Coastal Adaptation Study (Stage 1)
Coastal Adaptation Strategy (Stage 2)

For City of Victor Harbor

Main Report

To be read in conjunction with:

- Coastal cell reports (3)
- Engagement summary reports (Appendix 1 and 2)

Western, Bourman, and Hesp

October 2021

Integrated Coasts

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Citations

This document and the individual cell reports should be cited as:

Western, M, Hesp, P, Bourman, R, 2021, Coastal Adaptation Study for City of Victor Harbor, Integrated Coasts, South Australia.

Appendix 1 is a stand-alone document produced by Nicole Halsey, URPS and reports the process and findings of the community engagement for the Coastal Adaptation Study (Stage 1).

Engineering review and inputs were supplied by Magryn and Associates, T. Magryn, W. Souter.

Front Cover

City of Victor Harbor coastline, photographed by Coastal Management Branch, Department for Environment and Water in 2008.

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Contents

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- Professor Patrick Hesp (Flinders University) for evaluating SA Coast Protection Board beach profile lines and estimation of rates of shoreline recession.
- Professor Robert Bourman for his work on the geomorphology of the Victor Harbor coastline and input into the risk assessment process.
- Mike Hillman and Joram Downes for their input to this project.

Integrated Coasts wishes to thank City of Victor Harbor for their support for this project, in particular for Lee Jeffries ongoing support and management of the project.

Integrated Coasts acknowledges the contribution of:

- Nicole Halsey, URPS, for contributions to the community engagement process.
- Terry Magryn and Will Souter, Magryn and Associates, for engineering review and inputs to this project.

Executive summary

City of Victor Harbor (the Council) engaged Integrated Coasts in January 2021 to produce a coastal adaptation study (Stage 1) and a coastal adaptation strategy (Stage 2) for the coastline from the Bluff Boat Ramp to the eastern border of Council. The coastal adaptation study was completed in the months February to April. Community engagement was then managed by URPS in May, and Appendix 1 is a standalone report of the activities and findings from this process. The coastal adaptation strategy was developed in June and July 2021.

Project structure

The report is structured in two main sections. Part 1 reports the methodology utilized in the study and the coastal issues that are common to the entire coastline. This document represents Part 1 of the study. Part 2 of the study creates standalone reports for three coastal conservation cells within City of Victor Harbor as depicted in Nature Maps and designated as Fleurieu 10-12[1]. These cells are divided into minor cells to enable a more fine-grained assessment of the various locations along the coast.

The three cell reports that compile Part 2 are:

- McCracken-Hayborough (Cell F10)
- Victor Harbor Central (Cell F11)
- Encounter Bay (Cell F12).

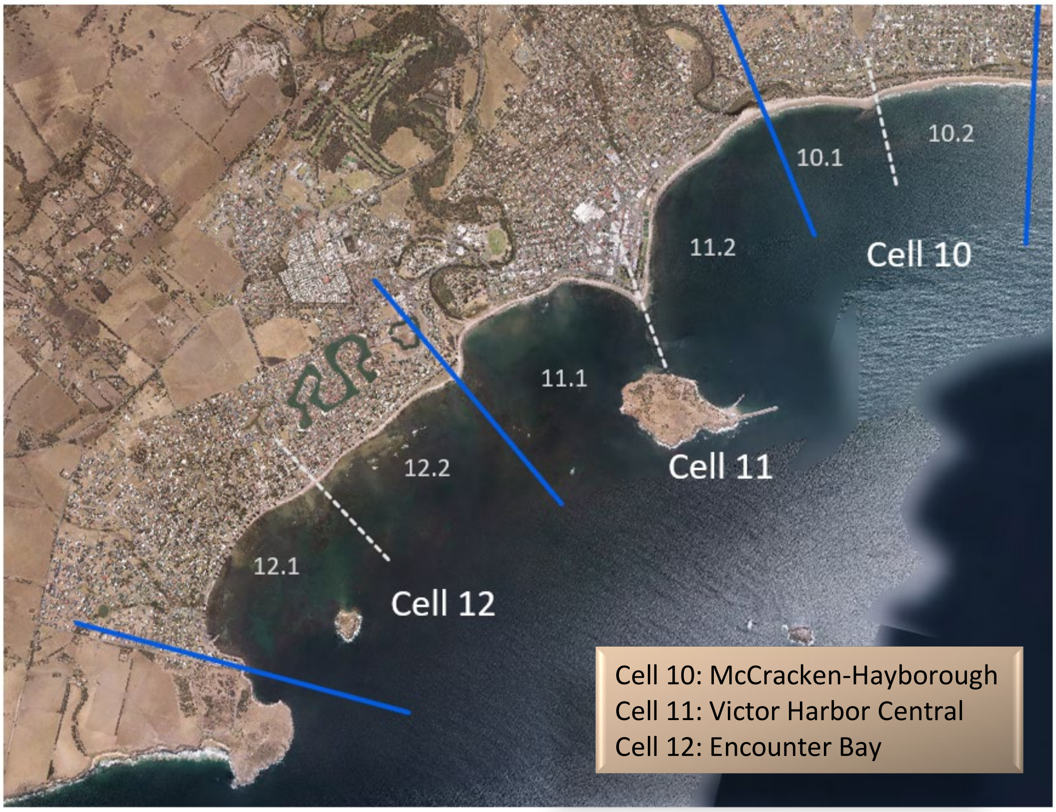

Figure 1. Coastal cells adopted for the study. Aerial photograph, City of Victor Harbor, 2018.

