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Climate Change Asset Vulnerability Assessment

Case study: Mornington Peninsula Shire

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A Marsden Jacob Report

Prepared for South East Councils Climate Change Alliance
Marsden Jacob Associates Pty Ltd
ABN 66 663 324 657
ACN 072 233 204

e. economists@marsdenjacob.com.au
t. 03 8808 7400

Office locations
Melbourne
Perth
Sydney
Brisbane
Adelaide

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Authors

Nadja Arold	Principal
Peter Kinrade	Associate Director
Amy Rogers	Senior Consultant

LinkedIn - Marsden Jacob Associates
www.marsdenjacob.com.au

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Contents

Executive Summary

Introduction

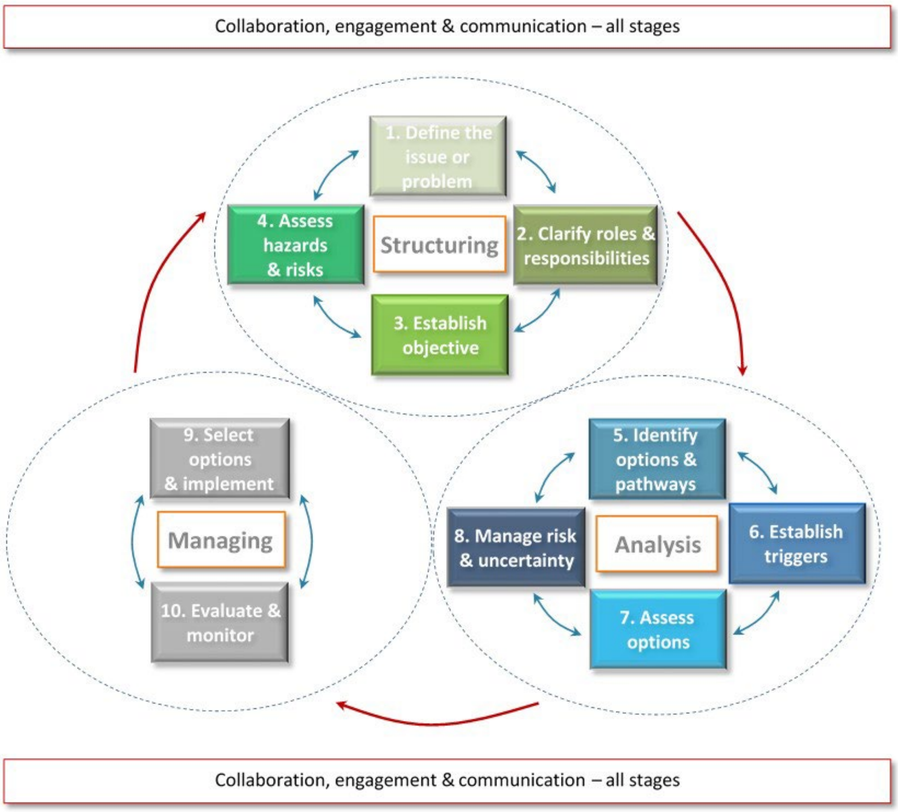
SECCCA member councils aim to better understand how their buildings, roads, drainage, and other assets will be impacted by climate change and associated extreme weather events. The *Climate Change Asset Vulnerability Assessment* project seeks to provide councils with this information. The case study phase of the project focusses on the financial and economic implications of climate change impacts on council assets and planning for those impacts.

This case study will assess options for mitigating or reducing flood damages in residential and commercial areas of Rosebud due to back-up of water at the Sixth Avenue stormwater outfall and connected drains and pits.

Climate change adaptation decision making

A sound decision-making process provides the foundation for effective climate change adaptation. Figure ES 1 identifies the key stages and steps comprising 'good practice' adaptation decision making.

Figure ES 1: Stages in the decision-making process



Working with the Mornington Peninsula Shire in a series of workshops, we have undertaken preliminary analysis relating to Steps 1 through 8 in that process, however the primary focus of our analysis has been on options assessment (Step 7).

Analysis of short term option

The options analysis focusses on two short-term options:

- **Option 1 – dune infiltration system:** This system divert and treat stormwater naturally through the sand dunes. The system will divert stormwater from the existing stormwater outfall through a series of pipes and basins to the sand dunes.
- **Option 2 – duckbill check valve:** A rubber check valve would be fitted to the end of the existing stormwater outfall. The valve opens to allow stormwater out during high flows, but closes over when water is not coming out of the pipe. It thereby prevents blockages of the pipe through incoming sand.

Cost-benefit analysis (CBA) is a method that compares monetary costs and benefits associated with each option. The scope of CBA is on social costs and benefits as opposed to the private cost and benefits assessed in a financial evaluation. This scope makes it well suited to measuring adaptation options from a community perspective, as will often be the basis for decision-making by councils. For our analysis, we assessed Option 1 and 2 against a business as usual (base case) option. The Business as Usual (BaU) option assumes that Council will continue with its preventative maintenance regime.

For the analysis, we quantified the damage costs of flooding by applying the Victorian Flood Rapid Assessment Model (RAM) to quantify flood damage costs to residential and commercial properties and roads, based on numbers of properties and lengths of roads impacted for different flood depths and flood return periods. Outcomes from our application of the RAM model to standing water flood depth and return period data1 produced an expected cost of flood damages of just over $4 million NPV over the next 50 years.

Although we were able to quantify the flood damages under BaU, we do not know precisely how implementation of either Option 1 or Option 2 will impact flood levels and associated damages under different recurrence intervals. Further flood modelling is required to assess these outcomes. For this reason, we applied a modified version of CBA for the analysis, referred to as threshold analysis. The threshold analysis was applied to test the question – “*By how much will the flood damages under Option 1 (dune infiltration system) or Option 2 (check valve) need to decrease below the flood damages incurred under BaU in order to justify the additional costs of Option 1 or Option 2 - that is, achieve a net positive NPV*?”

Results of the analysis are presented in Table ES 1 and Table ES 2.

