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Technical Note

Date: 4/5/2022

Client: Kingston District Council

Subject: Wyomi Beach – Seawall Alignment Review

1 Introduction

1.1. Background

In March 2021, Wavelength Consulting Pty Ltd (Wavelength) completed the Kingston Coastal Adaptation Strategy (CAS) for the coastline from Cape Jaffa to Blackford Drain (Figure 1). The CAS recommends specific priority adaptation pathways considering economic, environmental and community factors (Wavelength, 2021a).

A key recommendation of the CAS was to further assess the viability of a managed retreat pathway against a staged seawall (defend) approach to manage erosion risks in Section 4, Wyomi Beach (Figure 1). Investigations into the Wyomi Beach adaptation pathways was completed through 2021 (Wavelength, 2021b), which included an extensive community engagement program (KDC, 2021).

Based on community feedback, Kingston District Council (KDC) adopted the seawall (defend) approach in early 2022. Through the community engagement process, several residents raised concerns regarding the proposed seawall alignment and the potential impacts of a buried seawall on the established dune vegetation in the Wyomi area (KDC, 2021b).

KDC engaged Wavelength to develop seawall alignment options to present comparison of trade-offs, such as social, environmental and financial impacts. These preliminary seawall investigations are summarised in this Technical Note.

1.2. Objectives

The key objective of this study is to develop seawall alignments, including Order of Magnitude (OOM) costs and identified social and environmental impacts, for selection of a preferred seawall alignment.

1.3. Approach

The intent is for this Technical Note to be a standalone report providing technical background to the seawall alignments for community and stakeholder engagement and for grant funding applications.

This Technical Note is structured as follows:

- Section 2- Identification of coastal processes, structures and coastal management at Wyomi beach.
- Section 3 – Seawall extents, outlining the erosion risk to Wyomi and subsequent timing and triggers
- Section 0 - Staging and long-term costs for seawall alignments, including:
    - **Road Alignment** – Construct a seawall along the road alignment similar to the existing Stage 1 rock seawall.
    - **Protect all dune** – Construct a seawall on the seaward side of the dunes to maximise dune protection.
    - **Balanced alignment** – Construct a seawall to provide an approximate 20m buffer between the road and the rear of the seawall.
- Section 5 –Review of triple bottom line trade-offs of options

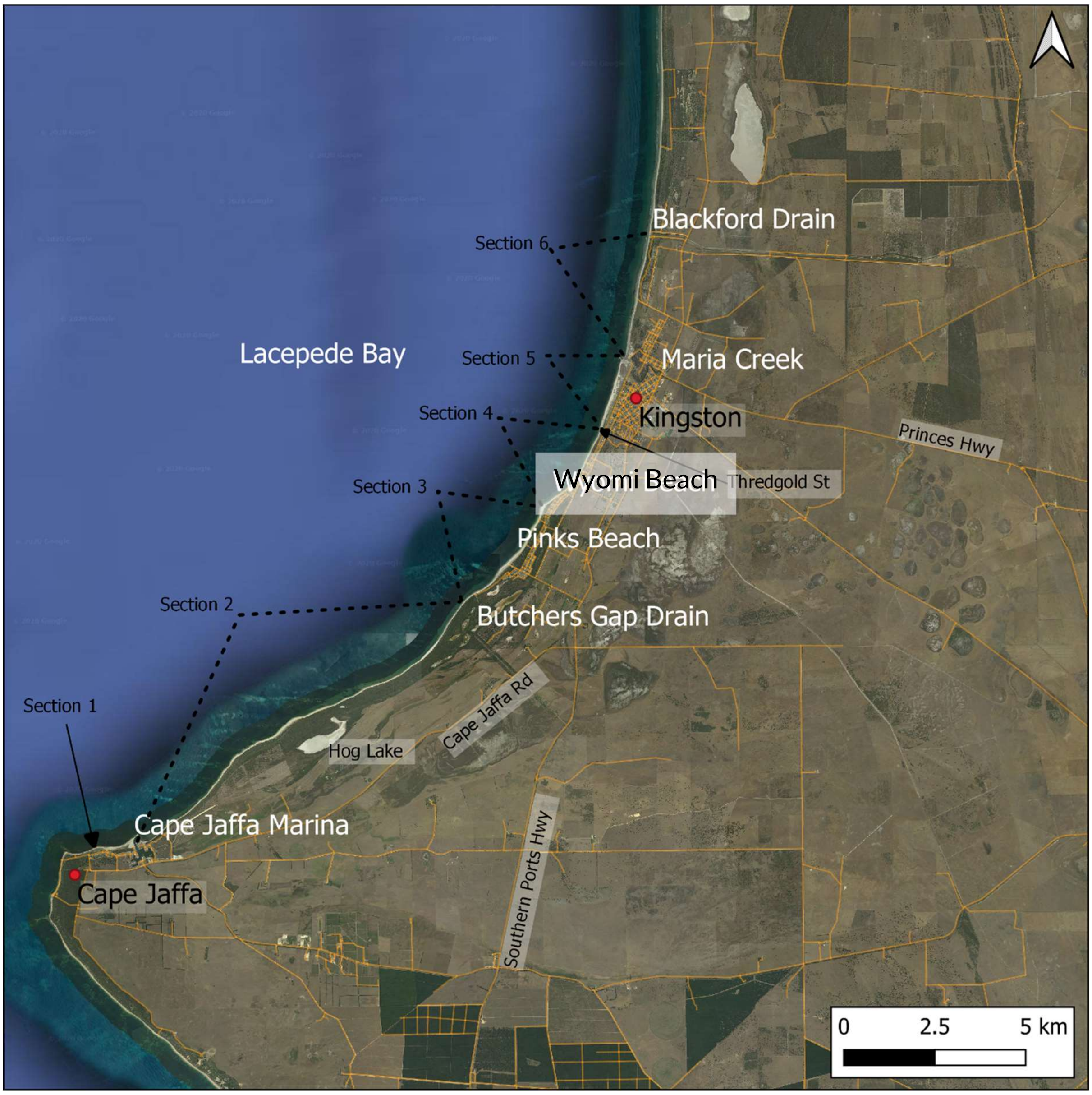

Figure 1: Kingston CAS Extent

2 Site Setting

2.1. Site Setting

Wyomi Beach is located approximately 2.5km south-west of the Kingston township (Section 4 on Figure 1). Over the last two decades ongoing erosion has resulted in the loss of approximately 10 to 15m of dune width, damaging paths and threatening Marine Parade.