[1] Nature Maps, Department for Environment and Water, SA Government.

Model of coastal adaptation

Integrated Coasts has adopted three broad principles of adaptation:

- Coastal adaptation takes place in localities (and therefore analysis is required to be fine-grained within secondary and tertiary coastal cells),
- Coastal adaptation will take place over a long period of time (and therefore the prime decision-making tool will be the outputs from ongoing monitoring)
- Coastal adaptation should be based on the analysis of physical data (and therefore up-to date digital models and access to tide and storm activity is essential).

In summary, a coastal adaptation study is only the initial starting point for coastal adaptation that will take place over decades. These principles are encapsulated in Figure 2.

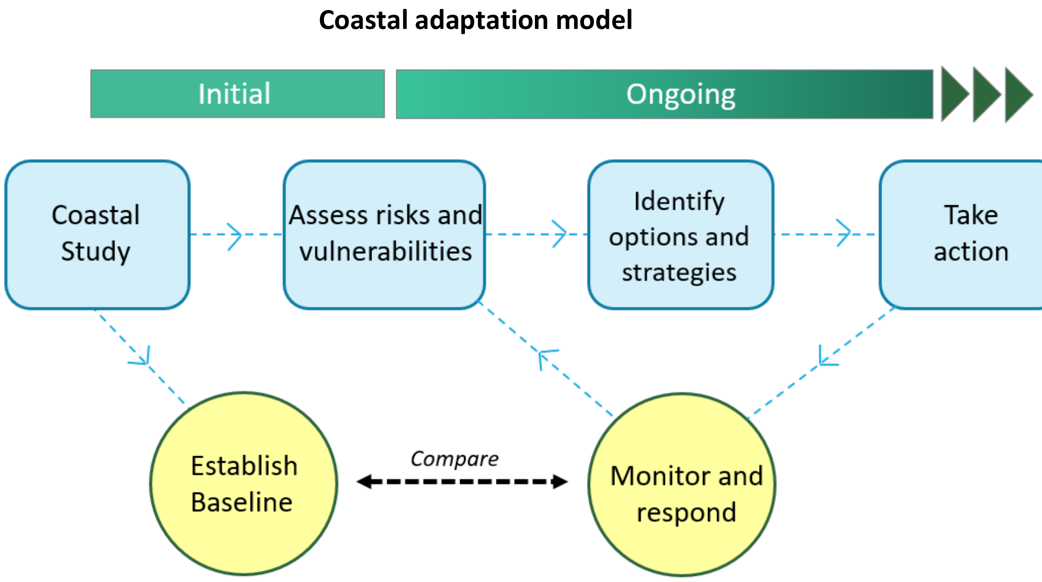

Figure 2. Coastal adaptation model – monitor and respond, Integrated Coasts, 2017

Considering Figure 2 there are three main outputs from this study: a baseline study, an assessment of risks and vulnerabilities for current and future eras, and a coastal adaptation strategy. A future monitoring program will provide the context in which the strategy is implemented.

<u>Baseline study</u>

Included in the baseline study is a comparative analysis of aerial photography from 1949, 2009 and 2018 to establish shoreline movement trends. Other historical photography from as early as 1850s provides an insight into the changes in the coastline over 150 years. South Australian Coast Protection Board has been conducting profile surveys of the ocean floor, beach and backshore at 5 locations along the coast since the 1970s. Archival research at Department for Environment and Water has identified accounts of previous storm and erosion impacts as well as prior coastal studies and assessments.

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Assess risks and vulnerabilities

The second output from the study is an assessment of risks and vulnerabilities. Historical shoreline analysis and a review of storm activity identifies erosion hotspots. Inundation mapping within the digital elevation model for current risk, 2050 risk, and 2100 risk, serves two purposes. In a location such as the Inman River, inundation mapping provides a risk outlook for dwellings and infrastructure in relation to flooding. In areas that are not vulnerable to inundation, an analysis of the impact of wave setup and wave runup on the backshore provides a way to identify the coastal areas that are likely to be vulnerable to impacts of sea level rise first. Erosion modelling using the Bruun Rule and shoreline translation/ recession methodology provides an outlook for erosion.

Coastal adaptation strategy

The third output is the coastal adaptation strategy which was prepared as Stage 2 of this project.

Purposes of the study

Considering the model for coastal adaptation, the general purposes of the coastal adaptation study are to:

- Create a baseline upon which to monitor future changes,
- Conduct scenario modelling from which to identify plausible futures,
- Identify key coastal issues and vulnerabilities,
- Provide a risk assessment for each coastal cell,
- Bring all previous work into one place of reference,
- Provide a basis for ongoing adaptation planning.

