elevations for the walls and revetments are shown in Table 5-1. These were obtained from the mid-term design crest levels in Table 4-1. The mid-term level was adopted (as for the other flood defence structures) because this project is likely to get materialised further away in the future, when the yet-to-be-defined triggers are met. Currently no flooding has been experienced in the area apart from the Napier Sailing Club (NSC) during far field tsunamis, king tides and some wave storm events (Redman P., NSC, *pers. comms*.).

Table 7-1: Design Crest Elevations for revetments.

Revetment	Short-term Design Crest Level (m HBRC vertical datum)
Revetment 1 (Pandora)	RL 13.00 m
Revetment 2 (West Quay)	RL 13.60 m
Existing crest level at Revetment 1	RL 11.75 m
Existing crest level at Revetment 2	RL 12.50 m

7.2 Geometry

Given that the design crest elevations are above the existing land elevations, a concrete wall is required to provide water tightness to the revetment (Figure 7-1). Appendix A shows typical cross section designs for different heights and locations.

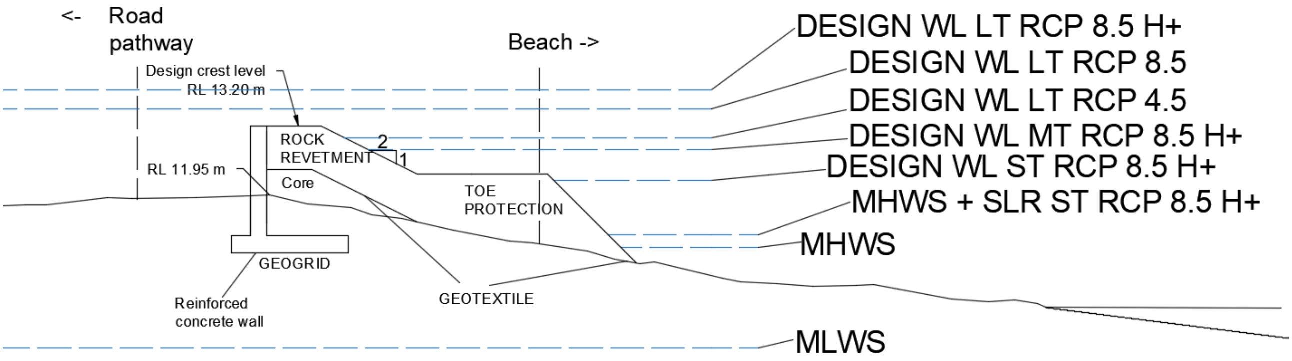


Figure 7-1: Typical design cross section of cantilever reinforced concrete wall and revetment.

7.3 Revetment

A 2:1 (H:V) slope rock revetment (2 layers 100 Kg limestone rock armour) has been specified. Wave conditions for rock sizing and scour estimates were calculated as per in section 4.6. Rock size and layer thickness were estimated following USACE (2006, Part VI-5). A Dutch toe has been specified to minimise excavation in sumberged conditions as for the stopbank designed in section 5.6. A geotextile filter of adequate apparent opening size and resistance was specified under the armour.

7.4 Wall

A reinforced concrete cantilever wall has been specified in order to provide an impervious barrier for the flood defence. Different walls were designed for extreme water levels ranging from RL 12.5 m to RL 14.5 m according to Table 4-1. Two future adaptation alternatives for future design water levels were considered:

- **Future Adaptation Alternative 1**: The wall was designed for a water level equal to its design crest elevation. This means that if future design levels increase above the design value, the wall may have a lower freeboard, the level of protection will decrease, or, it will need to be strengthened or completely rebuilt to achieve the required level of protection.
- **Future Adaptation Alternative 2:** The buried part of the wall was designed for a higher water level (RL 14.5 m), which is higher than the current design crest elevation. The part of the wall above ground up is constructed up to the design water level, which allows raising it more easily in the future. This alternative is more expensive but it allows for easier adaptation if the sea level rises so that the initial design crest level can no longer provide adequate protection.

7.4.1 Geometry

A typical cantilever reinforced concrete wall geometry was considered for the different design water levels (Figure 7-2). The dimensions of its different components were optimised in order to satisfy the stability criteria required.

The layout location of the wall was located so that the new revetment coincided (if possible) with the existing rock revetment. Another criterion was that the wall should not touch the existing amenities and structures such as footpaths. Lidar data and aerial photographs were used in this process.

For Revetment 1 the existing tyre revetment will need to be removed and appropriately disposed.

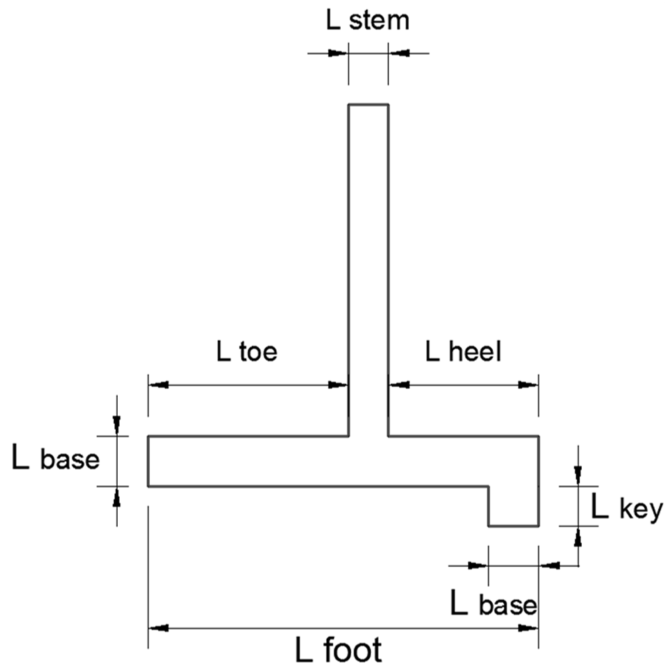


Figure 7-2: Parameter definition cantilever wall.

7.4.2 Stability design

The analysis and design of the cantilever retaining wall was carried out using a bespoke MS Excel 2010 spreadsheet based on the Allowable Stress Design method and Goodchild & Webster (2003) spreadsheets, where the latter were based on the LFRD method and the Concrete design British Standard BS 8110:2003. To ensure the stability of the retaining wall, the footing structure and soil must resists overturning and sliding, the material stresses and the bearing pressures on the soil.

__Environmental loads__

The following forcings were considered for the wall design (Figure 7-3):

- Debris impact: A 500 kN/m horizontal force applied at the wall crest.
- Hydrostatic pressure: This was considered for two conditions and a sea water density of 1025 kg/m^3:
    - Fully submerged soil at both (landward and seaward) sides, fully submerged revetment and core.
    - Fully submerged soil at the seaward side and dry soil at the landward side, fully submerged revetment and core.

  These forces were applied on both the horizontally and vertically oriented wall surfaces.
- Buoyancy (uplift): Considered a linear pressure distribution from the seawards side to the landwards side for the two cases explained above.
- Horizontal soil pressures: Active and passive forces for non-cohesive sandy soils using standard horizontal soil pressure coefficients (K_a=0.33, K_p=3).
- Vertical soil pressures: Soil pressures were considered on the toe and heel of the wall.

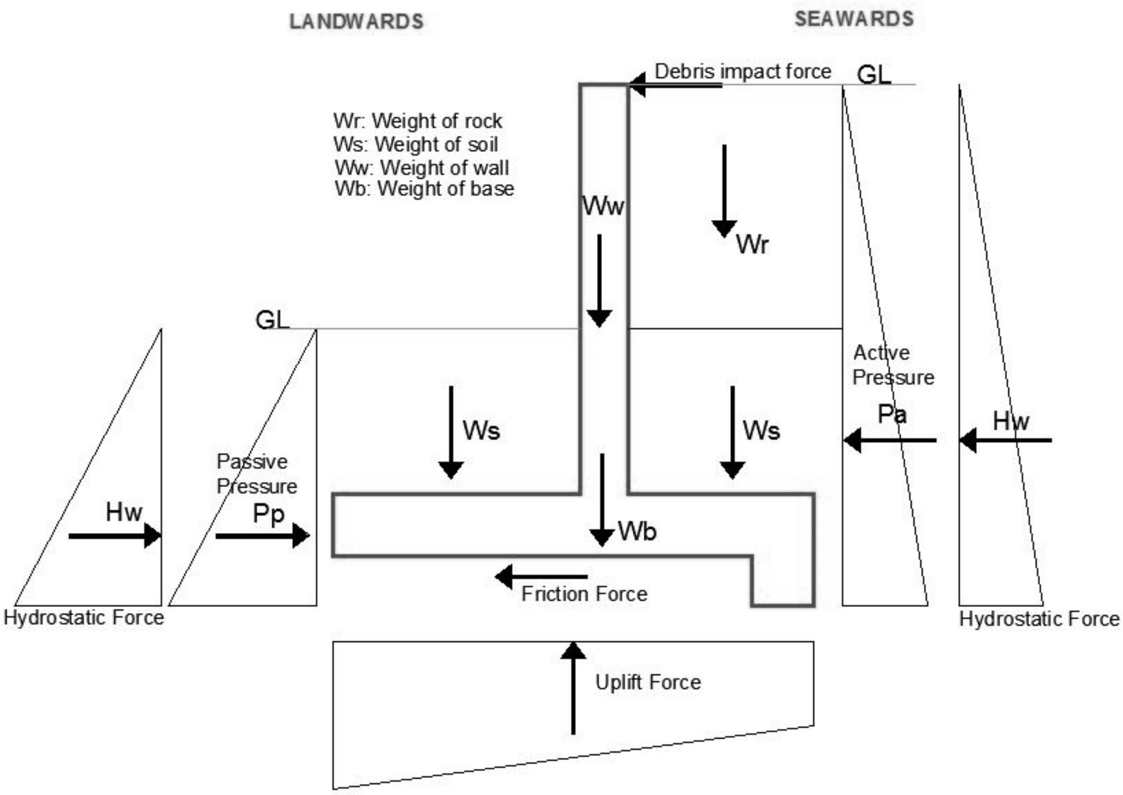


Figure 7-3: Forces acting on the cantilever retaining wall.

<u>Overall stability</u>

The wall was designed against the overturning and sliding failure modes considering a global safety factor of 1.2. The forces and moments balance considered the environmental forcings, structure weight and wall base friction.

<u>Geotechnical stability</u>

The geotechnical soil bearing capacity was assumed to be equal to the value provided by Tonkin & Taylor (2017a, 2017b). The ground bearing pressures were calculated taking into account the effect of vertical loads applied from the base to the soil and their eccentricity (required to be less than B/6, B=width of footing).

<u>Internal stability</u>

Reinforcement bars were specified to resist unacceptable cracking (< 0.3 mm) and structural failure (using the standard load enhancement factors in the LFRD method; Goodwill & Webster, 2003). The reinforcing cover and the concrete strength were specified as 60 mm and 45 MPa respectively, in order to provide appropriate durability (corrosion protection) for the site exposure (NZS 3101.1, 2006). The characteristic strength of the steel reinforcement bars (f_y) was assumed as 500 MPa as per the local suppliers.

The required flexural reinforcement was calculated at three critical sections: at the stem base, the toe and heel at the face of the stem, where shear and cracking checks were undertaken.

7.4.3 Water tightness and expansion joints

Vertical expansion joints were considered every 6 m, with a hydrophilic sealant specified for leakage control and durability purposes. A horizontal expansion joint was considered at the base of the wall where a waterproofing sealant must also be applied in order to prevent the corrosion of the reinforcement.

7.5 Long-term resilience, durability and adaptability

Two alternatives for a range of design water levels have been considered to account for future adaptability for sea level rise and the respective increased loads (section 7). The reinforcement cover, concrete strength and expansion joints were specified to provide corrosion protection to the reinforcement for the design life (> 50 years, section 7.4.2).

7.6 Costing

Costing for the construction of the cantilever wall and revetment were estimated from projects undertaken by HBRC, local suppliers and the New Zealand Construction Handbook (Rawlinsons, 2013). A 10% increase in future prices and a 25% increase for contingency costs has been included.

The two future adaptation alternatives for a range of different design crest levels (Section 7.4) were designed and costed (Table 7-2). The detailed cost estimate for all the different design crest levels and alternatives are shown in Appendix A, and an example of this detail is shown in Table 7-3.

For the total costs in Section 9, 3% of the construction cost has been included as an allowance for capital carbon emission offsetting, and a 0.07%/y of the maintenance cost for the operational offsetting. A provision for structural repairs due to erosion or settlement has been included as 5% of the construction cost every 20 years. Operations supervision has been considered as 5% of the maintenance cost. A 5% allowance has been considered for design and a 10% allowance for consenting.

Table 7-2: Costing for the cantilever wall and revetment at different design crest levels. Bold numbers show values for the design crest levels specified in section 7.1

Design crest level (m)	Cost (NZD)			
	Alternative 1		Alternative 2	
	Revetment 1 (Pandora)	Revetment 2 (West Quay)	Revetment 1 (Pandora)	Revetment 2 (West Quay)
12.5	$ 184,980	-	$ 407,114	-
13.0	$ 340,838	$ 255,361	$ 464,419	$ 360,321
13.2	**$387,668**	$306,163	**$491,211**	$395,362
13.4	$434,498	**$356,965**	$518,003	**$430,403**
13.5	$ 457,913	$ 382,366	$ 531,399	$ 447,923
14.0	$ 632,767	$ 547,213	$ 584,297	$ 538,429
14.5	$ 728,229	$ 647,028	$ 643,847	$ 591,257

Table 7-3: Construction cost detail for Alternative 1, Revetment 1, design crest level RL 13.5 m shown as an example. All tables including this detail are shown in Appendix A.

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	479	$ 1.50	$ 718
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	823	$ 8.40	$ 6,917
6	Soil improvement (Dynamic Compaction)	m2	265	$ 30.31	$ 8,041
7	Geogrid	m2	265	$ 5.00	$ 1,327
8	Excavation, stockpile, compact fill	m3	776	$ 6.00	$ 4,653
9	Dispose clean fill	m3	183.49	$ 6.00	$ 1,101
10	Supply, place Geotextile	m2	633	$ 5.00	$ 3,166
11	Supply and Place Rock (limestone or greywacke)	m3	1,023	$ 80.00	$ 81,850
12	Topsoil, grass and harrow	m2	352	$ 0.20	$ 70
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	200	$ 761.50	$ 152,118
17	Expansion joints and sealant	m	113	$ 391.50	$ 44,161
18	Supervision	week	4	$ 2,000	$ 8,200
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 339,195**
20	Contingency	LS	25%	$ 339,195	$ 84,799
21	Future increase	LS	10%	$ 339,195	$ 33,919
Total Construction Cost					**$ 457,913**

8 Road raising

NCC has carried out a Rough Order Costing to raise Pandora Rd to provide continuity the flood defence. The costing included raising the road to a range of crest levels from RL 12.5 m to RL 14.5 m. The existing level is RL 12.0 m.

The following assumptions were made:

- The costing includes 30 % contingency on all rates.
- Raising all services were raised when over 1m of fill.
- Fibre is present.
- Power is transferred to be underground when at 1.5m and above
- Street lighting numbers remains the same
- Prices are based on current rates
- No access points are to be constructed off the raised section of road

Additionally, NCC considered necessary to replace the bridge as the services should not get flooded. This is required for crest levels above RL 13.0 m. Bridge costs are estimated to be within $3 million to $5 million.

A 10% allowance for future price increase was considered in the summary in Table 8-1. Detailed costing provided by NCC is included in Appendix C.

For the total costs in Section 9, carbon emissions offsetting has been estimated in 3%. No operational costs have been included as this should be similar to those already in place for the existing road. A 5% allowance has been considered for design and a 10% allowance for consenting.

A design crest level of RL 13.6 m equal to that for Stopbank 3 has been considered for the costing in Section 9.

Table 8-1: Summary costing for raising Pandora Rd.

Crest Level (m HBRC datum)	Construction Cost (millions of NZD)		
	NCC Estimate	Bridge	Future price increase (10%)
12.5	$ 1.8	0.0	$ 2.0
13.0	$ 2.5	0.0	$ 2.7
13.5	$ 5.1	4.0	$ 10.0
14.0	$ 6.1	4.0	$ 11.1
14.5	$ 6.9	4.0	$ 12.0

9 Flood barrier

Given that raising the road was found to be a significant cost, a mobile flood barrier alternative has been included. This type of barrier is put in place at times of inundation risk. Costing information has been obtained from the Criterion Bridge flood barrier recently built by the Waikato Regional Council (Figure 9-1, Morphet, 2018; Tim Collinwood, Flood Control International, *pers. comms.*, 2020; Appendix D).

Adaptation for this project was carried out in conjunction with NCC considering the most recent projects for the area, which involve altering the road layout between the bridge and roundabout. NCC Senior Road Engineer, Tony Mills developed a rough order costing estimate for the flood barrier (Table 9-1).

Table 9-1: Rough order costing estimate Flood Barrier carried out by NCC.

