

Tasmanian Coastal Adaptation Pathways Project – Georges Bay

Tasmanian Coastal Climate Adaptation Pathways Project
July 2012



Independent insight.



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EXECUTIVE SUMMARY

This report informs the St Helens and wider Georges Bay and Break O’Day community about coastal risks in light of sea level rise resulting from climate change. It also considers ways to respond to risks while considering the values of the local community and the wider benefits of this coastal area.

This report has been prepared as part of the Tasmanian Coastal Adaptation Pathways study. The adopted pathway approach does not prescribe a one-size-fits-all solution, but as the word ‘pathway’ suggests, is a process to achieve adaptation responses in individual coastal areas

Georges Bay is situated along the east coast of Tasmania. It is connected to the sea through a narrow opening between Dora Point and Point Blanche. The Georges River is the main feeder water way of fresh water into the bay from the wider catchment area.

Coastal hazards

Rainfall and river run-off can have a significant impact on the water surface level of Georges Bay, which is illustrated by the significant floodings in January 2011 when the roads into St Helens were closed. Binalong Bay Rd floods a number of occasions each year. As a result of climate change, it is projected that future rainfall intensities during extreme rainfall events will increase.

The Georges Bay surface level varies with river run-off and rainfall intensities, tides, storms and wave effects. The combined effects can lead to extreme surface levels. The most extreme heights occur with a lower probability. Sea level rise is estimated to add about 0.3 m to the mean sea level by 2050 and 0.9m by 2100, compared to 1990 levels. The combined results of these effects are expressed in a range with upper and lower limits. At the upper limit, the surface level could rise to about 2.3 metres AHD at present day, and to about 3.7 metres AHD by 2100. At the lower limit, assuming extreme river flood, storm surge and wind events are totally independent, a 1% probable extreme surface level event is expected to reach about 1.3 metres AHD at present day, and 2.3 metres AHD by 2100.

Surface Level after an Extreme Event (1% AEP), 2011-2010

	Present day	2050	2100
Lower limit (m AHD)*	1.25	1.6	2.3
Upper limit (m AHD)**	2.3	3.0	3.7

* assuming river flood events, storm surge events and wind events are completely independent, and assuming a wind fetch of 2,000 metres ** assuming river flood events, storm surge events and wind events are completely dependent, and assuming a wind fetch of 5,000 metres

As a result of climate change, the surface level of Georges Bay will be higher during extreme events. The consequences are expected to be (if nothing is done to prevent this):

- More frequent flooding of St Helens town centre
- More frequent flooding of main roads, most notably Binalong Bay Rd, sections of St Helens Point Rd and of the Tasman Hwy
- Land slide risks near Stieglitz will increase
- Aquaculture farms, Ben Lomond water sewage treatment plant and other operations will become subject to flooding at a more regular basis
- Low lying coastal properties will increasingly experience flooding

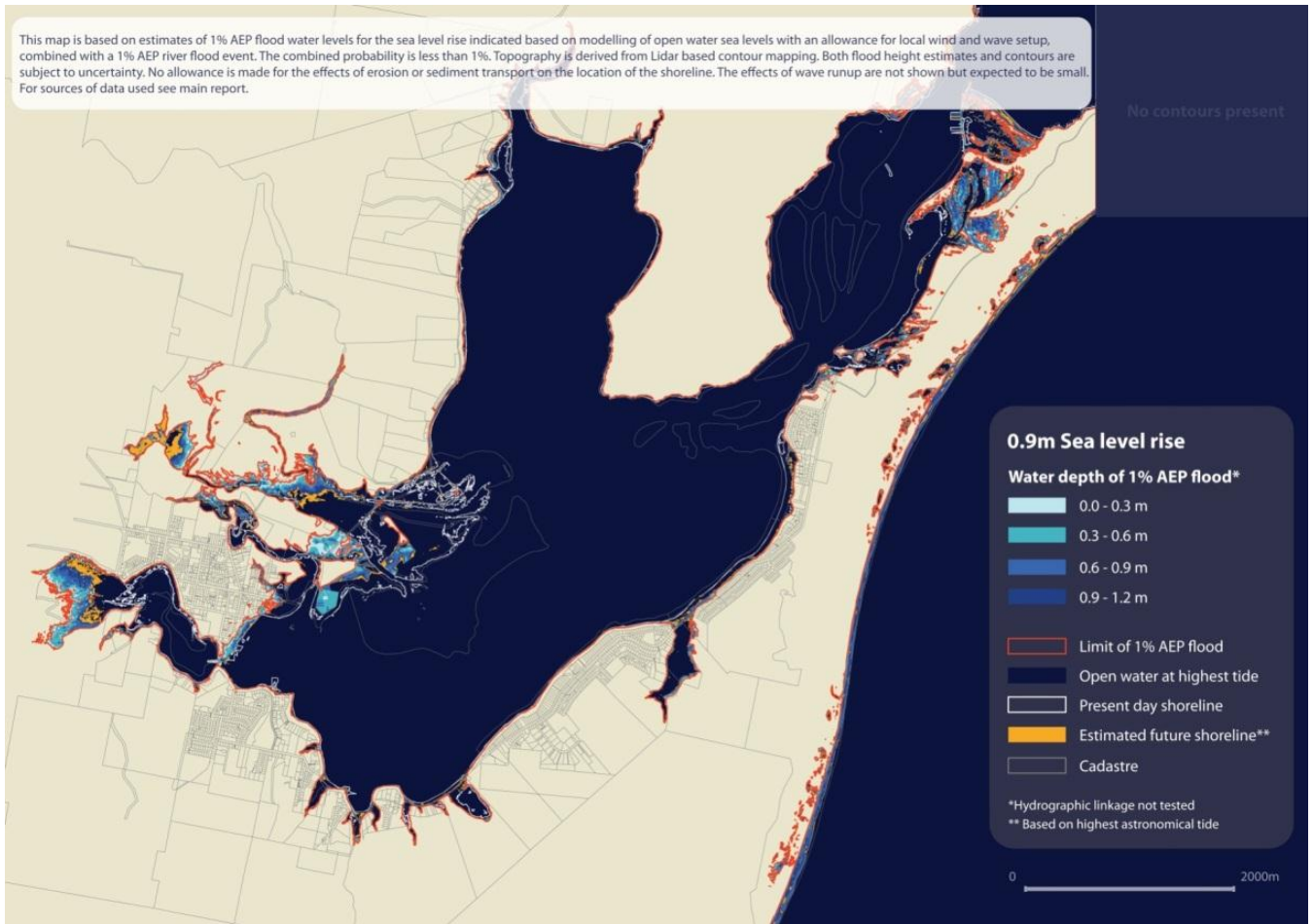
Note that all surface level values are ‘best estimates’ and subject to inaccuracies. Erosion and dynamics within the Bay have not been taken into account in the modelling. Importantly, the rate at which climate change and its impacts will occur will remain to be a factor of uncertainty for some time.

The map below illustrates where the coastline would be with a sea level rise of 0.9 metres, which is expected to occur by 2100. It also shows the depth of flooding as a result of a 1% AEP extreme storm event.

Likely Inundation at Georges Bay for extreme storm event (1% AEP), 0.9 m sea level rise

This map is based on estimates of 1% AEP flood water levels for the sea level rise indicated based on modelling of open water sea levels with an allowance for local wind and wave setup, combined with a 1% AEP river flood event. The combined probability is less than 1%. Topography is derived from Lidar based contour mapping. Both flood height estimates and contours are subject to uncertainty. No allowance is made for the effects of erosion or sediment transport on the location of the shoreline. The effects of wave runup are not shown but expected to be small. For sources of data used see main report.

No contours present



Current planning scheme mechanisms

The draft Break O' Day Planning Scheme uses zone and code provisions for addressing coastal vulnerability. There are three new codes in the draft planning scheme which relate to coastal vulnerability: the Landslip Zone, Flood Prone Areas Code and the Coastal Code.

The planning scheme does not identify timeframes to the high water mark. It is further required to set back 1 kilometre from the high tide mark, which does not reflect actual coastal vulnerability. This may therefore overestimate actual risk for elevated rocky shores and potentially underestimate risk for flat, low lying coastal plains over the life of a longer lived asset.

In regards to the code provisions, the planning scheme does identify an acceptable level of risk for flood prone areas. The scheme does not however identify a timeframe for risk and does not consider changes in risk explicitly. In relation to development in coastal dune systems the scheme does not identify (un)acceptable levels of risk and does not recognise changes in risk over time.

Costs of risks in the study area

As part of this study an assessment was made of the properties at risk by inundation or sea level rise to 2100. Risk is the result of the total damage times the probability of an event happening. While the total damages of an event actually happening can be very substantial, the probability of it happening is often quite low. Therefore, the total risk (in \$) may be substantially below the total damages of an extreme event.

Around 35 dwellings and agricultural structures along the coastline of the study area are at risk of inundation at present-day¹. There are only 18 dwellings with above floor inundation levels. By 2050, there will be about 22 dwellings with floor levels below the 1% AEP flood level. By 2100, about 43 dwellings will have floor levels below 1% AEP level.

The dwellings at present-day risk are expected to experience some substantial damages over time, along with future sea level rises, which represent 29% to 34% of the replacement value in NPV terms under the base case. This risk level far exceeds what is normally considered an acceptable level (i.e. about 5%), as discussed in Appendix 2.

The total cost of risk (in present day values) to structures is between **\$1.1 million and \$1.4 million to 2100**, depending on whether owners continue to maintain their dwellings. If 1% AEP flood levels reach the upper limit variation, then the total cost of risk would be between \$1.6 million and \$1.9 million.

In addition, by 2100, about 19 parcels are expected to be mostly underwater at most high tides and may be lost to occupants with an estimated net present value of **\$0.2 million**.

The estimated damages of an extreme storm event actually occurring can be significant. **By 2100, an extreme storm event (1% AEP) is estimated to cause \$3 million worth of damage** (base scenario, without structure depreciation) if the existing buildings or comparable ones are still in their current locations and elevations.

Values in the study area

People occupy and use areas near the coast, some of which are exposed to coastal hazards, because they derive value from doing so. In fact, coastal property values are typically higher than similar sized properties inland, showing the premium value placed on these areas. Other public, natural and economic values are major contributors of value from the 'use' of the coasts.

Property values

The property value analysis (residential properties only) shows that 30% of the land value² is derived from the fact they have bay frontage.

¹ Risk, if not specified, refers to more than 0.01% chance of having an over floor flood.

² Of properties at risk of being flooded by a high tide by 2100

³ Of properties at risk of being flooded by a high tide by 2100 for other areas. As a result there were subareas with quite distinct

To entirely exclude future development on these properties, either if an owner wishes to extend or redevelop the existing structure, would largely destroy that land value for property where the structure is nearing the end of its service life. If such a policy was applied to land susceptible to a 1% AEP storm event by 2100, up to \$2.8 million of land value would be lost over time.

For property owners, it would be worth spending up to about \$60,000 per property for methods that protect the property but do not compromise the amenity achieved from a water front location, as an alternative to restricting development.

Other values

The natural values of Georges Bay include bird areas of natural beauty, feeding areas, beaches and fish habitat. The bay is also the production environment for commercially farmed oysters. The natural values of the estuary have been moderately impacted by human activity. The Georges Bay area is an intrinsic part of the identity of the region and is greatly valued by its residents.

The tourism sector in the Georges Bay area is significant and relies significantly on the natural and recreation values the bay has to offer.

Extreme river flooding events (due to rainfall) as a result of climate change have the ability to impact on the salinity and the water quality of the bay on a more frequent basis than at present day. Massive oyster mortality and significant economic damage after the January 2004 storm suggests future losses may become more significant.

Adaptation options

In the case of Georges Bay, there are a number of options that are potentially relevant to the impacts identified:

- **Raise land levels** in St Helens township and other low lying residential areas;
- In combination with the previous measure, **a dyke or levee** around St Helens over the long term (likely after 2100);
- **Raise roads and services** of key infrastructure including Binalong Bay Road or alternative route (which would involve a long bridge), sections of Tasman Hwy and of St Helens Point Rd, the sewage treatment plant and pumping stations;
- **An alternative route** for Binalong Bay Road, instead of raising and building a bridge at Binalong Bay Road, Reids Rd could be upgraded to become the main road connection to Binalong Bay. Similarly, it may be possible to build a new road further land inward to replace St Helens Point Rd in the long term, if any environmental values can be managed appropriately;
- **Seal the sewer system;**
- **Improve the drainage capacity** to more effectively drain water from St Helens streets (possibly in combination with the next option);
- Implement a **water retention area** to drain water to from St Helens streets;
- **Retreat or protection of properties** prone to inundation or redevelopment of structures in less vulnerable form (higher floor levels).

Adaptation Pathways

In preparation for community consultation, a number of different pathways for responding to climate change were developed for four locations:

- Lower George River mouth, flood plain and banks
- St Helens town centre and adjacent residential area
- the southern coast of the Bay (Tasman Hwy and St Helens Pt Rd)
- flood prone areas in the environmental management zone (Medeas Cove, St Helens Pt and Humbug Pt).

The identified pathways for the Lower George River mouth are:

- **Pathway 1 –Retreat and establish an alternative route to Binalong Bay Road**
This pathway allows maximum freedom for natural processes with a minimum of intervention or resistance from development or protection works.
- **Pathway 2 – Maintain Binalong Bay Road as long as practical**
This pathway protects property and protection may have some impact on natural areas and the other values of the community.
- **Pathway 3 – Long term protection of Binalong Bay Road with significant engineering**

This pathway concentrates on protecting the existing assets and development potential. It assumes that the rate and extent of change will be manageable using available options and that any necessary protection and adaptation options will be acceptable.

The identified pathways for St Helens town centre are:

- **Pathway 1 – Long term relocation of town centre**
This pathway allows maximum freedom of natural processes with a minimum of intervention from development or protection works. The town centre would in the long term relocate to higher ground.
- **Pathway 2 – Long term protection of town centre**
This pathway concentrates on protecting the existing and future community where it is. It assumes change will be manageable by raising the town centre, hardening foreshores and improved stormwater drainage.

The identified pathways for the southern coast of the Bay (Tasman Hwy and St Helens Pt Rd) are:

- **Pathway 1 – Allow natural processes to develop while also retaining road access**
This pathway protects property but only where that protection has a minimal impact on natural areas and the other values of the community. Where there is an apparently irreconcilable conflict, the preference goes to protecting natural and shared community assets, not private property.
- **Pathway 2 – Retain existing road access while allowing natural processes if practical**
While sharing many features of the previous pathway, this option gives priority to property over natural values where there is a conflict or tradeoff.
- **Pathway 3 – Retain road access and support further development**
This pathway concentrates on protecting the existing and future community. It assumes that the rate and extent of change will be manageable using available options and that any necessary protection and adaptation options will be acceptable.

The identified pathways for natural flood prone areas in the Environmental Management Zone are:

- **Pathway 1 – Let nature take its course and retreat development to allow natural processes**
This pathway would allow natural processes to unfold. Where it would interfere or negatively impact on natural processes, any of the existing limited development would be demolished. Roads through low lying areas would be rerouted or raised as bridges and other infrastructure would be removed to allow the areas to transform into saltmarsh, tidal wetlands and eventually open water.
- **Pathway 2 – Attempt to intervene to manage the types of ecosystems that develop**
This pathway would aim to manage natural values and consider options to actively help ecosystems to migrate and/or be sustained. This pathway would also give priority to natural processes and, where deemed necessary, to actively manage ecosystems.
- **Pathway 3 – Some development while protecting important natural values**
This pathway aims to allow for development to intrude into natural areas if the natural values are deemed to be of minor significance, or if the natural values are expected to be lost due to climate change anyway.

The community's perspective

Two locations, with quite different issues, were investigated at workshops held on Saturday 14th of April. The morning session focussed on the river mouth and the Binalong Bay Road area and the afternoon session on St Helens town³.

Interested residents and businesses were invited to register to attend the workshops. Both locations were addressed in a session lasting 2 hours. Over the two hours participants examined the following for the scenarios they were investigating:

- The pros and cons and desirability of each scenario
- Whether they believed each scenario was plausible
- What if conditions change (eg. sea level rises faster or slower than anticipated, there are technological advances, or property prices rise or fall)
- Who decides
- Who pays
- Preferred pathway

Over the entire day, about 17 community members attended the workshops. Also attending were two Councillors and observers from Council and State Government.

³ The study area for Georges Bay was significantly larger than for other areas. As a result there were subareas with quite distinct issues. The workshop sessions addressed this by taking a location approach.

Lower George River mouth, flood plains and banks

The participants expressed the view it is worthwhile to retain access via Binalong Bay Road for some time. However, the costs of maintaining the road in the long term may be well beyond the means of the community. Pathway 2 was expected to buy at least some time for the existing residents and property owners to enjoy and use their properties.

St Helens Town Centre and adjacent residential areas

The participants had varying views towards the pathways, but the majority leaned towards the second pathway (Long term protection of the town centre). Key considerations are retaining the links of the town centre to the waterfront and the protection of the character of the town. With the fragile economy in mind, relocation may risk losing tourist numbers and spending.

During the discussions about how to make the preferred pathways work, the attendants of the workshops identified the following key issues:

- There is a need to better understand the mobility of the lower river mouth, silting and the risks of the river 'jumping' to another canal, potentially posing risk to the town of St Helens
- There is a need for more detailed and comprehensive cost estimates of the adaptation options
- The wider community should be informed about this project and its possible outcomes
- There is a short term need to address issues of filling land and potential detrimental impacts on neighbouring properties. In the long term, a clear plan must be prepared to guide the gradual raising of land, properties and infrastructure as well as stormwater drainage
- There is a need for a clear decision framework for coastal adaptation and Council would be the preferred responsible authority.

The way forward

Based on the findings of this study, and also to address any gaps in terms of knowledge, decision making and funding, the following recommendations were made (grouped by subject):

Understanding of current and expected hazards and adaptation works

Recommendation: To include modelling of local peak rainfall dynamics in St Helens in conjunction with sea level rise to better identify flood risk, as well as modelling drainage capacity in potentially flood affected areas that are developed or proposed for development.

Recommendation: To undertake additional analysis of erosion and the mobility of the George River mouth and the realistic options for erosion protection works (for both Binalong Bay Rd and the northern edge of the town of St Helens) including their likely effectiveness and impacts.

Recommendation: To review the planning scheme to address possible adverse impacts of filling to adjacent property owners. In the longer term, if a strategy to protect St Helens is adopted, a strategy for raising land and properties and for drainage management will need to be adopted and implemented.

A better knowledge of the environment

Recommendation: To prepare a detailed assessment of the environmental values of the areas around Georges Bay, including consideration of the likely changes that sea level rise and climate change will bring. Identify areas of high environmental significance that need consideration in any adaptation works, either to assist with the adaptation of the natural area or to ensure that adaptation measures to protect built assets do not adversely affect important natural areas.

Recommendation: To inform the community about significant environmental values that have been identified, and to explain why they are important to both the local and wider community.

Adaptation requires funding

Recommendation: That an assessment is undertaken to more accurately estimate the likely costs of adaptation options, and also to consider who benefits from different adaptation options. Priority should be given to options for Binalong Bay Rd and a possible retreat to the alternative route of Reids Rd.

Recommendation: That an approach be formulated to identify the budget required and the sources of funds to raise the money required. It is considered that this should be done on a staged basis over a period of about 5 years, with priority given to identification of and responding to road flooding and stormwater drainage.