The coastal adaptation study provided the basis to formulate the coastal adaptation strategy.

Previous study

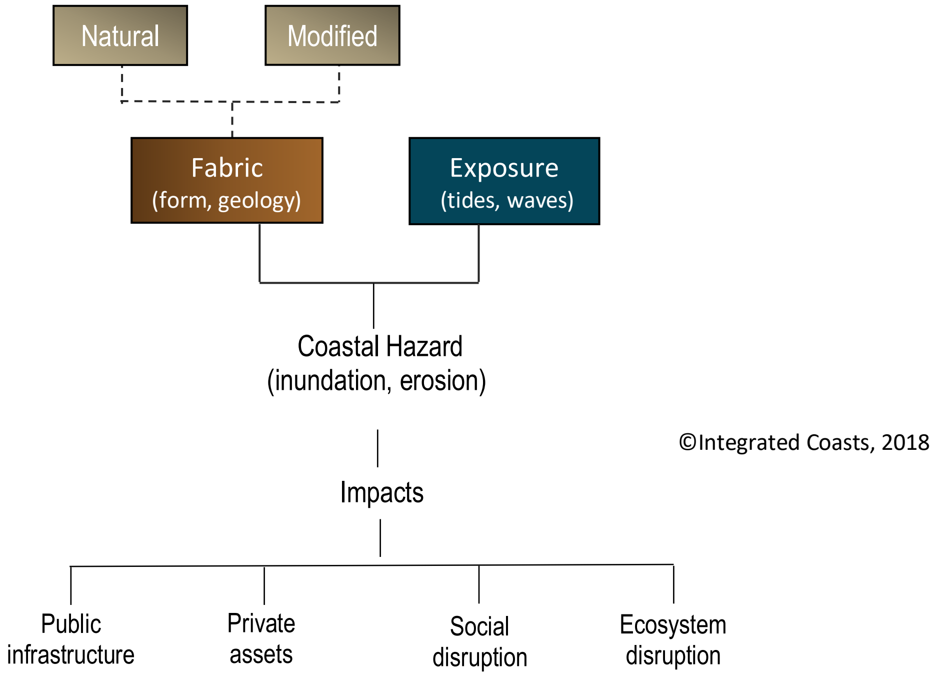
The City of Victor Harbor has completed previous coastal studies, or studies that relate to decisions within the coastal zone, and these have been reviewed and incorporated into this current study. These studies include:

- Foreshore Protection Study, Magryn, 2006.
- Coastal Engineering Report (Erosion) – Victor Harbor, Coastal Management Branch, 2009.
- Victor Harbor Coastal Management Study, Australian Water Environments, 2013.
- Climate Change Adaptation Plan for Adelaide Hills, Fleurieu Peninsula and Kangaroo Island, Seed Consulting and URPS, 2016.
- Victor Harbor Foreshore Coastal Park – Open Space Plan, Bechervaise and Associates, 2003.
- Urban Stormwater Management Plan, Kellogg Brown and Root, 2005
- Southern Fleurieu Coastal Action Plan and Conservation Priority Study, Caton et al., 2007
- City of Victor Harbor Recreation and Open Space Strategy, Suter Planners, 2017.

Conceptual assessment framework

Coastal hazards experienced along a section of a coastline can be generally framed in terms of the nature of the 'fabric' (the nature of the geology and form) in the context of the nature of the 'exposure' (the impact of wind, tides, waves) (Figure 3). A conceptual framework provides a consistent way to evaluate a complex issue, and in such a way that communication with all levels of stakeholders is enhanced. The flow of the assessment within this study follows the flow of the conceptual framework for each of the coastal localities (also known as cells).

Figure 3: Conceptual assessment framework



Risk assessment

Risk assessment is conducted at two levels within the conceptual framework. The first risk assessment categorises the risk to a coastal cell in relation to inundation and erosion. The focus of this risk assessment is upon the inherent characteristics of the coast and not focussed on any potential threat to human infrastructure of natural ecology.
Impacts of erosion and inundation hazards are then considered within four receiving environments:

- Public infrastructure
- Private assets
- Social disruption
- Ecosystem disruption.

Hazard impacts are also considered in two eras: the 'current outlook', and the 'future outlook'. In this study, future outlook means the end of this century. We use Council's risk assessment framework that utilises a 'likelihood – consequence' matrix to allocate risk. The term social disruption covers two aspects from the risk assessment framework – community concern and public safety.

Project Scope

The climate change driver under consideration in this project is sea level rise. In this project we focus on the direct impacts of actions of the sea upon backshores along the coast. Other climate change impacts, such as the projection of a drier climate may produce less vegetation in dunes, and further exacerbate erosion, but these impacts are difficult to quantify and are not addressed. In this study the impact of rising sea levels upon backshores can be quantified through sea flood modelling within digital models. Associated with these direct risks are a range of indirect risks. For example, the potential loss of a beach from erosion is a potential social and economic risk (if the beach is related to economic activity such as tourism). A political risk may occur when decision makers act in ways the communities do not support. However, all of these are indirect risks are derived from the direct risks to the coastline from inundation or erosion. In summary, in a bid to increase certainty, this project evaluates the *direct impacts* of inundation and erosion in the context of *rising sea levels*. In a bid to contain focus, this study assesses the *direct risks* to assets, people and ecosystems that are positioned within coastal regions.