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[1] Purchased by Mornington Peninsula Shire Council from JBA

Table ES 1: Threshold analysis (in $’000 over 50 years)

	Business as Usual	Option 1 Dune infiltration	Option 2 Check Valve
Costs			
Operation and Maintenance Cost	43	207	43
Capital Costs	-	518	102
PV Costs	**43**	**725**	**145**
Flood Damages (threshold test min. value)	4,006	3,323	3,904
PV	**4,049**	**4,048**	**4,049**

Marsden Jacob Analysis

Table ES 2: Threshold analysis – incremental results (in $’000 over 50 years)

	Option 1 Dune infiltration	Option 2 Check Valve
Costs		
Operation and Maintenance Cost	164	-
Capital Costs	518	102
PV Costs	**682**	**102**
Benefits (Avoided Cost)		
Avoided Flood Damages (threshold value)	683	102
PV Benefits	**683**	**102**
NPV	1	0

Marsden Jacob Analysis

The information in the tables reveal that investing in Option 1 would need to reduce flood damage costs by $683,000 NPV over 50 years, i.e. by 17.1% below BaU flood damage costs to justify that investment. Investing in Option 2 would need to reduce flood damage costs by $102,000 NPV over 50 years, i.e. by 2.6% below BaU flood damage costs to justify that investment. Either of these outcomes would appear to be realistic. Furthermore, the results presented here are likely to be conservative, with flood damage cost estimates under BaU likely to be understated because the flood modelling on which they are based does not reflect the latest climate change projections or capture the combined effects of overland flooding and coastal inundation.

Conclusions and next steps

Overall, results of the analysis indicate that there is a prima facie case for implementing either Option 1 or Option 2. This case, of course, rests on the supposition that implementing either of the options will decrease the flood damages to residential and commercial properties and roads by at least 17.1% (Option 1) or 2.6% (Option 2) compared to the flood damage costs estimate under BaU. The case is bolstered by the fact that the flood modelling data, upon which the flood damage analysis for this case study draws, almost certainly understates the impacts of overland flooding on the study area.

Notwithstanding the prima facie case for implementing the either option, further analysis could be warranted before decisions are made on implementation. That analysis should seek to draw on the latest coastal inundation and flood modelling analysis currently being undertaken by CSIRO for DELWP.

1. Introduction

SECCCA member councils aim to better understand how their buildings, roads, drainage, and other assets will be impacted by climate change and associated extreme weather events. The *Climate Change Asset Vulnerability Assessment* project seeks to provide councils with this information. The project also aims to help councils understand the potential risks to the community of anticipated climate change and how climate change is likely to impact the delivery of community services.

The case study phase of the project focusses on the financial and economic[2] implications of climate change impacts on council assets and planning for those impacts. The purpose of the case studies is to:

- provide a focus for efforts to achieve a more detailed vulnerability assessment, analysis of adaptation options and hence the provision of a more in-depth set of outcomes;
- provide the basis of mentoring sessions that aim to develop council capability in planning for anticipated climate change and assessing adaptation options; and
- provide practical exemplars for future reference by councils when undertaking assessments of adaptation options.

To these ends, the case studies will:

- step through the process with practical and relevant examples, and
- package up the process so that it can be reapplied and is translatable.

This case study will assess options for mitigating or reducing flood damages in residential and commercial areas of Rosebud due to back-up of water at the Sixth Avenue stormwater outfall and connected drains and pits.

We emphasize that this case study presents a preliminary assessment of short-term adaptation options and, as such, provides guidance on the potential direction of future adaptation. Decisions on short and longer-term adaptation options may need to be accompanied by more detailed analysis at different stages of the decision-making process, which are discussed in the following section.

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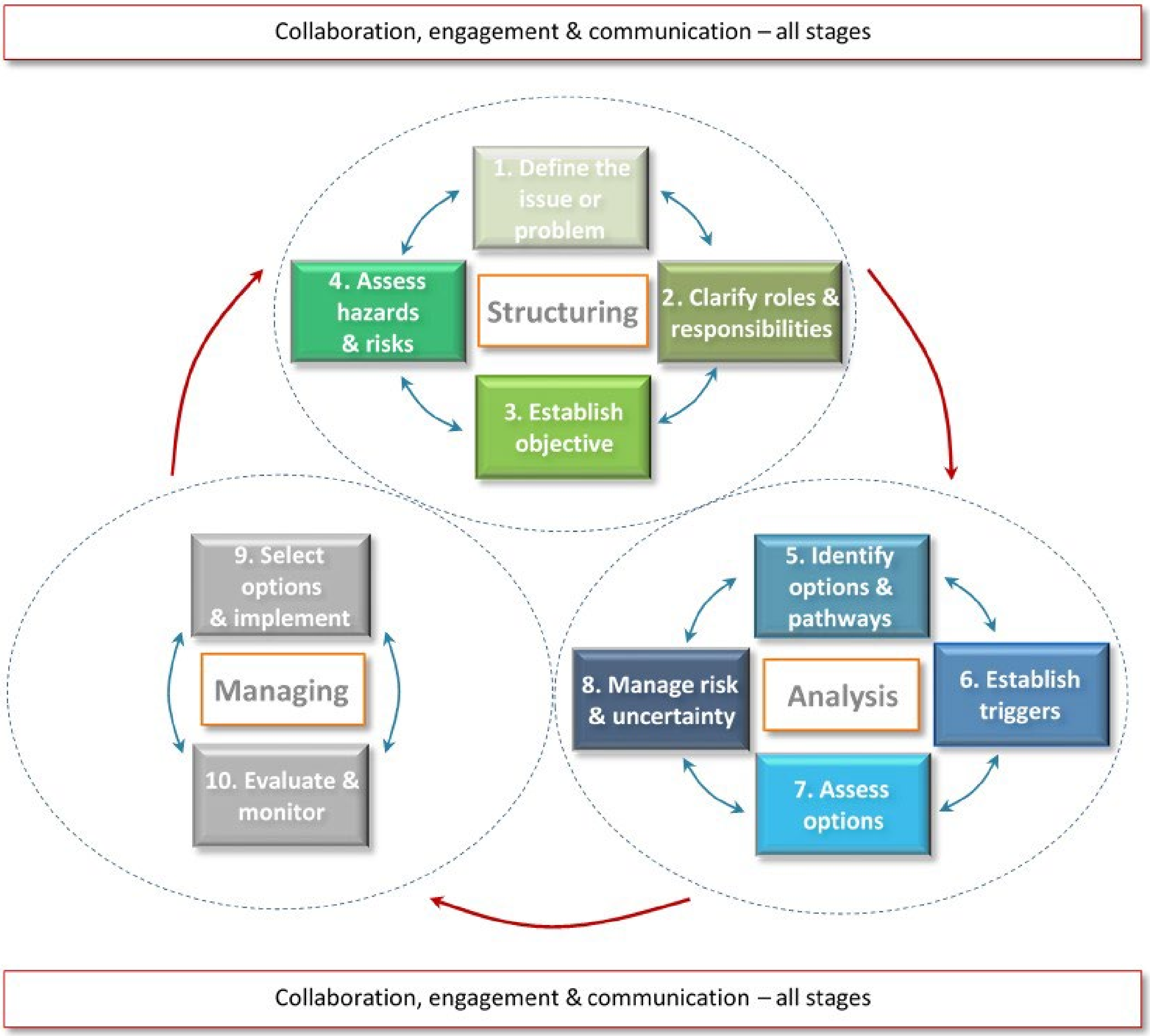
[2] Financial analysis is focused on the direct financial implications of climate change and adaptation options for Council. Economic analysis considers the financial implications plus the direct and indirect implications for the broader community.