Local community and wider community values and objectives

Recommendation: To work with the state government to develop a framework for the development of coastal adaptation plans that have state backing and recognition, and balance the priorities of both the local and wider community.

1 INTRODUCTION AND AIM

1.1 Introduction

The aim of this report is to inform the St Helens and wider Georges Bay and Break O’Day community about coastal risks in light of sea level rise resulting from climate change. It also considers ways to respond to risks while considering the values of living around Georges Bay and other economic and recreational benefits of this coastal area.

A better understanding of the issues and possible responses will help the community to make informed decisions to respond to sea level rise and its potential impacts.

The report starts with an overview of the potential coastal hazards (inundation, erosion) at the present day and expected changes in the future as a result of expected sea level rise.

The report then describes the potential damages that may occur as a result of sea level rise and extreme storm events. It also describes how likely it is that damages would occur, now and in the future.

While coastal risks may increase over time, the area will continue to exhibit a range of specific values, such as access to the beach and the river, which make it attractive to live and recreate there. In deciding how to respond to sea level rise, it is important to not only consider the risks but also the values or benefits of using the land.

The report therefore considers the benefits of the Georges Bay area, and any values that may be foregone if new development is prohibited or lost if existing development is required to retreat.

The final part of the report provides an overview of potential responses or options to respond to sea level rise. This last section considers those options that are potentially relevant in the Georges Bay area.

1.2 Background to this Report

This report has been prepared as part of the Tasmanian Coastal Adaptation Pathways study. SGS has been engaged to assist the Local Government Association of Tasmania (LGAT), working with the Tasmanian Climate Change Office (TCCO) and the Tasmanian Planning Commission (TPC), and relevant Councils to develop future pathways for climate change adaptation in four coastal areas in Tasmania:

- Lauderdale (Clarence City Council)
- St Helens/Georges Bay (Break O’Day Council)
- Port Sorell (Latrobe Council)
- Kingston Beach (Kingborough Council).

Funding for the Tasmanian Coastal Adaptation Decision Pathways (TCAP) project has been provided via the Australian Government’s Coastal Adaptation Decision Pathways program, with matching contributions from project partners. Project partners include LGAT, TCCO, TPC, the four councils, Antarctic Climate and Ecosystems Cooperative Research Centre and the University of Tasmania.

The TCAP project aims to significantly improve the ability of Tasmanian decision makers and communities to plan and respond to likely futures for coastal communities. The results and lessons learnt from the four project sites can then be applied in other coastal areas.

This report summarises the coastal climate adaptation pathway work and findings so far for the Georges Bay (Break O’Day Council) project site.

1.3 Coastal Climate Adaption Pathways

Based on previous and ongoing work, SGS developed guidelines for communities and states for coastal climate adaptation pathways. The adaptation pathways cover approximately 15 steps in total and present a consultative approach involving the community, local and other government, land managers and other key stakeholders. The pathway approach does not prescribe a one-size-fits-all solution, but as the word 'pathway' suggests, is a process to achieve adaptation responses.

It is anticipated that this study will progress Break O'Day Council to approximately step 9 of the 15 step pathway. The 15 steps are as follows:

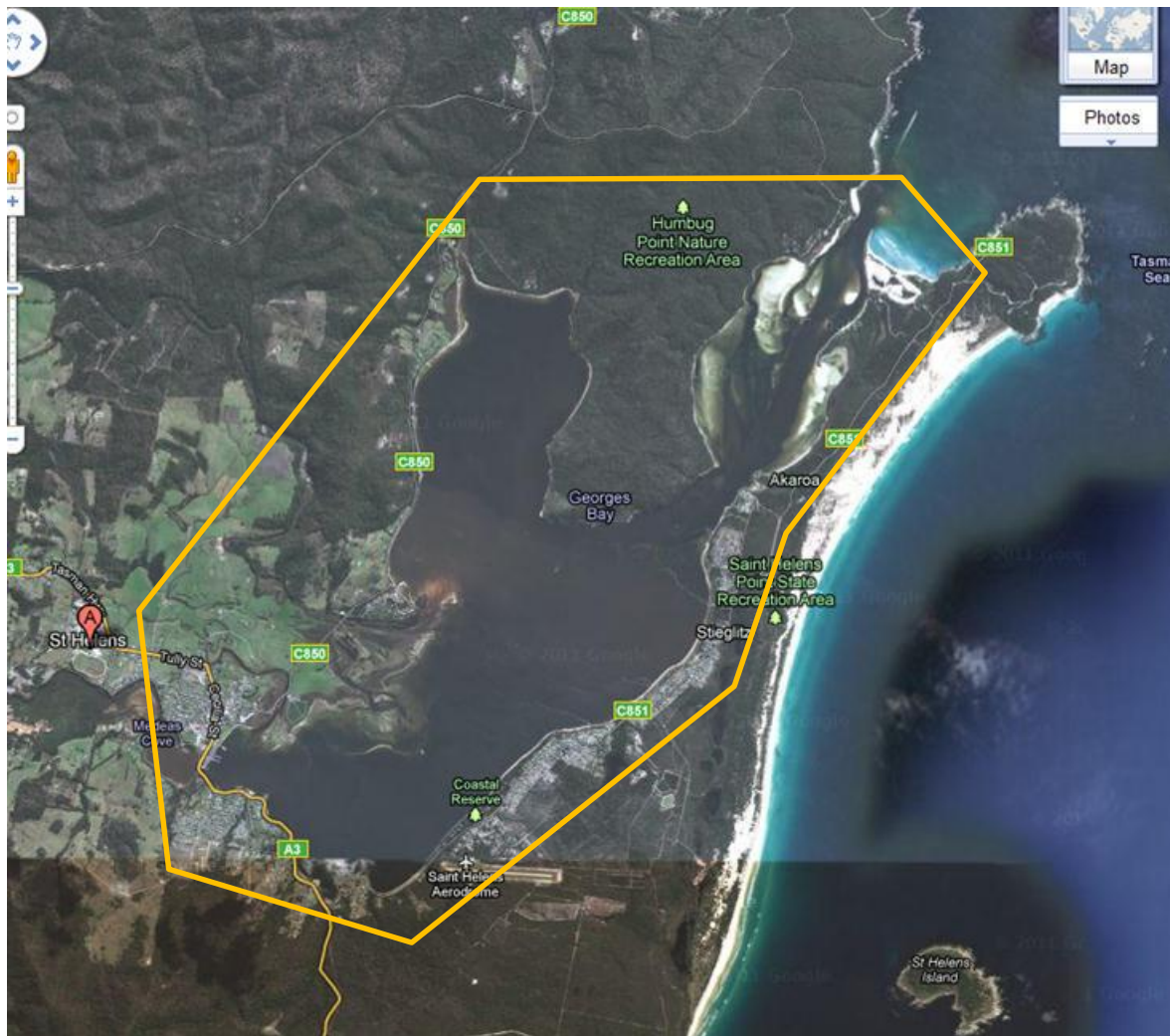
1. Establish hazards and future sea level rise effects and map at the local/relevant scale
2. Interim planning scheme amendment in hazard areas
3. Assess assets at risk
4. Establish the expected cost of risk
5. Assess the value of occupation or use
6. First cut assessment of adaptation options and costs
7. Plan and implement necessary short term protection works in hazard areas
8. Establish preliminary policy and decision making framework
9. Strategic options assessment (Scenario Planning)
10. Detailed assessment of short listed options
11. Select preferred scenario
12. Establish financial framework
13. Revised 'final' planning scheme
14. Implementation
15. Review

Each section of this report relates to one of these 15 steps and this is identified at the start of each section. This report as a whole can be seen as a component of Step 6.

1.4 Georges Bay – Project Site Introduction

Georges Bay is situated along the east coast of Tasmania. It is connected to the sea through a narrow opening between Dora Point and Point Blanche. Around the bay, which covers an area of approximately 20 square kilometres, are the residential areas of St Helens and Stieglitz and some smaller towns (Akaora, Parkside, Parnella, Hillcrest, Chimney Heights and Bayview). The Georges River is the main feeder water way of fresh water into the bay from the wider catchment area. The Humbug Point Nature Recreation Area takes up most of the land that borders the bay to the north.

FIGURE 1 GEORGES BAY PROJECT SITE



The hydrodynamics of Georges Bay show a high tide volume of around 115 million cubic meters. Water depths in Georges Bay are approximately between 4m (Moulting Bay) to over 25m in the wider upper reaches of the bay. At high tide, water flows across the entire bay except in the Humbug Point area, where water moves out of Moulting Bay and into Georges Bay proper. During low tide, water tends to move in a circular pattern out of Moulting Bay and flows along the western shore out of Georges Bay, except in the Humbug Point area, where water moves along the eastern shore (Crawford & Mitchell, 1999).

1.5 This Report

The remainder of this report describes the findings so far for the Georges Bay project site. It covers:

- Current day and future coastal risks
- Current relevant planning scheme mechanisms
- Costs of risks in the study area
- Current property values, public benefit and other values in the project site
- Adaptation options with an introduction that explains what is likely to happen if nothing is done to manage current and future risks.
- Possible pathways for adaptation
- The community's perspective on the identified risks and options
- A proposed way forward from here

2 COASTAL HAZARDS

Georges Bay is connected to the sea via a narrow waterway that runs between Dora Point and Point Blanche. In the opening towards the sea there is an underwater barway which at times reduces the depth and boat access to Georges Bay and St Helens port. While the water in the bay is mainly salty, fresh water flows in from Georges River and some smaller water ways. In case of extreme rainfall events, water levels in the river and bay rise significantly and flooding can result. The pace at which water flows out of the bay into the sea may not keep pace with the volumes that flow in from the river. The flooding may be exacerbated by a high tide which further reduces the volume of water that can flow out into the sea.

This section relates to Step 1 of the coastal adaption pathway process.

2.1 Georges Bay River Flooding

Rainfall and river run-off can have a significant impact on the water surface level of Georges Bay. At the latest flooding event on 12 and 13 January 2011, 148 mm of rain fell, resulting in flash flooding and closure of all roads into the town. In January 2004, a total of 234 mm of rain fell in St Helens and 284 mm in the upper catchment, resulting in flooding.

River flooding causes roads to be flooded. Binalong Bay Rd floods on a number of occasions every year as a result of the water levels in Georges River. Simply raising Binalong Bay Rd to above the long term extreme surface level is not an option, because the road would then function as a dam, increasing flooding issues upstream in the Georges River.

FIGURE 2 BINALONG BAY ROAD WITHOUT AND WITH FLOODING



As a result of climate change, it is projected that future rainfall intensities during extreme rainfall events⁴ will increase. This was concluded as part of the Climate Futures for Tasmania (CFT) project by the Antarctic Climate and Ecosystems Collaborative Research Centre (ACE CRC). The projected increases⁵ in rainfall during extreme rainfall events is about 42% for a 20 ARI event and about 47% for a 100 ARI event (Pitt & Sherry, 2011).

Climate change is also projected to impact river run-off levels of Georges River. The CFT project has provided estimates for changes in river run-off due to higher temperatures resulting from climate change. Run-off for the Georges Bay catchment is projected to increase by about 12% on average, and by about 60% during summer months (Pitt & Sherry, 2011).

⁴ 24 hr rainfall events with an average return interval (ARI) of 20 years and of 100 years

⁵ Period 2070-2099 compared to 1961-1990

The combined contributions of increased rainfall intensities and river run-off are expected to add about 50 cm extra by 2091 for a 1% probable river flood event. At present day, a 1% annual exceeded probability (AEP) event adds about 82 cm to the surface level and by 2091 this is expected to increase to approximately 136 cm (Table 1).

The contributions have been estimated as part of the Pitt & Sherry (2011) report on the basis of assumptions that simplify the processes involved⁶, and may be regarded as a best guess.

TABLE 1 POTENTIAL CONTRIBUTIONS OF RIVER FLOODING AND RUN-OFF TO GEORGES BAY

ARI ⁷	AEP ⁸	Georges Bay surface elevation (metres) 6 hr inflow		
		2011	By 2050	By 2091
20	5%	0.52	0.75	0.84
50	2%	0.69	1.01	1.13
100	1%	0.82	1.21	1.36
1,000	0.1%	1.26	1.90	2.16

Source: Pitt & Sherry, 2011

2.2 Georges Bay Storm Surge and Sea Level Rise

High tides push up the surface level of Georges Bay by about the difference between the average low and high tide level. Storm surges push up the surface level of Georges Bay further.

In 2010, research was undertaken to project the contribution of extreme storm surges and extreme tides to the average sea level (Pitt & Sherry for Break O’Day Council). At the present day, the potential storm surge height of a 1% AEP event is between 1 and 1.1 m above the Australian Height Datum (AHD)⁹.

Sea level rise is estimated to add about 0.3 m to the mean sea level by 2050 and 0.9m by 2100, compared to 1990 levels. The estimates are based on sea level rise projections by IPCC, and were provided in a report to Council by WRL about sea level rise in Georges Bay¹⁰ (Mole & Carley, 2010).

As a result of a 1% AEP event, the potential storm surge height in Georges Bay will likely be around 1.4 metres AHD by 2050 and 2 metres AHD by 2100, as shown in the table below.

⁶ The contribution of the river flood to inundation levels within Georges Bay can be broadly estimated by assuming that an incoming tide will contribute to restricting the river water from exiting the bay. In the event that peak river flows occur for the full incoming tide, corresponding to fully restricted outflow from the bay, the inundation depth of freshwater can be estimated through simply distributing the inflowing volume evenly across the surface area of the bay. A simple bathtub model has been applied with no gradient modelled for the surface, whereby in reality the impact on the Georges Bay surface levels may be greater at the immediate inflow point of the river mouth and lower at the point of exit. It was also assumed the inflow is distributed directly and evenly over the bay.

⁷ The Average Return Interval, expresses the likelihood for an event to occur as the average number of years between occurrences of an extreme event.

⁸ The Annual Exceedance Probability is a way to express the likelihood for an extreme event to occur.

⁹ Australian Height Datum is used as a reference base for water surface levels, in Tasmania based on average sea level for 1972 at the tide gauges in Burnie and Hobart

¹⁰ The projections are largely in line with the IPCC high sea level rise scenarios. Since the IPCC projections were published, more recent research suggests sea level rise may exceed the IPCC projections.

TABLE 2 POTENTIAL STORM SURGE HEIGHT, GEORGES (M AHD), 2011-2100*

ARI	AEP	Present day	By 2050 or 0.3m SLR	By 2100 or 0.9m SLR
20	5%	1.00	1.30	1.90
50	2%	1.03	1.33	1.93
100	1%	1.06	1.36	2.96
1,000	0.1%	1.12	1.42	2.02

* Including sea level rise

Source: Pitt & Sherry (2011), derived from Mole & Carley (2010)

In addition to tidal storm surge and sea level rise, wind and wave setup also contribute to the Georges Bay surface level along sections of coast. Wind setup is influenced by the direction of the wind and the distances it travels over the bay (fetch distances). For Georges Bay, the fetch distances mostly lie between 2,000 metres and 5,000 metres. Combined, the wind and wave setup potentially add between 0.2m and 0.4m to the surface level in the case of a 1% AEP event, as shown in the table below.

TABLE 3 POTENTIAL WIND AND WAVE SETUP CONTRIBUTIONS TO THE GEORGES BAY SURFACE LEVEL

ARI	AEP	2,000m fetch	5,000m fetch
20	5%	0.13	0.30
50	2%	0.14	0.36
100	1%	0.16	0.40

Source: Pitt & Sherry (2011), derived from Mole & Carley (2010)

The fetch distance determines the setup contributions to a large extent as is evidenced by the difference in contributions between the 2,000m and 5,000m fetch.

2.3 Georges Bay Surface Levels

The Georges Bay surface level varies with river run-off and rainfall intensities, tides, storms and wave effects. The combined effects can lead to extreme surface levels. The most extreme heights occur with a lower probability.

To understand the future impacts of climate change on the surface level of Georges Bay during extreme events, upper and lower limits were calculated (Table 4 & Table 5). The range between these limits represents the likely future surface level heights that can be expected. The range also reflects the degree of uncertainty about the possible impacts of climate change.

At the upper limit of this range, the surface level could rise to about 2.3 metres AHD at present day, and to about 3.7 metres AHD by 2100 (Table 4). This would occur when a 1% AEP river flood coincides with both a 1% AEP storm surge event and a 1% AEP wind event. It assumes that these events are totally dependent. This estimate must therefore be seen as an upper limit, or at least that the annual probability of such a combined event is likely to be less than 1%.

If it is assumed that the event types are completely independent, the chance of them coinciding is much lower as can be seen in the table below (third column).

In reality, if there is an extreme storm event it will likely bring along *some* rainfall and wind. There is *some* relation between these types of meteorological conditions, but not a relationship of total dependency.

TABLE 4 UPPER LIMITS GEORGES BAY SURFACE LEVELS*, BY PROBABILITY (M AHD)

AEP Totally dependent	ARI Totally dependent	AEP Totally independent	Present day	2050	2100
40%	2	6%	1.17	1.51	2.13
18%	5	0.6%	1.42	1.83	2.47
10%	10	0.1%	1.62	2.05	2.69
5%	20	0.01%	1.82	2.35	3.04
2%	50	0.0008%	2.08	2.70	3.42
1%	100	0.0001%	2.27	2.96	3.71

*long fetch (5,000 metres) and assuming probabilities are totally dependent
Source: Pitt & Sherry (2010)

At the lower limit, assuming extreme river flood, storm surge and wind events are totally independent, a 1% probable extreme surface level event is expected to reach about 1.3 metres AHD at present day (Table 5). By 2100, and a sea level rise of 0.9 metre, a 1% probable extreme event would reach 2.3 metres AHD.

TABLE 5 LOWER LIMITS GEORGES BAY SURFACE LEVELS*, BY PROBABILITY (M AHD)

AEP Totally independent	ARI Totally independent	Present day	2050	2100
40%	2	0.90	1.20	1.80
18%	5	1.00	1.30	1.90
10%	10	1.05	1.36	2.00
5%	20	1.10	1.44	2.10
2%	50	1.19	1.55	2.20
1%	100	1.25	1.64	2.30

*short fetch (2,000 metres) and assuming probabilities are totally independent
Source: Pitt & Sherry, 2010

The table below is a summary of the projected increases to the surface level height in Georges Bay as a result of an extreme event with a probability of 1% and climate change. These are the combined effects of sea level rise, storm surge, extreme and increasing rainfall intensities and changes in river run-off.

Presently, the surface level may reach 1.25 metre AHD (lower limit) to 2.3 metre AHD (upper limit) as a result of an extreme weather event. With a sea level rise of 0.9 metres, which may occur around 2100, the surface level may increase to 2.3 metres AHD (lower limit) or up to 3.7 metres AHD (upper limit).

TABLE 6 SURFACE LEVEL AFTER AN EXTREME EVENT (1% AEP), 2011-2010

	Present day	2050	2100
Lower limit (m AHD)*	1.25	1.6	2.3
Upper limit (m AHD)**	2.3	3.0	3.7

* assuming river flood events, storm surge events and wind events are completely independent, and assuming a wind fetch of 2,000 metres

** assuming river flood events, storm surge events and wind events are completely dependent, and assuming a wind fetch of 5,000 metres

Source: Pitt & Sherry, 2011

At present day, parts of the town of St Helens floods as a result of heavy rainfall in combination with high surface levels in Georges Bay. During those extreme weather episodes, water cannot be drained quickly from the streets and the streets become inundated (see photo below).