General findings - summary of coastal hazards

Inundation

Generally, the coastline of City of Victor Harbor is set above current sea-flood risk apart from the overtopping of protection works in the vicinity of the reserve and playing fields on Flinders Parade. However, if seas rise as projected post 2050, seawater flows will increasingly overtop protection works along Flinders Parade and flow over Franklin Parade between Tabernacle Road and The Bluff boat ramp. Without intervention, these areas are not likely to be viable for their intended uses later in the century. Increasing levels of seawater flowing up the estuaries post-2050 will eventually overtop the levee around the caravan park and possibly flow into the residential area on the northern side of Hindmarsh River (to be confirmed). The modelling suggests that seawater will overtop the banks of the rivers in places, causing ecosystem disruption, but the impact upon roads and urban infrastructure may be low.

Erosion

Prior to 2050, erosion will increase around the coastline with distances of recession likely to be measured in metres. Beach and dune locations are likely to suffer cyclic recession but also may rebuild over time (The Esplanade Beach, McCracken, Hayborough). Locations where the backshore is an unprotected embankment are likely to experience permanent erosion damage and recession (Encounter Bay, Bridge Terrace). In locations where humans have placed hold points (protection items), sand levels in these regions are projected to drop with the result that some beaches may be lost (Flinders Parade, Encounter Bay). If seas rise as projected post 2050, erosion will substantially increase with shoreline recession measured in decametres. Beach and dune locations are likely to suffer significant erosion with retreat back to esplanade roads (The Esplanade Beach), and to the trainline (McCracken, Hayborough). Unprotected embankments are likely to experience permanent erosion damage and recession (Encounter Bay, Bridge Terrace). In locations where humans have placed hold points (protection items), sand levels in these regions are projected to drop so that beaches are completely lost and protection works undermined (Flinders Parade, Encounter Bay).

Implications for coastal adaptation

The implications of the findings of this study in the context of coastal adaptation include:

Settlement history

1. The practice of laying out urban settlements with an esplanade road between coastal open space and private assets means that a buffer has been created between the coastline and private property. Therefore, the main focus for coastal adaptation will be for Council to manage its own public assets in the context of rising sea levels.
2. Irrespective of (1), there is unlikely to be any legal requirement for Council to protect private assets. Furthermore, it has been the State Government's policy since 1980 not to fund the protection of private property.
3. Councils were only required to consider actions of the sea in planning decision after ~1990. Before this time, the implications of sea level rise were generally unknown and therefore Councils are unlikely to be liable for decision making in the absence of knowledge or policy.

Geomorphology

4. The coastline has been formed over the last 4-5000 years within softer sediments as waves refracted around the hard granite outcrops (The Bluff, Port Elliot, and the islands). If seas rise as projected, then the rate of change on these softer landforms can be expected to increase but the hard outcrops will continue to maintain the general shape of the shoreline.
5. The lowland areas were likely formed when seas were 1m higher than present about 4-5000 years ago. The foreshore areas of The Esplanade Beach, Flinders Parade, Bridge Terrace and Franklin Parade were underwater at this time and were moulded into their current shape as sea levels decreased. This recent geomorphological history is relevant to consider in the context of projected sea level rises of 1m.

Coastal Fabric

6. The erodibility of the Victor Harbor coastline can be generally characterised as *low-moderate* due to the sheltered nature of the coastline or the presence of protection items (e.g. Flinders Parade) or *high erodibility* assigned to The Esplanade Beach.

7. Some areas of the coastline have been stable over a long period of time (Encounter Bay near The Bluff boat ramp, the coast along Bridge Terrace, and the coastline from Hindmarsh River to Chiton Rocks). The Esplanade Beach and the beaches within Encounter Bay undergo cycles of accretion and erosion. However, erosion has been the greater tendency since the 1990s, especially within a stormy period from 2004 to 2011.

8. Generally, the backshores in the Victor Harbor region have been heavily modified by urban settlement with the installation of roads, carparks, playing fields and a trainline that runs above the beach at McCracken and Hayborough. Protection items have been progressively added to backshores to protect these urban structures. All of these structures act as 'hold points' preventing the shoreline from adapting naturally in the context of rising sea levels.