2. Climate change adaptation decision-making process

A sound decision-making process provides the foundation for effective climate change adaptation. Figure 1 identifies the key stages and steps comprising 'good practice' adaptation decision making. Working with the City of Port Phillip in a series of workshops, we have undertaken some preliminary analysis relating to Steps 1 through 8 in that process, however the primary focus of our analysis has been on assessing the short-term adaptation options (Step 7) and consideration of uncertainties in the analysis (Step 8). Steps 1 to 6 are discussed briefly in this section, with more detailed discussion of Steps 7 and 8 provided in the following section.

Figure 1: Stages in the decision-making process



Source: Marsden Jacob Associates

2.1 Statement of the problem

Residential and commercial areas of Rosebud can be subject to flooding due to back-up of water at the Sixth Avenue stormwater outfall and connected drains and pits.

These flood events are often linked to a combination of extreme rainfall as well as high tides and storm surges. Flooding occurs during extreme rainfall events when there is a backup of stormwater in the Sixth Avenue outfall and connected drains and pits. Backup occurs when the outfall is under water during high tides and/or there are pipe blockages due to sand movement.

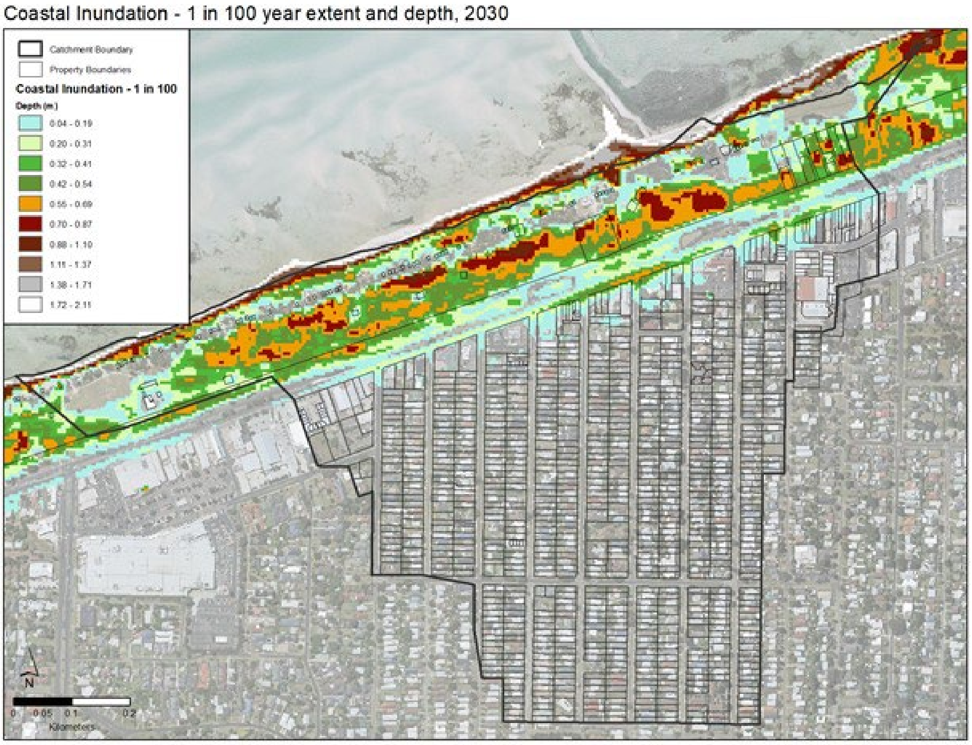
Flooding is likely to be exacerbated by climate change and a potential increase in the frequency of extreme rainfall events and/or maximum rainfall intensity. In addition, sea level rise and associated higher tides and storm surges may intensify the issue as the outfall will be under water for longer.

There are approximately 150 stormwater outfalls in Port Phillip Bay and numerous outfalls in Mornington Peninsula Shire, including three in the vicinity of the study area. The Sixth Avenue outfall has been selected as the focus of the case study because:

- the outfall is the responsibility of Council, in contrast to some other outfalls, which are partly or solely the responsibility of Melbourne Water,
- it has a reasonably discreet catchment, and
- local flood modelling for the area has been sourced, which captures the impacts of rainfall and storm surge events

This case study is focused on options to mitigate the impacts of inundation, linked to extreme rainfall and inland flooding on residential and commercial properties as well as road infrastructure located in the sub-catchment.

Figure 2: Coastal inundation under 82cm Sea Level Rise and Storm Surge



Source: *Spatial Vision analysis*

Figure 3: Inland flooding (1 in 100 year flood extent)

Source: *Spatial Vision analysis*

2.2 Objective for the Sixth Avenue stormwater outfall catchment

A clearly defined objective is important to assist Council with the process of identifying, filtering and assessing adaptation options and for identifying a ‘decision rule’, which will guide selection of a preferred option or options. A clearly defined objective will also help Council to understand when it needs to be making decisions on adaptation (triggers).

Rosebud has seen repeated and serious flooding in residential and commercial areas due to the stormwater outfall being under high tide levels and buried under back sand. A primary objective is therefore to ensure that flooding of and associated damages to residential and commercial areas of Rosebud are minimised through the cost-effective implementation of an infrastructure upgrade and/or maintenance regime.