Previous work by Wavelength and others suggest that Wyomi Beach is particularly sensitive to storm erosion, as outlined below:

- Sand moves from south to north along the coast in this area, with an estimated transport rate of 30,000 to 50,000 m^3 per year (Wavelength, 2020a), as shown in Figure 2. From March 2016 to October 2018, it was estimated that a total volume of approximately 100,000 m^3 was lost from the Wyomi Beach area, which is approximately 40,000 m^3 per year (Wavelength, 2020a).
- Analysis of the DEW beach profile 715008 (shown in Figure 2), shows the largest erosion recorded since 2005 was between March-2016 and May-2017, with approximately 10 to 15m of dune width lost (Wavelength, 2020b). Most of this erosion is likely to have occurred during a large storm event between 10th and 13th July 2016.
- Further analysis of the DEW profile suggests sand is lost at a rate of **approximately 15 m^3/m** per year with relatively few storms and **up to 45 m^3/m** per year with several large storms, such as 2016 (Wavelength, 2021c).
- Recent analysis of the Wyomi nourishment area by Flinders University (Coote et al, 2019) suggests that the longshore transport rate can increase by a factor of 27 during storm conditions. Therefore, 2 days of storm conditions may contribute up to 15% of the annual transport (Coote et al, 2019).

2.2. Existing Coastal Management

In recent years, KDC has constructed several seawall structures to protect assets at Wyomi Beach, including a 400m rock seawall (Stage 1) and two temporary Geotextile Sand Container (GSC) seawalls (refer Figure 2 and Table 1).

Whilst longer term adaptation pathways were being developed, nourishment was selected by KDC as the preferred short-term management approach at Wyomi Beach. Three nourishment campaigns have been completed in recent years:

- In May/June 2020, KDC placed approximately 13,000 m^3 nourishment to the north and south of the rock seawall.
- In May to July 2021, KDC placed approximately 11,000 m^3.
- In late April 2022, KDC placed approximately 11,000 m^3.

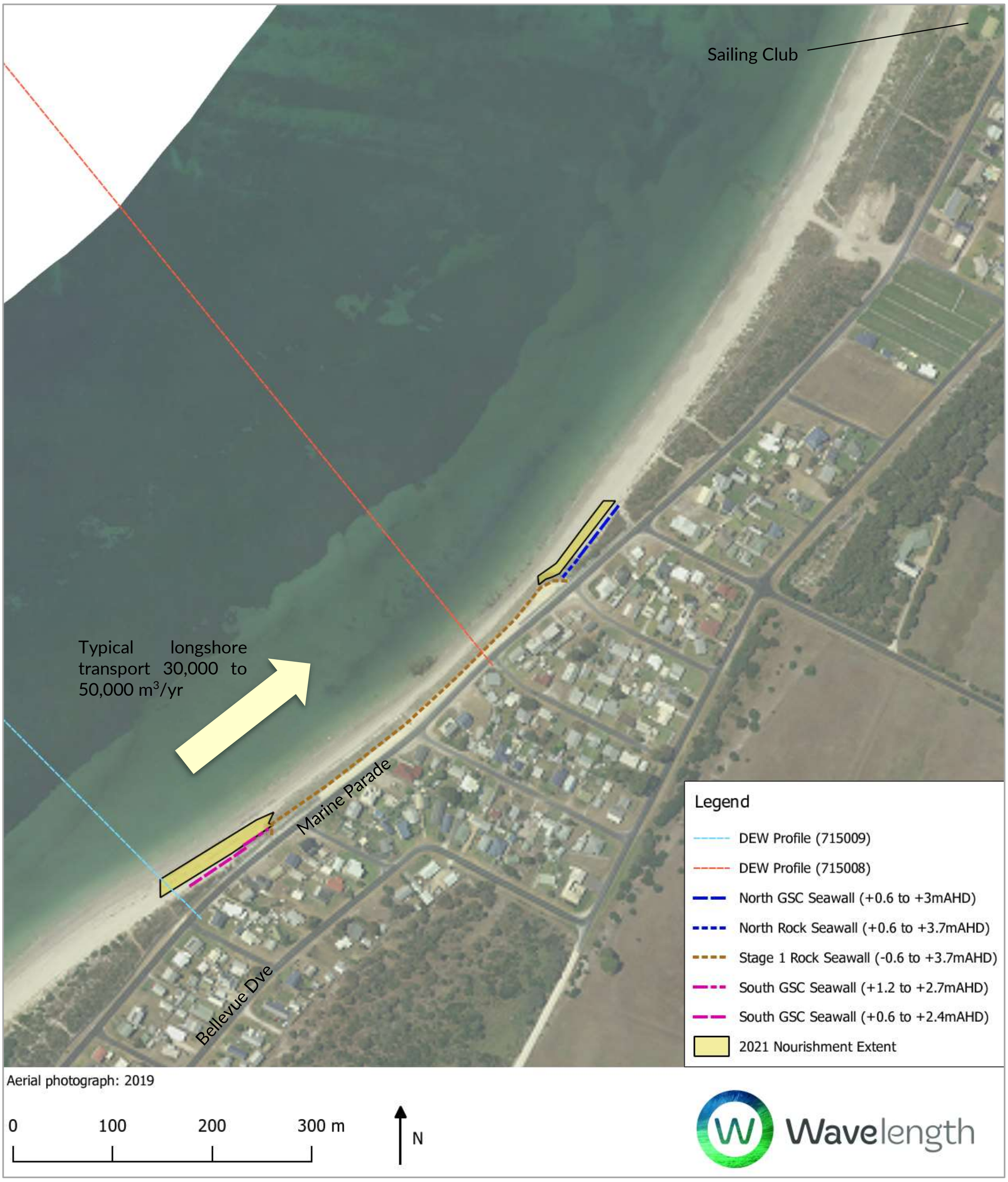

Figure 2: Wyomi area with coastal protection structures and nourishment

Table 1: Existing coastal protection structure details

Location	Structure Description	Date constructed	Approximate Length (m)
North	North 2.5m^3 GSC seawall	April 2019	72
	North ad hoc rock seawall	Mid 2018	22
Centre	Stage 1 rock seawall	April – May 2018	395
South	South 0.75m^3 GSC seawall	April 2019[1]	28
	South 2.5m^3 GSC seawall	April 2019	72

Notes: 1. Original 0.75m^3 GSC seawall constructed post July-2016 and upgraded with a top row of 2.5m^3 GSCs in April 2019.