Coastal exposure

9. South Australian Coast Protection Board has adopted sea level rise policy standards of 0.30m sea level rise by 2050 and 1.0m sea level rise by 2100 compared to levels in 1990. These policy standards are based on the assessments of the Intergovernmental Panel on Climate Change (IPCC) and are congruent with IPCC sea level rise projection scenario for RCP 8.5.
10. Nature Maps (SA) assesses the exposure of City of Victor Harbor coastline within the context of South Australian marine waters as: *sheltered* with *low wave energy* for the coastline from The Bluff boat ramp to the causeway and *moderate* with *low-moderate wave energy* for the coastline from the causeway to the eastern border of Council.
11. Previous storm activity was identified by the review of old newspapers, archives at Department of Environment and Water, and contributions provided by the community. Storm activity was prevalent in 1920s to 1940s, 1970s and 2007 to 2011. Storms were often reported overtopping into the playing fields on Flinders Parade. No previously unknown storm event was identified that caused significant inundation of urban areas.
12. Routine high-water events and the rarer storm surge events are likely to have the following impacts on the coastlines by 2050:
    - Increased overtopping of roads (Franklin Parade) and reserves (Flinders Parade).
    - Soft sediment plains and slopes – recession of the shoreline (measured in metres).
    - Human intervention – where backshores have been changed to hard surfaces (rock and seawalls), sand levels are likely to decline on the beach.
    - The scenario modelling suggests that the impact within the estuaries may not be significant enough to cause major disruption. The levee around the caravan park is likely to be high enough and the levee and retaining wall on the northern side of Hindmarsh River is likely to prevent incursion of water into residential areas.
13. Routine high-water events (occurring at much higher rates than current) and storm surges are likely to have the following impact on the coastline by 2100 if seas rise as projected:
    a. Significant and regular overtopping of Franklin Parade (and some inland flows between Fountain Ave and Tabernacle Road) which is likely to make this road unviable without intervention. Significant and regular overtopping into Soldiers Memorial Gardens and the playing fields, with water flows over Flinders Parade in places. It is unlikely that the gardens and playing fields would be viable if seas rise as projected (or at least without major intervention along the shoreline).
    b. Soft sediment plains and slopes (McCracken, Hayborough, Bridge Terrace, Kent Reserve) would suffer significant recession (likely to be measured in decametres).
    c. Human intervention – where backshores have been changed to hard surfaces (rock and seawalls), sand levels will decline so that beaches are lost in some locations.
    d. Seawater flows into estuaries would overtop the caravan park levee and likely flow into residential areas adjacent the Hindmarsh River (but surveying is required to confirm the latter). The modelling suggests that seawater may not flow over Bay Road into the area in which the City of Victor Harbor and Civic Centre is situated but sea water would likely flow over banks causing disruption to ecologies.

Stormwater

14. In general, City of Victor Harbor is managing the stormwater run-off from urban environments so that erosion in backshores is avoided. However, in the context of projected sea level rise two issues are relevant. In some locations (The Esplanade Beach) storm water outlets are situated at the back of the dune system. This means that the dune system cannot be built up and consolidated with vegetation. Additionally, many storm water outlets are set at low elevation. Therefore, as sea levels rise these will increasingly be impeded in their operation and the potential for inland flooding may be exacerbated.

Coastal adaptation strategy (2021- 2031)

The second stage of the project was to create a coastal adaptation strategy for implementation over the course of the next decade.

McCracken-Hayborough (Cell 10)
McCracken coastline is categorised as a fine-medium sandy beach which is backed by a vegetated dune that rises up to embankment upon which the trainline is situated. The coastline undergoes cycles of erosion and accretion, but overall has generally accreted since 1949. Urban development is situated ~25 to 50m landward of the trainline. The erosion modelling indicates that the dune system seaward of the trainline will erode away by 2100 and the embankment under the trainline will come under attack. Irrespective of whether the trainline can be protected or will need to be removed, the embankment will prevent any direct attack from the sea to the base of the coastal slope upon which the settlement of McCracken is situated. The short to mid-term strategy is to monitor and maintain the existing vegetated dune system using environmental management techniques. Storm water outlets should be designed to minimise scouring on the beach and so that they can be adapted to the cycles of accretion and recession that take place on this beach, as well as the long-term recession that is likely if sea level rises as projected.

Adaptation Strategy: McCracken-Hayborough (Cell 10)					
Approach	**Short-term strategy 2020**	**Mid-term strategy 2050**	**Long-term strategy 2100**	**Adaptation Type**	**Monitoring strategy**
Incremental [Monitor and Respond]	[Hold the line with vegetated dune system, adjust location of storm water outlets]	[Hold the line with vegetated dune system]	Either protect the trainline, or managed retreat (remove the trainline)	Environmental: Maintain dune Engineering: Identify solutions to improve storm water management on beaches.	Shoreline position Storm impacts on backshores Analyse offshore profile lines.

Victor Harbor Central (Cell 11)

<u>The Esplanade Beach (Cell 11.1)</u>

The Esplanade Beach is a coarse sand beach backed by narrow low height vegetated dunes and either a car park or reserve positioned behind the dunes. The Esplanade Road is ~50m from the highwater mark. This beach undergoes cycles of erosion and accretion. If seas rise as projected, then the longer-term trend will be for erosion and recession of the dune. The short to mid-term strategy is to remove the gaps along this beach (e.g. storm water outlets) and create a well-vegetated dune system. The longer-term strategy is to maintain the dune system for as long as feasible and manage the retreat of the dune if this occurs with sand nourishment and vegetation. Harder protection works such as concrete block sea walls may prove useful within the dunes to slow recession. If the coast recedes back to the carpark, then hard protection will be required.