2.3 Roles & responsibilities

Mornington Peninsula Shire Council has primary responsibility for the management of stormwater outfall. As such, it is responsible for ongoing inspections and maintenance, as well as refurbishments.

2.4 Hazard assessment

For the hazard assessment we have relied on flood risk and coastal inundation modelling, as shown in Figure 2 and Figure 3. While this level of flood modelling is sufficient for a preliminary assessment of this nature, a more detailed assessment of the options would benefit from a combined hazard assessment considering both inland flooding and coastal inundation as well as the latest climate change projections. We understand that a hazard assessment of this nature is currently being undertaken by CSIRO for DELWP.

2.5 Adaptation options, pathways and timing

2.5.1 Overview of options and pathways

The options focus around the Sixth Avenue stormwater outfall and how to improve the drainage of the sub-catchment in Rosebud during (extreme) rainfall events and also high tides. As climate change impacts become more marked over time, sequencing of options (adaptation pathways) is likely to be necessary to address changed conditions or circumstances over time and/or because options differ in flexibility and/or life span.

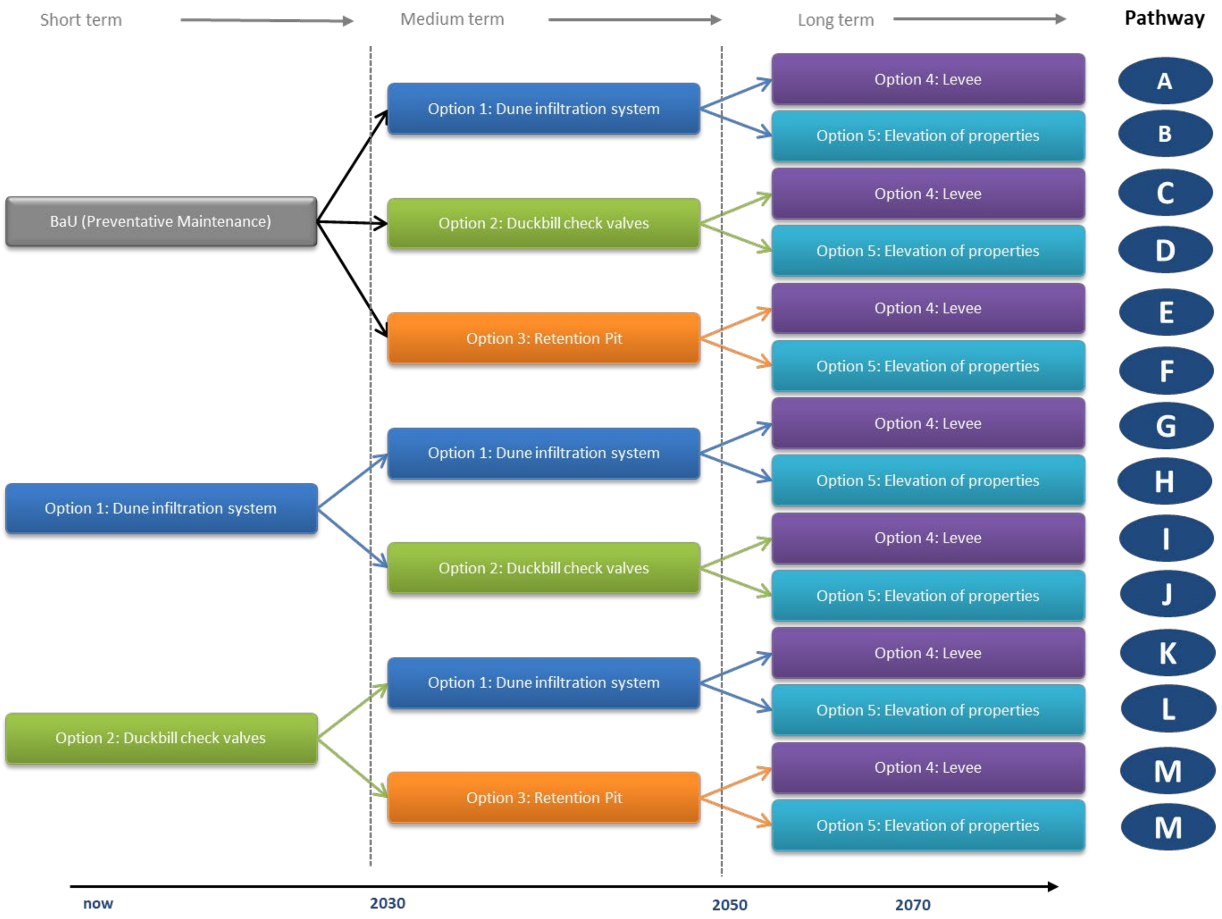
Preliminary examination of adaptation pathways, considering both short- and long-term adaptation options was undertaken and discussed with Council stakeholders. The short- and longer-term options identified include:

- Preventative maintenance of the drainage outfalls to avoid blockages
- Dune infiltration – redesign of the outfall involving underground pipes branching out of the main pipe to enable water to be dispersed through the beach and dunes.

- Duckbill check valves to prevent sand backtracking.
- Installation of a retention pit in the foreshore area. The basin would be designed to temporarily hold water during high tides and then released when the tide is low.
- Construction of a levee to divert water away from properties and into open spaces.
- Elevating of properties in the flood path, e.g. through planning approvals for major renovations or rebuilds.

These options can be combined into a series of alternative adaptation pathways that capture different options and different sequencing of options over time. Examples of alternative adaptation pathways are shown in Figure 4.