3 Seawall extents

Development of the future seawall staging requires consideration of the timing and extent of the erosion hazard now and into the future. Seawall staging should therefore be planned in advance, such that sufficient time is given to the planning and implementation of future stages and so that assets are not exposed to an intolerable level of erosion risk.

3.1. Erosion risk

The *Kingston CAS Erosion and Inundation Mapping Technical Note* (Wavelength, 2021d) outlines the key inputs of the erosion hazard lines, identifying assets at risk for the present day, 2050 and 2100 planning horizons.

To provide a more detailed, site specific review of coastal erosion risk, intermediate hazard lines have also been developed for a 2030 and 2070 planning horizon.

The erosion allowances to develop the erosion hazard lines are summarised below:

- **S1 erosion allowance** – A present day storm erosion allowance of 16m based on SBEACH modelling presented in Wavelength (2021d).
- **S2 erosion allowance** – On-going erosion rate of approximately 1m/yr based on historical shoreline movements (Wavelength, 2021d).
- **S3 erosion allowance -** A bruun factor of 50 (BR50) was calculated based on beach profiles. This was applied to the following Sea Leve Rise (SLR) values.
    - 2030 = 0.1m SLR
    - 2050 = 0.3m SLR
    - 2070 = 0.6m SLR
    - 2100 = 1m SLR

These allowances have been combined for the five scenarios, giving the Possible Zone of Recession (ZR) presented in Table 2. The Possible ZR lines have been presented for the five scenarios in Figure 3.

The Possible ZR is not a prediction of the future shoreline recession, instead indicating a risk of erosion that is likely to be intolerable when the asset or property line is seaward of the hazard line.

Table 2: Summary of setback allowances

<table>
<tr><th rowspan="2">Scenarios</th><th colspan="4">Possible Zone of Recession (m)</th></tr>
<tr><th>S1</th><th>S2</th><th>S3</th><th>Total</th></tr>
<tr><td>Present Day</td><td rowspan="5">16</td><td colspan="2">-</td><td>16</td></tr>
<tr><td>2030</td><td>8</td><td>5</td><td>29</td></tr>
<tr><td>2050</td><td>30</td><td>15</td><td>61</td></tr>
<tr><td>2070</td><td>50</td><td>30</td><td>96</td></tr>
<tr><td>2100</td><td>80</td><td>50</td><td>146</td></tr>
</table>

Figure 3: Wyomi erosion hazard map

3.2. Staging timeframes

The previous section highlighted that the Wyomi shoreline is likely to continue to erode over the coming decades. The full extent and rate of the erosion is uncertain, particularly in the area of transition from the accreting shoreline at Pinks Beach to the eroding shoreline at Wyomi Beach.

Given much of the Wyomi shoreline is expected to continue to erode, future seawall stages should be proactively planned to provide adequate time between stages. For the purposes of this preliminary study, the following staging timeframes have been assumed:

- The Stage 2 seawall is constructed as soon as possible (i.e. 2023) and provides protection to assets over the 2030 Possible ZR line (Figure 3).
- Future stages beyond 2030 were assumed to be constructed approximately every 20 years, extending over the relevant risk extent (e.g. 2050 and 2070 Possible ZR lines in Figure 3) before the next stage is triggered (refer below).

3.3. Staging triggers

As the Wyomi shoreline continues to erode in the future, triggers are recommended to be used to pro-actively plan the future stages of the seawall. That is, when a trigger is reached, planning for the next seawall stage commences. This means that future stages would be constructed based on the actual erosion rates experienced (and triggers being reached) rather than based on the timeframe assumptions above.

For the purposes of this preliminary study, a trigger distance of approximately 16m between the vegetation line and the rear of the seawall crest has been used, as shown in Figure 4.

This trigger distance provides approximately 5 years for the seawall to be planned and implemented, with a correspondingly low risk of being exceeded in a storm event (i.e. ~5% chance of the 1% AEP storm event occurring over this time).

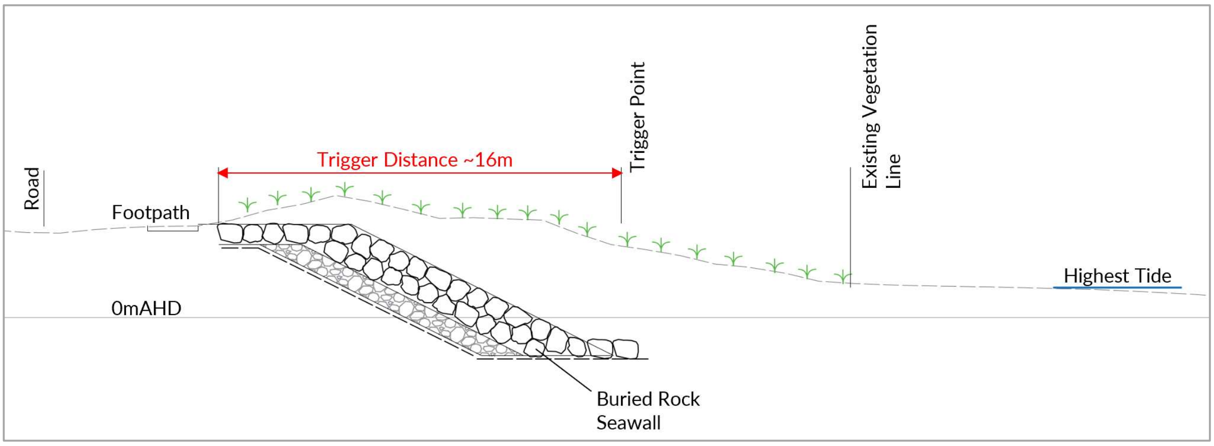

Figure 4: Seawall staging trigger example

Shoreline monitoring is required at both ends of the seawall to continually monitor the shoreline position against the trigger. Should the shoreline be eroding at a rate faster than the predicted or a significant increase in storminess is observed, the trigger distances can be re-assessed.