Adaptation Strategy: Esplanade Beach (Cell 11.1)					
Approach	**Short-term strategy 2020**	**Mid-term strategy 2050**	**Long-term strategy 2100**	**Adaptation Type**	**Monitoring strategy**
Incremental [But formalise a strategy]	[Hold the line] Develop a consolidated dune from Inman River to Causeway	[Hold the line} Maintain the dune – manage any permanent recession	[Managed retreat and then hold the line] Implement hard protection works when required.	Environmental (soft): Use natural dune system Engineering: Employ hard protection works if required post 2050.	Use quarterly terrain modelling using drone technology to provide inputs for sand nourishment and vegetation growth. Then lower-cost strategies.

Flinders Parade (Cell 11.2)

Fine to medium sandy beach backed by rock or concrete seawall from the causeway to bowling club, then very narrow, low height dune backed by walking path and playing fields. In the mid-1800s the foreshore contained a small dune system that extended back to Franklin Parade. Larger swells from the Southern Ocean have created the curve in the bay and these swells overtop the defences in the vicinity of Soldiers Memorial Gardens and bowling club. Sand has been declining on the beach.

Consideration is required as to the viability of long-term protection along Flinders Parade. If seas rise as projected, then the defences required will be of significant height which will tend to 'cut off' the community from the coast. Holding the line at its current location will also remove a useable beach. The adaptation proposal for this minor cell is for Council and the community to consider developing a master plan that will create a new layout for this section of the coast that will be designed to absorb the impact of the sea more effectively over time, remove storm water outlets from the beach, and create spaces adjacent the coast for the community to enjoy.

Adaptation Strategy: Flinders Parade (Cell 11.2)					
Approach	**Short-term strategy 2020**	**Mid-term strategy 2050**	**Long-term strategy 2100**	**Adaptation Type**	**Monitoring strategy**
Transformative [Consider developing a master plan]	Develop a master plan that considers alternative layouts]	If alternative layouts not implemented – raise protection works	If alternative layouts not implemented – raise protection works	Engineering (hard): Required for protection. Environmental: If sand beach is implemented.	Storm impacts on backshores Analyse offshore profile lines

Encounter Bay (Cell 12)

The Bluff Boat Ramp to Tabernacle Road (Cell 12.1)

The coastline from the Bluff Boat Ramp to Yilki is categorised as a coarse sand beach backed by an embankment that has been created to accommodate increasing amounts of urban structures (carparks, road lanes, bikeway). Increasing storm activity since 1990s has resulted in most of the backshore having some form of protection from Nevin St to Yilki.

Overtopping of the frontal defences occurs in this current time on high tides and larger swells. Sea level rise will increase the height and frequency of these events. The short to mid-term strategy is to design and implement a protection strategy that utilises the proposed bike track as the 'spine' of the defence system and to which protection works can be abutted. Storm water outlets should be designed and adapted to minimise scouring of the beach. The longer-term strategy post 2050 is harder to determine and will depend on the rate of sea level rise. The strategy is likely to involve maintaining protection works, increasing the elevation of properties (and perhaps roads) and accommodating some overtopping.

Adaptation Strategy: The Bluff Boat Ramp to Tabernacle Road (Cell 12.1)					
Approach	**Short-term strategy 2020**	**Mid-term strategy 2050**	**Long-term strategy 2100**	**Adaptation Type**	**Monitoring strategy**
Incremental [But formalise a strategy]	[Hold the line] Install bikeway to act as 'spine' to defence works. Add other protection as required.	[Hold the line] Ensure that the works installed now will manage 2050	[hold the line] but more difficult to identify and will depend on rates of sea level rise	Engineering (hard): Concrete bikeway and rock or concrete protection. Environmental: Where possible retain natural beaches and dunes.	Initial: monitor the wave effects of 2-3 storms. Longer term: Sand levels, Dune position, offshore profile.

Tabernacle Road to Kent Reserve (Cell 12.2)

The Encounter Bay coastline (Yilki to Kent Reserve) is categorised as a narrow coarse sand beach backed by embankments or dunes. The larger swells from the Southern Ocean wrap around the Bluff and Wright Island and periodically impact the backshores. Rock protection has been installed in three segments between Tabernacle Road and Bartel Terrace.

The backshores within Cell 12-2 are generally at higher elevation than in Cell 12-1. The short to mid-term strategy is to review the current protection works and design and install rock revetment to protect from Tabernacle Road to Bartel Boulevard. In the vicinity of Kent Reserve no protection works are currently required. Storm water outlets should be designed and adapted to minimise scouring of the beach. The longer-term strategy post 2050 is harder to determine and will depend on the rate of sea level rise. The strategy is likely to involve maintaining and improving protection, while managing the retreat of beaches such as those near Kent Reserve.