FIGURE 3 FLOODING IN THE STREETS OF ST HELENS



As a result of climate change, the surface level of Georges Bay during extreme events will be higher in the future than at present day. Consequently, this will increase the frequency of arterial roads to/from St Helens being flooded, most notably Binalong Bay Rd. Also, it will become more difficult than at present day to drain excess water from rainfall out of St Helens. As a result, the town will become flooded more regularly and for longer periods of time (the effect of flooding from localised runoff in the town centre is not included in the modelling and the maps).

FIGURE 4 LAND SLIDE RISKS NEAR STIEGLITZ



There are some areas at risk of landslide that are in close proximity to Georges Bay. Rising surface levels can potentially undermine these sensitive shorelines thereby increasing the risk of landslide. This issue is most urgent in lower parts of Stieglitz. At most locations, St Helens Point Road lies lower than the residential properties. With sea level rise, the road would be affected increasingly during extreme events before residential properties above the highway would be affected next.

Note that all surface level values are 'best estimates' and subject to inaccuracies:

- Inundation depths for 1% AEP events may vary between 2.3 and 3.7 m AHD
- Water levels are assumed to increase evenly and directly (no time delay) over Georges Bay
- Coastal evolution (that is erosion and deposition of sediment changing the shape of the shoreline) is not taken into account
- Some internal dynamics of the bay have not been taken into account in the modelling.

2.4 Georges Bay Inundation with Climate Change

Future bay surface levels will increase as climate change causes sea levels to rise and there is increased river flooding. The following series of maps shows two features for a given sea level rise:

- The approximate shoreline given current topography, assuming little or no erosion
- The area flooded in a 1% AEP (100 yr ARI) extreme surface level event with an indication of the depth of flood.

These maps have been produced for present day and a sea level rise of 0.3m and 0.9m. These might be considered to be roughly 40 years and 80-100 years into the future. This corresponds roughly to the highest sea level rise rate estimated by the IPCC, Fourth Assessment Report. The current rate of sea level rise is just over 3 mm per year, double the average rate during the twentieth century and at the highest rate estimated by the IPCC.

The first map (Figure 5) shows current day flood levels of an extreme event (1% AEP). This and the following maps show the projected average inundation levels. These are the average of the upper and the lower inundation levels presented in the previous section (Section 2.3). Such an extreme event at present day would result in flooding of the area around the mouth of Georges River and Binalong Bay Rd would become flooded. If the event is combined with heavy rainfall in the town of St Helens, rainwater drainage is constrained resulting in the flooding of streets in the centre of town. Towards Stieglitz, along St Helens Point Road, segments of the road would become inundated too.

With a sea level rise of 0.3 metres, which may occur around 2050, an increased land area would be under water at the highest astronomical tide level (the basis of the estimated future shoreline). This means these areas would be under water for many high tides.

Figure 6 shows this is likely to occur in the area of the mouth of Georges River and Chimneys Lagoon at Stieglitz. Some of the land at St Helens Point may slowly become a wetlands area.

With a sea level rise of 0.3m, increasingly more sections of roads become under threat of inundation from a 1% AEP event. This is true for Binalong Bay Rd at the river mouth, St Helens Point Rd with stretches towards Stieglitz and Akaroa. Also, two to three sections of the Tasman Hwy, just south of St Helens, would become inundated as a result of a 1% AEP storm. The aquaculture farms along Binalong Bay Road and the Ben Lomond water sewage treatment plant will increasingly be subjected to inundation.

With a sea level rise of 0.9 metres, which is expected to occur around 2100, some of the areas alluded to above would become below the highest astronomical tide level (Figure 7). A significant section of Binalong Bay Road would be affected as it traverses an area that will virtually become part of Georges Bay. Road segments that were previously at risk of inundation would lie below the highest astronomical tide level. Increasingly, more (parts of) properties would lie below the highest astronomical tide mark. Aquaculture farms (onshore assets) and the sewage treatment plant would likely drown with 0.9m sea level rise.

FIGURE 5: LIKELY INUNDATION AT GEORGES BAY FOR EXTREME STORM EVENT (1% AEP), PRESENT DAY

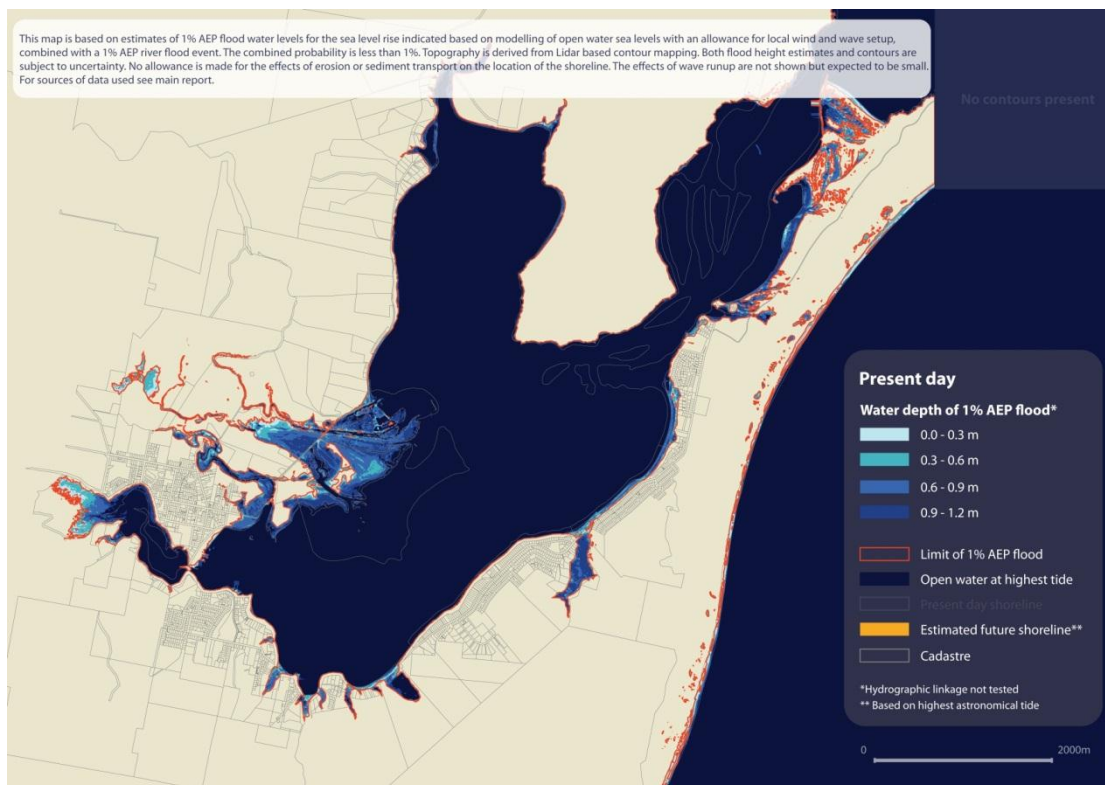


FIGURE 6: LIKELY INUNDATION AT GEORGES BAY FOR EXTREME STORM EVENT (1% AEP), 0.3 M SEA LEVEL RISE

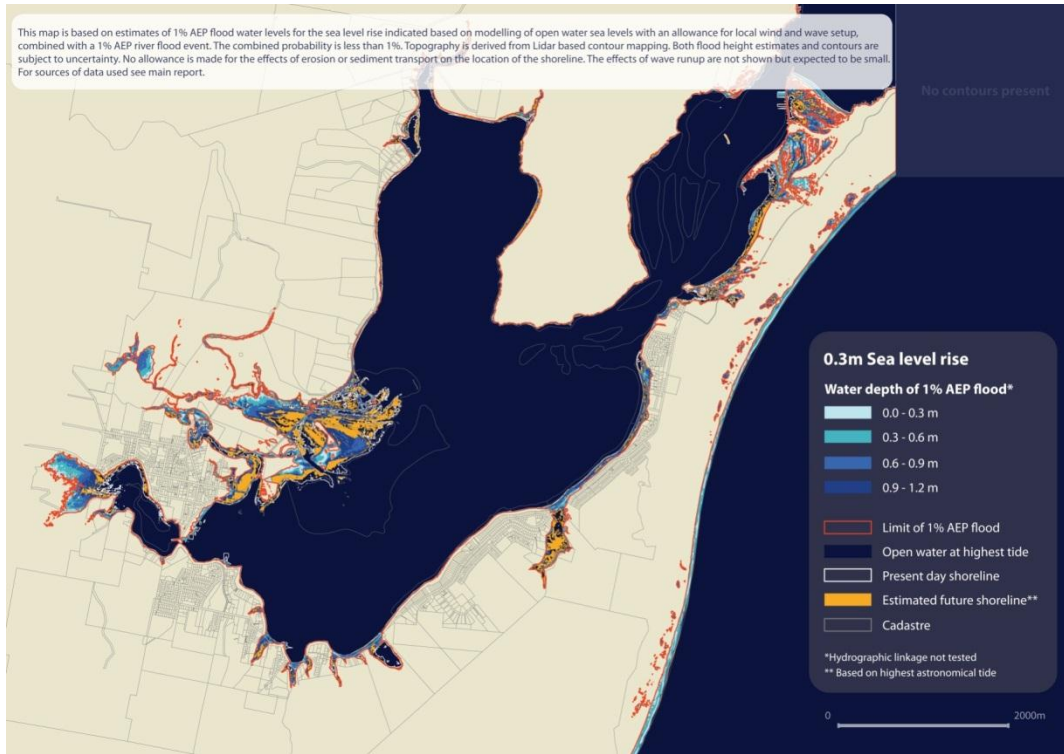
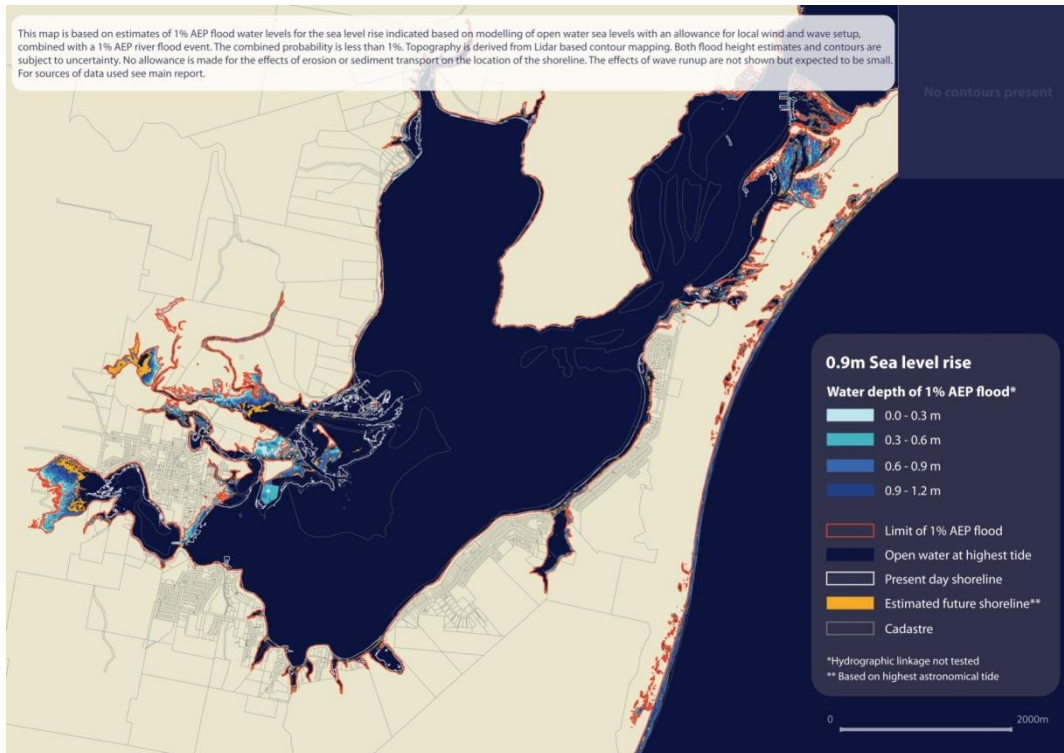


FIGURE 7: LIKELY INUNDATION AT GEORGES BAY FOR EXTREME STORM EVENT (1% AEP), 0.9 M SEA LEVEL RISE



3 PLANNING SCHEME MECHANISMS

This section describes how the current planning scheme deals with coastal risks in Break O'Day municipality.

As part of Step 2 (interim planning scheme amendment in hazard areas) of the adaptation pathway process, the current planning scheme of Break O'Day Council and relevant regional directions were reviewed.

3.1 Regional Context

As part of the regional planning initiative and the *Planning Directive 1 – The Format and Structure of Planning Schemes (May 2011)*, municipalities are working towards new planning schemes based on the new Planning Scheme Template for Tasmania. This will align future planning schemes including consistent zonings, layout and terminology. It is intended the new planning schemes take effect in 2012.

Since more data and knowledge is required prior to implementing measures, the Tasmanian Planning Commission initiated the Tasmanian Coastal Vulnerability Project. The project aims to deliver GIS map layers identifying inundation and erosion risks in coastal areas under various climate change scenarios.

The Tasmanian Planning Commission has established a Coastal Planning Advisory Committee to scope the advancement of the Tasmanian coastal planning framework.

The Department of primary Industries, Parks, Water and Environment (DPIPWE) has developed tools to assist with risk-based management and planning for infrastructure, assets and values in coastal zones¹¹.

At the regional level, it is important to note that in October 2011 the Minister for Planning declared the *Regional Land Use Strategy of Northern Tasmania*. The strategy identifies key strategic land use issues that need to be resolved. Natural Hazards; Climate Change Adaption; and Coasts, Waterways and Wetlands are addressed in the framework under Part D – Regional Planning Policies. Among other things, it recognises the need to identify areas at high risk of sea level rise, storm surge inundation and shoreline recession.

Vision East Land Use Framework was undertaken to consider the particular strategic issues for the east coast of Tasmania. Vision East does not have statutory status. Clause 5.2 of the framework recognises that climate change may increase the likelihood of natural hazards and risks. Sea level rise, storm surge and flooding are key hazards.

Policies contained at Clause 5.2 that are relevant to climate change effects on coastal areas include:

1. Apply the precautionary principle when considering climate change risks.
2. Protect and extend carbon sinks to assist in reducing climate change effects.
3. Plan for sea level rise in accordance with relevant State policy.
4. Manage development in areas subject to inundation, flooding, bushfire, and instability, having regard to future trends and relevant State policies.

The policies are not always clear and provide little direction. The precautionary principle requires caution about causing serious irreversible damage to the environment in the face of uncertainty.

¹¹ DPIPWE (2010), *Tasmanian Coastal Works Manual: A best practice management guide for changing coastlines*.

3.2 Break O’Day Council Planning Scheme 1996

The Break O’Day Planning Scheme uses zone and code provisions to address the impacts of natural hazards.

Coastal risks are addressed in the zone provisions as ‘**Development in areas at risk from natural hazards**’ and the issue is addressed in the Urban Zone (Clause 7, Issue 6), Natural Resources Zone (Clause 10, Issue 8) and the Environment Protection Zone (Clause 11, Issue 10). The objective is to ‘ensure that natural hazards are identified and addressed at the time of development’.

In regards to ‘**Development in areas at risk from natural hazards**’ the provisions rely on the applicant to identify and assess hazards, without providing standards in relation to methods and required professional standards. The provisions do not define the terms ‘moderate risk’ and ‘high risk’, nor does it demonstrate how it responds to changing levels of risk as sea levels rise.

Coastal risks are addressed at Clause 19 Siting of Development Code, Issue 3 ‘**development on coastal landforms**’. The objective is ‘to ensure that development of unstable land forms does not result in degradation of those landforms’. It restricts development in certain coastal environments without assessing the actual risk of sea level rise. It does not recognise that risk may change over time.

3.3 Break O’Day Council Draft Interim Planning Scheme 2011

Break O’Day Council has drafted a new planning scheme using the new state planning template to align with the *Regional Land Use Strategy of Northern Tasmania*. The Interim Planning Scheme is still in draft form.

The draft Break O’Day Planning Scheme still uses zone and code provisions for addressing coastal vulnerability. There are three new codes in the draft planning scheme which relate to coastal vulnerability: the Landslip Zone, Flood Prone Areas Code and the Coastal Code. The Siting of Developments Code which was in the 1996 Planning Scheme has been removed.

A greater number of zones contain provisions relating to **Development in areas at risk from natural hazards**:

- General Residential Zone
- Low Density Residential Zone
- Village Zone
- Rural Living Zone
- Environmental Living Zone
- Rural Resource Zone
- Environmental Management Zone.

The Environmental Living Zone and the Rural Resource Zone also contain restrictions on the proximity of subdivisions to the high water mark.

The planning scheme does not however identify timeframes to the high water mark. It is further required to set back 1 kilometre from the high tide mark, which does not reflect actual coastal vulnerability. This may therefore overestimate actual risk for elevated rocky shores and potentially underestimate risk for flat, low lying coastal plains over the life of a longer lived asset.

In regards to the code provisions, the planning scheme does identify an acceptable level of risk for flood prone areas. The scheme does not however identify a timeframe for risk and does not consider changes in risk explicitly. In relation to development in coastal dune systems the scheme does not identify (un)acceptable levels of risk and does not recognise changes in risk over time.

4 COST OF RISK

This section assesses properties at risk of being affected by inundation or sea level rise to 2100. The total risk is expressed in net present value, which is the present day value (in \$) of future costs of damage (cash flows).

This analysis relates to Step 3 of the adaptation pathway process.

In reading this section, it is important to define the term **risk**. Risk is the result of the **total damage** times the **probability** of an event happening. While the total damages of an event actually happening can be very substantial, the probability of it happening is often quite low. Therefore, the total risk (in \$) may be substantially below the total damages of an extreme event.

The analysis of the costs of risks presented here are for private properties and agricultural structures only. Infrastructure, public amenities and open space also may be damaged by coastal inundation. The same level of information about the cost of damage as a result of flooding is not readily available for infrastructure as it is for dwellings. However, further consultation with some infrastructure agencies is expected to provide some indication of expected costs.

A description of the method to determine risks is provided in Appendix 1.

4.1 Inundation Risks

The key findings about inundation risks in Georges Bay are summarised below¹²:

- Around 35 dwellings and agricultural structures along the coastline of the study area are at risk of inundation at present-day¹³. Of those, 30 improvements have a less than 10% chance of above-floor flood. The rest of those at present day risk have an over-floor flood chance of more than 20%.
- With a sea level rise of 0.25 m (expected by about 2050), there will only be 9 additional structures at potential inundation risk. However, the chance that those at present-day risk get flooded is likely to triple from 5% (with no sea level rise) to 15%.
- With a sea level rise of 1 m (expected by about 2100), those at present-day risk are expected to get flooded even more frequently, with an average probability of 60% for a 0 – 1 m flood depth and a probability of around 5% for a 1 - 3 m flood depth.
- By 2100, there will be an additional 86 improvements (eg buildings or dwellings) at some level of risk from flooding, with 47 of those located in St Helens suburb. Of those at potential risk in 2100, up to 50 improvements will be inundated by a 1% AEP (100 year ARI) flood with an average above-floor depth of 0.9 m. The 1% AEP is generally regarded as an indication of what is perceived as an acceptable level of risk.

The table below shows the estimated number of properties in Georges Bay that would be flooded above floor level by an event with a 1% AEP (100 year ARI) at present day sea levels, with 0.25 m sea level rise and with 1.0 m sea level rise.