NAPIER CITY COUNCIL Te Kaunihera o Ahuriri

Project: Installation of flood barrier on Pandora Road

Rough Order Costs

Estimate is based on an existing levels of 12.0m

Item	Description	Unit	Qty	Rate	Amount
1	**PROJECT MANAGEMENT**				**$ 90,000.00**
1.1	Design	LS	1	$ 40,000.00	$ 40,000.00
1.2	Project management including MS&QA	LS	1	$ 25,000.00	$ 25,000.00
1.3	Engineer to contract	LS	1	$ 25,000.00	$ 25,000.00
2	**PRELIMINARY & GENERAL**				**$ 75,000.00**
2.1	Site establishment & dis-establishment	LS	1	$ 20,000.00	$ 20,000.00
2.2	Site security/Traffic management	LS	1	$ 20,000.00	$ 20,000.00
2.3	Environmental Compliance	LS	1	$ 20,000.00	$ 20,000.00
2.4	Contract management (H&S plans etc.)	LS	1	$ 10,000.00	$ 5,000.00
2.5	Contractor setting out, location of services etc.	LS	1	$ 10,000.00	$ 10,000.00
3	**GROUNDWORKS**				**$ 10,000.00**
3.1	Site Clearance	LS	1	$ 5,000.00	$ 5,000.00
3.2	Cut to waste for barrier foundations	m^3	25	$ 200.00	$ 5,000.00
4	**BARRIER**				**$ 540,500.00**
4.1	Supply of barrier from UK	LS	1	$ 370,000.00	$ 370,000.00
4.2	Concrete ground beam for the barrier	m^2	50	$ 200.00	$ 10,000.00
4.3	Concrete approaches on carriageway for support of braces	m^2	25	$ 200.00	$ 5,000.00
4.4	Install of barrier including running gear	LS	1	$ 55,500.00	$ 55,500.00
4.5	Concrete cavity under earth bund	LS	1	$ 100,000.00	$ 100,000.00
5	**EARTH BUND**				**$ 20,000.00**
5.1	250m long by 2m high with 10m "ramps"	m^3	400	$ 50.00	$ 20,000.00
6	**CARRIAGEWAY & FOOTPATHS**				**$ 89,250.00**
6.1	Supply and construct M4 basecourse layer 150mm thick	m^3	45	150	$ 6,750.00
6.2	Supply and construct AP65 sub-base layer 250mm thick in roundabout circulating areas	m^3	75	100	$ 7,500.00
6.3	Supply & place 100mm structural asphalt	m^2	200	100	$ 20,000.00
6.4	Supply and Install 100mm Concrete Footpath will 75mm AP40 base	m^2	500	100	$ 50,000.00
6.5	Road marking	LS	1	5000	$ 5,000.00
7	**UTILITIES**				**$ 25,000.00**
7.1	Telecommunications installation for alarms/communications	LS	1	$ 10,000.00	$ 10,000.00
7.2	Unision installation for power supply	LS	1	$ 15,000.00	$ 15,000.00
8	**LANDSCAPING**				**$ 25,000.00**
8.1	Implementation of landscaping plan	LS	1	$ 10,000.00	$ 10,000.00
8.2	Handrail to protect fall from height	m	100	$ 150.00	$ 15,000.00
				SUB TOTAL	$ 874,750.00
				CONTINGENCY	$ 262,425.00
				TOTAL (GST exclusive)	**$ 1,137,175.00**

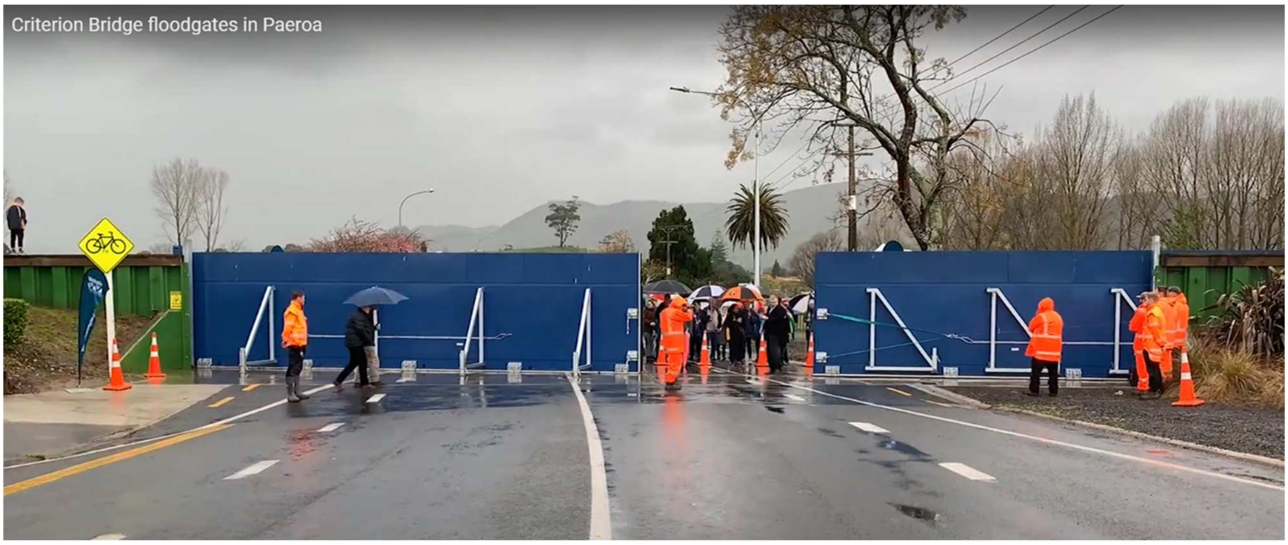


Figure 9-1: Flood barrier Criterion Bridge, Paeroa, Waikato Region (Waikato Regional Council youtube channel, 2020, https://www.youtube.com/watch?v=KmwluKLpiy8).

10 Stormwater drainage

Additional stormwater drainage (by the means of floodgates, piping, channels, pump stations, etc.) is likely to be required to evacuate stormwater from inside the defences into the sea. A recent conversation with NCC (Santha Agas, Team Leader Three waters), provided preliminary insights on this issue. The construction cost of this system was estimated between 3 and 10 million NZD, which may depend on many factors. The drainage network may be the item that has the greatest uncertainty.

NCC mentioned that they were in the early stages of preparing the Ahuriri Masterplan Stormwater Study, which may include the coastal strategy works and provide with better estimates.

A cost of 7 million NZD will be considered for the construction of the stormwater system for coastal adaptation. No design and consenting costs will be included, as NCC will likely need to do this whether or not the coastal strategy works are implemented. Carbon emissions offsetting is considered at 1% of the construction cost. A 0.5% yearly maintenance allowance is included.

No cost variation for different design crest levels was considered.

11 Costing

Cost estimates have been calculated for five options:

- Option 1a: Flood defences bypassing NSC and raising Pandora road. Includes building all the flood defences but bypassing NSC (Figure 3-1).
- Option 1b: Flood defences bypassing NSC and flood barrier in Pandora road. Includes building all the flood defences but bypassing NSC (Figure 3-1).
- Option 2a: Flood defences and upgrading NSC and raising Pandora road. Includes upgrading NSC and building all the flood defences in option 1 except for Stopbank 3 (Figure 3-1).
- Option 2b: Flood defences and upgrading NSC and flood barrier in Pandora road. Includes upgrading NSC and building all the flood defences in option 1 except for Stopbank 3 (Figure 3-1).
- Option 3: Storm surge barrier. Includes building an inflatable storm surge barrier at the entrance of the Inner Harbour. No flood defences in options 1 and 2 are required until the sea level reaches long-term values and permanent inundation begins to take place.

11.1 Option 1a: Flood defences bypassing NSC and raising of Pandora Rd

Table 11-1 shows costing for all the different components of the flood defence for Option. Costing contains the construction cost detailed in previous sections of the report and allowances for detail design, consenting carbon emissions offsetting and operational cost. The values shown correspond to the design crest elevations specified in previous sections for each component of the flood defence. For the cantilever wall and revetments, costing for alternative 2 has been included as the values are higher than for alternative 1 (24%), but it provides better long-term resilience and adaptability.

The net present value was calculated using a 3% discount rate over 20 years as per previous work in stage 3 of the strategy (Infometrics, 2017) and the main concept design report (Beya & Asmat, 2021).

Table 11-2 shows linear rates calculated from Table 11-1. Stopbanks are significantly less costly than cantilever walls, revetments and steel sheetpile walls, but it is not always possible to build them.

A sensitivity test on the total cost by changing the design water level in ±0.5 m is shown in Table 11-3. This is intended to assist in the decision-making process regarding the adoption of different levels of protection (risk) and the uncertainties inherent in the design water level.

Table 11-1: Costing for all the flood defences in Option 1a.

Capital cost item (millions of NZD)	Stopbank 1	Stopbank 2	Stopbank 3	Sheetpile	Revetment 1	Revetment 2	Road raising	Stormwater	Total
Detail design (5% construction)	$ 0.08	$ 0.01	$ 0.01	$ 0.04	$ 0.02	$ 0.02	$ 0.46	$ -	**$ 0.66**
Consenting (10% construction)	$ 0.16	$ 0.02	$ 0.03	$ 0.07	$ 0.05	$ 0.05	$ 0.93	$ -	**$ 1.31**
Carbon emissions offsetting	$ 0.016	$ 0.002	$ 0.003	$ 0.004	$ 0.014	$ 0.014	$ 0.279	$ 0.070	**$ 0.40**
Construction	$ 1.63	$ 0.24	$ 0.29	$ 0.73	$ 0.46	$ 0.47	$ 9.29	$ 7.00	**$ 20.11**
Total capital	**$ 1.89**	**$ 0.27**	**$ 0.34**	**$ 0.85**	**$ 0.55**	**$ 0.55**	**$ 10.96**	**$ 7.07**	**$ 22.48**
Operational cost (thousands of NZD/y)	**Stopbank 1**	**Stopbank 2**	**Stopbank 3**	**Sheetpile**	**Revetment 1**	**Revetment 2**	**Road raising**	**Stormwater**	**Total**
Maintenance	$ 4.11	$ 0.78	$ 0.81	$ 2.00	$ 1.16	$ 1.17	$ -	$ 35.00	**$ 45.02**
Operations supervision (5% Maintenance)	$ 0.21	$ 0.04	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ -	$ 1.75	**$ 2.25**
Carbon emissions offsetting	$ 0.21	$ 0.04	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ -	$ 1.75	**$ 2.25**
Total operational	**$ 4.52**	**$ 0.86**	**$ 0.89**	**$ 2.20**	**$ 1.28**	**$ 1.28**	**$ -**	**$ 38.50**	**$ 49.53**
Net present value (3% discount rate) in millions of NZD	**$ 1.95**	**$ 0.29**	**$ 0.35**	**$ 0.88**	**$ 0.57**	**$ 0.57**	**$ 10.96**	**$ 7.64**	**$ 23.22**
Length (m)	1,070	190	180	204	110	130	30	-	1,914
Crest level (RL m)	13.0	13.0	13.6	12.9	13.0	13.6	13.6	-	-

Table 11-2: Linear rates calculated for the different type of flood defences Option 1a.

Flood defence	Length (m)	Rate (NZD/m)	
		Construction cost	Net present value
Stopbank 1	1070	$1,520	$1,826
Stopbank 2	190	$1,241	$1,507
Stopbank 3	180	$1,627	$1,960
Sheetpile	204	$3,594	$4,313
Revetment 1	110	$4,222	$5,155
Revetment 2	130	$3,585	$4,377

Table 11-3: Sensitivity analysis on the construction cost by varying design crest level in ± 0.5 m.

Flood defence type ↓ Design crest elevation →	Construction Cost (millions of NZD)				
	0	+ 0.5	- 0.5	Variation	
Stopbank 1	$1.63	$1.89	$1.41	16%	-13%
Stopbank 2	$0.24	$0.27	$0.20	15%	-15%
Stopbank 3	$0.29	$0.34	$0.27	17%	-7%
Sheetpile	$0.73	$0.81	$0.60	11%	-18%
Revetment 1	$0.46	$0.53	$0.41	14%	-12%
Revetment 2	$0.47	$0.55	$0.38	18%	-19%
Road raising	$9.29	$10.26	$7.00	10%	-25%
Stormwater	$7.00	$7.00	$7.00	0%	0%
Total	**$20.11**	**$21.66**	**$17.27**	**8%**	**-14%**

11.2 Option 1b: Flood defences bypassing NSC and a flood barrier in Pandora Rd

This option is similar to Option 1b but instead of raising Pandora road, it includes a flood barrier (Table 11-4). The flood barrier was considered to have no sensitivity to the design crest level within the ±0.5 m sensitivity test range, producing a ±5% variation in the total construction cost.

Table 11-4: Costing for all the flood defences in Option 1b

Capital cost item (millions of NZD)	Stopbank 1	Stopbank 2	Stopbank 3	Sheetpile	Revetment 1	Revetment 2	Flood Barrier	Stormwater	Total
Detail design (5% construction)	$ 0.08	$ 0.01	$ 0.01	$ 0.04	$ 0.02	$ 0.02	$ 0.05	$ -	**$ 0.24**
Consenting (10% construction)	$ 0.16	$ 0.02	$ 0.03	$ 0.07	$ 0.05	$ 0.05	$ 0.10	$ -	**$ 0.49**
Carbon emissions offsetting	$ 0.016	$ 0.002	$ 0.003	$ 0.004	$ 0.014	$ 0.014	$ 0.031	$ 0.070	**$ 0.15**
Construction	$ 1.63	$ 0.24	$ 0.29	$ 0.73	$ 0.46	$ 0.47	$ 1.05	$ 7.00	**$ 11.87**
Total capital	**$ 1.89**	**$ 0.27**	**$ 0.34**	**$ 0.85**	**$ 0.55**	**$ 0.55**	**$ 1.24**	**$ 7.07**	**$ 12.75**
Operational cost (thousands of NZD/y)	**Stopbank 1**	**Stopbank 2**	**Stopbank 3**	**Sheetpile**	**Revetment 1**	**Revetment 2**	**Flood Barrier**	**Stormwater**	**Total**
Maintenance	$ 4.11	$ 0.78	$ 0.81	$ 2.00	$ 1.16	$ 1.17	$ 15.0	$ 35.00	**$ 60.02**
Operations supervision (5% Maintenance)	$ 0.21	$ 0.04	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ 0.75	$ 1.75	**$ 3.00**
Carbon emissions offsetting	$ 0.21	$ 0.04	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ 0.75	$ 1.75	**$ 3.00**
Total operational	**$ 4.52**	**$ 0.86**	**$ 0.89**	**$ 2.20**	**$ 1.28**	**$ 1.28**	**$ 16.5**	**$ 38.50**	**$ 66.03**
Net present value (3% discount rate) in millions of NZD	**$ 1.95**	**$ 0.29**	**$ 0.35**	**$ 0.88**	**$ 0.57**	**$ 0.57**	**$ 1.48**	**$ 7.64**	**$ 13.73**
Length (m)	1,070	190	180	204	110	130	30	-	1,914
Crest level (RL m)	13.0	13.0	13.6	12.9	13.0	13.6	13.4	-	-

11.3 Option 2a: Flood defences and NSC upgrade

Table 11-5 shows the costing for Option 2a. No maintenance cost was estimated for NSC as its current maintenance and minor upgrades are undertaken privately by NSC with at zero cost to NCC. A variation of 2.5 million NZD was (very) roughly estimated for NSC from differences in the filling volumes, seawall and revetment dimensions when varying the design crest elevation in ± 0.5 m.

Table 11-5: Costing for all the flood defences in Option 2a

Capital cost item (millions of NZD)	Stopbank 1	Stopbank 2	Sheetpile	Revetment 1	Revetment 2	NSC upgrade	Road raising	Stormwater	Total
Detail design (5% construction)	$ 0.08	$ 0.01	$ 0.04	$ 0.02	$ 0.02	$ 1.19	$ 0.46	$ -	**$ 1.83**
Consenting (10% construction)	$ 0.16	$ 0.02	$ 0.07	$ 0.05	$ 0.05	$ 2.38	$ 0.93	$ -	**$ 3.66**
Carbon emissions offsetting	$ 0.016	$ 0.002	$ 0.004	$ 0.014	$ 0.014	$ 0.238	$ 0.28	$ 0.07	**$ 0.64**
Construction	$ 1.63	$ 0.24	$ 0.73	$ 0.46	$ 0.47	$ 23.76	$ 9.29	$ 7.00	**$ 43.57**
Total capital	**$ 1.89**	**$ 0.27**	**$ 0.85**	**$ 0.55**	**$ 0.55**	**$ 27.56**	**$ 10.96**	**$ 7.07**	**$ 49.70**
Operational cost (thousands of NZD/y)	**Stopbank 1**	**Stopbank 2**	**Sheetpile**	**Revetment 1**	**Revetment 2**	**NSC upgrade**	**Road raising**	**Stormwater**	**Total**
Maintenance	$ 4.11	$ 0.78	$ 2.00	$ 1.16	$ 1.17	$ -	$ -	$ 35.00	**$ 44.22**
Operations supervision (5% Maintenance)	$ 0.21	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ -	$ -	$ 1.75	**$ 2.21**
Carbon emissions offsetting	$ 0.21	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ -	$ -	$ 1.75	**$ 2.21**
Total operational	**$ 4.52**	**$ 0.86**	**$ 2.20**	**$ 1.28**	**$ 1.28**	$ -	**$ -**	**$ 38.50**	**$ 48.64**
Net present value (3% discount rate) in millions of NZD	**$ 1.95**	**$ 0.29**	**$ 0.88**	**$ 0.57**	**$ 0.57**	**$ 27.56**	**$ 10.96**	**$ 7.64**	**$ 50.42**
Length (m)	1,070	190	204	110	130	410	30	-	**2,144**
Crest level (RL m)	13.0	13.0	12.9	13.0	13.6	13.5	13.6	-	-

11.4 Option 2b: Flood defences with flood barrier in Pandora Rd and NSC upgrade

This option is similar to Option 2a but instead of raising Pandora road, it includes a flood barrier (Table 11-6). The flood barrier was considered to have no sensitivity to the design crest level within the ±0.5 m sensitivity test range, producing ±9% variation in the total construction cost.