Figure 4: Examples of adaptation pathways, Sixth Avenue Stormwater Outfall

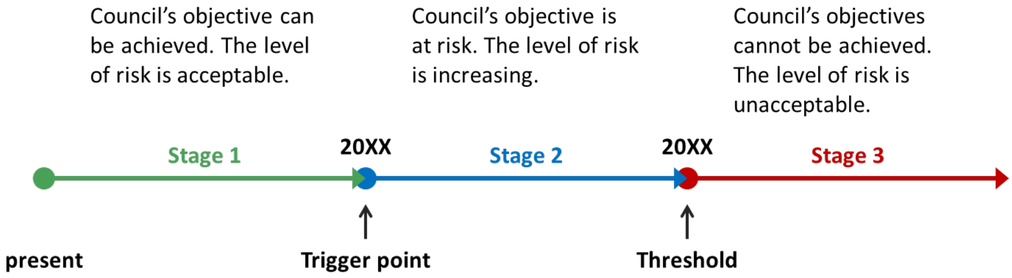


2.5.2 Triggers

Climate change poses significant uncertainties, with a range of plausible future scenarios for sea level rise and other climate related hazards. Climate change projections on the local and regional level are being continually revised as new information and data become available. This calls for a flexible and adjustable approach to climate change adaptation to avoid premature redundancy of valuable infrastructure and putting communities and assets at risk.

Triggers carefully selected to fit given circumstances and options, can serve as 'red flags' and prompt management response and/or implementation of a predefined option or set of options at an appropriate time. Triggers support adaptation strategies that maintain the acceptable level of risks and only implement adaptation actions, if actual changes in risk start to eventuate. Triggers can be linked to physical, social or planning/policy changes.

Figure 5: Appropriate timing of adaptation options



Source: Marsden Jacob after "The Time Continuum Model" (Fisk and Kay (2010))

2.5.3 Option selected for analysis

This preliminary analysis focusses on short-term options, including the installation of:

- **Option 1 – dune infiltration system:** This system divert and treat stormwater naturally through the sand dunes. The system will divert stormwater from the existing stormwater outfall through a series of pipes and basins to the sand dunes.
- **Option 2 – duckbill check valve:** A rubber check valve would be fitted to the end of the existing stormwater outfall. The valve opens to allow stormwater out during high flows, but closes over when water is not coming out of the pipe. It thereby prevents blockages of the pipe through incoming sand.

3. Analysis of short-term option

3.1 Overview of approach

Cost-benefit analysis (CBA) is a method that compares monetary costs and benefits associated with each option. The scope of CBA is on social costs and benefits as opposed to the private cost and benefits assessed in a financial evaluation. This scope makes it well suited to measuring adaptation options from a community perspective, as will often be the basis for decision-making by councils.

CBA enables comparison of alternative options to determine which options will provide net benefits to society and the option that will contribute the greatest benefit. The method can also be used to compare projects of different scales and timeframes.

For our analysis, we assessed Option 1 and 2 against a business as usual (base case) option.

The **Business as Usual** (BaU) option assumes that Mornington Peninsula Shire will continue to undertake ongoing preventative maintenance. This includes regular inspections according to the schedule, such as monthly inspection and, if necessary, cleaning of the stormwater outfall, the drainage line and the gross pollutant trap (GPT).

For the analysis we considered the following key costs and benefits of Option 1 relative to BaU:

- incremental capital and operation and maintenance cost of implementing Option 1 or Option 2 relative to the costs of BaU (ongoing maintenance); and
- avoided costs of flood and inundation impacts associated with the installation of Option 1 or Option 2.

3.1.1 Flood damages

For the analysis, we utilised JBA flood data purchased by Council and quantified the damage costs of flooding by applying the Victorian Rapid Appraisal Method for Floodplain Management[3] (Flood RAM) to quantify flood damage costs to residential and commercial properties and roads, based on numbers of properties and lengths of roads impacted for different flood depths and flood return periods. Outcomes from our application of the RAM model to standing water flood depth and return period data[4] produced an expected cost of flood damages of just over $4 million NPV over the next 50 years (see section 3.3.3 for further discussion of the analysis).

3.1.2 Threshold analysis

Note, although we were able to quantify the flood damages under BaU, we do not know precisely how the implementation of either Option 1 or Option 2 will impact the flooding under different recurrence intervals. For this reason, we applied a modified version of CBA for the analysis, referred to as **threshold analysis**. Threshold analysis is used to test the impact of an option on a key unknown

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[3] Department of Sustainability and Environment (DSE), 2009, Review of Flood RAM Standard Values

[4] Purchased by Mornington Peninsula Shire Council from JBA

benefit (in this case change in flood damages) necessary to achieve breakeven (i.e. a positive NPV or benefit/cost ratio of >1) for that option. In this case, we have applied threshold analysis to test the question – *"By how much will the flood damages under Option 1 (dune infiltration system) or Option 2 (check valve) need to decrease below the flood damage occurred under BaU in order to justify the additional costs incurred by Option 1 or Option 2 - that is, achieve a net positive NPV?"*

3.2 Results

Table 1 shows the present value of costs under BaU and Options 1 and 2 over 50 years from 2021 to 2071 and, hence, the incremental net cost of Options 1 and 2. The PV of the incremental cost of Option 1 and Option 2 are estimated to be $682,000 and $102,000, respectively. These incremental costs provide us with the threshold value against which to test the avoided flood damage benefits of Options 1 and 2.

The results are based on the following generic assumptions:

- 4% real discount rate (with sensitivities of 2% and 7%)
- 50 year analysis period
- all cost and benefit values are in 2020 dollars.

Table 1: Present value costs of BaU and Option 1 (in $'000 over 50 years)

	Business as Usual	Option 1	***Option 1*** *incremental costs*	**Option 2**	***Option 2*** *incremental cost*
Operation and Maintenance Cost	43	207	*164*	43	-
Capital Cost	-	518	*518*	102	*102*
PV Costs	**43**	**725**	***682***	145	***102***

Source: Marsden Jacob Analysis

Table 2 and Table 3 present the results of the threshold analysis.

Table 2: Threshold analysis (in $'000 over 50 years)

	Business as Usual	Option 1 Dune infiltration	**Option 2** Check Valve
Costs			
Operation and Maintenance Cost	43	207	43
Capital Costs	-	518	102
PV Cost	**43**	**725**	**145**
Flood Damages (threshold test min. value)	4,006	*3,323*	3,904

	Business as Usual	Option 1 Dune infiltration	**Option 2** Check Valve
PV	**4,049**	***4,048***	**4,049**

Source: Marsden Jacob Analysis

Table 3: Threshold analysis – incremental results (in $'000 over 50 years)

	Option 1 Dune infiltration	**Option 2** Check Valve
Costs		
Operation and Maintenance Cost	164	-
Capital Costs	518	102
PV Cost	**682**	**102**
Benefits (Avoided Cost)		
Avoided Flood Damages	683	102
PV Benefits	**683**	**102**
NPV	**1**	**0**

Source: Marsden Jacob Analysis

The information in the tables reveal that investing in Option 1 would need to reduce flood damage costs by $683,000 NPV over 50 years, i.e. by 17.1% below BaU flood damage costs to justify that investment. Investing in Option 2 would need to reduce flood damage costs by $102,000 NPV over 50 years, i.e. by 2.6% below BaU flood damage costs to justify that investment. Either of these outcomes would appear to be realistic. Furthermore, the results presented here are likely to be conservative, with flood damage cost estimates under BaU likely to be understated because the flood modelling on which they are based do not reflect the latest climate change projections or capture the combined effects of overland flooding and coastal inundation (see section 3.3.3).