¹² In order to calculate net present values, it was required to link specific years to specific levels of sea level rise. For modelling purposes, 0.25m sea level rise with 2010 as a base level was linked to 2050 and 0.9m to 2100. These levels are reasonably consistent with the levels referred to earlier that are based on levels determined by IPCC and compare sea level rise to 1990 sea levels. Nonetheless, there is uncertainty about the exact levels of sea level rise that will occur in the future.

¹³ Risk, if not specified, refers to more than 0.01% chance of having an over floor flood.

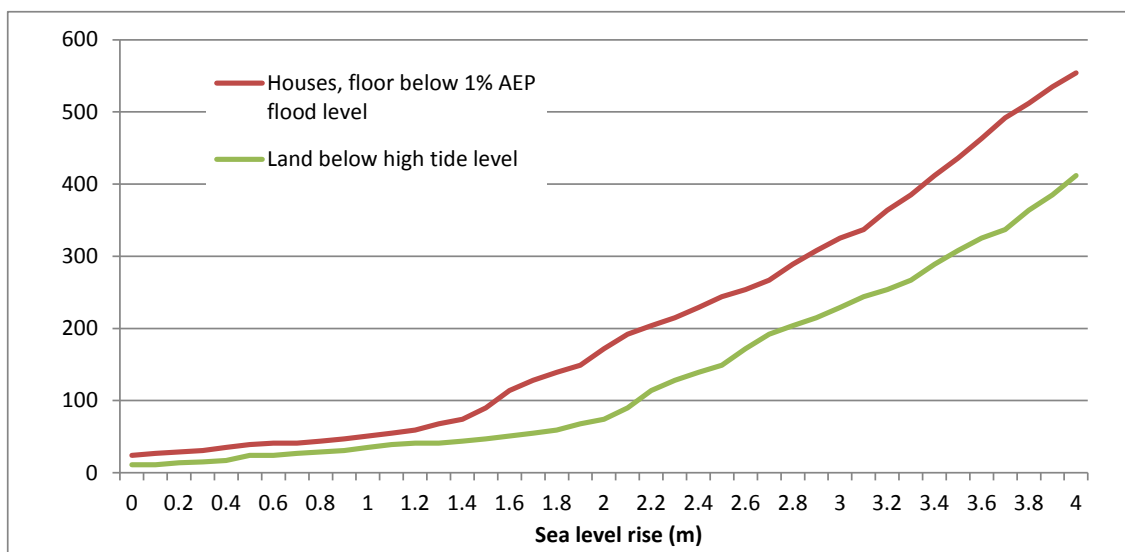
TABLE 7: INUNDATED PROPERTIES AND OVER-FLOOR DEPTH CAUSED BY 1% AEP FLOOD

	Estimated No. of inundated properties	Average over-floor depth (m)
No sea level rise (present day)	18	0.32
0.25 m (perhaps by 2050)	22	0.47
1.0 m (perhaps by 2100)	43	0.82

Source: SGS estimates (2011)

The figure below (Figure 8) shows the number of dwellings with floor below the flood level of a 1% probable event. The number of dwellings below the flood floor level increases slowly up to about 1.3 m of sea level rise. With a sea level rise of more than 1.3 m, the number of dwellings potentially affected by a 1% probable storm increases more quickly.

FIGURE 8: DWELLINGS AFFECTED BY A 1% AEP FLOOD AND PARCELS BELOW THE HIGH TIDE LEVEL, GEORGES BAY



Source: SGS (2012)

4.2 Property Risks

The estimated risks (structure damages x probability) to dwellings and agricultural structures are likely to increase over time as a result of climate change. The previous section indicated that some dwellings will become flooded on a very regular basis in the future with climate change. It is most likely that owners of these properties would not continue to reinvest without proper protection, reducing the chance for further future damages. As a rule of thumb, properties are likely to be abandoned or properly protected once the risk of a flood exceeds 10% of the structure replacement value.

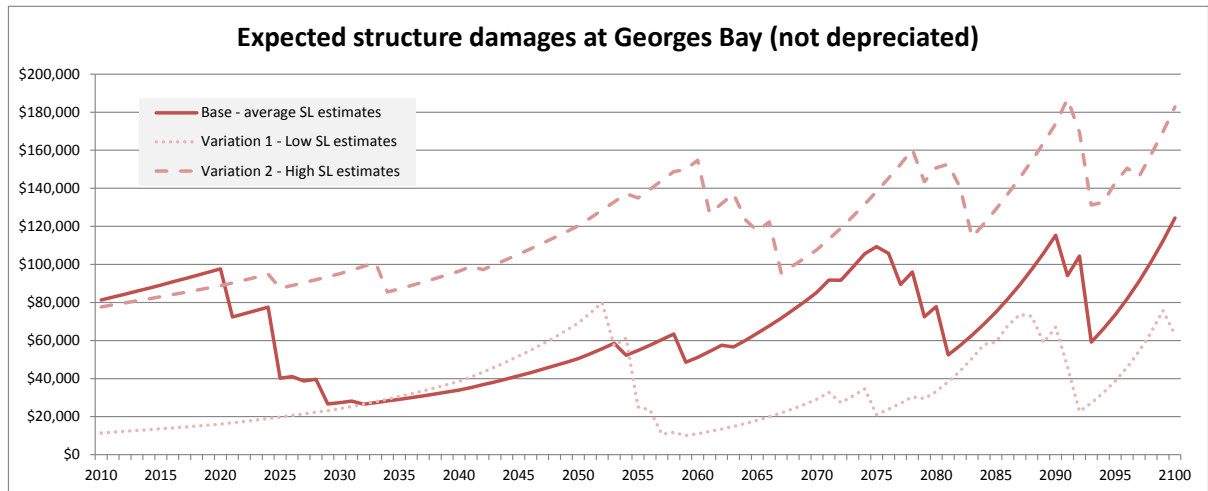
The charts below depict the expected risks (structure damages x probability) in dollar values over time. As there is some uncertainty in flood frequency estimates and land elevation levels, the risks to properties in Georges Bay over time were calculated according to three cases to test the sensitivity of the outcome to this uncertainty:

- Base case – based on the average surface height levels of the upper and the lower limits (1% AEP) presented in section 2, Coastal Hazards
- Variation 1 – based on the lower limit projected surface height levels (1% AEP)
- Variation 2 – based on the upper limit projected surface height levels (1% AEP).

The estimated risk is calculated for each property within the study area for each year by considering likelihood/probability of different surface levels occurring and associated structure damages (derived from the damage curve) with climate change. The total risk in Georges Bay is a sum of the risk to all properties.

The figure below shows the risk to structures assuming the properties are fully maintained over time with a minimum level of depreciation in structure value (Figure 9). The curve has a zig zag pattern because the risk to a structure is no longer accounted for once it reaches 10% of the replacement value in any one year.

FIGURE 9: EXPECTED ANNUAL FLOOD DAMAGES IN GEORGES BAY, WITHOUT DEPRECIATION

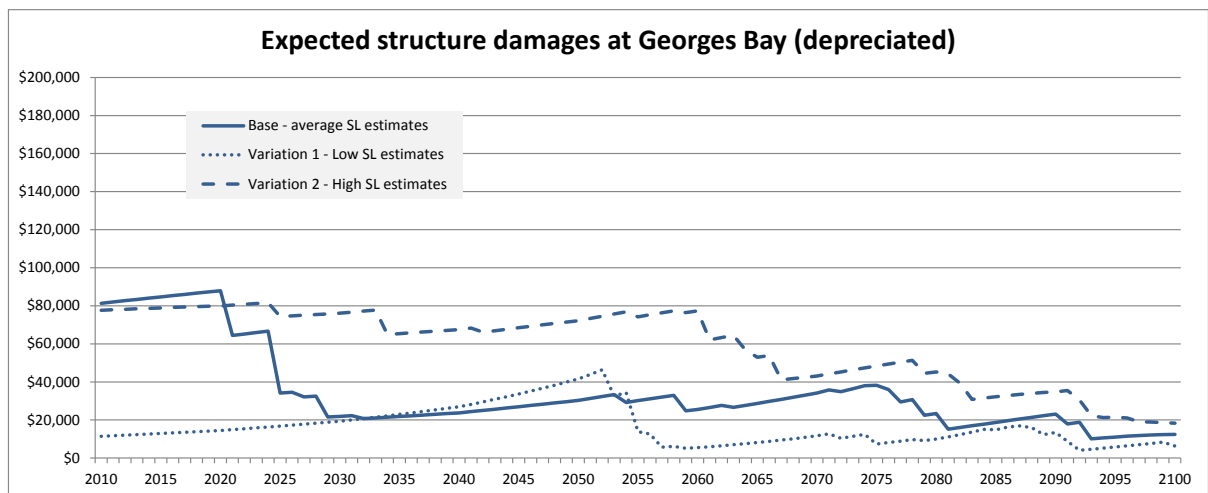


Source: SGS (2011)

If the properties are fully maintained and renewed over time (but are not expanded or upgraded), with minimum level of depreciation in structure value, the structure damages at Georges Bay by 2100 are expected to be around \$180,000 per year under variation 1 and almost \$60,000 under variation 2.

If the structure value is assumed to be fully written off in 100 years (with 1% depreciation rate per annum), and no new investment in the affected dwellings, the expected damage per annum by 2100 is significantly lower and likely to be under \$20,000 under the three variations (Figure 10).

FIGURE 10: EXPECTED ANNUAL FLOOD DAMAGES IN GEORGES BAY, WITH DEPRECIATION



Source: SGS (2011)

The net present values (NPV) of these expected future coastal inundation structure risks are calculated using a real discount rate of 5% per annum and are provided in the table below (Table 8).

Without structure depreciation (i.e. assuming ongoing investment on maintenance and capital upgrade), the NPV of the future risks amounts to \$1.4 million under the base case¹⁴, with a wide range from about \$0.5 million up to \$1.9 million if the low and high variations are considered.

If the properties in Georges Bay are assumed to be fully depreciated in 100 years (i.e. not properly maintained and upgraded), the NPV of the structure risks is \$1.1 million under the base case, with a range of between \$0.4 million and \$1.6 million.

TABLE 8 NPVS OF TOTAL STRUCTURE DAMAGES (\$ MILLION)

	Variation	NPV of total structure damages
Without structure depreciation	<i>Base case</i>	\$1.4
	<i>Variation1 (lower limit)</i>	\$0.5
	<i>Variation2 (upper limit)</i>	\$1.9
With structure depreciation	<i>Base case</i>	\$1.1
	<i>Variation1 (lower limit)</i>	\$0.4
	<i>Variation2 (upper limit)</i>	\$1.6

Source: SGS estimates, 2011

Most of the flood risk expressed as NPV is incurred by the properties at present-day risk. The table below shows that the total risk to structures at present day risk is high compared to their value: 34% compared to a negligible 0.08% for properties at future risk, according to base case and without depreciation. Also the vast majority of the present day value of risk is borne by properties that are at present day risk: \$1.4 million is borne by structures at present day risk and only about \$3,000 is borne by structures at risk with 1 m sea level rise (no depreciation, base case).

TABLE 9 NPV'S AS SHARE OF STRUCTURE VALUE

		<i>Structures with at least some present day risk</i>	<i>Structures not at present day risk, but at risk with 1m SLR</i>
	Current value (\$m)	\$4.0	\$14.0
	Number of structures	35	95
No depreciation	<i>Base scenario</i>	34%	0%
	<i>Variation1 (lower limit)</i>	12%	0%
	<i>Variation2 (upper limit)</i>	47%	3%
With depreciation	<i>Base scenario</i>	29%	0%
	<i>Variation1 (lower limit)</i>	9%	0%
	<i>Variation2 (upper limit)</i>	22%	2%

Source: SGS calculations, 2012

Although the expected risk seems relatively low in today's value, the damage of an extreme storm event when it actually does occur can be quite significant. The table below (table 10) shows the potential damage caused by an extreme storm with a 1% probability of occurring. It shows that a flood of 1% chance could result in a total damage of around \$3 million in 2100 under the base case if the dwellings are well maintained.

¹⁴ It is the net present value of all the annual costs shown in Figure 7 up to 2100

TABLE 10: TOTAL DAMAGES CAUSED BY 1% AEP FLOOD

Variation		Total damages caused by 1% AEP (100 yr ARI) flood		
		2010	2050	2100
Without structure depreciation	<i>Base scenario</i>	\$870,000	\$1,300,000	\$3,000,000
	<i>Variation1 (lower limit)</i>	\$260,000	\$490,000	\$2,000,000
	<i>Variation2 (upper limit)</i>	\$2,000,000	\$2,500,000	\$5,700,000
With structure depreciation	<i>Base scenario</i>	\$870,000	\$770,000	\$300,000
	<i>Variation1 (lower limit)</i>	\$260,000	\$290,000	\$200,000
	<i>Variation2 (upper limit)</i>	\$2,000,000	\$1,500,000	\$600,000

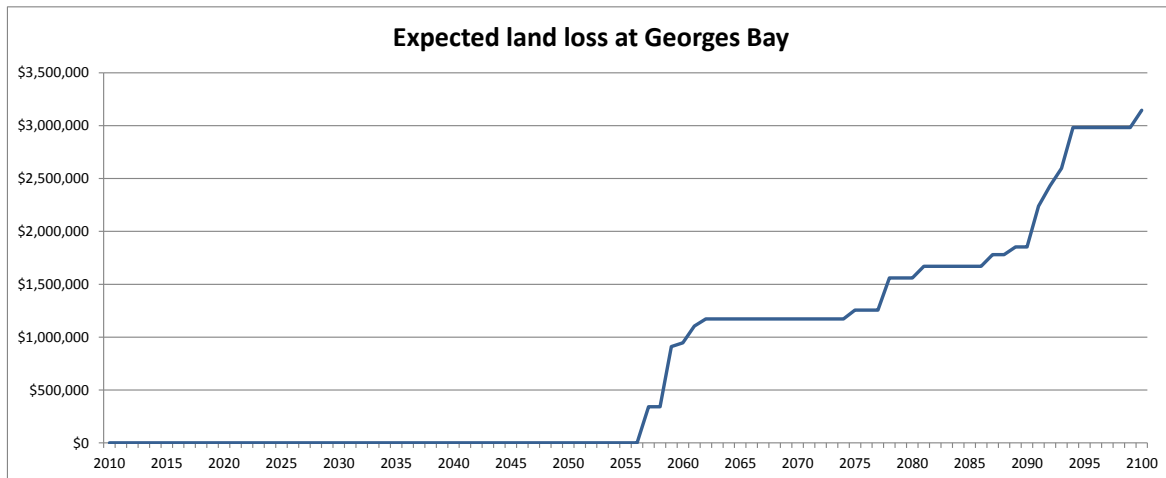
Source: SGS estimates (2011)

A significant share of potential damage in the future will be contributed by those dwellings that are at risk today. For the base case without depreciation, about 70% of damage is contributed by a handful of dwellings for a present day 1% AEP flood. By 2050, 50% of damage is still contributed by that same handful of dwellings. In 2100, 61% of the approximately \$3 million worth of damage is generated by those same properties.

As noted above, the most affected dwellings would likely see some form of response to reduce costs before the end of the century, either rebuilding above flood levels or retreating.

In addition to the structure damages as a result of the over-floor flood, we have estimated the value (Valuer General valuation) of land lost over time as the land is submerged. The figure below (Figure 11) shows the land value loss over time in Georges Bay based on the assumed future sea level rise.

FIGURE 11: EXPECTED LAND LOSS AT GEORGES BAY (CUMULATIVE)



Source: SGS (2011)

If nothing is done to raise the land affected or to otherwise protect structures on this land, residential and farm land will gradually be lost. With a 1 m sea level rise, which could occur by about 2100, 19 parcels of land may be lost with a total value of about \$3.1 million. The NPV of these losses is around \$160,000.

Other Costs

The calculations above include estimates of costs from flooding from the sea and river flooding for private property (land and dwellings). These estimates do not include risks and damages:

- To public infrastructure (roads, street lighting, water supply, sewer, damage to the sea wall, sports fields or other public amenities)
- To commercial premises in St Helens township
- From erosion, with known issues along the Binalong Bay Road and potential contributions to land slip near Stieglitz
- To other commercial infrastructure (telephone, electricity supply)

It is anticipated that most significant future damages would be incurred by the infrastructure providers in the area such as Council, Ben Lomond Water and DIER. To minimise damages, roads would need to be raised, bridges built, the sewage treatment plant raised, the pump station and pipes sealed and the street drainage system improved and possibly supported by a pump system.

Conclusion

In summary, the dwellings at present-day risk are expected to experience some substantial damages over time, along with future sea level rises, which represent 29% to 34% of the replacement value in NPV terms under the base case. This risk level far exceeds what is normally considered an acceptable level (i.e. about 5%), as discussed in Appendix 2.

The total cost of risk (in present day values) to structures is between **\$1.1 million and \$1.4 million to 2100**, depending on whether owners continue to maintain their dwellings. If 1% AEP flood levels reach the upper limit variation, then the total cost of risk would be between \$1.6 million and \$1.9 million.

In addition, by 2100, about 19 parcels are expected to be mostly underwater at most high tides and may be lost to occupants with an estimated net present value of **\$0.2 million**.

The estimated damages of an extreme storm event actually occurring can be significant. **By 2100, an extreme storm event (1% AEP) is estimated to cause \$3 million worth of damage** (base scenario, without structure depreciation) if the existing buildings or comparable ones are still in their current locations and elevations.

The majority of the risk up to 2100 is borne by a relatively small numbers of properties, including the few dwellings that are at some risk today. It is also likely that the dwellings at present day risk would likely see some form of response to reduce costs before the end of the century.

Over time, the risk and the number of dwellings affected are expected to increase, and this pace is expected to pick up as well. There are only 18 dwellings with floor levels estimated to be below the 1% AEP flood inundation height from a bay flooding event. By 2050, there will be about 22 dwellings with floor levels below the 1% AEP flood level. By 2100, about 43 dwellings will have floor levels below 1% AEP level.

The flood estimates are based on the effects of sea level rise and river flooding on bay inundation.

In practical terms:

- Well maintained, high quality buildings (with a long expected lifetime) that are close to or below the 1% AEP flood level would be well advised to invest¹⁵ in flood protection measures, such as flood skirts, that can be deployed when required **and** to pay attention to extreme weather forecasts.
- The owners of buildings that are either in poor to modest condition, or have been damaged by flood events, and that are close to or below the 1% AEP flood level, should consider whether it is worth reinvesting in the existing building or demolishing and rebuilding at a level above the flood or in a form that is resistant to flood damage.
- All occupants in hazard areas with properties at some risk, even if only for extreme events with a probability below 1% AEP, should have and rehearse an emergency response plan.
- Governments have an interest in prohibiting redevelopment that will be affected by a higher than acceptable risk of damage during its lifetime, including discouragement of reinvestment in existing properties that are, or will, be at higher than acceptable risk over their lifetime. However, such risks can be addressed by raising dwellings by relatively modest amounts even for quite long lifetimes.

¹⁵ Up to 20% of the structure's depreciated value assuming a 50 yr lifetime.

5 VALUES

In contemplating appropriate responses to sea level rise, it is important to also consider the benefits of occupying hazardous areas.

People occupy and use areas near the coast, some of which are exposed to coastal hazards, because they derive value from doing so. In fact, coastal property values are typically higher than similar sized properties inland, showing the premium value placed on these areas. Other public, natural and economic values are major contributors of value from the 'use' of the coasts.