4 Seawall Alignments

4.1. Approach

The seawall alignments have been investigated as below:

1. Development of staging plans, including seawall staging lengths and alignments.
2. Preliminary design of seawall section used in analysis.
3. Calculation of Order of Magnitude capital and on-going costs.

Further detail on these steps is provided below.

4.2. Seawall Alignment Staging Plans

In conjunction with the erosion hazard lines (Figure 3) and timeframes and triggers set out in Section 3.2 and 3.3, three seawall alignments have been developed. Details of these alignments, their key objectives and assumptions are outlined below:

- **Road Alignment** (presented in Appendix A):
    - Description: The seawall alignment sits along the road, as landward as possible, similar to the existing Stage 1 rock seawall
    - Objective: Optimise for asset protection and to defer/delay construction as long as possible.
    - Assumptions:
        - Seawall would be buried under the dunes, resulting in significant excavations volumes and dune disturbance (refer Section 5.2 for details).
        - All existing GSC seawalls would be removed.
        - Smaller assets or assets at the end of their design life that can be readily relocated behind the seawall alignment, such as the footpath and Sailing Club, are assumed to be relocated (rather than the seawall protecting their current location).
- **Protect All Dunes Alignment** (presented in Appendix B):
    - Description: The seawall alignment sits on the seaward side of the existing dune scarp.
    - Objective: Optimise for dune protection.
    - Assumptions:
        - Assumes all dune vegetation is important and needs to be protected. Seawall would be built on the seaward side of the dunes from the present day and extend over the 2050 erosion extent.
        - GSC seawalls would be maintained.
        - The Sailing Club is outside the area of protection and is assumed to be relocated.
- **Balanced Alignment** (presented in Appendix C):
    - Description: The seawall alignment provides a 20m buffer between the road and rear crest of the seawall.
    - Objective: A balanced approach that optimises for protection of assets and some dune vegetation.
    - Assumptions:
        - This seawall alignment would be partly buried under the dunes at the northern and southern ends.

- Temporary seawall returns (i.e. extensions of the seawall perpendicular to the seawall alignment) have been included in the design. These returns are located on the unprotected ends of the seawall to provide additional protection against seawall end scour, covering the 2030 possible erosion extent.
- Approximately 1/3 of the GSC seawalls on both ends would require partial removal.
- Smaller assets or assets at the end of their design life that can be readily relocated behind the seawall alignment, such as the footpath and Sailing Club, are assumed to be relocated (rather than the seawall protecting their current location).

4.3. Seawall section

A preliminary Stage 2 seawall section has been developed for use in the cost estimates (Section 4.4), as presented in Figure 5 on the following page.

Key assumptions related to the design of the preliminary section are outlined below:

- The seawall was designed to the 1% Annual Exceedance Probability (AEP) design storm event.
- Assumes a design life of 30 years to 2050, including:
  - 0.3m sea level rise allowance, and
  - beach erosion of 45m (S2 + S3).
- The SBEACH model was used to calculate the design wave and water levels conditions, which are summarised in Appendix D.
- The SBEACH profile location was measured at Robert Ave (DEW profile 715009) shown on Figure 2.
- A rock armour size of 1.5t and slope of 1V:2H was calculated using the Van der Meer design formulae for shallow water conditions (CIRIA, 2007).
- Crest levels and widths were calculated using overtopping Equation 6.6 from the European Overtopping Manual (EurOtop, 2018), assuming a limiting overtopping rate of 50 L/s/m for unprotected promenade.
- Toe design:
  - The toe depth of -1.5 mAHD was calculated based on the maximum erosion depth modelled in SBEACH.
  - Lessons learnt from the Stage 1 seawall were incorporated into the toe design, including:
    - a deeper and narrower toe to reduce impacts on beach widths, and
    - no wrapping of the geotextile around the toe rocks, which tore in the Stage 1 seawall area.
- Figure 5 shows the Stage 2 section for the Balanced alignment at Robert Ave. This section has been applied to all seawall alignment options. Some reductions in rock size could be achieved in buried seawall segments, which would be confirmed in detailed design.

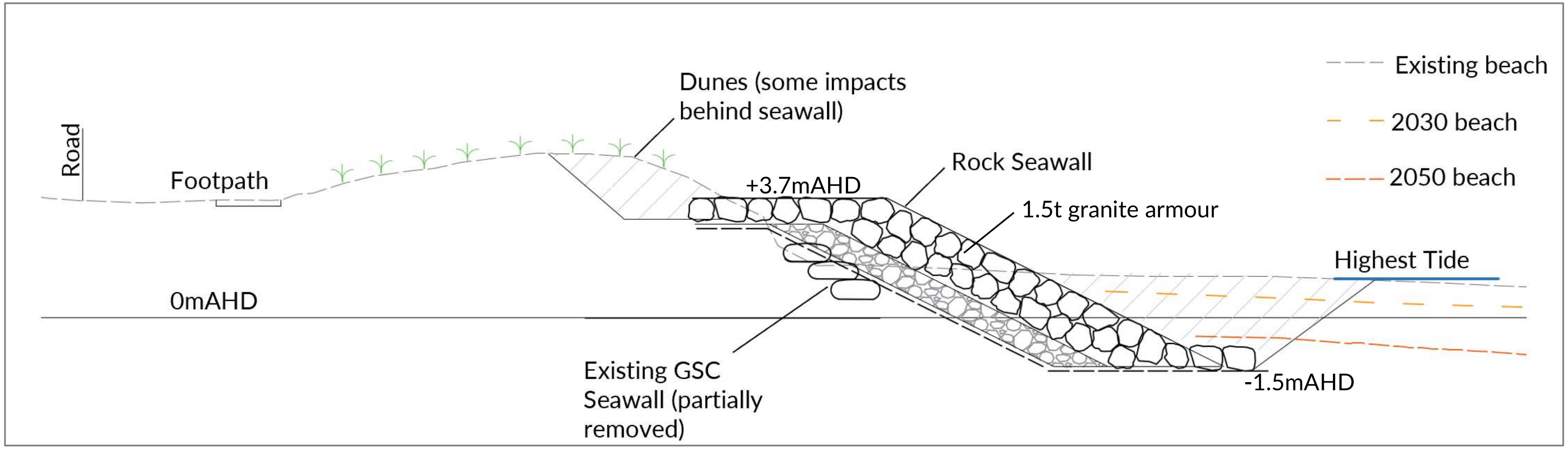

Figure 5: Preliminary Stage 2 seawall section

4.4. Net Present Value Calculations

Order of magnitude capital and recurrent maintenance cost estimates for the seawall alignments have been estimated. These costs are then taken as inputs to a Net Present Value (NPV) analysis. NPV analysis provides an indication of the relative costs of the pathways over time, considering capital and on-going costs.