Adaptation Strategy: Tabernacle Road to Kent Reserve (Cell 12.1)					
Approach	**Short-term strategy 2020**	**Mid-term strategy 2050**	**Long-term strategy 2100**	**Adaptation Type**	**Monitoring strategy**
Incremental [monitor and respond]	[hold the line] Assess current protection/ damage. Progressively upgrade	[hold the line] maintain protection works.	[hold the line]maintain protection is the likely strategy.	Engineering (hard): Rock revetment is likely choice. Environmental: Where possible retain natural beaches and dunes.	Initial: monitor the wave effects of 2-3 storms. Longer term: Sand levels, Dune position, offshore profile.

Coastal adaptation tasks (2021- 2031)

It is recommended that the following tasks be implemented. Some of these items require either further design parameters and direction, and some will require long lead times in community and stakeholder engagement.

Coastal Adaptation Tasks				
Task	**Cell**	**Reason**	**Priority**	**Timing**
1. Develop a long-term monitoring program.	Council wide	It is essential to understand how the coast operates and when it may be operating outside of its normal parameters due to sea level rise.	High	1-2 years
2. Assess storms (2-3) of varying magnitude to identify appropriate wave effect allocations for the various parts of Victor Central.	Council wide	Currently wave effects are set at 0.30m for wave setup and 0.30m for wave runup for Cells 11 and 12. These are likely either too low, or not appropriate for all sections of the coast. Identifying wave effects for defined localities will aid in design of protection items and provide a more accurate context for ongoing management.	High	1-2 years
3. Conduct a feasibility study and cost estimates to reduce the flow of storm water to the beach from two outlets adjacent Hayward Court.	McCracken Hayborough Cell 10.1	Storm water is scouring the beach, reducing sand levels around outlets, and in some locations preventing the dune from establishing. It may be feasible to combine outlets.	Low	Within 5 years
4. Upgrade storm water outlet at Yandra Terrace with design able to be adjusted for cycles of erosion / accretion.	McCracken Hayborough Cell 10.2	Storm water is scouring the beach, reducing sand levels around the outlet and preventing the dune from establishing. Council has already contracted a storm water consultant.	High	1-2 years

5. Ascertain ownership of the old retaining wall, assign a function to the structure as something other than 'retaining wall'.	McCracken-Hayborough	This asset is no longer fit for the purpose of protecting the trainline and therefore should be removed or assigned a new function such as mechanism for 'dune stabilisation'.	Low	Within 5 years
6. Survey the levee surrounding the caravan park and report suitability for protecting to 2050.	Victor Central Cell 11.1	It is not clear from the digital elevation model whether the levee system is high enough and stable enough to protect for sea-flood scenario 2050.	Low	Within 5 years
7. Design and implement a program to consolidate and vegetate the dune system from the Inman River to the causeway. Remove gaps (storm water outlets and pedestrian points)	Victor Central Cell 11.1	The distance between the esplanade road and the shoreline is sufficiently wide enough to implement a soft management approach. Storm water outlets would need to be relocated to make this proposal viable.	High	Planning: 1-2 years Implement: within 5 years
8. Consider creating a master plan for the Flinders Parade – Bridge Terrace precinct.	Victor Central Cell 11.2	It will be difficult to protect this area if seas rise as projected. The location is a significant area in the context of a historic town. It is recognised that this process will involve extensive engagement with stakeholders and therefore the first step is intentionally kept simple.	Moderate	1-2 years (master plan only)
9. Design, cost and implement bikeway (pathway) from Tabernacle Road to the tree line north of the Bluff Boat Ramp constructed at sufficient height to manage sea level rises projected to 2050.	Encounter Bay Cell 12.1	This proposal will create a 'spine' for the protection strategy in this region to which protection can be added or replaced as required.	Moderate	1-2 years (design and plan) 5 years implement (but Yilki area sooner)
10. Assess the protection works from Tabernacle Road to Bartel Boulevard and upgrade/ repair if required	Encounter Bay Cell 12.1	Very recent storms have eroded the works in vicinity of Bartel. Some of the protection works are buried under the embankment.	High	Now (repairs may be required)

Part 1:

Coastal Adaptation Study

Completed February to April 2021

Part 1 of the project establishes a baseline understanding of how the coast was formed, how humans have interacted with the coast over time, how the coast has been performing over the last century. Current risks and vulnerabilities are identified, and the sea-flood modelling provides a basis to assess potential risks and vulnerabilities in the context of timeframes 2050 and 2100.

Part 2 of the project provides an adaptation strategy with a specific focus on actions and plans required for the time period 2021 – 2031. However, because assets constructed in the coastal zone usually have long life spans and because long lead times are often required to prepare for adaptation responses, in the first instance this strategy maintains a focus on sea-flood risk for 2050. Additionally, in locations of high social importance such as within Victor Central, the strategy also considers the longer-term adaptation context for 2100.

Document structure

The report is structured in two main sections. Section 1 reports the methodology utilised in the study and the coastal issues that are common to the entire coastline. Section 2 of the study creates standalone reports for the three Coastal Conservation Cells found between the Bluff Boat Ramp and the eastern border of the Council area (at Investigator Carpark). This document represents Section 1 of the study.