If the planning response to sea level rise prevents all (re)development in areas potentially at risk, many of the values from using and occupying these areas would be foregone, while other natural values may or may not gain from excluding development.

This section describes the private property values and other benefits of the Georges Bay coastal location. Property values and the factors that drive differences between land values (eg a premium placed on waterfront blocks compared to inland blocks) are relatively easy to evaluate. However, the attractions of the suburb as a whole may be increased by the setting shared by all property in the suburb – the presence of a beach and natural areas as well as man-made amenities and services (eg St Helen's town centre). Natural areas may enhance property value, but they also provide benefits to the wider community, as discussed below. However, these benefits are harder to evaluate – there is no clear market to demonstrate their value – and may be quite variable for different people.

The reporting in this section relates to the work and findings of Step 5 of the adaptation pathway process: Value of Coastal Hazard Areas.

Private property values

Residents in hazardous areas derive a private property benefit from living in these areas. In order to assess the potential impacts of climate change and adaptation measures on coastal properties, one needs to understand how significant the premium of living there is. Once established, it is possible to assess how this value (private premium) may change as a result of climate change and adaptation. For instance, planning measures to prohibit development in hazardous locations may result in loss of value due to some of the examined characteristics (for instance, beach front access).

Regression analysis was undertaken to determine the contributions to the value of land of various attributes, such as lot size, proximity to the beach and proximity to services.

Other values

Additional analysis was undertaken to better understand the 'other' values of the coastal area. These different values affect different people in different ways and interact with each other. These other values are often of a more intrinsic nature and include:

- natural values, such as natural beauty and habitat for threatened species;
- public or social values, such as enjoying and recreating at the beach, fishing, amenity values, exercise opportunities that promote an active and healthy lifestyle; and,
- economic values, such as the number of jobs in coastal related economic activities, such as commercial and recreational fishing and tourism.

5.1 Private Property Values

The following factors¹⁶ determine and contribute to land value in Georges Bay:

- Lot area (square metres)
- Distance from industry (metres)
- Distance from bay (metres)
- Elevation (metres)
- Bay front access (yes or no)
- Land slip prone location (yes or no).

Some of these variables, such as waterfront access and elevation, may place the property in a potentially hazardous location.

The key findings of the analysis show that:

- The constant is the value of a lot when all other land attributes are zero. It can be interpreted as the average intrinsic value of land in the study area. In this case, the intrinsic value of \$65,641 represents 68% of the average value of the land parcel.
- One additional square metre of lot area will, on average, increase land value by \$11.
- Each metre distant from industry increases land value by \$1.5. The average distance from industry is 3,703 metres and the average contribution to land value of this variable is \$5,628.
- Each metre from the bay reduces land value by \$59. This shows that lots closer to the bay have greater value.
- Each metre elevation above the average sea level increases the value of land by \$550.
- The value derived from having bay front access is \$59,390.
- The value of lots located in land slip prone areas is reduced by \$32,100.

In Georges Bay, no properties are expected to lie below the average high tide level at present day or with 0.25m sea level rise (about 2050). By 2100, and an assumed sea level rise of 1 metre, about 10 properties would risk being under water at high tide. Bay front access is a common characteristic among these properties.

In addition, there are 8 dwellings¹⁷ at risk from inundation from a 1% AEP event at present day. With a sea level rise of about 0.25m, which could occur by about 2050, there may be 12 dwellings at risk, and with a 1.0m sea level rise (about 2100) there may be 23 dwellings at risk.

About 30% of the land value of the properties at risk of being flooded at high tide by 2100, and those at risk from inundation by a 1% AEP flood event, is derived from the fact they have a bay front location.

TABLE 11: VALUE COMPOSITION FOR LOTS AT RISK BY 2100

	Below annual high tide		Flood risk of 1% AEP	
	Land value (\$)	Share of value (%)	Land Value (\$)	Share of value (%)
Total value due to bay front access	\$0.4	27%	\$0.8	29%
Total value due to intrinsic value, land slip prone location and distance from bay	\$0.5	38%	\$1.2	44%
Total value due to other attributes	\$0.5	35%	\$0.8	27%
Total estimated land value	\$1.4	100%	\$2.8	100%

Source: SGS (2011)

To entirely exclude future development on these properties, either if an owner wishes to extend or redevelop the existing structure, would largely destroy that land value for property where the structure is nearing the end of its service life. If such a policy was applied to land susceptible to a 1% AEP storm event by 2100, up to \$2.8 million of land value would be lost over time.

¹⁶ Full definitions of these variables and their derivations are provided in Appendix 3.

¹⁷ Excluding any agricultural structures which were included in the risk analysis..

For property owners, it would be worth spending up to about \$60,000 per property for methods that protect the property but do not compromise the amenity achieved from a water front location, as an alternative to restricting development.

5.2 Other Values

Natural Environmental Values

The natural values of the St Helens study area are closely related to its tourism and recreational capacities. The beaches and Georges Bay are recognised as areas of natural beauty. In addition, the study area is part of the St Helens Important Bird Area which consists of Paddys and St Helens islands, Maurouard Beach and Peron Dunes and the inner parts of Georges Bay. The bay has intertidal flats that are important feeding areas for birds, such as the Pied Oystercatchers.

The Humbug Point Nature Recreation Area lies for an important part within the study area. St Helens Point State Recreation Reserve lies partly within the study area. Both are reserves recognised by the Tasmanian Parks & Wildlife Service within the category of 'other reserves', and they are not categorised as national park or heritage area.

In terms of conservation significance, Georges Bay was ranked Class D, an estuary of low conservation significance, meaning that the estuary and associated catchment have been moderately degraded by human impacts (Edgar et al., 1999). The report recommended the estuary should be made available for a variety of recreational and commercial purposes, and remediation processes should be assisted where practical.

The estuary provides the production environment for commercially farmed oysters. Water quality and salinity are important for the growth and health of the oysters (among which TAFI, 2007). These conditions may be impacted by increased fresh water inflow from Georges River and sea level rise.

Public and Social Values

The key recreational values are the beaches, Georges Bay and the access to the sea. Recreational fishing takes place in Georges Bay and Georges Bay also provides access to the sea for marine fishing.

Georges Bay is a key element of the identity of St Helens and the other towns around the bay.

There are a significant number of seasonal residents in St Helens who own shacks and second homes.

Economic Values

The economic values that are relevant to the study area are dominated by the tourism, fishing and aquaculture industries, with some contribution from farming on the Lower Georges River flood plain. The first three industries depend strongly on the natural and recreation values the study area has to offer.

Tourism is closely related to the natural values of Georges Bay: its beaches, bird watching, fishing opportunities and access via the bay to the sea, which offers additional fishing opportunities. There are reportedly 11 recreational fishing vessels operating from St Helens (MAST, 2007). There is one known fishing charter operator but it is likely that some of the commercial fishermen also provide for occasional charters.

According to data published by Tourism Tasmania, the St Helens area attracts approximately 70,000 interstate visitors per year that stay 2.1 days on average (average over a four year period from July 2007 to June 2011). There is no available estimate of the number of intrastate visitors.

According to the ABS Journey to Work data, the Break O'Day municipality provides approximately 181 tourism jobs. This represents 11.1% of the local economy, which is a significant share. A large portion of these jobs would be located within the St Helens study area. The total expenditures by interstate visitors to the St Helens area are estimated to have reached an average \$25 million per year over the last four years.

The aquaculture industry in the study area consists of oyster farming. The industry provides for 39 jobs and represents 2.4% of total employment within the municipality. The industry indirectly generates jobs in the processing and transport industries. The relative value add of this industry is high. Oyster farming occurs in Georges Bay. The Bay is fed with fresh water from Georges River. High rainfall events can temporarily affect the salinity levels of the water in the bay, thereby impacting the oysters. Also, concerns have been raised about the water quality of fresh water streaming into the bay, especially after heavy rainfall. These concerns relate to the presence of toxins (from herbicides and/or natural sources) in the water. There have been several events where high levels of oyster mortality occurred after heavy rainfall. As an example, more than 90% oyster mortality occurred after the major flood event in January 2004. The commercial value of cultivated oysters that died following the 2004 flood event has been estimated by the farmers to be worth \$1.6 million (Tasmanian Seafood Industry Council).

The commercial fishing industry has a long established history in the St Helens area. In 2006, the industry provided for 21 jobs in commercial and marine fishing in the municipality. This represents 1.3% of total employment. The port of St Helens is reportedly also used by vessels from elsewhere. According to DPIW data, in 2006/07 there were 34 vessels using the port for rock lobster fishing and eight vessels for scallop fishing (MAST, 2007). There are about 15 commercial fishing vessels based at St Helens.

The table below provides a summary overview of the natural, social and economic values of Georges Bay.

TABLE 12 SUMMARY OVERVIEW OF NATURAL, SOCIAL AND ECONOMIC VALUES OF GEORGES BAY

Value	Description	Quantity / Order of Magnitude
natural areas	beaches, Georges Bay (IBA), Humbug Point Nature Recreation Reserve and St Helens Point State Recreation Reserve	<ul style="list-style-type: none"> reserves recognised by P&W, not as national parks or heritage areas Georges Bay is part of the St Helens Important Bird Area
enjoyment of natural areas	recreation and amenity	<ul style="list-style-type: none"> 2,004 residents 150,200 interstate visitors
boating and fishing	recreation	<ul style="list-style-type: none"> 2,004 residents 150,200 interstate visitors
tourism	tourism industry	<ul style="list-style-type: none"> 180.5 jobs 11.1% of total employment
aquaculture	Jobs oyster farms in Georges Bay	<ul style="list-style-type: none"> 39 jobs 2.4% of total employment
fishing (professional)	jobs/income/turnover generated by fishing activities	<ul style="list-style-type: none"> 21 jobs 1.3% of total employment
		<ul style="list-style-type: none"> Approx. 15 vessels based in St Helens
	jobs in recreational boating	<ul style="list-style-type: none"> 3 jobs 0.2% of total employment
		<ul style="list-style-type: none"> Approx. 11 vessels for charter fishing

5.3 Conclusion Georges Bay Values

Properties in the Georges Bay area have significant value premiums due to their frontage to the bay. For some properties, this bay frontage also means that they are susceptible to the potential increased bay surface levels as a result of sea level rise, intense rainfall events and extreme wind events. Under the influence of climate change, these properties have increased risks of being affected. Also, increasingly more properties may be affected by these risks. By 2100, about 10 properties would lie below the average high tide mark of the bay, and 23 residential properties would be at risk of being flooded by a 1% AEP surface height event.

To entirely exclude future development on these properties, either if an owner wishes to extend or redevelop the existing structure, would largely destroy that land value for property where the structure is nearing the end of its service life. If such a policy was applied to land susceptible to a 1% AEP storm event by 2100, up to \$2.8 million of land value would be lost over time.

For the property owners it would be worth spending up to about \$60,000 per property in methods that protect the property but do not compromise the amenity achieved from a water front location, as an alternative to restricting development.

The natural values of Georges Bay include bird areas of natural beauty, feeding areas, beaches and fish habitat. The bay is also the production environment for commercially farmed oysters.

The natural values of the estuary have been moderately impacted by human activity. Amongst other things, this would mean that the estuary can be used for a variety of recreational and commercial purposes. Remediation processes should be assisted where practical.

The Georges Bay area is an intrinsic part of the identity of the region and is greatly valued by its residents. The bay has a range of recreational values, including beaches, fishing and access to the sea.

The tourism sector in the Georges Bay area is significant and relies significantly on the natural and recreation values the bay has to offer.

Extreme river flooding events (due to rainfall) as a result of climate change have the ability to impact on the salinity and the water quality of the bay on a more frequent basis than at present day. Massive oyster mortality and significant economic damage after the January 2004 storm suggests future losses may become more significant.

6 ADAPTATION OPTIONS

6.1 What if nothing is done?

Before discussing any options to adapt to projected impacts of sea level rise, it is important to consider what would happen if nothing is done. That is, what would the impacts be if nature were to take its course and no measures were undertaken to manage the risks?

Georges Bay experiences high water levels as a result of storms, rainfall, river run-off and tidal effects. Over time, the surface level will increase further as a result of sea level rise and more intense river flooding¹⁸.

Even for present day conditions, extreme events result in road flooding, most notably at Binalong Bay Road and sections of the Tasman Hwy and St Helens Point Rd. The town of St Helens gets inundated regularly when water from rainfall cannot be drained rapidly from the town. Drainage from the town is particularly constrained when the bay surface level is high. Also, some properties get inundated with extreme events and some properties would be inundated above floor level if an extreme event occurs.

With sea level rise, these effects will occur more frequently. Extreme surface level events may increase the level of the bay to 2.3 to 3.7m AHD once sea level rise reaches 0.9m (which is around 2100).

As sea levels rise and if nothing is done, some road sections would become inundated regularly. With a sea level rise of 0.25 m (expected to occur around 2050), areas such as part of the mouth of Georges Bay and Chimneys Lagoon at Stieglitz would be below the higher high tide level. Along Binalong Bay Road, aquaculture farms and the Ben Lomond water sewage treatment plant will increasingly be subjected to inundation if nothing is done.

With a sea level rise of 0.9m (around 2100), a small number of properties would lie below the higher high tide level. The mouth of the Georges River would become part of the bay. Aquaculture farms (onshore assets) and the sewage treatment plant would likely drown with 0.9m sea level rise. Road segments that were previously at risk of inundation from extreme events would lie below the average high tide level. Over 10 properties would lie below the annual high tide level, while over 40 would become inundated from an extreme event (1% AEP).

The oyster and mussel industry would incur damage from extreme river flooding events at a more frequent basis. The lower salinity level and alleged poor water quality, as a result of the increased inflow from the river and smaller waterways, have resulted in significant damage to the industry in the past. If nothing is done, these damages would occur more frequently.

It is anticipated that most significant future damages would be incurred by the infrastructure providers in the area, including Council, Ben Lomond Water and DIER. To minimise damages, roads would need to be raised, bridges built, other assets raised, pump stations and pipes sealed, and the street drainage system improved and possibly supported by a pump system.

The risks to infrastructure (in terms of \$ NPV) have not been assessed in detail.

6.2 Options

This section reports on the work undertaken and preliminary findings relating to Step 6 of the pathway process: First cut assessment of adaptation options and costs.

¹⁸ Which are both climate change induced effects

There are different options that can help Georges Bay adapt to the impacts of coastal impacts of climate change. The different options relate to different types of impacts resulting from erosion and inundation. The effectiveness of options varies considerably, depending on the characteristics of coastal areas (such as sandy or rocky coast line) and the location-specific impacts of sea level rise.

In the case of Georges Bay, there are a number of options that are potentially relevant to the impacts identified:

- **Raise land levels** in St Helens township and other low lying residential areas;
- In combination with the previous measure, **a dyke or levee** around St Helens over the long term (likely after 2100);
- **Raise roads and services** of key infrastructure including Binalong Bay Road or alternative route (which would involve a long bridge), sections of Tasman Hwy and of St Helens Point Rd, the sewage treatment plant and pumping stations;
- **An alternative route** for Binalong Bay Road, instead of raising and building a bridge at Binalong Bay Road, Reids Rd could be upgraded to become the main road connection to Binalong Bay. Similarly, it may be possible to build a new road further land inward to replace St Helens Point Rd in the long term, if any environmental values can be managed appropriately;
- **Seal the sewer system;**
- **Improve the drainage capacity** to more effectively drain water from St Helens streets (possibly in combination with the next option);
- Implement a **water retention area** to drain water to from St Helens streets;
- **Retreat or protection of properties** prone to inundation or redevelopment of structures in less vulnerable form (higher floor levels).

Detailed descriptions of the following options are provided in the Coastal Adaptation report. Short descriptions are provided below.

Raise Land Levels

Raising the land level of developed low lying land above the expected sea storm surge level is one of the most secure and sustainable responses to rising sea levels. It also has the potential to significantly alter the natural values and the 'look and feel' of a place. If implemented, filling could be adopted in the planning scheme for new development or major re-development in identified inundation hazard affected areas (but outside of the river valley).

Typically the edge of the raised land would need some protection from erosion (sea dyke or levee). Some of the foreshore of St Helens has already been filled and hardened.

While raising land above the storm surge height can avoid inundation, it represents a complete obliteration of the existing flora and fauna in the filled area and may also have significant impacts at the source of the fill material. Given the heavily developed character of the urban part of St Helens, natural values are generally of limited concern. However, the fringes of the river provide significant wetland areas and habitat, so filling towards these areas should be avoided.

If the filling is done in stages, such a patchwork filling approach may create problems with drainage unless some considerable thought and planning is put in place to anticipate and manage this issue. A patchwork of fill may also lead to overland flow problems, where higher ground from filling displaces water to or obstructs drainage from lower ground.

Raise Roads and Services

Raising roads may be necessary to provide access to properties, including those that are not directly affected by coastal hazards but depend upon roads in the flood hazard area for access. In low lying areas, raising roads implies continued commitment to maintaining a community in an area that is expected to be exposed to current or future flood hazards.

Raising Binalong Bay Road may be an option, but only to the very high tide level. Raising the road too much will result in the road acting as a dam at the mouth of Georges River during an extreme event. This would lead to increased river flooding. Therefore, a significant stretch of road of approximately 600 metres would need to be replaced by a bridge or a structure that allows sufficient water flow through. This is likely to be an expensive option. Another alternative involves upgrading the alternative route to Binalong Bay (see Upgrade Alternative Route).

Indicatively, the cost of raising a suburban road by 0.5 metres is \$1,200 per metre and by 1 metre is \$1,600 per metre. The costs for raising a main road, such as Binalong Bay Road, would be much higher, perhaps \$2,000-\$5,000 or more to raise it by 1.0 m, especially where the sides need to be protected against erosion. In the case of Binalong Bay Road, raising the road too much at once may result in extra river flooding (when the road acts as a dam). More frequent and gradual raising may therefore be required, leading to extra costs.

For major highways such as the Tasman Hwy the cost of raising the road is higher still, including hardening of seaward face (depending on exposure). A number of segments along the Tasman Hwy may need to be raised to reduce inundation risks by 2050.

It is most appropriate and cost effective to raise roads when roads are being resurfaced or otherwise undergoing major repairs.

Dyke or Levee

Dykes and levees provide a barrier that keep flood waters from inundating adjacent land. In St Helens, a dyke or levee could be used to protect against extreme events and to provide a hardened boundary to resist erosion, with the land gradually filled behind it to reduce the need to pump out stormwater and reduce the consequences of a catastrophic failure (breach or overtopping). Some of the foreshore of St Helens has already been filled and hardened.

Dykes are generally earth embankments, but may also consist of, or be reinforced by, masonry walls, sheet piles, surface hardening or other enhancements, where flow rates, space limitations or other conditions require.

Dykes generally require rain and incoming stormwater to be pumped from the area to prevent flooding if the land behind receives significant rain runoff during a storm. Water may also move through soils, raising water tables to near or above the surface, requiring almost constant pumping if the land is close to or below mean sea level.

The elevated barrier may act as a visual and psychological barrier between the community and the shore, changing the character of the area. Alternatively, a road along the top of the dyke may be regarded as an enhancement. If overtopped, erosion of the top of the levee or dyke can lead to rapidly increasing flows. If the overtopping occurs early in the flood event, substantial water may enter the protected area and flood to a substantial depth.

If the wall fails entirely in one section, flooding may approach levels that occur in the absence of the dyke or levee. The costs for dykes vary enormously, depending on the initial site conditions, degree of wave exposure, specific erosion dynamics, the outcome sought, etc.