Table 11-6: Costing for all the flood defences in Option 2b

Capital cost item (millions of NZD)	Stopbank 1	Stopbank 2	Sheetpile	Revetment 1	Revetment 2	NSC upgrade	Flood Barrier	Stormwater	Total
Detail design (5% construction)	$ 0.08	$ 0.01	$ 0.04	$ 0.02	$ 0.02	$ 1.19	$ 0.05	$ -	**$ 1.42**
Consenting (10% construction)	$ 0.16	$ 0.02	$ 0.07	$ 0.05	$ 0.05	$ 2.38	$ 0.10	$ -	**$ 2.83**
Carbon emissions offsetting	$ 0.016	$ 0.002	$ 0.004	$ 0.014	$ 0.014	$ 0.238	$ 0.031	$ 0.07	**$ 0.39**
Construction	$ 1.63	$ 0.24	$ 0.73	$ 0.46	$ 0.47	$ 23.76	$ 1.05	$ 7.00	**$ 35.33**
Total capital	**$ 1.89**	**$ 0.27**	**$ 0.85**	**$ 0.55**	**$ 0.55**	**$ 27.56**	**$ 1.24**	**$ 7.07**	**$ 39.97**
Operational cost (thousands of NZD/y)	**Stopbank 1**	**Stopbank 2**	**Sheetpile**	**Revetment 1**	**Revetment 2**	**NSC upgrade**	**Flood Barrier**	**Stormwater**	**Total**
Maintenance	$ 4.11	$ 0.78	$ 2.00	$ 1.16	$ 1.17	$ -	$ 15.0	$ 35.00	**$ 59.22**
Operations supervision (5% Maintenance)	$ 0.21	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ -	$ 0.8	$ 1.75	**$ 2.96**
Carbon emissions offsetting	$ 0.21	$ 0.04	$ 0.10	$ 0.06	$ 0.06	$ -	$ 0.8	$ 1.75	**$ 2.96**
Total operational	**$ 4.52**	**$ 0.86**	**$ 2.20**	**$ 1.28**	**$ 1.28**	$ -	$ 16.5	**$ 38.50**	**$ 65.14**
Net present value (3% discount rate) in millions of NZD	**$ 1.95**	**$ 0.29**	**$ 0.88**	**$ 0.57**	**$ 0.57**	**$ 27.56**	**$ 1.48**	**$ 7.64**	**$ 40.94**
Length (m)	1,070	190	204	110	130	410	30	-	**2,144**
Crest level (RL m)	13.0	13.0	12.9	13.0	13.6	13.5	13.6	-	**-**

11.5 Option 3: Storm surge barrier

A third option to the flood defences and NSC upgrade could be the installation of a storm surge barrier. An inflatable tube barrier appears to be one of the most cost-effective alternatives amongst the different type of barriers. The Ramspol barrier, built in the Netherlands in 2002, closes a 360 m long waterway with an inflatable tube during a storm surge event. The construction cost of this barrier was 48 million Euros (Deltares, 2018). The Ahuriri harbour entrance is about 100 m wide, therefore a (very) rough scaling of this cost indicates that a barrier of this type may cost in the order of **30 million NZD**, plus the operational and maintenance costs.

Figure 11-1: Approximate location and length of storm surge barrier for Option 3.

Figure 11-2: Ramspol Storm surge barrier in operation (credits: Ministry of Infrastructure and Water Management, The Netherlands).

12 Discussion and Conclusions

A concept design and costing has been carried out for the flood defences outlined as preferred pathways in the Clifton to Tangoio 2120 Coastal Strategy. The design considers alternatives for long-term resilience, adaptability and uncertainty in future sea levels.

There are differences in the extreme levels considered by Goodier (2007) and Tonkin & Taylor (2016), with the present design crest levels been 1 m and 1.6 m higher. This difference is because those authors specified extreme future water levels and not design water levels, which normally include freeboard. Another reason is that those studies did not account for land subsidence, updated sea level rise information, local effects inside the harbour and estuary such as seiches, wind set-up and wave run-up. Further analysis is recommended to better quantify the latter phenomena, as well as the combined probability of all water level components coinciding in time.

A freeboard larger than 0.6 m could have been considered as the design guidelines (e.g. USACE, 2000; CIRIA, 2013) also recommend values greater than 1 m. Also, recent discussions on the Hawke's Bay river stopbanks may require raising the freeboard from 0.6 m to 1 m. For the present design, it was recognised that a degree of conservatism may be present in the estimate of the combined water levels. Thus, it was considered that including a larger freeboard for this design may produce excessively high design crest levels.

In other words, a higher freeboard could be implicitly included in the different components of the water levels. In the detail design phase, instead of using a freeboard, a risk-based design approach may be chosen to define the design water level in which no freeboard may be included but instead enhancement factors for each other component defining the crest level (similarly to the LRFD method in structural engineering; USACE, 2000, Section 6-1).

All design crest levels were defined using a sea level rise of 0.58 m mid-term RCP 8.5 H+ scenario (MFE, 2017). Considering that the mid-term sea level rise predictions for RCP 2.6 and RCP 4.5 are 0.30 m and 0.34 m, it could mean that the proposed design may have 0.24 m – 0.28 m of extra freeboard. Another way to look at this is, given that the long-term sea level rise predictions for the less conservative scenarios are 0.54 m and 0.65 m respectively, the design may provide protection for the long-term if these scenarios are confirmed by future reality.

Large low-lying land areas have been identified as potentially floodable in the future, and extended protection may be required. Further analysis is recommended on this issue.

The sheetpile wall has been designed for a 20 years design life because the effectiveness of the corrosion protection measures was not able to guarantee a longer design life. Another reason was that if larger future water levels need to be accommodated, the buried depth of the pile would need to be increased, unless it is designed that way from the beginning and requiring a long duration design, all of the latter at an extra cost. Nevertheless, including cathodic protection and coating may significantly extend the design life of a sheetpile wall. Corrosion rates in the buried part may be less severe than those considered in the design. Further site-specific research on corrosion rates and the effectiveness of coating systems, especially in the buried part is recommended.

A reinforced concrete sheetpile or a cantilever wall may also provide other alternatives to the steel sheetpile wall. Also, the Ahuriri Master Plan (NCC, 2018) indicates the intention of purchasing land and creating an amenity along the area which may allow building a stopbank instead of the projected sheetpile. This may be a less costly solution for this location.

The cantilever wall and revetment is considered a robust and durable barrier. However, caution must be taken in the design of the wall so that the long-term risk of corrosion for the reinforcement is minimised. The existing revetment at West Quay has rocks of near 1 m diameter. For aesthetic reasons, it may be required to utilise rocks of this size instead of those specified in this study (100 Kg). This would increase the cost as a larger armour layer thickness will require larger rock volumes. For this type of structure an alternative that allows for an easier long-term adaptation was considered. However, since this alternative requires a bigger foundation, it is 24 % more costly than the alternative that does not allow to easily raise the crest level in the future.

An allowance of 7 million NZD for additional stormwater drainage requirements was included as a very rough order cost. The Ahuriri Master Plan Stormwater study could provide better estimates for the additional stormwater systems required as a consequence of the coastal strategy works.

In general, the sensitivity test on the design crest level showed a maximum variation of ±14% in the total cost of flood defences. This suggests that uncertainties in the design crest level are unlikely to significantly change the results of this report for the following funding work for the strategy.

The most expensive items in the flood defences resulted to be associated to complications unforeseen in the Stage 3 estimate: Including the Napier Sailing Club, raising Pandora Rd and providing for an additional stormwater drainage system.

Practical solutions for including the Napier Sailing Club inside the flood defences are comparatively very expensive of the order of 20 million NZD. Hybrid solutions that provide a higher standard of protection to commercial and residential areas and a lower level of protection or adaptable infrastructure may prove to be a more economical solution.

The raising of Pandora Rd has an estimated construction cost of 10.96 million NZD with a maximum of 25% of change in cost when varying the design crest level ±0.5 m. Given the high cost of this, a mobile flood barrier has been included as an alternative to the road raising at 1.05 million NZD construction cost but with a higher maintenance cost.

For options 1a, 1b, 2a and 2b there is a high risk of consenting failure due to the ecological and environmental implications of altering the Ahuriri estuary and in particular the loss of intertidal area that would occur in the future with the projected sea level rise if flood defences are in place. For these options, environmental mitigation such as the creation of an artificial estuarine intertidal area in the present Ahuriri Lagoon farm may be required at an additional cost.

If a level of expenditure of the order of tens of millions can be afforded (as estimated for the above mentioned options) it is recommended to seriously consider the construction of a storm surge barrier at the entrance of the Ahuriri Harbour (option 3).

Long-term visual impact should be accounted for in the planning of the area, as the seaview from the existing ground levels will be diminished. This aspect should not be underestimated as the master plan involves significant investment in this area, and aesthetically acceptable solutions may considerably increase the cost of the flood defences.

Long-term resilience and adaptability has been incorporated into the design where raising of the defences can be undertaken in the future if needed. Stopbanks can be raised relatively easily provided there is enough space. Steel sheetpile walls cannot be safely specified for long design lifetimes due to the possibility of corrosion damage. Therefore, the sheetpile design considers its replacement after the end of its life. The cantilever wall and revetment preferred option includes, at a higher capital cost, a design for which the buried part of the wall can withstand the loadings from raising its crest in the future.

Overall, the Stage 3 of the strategy identified an average build cost of 2 million NZD for the inundation protection required for Pandora. This study indicates construction costs in excess of 4 million NZD for the flood defences (not including Pandora Rd crossing, upgrading NSC and additional stormwater systems). If including the latter, that cost can increase up to $43.6 million.

13 Recommendations

- The costing information provided in this report is considered appropriate for the funding work required for this stage of the coastal strategy.
- Establish an on-going monitoring programme of water levels in the harbour and estuary and outside the estuary in order to have information to better estimate extreme water levels.
- Undertake a flood study for the estuary and Ahuriri lagoon including coastal, inland flooding and the future plans for the Ahuriri lagoon. This in order to better understand the large areas identified at potential future risk, assess the need for extended flood defences.
- Include updated sea level rise and vertical land movement information.
- Continue conversations with Napier Sailing Club to refine future solutions.
- Include the coastal strategy works into the Ahuriri Masterplan.
- Investigate site-specific corrosion rates in the atmospheric and buried parts, with and without corrosion protection systems, in order to assist future detail designs and better estimate the design life of the structures.
- Review consentibility risks for the flood defence options.

14 References

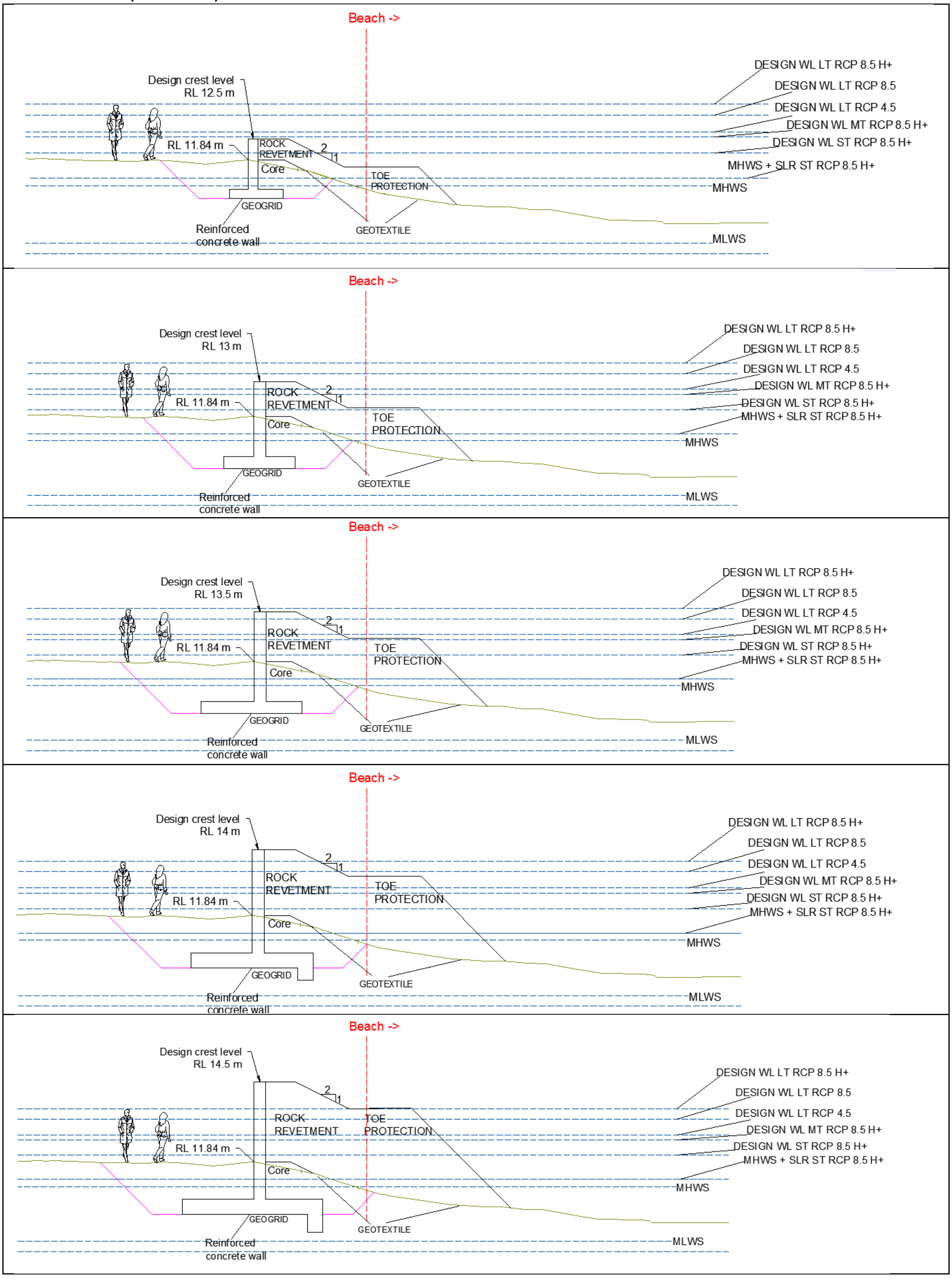
- Bendall. S. (2018). Report of the Northern and Southern Cell Assessment Pannels - Clifton to Tangoio Coastal Hazards Strategy 2120. Mitchell-Daysh [available 15-10-2019 https://www.hbcoast.co.nz/assets/Document-Library/Assessment-Panel-Report-FINAL-28.2.18-reduced-size.pdf].
- Beavan R. J. & Litchfield N. J. (2012). Vertical land movement around the New Zealand coastline: implications for sea level rise. GNS Science Report 2012/29.
- Beya J., Asmat C. (2021). Short-term concept design and costing - Clifton to Tangoio 2120 Coastal hazards strategy - Stage 4 - Design workstream Wave, shoreline evolution and gravel barrier response modelling - Groynes design and cost estimates. HBRC report 5537.
- Goodchild C. H., Webster R. M. (2003). Spreadsheets for concrete design to BS 8110 and EEC2. British Cement Association, Reinforced Concrete Council.
- CIRIA (2007). The Rock Manual, CIRIA C683.
- CIRIA (2013). The International Levee Handbook. CIRIA C731.
- Deltares (2018). Overview storm surge barriers. Memorandum prepared for Danish Coastal Authority (DCA). Reference: 11201883-002-ZKS-0001. [Available 27-01-2020 http://www.masterpiece.dk/UploadetFiles/10852/25/Deltares_2018_Overview_storm_surge_barriers_komprimeret.pdf].
- EurOtop (2018). Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application. Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B., [Available 08-01-2020 www.overtopping-manual.com].
- Goodier (2007). Ahuriri Estuary 2D Model Analysis. HBRC Plan Number 3986. AM 07/20. [Available 08-01-2020 https://herbi.hbrc.govt.nz/site/LandDraina/_layouts/15/WopiFrame.aspx?sourcedoc=/site/LandDraina/Catchments/Ahuriri/3986%20AM0720%20Ahuriri%20Estuary%202D%20Model%20Analysis.doc&action=default&DefaultItemOpen=1].
- Goodier C. (2016). Clifton to Tangoio Coastal Strategy - Coastal Inundation Modelling Notes. Modelling done during July 2015 to May 2016 (unpublished work).
- Hammond, G. P., & Jones, C. I. (2008). Embodied energy and carbon in construction materials. Proceedings of the Institution of Civil Engineers - Energy, 161(2), 87-98. https://doi.org/10.1680/ener.2008.161.2.87.
- Infometrics (2017). Real Options Analysis of Strategies to Manage Coastal Hazard Risks. Southern Units J-L. Report prepared for Hawke's Bay Regional Council [available 26-09-2019 https://www.hbcoast.co.nz/assets/Document-Library/Other-documents/Real-Options-Analysis-of-Strategies-to-Manage-Coastal-Hazard-Risks-Southern-Units-J-L.pdf].
- IPCC (2019): Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E.

Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press. [Available 08-01-2020 https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/]

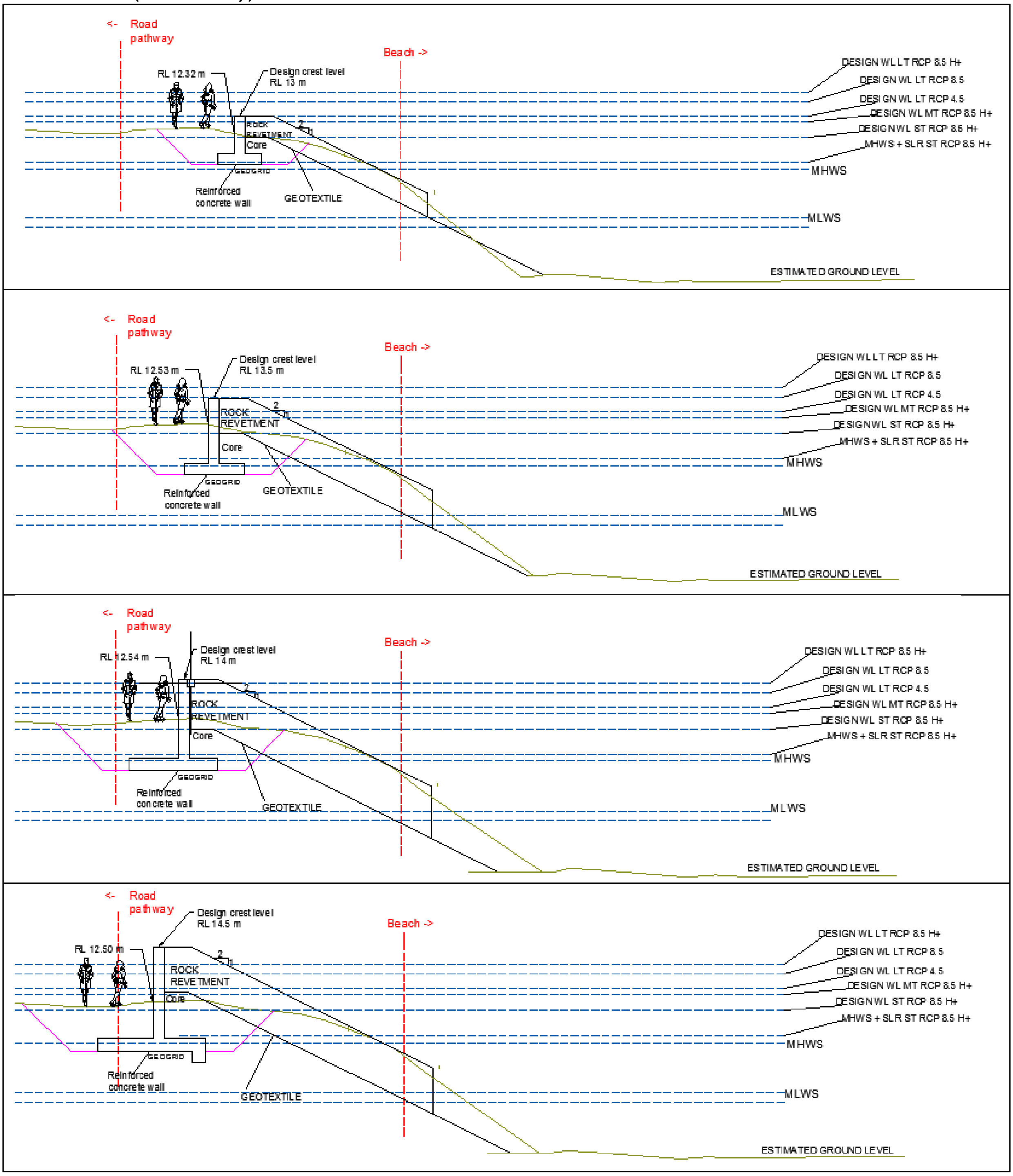
- MFE (2017). Coastal Hazards and Climate Change – Guidance for Local Government. Ministry for the Environment - New Zealand.
- Morphet A. (2018). Project closedown report Criterion Bridge Left Bank Stoplog Replacement. Waikato Regional Council Report (Draft).
- NCC (2018). Ahuriri Estuary & Coastal Edge Masterplan. Napier City Council [Available 06-01-2020 https://www.napier.govt.nz/assets/Documents/Ahuriri-Masterplan/Ahuriri-Estuary-Masterplan-Final-10-August-2018.pdf].
- NZS 3101.1 (2006). Concrete Structures Standard. Part 1: Design of concrete structures. Standards New Zealand.
- Rawlinsons Limited (2013). Rawlinsons New Zealand Construction Handbook. Auckland, NZ.
- SNZ TS 3404 (2018). Standards New Zealand Technical Specification. Durability requirements for steel structures and components.
- Tonkin & Taylor (2016). Clifton to Tangoio Coastal Hazards Strategy 2120 – Coastal Hazards Assessment. Report prepared for HBRC, NCC and HDC Job number: 20514.005.CHA.v8.
- Tonkin & Taylor (2017a). Geotechnical Investigation Report 73 & 75 Thames Street, Pandora, Napier. Prepared for Napier Port, Job Number 1001714.v1.0.
- Tonkin & Taylor (2017b). Humber Street Toilet Block Geotechnical Investigation Report. Prepared for Napier City Council, Job Number 1003274.0000.
- USACE (2000). Design and Construction of Levees. Publication EM 1110-2-1913 US Army Corps of Engineers.
- USACE (2006). Coastal Engineering Manual. US Army Corps of Engineers.

Appendix A Typical cantilever wall and revetment cross sections

Revetment 1 (Pandora)



Revetment 2 (West Quay)



Appendix B Cost estimate for the cantilever wall and revetment

PANDORA - ALTERNATIVE 1:

Design Crest Level at 12.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	347	$ 1.50	$ 521
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	10	$ 8.40	$ 85
6	Soil improvement (Dynamic Compaction)	m2	133	$ 30.31	$ 4,020
7	Geogrid	m2	133	$ 5.00	$ 663
8	Excavation, stockpile, compact fill	m3	357	$ 6.00	$ 2,143
9	Dispose clean fill	m3	76.49	$ 6.00	$ 459
10	Supply, place Geotextile	m2	557	$ 5.00	$ 2,786
11	Supply and Place Rock (limestone or greywacke)	m3	460	$ 80.00	$ 36,819
12	Topsoil, grass and harrow	m2	221	$ 0.20	$ 44
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	77	$ 611.00	$ 47,201
17	Expansion joints and sealant	m	59	$ 194.00	$ 11,407
18	Supervision	week	2	$ 2,000	$ 4,000
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 137,022**
20	Contingency	LS	25%	$ 137,022	$ 34,256
21	Future increase	LS	10%	$ 137,022	$ 13,702
Total Construction Cost					**$ 184,980**

Design Crest Level at 13.0m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	415	$ 1.50	$ 622
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	12	$ 8.40	$ 103
6	Soil improvement (Dynamic Compaction)	m2	187	$ 30.31	$ 5,676
7	Geogrid	m2	187	$ 5.00	$ 936
8	Excavation, stockpile, compact, fill	m3	661	$ 6.00	$ 3,968
9	Dispose clean fill	m3	144	$ 6.00	$ 867
10	Supply, place Geotextile	m2	582	$ 5.00	$ 2,910
11	Supply and Place Rock (limestone or greywacke)	m3	738	$ 80.00	$ 59,006
12	Topsoil, grass and harrow	m2	288	$ 0.20	$ 58
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	153	$ 718.50	$ 109,889
17	Expansion joints and sealant	m	89	$ 391.50	$ 34,765
18	Supervision	week	3	$ 2,000	$ 6,800
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 252,472**
20	Contingency	LS	25%	$ 252,472	$ 63,118
21	Future increase	LS	10%	$ 252,472	$ 25,247
Total Construction Cost					**$ 340,838**

Design Crest Level at 13.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	479	$ 1.50	$ 718
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	823	$ 8.40	$ 6,917
6	Soil improvement (Dynamic Compaction)	m2	265	$ 30.31	$ 8,041
7	Geogrid	m2	265	$ 5.00	$ 1,327
8	Excavation, stockpile, compact fill	m3	776	$ 6.00	$ 4,653
9	Dispose clean fill	m3	183.49	$ 6.00	$ 1,101
10	Supply, place Geotextile	m2	633	$ 5.00	$ 3,166
11	Supply and Place Rock (limestone or greywacke)	m3	1,023	$ 80.00	$ 81,850
12	Topsoil, grass and harrow	m2	352	$ 0.20	$ 70
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	200	$ 761.50	$ 152,118
17	Expansion joints and sealant	m	113	$ 391.50	$ 44,161
18	Supervision	week	4	$ 2,000	$ 8,200
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 339,195**
20	Contingency	LS	25%	$ 339,195	$ 84,799
21	Future increase	LS	10%	$ 339,195	$ 33,919
Total Construction Cost					**$ 457,913**

Design Crest Level at 14.0m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	495	$ 1.50	$ 742
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	13	$ 8.40	$ 105
6	Soil improvement (Dynamic Compaction)	m2	320	$ 30.31	$ 9,696
7	Geogrid	m2	320	$ 5.00	$ 1,600
8	Excavation, stockpile, compact fill	m3	839	$ 8.40	$ 7,049
9	Dispose clean fill	m3	261.52	$ 6.00	$ 1,569
10	Supply, place Geotextile	m2	678	$ 5.00	$ 3,389
11	Supply and Place Rock (limestone or greywacke)	m3	1,348	$ 80.00	$ 107,802
12	Topsoil, grass and harrow	m2	368	$ 0.20	$ 74
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	278	$ 804.50	$ 223,484
17	Expansion joints and sealant	m	130	$ 589.00	$ 76,334
18	Supervision	week	5	$ 2,000	$ 10,000
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 468,716**
20	Contingency	LS	25%	$ 468,716	$ 117,179
21	Future increase	LS	10%	$ 468,716	$ 46,872
Total Construction Cost					**$ 632,767**

Design Crest Level at 14.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	527	$ 1.50	$ 790
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	13	$ 8.40	$ 105
6	Soil improvement (Dynamic Compaction)	m2	375	$ 30.31	$ 11,352
7	Geogrid	m2	375	$ 5.00	$ 1,873
8	Excavation, stockpile, compact fill	m3	961	$ 8.40	$ 8,074
9	Dispose clean fill	m3	257.59	$ 6.00	$ 1,546
10	Supply, place Geotextile	m2	710	$ 5.00	$ 3,550
11	Supply and Place Rock (limestone or greywacke)	m3	1,652	$ 80.00	$ 132,172
12	Topsoil, grass and harrow	m2	400	$ 0.20	$ 80
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m2	290	$ 869.00	$ 252,251
17	Expansion joints and sealant	m	152	$ 589.00	$ 89,764
18	Supervision	week	6	$ 2,000	$ 11,000
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 539,429**
20	Contingency	LS	25%	$ 539,429	$ 134,857
21	Future increase	LS	10%	$ 539,429	$ 53,943
Total Construction Cost					**$ 728,229**

PANDORA - ALTERNATIVE 2:

Design Crest Level at 12.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	527	$ 1.50	$ 790
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	10	$ 8.40	$ 85
6	Soil improvement (Dynamic Compaction)	m2	375	$ 30.31	$ 11,352
7	Geogrid	m2	375	$ 5.00	$ 1,873
8	Excavation, stockpile, compact fill	m3	961	$ 6.00	$ 5,767
9	Dispose clean fill	m3	257.59	$ 6.00	$ 1,546
10	Supply, place Geotextile	m2	557	$ 5.00	$ 2,786
11	Supply and Place Rock (limestone or greywacke)	m3	460	$ 80.00	$ 36,819
12	Topsoil, grass and harrow	m2	400	$ 0.20	$ 80
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	212	$ 869.00	$ 184,442
17	Expansion joints and sealant	m	104	$ 194.00	$ 20,254
18	Supervision	week	4	$ 2,000	$ 8,900
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 301,566**
20	Contingency	LS	25%	$ 301,566	$ 75,391
21	Future increase	LS	10%	$ 301,566	$ 30,157
Total Construction Cost					**$ 407,114**

Design Crest Level at 13.0m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	527	$ 1.50	$ 790
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	12	$ 8.40	$ 103
6	Soil improvement (Dynamic Compaction)	m2	375	$ 30.31	$ 11,352
7	Geogrid	m2	375	$ 5.00	$ 1,873
8	Excavation, stockpile, compact, fill	m3	961	$ 6.00	$ 5,767
9	Dispose clean fill	m3	258	$ 6.00	$ 1,546
10	Supply, place Geotextile	m2	582	$ 5.00	$ 2,910
11	Supply and Place Rock (limestone or greywacke)	m3	738	$ 80.00	$ 59,006
12	Topsoil, grass and harrow	m2	400	$ 0.20	$ 80
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	232	$ 869.00	$ 201,394
17	Expansion joints and sealant	m	116	$ 194.00	$ 22,582
18	Supervision	week	5	$ 2,000	$ 9,740
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 344,014**
20	Contingency	LS	25%	$ 344,014	$ 86,004
21	Future increase	LS	10%	$ 344,014	$ 34,401
Total Construction Cost					**$ 464,419**

Design Crest Level at 13.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	527	$ 1.50	$ 790
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	823	$ 8.40	$ 6,917
6	Soil improvement (Dynamic Compaction)	m2	375	$ 30.31	$ 11,352
7	Geogrid	m2	375	$ 5.00	$ 1,873
8	Excavation, stockpile, compact fill	m3	961	$ 6.00	$ 5,767
9	Dispose clean fill	m3	257.59	$ 6.00	$ 1,546
10	Supply, place Geotextile	m2	633	$ 5.00	$ 3,166
11	Supply and Place Rock (limestone or greywacke)	m3	1,023	$ 80.00	$ 81,850
12	Topsoil, grass and harrow	m2	400	$ 0.20	$ 80
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	251	$ 869.00	$ 218,347
17	Expansion joints and sealant	m	128	$ 194.00	$ 24,910
18	Supervision	week	5	$ 2,000	$ 10,160
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 393,629**
20	Contingency	LS	25%	$ 393,629	$ 98,407
21	Future increase	LS	10%	$ 393,629	$ 39,363
Total Construction Cost					**$ 531,399**

Design Crest Level at 14.0m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	527	$ 1.50	$ 790
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	13	$ 8.40	$ 105
6	Soil improvement (Dynamic Compaction)	m2	375	$ 30.31	$ 11,352
7	Geogrid	m2	375	$ 5.00	$ 1,873
8	Excavation, stockpile, compact fill	m3	961	$ 6.00	$ 5,767
9	Dispose clean fill	m3	257.59	$ 6.00	$ 1,546
10	Supply, place Geotextile	m2	678	$ 5.00	$ 3,389
11	Supply and Place Rock (limestone or greywacke)	m3	1,348	$ 80.00	$ 107,802
12	Topsoil, grass and harrow	m2	400	$ 0.20	$ 80
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	271	$ 869.00	$ 235,299
17	Expansion joints and sealant	m	140	$ 194.00	$ 27,238
18	Supervision	week	5	$ 2,000	$ 10,700
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 432,812**
20	Contingency	LS	25%	$ 432,812	$ 108,203
21	Future increase	LS	10%	$ 432,812	$ 43,281
Total Construction Cost					**$ 584,297**

Design Crest Level at 14.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	527	$ 1.50	$ 790
3	Remove existing rock revetment	m3	-	$ 6.00	$ -
4	Remove and dispose tyre revetment	Tonne	27	$ 270.00	$ 7,372
5	Load, cart, fill Core	m3	13	$ 8.40	$ 105
6	Soil improvement (Dynamic Compaction)	m2	375	$ 30.31	$ 11,352
7	Geogrid	m2	375	$ 5.00	$ 1,873
8	Excavation, stockpile, compact fill	m3	961	$ 6.00	$ 5,767
9	Dispose clean fill	m3	257.59	$ 6.00	$ 1,546
10	Supply, place Geotextile	m2	710	$ 5.00	$ 3,550
11	Supply and Place Rock (limestone or greywacke)	m3	1,652	$ 80.00	$ 132,172
12	Topsoil, grass and harrow	m2	400	$ 0.20	$ 80
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m2	290	$ 869.00	$ 252,251
17	Expansion joints and sealant	m	152	$ 194.00	$ 29,566
18	Supervision	week	6	$ 2,000	$ 11,000
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 476,924**
20	Contingency	LS	25%	$ 476,924	$ 119,231
21	Future increase	LS	10%	$ 476,924	$ 47,692
Total Construction Cost					**$ 643,847**