Importantly in NPV analyses, costs that are incurred later, have a reduced value in present day dollars. Therefore, the above staging plans have attempted to optimise the NPV of each pathway, deferring costs until required.

The cost estimates presented are to be used as a guide only, detailed costings should be developed following selection of an option for detailed design and implementation. Key NPV assumptions related to each alignment are summarised in Section 4.4.1, with the full NPV cost breakdowns presented in Appendices E to G.

Table 3: Seawall Alignment NPV Results

	Alignment Option		
	Road Alignment	**Protect All Dunes**	**Balanced**
2023	$2,300,000	$5,700,000	$2,600,000
2030	$3,700,000	$5,800,000	$4,200,000
2050	$5,900,000	$7,400,000	$6,100,000

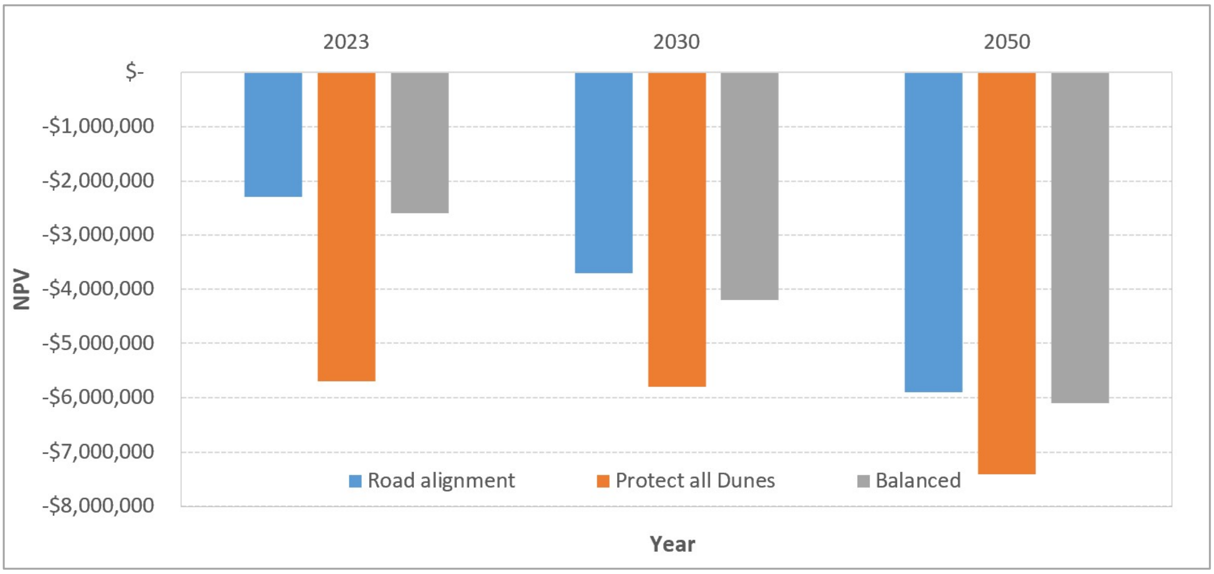

Figure 6: Seawall Alignment NPV Results

4.4.1. Staging and NPV Assumptions

NPV analysis:

- A discount rate of 5% was used in the NPV calculations.
- NPV calculations were prepared over a 30 year period to the end of the 2050 scenario. This provides protection to the 2070 erosion extent and provides an indication of the relative costs of the alignments over the longer term.
- Costings are based on 2022 value and costs. These costings are reflective of a point in time and given the timeframes for implementation are unknown, costings will need to be revised prior to commencing works.

Seawall Staging:

- The timing and description of the new seawall staging works, upgrades and repairs are presented in:
  - Table 4 for the Road and Balanced alignments, and
  - Table 5 for the Protect all Dunes alignment
- The seawall staging plans are presented in Appendix A to C, with the full seawall staging NPV analysis results presented in Appendices E to G.

Seawall armour size upgrades (next page):

- For sea level rise beyond 2050, wave conditions are expected to cause the existing 1.5t armour on the existing seawall to fail (CIRIA, 2017), requiring 4t armour to remain stable in the 1% AEP storm event.

Seawall repairs:

- Seawall repairs are required approximately every 20 years and are assumed to involve replacing ~5% and repositioning ~20% of the armour rocks.

Construction rates:

- Seawall construction costs, including upgrades and repairs, are based on recent supply and placement rates from a local contractor (pers comm. John Clarke 24/3/22). This contractor has recent local knowledge of the seawall construction costs, having constructed the Stage 1 rock seawall in 2018.
- Rates include recent increases in fuel prices.

Dune excavation and disturbance:

- Dune excavation volumes and dune disturbance areas were estimated based on the length of seawall anticipated to buried at the time of construction.
- The staging plans and erosion hazard lines were used to define buried segment lengths.
- A typical dune height of +4mAHD, excavation depth of -1.5 mAHD and excavation slope of 1V:1.5H was used to calculate excavation volumes and areas.