An option that could occur in combination with a dyke or levee is to raise land levels and infrastructure and services (see raise land levels and raise infrastructure and services).

Upgrade the Alternative Route

The upgrading of Binalong Bay Road may be very expensive and therefore identifying and upgrading an alternative route would likely be a more cost effective alternative. The most likely alternative route to Binalong Bay is through the Mount Pearson State Reserve, which is currently a gravel road. This road would need to be upgraded and a higher bridge would need to be constructed to cross Georges River. Both the road and the bridge need to be high enough above the future increased river runoff and flood levels.

An alternative route would change the connectedness of areas. The alternative route is longer and less attractive to tourists. In considering this option, it is important to assess what risks, such as bush fire, this alternative route may be subject to.

The cost of this option is uncertain and would involve raising, possibly widening, and hardening the road and the construction of a bridge.

Seal the Sewer System

This option involves designing and maintaining sewer systems so they can operate while submerged or below the ground water table. It is suitable for newer systems because of recent improvements in jointing and sealing systems and materials technology.

The costs with this option are associated with sealing the system. If pressure or vacuum systems are required, this will further increase the cost.

Improve the Drainage Capacity

Many stormwater outflows are at or near sea surface level. When a storm surge occurs, rainfall runoff not only cannot get out, but sea water can enter storm water systems. Where the rainfall outflow is restricted by elevated sea surface levels, the 'backed up' stormwater may contribute to inundation in some areas. This is the case in St Helens, which remains above the extreme bay surface level, but is not able to drain excess water from rainfall during some extreme events quickly enough to prevent flooding. The option would be useful in those cases where high bay water levels coincide with heavy rainfall.

This option may be applied in combination with water retention areas where excess water is temporarily stored to alleviate flooding in developed/residential areas (see water retention area).

The costs involve installing much larger capacity storm water pipes. The works would involve significant ground works in the streets of St Helens with significant disturbances to everyday life while the new system is being implemented.

Implementing Water Retention Areas

Water retention or detention basins provide temporary storage of stormwater runoff at or near the initial point of flooding. This technique reduces the amount of flooding during large rainfall surges and following the surge slowly redistributes rainfall into the drainage system. This option can reduce peak flood levels for extreme events.

Retention areas require a relatively large area in a suitable point in the drainage pattern. It may be difficult to find such a site or land may be relatively costly if it is located near a town centre or similar. Alternatively, the basin may be useable as an open space or amenity for the community. Such dual use may impact the effectiveness of the basin. If rainfall intensities increase with climate change, the retention capacity may need to be expanded.

The costs mainly involve the cost of land or the opportunity cost of land.

Protection of Individual Properties

Protecting individual properties from erosion and inundation can be done in different ways, including:

- Elevated substructures (raised slab or floor, poles, non-inhabited ground floor;
- Flood barriers to protect existing dwellings from short term extreme events (not practical if water levels are permanently high);
- Moveable dwellings;
- Water proof or resistant construction not affected by temporary flooding; and
- Floatable dwellings.

Planned Retreat

Progressive retreat means the loss of private and other property. In spite of this, it may prove to be the lowest cost long term alternative available, especially if the cumulative cost of protection into the future is considered. This is especially true where there are a limited number of houses under threat. The cost of planned retreat can be diminished to the cost of land if a process of planned disinvestment occurs, such as not redeveloping and/or extending existing properties.

7 PATHWAY SCENARIOS BY LOCATION

In preparation for community consultation, a number of different pathways for responding to climate change were developed for four locations:

- Lower George River mouth, flood plain and banks
- St Helens town centre and adjacent residential area
- the southern coast of the Bay (Tasman Hwy and St Helens Pt Rd)
- flood prone areas in the environmental management zone (Medeas Cove, St Helens Pt and Humbug Pt).

Community workshops were organised to explore different pathways to respond to projected changes, ranging from letting nature take its course to protect 'at all cost' and intensify development and land use patterns in risk prone areas. The workshops covered the first two locations or areas. These areas are expected to experience impacts from climate change before 2100. The latter two areas are likely to experience impacts more than 100 years from now. It is not useful to consider these decisions now, as by that time the circumstances may be vastly different from now, and it is unknown what would be the best decisions would be in these circumstances. There was also limited interest from the community in exploring these latter two areas.

7.1 Area 1: Lower George River mouth, flood plains and banks

Much of the land at the bottom of the catchment will be below the highest high tide level with 0.9 m of sea level rise. There are multiple channels in the lower reaches, where river floods overflow from the current main river channel to adjacent channels. There is concern about a large flood jumping to the more southerly channel near the major bend of the river, and in doing so diverting large, potentially erosive flows to the channel adjacent to development on the north side of St Helens. Flow from this channel from recent floods has already eroded the bank beside Binalong Bay Road to very close to the road edge by the sewage treatment plant, and sections along Cecelia Street. A number of areas along the existing and potential flood channels may be subject to erosion due to the strong flows experienced in major floods.

Substantial erosion protection works have been built at a major bend to reduce the risk of a breakout from this channel in the river mouth, but major floods still overtop the banks. Secondary levees on the land behind attempt to divert flood flows from farm assets, but these diversions may affect adjacent properties, sometimes adversely. Binalong Bay Road and some sections of bridge were raised in the early 2000s in response to frequent overtopping by flood flows cutting off Binalong Bay Road. Since raising the road there have still been several instances per year of flood flows covering the road for a number of hours at a time. Also, the road may be affected by erosion at the channel banks. Given the potential for the channels to move in extreme flood events, this may require repeated responses.

One uncertainty in addressing this area is the potential for more intense rainfall to increase peak river flows during floods. As with most elements of climate change, the potential for change and the expected direction may be known, but large uncertainties remain regarding the scale of the change.

There are a number of farming and rural residential properties in the flood plain, although development is generally on higher ground that has not been affected by floods to date. However, access roads such as Cecelia Street, are cut off in flood conditions and may be damaged. Sewer reticulation and pumping stations in affected areas would need to be sealed and made flood proof to avoid health and environmental risks.

Pathway 1 – Retreat and establish an alternative route to Binalong Bay Road

This pathway allows maximum freedom for natural coastal processes to unfold with a minimum of intervention from development or protection works. Where severe flooding threatens structures with failure in the short term, they would be removed if they cannot resist the hazard. (Re)development in affected areas would not be allowed.

Property owners would be allowed to take action that extends the life of their existing structures by making it resistant to erosion or flooding (flood skirts, other waterproofing, underpin foundations), but only within their own property boundary, as long as it has no impact on adjacent areas. Filling and raising land would generally not be allowed, nor would hardening shorelines with rocks or concrete.

According to this pathway, nature is allowed to take its course. For the George River delta this means a strategy of retreat for affected structures and infrastructure in the longer term. With some protection to existing structures it would likely be possible to stay in the area for the next 30 to 40 years. Binalong Bay Road would become flooded more frequently, until a point where the road cannot be maintained without raising it. The mouth of Georges River would gradually become (tidal) wetlands and with a sea level rise of about 0.9m, significant areas of the river mouth would have become part of the bay at higher tides.

This would initiate a process of retreat from the river flood plain. Investment would be directed towards a safer, more sustainable alternative road access to Binalong Bay (Reids Road). This would involve restricting future development in the flood plain and river mouth, withdrawing services and roads and re-siting the sewage treatment plant at the end of its service life (approx 2050). The Ben Lomond Water sewage treatment plant may require protection to enable the facility to reach the end of its lifetime. After that, the treatment plant is expected to be dismantled. This may also be required for land based assets of aquaculture farms.

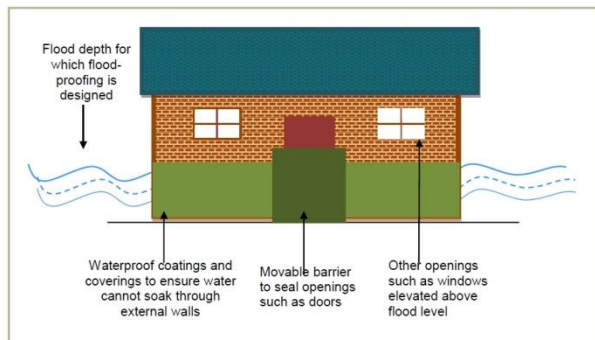
Tides would be allowed to encroach freely on land in the flood plain, converting pasture to coastal wetlands. Existing dwellings that are high enough to be above flood levels and safe from erosion could remain, but would be responsible for contributing to any upgrade or repairs required to maintain road access.

Options likely for this Pathway

Major works and modifications to the landscape would not be permitted under this scenario. Most work would involve 'clearing away' and reconfiguring infrastructure to remain serviceable. Further responses would include private action to reduce flood damage, repair and maintenance after events, and ultimately retreat. The alternative route to Binalong Bay Road would be the most significant measure within this pathway.



Wetlands move shoreward



Flood protection for existing buildings

Indicative cost estimates Pathway 1 for:

- Actions over the 0-10 Year Timeframe: \$20,000-\$50,000 per annum
- Actions over the 10-40 Year Timeframe: \$200,000 to \$400,000 per annum (mostly upgrade Reids Road, bridge)
- Actions over the 40+ Year Timeframe: ~\$30,000-\$40,000 per annum (cost of retreat – lost farm land and assets, potential reduction in tourism to Binalong Bay may be higher).

Pathway 2 – Maintain road and bridges along Binalong Bay Road as long as practical

This pathway protects property and may have some impact on natural areas and the other values of the community. Where there is an apparently irreconcilable conflict, the preference goes to protecting shared community assets. Protection and adaptation options that result in changes to the character of the area that reduce its attractiveness and property value would not be pursued.

This pathway allows Binalong Bay Road and bridges to be maintained as long as practical. In the medium term, the road and bridges would be elevated to provide reliable access to Binalong Bay. This may involve realigning sections of the road away from river channels to reduce vulnerability to erosion.

Flood levels and erosion in the river mouth would be monitored to ensure future upgrades to the road are made in a timely fashion. This would need to be monitored as sea level rise and rainfall intensity trends become clearer. The long term alternative route to Binalong Bay Road would be Reids Road through Mount Pearson State Reserve. It would need to be upgraded and would also require a higher bridge above potential future flood levels (1% AEP). This major project would need to occur when upgrading Binalong Bay Road clearly becomes untenable, say after 2050.

Limited development would be allowed on higher areas of land (above flood level for the lifetime of the asset), where access can be gained directly from Binalong Bay Road. In case of indirect access, the development would be responsible for maintaining access to the site. Development would be required to have floor levels above 1% AEP flood heights. In the longer term (past 2100), maintaining access via Binalong Bay Road may become uneconomic. The Ben Lomond Water sewage treatment plant would likely require protection to enable the facility to reach the end of its lifetime, which would be between 2030 and 2040. After that, the treatment plant may retreat, but redevelopment at site may be possible if designed to withstand expected flood levels with minimal risk.

Options likely for this Pathway

Under this pathway roads, infrastructure and houses in hazard areas will be raised to adapt to rising sea levels. Within a 10 to 40 year timeframe, bridge over the George River would likely be replaced by a higher and longer bridge and more of the road would become a causeway. In the long run, a strategy of retreat would be followed.



Causeway and bridge across George River



New houses elevated on piles

Indicative cost estimates Pathway 2 for:

- Actions over the 0-10 Year Timeframe: \$50,000 - \$120,000 per annum
- Actions over the 10-40 Year Timeframe: \$150,000 to \$200,000 per annum
- Actions over the 40+ Year Timeframe: \$250,000-\$300,000 per annum

Pathway 3 – Long term protection of Binalong Bay Road with significant engineering

This pathway concentrates on protecting existing assets and development potential. It assumes that the rate and extent of change will be manageable using available options and that any necessary protection and adaptation options will be acceptable. Intensification of development provides a greater base of contributors to any protection works, so some intensification is permitted where it does not compromise values for the area. While natural areas may be affected, they will be modified in ways that the community accepts.

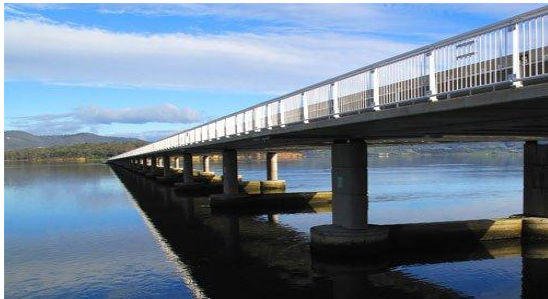
This pathway aims to maintain and raise Binalong Bay Road as needed with bridges spanning sufficient number and width of channels to permit peak flows to pass without overtopping roads.

River channels near the road would have banks hardened sufficiently up and downstream to prevent erosion affecting the road or bridge abutments. Land in the 'delta' area could be developed subject to filling above the expected flood height for the life of the development. Where property abutted the river channels, provision for protection from erosion by the river would be required. These raised areas would provide well defined islands of development joined by bridged river channels. River flows in the vicinity of the road would no longer 'wander' but be constrained to the hardened channels.

If protection is feasible (by raising or other protection), existing development, including the treatment plant and aquaculture farms, could remain where they are. In order to improve the financial feasibility of the protection measures, land use could be intensified in order to have a sufficient rates base. With a sea level rise of 2 to 3 metres, it may become unaffordable in the very long term to continue to protect properties, infrastructure and services, and retreat may follow

Options likely for this Pathway

Options under this pathway include a long bridge of 600 to 800 metres which would be required to pass across the river mouth, raising dwellings, infrastructure, services and land and hardening of river banks.



Elevated bridge over river sections



Elevated and hardened coastal road, causeway sections



Fill to raise land levels of 'islands'

Indicative cost estimates Pathway 3 for:

- Actions over the 0-10 Year Timeframe: \$50,000-\$120,000 per annum
- Actions over the 10-40 Year Timeframe: \$150,000 to \$200,000 per annum
- Actions over the 40+ Year Timeframe: \$400,000-\$600,000 per annum but gain increased land use.

7.2 Area 2: St Helens town centre and adjacent residential areas

Analysis shows that the town centre is above the expected flood levels in Georges Bay, even with sea level rise of up to 0.9 m including some allowance for contributions by river flooding to high Bay levels. Areas of the foreshore would be susceptible to flooding in extreme storm events, particularly near the Tidal Waters Resort, an area fringed by wetlands. The foreshore adjacent to the town centre, formerly wetlands, has already been filled and the raised shoreline hardened. A few houses in the vicinity of Quail Street/Cameron Street/Lindsay Parade would be affected with an extreme storm event and sea level rise of 0.9 m – that is, in about 90 years time.

The town centre is already experiencing flooding from rainfall in combination with high tides due to inadequate drainage capacity. With sea level rise, St Helens town centre would become inundated more frequently after intense rainfall in combination with high surface levels in the bay. As a result of climate change, the amount of rain during extreme rainfall events is expected to increase. The severity of this increased flooding from rainfall was not modelled as part of this project. Sewer reticulation and pumping stations in affected areas would need to be sealed and made flood proof to avoid health and environmental risks.

In the short term, Council plans are well under way to improve the drainage of the town centre to reduce flooding from rainfall with larger drainage pipes. These works will be complete whichever adaptation pathway is chosen.

The northern edge of the town bounds the George River. This edge may be subject to river erosion along the banks, but is generally high enough that floods have limited opportunity to overtop embankments.

In the longer term with sea level rises greater than 1.0-1.5 m, more of the town will progressively be subject to flooding in extreme events, if there is no adaptive response. As the commercial centre of the town is among the lowest areas, that raises questions over the long term pathway to be followed for the town centre in particular.

The effects of changes in rainfall patterns and drainage effectiveness should be monitored and modelled.

Pathway 1 – Long term relocation of town centre

This pathway allows maximum freedom for natural coastal processes to unfold with a minimum of intervention or resistance from development or flood protection works. Where erosion or severe flooding threatens structures with failure in the short term, they would be removed if they cannot resist or recover from the hazard. Where property is regularly inundated, it would eventually not be worth repairing and be abandoned. Redevelopment in affected areas would not be permitted. Little, if any, new development would be allowed, and certainly no intensification of existing developed areas (subdividing existing residential areas) subject to hazard.

Property owners would be allowed to take action that extends the life of their existing structures by making them resistant to erosion or flooding (flood skirts, other waterproofing, underpin foundations), but only within their own property boundary, as long as it has no impact on adjacent areas. Filling and raising land would generally not be allowed, nor would hardening shorelines with rocks or concrete or even beach nourishment. Owners would be responsible for clearing a site of structures etc if/when it is eventually abandoned.

This pathway allows nature to mostly take its course. It requires Council to plan for the long term relocation of the town centre to higher ground. Lower lying areas that comprise the current town centre would gradually be allowed to flood with rising sea levels, except that a road through the area would be maintained for access and continuity of the Tasman Highway.

Under this pathway, a new town centre location would have to be identified and the ability to develop it as a town centre protected by zoning or other controls.

The development of the new town centre would occur when water levels are such that the town centre floods regularly. However, this is not likely to occur until late in this century at the earliest (and will be informed by the recommended monitoring and modelling of changed rainfall patterns over St Helens). When the need does arrive, early moves could be made by government institutions to the new town centre and contribute to attracting traffic, thereby making it easier for commercial development to follow.

The hardened foreshores would be maintained to resist erosion. Properties at risk would be allowed to implement protection measures to extend the lifetime of the assets if this has no adverse impacts on natural values or adjacent properties. Intensification and redevelopment would be discouraged in areas below the high tide level of reached in 2100. Filling of private properties would not be allowed. Infrastructure would not be raised. To minimise the health

and environmental risk, the sewer system (pipes, connections and pump station) in low lying areas would need to be sealed in the medium term (with a sea level rise of about 0.25m).

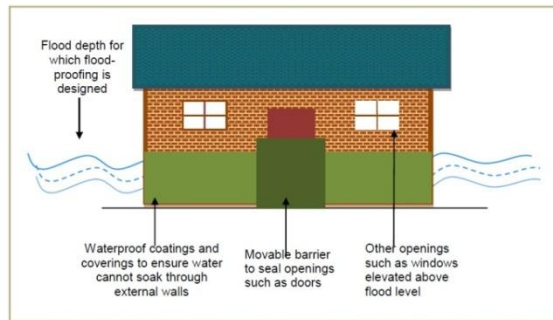
Over the long term, from 2100 onwards, retreat would occur from properties below the annual high tide level.

Options likely for this Pathway

The long term relocation of the town centre would be the main focus of this pathway and would involve strategic planning and incentives/support for businesses to relocate. An updated drainage system would reduce impacts in the short term. Further options include private action to reduce flood damage to properties, and ultimately retreat from uninhabitable properties. The main road connection through St Helens would need to be raised.



Wetlands move shoreward



Flood protection for existing buildings

Indicative cost estimates Pathway 1 for:

- Actions over the 0-10 Year Timeframe: \$20,000 per annum
- Actions over the 10-40 Year Timeframe: \$40,000 per annum
- Actions over the 40+ Year Timeframe: \$80,000 per annum plus loss of usable higher value waterfront land.

Pathway 2 – Long term protection of town centre

This pathway concentrates on protecting the existing and future community where it is. It assumes that the rate and extent of change will be manageable using available options and that any necessary protection and adaptation options will be acceptable. Intensification of development provides a greater base of contributors to protection works, so some intensification is permitted where it does not compromise community values for the town. For example, subdivisions and multi-storey development may be permitted making filling of lots more cost effective as a way of combating inundation, while allowing sufficient floodways to control runoff.