WEST QUAY - ALTERNATIVE 1:

Design Crest Level at 13.0m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	561	$ 1.50	$ 841
3	Remove existing rock revetment	m3	376	$ 6.00	$ 2,256
4	Remove and dispose tyre revetment	Tonne	-	$ 270.00	$ -
5	Load, cart, fill Core	m3	304	$ 8.40	$ 2,550
6	Soil improvement (Dynamic Compaction)	m2	215	$ 30.31	$ 6,506
7	Geogrid	m2	215	$ 5.00	$ 1,073
8	Excavation, stockpile, compact, fill	m3	206	$ 6.00	$ 1,238
9	Dispose clean fill	m3	147	$ 6.00	$ 880
10	Supply, place Geotextile	m2	644	$ 5.00	$ 3,222
11	Supply and Place Rock (limestone or greywacke)	m3	274	$ 80.00	$ 21,933
12	Topsoil, grass and harrow	m2	361	$ 0.20	$ 72
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	146	$ 611.00	$ 89,511
17	Expansion joints and sealant	m	92	$ 391.50	$ 36,175
18	Supervision	week	2	$ 2,000	$ 3,400
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 189,157**
20	Contingency	LS	25%	$ 189,157	$ 47,289
21	Future increase	LS	10%	$ 189,157	$ 18,916
Total Construction Cost					**$ 255,361**

Design Crest Level at 13.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	690	$ 1.50	$ 1,034
3	Remove existing rock revetment	m3	376	$ 6.00	$ 2,256
4	Remove and dispose tyre revetment	Tonne	-	$ 270.00	$ -
5	Load, cart, fill Core	m3	426	$ 8.40	$ 3,575
6	Soil improvement (Dynamic Compaction)	m2	295	$ 30.31	$ 8,946
7	Geogrid	m2	295	$ 5.00	$ 1,476
8	Excavation, stockpile, compact fill	m3	357	$ 6.00	$ 2,140
9	Dispose clean fill	m3	220.47	$ 6.00	$ 1,323
10	Supply, place Geotextile	m2	647	$ 5.00	$ 3,234
11	Supply and Place Rock (limestone or greywacke)	m3	625	$ 80.00	$ 49,980
12	Topsoil, grass and harrow	m2	487	$ 0.20	$ 97
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	176	$ 718.50	$ 126,722
17	Expansion joints and sealant	m	147	$ 391.50	$ 57,551
18	Supervision	week	3	$ 2,000	$ 5,400
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 283,234**
20	Contingency	LS	25%	$ 283,234	$ 70,809
21	Future increase	LS	10%	$ 283,234	$ 28,323
Total Construction Cost					**$ 382,366**

Design Crest Level at 14.0m

Item	Description	Unit	Quantity	Rate		Amount	
1	Site establishment	LS	100%	$	5,000	$	5,000
2	Stripping base	m2	809	$	1.50	$	1,214
3	Remove existing rock revetment	m3	376	$	6.00	$	2,256
4	Remove and dispose tyre revetment	Tonne	-	$	270.00	$	-
5	Load, cart, fill Core	m3	381	$	8.40	$	3,198
6	Soil improvement (Dynamic Compaction)	m2	429	$	30.31	$	13,012
7	Geogrid	m2	429	$	5.00	$	2,147
8	Excavation, stockpile, compact fill	m3	422	$	8.40	$	3,549
9	Dispose clean fill	m3	287.65	$	6.00	$	1,726
10	Supply, place Geotextile	m2	745	$	5.00	$	3,726
11	Supply and Place Rock (limestone or greywacke)	m3	1,017	$	80.00	$	81,341
12	Topsoil, grass and harrow	m2	606	$	0.20	$	121
13	Construct, maintain haul roads	LS	0%	$	5,000	$	-
14	Watercart	hr	100	$	85.00	$	8,500
15	Erosion control	LS	20%	$	5,000	$	1,000
16	Reinforced Concrete 45MPa	m3	204	$	761.50	$	155,632
17	Expansion joints and sealant	m	189	$	589.00	$	111,321
18	Supervision	week	3	$	2,000	$	6,600
19	Traffic management	LS	100%	$	5,000	$	5,000
Subtotal						**$**	**405,343**
20	Contingency	LS	25%	$	405,343	$	101,336
21	Future increase	LS	10%	$	405,343	$	40,534
Total Construction Cost						**$**	**547,213**

Design Crest Level at 14.5m

Item	Description	Unit	Quantity	Rate		Amount	
1	Site establishment	LS	100%	$	5,000	$	5,000
2	Stripping base	m2	837	$	1.50	$	1,256
3	Remove existing rock revetment	m3	376	$	6.00	$	2,256
4	Remove and dispose tyre revetment	Tonne	-	$	270.00	$	-
5	Load, cart, fill Core	m3	755	$	8.40	$	6,345
6	Soil improvement (Dynamic Compaction)	m2	537	$	30.31	$	16,265
7	Geogrid	m2	537	$	5.00	$	2,683
8	Excavation, stockpile, compact fill	m3	495	$	8.40	$	4,154
9	Dispose clean fill	m3	427.51	$	6.00	$	2,565
10	Supply, place Geotextile	m2	815	$	5.00	$	4,073
11	Supply and Place Rock (limestone or greywacke)	m3	969	$	80.00	$	77,488
12	Topsoil, grass and harrow	m2	635	$	0.20	$	127
13	Construct, maintain haul roads	LS	0%	$	5,000	$	-
14	Watercart	hr	100	$	85.00	$	8,500
15	Erosion control	LS	20%	$	5,000	$	1,000
16	Reinforced Concrete 45MPa	m2	253	$	804.50	$	203,246
17	Expansion joints and sealant	m	221	$	589.00	$	130,122
18	Supervision	week	5	$	2,000	$	9,200
19	Traffic management	LS	100%	$	5,000	$	5,000
Subtotal						**$**	**479,280**
20	Contingency	LS	25%	$	479,280	$	119,820
21	Future increase	LS	10%	$	479,280	$	47,928
Total Construction Cost						**$**	**647,028**

WEST QUAY - ALTERNATIVE 2:

Design Crest Level at 13.0m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	837	$ 1.50	$ 1,256
3	Remove existing rock revetment	m3	376	$ 6.00	$ 2,256
4	Remove and dispose tyre revetment	Tonne	-	$ 270.00	$ -
5	Load, cart, fill Core	m3	304	$ 8.40	$ 2,550
6	Soil improvement (Dynamic Compaction)	m2	537	$ 30.31	$ 16,265
7	Geogrid	m2	537	$ 5.00	$ 2,683
8	Excavation, stockpile, compact, fill	m3	495	$ 6.00	$ 2,967
9	Dispose clean fill	m3	428	$ 6.00	$ 2,565
10	Supply, place Geotextile	m2	644	$ 5.00	$ 3,222
11	Supply and Place Rock (limestone or greywacke)	m3	274	$ 80.00	$ 21,933
12	Topsoil, grass and harrow	m2	635	$ 0.20	$ 127
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	152	$ 804.50	$ 122,295
17	Expansion joints and sealant	m	158	$ 391.50	$ 61,826
18	Supervision	week	4	$ 2,000	$ 7,460
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 266,905**
20	Contingency	LS	25%	$ 266,905	$ 66,726
21	Future increase	LS	10%	$ 266,905	$ 26,690
Total Construction Cost					**$ 360,321**

Design Crest Level at 13.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	837	$ 1.50	$ 1,256
3	Remove existing rock revetment	m3	376	$ 6.00	$ 2,256
4	Remove and dispose tyre revetment	Tonne	-	$ 270.00	$ -
5	Load, cart, fill Core	m3	426	$ 8.40	$ 3,575
6	Soil improvement (Dynamic Compaction)	m2	537	$ 30.31	$ 16,265
7	Geogrid	m2	537	$ 5.00	$ 2,683
8	Excavation, stockpile, compact fill	m3	495	$ 6.00	$ 2,967
9	Dispose clean fill	m3	428	$ 6.00	$ 2,565
10	Supply, place Geotextile	m2	647	$ 5.00	$ 3,234
11	Supply and Place Rock (limestone or greywacke)	m3	625	$ 80.00	$ 49,980
12	Topsoil, grass and harrow	m2	635	$ 0.20	$ 127
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	186	$ 804.50	$ 149,279
17	Expansion joints and sealant	m	179	$ 391.50	$ 70,047
18	Supervision	week	4	$ 2,000	$ 8,060
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 331,794**
20	Contingency	LS	25%	$ 331,794	$ 82,949
21	Future increase	LS	10%	$ 331,794	$ 33,179
Total Construction Cost					**$ 447,923**

Design Crest Level at 14.0m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	837	$ 1.50	$ 1,256
3	Remove existing rock revetment	m3	376	$ 6.00	$ 2,256
4	Remove and dispose tyre revetment	Tonne	-	$ 270.00	$ -
5	Load, cart, fill Core	m3	381	$ 8.40	$ 3,198
6	Soil improvement (Dynamic Compaction)	m2	537	$ 30.31	$ 16,265
7	Geogrid	m2	537	$ 5.00	$ 2,683
8	Excavation, stockpile, compact fill	m3	495	$ 6.00	$ 2,967
9	Dispose clean fill	m3	428	$ 6.00	$ 2,565
10	Supply, place Geotextile	m2	745	$ 5.00	$ 3,726
11	Supply and Place Rock (limestone or greywacke)	m3	1,017	$ 80.00	$ 81,341
12	Topsoil, grass and harrow	m2	635	$ 0.20	$ 127
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m3	219	$ 804.50	$ 176,262
17	Expansion joints and sealant	m	200	$ 391.50	$ 78,269
18	Supervision	week	4	$ 2,000	$ 8,420
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 398,836**
20	Contingency	LS	25%	$ 398,836	$ 99,709
21	Future increase	LS	10%	$ 398,836	$ 39,884
Total Construction Cost					**$ 538,429**

Design Crest Level at 14.5m

Item	Description	Unit	Quantity	Rate	Amount
1	Site establishment	LS	100%	$ 5,000	$ 5,000
2	Stripping base	m2	837	$ 1.50	$ 1,256
3	Remove existing rock revetment	m3	376	$ 6.00	$ 2,256
4	Remove and dispose tyre revetment	Tonne	-	$ 270.00	$ -
5	Load, cart, fill Core	m3	755	$ 8.40	$ 6,345
6	Soil improvement (Dynamic Compaction)	m2	537	$ 30.31	$ 16,265
7	Geogrid	m2	537	$ 5.00	$ 2,683
8	Excavation, stockpile, compact fill	m3	495	$ 6.00	$ 2,967
9	Dispose clean fill	m3	428	$ 6.00	$ 2,565
10	Supply, place Geotextile	m2	745	$ 5.00	$ 3,726
11	Supply and Place Rock (limestone or greywacke)	m3	1,017	$ 80.00	$ 81,341
12	Topsoil, grass and harrow	m2	635	$ 0.20	$ 127
13	Construct, maintain haul roads	LS	0%	$ 5,000	$ -
14	Watercart	hr	100	$ 85.00	$ 8,500
15	Erosion control	LS	20%	$ 5,000	$ 1,000
16	Reinforced Concrete 45MPa	m2	253	$ 804.50	$ 203,246
17	Expansion joints and sealant	m	221	$ 391.50	$ 86,490
18	Supervision	week	5	$ 2,000	$ 9,200
19	Traffic management	LS	100%	$ 5,000	$ 5,000
Subtotal					**$ 437,968**
20	Contingency	LS	25%	$ 437,968	$ 109,492
21	Future increase	LS	10%	$ 437,968	$ 43,797
Total Construction Cost					**$ 591,257**

Appendix C NCC Rough Order Costing for Raising Pandora Rd

NAPIER CITY COUNCIL
Te Kaunihera o Ahuriri

Project: **Raising Pandora Road to RL 12.5m**

Rough Order Costs

Estimate is based on an existing levels of 12.0m

Item	Description	Unit	Qty	Rate	Amount
1	**PRELIMINARY & GENERAL**				**$ 215,000.00**
1.1	Establishment & Dis-establishment	LS	1	$ 50,000.00	$ 50,000.00
1.2	Project management inc. design	LS	1	$ 100,000.00	$ 100,000.00
1.3	Site security/Traffic management	LS	1	$ 20,000.00	$ 20,000.00
1.5	Environmental Compliance	LS	1	$ 10,000.00	$ 10,000.00
1.6	Affected parites liaison	LS	1	$ 5,000.00	$ 5,000.00
1.7	Contract management (H&S plans etc.)	LS	1	$ 20,000.00	$ 20,000.00
1.8	Contractor setting out, location of services etc.	LS	1	$ 10,000.00	$ 10,000.00
2	**EARTHWORKS**				**$ 50,000.00**
2.1	Site Clearance	LS	1	$ 50,000.00	$ 50,000.00
3	**CONCRETE WORK**				**$ 169,500.00**
3.3	Supply and Install Kerb & Channel	m	700	$ 100.00	$ 70,000.00
3.5	Supply and Install Pram Crossing	LS	10	$ 500.00	$ 5,000.00
3.6	Supply and Install 100mm Concrete Footpath will 75mm AP40 base	m^2	1050	$ 90.00	$ 94,500.00
4	**ROAD MARKING**				**$ 45,000.00**
4.1	First Road Marking	LS	1	$ 20,000.00	$ 20,000.00
4.2	Second Road Marking	LS	1	$ 15,000.00	$ 15,000.00
4.3	Relocation of existing signs	LS	1	$ 10,000.00	$ 10,000.00
5	**PAVEMENT & SURFACING CONSTRUCTION**				**$ 603,000.00**
5.1	Supply and construct M4 basecourse layer 150mm thick	m^3	420	150	$ 63,000.00
5.2	Supply and construct AP65 sub-base layer 250mm thick in roundabout circulating areas	m^3	700	100	$ 70,000.00
5.3	Supply & place 100mm structural asphalt	m^2	2800	100	$ 280,000.00
5.4	Supply & place 40mm asphalt wearing course	m^2	2800	50	$ 140,000.00
5.5	Adjust service lids	No.	50	1000	$ 50,000.00
6	**UTILITIES**				**$ 10,000.00**
6.1	Supply and construct 600mm dia. Sump	No.	4	$ 2,500.00	$ 10,000.00
7	**STREET LIGHTING**				**$ 70,000.00**
7.1	Supply and install new street lighting column utilising exising LED lamps	No.	10	$ 5,000.00	$ 50,000.00
7.2	Supply & install new power supply	m	200	$ 100.00	$ 20,000.00
8	**LANDSCAPING**				**$ 250,000.00**
8.1	Implementation of landscaping plan	LS	1	$ 250,000.00	$ 250,000.00
				SUB TOTAL	$ 1,412,500.00
				CONTINGENCY	$ 423,750.00
				TOTAL (GST exclusive)	**$ 1,836,250.00**

NAPIER CITY COUNCIL
Te Kaunihera o Ahuriri

Project: **Raising Pandora Road to RL 13.0m**

Rough Order Costs

Estimate is based on an existing levels of 12.0m

Item	Description	Unit	Qty	Rate	Amount
1	**PRELIMINARY & GENERAL**				**$ 215,000.00**
1.1	Establishment & Dis-establishment	LS	1	$ 50,000.00	$ 50,000.00
1.2	Project management inc. design	LS	1	$ 100,000.00	$ 100,000.00
1.3	Site security/Traffic management	LS	1	$ 20,000.00	$ 20,000.00
1.5	Environmental Compliance	LS	1	$ 10,000.00	$ 10,000.00
1.6	Affected parites liaison	LS	1	$ 5,000.00	$ 5,000.00
1.7	Contract management (H&S plans etc.)	LS	1	$ 20,000.00	$ 20,000.00
1.8	Contractor setting out, location of services etc.	LS	1	$ 10,000.00	$ 10,000.00
2	**EARTHWORKS**				**$ 537,500.00**
2.1	Site Clearance	LS	1	$ 50,000.00	$ 50,000.00
2.2	Supply and construct engineering fill	m^3	4875	$ 100.00	$ 487,500.00
3	**CONCRETE WORK**				**$ 169,500.00**
3.3	Supply and Install Kerb & Channel	m	700	$ 100.00	$ 70,000.00
3.5	Supply and Install Pram Crossing	LS	10	$ 500.00	$ 5,000.00
3.6	Supply and Install 100mm Concrete Footpath will 75mm AP40 base	m^2	1050	$ 90.00	$ 94,500.00
4	**ROAD MARKING**				**$ 45,000.00**
4.1	First Road Marking	LS	1	$ 20,000.00	$ 20,000.00
4.2	Second Road Marking	LS	1	$ 15,000.00	$ 15,000.00
4.3	Relocation of existing signs	LS	1	$ 10,000.00	$ 10,000.00
5	**PAVEMENT & SURFACING CONSTRUCTION**				**$ 603,000.00**
5.1	Supply and construct M4 basecourse layer 150mm thick	m^3	420	150	$ 63,000.00
5.2	Supply and construct AP65 sub-base layer 250mm thick in roundabout circulating areas	m^3	700	100	$ 70,000.00
5.3	Supply & place 100mm structural asphalt	m^2	2800	100	$ 280,000.00
5.4	Supply & place 40mm asphalt wearing course	m^2	2800	50	$ 140,000.00
5.5	Adjust service lids	No.	50	1000	$ 50,000.00
6	**UTILITIES**				**$ 10,000.00**
6.1	Supply and construct 600mm dia. Sump	No.	4	$ 2,500.00	$ 10,000.00
7	**STREET LIGHTING**				**$ 70,000.00**
7.1	Supply and install new street lighting column utilising exising LED lamps	No.	10	$ 5,000.00	$ 50,000.00
7.2	Supply & install new power supply	m	200	$ 100.00	$ 20,000.00
8	**LANDSCAPING**				**$ 260,000.00**
8.1	Implementation of landscaping plan	LS	1	$ 250,000.00	$ 250,000.00
8.2	TL-3 Guard rail	m	100	$ 100.00	$ 10,000.00
				SUB TOTAL	$ 1,910,000.00
				CONTINGENCY	$ 573,000.00
				TOTAL (GST exclusive)	**$ 2,483,000.00**