Table 4: Seawall Staging Summary – Road Alignment and Balanced Alignment

Indicative Timeframe	Description of Seawall Works		
	New Seawall Stage	**Upgrade**	**Repairs**
2023	Remove existing GSC seawalls and ad-hoc rock seawall as required & Construct **Stage 2 Seawall** 1.5t armour	-	-
2030	Construct **Stage 3 Seawall** 1.5t armour	-	Repair Stages 1 & 2
2050	Construct **Stage 4 Seawall** 1.5t armour	Upgrade armour Stages 1 to 3 4t armour	Repair Stages 1 to 3

Table 5: Seawall Staging Summary – Protect All Dunes Alignment

Indicative Timeframe	Description of Seawall Works		
	New Seawall Stage	**Upgrade**	**Repairs**
2023	Construct **Stage 2 Seawall** 1.5t armour	-	-
2030	-	-	Repair Stages 1 & 2
2050	-	Upgrade armour Stages 1 to 2 4t armour	Repair Stages 1 & 2

5 Triple bottom line

The three seawall alignments are expected to have different benefits and constraints. A high-level review of the triple bottom line has been undertaken considering the following factors:

1. Maintaining a beach for as long as possible.
2. Short and long-term impacts on the dune vegetation.
3. Flexibility of the alignment to future changes in coastal processes.
4. Construction and maintenance costs.

Key findings of the review are presented in Table 6, with further details provided in the following sections.

Table 6: Seawall Alignment Trade-offs

	Beach Impact	Long Term Dune Loss	Flexibility	$$ Cost Stage 2 (2023)
Road alignment	Low	High	High	$2.3M
Protect all dunes	High	Low	Low	$5.7M
Balanced (20m buffer)	Moderate	Moderate	Moderate	$2.6M

5.1. Beach Impact

The Wyomi shoreline has a long history of erosion, which is expected to increase over time with future sea level rise. Given this on-going erosion, most of the beach in front of the Wyomi seawall is expected to be lost over time.

On an eroding coastline, such as Wyomi, seawalls have several impacts on the coastal processes, as described below:

- Seawalls trap dune sand behind the seawall, which is then unavailable to feed onto the beach during storm events. This leads to a cross shore sediment deficit leading to erosion in front of the seawall. This can also lead to end scour when a longshore transport deficit is formed between the seawall and adjacent shoreline.
- Seawalls increase wave reflections, pushing beach sand offshore and eroding the beach face. When waves approach from an angle, wave reflections can also lead to increased longshore currents moving along the seawall face.
- With sea level rise, less beach width will be available, as the beach is inundated more frequently (a different process from erosion).

The eventual loss of the beaches in front of the seawall was identified as a significant impact during the Wyomi long term adaptation pathways investigations and discussed at length with the community and KDC during the community engagement.

The seawall alignments presented in this report will not prevent the beach from eroding. However, they can be set back from the coastline to minimise the impacts on the beach and maintain a beach for as long as possible. Therefore, alignments that are buried or set back from the beach (proposed Road and Balanced alignment), have less impact on the coastal processes and a lower beach impact. Alignments built directly on the erosion scarp (Protect All Dunes alignment), in front of the dune, are expected to have an impact on the coastal processes from the outset and have a higher beach impact.

5.2. Dune Impact

Dunes are an important coastal habitat and are highly valued by Wyomi residents. Unfortunately, it's not possible to construct a seawall without having some form of impact on the dune vegetation.

The dune impact can be short term or long term, as described below:

- Short term impacts:
  - During seawall construction, some form of dune disturbance is required to gain construction access and to tie the seawall into the natural levels.
  - Short term disturbance has the potential to create wind blown sand issues, which has historically been a problem at Wyomi when dunes have been disturbed.
  - Alignments with a smaller dune disturbance area have an advantage over alignments with a larger disturbance area.
  - The estimated dune disturbance for the 3 seawall alignment options are summarised in Table 7.
- Long term impacts:
  - On an eroding coastline, such as Wyomi, dunes seaward of the seawall will be lost over time.
  - The further seaward a seawall is constructed, the more dune vegetation is protected, however, this comes with faster beach loss (refer Section 5.1).
  - It's important to note that the dune vegetation protected behind a seawall may degrade over time and will not be a fully 'natural' system. The dunes behind the seawall will no longer be fed by wind-blown sand processes, which may lead to a change in the dune habitat towards species that prefer less wind-blown sand.

Table 7: Short Term Dune Disturbance

	Alignment Option Disturbance Area (m^2)		
	Road Alignment	**Protect All Dunes**	**Balanced**
2023	4,000	3,400	3,400
2030	3,800	-	2,900
2050	6,500	-	2,400
Total	**14,300**	**3,400**	**8,700**

5.3. Flexibility

The Wyomi shoreline is complex, particularly the transition area between the accreting coastline at Pinks Beach and the eroding coastline at Wyomi. It's uncertain how the future shoreline will evolve in response to sea level rise, so flexibility is an important consideration for the seawall alignments.

As outlined in Section 5.1, a buried seawall, set back from the beach, has less of an impact on coastal processes. On an eroding coast, this provides more time for coastal processes to continue naturally before the next seawall stage is triggered for planning. This means alignments set further from the coast are considered a more flexible option.

On the other hand, a seawall that is built in front of the erosion scarp, essentially draws a line in the sand, interfering with coastal processes from the outset. This pre-empts future erosion rates, offering less time before the next stage is triggered for construction. This would be considered a less flexible approach.

6 Key Findings and Recommendation

Wyomi has experienced significant coastal erosion, which is expected to continue with multiple assets at risk of erosion to 2100. A seawall adaptation pathway has been selected to mitigate this risk over the longer term.

Given feedback related to dune disturbance that was received during community engagement, the costs and benefits of three seawall alignments have been considered. These three alignments include:

- Road alignment, which optimizes for protection of assets and defers construction as long as possible.
- Protect all dunes alignment, which optimises for protection of existing dune vegetation.
- Balanced alignment, which seeks a balance between the options, offering an approximate 20m dune buffer between the road and the rear crest of the seawall.

Key findings

- Road alignment:
  - The road alignment has the lowest cost, is the most flexible and has the lowest short term impact on the beach.
  - This option would result in the eventual loss of a significant area of dune and would also disturb the largest amount of dune vegetation during seawall construction, a significant construction risk given the history of wind blown sand in the area.
- Protect all dunes alignment:
  - This alignment has the highest cost, is the least flexible and would reduce beach widths from the outset.
  - It does protect a large amount of dune buffer over the long term, however, given the high costs and impacts, this alignment is not recommended.
- Balanced alignment:
  - The balanced alignment falls between the two options.
  - For only a slight increase in financial costs ($0.2M to 2050), the balanced alignment maintains some dune vegetation and has a moderate short term disturbance area.
  - Given the ends of the seawall would be buried, this option has a moderate short term impact on the beach width and provides some planning flexibility.