The aim of this pathway is to protect the town centre and adapt in situ. To adapt to ongoing sea level rise, the properties, infrastructures and facilities need to be raised over time. It is likely that as part of the planning process it would be required that any new structures and significant redevelopment would need to be on a raised level and for the land to be filled at some stage too. The amount by which land, infrastructure and services would need to be raised would be determined on the expected lifetime of the asset and the expected damage from a 1% AEP storm event by the end of its remaining life.

In general, one would raise the land when redeveloping a structure or during the normal rebuilding cycle for roads or other infrastructure. Where this cannot be achieved, there may be some cost for lifting existing assets. A managed approach would need to be adopted to ensure land is raised/filled over time, and that appropriate stormwater measures are undertaken to prevent issues with properties that have not (yet) been raised. A drainage management plan would be used as a guide for land filling. To further improve the drainage, a water retention area can store peak flows until the bay drops after a storm event allowing the water to be drained into the bay.

In the long term (likely after 2100), the town centre would be protected by a dyke or levee with a hardened outer face to prevent erosion. This would possibly enclose the town. The land within would eventually be raised. The town drainage system would need to be able to drain excess water out into a retention area or into the bay itself, possibly aided by a pumping system. Parts of the dyke could be used as a promenade and/or road.

Options likely for this Pathway

Likely options in this pathway include raising built structures, infrastructure, roads and land, protecting the area with a dyke or levee and potentially developing a water retention basin.



Dyke in Holland



Retention basin

Indicative cost estimates Pathway 2 for:

- Actions over the 0-10 Year Timeframe: \$40,000 per annum
- Actions over the 10-40 Year Timeframe: \$65,000 per annum
- Actions over the 40+ Year Timeframe: \$110,000 - \$260,000 per annum (mostly cost of the dyke).

7.3 Area 3: Southern Coast of the Bay, Tasman Highway and St Helens Point Road

The southern coast of the bay, from where the Tasman Highway and St Helens Point Road follow the coast to the end of the residential zone, generally rises fairly steeply from the shoreline to higher ground. As a result, the shoreline does not move very far inland due to inundation as the sea level rises and flooding does not penetrate far inland.

There are however a number of low lying areas near Kirwans Beach, Lions Park, O'Connors Beach and the land around Chimneys Lagoon, many of which are already marshy or open water with wetland edges.

Other areas subject to flooding near residential land are along the coastal strip from Chimneys Lagoon to near the northern end of the residential development and a shorter section between the road and O'Connors Beach. This strip of 50-75 m width will become the intertidal zone with 0.9m sea level rise. The coastal strip and Chimneys Lagoon are zoned environmental management.

Some sections of the coastal roads have been subject to impacts from rain water runoff during heavy rainfall events, as water from the hills behind saturates the roadbed. While high tides and storms may reduce the rate of drainage or contribute to water logging of the road bed to some extent, the main problem appears to be inadequate drainage of heavy rainfall. It may take more detailed technical examination to confirm this.

With sea level rise and without adaptive action, about 2 kilometres of roads crossing the low lying areas will be subject to flooding. The water table will rise to inundate the low lying land, even if the roads keep it separated from the coast. Sewer reticulation and pumping stations in affected areas would need to be sealed and made flood proof to avoid health and environmental risks.

Parts of the coast along St Helens Point Road, near Chimney Heights, show evidence of land slip. The former coast road at the foot of this steep area has been eroded by the water in the bay. At this point, there is still a residual strip of roadbed along the shoreline, but at times waves may wash over this and help to undermine the stability of the slope. While slope stability may be an issue even without wave effects on the base, continued erosion of the base will certainly accelerate any slippage that otherwise may occur in the future.

Pathway 1 – Allow natural processes to develop while also retaining road access

This pathway protects property but only where that protection has a minimal impact on natural areas and the other values of the community. Where there is an apparently irreconcilable conflict, the preference goes to protecting natural and shared community assets, not private property. Given the priority placed on natural values, there is also consideration of promoting and sustaining natural ecosystems in the face of climate change stresses where existing development may form a constraint. This would include permitting wetlands to migrate inland or to assist them to rise with the sea level where possible. In general, intensification of development would be discouraged unless it clearly did not have any negative impact on natural values or may have a positive effect.

With a sea level rise of 0.25m, expected around 2050, roads inundated at present day by a 1% AEP event would be inundated more frequently. Floods would mostly be less than 300mm above road levels. With a 0.9m sea level rise, expected around 2100, some road segments would flood regularly in the highest tides.

In the long term, with frequent flooding these segments could be moved inland to service the local communities where possible, or an alternative route may be developed in conjunction with new development higher up the hill. If roads need to be raised instead of rerouted, allowance should be made for tidal flushing of wetland areas shoreward of the road.

The risk of landslide may increase by the undermining effects of water level rise and storms on foreshores that are at risk of landslide at the present day. No shore protection works would be undertaken along the landslip areas. No new development would be allowed in areas that may be subject to landslide in the long term. Towards Stieglitz and Akaora, low lying areas would first become wetlands and in the longer term would drown. While the coastal strip would be allowed to be inundated, this approach would permit most of the existing residential areas in St Helens, Stieglitz and Akaora to continue to be occupied for this century and a while beyond.

Options likely for this Pathway

Under this pathway, the following options might be adopted:

- Rerouting of roads and services;
- Raising roads and building bridges with sufficient allowance for tidal flushing; and
- Retreat from the few properties that become regularly inundated.



Tidal flushing



Wetlands move landward

The indicative costs for this pathway depend primarily on the costs of bridges or major culverts to allow tidal flushing. In some areas, alternative access may be provided from development higher on the hillside, making costs minimal for these sections if access is provided in conjunction with the new development.

Pathway 2 – Retain existing road access while allowing natural processes if practical

While sharing many features of the previous pathway, this option gives priority to property over natural values where there is a conflict or tradeoff. Protection and adaptation options that result in changes to the character of the area that reduce its attractiveness and property value would not be pursued.

This pathway would keep future inundated areas undeveloped and 'natural' but raise roads with only the necessary drainage connections to the bay. To manage protection for sea level rise in the long term, any properties, infrastructure and facilities in the affected areas would need to be raised over time, but there is little of this. It is likely that any new structures and significant redevelopment affected in existing developed areas would need to occur on a raised level and that land would also need to be filled. The amount by which land, infrastructure and services would need to be raised would be determined by the expected lifetime of the asset and the expected level at which the asset would be susceptible to damage from a 1% AEP storm event. In general, new development through intensification and subdivision would be discouraged. The raising of the roads would be timed to coincide with the normal rebuilding cycle for roads or other infrastructure.

Low lying areas would become wetlands and in the longer term would drown. The risk of landslide may increase by the undermining effects of water level rise and storms on foreshores that are at risk of landslide at the present day. No new development would be allowed in areas that may be subject to landslide in the long term.

With a 0.25m sea level rise, low lying road segments would become inundated more regularly, but mostly by less than 300mm. In the longer term, some road segments would gradually be below the astronomical high tide (with 0.9m sea level rise). These road segments along the Tasman Highway and St Helens Point Road need to be raised over the next 40+ years. Where roads are raised, the low areas will become fresh water or brackish ponds, separated from the bay and the high roads to reduce the chances of extreme events affecting property on the landward side of the road.

The effectiveness and the costs and benefits of this approach would permit most of the existing residential areas in St Helens, Stieglitz and Akaora to continue to be occupied for this century and some time beyond.

Options likely for this Pathway

Under this pathway, the following options would possibly be adopted:

- Raising roads and building bridges with minimal allowance for drainage, hardening of the seaward face
- Raise properties
- Filling of properties.



Houses on piles

The costs for this pathway may be slightly lower than for Option 1, where bridges or culverts allowing flushing are likely to cost more than just raising the road as a causeway with minimal drainage allowance under the road. The wetlands may not have as high an environmental value compared to if they were well connected to the bay.

Pathway 3 – Retain road access and support further development

This pathway concentrates on protecting the existing and future community. It assumes that the rate and extent of change will be manageable using available options and that any necessary protection and adaptation options will be acceptable. Intensification of development provides a greater base of contributors to any protection works, so some intensification is permitted where it does not compromise community values for the suburb. For example, further development in affected areas may be permitted by filling lots as a way of combating inundation, while allowing sufficient floodways to control runoff. While natural areas along the coast are affected, they result in some relatively high value real estate and reduce the need to develop further up the hill if there are also environmental values worth protecting there.

To manage the risks from sea level rise, the land, dwellings, roads and infrastructure would gradually be raised, in accordance with the previous pathway. The low lying areas would be allowed to be filled and developed, with suitable provision for drainage, and with the road contributing to protection of the property by being hardened on the seaward side and raised if necessary.

Protection against coastal erosion would be provided to the base of the landslip area to contribute to diminishing risk. Towards Akaroa and Stieglitz there are residential pockets that would require protection against erosion (hardening of shoreline) and raising of land and the built environment. Where feasible and effective, shorelines would be hardened to reduce landslide risks and erosion. Roads would likely be raised every time they are redeveloped, depending on their service quality. Roads would likely be raised sufficient to withstand a 1%AEP storm over its service lifetime.

In order to improve the financial feasibility of the protection measures, residential land use would be allowed to intensify.

Options likely for this Pathway

Under this pathway the following options would possibly adopted:

- Raising roads
- Raise properties by filling
- Hardening of foreshores.



Elevated and hardened coastal road



Fill to raise land levels

While the costs for this pathway to 2100 would be higher than pathway 2, it would produce new, relatively high value parcels that offset the costs. The loss would be in environmental values that have not been evaluated.

7.4 Area 4: Natural flood prone areas in the Environmental Management Zone

The low lying natural areas in the Environmental Management Zone in Medeas Cove, St Helens Point and Humbug Point will be affected by sea level rise. These are among the most extensive areas affected by sea level rise around Georges Bay. At present, they mostly have limited development and with current zoning would remain principally natural areas, managed for environmental values. There are few built assets that will be affected by future periodic or regular inundation. Changes will occur in the local ecology, with a progression from terrestrial to salt marsh to inter-tidal flats and eventually open water. Each of these developing ecological communities may provide habitat and environmental services if permitted to develop.

Some areas do have property assets, including the area near Lords Point (Simeon Place) which will become surrounded by open water and wetlands with a 0.9m sea level rise. Other assets include roads (St Helens Point Road) and any other infrastructure (power, water supply, stormwater) that may run through the area.

The pathways described below are related to the pathways for the Lower Georges River mouth and the Southern coast of the bay. These pathways consider in some detail how natural values in these areas would be treated.

Pathway 1 – Let nature take its course and retreat development to allow natural processes

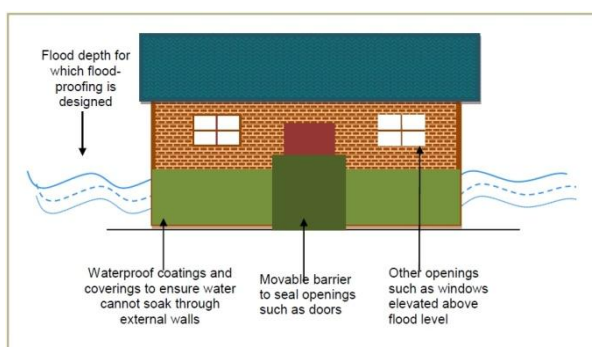
This pathway would allow natural processes to unfold. Where it would interfere or negatively impact on natural processes, any of the existing limited development would be demolished. Roads through low lying areas would be rerouted or raised as bridges and other infrastructure would be removed to allow the areas to transform into saltmarsh, tidal wetlands and eventually open water. There would be some allowance to protect individual assets to extend their use to reach their remaining service life, provided there are no adverse impacts on natural values. Where infrastructure needed to service an area cannot be provided without damaging natural values, or is too costly, private development would likely need to retreat or go without the infrastructure.

Options likely for this Pathway

- Protect individual properties where there are no adverse impacts on natural values
- Retreat properties and infrastructure.



Wetlands move shoreward



Flood protection for existing buildings

Pathway 2 – Attempt to intervene to manage the types of ecosystems that develop

This pathway would aim to manage natural values and consider options to actively help ecosystems to migrate and/or be sustained. This pathway would also give priority to natural processes and, where deemed necessary, to actively manage ecosystems. This may involve preparing 'routes' for wetlands to transgress to new areas as sea levels rise. This may also involve actively managing existing wetlands by allowing additional sediments into the area so they can build up as sea levels rise. It could help retaining wetlands that would otherwise have become open water to retain their role as wetlands for longer. Such active management would be considered particularly where wetlands have nowhere to 'migrate' to.

Where it would interfere or negatively impact on natural processes, development would need to be adapted to permit natural processes. The low lying roads along the coast would be modified to allow for sufficient tidal flushing or to allow wetlands to build up.

There would be allowance to protect individual assets to extend use towards their remaining service life or to redevelop, as long as there are no significant adverse impacts on natural values.

Options likely for this Pathway

- Protect individual properties where there are no adverse impacts on natural values;

- Adapt infrastructure and development to minimise impacts on natural processes;
- Actively manage to encourage retention of certain ecosystems (eg wetlands); and
- Retreat properties and infrastructure.



Restoring wetlands

Pathway 3 – Some development while protecting important natural values

This pathway aims to allow for development to intrude into natural areas if the natural values are deemed to be of minor significance, or if the natural values are expected to be lost due to climate change anyway. Development could be allowed under the condition it is to be demolished once the risk of inundation or erosion due to climate change becomes unacceptable. Alternatively, the development would be protected against the impacts of climate change, even if there would be adverse impacts on natural values where those values are minor or where the affected area is small.

Options likely for this Pathway

- New, low impact development;
- Protect properties and infrastructure; and
- Retreat .



Examples of floating house



Example of moveable house



Floating road

7.5 Exploring the Pathways

During the workshops, a number of questions were explored with the participants:

- What are the positives? The negatives?
- What does the overall balance feel like? Is it 'desirable'?
- Is it a plausible scenario? Can I imagine this actually happening? Is it likely to happen? If not, why not?
- Could it be made to happen and if so, what would be required? Would that be desirable or acceptable?
- How might things develop differently if:
 - Sea levels don't rise? Rise faster? It becomes stormier and erosion increases? Erosion stops by itself? (the experts just got it wrong!)
 - Property values fall independent of the course of action being chosen (ie in general or at least all coastal, not just locally eg sea becomes smelly from acidification; the economy crashes)?
 - Property values rise strongly? (coastal risks perceived as manageable, large population increase)
 - A major storm hits and greatly changes the local environment.
 - Some major technology trend or innovation?
 - How would it happen?
 - Who decides and who pays? Why those in particular?
 - How critical is it that these particular organisations/ individuals decide and or pay?
 - How might this arrangement be established?
 - How could this process fail? (eg disagreements, unwilling/unable to pay).
 - What happens if this process fails – how would things 'fall apart' and who suffers?

After exploring this area, what pathway do participants think is a realistic option for the natural areas in Georges Bay?

7.6 The Workshops

Two locations, with quite different issues, were investigated at workshops held on Saturday 14th of April. The morning session focussed on the river mouth and the Binalong Bay Road area and the afternoon session on St Helens town¹⁹.

The session on Lower George River mouth, flood plains and banks explored the following three pathways:

- **Pathway 1 –Retreat and establish an alternative route to Binalong Bay Road**
This pathway allows maximum freedom for natural processes with a minimum of intervention or resistance from development or protection works.
- **Pathway 2 – Maintain Binalong Bay Road as long as practical**
This pathway protects property and protection may have some impact on natural areas and the other values of the community.
- **Pathway 3 – Long term protection of Binalong Bay Road with significant engineering**
This pathway concentrates on protecting the existing assets and development potential. It assumes that the rate and extent of change will be manageable using available options and that any necessary protection and adaptation options will be acceptable.

The session on St Helens town centre explored the following two pathways:

- **Pathway 1 – Long term relocation of town centre**
This pathway allows maximum freedom of natural processes with a minimum of intervention from development or protection works. The town centre would in the long term relocate to higher ground.

¹⁹ The study area for Georges Bay was significantly larger than for other areas. As a result there were subareas with quite distinct issues. The workshop sessions addressed this by taking a location approach.

- **Pathway 2 – Long term protection of town centre**
This pathway concentrates on protecting the existing and future community where it is. It assumes change will be manageable by raising the town centre, hardening foreshores and improved stormwater drainage.

Interested residents and businesses were invited to register to attend the workshops. Both locations were addressed in a session lasting 2 hours. Over the two hours participants examined the following for the scenarios they were investigating:

- The pros and cons and desirability of each scenario
- Whether they believed each scenario was plausible
- What if conditions change (eg. sea level rises faster or slower than anticipated, there are technological advances, or property prices rise or fall)
- Who decides
- Who pays
- Preferred pathway

Over the entire day, about 17 community members attended the workshops. Also attending were two Councillors and observers from Council and State Government.

In addition to these two locations, there were two other locations with different issues. These were the Southern Coast of the Bay, Tasman Highway and St Helens Point Road, and natural flood prone areas in the Environmental Management Zone. In these locations, most of the effects of sea level rise would start to become apparent more than 100 years from now. Exploring possible decisions that may not be considered within the next hundred years is not particularly relevant. There was limited interest from the community to participate in workshops for these locations. As a result, these locations were not explored during workshops.

7.7 Workshop summary and preferred pathways

Lower George River mouth, flood plains and banks

The session on the river mouth area and Binalong Bay Road that crosses through this area explored three different options: retreat and upgrading the alternative route, maintain Binalong Bay Road as long as practical and then retreat to alternative route, and protect Binalong Bay Road with significant engineering.

The biggest advantages of the three pathways are shown below.

Pathway 1	Pathway 2	Pathway 3
PROS		
Affordable	Retains tourism	Retains tourism
Nature takes its course anyway	Maintains access for some time	River will be contained, cannot jump and impact on town
	Buys time	
CONS		
Little time to adapt	Investing funds in a road that will be abandoned anyway	Change of character
Loss of properties and access in the short term		Cost and ability to pay

The preferred direction was a pathway that would be somewhere between 1 and 2: to buy time at minimal cost while in the meantime upgrading the alternative route of Reids Road. Pathway 1 was seen as providing too little time for property owners and the community to adapt. Pathway 3 gained some support, but if it required significant contributions towards funding from the local community, this pathway was expected to be too expensive to bear. Pathway 2 was seen as somewhat favourable because it buys property owners and the community time to adapt. A negative aspect was that money would be spent on something that had to be abandoned anyway. It was therefore regarded that there should be a response where the aim would be to retreat to an alternative road, while buying some time at a minimal cost to adapt.

In short, the participants expressed the view it is worthwhile to retain access via Binalong Bay Road for some time. However, the costs of maintaining the road in the long term may be well beyond the means of the community. This pathway was expected to buy at least some time for the existing residents and property owners to enjoy and use their properties.

St Helens Town Centre and adjacent residential areas

The session on the future of the town centre explored two pathways. The first pathway allows nature to take its course and requires the long term relocation of the centre to higher ground. The second pathway provides long term protection of the town centre where it is today.

The participants had varying views towards the pathways, but the majority leaned towards the second pathway. Key considerations are retaining the links of the town centre to the waterfront and the protection of the character of the town. With the fragile economy in mind, relocation may risk losing tourist numbers and spending.

7.8 How to make it work? Community perspective

The local economy is quite fragile; the population basis is small and population is ageing. In addition, tourism is a volatile industry and subject to the region's accessibility issues. The roads to the region are regularly closed as a result of extreme rainfall and landslide events.