3.2.1 Sensitivity analysis

The threshold analysis is necessarily based on a series of assumptions, which means that there is a degree of uncertainty around the results. Sensitivity testing has been undertaken to clarify which assumptions can materially change the results. The following sensitivity tests have been undertaken:

- discount rates of 2% and 7%
- changes in capital and operating cost of both a 20% increase and decrease
- changes in the assumed floor level of residential houses in the flood damage cost calculations.

Sensitivity analysis results are presented in Table 4. The results show that:

- The results are sensitive to changes in the discount rate. A lower discount rate of 2% gives more weight to costs and benefits in future years and therefore has a greater impact on Option 1. A decrease in flood damages of 14.80% - rather than 17.05% - would suffice for Option 1 to generate a small net benefit relative to BaU. For Option 2 a decrease in flood damages of 2.35% - rather than 2.55% - would be required to achieve a net benefit.

- Conversely, a higher discount rate of 7% means that less weight is given to future benefits. That is, the flood damages would need to decrease by about 20.9% for Option 1 and 2.9% for Option 2 to generate a net benefit.
- An increase in operation and maintenance costs of 20% only has a minor effect on the results. Under Option 1, the decrease in flood damages increases to 17.85% (from 17.05%). Under Option 2, the required decreases in flood damages does not change because the operation and maintenance costs are the same as under BaU.
- An increase in capital costs of 20% for the options means that the avoided flood damages under Option 1 and 2 would need to increase by 19.65% (from17.05%) and 3.10% (from 2.55%), respectively. Conversely, a decrease in capital costs means that avoided flood damage costs under Option 1 and 2 would only need to be 14.45% and 2.05%, respectively.
- In addition, we tested the impacts of lower and higher floor levels on the flood damages and the associated avoided flood damages required to produce net benefits. The base case assumes floor levels of 150mm. The extreme floor levels of 0mm and 3000mm provide an upper and lower bound to the avoided damage costs that need to be achieved. Floor levels of 300mm would require a significantly higher reduction in flood damages, as flood damages are lower overall due to the assumed higher floor levels. Option 1 requires a 59.2 % reduction in damages and Option 2 an 8.85% reduction. Conversely, the avoided flood damages under the options would need to be much lower with lower floor levels of 0mm. We note that floor levels of 0mm are not realistic, but this scenario presents a lower bound for the avoided flood damage costs necessary to generate a net benefit.

Table 4: Summary of sensitivity analysis results ($’000)

	Decrease in flood damages required to meet threshold test (%)	
	Option 1 Dune infiltration	Option 2 Check valve
Base assumptions	17.05	2.55
Discount rate 2%	14.80	2.35
Discount rate 7%	20.90	2.90
Operation & Maintenance +20%	17.85	2.55
Operation & Maintenance -20%	16.25	2.55
Capital costs +20%	19.65	3.10
Capital costs -20%	14.45	2.05
Floor level (0 mm)	15.05	2.25

	Decrease in flood damages required to meet threshold test (%)	
Floor level (300mm)	59.20	8.85

3.3 Underlying assumptions

The following sections set out the major underlying assumptions, such as the capital cost, operation and maintenance coast and the benefits or avoided costs (flood damages) obtained from improving the stormwater and drainage system at Sixth Avenue in Rosebud.

3.3.1 Capital costs

The major cost driver of the CBA is the capital cost for the installation of a dune infiltration system (Option 1) or the installation of a duckbill check valve (Option 2). The capital costs and asset lives for the options are shown in Table 5. There are no capital costs required under BaU.

Table 5: Capital costs for Option 1 and Option 2

Item	Option 1 Dune Infiltration	Option 2 Check valve
Capital Cost ($)	400,000	40,000
Asset Life (years)	30	10

Source: Estimate provided by Mornington Peninsula Shire, 20 October 2021

The capital costs for Option 1 are based on the bio infiltration basin currently being installed by Council near Rye.

3.3.2 Operation and maintenance costs

Operation and maintenance costs are incurred under all three options (see Table 6). Under BaU, the pits and pipelines on the system are on a 36 monthly program inspection schedule and cleaned as required. This equates to a cost of approximately $1,500 to $2,000 per year, covering the inspectors, operators and plant costs for the cleansing of the outfall and associated GPT and drainage line. For this CBA we have conservatively applied a cost of $2,000 per year. These costs also apply under the options as ongoing inspections and clean outs will continue to be required.

Options 1 and 2, estimate for operation and maintenance costs were not supplied.

We have therefore calculated an estimate based on a percentage of capital costs for Option 1, assumes operation and maintenance costs of 2.0% of capital costs plus the ongoing inspections and cleaning carried out under BAU, totalling $10,000 per year.

Under Option 2, we assumed that maintenance and operation costs would be the same as under BaU, with the check valve being inspected as part of the existing regime.

Table 6: Operation and maintenance costs for BaU, Option 1 and Option 2

Item	BaU	Option 1 Dune Infiltration	Option 2 Check valve
Operation and maintenance cost ($ per year)	2,000	10,000	2,000

3.3.3 Flood damages

Flood damage costs for a range of flood events (20 year, 50 year, 100 year, 200 year and 500 year ARI events) were estimated using the rapid appraisal method for Floodplain Management (Flood RAM). Flood RAM is a methodology for the rapid and consistent evaluation of floodplain management measures in a benefit cost analysis framework. Flood RAM enables estimates of flood damages to be made for an area without the need for excessive data. It ensures consistency and hence comparability across different evaluations.