	Project:	Raising Pandora Road to RL 13.5m
NAPIER CITY COUNCIL Te Kaunihera o Ahuriri		Rough Order Costs

Estimate is based on an existing levels of 12.0m

Item	Description	Unit	Qty	Rate	Amount
1	**PRELIMINARY & GENERAL**				**$ 485,000.00**
1.1	Establishment & Dis-establishment	LS	1	$ 75,000.00	$ 75,000.00
1.2	Project management inc. design	LS	1	$ 150,000.00	$ 150,000.00
1.3	Site security/Traffic management	LS	1	$ 50,000.00	$ 50,000.00
1.5	Environmental Compliance	LS	1	$ 100,000.00	$ 100,000.00
1.6	Affected parites liaison	LS	1	$ 50,000.00	$ 50,000.00
1.7	Contract management (H&S plans etc.)	LS	1	$ 50,000.00	$ 50,000.00
1.8	Contractor setting out, location of services etc.	LS	1	$ 10,000.00	$ 10,000.00
2	**EARTHWORKS**				**$ 1,520,000.00**
2.1	Site Clearance	LS	1	$ 20,000.00	$ 20,000.00
2.2	Supply and construct engineering fill	m^3	9750	$ 100.00	$ 975,000.00
2.3	Concrete block retaining wall (>1m)	m	700	$ 750.00	$ 525,000.00
3	**CONCRETE WORK**				**$ 169,500.00**
3.3	Supply and Install Kerb & Channel	m	700	$ 100.00	$ 70,000.00
3.5	Supply and Install Pram Crossing	LS	10	$ 500.00	$ 5,000.00
3.6	Supply and Install 100mm Concrete Footpath will 75mm AP40 base	m^2	1050	$ 90.00	$ 94,500.00
4	**ROAD MARKING**				**$ 45,000.00**
4.1	First Road Marking	LS	1	$ 20,000.00	$ 20,000.00
4.2	Second Road Marking	LS	1	$ 15,000.00	$ 15,000.00
4.3	Relocation of existing signs	LS	1	$ 10,000.00	$ 10,000.00
5	**PAVEMENT & SURFACING CONSTRUCTION**				**$ 603,000.00**
5.1	Supply and construct M4 basecourse layer 150mm thick	m^3	420	150	$ 63,000.00
5.2	Supply and construct AP65 sub-base layer 250mm thick in roundabout circulating areas	m^3	700	100	$ 70,000.00
5.3	Supply & place 100mm structural asphalt	m^2	2800	100	$ 280,000.00
5.4	Supply & place 40mm asphalt wearing course	m^2	2800	50	$ 140,000.00
5.5	Adjust service lids	No.	50	1000	$ 50,000.00
6	**UTILITIES**				**$ 762,500.00**
6.1	Telecommunications installation and relocation	LS	1	$ 75,000.00	$ 75,000.00
6.2	Unision installation and relocation	LS	1	$ 150,000.00	$ 150,000.00
6.3	Gas installation and relocation	LS	1	$ 150,000.00	$ 150,000.00
6.4	Supply and install 150mm dia. Water main	m	850	$ 150.00	$ 127,500.00
6.5	Raise water service boxes	No.	15	$ 1,000.00	$ 15,000.00
6.6	Supply and Install DN150 Sewer Main	m	400	$ 300.00	$ 120,000.00
6.7	Supply and Install DN1050 Manhole RC	No.	5	$ 5,000.00	$ 25,000.00
6.8	Supply and construct 600mm dia. Sump	No.	4	$ 2,500.00	$ 10,000.00
6.9	Supply and Install Stormwater outlets (NCC)	LS	3	$ 15,000.00	$ 45,000.00
6.10	Supply and Install DN 300 RC	m	150	$ 300.00	$ 45,000.00
7	**STREET LIGHTING**				**$ 70,000.00**
7.1	Supply and install new street lighting column utilising exising LED lamps	No.	10	$ 5,000.00	$ 50,000.00
7.2	Supply & install new power supply	m	200	$ 100.00	$ 20,000.00
8	**LANDSCAPING**				**$ 260,000.00**
8.1	Implementation of landscaping plan	LS	1	$ 250,000.00	$ 250,000.00
8.2	TL-3 Guard rail	m	100	$ 100.00	$ 10,000.00
				SUB TOTAL	$ 3,915,000.00
				CONTINGENCY	$ 1,174,500.00
				TOTAL (GST exclusive)	**$ 5,089,500.00**

		Project:	Raising Pandora Road to RL 14.0m
NAPIER CITY COUNCIL Te Kaunihera o Ahuriri			Rough Order Costs

Estimate is based on an existing levels of 12.0m

Item	Description	Unit	Qty	Rate	Amount
1	**PRELIMINARY & GENERAL**				**$ 740,000.00**
1.1	Establishment & Dis-establishment	LS	1	$ 75,000.00	$ 75,000.00
1.2	Project management inc. design	LS	1	$ 200,000.00	$ 200,000.00
1.3	Site security/Traffic management	LS	1	$ 70,000.00	$ 70,000.00
1.5	Environmental Compliance	LS	1	$ 200,000.00	$ 200,000.00
1.6	Affected parites liaison	LS	1	$ 150,000.00	$ 150,000.00
1.7	Contract management (H&S plans etc.)	LS	1	$ 35,000.00	$ 35,000.00
1.8	Contractor setting out, location of services etc.	LS	1	$ 20,000.00	$ 10,000.00
2	**EARTHWORKS**				**$ 2,042,500.00**
2.1	Site Clearance	LS	1	$ 20,000.00	$ 20,000.00
2.2	Supply and construct engineering fill	m^3	14625	$ 100.00	$ 1,462,500.00
2.3	Concrete block retaining wall (1m)	m	700	$ 800.00	$ 560,000.00
3	**CONCRETE WORK**				**$ 169,500.00**
3.3	Supply and Install Kerb & Channel	m	700	$ 100.00	$ 70,000.00
3.5	Supply and Install Pram Crossing	LS	10	$ 500.00	$ 5,000.00
3.6	Supply and Install 100mm Concrete Footpath will 75mm AP40 base	m^2	1050	$ 90.00	$ 94,500.00
4	**ROAD MARKING**				**$ 45,000.00**
4.1	First Road Marking	LS	1	$ 20,000.00	$ 20,000.00
4.2	Second Road Marking	LS	1	$ 15,000.00	$ 15,000.00
4.3	Relocation of existing signs	LS	1	$ 10,000.00	$ 10,000.00
5	**PAVEMENT & SURFACING CONSTRUCTION**				**$ 603,000.00**
5.1	Supply and construct M4 basecourse layer 150mm thick	m^3	420	150	$ 63,000.00
5.2	Supply and construct AP65 sub-base layer 250mm thick in roundabout circulating areas	m^3	700	100	$ 70,000.00
5.3	Supply & place 100mm structural asphalt	m^2	2800	100	$ 280,000.00
5.4	Supply & place 40mm asphalt wearing course	m^2	2800	50	$ 140,000.00
5.5	Adjust service lids	No.	50	1000	$ 50,000.00
6	**UTILITIES**				**$ 762,500.00**
6.1	Telecommunications installation and relocation	LS	1	$ 75,000.00	$ 75,000.00
6.2	Unision installation and relocation	LS	1	$ 150,000.00	$ 150,000.00
6.3	Gas installation and relocation	LS	1	$ 150,000.00	$ 150,000.00
6.4	Supply and install 150mm dia. Water main	m	850	$ 150.00	$ 127,500.00
6.5	Raise water service boxes	No.	15	$ 1,000.00	$ 15,000.00
6.6	Supply and Install DN150 Sewer Main	m	400	$ 300.00	$ 120,000.00
6.7	Supply and Install DN1050 Manhole RC	No.	5	$ 5,000.00	$ 25,000.00
6.8	Supply and construct 600mm dia. Sump	No.	4	$ 2,500.00	$ 10,000.00
6.9	Supply and Install Stormwater outlets (NCC)	LS	3	$ 15,000.00	$ 45,000.00
6.10	Supply and Install DN 300 RC	m	150	$ 300.00	$ 45,000.00
7	**STREET LIGHTING**				**$ 70,000.00**
7.1	Supply and install new street lighting column utilising exising LED lamps	No.	10	$ 5,000.00	$ 50,000.00
7.2	Supply & install new power supply	m	200	$ 100.00	$ 20,000.00
8	**LANDSCAPING**				**$ 260,000.00**
8.1	Implementation of landscaping plan	LS	1	$ 250,000.00	$ 250,000.00
8.2	TL-3 Guard rail	m	100	$ 100.00	$ 10,000.00
				SUB TOTAL	$ 4,692,500.00
				CONTINGENCY	$ 1,407,750.00
				TOTAL (GST exclusive)	**$ 6,100,250.00**

NAPIER CITY COUNCIL
Te Kaunihera o Ahuriri

		Project:	Raising Pandora Road to RL 14.5m		
			Rough Order Costs		

Estimate is based on an existing levels of 12.0m

Item	Description	Unit	Qty	Rate	Amount
1	**PRELIMINARY & GENERAL**				**$ 740,000.00**
1.1	Establishment & Dis-establishment	LS	1	$ 75,000.00	$ 75,000.00
1.2	Project management inc. design	LS	1	$ 200,000.00	$ 200,000.00
1.3	Site security/Traffic management	LS	1	$ 70,000.00	$ 70,000.00
1.5	Environmental Compliance	LS	1	$ 200,000.00	$ 200,000.00
1.6	Affected parites liaison	LS	1	$ 150,000.00	$ 150,000.00
1.7	Contract management (H&S plans etc.)	LS	1	$ 35,000.00	$ 35,000.00
1.8	Contractor setting out, location of services etc.	LS	1	$ 20,000.00	$ 10,000.00
2	**EARTHWORKS**				**$ 2,670,000.00**
2.1	Site Clearance	LS	1	$ 20,000.00	$ 20,000.00
2.2	Supply and construct engineering fill	m^3	19500	$ 100.00	$ 1,950,000.00
2.3	Concrete block retaining wall (1.5m)	m	700	$ 1,000.00	$ 700,000.00
3	**CONCRETE WORK**				**$ 169,500.00**
3.3	Supply and Install Kerb & Channel	m	700	$ 100.00	$ 70,000.00
3.5	Supply and Install Pram Crossing	LS	10	$ 500.00	$ 5,000.00
3.6	Supply and Install 100mm Concrete Footpath will 75mm AP40 base	m^2	1050	$ 90.00	$ 94,500.00
4	**ROAD MARKING**				**$ 45,000.00**
4.1	First Road Marking	LS	1	$ 20,000.00	$ 20,000.00
4.2	Second Road Marking	LS	1	$ 15,000.00	$ 15,000.00
4.3	Relocation of existing signs	LS	1	$ 10,000.00	$ 10,000.00
5	**PAVEMENT & SURFACING CONSTRUCTION**				**$ 603,000.00**
5.1	Supply and construct M4 basecourse layer 150mm thick	m^3	420	150	$ 63,000.00
5.2	Supply and construct AP65 sub-base layer 250mm thick in roundabout circulating areas	m^3	700	100	$ 70,000.00
5.3	Supply & place 100mm structural asphalt	m^2	2800	100	$ 280,000.00
5.4	Supply & place 40mm asphalt wearing course	m^2	2800	50	$ 140,000.00
5.5	Adjust service lids	No.	50	1000	$ 50,000.00
6	**UTILITIES**				**$ 762,500.00**
6.1	Telecommunications installation and relocation	LS	1	$ 75,000.00	$ 75,000.00
6.2	Unision installation and relocation	LS	1	$ 150,000.00	$ 150,000.00
6.3	Gas installation and relocation	LS	1	$ 150,000.00	$ 150,000.00
6.4	Supply and install 150mm dia. Water main	m	850	$ 150.00	$ 127,500.00
6.5	Raise water service boxes	No.	15	$ 1,000.00	$ 15,000.00
6.6	Supply and Install DN150 Sewer Main	m	400	$ 300.00	$ 120,000.00
6.7	Supply and Install DN1050 Manhole RC	No.	5	$ 5,000.00	$ 25,000.00
6.8	Supply and construct 600mm dia. Sump	No.	4	$ 2,500.00	$ 10,000.00
6.9	Supply and Install Stormwater outlets (NCC)	LS	3	$ 15,000.00	$ 45,000.00
6.10	Supply and Install DN 300 RC	m	150	$ 300.00	$ 45,000.00
7	**STREET LIGHTING**				**$ 70,000.00**
7.1	Supply and install new street lighting column utilising exising LED lamps	No.	10	$ 5,000.00	$ 50,000.00
7.2	Supply & install new power supply	m	200	$ 100.00	$ 20,000.00
8	**LANDSCAPING**				**$ 260,000.00**
8.1	Implementation of landscaping plan	LS	1	$ 250,000.00	$ 250,000.00
8.2	TL-3 Guard rail	m	100	$ 100.00	$ 10,000.00
				SUB TOTAL	$ 5,320,000.00
				CONTINGENCY	$ 1,596,000.00
				TOTAL (GST exclusive)	**$ 6,916,000.00**

Appendix D Flood barrier costing information

Email communications Tim Collingwood and Adrian Morphet.

Jose
Unfortunately we never get involved in the civils design or construction, and have no idea of the costs. For installation it often ends up being say 15% of the supply price.
Paeroa was slightly different to most jobs as we re-used the foundations that were already there for the demountable barrier system that preceded our gates. For the construction not sure of the soils, so there may need to be piling. Our gates would need a slab all the way across the roads though.

Maintenance would be minimal if above ground gates. I know at Paeroa they close the gates annually and I suspect they undertake any minor maintenance on that same day.

I appreciate not as full an answer as maybe you hoped for but I hope this helps.

Kind Regards

Tim Collingwood

Kilworthy Park, Tavistock, Devon PL19 0FZ
0: 01822 619730
E: Tim.Collingwood@Floodcontrolint.com

From: Jose Beya <Jose.Beya@hbrc.govt.nz>
Sent: 07 September 2020 06:13
To: Tim Collingwood <tim.collingwood@floodcontrolint.com>
Cc: Craig Goodier <Craig@hbrc.govt.nz>; Robin Malley <robinm@napier.govt.nz>; Andy Couch <andy.couch@floodcontrolint.com>
Subject: RE: Flood barrier estimate Ahuriri New Zealand

Dear Tim,
Thank you for sending me this information and a view on the different type of systems available and your view of the optimal system for the location.
Yes, I think the cost estimates you've given me are good for the current stage of the project, but I'd like to get an idea of how much the installation and accompanying civil works may cost. Do you have an idea about how much would that be based on previous projects? I know that the Paeroa system ended up costing $1m NZD including design, construction and project management for a clear opening of 21m. Do you know how much maintenance and maintenance cost would be required?
Best regards

Jose Beya
Principal Engineer
06 833 8058
Hawke's Bay Regional Council | Te Kaunihera ā-rohe o Te Matau a Māui

159 Dalton Street, Napier 4110 | hbrc.govt.nz
Enhancing Our Environment Together | Te Whakapakari Tahi I Tō Tātau Taiao

From: Tim Collingwood <tim.collingwood@floodcontrolint.com>
Sent: Thursday, 3 September 2020 8:35 PM
To: Jose Beya <Jose.Beya@hbrc.govt.nz>
Cc: Craig Goodier <Craig@hbrc.govt.nz>; Robin Malley <robinm@napier.govt.nz>; Andy Couch <andy.couch@floodcontrolint.com>
Subject: RE: Flood barrier estimate Ahuriri New Zealand

Jose
Many thanks for your email.
So there are two main options I would have thought for these openings. You could go for an in-ground barrier. However, you need to consider the load/ fatigue of being constantly driven over / braked on etc., which may be a problem. Also, it is hard to find a reliable anti-slip deck material that doesn't need regular maintenance. Then further issues with the thing always being in the highway (so the highway needs to close for any maintenance as the first thing you need to do is raise the barrier), and effects of de-icing salts and finally after a flood the pit needs cleaning before you can lower the gate again..

A sliding gate would not have most of these issues, as all above ground and except for the groundbeam all normally away from the highway so maintenance is easier.. If a double gate then you can also close one part of the gate with one lane still running and only have a smaller gate to quickly shut / open as required, so the highway is disrupted for as little time as possible..Or you could do a sliding gate like Paeroa for most of the opening and have say a 4m wide swing gate on the central reserve to close to it finally – for the 16m length..