Estuary mobility study

Before being able to make more informed decisions, the participants expressed the concern that some aspects were not appropriately taken into account in the hazard assessment. The 'route' of the river mouth is quite mobile. There are examples of the river jumping to another channel. The further south the river jumps, the more risks there are for St Helens. Sometimes the main river channel is blocked by debris.

The community expressed the view there was a need to better understand the mobility of the Georges River, issues of silting and any risks to property owners and the town of St Helens. If a study was undertaken, it should also consider the pathways and proposed works and any impacts they would have.

More detailed cost estimates

Another concern expressed was in regards to the broad cost estimates provided. The estimates provide fairly wide range estimates and may not yet include all costs involved. More accurate cost estimates are required before any final decision could be made.

Informing the Community

The participants expressed the view that the wider community should be informed about this project and its findings. Although Council has undertaken an information session and has sent around Council newsletters and invitations to the workshops to all community members, there was an impression that many community members are not aware of it yet.

Raising land, properties and infrastructure

In regards to raising the town centre of St Helens, the workshop participants viewed the management of raising roads, structures, land and services gradually over time as a key issue for the preferred pathway.

Raising would have to occur according to a staged approach. The participants expressed the need for a solid long term plan that provides trigger points to determine when and how much to raise.

In regards to planning, some participants expressed concerns in relation to subdivisions in low lying areas. An example was mentioned where filling of a new subdivision exacerbated flood issues on adjacent properties. Any long term plans to raise land would need to consider drainage too. In addition, this is current issue that would need to be addressed in the short term²⁰.

²⁰ Several participants mentioned streets and back gardens are flooded on a yearly basis. This current issue is being addressed by Council that is in the process of increasing the stormwater drainage capacity.

Decision making for adaptation

Decision making would need to be informed by monitoring sea level rise and rainfall patterns, especially the frequency and severity of extreme rainfall events.

It was preferred that overall decision making relating to climate adaptation would lie with Council, and that any decision making would occur in consultation with the community.

8 WHERE TO FROM HERE?

This section provides overall conclusions on the project, the assessments, and the community consultation findings. In broad terms it provides direction to the way forward from here. Many lessons have been learned, but also, it is clear many gaps in terms of knowledge, decisions making and funding still exist. The following conclusions will illustrate this and also suggest possible ways to address issues. Interestingly enough, the findings are largely true for the other three case study areas too. The consistency in findings supports us in our conviction that some of the issues can and should be addressed collectively and at a State (or even national) level.

Understanding of current and expected hazards and adaptation works

For the town of St Helens filling of land has been occurring and according to anecdotal evidence has caused drainage and/or flooding issues to neighbouring properties. In the long term raising land and property and drainage management may be opted for as the preferred pathway. A long term management plan to will be required to guide and implement this strategy.

The hazards from inundation from the sea have been documented by the project for present day and for sea level rise of 0.3 and 0.9 m. However the additional impact of flooding from peak rainwater runoff locally in the town of St Helens was not well established. This would require more detailed modelling of the rainfall and runoff dynamics as a result of climate change and was not part of the project.

Although locations subject to erosion were identified, the dynamics of the Georges River mouth were not fully taken into account. In addition, the silting of Georges River and the river 'jumping canals' and likely evolution of this remain poorly assessed. Thus the overall hazard is arguably understated.

The impacts works to resist erosion would have on the dynamics of the area including the likely impacts on silting, environmental changes and impacts on the wider coast and nearby coastal development are poorly understood. For example in the Clarence work, these impacts were explored in the 'reality check' stages after the community workshops. The experience from Lauderdale (Clarence) shows that it takes significant investigation to get a good understanding of erosion risk. This is essential both to identify effective strategies to mitigate erosion risk and to have a clear understanding of the impacts of these strategies, not only on the erosion risk but wider impacts. The complexity in tidal estuaries partly exposed to open water is even more complex.

Recommendation: To include modelling of local peak rainfall dynamics in St Helens in conjunction with sea level rise to better identify flood risk, as well as modelling drainage capacity in potentially flood affected areas that are developed or proposed for development.

Recommendation: To undertake additional analysis of erosion and the mobility of the George River mouth and the realistic options for erosion protection works (for both Binalong Bay Rd and the northern edge of the town of St Helens) including their likely effectiveness and impacts.

Recommendation: To review the planning scheme to address possible adverse impacts of filling to adjacent property owners. Requirements need to be incorporated about where land fill is allowed and under what circumstances, i.e. land fill should not be allowed to have negative impacts on drainage on nearby properties. In the longer term, if a strategy to protect St Helens is adopted, a strategy for raising land and properties and for drainage management will need to be adopted and implemented.

A better knowledge of the environment

The wider community has an interest in protecting environmental values that may provide important ecosystem services (fish breeding, water filtration and nutrient reduction, etc.), habitat, particularly for threatened species. Protecting these values may in some cases make protecting property more difficult, more expensive or entirely impractical, potentially raising tensions between local interests and those of the wider community. While this possible tension was less of an issue in regards to the two locations addressed in the workshops (long term

protection was mostly not seen as feasible in the Georges River mouth, and the foreshore of St Helens involves land that has already been altered significantly), this issue may be significant in regards to the remaining two areas (southern coast of Georges Bay and the Environment Management zone).

It is important to gain an understanding of the impact of any interventions on the wider estuary including impacts on the ecosystem services, threatened species and environmental amenity values. Areas with high environmental values need to be identified as well as their likely response to sea level rise and other climate change effects.

Where areas that have high environmental values are identified, assessment should identify the practical options to support their continued viability. In some cases there may be no action that can ensure they continue to provide environmental services or critical habitat. In other cases, development or adaptation initiatives may either reinforce or undermine their continued existence. While not all natural environments can be preserved, the most valuable should be clearly identified and supported to the extent possible, even where property protection is given a priority.

Communities are often not fully aware of the environmental values in their coastal areas. A greater awareness of these values may also enable a wider support for adaptation works where the protection of private property is not the only consideration.

Recommendation: Prepare a detailed assessment of the environmental values of the areas around Georges Bay, including consideration of the likely changes that sea level rise and climate change will bring. Identify areas of high environmental significance that need consideration in any adaptation works, either to assist with the adaptation of the natural area or to ensure that adaptation measures to protect built assets do not adversely affect important natural areas.

Recommendation: To inform the community about significant environmental values that have been identified, and to explain why they are important to both the local and wider community.

Longer term planning context

The strong desire to protect existing investments suggests an important reason not to allow development in areas where environmental modification is likely to have undesirable impacts. It would be highly desirable to review the planning scheme in coastal areas within the LGA to ensure that development is not permitted in any areas of environmental significance that would be affected adversely by new development seeking to protect itself in the future.

Once it is accepted that there are few critical environmental values remaining in an area, the imperative to protect property becomes even more elevated. The debate then turns to the amenity merits of one or another form of protection.

For eroding coasts, once the limits of protection via 'soft measures' such as beach nourishment are reached, effective erosion protection works are generally intrusive and change the character to the area. This will deter those seeking natural beaches from the area but may remain attractive to those accepting breakwater, groynes, and other coastal works such as promenades along hardened coasts. As natural beaches become less common, they are likely to be more highly valued – and protected. It may be desirable to identify those undeveloped beaches most highly regarded by the wider community and protect them for the long term by prohibiting development within potential erosion zones. For existing development behind highly attractive beaches, it will be much harder to limit redevelopment or resist the demands to protect existing properties.

Recommendation: Review priority coastal areas of high value to the community for aesthetic, amenity or natural values that could not be protected from climate change impacts, if developed, without compromising these values. Amend the planning scheme to ensure development controls reflect this.

Adaptation requires funding

Both the recommended investigations above and the works required for adaptation will require significant funds. For example, Clarence City Council has spent close to \$500,000 to date and the most recent investigations further changed the recommended response significantly from that suggested by earlier, less detailed work. It appears that there are few shortcuts to achieving a good understanding of the local issues that need to be addressed to adapt to climate change in a responsible way.

Under the principle put forward in the TCAP project that there will be no subsidy to assist people to occupy hazardous locations, and consistent with the recommendation of the report on funding and decision making, it is expected that the funds would be raised substantially by a special rate levies on property within the identified hazard areas. Some transition assistance may be available from national or state programs to support climate change adaptation, emergency planning or other relevant programs.

The existing cost estimates for adaptation for the town of St Helens and of Binalong Bay Rd with a strategy to retreat to an alternative route in the medium term are broad and may not consider all costs involved. The costs of for instance upgrading Reid Rd as an alternative route to Binalong Bay may be significant. The region is an important tourism destination in Tasmania. Those who benefit from retaining access to Binalong Bay (and other parts of the Georges Bay area) are not only local residents, but also local tourism operators, non-permanent residents, tourists and the tourism industry in general. When the wider community (also) benefits from adaptation options, there will be a case to seek contributions to cover the costs from a wider base than just the local residents.

Recommendation: That an assessment is undertaken to more accurately estimate the likely costs of adaptation options, and also to consider who benefits from different adaptation options. Priority should be given to options for Binalong Bay Rd and a possible retreat to the alternative route of Reids Rd.

Recommendation: That an approach be formulated to identify the budget required and the sources of funds to raise the money required. It is considered that this should be done on a staged basis over a period of about 5 years, with priority given to identification of and responding to road flooding and stormwater drainage.

Local community and wider community values and objectives

The people from the local community attending the community workshops have made it clear that they generally place a priority on the protection of property, even if it requires some modification of the local environment. In general there was concern to keep the key amenity values. However, given real threat to property, most supported significant interventions to avoid property loss in developed areas, such as the town of St Helens.

However, the values the wider community holds in respect to certain areas may vary from local residents and property owners. As a rule of thumb, natural values and ecosystem services (such as fish breeding areas) are values by the wider community. Protecting natural values may interfere with protecting natural values. State and Federal legislation in some cases addresses these wider interests. Also State and sometimes Federal agencies and other stakeholders from outside the area will need to support the chosen direction for it to be effective. For instance, state owned and managed infrastructure such as roads can only be raised if this strategy is backed by the relevant State agency. For them to do so, any actions must be consistent with the legislative and other obligations of their organisations.

A process for agreeing a plan and reconciling different interests has been proposed in a paper prepared to 'reality check' the proposed pathway for Lauderdale in Clarence: *Decision Making and Funding for Coastal Adaptation*. This proposes that an adaptation management plan would be developed and formally adopted under a State government framework. The process would have parallels with the development of a planning scheme with opportunities to make representations and appeals, and input from state agencies and review by an authority to confirm compliance with relevant legislation. By having State backing, it would reduce the burden on Local Government for any impacts arising from implementing the plan. The content of this paper would equally apply to Port Sorell, or any other community in Tasmania facing similar issues.

At present the State does not enable such a plan to be prepared and recognised.

Recommendation: To work with the state government to develop a framework for the development of coastal adaptation plans that have state backing and recognition, and balance the priorities of both the local and wider community.

APPENDIX 1 COST OF RISK – METHOD

The method used to determine the present value of expected damages associated with coastal inundation risks in Georges Bay (and the other project sites) is as follows:

1. Estimate the elevation level of each property within each project site, by overlaying the Geocoded National Address File (G-NAF) points to the earth surface image (LiDAR DEM²¹)
2. Obtain the present-day water surface profile of each area that gives the depth of forecast coastal floods (and riverine floods in some areas) by their return interval or exceedance probability
3. Add the expected sea level rise over time to derive the future water surface profile
4. Derive the current and future inundation depth from floods of certain frequencies by differencing the water surface with the earth surface plus the floor height above the ground
5. Estimate the expected costs of inundation risks over time, in consideration of the likelihood of occurring different flood events and potential damage at different depths (damage curve)
6. Discount the expected damages over time back to today's value.

A detailed description of the method and the inputs in the modelling are provided in the Hedonic Value Model Report.

²¹ Digital elevation model representing the surface heights of the land, measured through the light direction and ranging (LiDAR), similar to "radar" but using infrared laser light pulses instead of radio pulses

APPENDIX 2 ACCEPTABLE LEVELS OF RISK

For risks that do not change over time, potential damage from events with an annual probability at or below 1% is often considered an **acceptable level of risk**²². A property that has a floor just at the 1% AEP flood level has an expected damage in any given year of 0.2 - 0.35% of the value of the structure²³ in Kingston Beach, Georges Bay and Port Sorell. On a structure worth \$100,000, this corresponds to an expected annual damage of \$200 to \$350 if exposed to this level of risk from inundation from the sea.

Without sea level rise, this value would remain the same each year. The lifetime NPV of expected damage would increase with the expected life of the structure. Column 2 of the tables below summarises the NPV (expressed as a % of the replacement value of improvements, using a discount rate of 5%) of the expected lifetime damage for different lifetimes.

With a longer lifetime the amount of expected damage increases, but beyond about 60 years, the increase is greatly reduced by discounting. For a 90 year lifetime, this increase to about 7.4% in Kingston Beach, 5.2% in Georges Bay and 4.8% in Port Sorell. This provides a benchmark against what is typically considered to be an acceptable risk for dwellings in each location.

NPV EXPECTED COST OF RISK, WITH AND WITHOUT SEA LEVEL RISE, IN KINGSTON BEACH (WITH FLOOR AT 1% AEP FLOOD LEVEL IN 2010),

Length of time (years)	No sea level rise	With sea level rise	Increase in floor level for similar risk as no sea level rise (m)
10	3.1%	3.7%	0.02
20	4.8%	6.9%	0.04
30	5.8%	10.4%	0.06
40	6.4%	14.3%	0.08
50	6.8%	19.1%	0.11
60	7.1%	24.5%	0.13
70	7.2%	30.4%	0.15
80	7.3%	36.5%	0.17
90	7.4%	42.1%	0.19

Source: SGS (2012)

²² Different acceptable levels of risk would be applied to different uses. A much lower level of risk would be used for a school or hospital compared to a boat shed or car port.

²³ It is normal to require a freeboard above the predicted flood level, usually of about 0.3 m. The expected damage for such a building could be even less, but the freeboard is often used to compensate for uncertainties in the estimate of actual flood levels.

NPV EXPECTED COST OF RISK, WITH AND WITHOUT SEA LEVEL RISE, IN GEORGES BAY (WITH FLOOR AT 1% AEP FLOOD LEVEL IN 2010)

Length of time (years)	No sea level rise	With sea level rise	Increase in floor level for similar risk as no sea level rise (m)
10	2.2%	2.8%	0.05
20	3.3%	4.9%	0.07
30	4.1%	6.6%	0.09
40	4.5%	8.1%	0.11
50	4.8%	9.6%	0.13
60	5.0%	11.3%	0.15
70	5.1%	13.3%	0.18
80	5.1%	15.8%	0.21
90	5.2%	19.3%	0.25

Source: SGS (2012)

NPV EXPECTED COST OF RISK, WITH AND WITHOUT SEA LEVEL RISE, IN PORT SORELL (WITH FLOOR AT 1% AEP FLOOD LEVEL IN 2010)

Length of time (years)	No sea level rise	With sea level rise	Increase in floor level for similar risk as no sea level rise (m)
10	2.0%	2.8%	0.06
20	3.1%	4.9%	0.08
30	3.8%	6.7%	0.96
40	4.2%	8.4%	0.12
50	4.5%	10.2%	0.14
60	4.7%	12.2%	0.16
70	4.8%	14.8%	0.19
80	4.8%	18.4%	0.22
90	4.8%	23.0%	0.26

Source: SGS (2012)

If it is assumed that the building depreciates over time, the value lost from a major flood would be less. The economic loss is only that of the depreciated value of the dwelling²⁴.

If the same dwelling is exposed to about 1.0 m of sea level rise over the next 90 years, the amount of expected damage increases each year as the probability of damaging floods (or the depth of a flood of a given probability) increases. The expected damage in a given year rises particularly quickly in later years as the rate of sea level rise increases and many more flood events are expected to be damaging. In that case, the NPV rises continuously as shown in the column 3 of tables above, because the rising damage offsets the effects of discounting.

As a result, the risk exposure is several times higher than that normally considered acceptable. The NPV of expected damages increases as a share of the existing replacement value, the longer the life of the structure. If this risk remains unmanaged in any way, the probability of a damaging flood event is quite high, and insurance is unlikely to be available. Either the household or the government will eventually be faced with the consequences of a flood. Usually where a large amount of property is damaged, government is faced with significant costs for clean-up, recovery and assistance to 'victims'.

The last column of the tables above shows how much higher a floor must be today to give an equivalent NPV risk of damage over a given period with sea level rise to one that is at 1% AEP level with no sea level rise, again without depreciation. The extra height required will be directly related to the intended or expected life of the dwelling: a short lived structure will only have to be a bit above the present day 1% AEP flood level as sea levels will not rise much in the short term; a long lived structure will need to be higher to cope with higher rises. Because of discounting, damage in the far future is not weighed as heavily as damage in the near future. This gives a much lower increase in floor height for a structure with a 90 year expected lifetime than might be suggested by an expected sea level rise of say, 1.0 m by 2100.

²⁴ If the building is damaged and needs to be repaired, the cost of the repairs would be the replacement cost, but the occupant ends up with a partially renewed structure.

Overall, it shows that for structures with an expected lifetime of less than 40 years, the increase in floor height above the present day 1% AEP level is very modest, less than 0.1 m. For comparable levels of risk in terms of NPV of property damage up to 90 years, increased floor height of 0.2–0.25 m would be required, still well less than the expected sea level rise of 1.0 m.

For dwellings with floor levels above the current 1% AEP flood level, risks for the first few decades are significantly lower than for those at the 1% AEP level. This is then offset by much higher risks in the later years. While the present value of those future risks is low because of discounting, in practical terms the annual probability rises well above 1% and it would be wise to protect the structure at that time if it still had a significant service life or not to reinvest and allow it to depreciate in the later part of its life.

APPENDIX 3 DESCRIPTION OF VARIABLES USED IN HEDONIC MODELLING

Abbreviation	Full name used in main body of report	Units	Description
Curr_LV	Land value	Nominal dollars	Land value estimated by the Office of Valuer General. This is the dependent variable in the regression model.
const	Constant	n.a.	This is the estimated constant term in the regression model. The constant is the land value when all other variables are zero (i.e. zero square metre lot size, zero metres from business and so on). The constant must always be included in the land value prediction equation. It can be interpreted as the intrinsic value of the land itself, when all other attributes are zero.
LotArea_sqm	Lot area	Square metres	The area of a lot.
Dist_Industrial	Distance from industry	Metres	The distance from the nearest industrial zone.
Dist_Bay	Distance from ocean	Metres	The distance from ocean water.
AHD	Elevation	Metres	Australian Height Datum (AHD) is the current official standard Australian height reference (ICSM, 2006). For Tasmania, it is based on mean sea level at Burnie and Hobart gauges in 1972. For a number of reasons, AHD is an approximation of mean sea level only. A property with one metre AHD is therefore one metre above mean sea level.
BF_Access	Beach front access	Yes (1) or No (0)	This is a dummy variable, where lots facing the beach are given a value of one, while those that are not facing the beach are given a value of zero.
River_Access	River front access	Yes (1) or No (0)	This is a dummy variable, where lots facing the river are given a value of one, while those that are not facing the river are given a value of zero.
LandSlipProne	Land slip /erosion prone land	Yes (1) or No (0)	Local planning scheme maps were used to determine landslip / erosion prone areas. This is a dummy variable, where lots on landslip areas are given a value of one, while those that are not are given a value of zero.

Source: SGS (2011)

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