Average annual damage cost

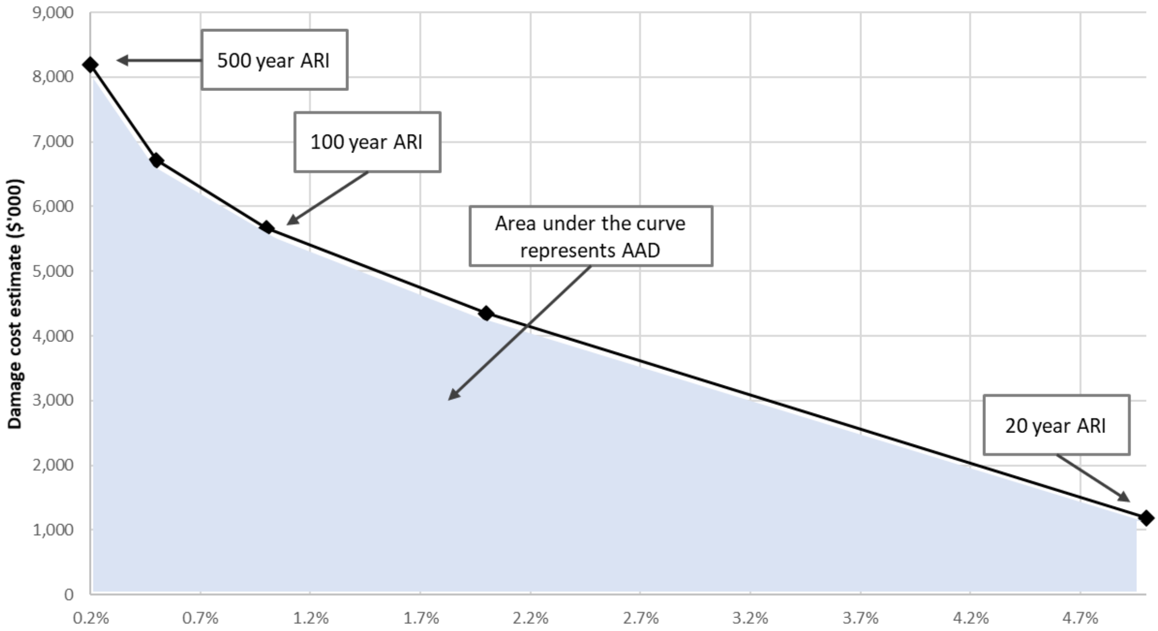
The economic impact of flooding is measured using the average annual damage (AAD) estimates. AAD were calculated using the flood mapping results, i.e. predicted depth of overfloor inundation under the 20 year, 50 year, 100 year, 200 year and 500 year ARI events for standing floods. We then estimate the flooding damage for each commercial and residential property and each flood event design scenario:

- For residential dwellings we used the over-floor inundation depth, type of building (i.e. single storey, two storey) and building and content damage cost estimates (see Table 9 and Table 10) to derive building and content damage for each property and each flood event. Internal and external clean-up costs were added for each flood affected dwelling.
- For commercial properties we used the over-floor inundation depth, floor area, actual building and content damage cost estimates (see Table 11) and added clean-up costs (40% of building and content damage cost).
- For roads we used an estimate of the length of inundated roads as well as the type of road (e.g. major highway, major sealed road, minor sealed road, unsealed road) to derive damage cost estimates.

We then estimated the flood damage curve for each scenario, by summing the damage costs for each flood event for all buildings and properties. The flood damage curve (or loss-probability curve) is based on the flood damage cost for a range of flood events / probabilities. Damage costs can be interpolated between known data points (e.g. between the 20 year ARI and 50 year ARI). Data points outside the range of the data sample have not been extrapolated.

The area under the flood damage curve represents the AAD (see example in Figure 6). The AAD is estimated by integrating the area below the flood damage curve or calculating the area under the curve.

Figure 6: Flood damage curve and average annual damage (AAD) under current conditions for standing flood



AAD Results

The following table presents the AAD results under base case assumptions for the Sixth Avenue sub-catchment. Base case assumptions include:

- all residential properties are assumed to be single storey dwellings; and
- finished floor levels are assumed to be 150mm above ground level.

The average annual flood damage estimate totals $186,500, with the majority (87%) of damage costs attributed to residential properties.

Table 7: AAD results for roads and properties with FFL 150mm above ground level, standing flood, existing conditions

	Average annual damages (AAD) ($)
Residential properties	161,700
Commercial properties	16,600
Roads	8,200
Total	**186,500**

We note that we only received standing flood data for the current conditions. As such, it is almost certainly that this data understates the impacts of flooding in the future because it does not capture the latest climate change projections or the combined effects of flooding and coastal inundation.

We have also calculated the AAD results for coastal inundation. These are presented in Table 8.

Table 8: AAD results for roads and properties with FFL 150mm above ground level, coastal inundation

	Average annual damages (AAD) ($)			
	Baseline	2030 - RCP4.5	2050 - RCP4.5	2090 - RCP4.5
Residential properties	48,700	347,500	518,000	1,239,600
Commercial properties	7,900	61,200	197,000	1,169,600
Roads	39,500	87,400	111,200	127,300
Total	**96,200**	**496,100**	**826,200**	**2,536,500**

We have not included the AAD from coastal inundation in the CBA, as this would significantly overstate the benefits (avoided flood damages). As noted earlier, a more detailed assessment of the options would benefit from a combined hazard assessment considering both inland flooding and coastal inundation as well as the latest climate change projections.

Actual versus potential damage cost

It is important to distinguish between potential and actual damage when assessing flood damage. Actual damage cost estimates should be used in analyses where there is evidence that property owners will have time to prepare for the flood event.

- *potential damage* is the damage that would occur if no remedial action is undertaken and the exposure to the flood event is not reduced.
- *actual damage* is the damage that occurs after actions have been taken to reduce the exposure to the flood event (e.g. sand bagging, removing valuable items, etc.).

Evidence shows that extended warning times and better preparedness reduce the actual damage costs from flooding. The Flood RAM report suggests that the actual damage costs for commercial buildings are typically about 44% of potential damage. The ratio of actual to potential damages varies more widely for residential properties, and will also vary across different areas and communities, depending on warning time and community experience with flooding.