Recommendation

Given benefits and constraints outlined above, it is recommended that Council consider progressing with the Balanced seawall alignment for stakeholder engagement, approvals and grant funding applications.

7 References

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Appendix A Road Alignment Seawall Staging Plan

Appendix B Protect All Dune Areas Staging Plan

Appendix C Balanced Seawall Staging Plan

Appendix D – Design Storm Conditions

Model Parameter	Value	Justification
Storm duration	72hrs	Based on the results of the analysis of the Cape de Couedic wave buoys (approx. 300km from Kingston) the median storm duration was found to be 43hrs (Shand et al., 2011). A 2016 storm event which caused significant erosion at Wyomi Beach (Wavelength, 2020b) had a longer duration of around 72 hours. This event consisted of two storm fronts. The extended duration of elevated water levels for this event is thought to be significant factor in the erosion that was observed.
100yr ARI wave height	1.65m	Analysis of recent modelling of wave conditions in Lacepede Bay (*Maria Creek Sustainable Infrastructure Project – Conceptual Understanding Technical Note*) estimated the 100 year ARI wave height at Maria Creek to be 1.65m. This has been applied across the study area. These 100yr ARI design wave heights were applied continually for the duration of the SBEACH model runs.
100yr ARI wave period	15s	Analysis of wave modelling results in Lacepede Bay (Wavelength, 2020a) found that wave periods are typically in the range of 5 to 20s with a mean of 13 second. The 2016 storm event had a peak wave period of 14.4s with a peak wave height of 1.65m. Therefore, conservatively for this analysis a 100 year wave period of 15s has been adopted.
Wave angle	Shore normal	Conservative approach for modelling storm erosion in SBEACH.
100yr ARI water level	100yr ARI water level = 1.6m AHD	A 100 year ARI water level estimate of +1.6m AHD at Kingston was calculated by the Coast Protection Board in 1993. The 2016 storm event was disaggregated into tide and tidal anomaly, with the tidal anomaly then factored and added back to the tidal signal so that the peak water levels corresponded with a 100yr ARI water level. This is considered a conservative but not unreasonable estimate of conditions given low pressure systems are responsible for large waves, strong winds and storm surges (Shand et al, 2013).
Sea Level Rise	0.3m to 2050	Applied to steady water level above. Sea level rise value as per Coast Protection Board recommendation for planning in SA.

Appendix E Road Alignment Seawall NPV Results

				Capital Costs				Seawall Upgrades			Seawall Maintenance			Asset Removal & Replacement			Net Present Value			
Years from Present	Year	Discount Factor	Seawall Stage	Item	Length exposed (m)	Length buried (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Capital	Upgrades	Mtce	Path removal
	2018		1	Stage 1 seawall constructed	395															
	2019																			
	2020																			
	2021	1.00000															$ -	$ -	$ -	$ -
0	2022	1.00000															$ -	$ -	$ -	$ -
1	2023	0.95238	2	Remove existing GSC seawalls and ad-hoc rock seawall & construct Stage 2 Seawall (north 110m, south 160m) - 1.5t armour	120	160	$ 2,278,571										$ 2,170,067	$ -	$ -	$ -
2	2024	0.90703															$ -	$ -	$ -	$ -
3	2025	0.86384															$ -	$ -	$ -	$ -
4	2026	0.82270															$ -	$ -	$ -	$ -
5	2027	0.78353															$ -	$ -	$ -	$ -
6	2028	0.74622															$ -	$ -	$ -	$ -
7	2029	0.71068															$ -	$ -	$ -	$ -
8	2030	0.67684	3	Construct Stage 3 Seawall (north 120m, south 100m) - 1.5t armour	0	225	$ 1,952,395				Repair Stages 1 & 2	675	$ 337,500				$ 1,321,458	$ -	$ 228,433	$ -
9	2031	0.64461															$ -	$ -	$ -	$ -
10	2032	0.61391															$ -	$ -	$ -	$ -
11	2033	0.58468															$ -	$ -	$ -	$ -
12	2034	0.55684															$ -	$ -	$ -	$ -
13	2035	0.53032															$ -	$ -	$ -	$ -
14	2036	0.50507															$ -	$ -	$ -	$ -
15	2037	0.48102															$ -	$ -	$ -	$ -
16	2038	0.45811															$ -	$ -	$ -	$ -
17	2039	0.43630															$ -	$ -	$ -	$ -
18	2040	0.41552															$ -	$ -	$ -	$ -
19	2041	0.39573															$ -	$ -	$ -	$ -
20	2042	0.37689															$ -	$ -	$ -	$ -
21	2043	0.35894															$ -	$ -	$ -	$ -
22	2044	0.34185															$ -	$ -	$ -	$ -
23	2045	0.32557															$ -	$ -	$ -	$ -
24	2046	0.31007															$ -	$ -	$ -	$ -
25	2047	0.29530															$ -	$ -	$ -	$ -
26	2048	0.28124												Sailing Club Removal		$ 178,000	$ -	$ -	$ -	$ 50,061
27	2049	0.26785															$ -	$ -	$ -	$ -
28	2050	0.25509	4	Construct Stage 4 Seawall (north 140m, south 180m) - 1.5t armour	0	325	$ 3,869,220	Upgrade armour to 4t Stages 1 to 3	900	$ 3,960,000	Repair Stages 1 to 3	900	$ 450,000	Path removal and replacement	330	$ 52,008	$ 987,013	$ 1,010,171	$ 114,792	$ 13,267
29																				
							$ 8,100,185			**$ 3,960,000**			**$ 787,500**			**$ 230,008**	**$ 4,478,539**	**$ 1,010,171**	**$ 343,225**	**$ 63,328**
																	$			**5,895,263**