However, on the 'pond' side of the road it doesn't look like you would have enough room to store a sliding gate. So a double swing gate might work here as only 12m across. There's the problem then of operating in high winds, so you would probably want some sort of mechanical assist such as manual hydraulic ram to swing open/ closed.

In terms of budget pricing – assuming double sliding gates as Paeroa to the 16m opening 2m high then this would be approx. $NZ 370k, delivered and not including GST, based on an imported UK gate
For the 12m opening 2m high then $300k should be about right for a double swing gate arrangement.

I hope this is OK for now? I can formalise and go into a little more detail if you want, but it looks like there is a way to go yet to get to final solution so hopefully these budget figures are fine.

Let me know if you need any further information, and will get to you.

Kind Regards

Tim Collingwood

Kilworthy Park, Tavistock, Devon PL19 0FZ
0: 01822 619730
E: Tim.Collingwood@Floodcontrolint.com

From: Jose Beya <Jose.Beya@hbrc.govt.nz>
Sent: 02 September 2020 01:07
To: Tim Collingwood <tim.collingwood@floodcontrolint.com>
Cc: Craig Goodier <Craig@hbrc.govt.nz>; Robin Malley <robinm@napier.govt.nz>
Subject: Flood barrier estimate Ahuriri New Zealand

Hi Tim,
Adrian Morphet from the Waikato Regional Council gave me your contact as we are looking at the option of using a flood barrier over a road to provide continuity to a future flood defence for the coastal strategy and he told me you could help me!
The strategy is looking at producing cost estimates of ±30% for the design options. We have the information for the flood barrier at Paeroa from the Waikato Council (https://www.youtube.com/watch?v=KmwluKLpiy8) and I was wondering if you would think it could be easily scaled in terms of length and height over the road to achieve the desired ±30% costing accuracy? Otherwise, would you be able to provide us with a quotation that meets that accuracy?
Please see attached the concept design draft report. The flood barrier would be required for options 1 and 2 across Pandora road. The current design includes raising the road but it was found to be too costly and we are now looking at a mobile barrier option. I have seen other designs that lay flat on the ground and are lifted when needed (e.g. https://www.youtube.com/watch?v=NuDshmb4fmA&t=10s)

I have included a drawing (see image below and dwg file) I just made using the existing lidar data (see spreadsheet) and the current flood defence designs adjacent to the road. The design considers a recommended crest height for the flood defences but it has information for a range of crest heights in order to help the decision makers whether it's best to build to a longer term flood level or it is more cost effective to do it for a short term level.
For a mobile wall, I would think it will make more sense to build it to a higher level as the cost increase is probably not huge for another 0.6m? That is why I have drawn the fixed and mobile walls in red as they are to be designed upon your recommendations. The design life time of the mobile barrier system will probably determine if it's worthwhile building it for a higher level or not as the expected increases are to occur in the long term (sea level rise due to climate change projections). However, as done for the cantilever wall in the report, it may pay to design the foundations and/or the fixed walls to a higher level. In case of the cantilever wall, my recommendation was to build the foundation strong enough to be able to raise the wall in the future due to short term aesthetic reasons and also because the relative cost to build a stronger the foundation was not too significant.

In this case the total height of the barrier is not as high as the Paeroa one so the cost may be lesser or another type of barrier may be better?

Best regards and thank you for taking the time to read this
Jose

ADRIAN MORPHET
Hi Jose,
Base slab was possibly over designed as it was across SH26.
Conditions were predominantly made ground and a sandy soil, with some earlier concrete structures/well encased drainage.
Cheers
Adrian

Adrian Morphet
| TEAM LEADER ENGINEERING DELIVERY | Engineering Delivery, Integrated Catchment Management

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Private Bag 3038, Waikato Mail Centre, Hamilton, 3240

From: Jose Beya <Jose.Beya@hbrc.govt.nz>
Sent: Monday, 31 August 2020 4:35 PM
To: Adrian Morphet <Adrian.Morphet@waikatoregion.govt.nz>
Subject: RE: Design and Costing Paeroa barrier

Thank you Adrian.
I think this is useful. I will email Tim directly to ask him how it would be better to scale this costs for the project to get a reasonable estimate.
I see that there was a significant increase in costs due to underestimated ground works.
What type of soils do you have there?
Cheers

Jose Beya
Principal Engineer
06 833 8058
Hawke's Bay Regional Council | Te Kaunihera ā-rohe o Te Matau a Māui
159 Dalton Street, Napier 4110 | hbrc.govt.nz
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From: Adrian Morphet <Adrian.Morphet@waikatoregion.govt.nz>
Sent: Friday, 28 August 2020 11:06 AM
To: Jose Beya <Jose.Beya@hbrc.govt.nz>
Subject: RE: Design and Costing Paeroa barrier

Hi Jose,
Sorry for the delay.
Attached are a basic drawing of the gates we installed, our Project Management Plan and the Closure Report. Hopefully they should contain most of the basic information on the project.
Have a quick look through them and let me know what else you need. Either e-mail or ring, my numbers on the bottom of the e-mail.

I've also attached Tim Collingwoods card, he's MD at Flood Control International Ltd in the UK. They are the people that designed and built the gates for us. Very helpful and approachable. He flew over to supervise the install.
Hope this helps
Adrian
PS I'm on leave next week, sorry.

Adrian Morphet
| TEAM LEADER ENGINEERING DELIVERY | Engineering Delivery, Integrated Catchment Management

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Private Bag 3038, Waikato Mail Centre, Hamilton, 3240

From: Jose Beya <Jose.Beya@hbrc.govt.nz>
Sent: Tuesday, 25 August 2020 10:04 AM
To: Adrian Morphet <Adrian.Morphet@waikatoregion.govt.nz>
Subject: Design and Costing Paeroa barrier

Hi Adrian,
Ghassan Basheer and Greg Ryan gave me your contact to get design and costing information for the flood barrier on Criterion Bridge in Paeroa. I used to work with them years back when the council was called Environment Waikato. Now I am working at the Hawke's Bay Regional Council.
We are considering on doing something similar in an estuary here in Hawkes Bay where, in order to provide continuity to a flood defence, the road would have to be raised at a high cost.
Would you be able to send me design and costing information about this project? I am interested in all sort of costings including capital, construction, project management, design, consenting, operation and maintenance.
For your interest please see attached a draft report, please do not distribute this around as it's still not official.
Best regards
Jose

Appendix E Peer review comments

Tonkin+Taylor

Job No: 1012724
17 May 2022

Hawke's Bay Regional Council
159 Dalton Street
Napier South
Napier 4110

Attention: Chris Dolley

Dear Chris

Hawke's Bay Coastal Strategy - Pandora options review

The sole purpose of this letter and the associated services performed by Tonkin & Taylor Limited ("T+T") is to undertake a limited review of, and comment on, the concept design report[1] for the Pandora coastal strategy prepared by Hawke's Bay Regional Council ("HBRC") engineering department in accordance with the scope of services set out in the contract between HBRC and T+T.

Following our initial concept design peer review, we provided a document tabulating our key comments on the 18 January 2022. A number of meetings have been held with the design team, prior to providing the review document, to discuss the implications of the findings and approaches that may be taken to resolve comments. We have been provided with two updated versions of the report during this process, which included revisions and addition of an extra option, and a final version that addressed some of the comments raised. The final report version and responses to our peer review comments were received on the 21 March 2022. The response to the peer review is attached to this letter.

It is our understanding that the purpose of the concept design is to allow for costing of scheme options to within +/- 30%. These costings will be used to inform a decision-making process and funding options. As such our comments are limited to those aspects that would require a fundamental change to the design and that are likely to affect the whole life scheme costs. We have applied engineering judgment to the appropriateness of the outputs; however, we have not checked individual calculations and have not had access to the models used.

1 Key findings

HBRC engineers have developed simple concepts defined in the coastal strategy into more detailed concept designs considering site specifics and constraints for different areas, and providing a range of solutions and options for the longer term. We acknowledge a lot of work has gone into the designs and costing exercise in order to provide more certainty on costs and the feasibility of options. We also recognise the limitations to the scope of work and that designs will continue to be refined as part of detailed design if adopted. It is our understanding that for the majority of minor

[1] HBRC (2022). Short-term concept design and costing - Clifton to Tangoio 2120 coastal strategy - Design workstream Flood defences Pandora Unit V3. Prepared by HBRC

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comments raised, the designers have elected to defer further work until a preferred option is selected and then those pertaining to the option can be addressed in a more detailed design stage.

1.1 Design conditions

Additional work is likely to be required to define the design conditions and criteria which will dictate the timing of works, the crest level and design specifics of structures. Both of which will have a bearing on the whole life costs of the strategy. It is our understanding that work is currently being commissioned to address these issues. We note that some of the review comments raised relating to design conditions have been addressed in the latest version of the report.

1.2 Large capital items

Cost estimates for the stopbanks and walls are considered to have a relatively high level of confidence, subject to the comments listed in the review. However, the 'big ticket items' that contribute the majority of the option costs, namely the raising of the road/bridge, upgrades to stormwater network, tidal barrier and sailing club upgrade, carry a high level of uncertainty and are unlikely to be accurate to within +/-30%. Development of these options would require significant additional work, and would need to be accompanied with an assessment of environmental effects to understand and consider the other impacts of this proposal along with financial costs. It is considered prudent to defer this until a preferred option is adopted.

1.3 Option timeline

Deferring the large capital items for as long as possible could improve the cost effectiveness of the strategy although this may result in higher costs for those items at a time in the future. Development of a timeline and triggers under different sea level rise (SLR) scenarios, and investigations into the feasibility of using low cost options (temporary flood barriers, accepting some nuisance flooding and road closures less than once per year) is considered a worthwhile option to better inform a cost benefit analysis.

It may be beneficial to split the approach into essential short to medium term options and those that would only be required in the long-term under a high SLR scenario, which may even constitute 'nice to haves' (e.g., it may be possible to deal with nuisance flooding under low probability events, that may be considered tolerable, an acceptable risk, or accommodated by other means).

2 Summary

The HBRC report provides enough detail to assess the feasibility of defence options, their appearance location and footprint. This allows for a relative assessment of high level costs and engagement with the community. It is our understanding that the current preferred option is a tidal barrier. We note that a lot of additional work is required for this option to confirm feasibility, effects of this option, and to increase the confidence in the cost estimates.

Work to date provides enough detail on alternative options, should they be selected in preference to the tidal barrier, to inform engagement and decision making. However, further design work and effects assessments would be required based on the comments in this review. We agree that this can be addressed in a more detailed design stage should an alternative option be selected.

High level cost estimates were based on similar work in the region and rates at the time the report was written. Over the last two years contractor rates and material costs have increased markedly, mainly due to the impacts of Covid-19, which may mean current rates are not within the specified +/- 30%. Given that a lot of the options are not due to be constructed for decades this uncertainty will always remain. We recommend the use of sensitivity testing when conducting a cost benefit analysis to explore the consequences of above inflation price increases.

3 Applicability

T+T's review was a form of limited technical review, undertaken on a level-of-effort basis, to provide additional assurance to the Client as to the quality of the Design. The responsibility for the Design remains fully with the Principal Consultant and T+T's review does not constitute a means by which that design responsibility can be passed on to T+T. This report has been prepared on behalf of, and for the exclusive use of, T+T's Client, and is subject to, and issued in accordance with, the provisions of the contract between T+T and the Client. T+T accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

Yours sincerely

Richard Reinen-Hamill
Technical Director: Coastal Engineering

17-May-22
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Tonkin+Taylor

Design Review Sheet (DRS) -				
Details of Design Package being reviewed			**Review**	
Project Title: Coastal Strategy – Design Workstream			**Reviewer Name:** Jonathan Clarke/Richard Reinen-Hamill	
Information: Flood Defences Pandora Unit			**Reviewer Role:** Peer Reviewer(s)	
Design Report Date / Ref no: November 2021			**Reviewer Company: Tonkin & Taylor Ltd**	
T+T Ref no: 1012724	**Response Rev Date:**	**Response Rev No:**	**Review Date:**	**Review Revision No:**
HBRC Design Package Manager: Jose Beya		1	1/11/2011	1
Design Review Stage: Concept Design	Click here to enter a date.	Click here to enter text.	Click here to enter a date.	Click here to enter text.
Review Due Date: Click here to enter a date.	Click here to enter a date.	Click here to enter text.	Click here to enter a date.	Click here to enter text.
	Click here to enter a date.	Click here to enter text.	Click here to enter a date.	Click here to enter text.

This package comprises:

☐ Specifications	☐ Spreadsheets	☐ Calculations
☐ Drawings	☐ Supplier data	☒ Reports
☒ Other: Hard copies of costing spreadsheet as Appendix		

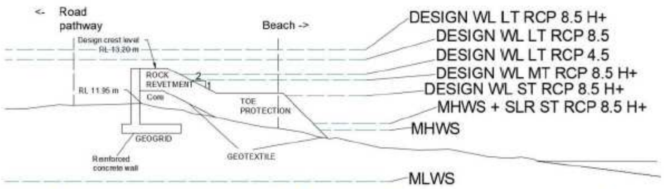
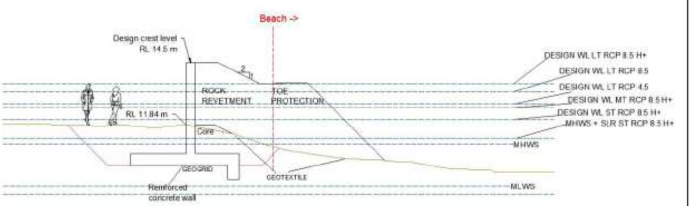
Item No.	Comments	Date	Responses	Date	Comment Closed (Y/N)
1	**Design conditions**				
1.1	**General** – Design water levels are considered high compared to previous estimates and those adopted in the coastal strategy. Some reasons for this are presented below. Generally the approach used to define design water levels uses a deterministic approach adding extreme values for each component, this has been shown to overestimate design levels when compared to a probabilistic method that considers the likelihood of coincident values for each component. The design water levels influence the timing of works and the crest levels of structures which has cost implications for the lifetime of the strategy	November 2021	A design level was required to define the height of the barrier. A probabilistic approach would have produced a different analysis but in the end a definitive level is required for a design. The magnitude of the cost of the barriers compared to other items is minor. Additionally, the preferred alternative is a storm surge barrier. This means fine tunning these designs is not a priority. In the future, if these alternatives are revisited, this observation should be considered. At the end of the executive summary the following paragraphs were included: *The peer review highlighted potential areas of improvement for this report, mainly for the inundation protection structures along the shoreline. However, the review was finalised after the results were presented to the community panels where it was decided to introduce the changes recommended by this report. These changes are:* • *The short-term preferred pathway changes from inundation protection to status-quo.* • *The preferred option from the inundation barriers along the pandora shoreline to the storm surge barrier at the mouth of the estuary.* *With these changes, additional refinements to the concept design suggested by the peer reviewer are not justified. However, peer review comments have been noted and shall be considered for future designs in the area (Appendix E).*	21-03-2022	Y
1.2	**Sea level rise** – A conservative approach has been taken in the report with the use of the RCP 8.5 H+ sea level rise scenario. Adopting the RCP 8.5M scenario for planning purposes may be more appropriate and consistent with guidance for existing infrastructure. We note that other SLR scenarios have been assessed for the LT, however these do not appear to have been used for defining structure crest heights. Design sea level rise figures used in the report are given as 0.24m (20 year/2040) and 0.58m (50 year/2070). MfE guidance (see below) gives values of 0.27m and 0.61m respectively for these timeframes relative to a 1986-2005 MSL baseline, however a reduction of ~0.1m is required to make them relative to a present day MSL and account for SLR that has already occurred (A reduction of 0.08 – 0.11m based on a 2020 baseline year). As presented the design report using 0.24m sea level rise over the next 20 years which equates to an average of 12mm/year and is significantly above the predicted increases set out in current guidance.	November 2021	As response to comment n 1.	21-03-2022	Y

Table 10: Decadal increments for projections of sea-level rise (metres above 1986–2005 baseline) for the wider New Zealand region (for the four future scenarios from figure 27)

NZ SLR scenario Year	NZ RCP2.6 M (median) [m]	NZ RCP4.5 M (median) [m]	NZ RCP8.5 M (median) [m]	NZ RCP8.5 H+ (83rd percentile) [m]
1986–2005	0	0	0	0
2020	0.08	0.08	0.09	0.11
2030	0.13	0.13	0.15	0.18
2040	0.18	0.19	0.21	0.27
2050	0.23	0.24	0.28	0.37
2060	0.27	0.30	0.36	0.48
2070	0.32	0.36	0.45	0.61