For this case study we have assumed a ratio of actual to potential damage of 44% for commercial properties. For residential properties, we have taken a conservative approach by not adjusting the potential damage costs.

Residential building and content damage

Building damage cost for residential buildings is a function of overfloor inundation and building type (see Table 9). Building damage cost are higher for single-storey dwellings as a greater area and also content is impacted by flooding.

Information on the building type was not available for residential properties. However, we note that a random search on google maps suggests that a large proportion of residential dwellings in the Sixth

Avenue sub-catchment are single storey buildings. In our base case assumptions we have therefore assumed that all buildings are single-storey buildings.

Table 9: Residential building damages ($2020)

Building Type	Damage cost function
Single-Storey Residential Building	y = 19,257 + 7,126 x
Two-Storey Residential Building	y = 13,480 + 4,892 x

Note: y = estimated damage; x = overfloor depth (m) (positive values only)

Source: Marsden Jacob Associates, based on DSE 2009

Similar to building damages, value of contents lost depends on overfloor inundation levels. This is shown in Table 10 by building type.

Table 10: Residential content damages ($2020)

Building Type	Depth of overfloor inundation (m)	Damage cost function
Single-Storey Residential Building	x ≤0	y = 0
	0 < x < 2	y = 32,187 + 32,187 x
	x ≥ 2	y = 96,560
Two-Storey Residential Building	x ≤0	y = 0
	0 < x < 2	y = 22,504 + 22,504 x
	x ≥ 2	y = 67,644

Note: y = estimated damage; x = overfloor depth (m) (positive values only)

Source: Marsden Jacob Associates, based on DSE 2009

Clean-up costs and external damages are accounted for in addition to building and content damages. Estimates recommended in the Flood RAM report have been adjusted for inflation. Clean-up costs are assumed to be $5,234 per flood affected property for internal clean-up and $1,308 per flood affected property for external clean-up. External damages are assumed to be $6,542 per flood affected property.

Commercial building and content damage

Actual damage cost estimates for commercial buildings depend on the depth of overfloor inundation and are shown in Table 11. Clean up costs are accounted for in addition to building and content damage and are estimated as 40% of building and content damage (DSE 2009).

Table 11: Commercial building and content damage (medium value contents) ($2015)

Depth of overfloor inundation (m)	Potential Damage ($/sqm)	Actual Damage ($/sqm)
3.00	702.6	309.7
2.70	702.6	309.7
2.40	702.6	309.7
2.10	702.6	309.7
1.80	562.6	248.0
1.50	526.0	231.9
1.20	421.3	185.7
1.00	350.7	154.6
0.90	333.6	147.1
0.60	281.3	124.0
0.50	263.0	115.9
0.30	200.2	88.2
0.20	176.6	77.9
0.10	132.1	58.3
0.05	94.2	41.5
0.00	52.3	23.1
-0.30	0.0	0.0

Damage to roads

The damage estimates for roads are driven by the type and length of road inundated as well as the duration of inundation and the velocity of flooding. The Flood RAM report therefore provides damage estimates for both major and minor floods (see Table 12).

Table 12: Unit damage cost for roads (per km of road inundated, $2020)

Road Type	Major Flood			Minor Flood		
	Initial road repair	Subsequent accelerated deterioration	**Total cost**	Initial road repair	Subsequent accelerated deterioration	**Total cost**
Major highway (4 lane)	287,848	143,924	**431,772**	143,924	71,962	**215,886**
Major sealed road	71,962	35,981	**107,943**	35,981	17,991	**53,972**

	Major Flood			Minor Flood		
Minor sealed road	39,252	19,626	**58,878**	19,626	9,813	**29,439**
Unsealed road	11,776	5,888	**17,663**	5,888	2,944	**8,832**

Source: Marsden Jacob Associates, based on DSE 2009

Finished Floor Levels

Data on Finished Floor Levels (FFL) was not available for dwellings within the catchment and assumptions had to be made to determine overfloor inundation for each dwelling. In line with previous work, we adopted the base case assumption of FFL 150mm above ground level.

Sensitivity testing was undertaken for FFL at existing ground levels and FFL 300mm above ground level. This allows us to determine an upper and lower bound of AAD.

4. Conclusions and next steps

4.1 Conclusions

Overall, results of the analysis indicate that there is a *prima facie* case for implementing either Option 1 or Option 2. This case, of course, rests largely on the supposition that implementing either of the options will decrease the flood damages to residential and commercial properties and roads by at least 17.05 % (Option 1) or 2.55% (Option 2) compared to the flood damage costs estimate under BaU (see also section 3.3.3). Although the estimates generated by the analysis are preliminary and are subject to significant uncertainties, a 17.05% or 2.55% decrease in flood damages would appear to be feasible given the improvements to the stormwater and drainage systems under the options. We note also that sensitivity analysis indicates that the range of uncertainty around the threshold value is not large (excluding floor levels of 300mm). These range from 14.80% to 19.65% for Option1 and 2.05% to 3.10% for Option 2.

Furthermore, as discussed in section 3.3.3, the flood modelling data, upon which the flood damage analysis for this case study draws, almost certainly understates the impacts of overland flooding on the study area.

4.2 Next steps

Notwithstanding the prima facie case for implementing either Option 1 or Option 2, further analysis could be warranted in some areas before decisions are made on implementation. That analysis should seek to draw on the latest coastal inundation and flood modelling analysis currently being undertaken by CSIRO for DELWP.

4.2.1 Financing and implementation plan

Depending on which option will be implemented, Council may need to give due consideration to the financing of the option and develop an implementation plan. Considerable capital costs of about $400,000 will be required to implement Option 1.

A program implementation plan for the Masterplan will need to be developed covering:

- funding and cost sharing;
- an implementation timetable;
- roles and responsibilities for the implementation; and
- program review.

4.2.2 Analysis of medium and long term protection options

The analysis presented in this report is only preliminary, and as we have previously emphasised, is subject to considerable uncertainty. Given this uncertainty and noting that the analysis only assessed options on a high level, further detailed analysis may be warranted. This includes analysis of measures that are designed to protect the area from the impacts of climate change, i.e. flooding, such as a levee or increased floor levels. That analysis will need to be underpinned by improved costal inundation and flood modelling for the area and preliminary design and costing of protection measures.