Appendix G Protect All Dunes Seawall NPV Results

				Capital Costs				Seawall Upgrades			Seawall Maintenance			Asset Removal & Replacement			Net Present Value			
Years from Present	Year	Discount Factor	Seawall Stage	Item	Length exposed (m)	Length buried (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Capital	Upgrades	Mtce	Path removal
	2018		1	Stage 1 seawall constructed	395															
	2019																			
	2020																			
	2021	1.00000															$ -	$ -	$ -	$ -
0	2022	1.00000															$ -	$ -	$ -	$ -
1	2023	0.95238	2	Construct Stage 2 Seawall (north 390m, south 450m) - 1.5t armour	840	5	$ 5,658,352										$ 5,388,907	$ -	$ -	$ -
2	2024	0.90703															$ -	$ -	$ -	$ -
3	2025	0.86384															$ -	$ -	$ -	$ -
4	2026	0.82270															$ -	$ -	$ -	$ -
5	2027	0.78353															$ -	$ -	$ -	$ -
6	2028	0.74622															$ -	$ -	$ -	$ -
7	2029	0.71068															$ -	$ -	$ -	$ -
8	2030	0.67684									Repair Stages 1 & 2	1235	$ 617,500				$ -	$ -	$ 417,948	$ -
9	2031	0.64461															$ -	$ -	$ -	$ -
10	2032	0.61391															$ -	$ -	$ -	$ -
11	2033	0.58468															$ -	$ -	$ -	$ -
12	2034	0.55684															$ -	$ -	$ -	$ -
13	2035	0.53032															$ -	$ -	$ -	$ -
14	2036	0.50507															$ -	$ -	$ -	$ -
15	2037	0.48102															$ -	$ -	$ -	$ -
16	2038	0.45811															$ -	$ -	$ -	$ -
17	2039	0.43630															$ -	$ -	$ -	$ -
18	2040	0.41552															$ -	$ -	$ -	$ -
19	2041	0.39573															$ -	$ -	$ -	$ -
20	2042	0.37689															$ -	$ -	$ -	$ -
21	2043	0.35894															$ -	$ -	$ -	$ -
22	2044	0.34185															$ -	$ -	$ -	$ -
23	2045	0.32557															$ -	$ -	$ -	$ -
24	2046	0.31007															$ -	$ -	$ -	$ -
25	2047	0.29530															$ -	$ -	$ -	$ -
26	2048	0.28124												Sailing Club Removal		$ 178,000	$ -	$ -	$ -	$ 50,061
27	2049	0.26785															$ -	$ -	$ -	$ -
28	2050	0.25509						Upgrade armour to 4t Stages 1 to 2	1235	$ 5,434,000	Repair Stages 1 to 2	1235	$ 617,500				$ -	$ 1,386,179	$ 157,520	$ -
							$ 5,658,352			**$ 5,434,000**			**$ 1,235,000**			**$ 178,000**	**$ 5,388,907**	**$ 1,386,179**	**$ 575,469**	**$ 50,061**
																	$			**7,400,615**

Appendix H Balanced Seawall NPV Results

Years from Present	Year	Discount Factor	Seawall Stage	Capital Costs				Seawall Upgrades			Seawall Maintenance			Asset Removal & Replacement			Net Present Value			
				Item	Length exposed (m)	Length buried (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Item	Length (m)	Nominal Cash Flow	Capital	Upgrades	Mtce	Path removal
	2018		1	Stage 1 seawall constructed	395															
	2019																			
	2020																			
	2021																$ -	$ -	$ -	$ -
0	2022	1.00000															$ -	$ -	$ -	$ -
1	2023	0.95238	2	Partial removal of existing GSC seawalls and ad-hoc rock seawall & construct Stage 2 Seawall (north 110m, south 160m) - 1.5t armour	210	135	$ 2,605,703										$ 2,481,622	$ -	$ -	$ -
2	2024	0.90703															$ -	$ -	$ -	$ -
3	2025	0.86384															$ -	$ -	$ -	$ -
4	2026	0.82270															$ -	$ -	$ -	$ -
5	2027	0.78353															$ -	$ -	$ -	$ -
6	2028	0.74622															$ -	$ -	$ -	$ -
7	2029	0.71068															$ -	$ -	$ -	$ -
8	2030	0.67684	3	Construct Stage 3 Seawall (north 120m, south 100m) - 1.5t armour	0	170	$ 2,234,520				Repair Stages 1 & 2	740	$ 370,000				$ 1,512,411	$ -	$ 250,431	$ -
9	2031	0.64461															$ -	$ -	$ -	$ -
10	2032	0.61391															$ -	$ -	$ -	$ -
11	2033	0.58468															$ -	$ -	$ -	$ -
12	2034	0.55684															$ -	$ -	$ -	$ -
13	2035	0.53032															$ -	$ -	$ -	$ -
14	2036	0.50507															$ -	$ -	$ -	$ -
15	2037	0.48102															$ -	$ -	$ -	$ -
16	2038	0.45811															$ -	$ -	$ -	$ -
17	2039	0.43630															$ -	$ -	$ -	$ -
18	2040	0.41552															$ -	$ -	$ -	$ -
19	2041	0.39573															$ -	$ -	$ -	$ -
20	2042	0.37689															$ -	$ -	$ -	$ -
21	2043	0.35894															$ -	$ -	$ -	$ -
22	2044	0.34185															$ -	$ -	$ -	$ -
23	2045	0.32557															$ -	$ -	$ -	$ -
24	2046	0.31007															$ -	$ -	$ -	$ -
25	2047	0.29530															$ -	$ -	$ -	$ -
26	2048	0.28124												Sailing Club Removal		$ 178,000	$ -	$ -	$ -	$ 50,061
27	2049	0.26785															$ -	$ -	$ -	$ -
28	2050	0.25509	4	Construct Stage 4 Seawall (north 140m, south 180m) - 1.5t armour	0	120	$ 2,732,874	Upgrade armour to 4t Stages 1 to 3	910	$ 4,004,000	Repair Stages 1 to 3	910	$ 455,000	Path removal and replacement	330	$ 52,008	$ 697,139	$ 1,021,395	$ 116,068	$ 13,267
							$ 7,573,097			**$ 4,004,000**			**$ 825,000**			**$ 230,008**	**$ 4,691,172**	**$ 1,021,395**	**$ 366,498**	**$ 63,328**
																	$			**6,142,393**