	The design report also includes a further increase in SLR based on the IPCC SROOC report (2019), which has now been officially released. However, this does not reflect current guidance or levels used in the wider strategy and based on our review constitutes little change in the short to medium term. It is recommended this is removed and any future changes to SLR are accommodated in the adaptive approach of the strategy.				
1.3	**Land subsidence** – Quoted values in the report are 2mm/year, this is double what is used in the strategy coastal hazard assessment, which states that shoreline between Tangoio Bluff and Cape Kidnappers have been subsiding at a rate between about 0 and 1 mm/year, but with uncertainties having that same order of magnitude. Although the 2mm/year is considered conservative the effect on total water level is relatively small.	November 2021	This value was recommended by Rob Bell who was working closely in these issues. We now have a more detailed estimate carried out by the Takiwa project. Values here are higher than 2mm/y in some areas of the strategy.	21-03-2022	Y
1.4	**Astronomical Tides** – Design water levels use MHWS levels as a base level opposed to HAT. This is considered reasonable given the joint probability of extreme storms occurring at the same time as HAT is very low.	November 2021	OK.	21-03-2022	Y
1.5	**Sea level Anomaly** – We agree with the assessment of the magnitude of the sea level anomaly, but often that is intrinsically built into probability assessments of extreme water levels based on historic records so may just add an extra level of conservatism	November 2021	Ok	21-03-2022	Y
1.6	**Storm surge and wave runup** – These values are provided as a combined value with no calculations so we are unable to comment on the values. We note however for the outer estuary that run-up from ocean waves is included as a separate value so there may be some double counting of wave runup potential.	November 2021	The methodology is explained in section 4.6.and design values values are shown in Table 4.1. The following phrase was added at the end of section 4.6 for clarity. *"The 2% AEP value plus a 5% increase due to potential future changes was selected for design."*	21-03-2022	Y
1.7	**Seiche** – The evidence for a seiche is anecdotal and no evidence of the driving forces that would create it are presented. We consider this value to be high considering the geometry of the estuary and the size of seiches recorded in larger water bodies. The adopted values of up to 0.3m contribute significantly to the design water level and requires further research to justify.	November 2021	Ok. That can be discussed in a future design if these options are pursued. Conservatism is adequate in this location given the assets and population protected. A decision on the amount of freeboard can include or not this effect if its quantification has not been assessed in detail. One of the concerns is that with increase sea levels resonance which is not occurring today may be observed in the future. I still consider that some consideration should be included to account for this potential phenomenon.	21-03-2022	Y
1.8	**Hydrodynamic reduction** – We agree that there is likely a reduction in tidal amplitude within the estuary, values given based off a previous modelling study of -0.1m in the inner harbour and -0.3m in the Pandora basin seem reasonable but no information was provided to validate the figures. Table 4-1 in the design report assigns a reduction of -0.3m to the west quay revetment and stopbank 3 which are closest to the estuary mouth, intuitively we would expect this value to be at the lower end (-0.1m). Conversely revetment 1 further up the estuary is only assigned a reduction of -0.1m. These values may need to be reviewed.	November 2021	There was an error in table 4-1 of the report and the following calculations. The report has been updated to reflect those changes. The differences found were not significant and did not affect the overall findings of the report	18-05-2022	Y
1.9	**Freeboard** – we support the adopted freeboard for the stopbanks as it contributes to the stability of the structure under extreme events and allows for some settlement. However, the design water levels already include values for wave run-up which may be considered part of the freeboard allowance. For the revetment and wall structures the 0.6m freeboard is likely not required and normal practice is to design the structures allowing for wave run-up to the crest of the structure under design conditions, or even a tolerable level of overtopping. No run-up or overtopping calculations are provided for the revetments so we are unable to quantify what effect this may have on the adopted crest level.	November 2021	Freeboard is normally used to account for hydraulic, geotechnical, construction, operation and maintenance uncertainties. Run-up calculations have been carried out as per section 4.6. The fact that the Ru%2 was used, means that minimal overtopping is allowed. Greater overtopping may be allowed in a future revisit of this design if heights may need to be		

			lowered for aesthetic or other purposes.		
2	**Concept Design/Layout**				
2.1	The report provides concept designs that fulfill the preferred pathway in the coastal strategy which specifies inundation protection for the Pandora industrial area, sailing club and surrounding assets for the duration of the strategy. For the most part this is achieved with stopbanks, or where space is constrained alternative vertical wall options.	November 2021	Ok	21-03-2022	Y
2.2	A number of additional items have been considered, including the raising of Pandora Road/Bridge, an upgrade to the sailing club, stormwater upgrades and a tidal barrier. All of these are high-cost items that have significantly increased the potential strategy costs for the Pandora unit from <$5M for the stopbanks and walls up to c. $50M.	November 2021	OK	21-03-2022	Y
3	**Stopbank Design**				
3.1	Stopbanks are proposed for most of the defended length, where available space allows, due to the lower costs and relative ease of construction. HBRC have constructed and maintain a network of stopbanks in the region and the design and geometry is reflective of these structures and considered appropriate.	November 2021	OK	21-03-2022	Y
3.2	**Geotechnical** – As specified in the report further work is required to investigate the need for ground improvements and the potential for seepage under the stopbank with the presence of gravels contributing to the permeability of the ground. This may require the excavation of existing ground and a lower foundation for the structure. An appropriate specification for the fill will also need to be defined as part of the detailed design process.	November 2021	OK	21-03-2022	Y
3.3	**Design Crest Elevations** – Crest elevations are considered appropriate based on the design water level and are between 0.5m to 0.9m above existing stopbank levels. This is reflective of future sea level rise out to the MT (50 years).	November 2021	OK	21-03-2022	Y
3.4	**Erosion Protection** – A rock revetment and toe protection are specified for the estuary side of each stopbank to provide erosion protection against waves and currents. The specified rock size is described as larger than required in order to prevent the manual rock movement by people, as has occurred elsewhere. No design wave heights are provided so we are unable to validate the rock size. The toe protection is in our opinion unnecessarily large for an estuary environment and given the height of ground levels above MLWS may be better achieved by excavating the toe into the ground. There is also scope in most areas for moving the stopbank landward to reduce erosion risk. As the rock makes up a significant portion of the costs (approximately one third) reducing	November 2021	From internal experience at HBRC, excavation in the wet area was avoided, that's why the falling apron toe was chosen as a design option. I agree that some cost saving could be achieved in terms of quantities; however, if constructability is compromised, the cost savings in materials would be compensated by losses due to these construction difficulties. At this stage, it's a safer option to assume this type of design. Further	21-03-2022	Y
	the rock size and accepting the manual handling risk and embedding the toe may reduce costs. This can be upgraded in the future with the placement of an additional layer of larger rocks to accommodate increased water levels and wave heights and any increase in the erosion risk over time.		refinements can be done in the future if these alternatives are revisited.		
3.5	**Cost estimates** – Detailed cost breakdowns are provided and based on similar works that have been conducted in the region. There are some potential cost savings, but also the potential for additional costs following the completion of more detailed ground investigations. On balance the linear rates of $1500 - $2000 are considered appropriate for the purposes of this report and decision making processes. However, we would caution the use of a 10% increase for future costs as construction and material costs have increased dramatically in the last few years and may be considerably more than those derived from previous works.	November 2021	OK	21-03-2022	Y
4	**Steel Sheetpile Design**				
4.1	A steel sheet pile wall is proposed for part of the industrial area in Pandora due to the lack of space available for other options. The wall design is appropriate for structures of this type.	November 2021	OK	21-03-2022	Y
4.2	**Design life** – A design life of 20 years has been adopted which is considered reasonable in the marine environment. Consideration to future adaption and raising of defences is considered for other options, however the sheetpile wall may need replacing in full. No erosion/toe protection is included with the design so we assume the wall is set far enough back that this is not an issue. If this is the case then consideration of a concrete wall may be appropriate which would have a longer design life and would allow for the raising of the structure without a complete replacement.	November 2021	OK	21-03-2022	Y
4.3	**Cost estimate** – A detailed cost breakdown is provided which is considered reasonable, however the linear rate of $3500-$4000 is considered at the lower end of estimates for similar structures elsewhere in NZ especially considering the large increases in construction and material costs over recent years, particularly for steel.	November 2021	OK	21-03-2022	Y
5	**Cantilever Wall/Revetment Design**				
5.1	A concept design for a cantilever wall and rock revetment is presented in the design report. The reasons for this choice are not explicitly stated it is assumed that the main reason is a lack of available space for constructing stopbanks that are specified elsewhere in the report.	November 2021	That's the reason. This is explained at the start of section 3.	21-03-2022	Y
5.2	**Rock sizing** – the report references the methodology for calculating the required rock size and thickness of the revetment layers but does not provide any calculations or rock sizes so we are unable to check this aspect of the design.	November 2021	OK	21-03-2022	Y
5.3	**Purpose of rock revetment** – This is unclear in the report and no case is made for using a standalone wall as an option. The revetment would provide some buttressing to the wall, provide erosion protection to the foreshore and reduce wave overtopping. However, in the low	November 2021	The purpose of the revetment is to protect the land against erosion, decrease overtopping, safety and aesthetics. A sole wall could be	21-03-2022	Y

	energy wave environment (especially along Pandora Pond) these functions may not require a full sized revetment and could be reduced in size and extent. No calculations are provided for overtopping under design conditions so we are unable to assess the contribution the revetment makes to reducing flooding risk behind the defence.		also an option however it may require future rock protection. At this stage it was considered better to build this safety early in the design.		
5.4	**Toe protection** – The design of the falling toe for protection against scour/erosion is considered over designed for the environment and the relative size of the revetment 1 (Figure 5.4-A). Given the toe of the structure is somewhat higher than MLWS at the time of construction it would be more practical to excavate and embed the toe of the revetment into the existing land, which would also reduce the structure footprint and occupation within the estuary The rock revetment is also not critical to preventing flooding which is for the most part governed by the concrete wall. Consequently, the revetment design can accommodate a higher level of tolerable damage.  Figure 5.4: Example drawing from report of cantilever wall and rock revetment 1 (p.28)	November 2021	See response to comment 3.4	21-03-2022	Y
5.5	**Structure crest level** – The report considers a number of crest heights and adopts levels of RL 13.2m and 13.4m respectively for revetment 1 and 2. These are considered practical as they equate to approximately 1m-1.5m above current land levels, and therefore still allow pedestrians a view over the wall, while accommodating the MT (50 year) design water level. Required crest heights are based on the design conditions discussed in Section 2. For the revetment structures there is no reference to any overtopping calculations specific to the structures. These would provide a better assessment of required crest heights and could incorporate a tolerable level of overtopping at the design water level. The report considers adaptation beyond the MT (50 year) epoch to increased sea level rise, which is achieved by raising the level of the concrete wall and revetment. For the LT (100 year) structure (Figure 5.5) this represents a retained height of 2.6m from the current ground level. Due to issues with restricting views, potential for water to seep under the structure and the increased consequence of failure this may not be practical. Raising ground levels on the landward side of the structure may address these issues.  Figure 5.5: Example drawing from report of long-term design for cantilever wall and rock revetment 1 (Appendix A)	November 2021	OK	21-03-2022	Y
5.6	**Cost estimate** – A detailed cost breakdown is provided which is considered reasonable, however the linear rate of $3000-$5000 is considered at the lower end of estimates for similar structures elsewhere in NZ especially considering the large increases in construction and material costs over recent years.	November 2021	OK	21-03-2022	Y
6	**Raising the Road**				
6.1	Raising of Pandora Road and replacement of the bridge have been considered by NCC whom provided rough order cost estimates for the work, which were included in the report. The report provides a breakdown of cost estimates provided by Napier City Council.	November 2021	OK	21-03-2022	Y
6.2	The report provides a range of elevation increases and associated costs, but there is little to support the adopted level of RL 13.4m, other than it is consistent with the proposed stopbank. An assessment of the likely frequency of inundation events and their severity would help understand the risks and when additional works would be required under the design sea level rise scenario. We note that the stopbank design includes the ability to raise the crest level which would be more difficult with the road/bridge.	November 2021	The level was chosen to be equal to the stopbank as this level includes reasonable conservatism. Options as flood barriers or raising the road could be included in the future if the level needs to be raised even higher.	21-03-2022	Y
6.3	No details of the design life of the works is apparent, which is a key consideration when looking at the affordability and option development. I.E. when would the raising of the road/bridge be required and when under the design SLR would it become obsolete. See sections	November 2021	Design life would be when the design parameters are exceeded. That's why using the conservative SLR scenario, a minimum of 50yr is expected, but it could be longer. Structures subject to corrosion are considered to have a lifetime		

			greater than 50 years. See sections called Long-term resilience, durability and adaptability for every type of structure.		
7	**Flood Barrier**				
7.1	A permanent flood barrier represents an adaptive response that would provide a level of protection against flooding during extreme events. Although less expensive than road/bridge raising options it does mean the road would be subject to periodic closure during storm events, the frequency of which would increase with sea level rise.	November 2021	OK	21-03-2022	Y
7.2	It is probable that a certain amount of nuisance flooding is considered tolerable as long as it is infrequent and does not cause any significant damage to property or assets. There are also other options such as temporary flood barriers (figure 7.2) that may be utilised in order to delay the requirement for larger capital expenditure, allow for a better understanding of sea level rise rates and time to develop a longer-term solution.  *Figure 7.2: Example of temporary flood barrier*	November 2021	OK	21-03-2022	Y
7.3	There is a physical limit on how much water can be retained by the barrier and an increased consequence of failure as flooding water depths increase should the structure fail. This may mean that raising of the road/bridge is still required within the strategy timeframe and that this should be included in the lifetime costs.	November 2021	OK	21-03-2022	Y
7.4	A more detailed analysis, using the design sea level rise scenario, of when the permanent structure would be required, how often the road is expected to be closed and if/when it would need to be replaced would allow for a more informed decision on the cost effectiveness of the approach compared to raising ground levels.	November 2021	OK	21-03-2022	Y
7.5	Cost estimates for construction and operation of the permanent barrier were provided by Napier City Council, based on a similar flood barrier (Criterion Bridge, Waikato), and are considered reasonable for the purpose of rough order costs.	November 2021	OK	21-03-2022	Y
8	**Stormwater Drainage**				
8.1	We agree that an upgrade to stormwater infrastructure is likely required to evacuate stormwater from inside the defences. Napier City Council provided a preliminary estimate of $3M - $10M for the works reflecting the high level of uncertainty	November 2021	OK	21-03-2022	Y
8.2	The report adopted a value of $7m for the works. It is probable that at least part of this cost would be required regardless of the strategy, so it may be prudent to exclude some costs from any cost benefit analysis or comparison with other options. We note the $7m figure also carries a great deal of uncertainty and makes up a large proportion of some of the option costs (e.g. >50% of option 1B). Although outside the scope of these works a better understanding of the true costs and how they would be distributed would allow for better decision making.	November 2021	OK	21-03-2022	Y
9	**Storm Surge Barrier**				
9.1	An alternative option of an inflatable tube storm surge barrier at the mouth of the estuary is proposed. This concept is based on the Ramspol barrier in the Netherlands. In theory a storm surge barrier would provide protection to the inner estuary during extreme events, however a lot of additional investigations and design work would be required in order to assess the feasibility of the design. This would include a detailed assessment of the seabed at the mouth of the estuary, sediment transport processes and the susceptibility of the barrier to seismic events. This option carries a risk of failure should the barrier fail to close, or fail, that may affect all exposed assets in the inner estuary that would be undefended without the operation of the barrier.	November 2021	OK	21-03-2022	Y
10	**Napier Sailing Club Upgrade**				
10.1	An upgrade to the sailing club is included as a cost item with a value of $27M. No breakdown of costs or further details are provided, but we assume this would include replacement of the current building, potentially raising land levels and other inundation mitigation measures. The costs for this may not be the responsibility of Napier City Council and without further details we are unable to comment on the proposals.	November 2021	OK	21-03-2022	Y
11	**Review Summary**				
11.1	The authors have developed a simple concept defined as a preferred option in the coastal strategy into a more detailed concept design considering site specifics and constraints for different areas and providing a range of solutions and options for the longer term. We	November 2021	OK	21-03-2022	Y

	acknowledge a lot of work has gone into the designs and costing exercise in order to provide more certainty on costs and the feasibility of options. We also recognise the limitations to the scope of work and that designs will be refined as part of detailed design if adopted.				
11.2	Additional work is likely required to define the design conditions which will dictate the timing of works and the crest levels of structures. Both of which will have a bearing on the whole life costs of the strategy. It may be beneficial to split the approach in to essential short to medium term options and those that would only be required in the long-term under a high SLR scenario, or may even only constitute 'nice to haves' (e.g. Deal with nuisance flooding under low probability events, that may be considered tolerable, an acceptable risk, or accommodated by other means)	November 2021	OK	21-03-2022	Y
11.3	Cost estimates for the stopbanks and walls are considered to have a high level of confidence, subject to the comments listed above. However, the 'big ticket items' that contribute the majority of the option costs, namely the raising of the road/bridge, upgrades to stormwater network, tidal barrier and sailing club upgrade, carry a high level of uncertainty and are unlikely to be accurate to within +/-30%. Development of these options would require a lot of additional work and it is considered prudent to defer this until a preferred option is adopted.	November 2021	OK	21-03-2022	Y
11.4	Deferring the large capital items for as long as possible improves the cost effectiveness of the strategy. Development of a timeline and triggers under different SLR scenarios, and investigations into the feasibility of using low cost options (temporary flood barriers, accepting some nuisance flooding and road closures less than once per year) is considered a worthwhile option to better inform a cost benefit analysis.	November 2021	OK	21-03-2022	Y
END OF COMMENT					