The coastal cell reports in Section 2 of the study are:

- McCracken-Hayborough (Cell Fleurieu 10)
- Victor Harbor Central (Cell Fleurieu 11)
- Encounter Bay (Cell Fleurieu 12)

Reading context

Readers requiring information on a particular location or region are advised to consult the relevant coastal cell report which adopt a highly visual format and are predominantly written in plain English. Readers who wish to know more about the methodology and technical aspects of the study are advised to read this report.

1. Introduction

City of Victor Harbor (the Council) engaged Integrated Coasts in January 2021 to produce a coastal adaptation study (Stage 1) and a coastal adaptation strategy (Stage 2) for the coastline from The Bluff boat ramp to the eastern border of Council. This report represents Stage 1 of the project. Community engagement was managed by URPS, and Appendix 1 is a standalone report of the activities and findings from this process.

1.1 Principles of coastal adaptation

Integrated Coasts has adopted three broad principles of coastal adaptation:

- Coastal adaptation takes place in localities,
- Coastal adaptation is an ongoing process,
- Coastal adaptation should initially be 'data-driven'.

1. Coastal adaptation takes place in localities

In comparison to other climate change hazards, sea-level-rise, and associated erosion, is unique. For example, a uniform increase of temperature of 1-2 degrees will uniformly affect a region such as the Fleurieu Peninsula. In contrast, a uniform increase of sea level of 0.5m is likely to produce a vast array of impacts, even within a ten-minute walk along the coast. The reason for the difference in the way that the hazards are experienced is that the impact of sea level rise is dependent like no other on the thresholds and tipping points that the geological layout presents at each location. Furthermore, the fabric of the geology, the bathometry of the seafloor, and the orientation of the coast to wind and wave exposure, all act as modifiers in the way in which sea level rise and associated erosion are experienced. Therefore, coastal adaptation, including the underpinning risk assessment procedures, must operate in a fine-grained way that appropriately deals with the local nature of the impacts. In light of this principle, the coastline has been divided into 12 cells according to their geological features and divided into minor cells for more fine-grained analysis as required[2].

2. Coastal adaptation is an ongoing process

Integrated Coasts recognises that coastal adaptation is a process that will take place over decades, and even centuries. Therefore, appropriate attention should be placed on forming the basis for a future monitoring program. And wherever a monitoring program is envisaged, a baseline is required. Without forming a baseline, future monitoring will have less meaning. In the context of coastal adaptation, the Ecology Dictionary provides the most appropriate definition of a baseline:

> A quantitative level or value from which other data and observations of a comparable nature are referenced… [and]
>
> Information accumulated concerning the state of a system, process, or activity before the initiation of actions that may result in changes.

[2] The division of cells is similar to that employed by Caton, 2007. In this study, Witton Bluff is assigned its own cell, and Aldinga Sands and Aldinga Beach are combined into one cell.

Two basic elements reside in the definition. To illustrate:

> A digital model created recently with associated imagery creates a digital baseline against which future erosion can be compared (i.e. monitored). Recapturing the data in five or ten years time will enable comparisons to be made against the original capture.
>
> Comparing photographic images of the shoreline position from the 1940s onward will provide a way to form a baseline understanding of 'the state of the system'. Once this baseline understanding of how a beach has been operating over time has been established, projections can be formulated about the possible future impact of sea level rise.

What is known as 'pathways' adaptation methodology is a commona way to undertake coastal adaptation. This methodology deals with uncertainty using three main ingredients: scenario planning, time, and triggers or thresholds[3]. A 'pathways' approach outlines plausible futures from which to identify key thresholds and triggers, and then considers alternative pathways when these are breached. However, Integrated Coasts holds the view that in most cases, less time should be given to extensive analysis to the timing of the likely breaching of thresholds, and more time allocated to initiating monitoring programs to track change over time. The only exception to this rule is when Council is considering whether to invest in upgrading or installing infrastructure. In these cases, an analysis of the timing of impacts is useful, and the precautionary principle should apply[4].

3. Coastal adaptation should initially be 'data driven'

Community engagement is best sought once the physical context of adaptation has been established as outlined in (2) above. The first steps of any coastal adaptation process should be to identify the physical baseline, then to conduct scenario analysis to identify plausible futures, and then to communicate these realities to the community. Community views on coastal adaptation matters can vary significantly. On one hand, some community members have an apocalyptic view of climate change and imagine that sea level rise will wreak broadscale havoc on their shores. On the other hand, are those who would maintain that nothing much has changed on their shores over time, and changes in the future are likely to be small. Additionally, sometimes unrealistic expectations exist about what Council can do about the impacts of sea level rise and imagine that whole coastlines can be protected. In summary, by conducting a physical analysis of the coastline and the likely impacts of sea level rise over the course of a century enables the appropriate context for the community to consider the issues. This principle ensures that the community's understanding and expectations are managed as much as possible within physical realities. If all stakeholders have a shared understanding of the local context then it is more likely they will work together to arrive at common solutions.

In summary, a coastal adaptation study is the starting point for coastal adaptation that will take place over decades. These principles are encapsulated in Figure 1 and the context of this study is depicted within the dotted red square.

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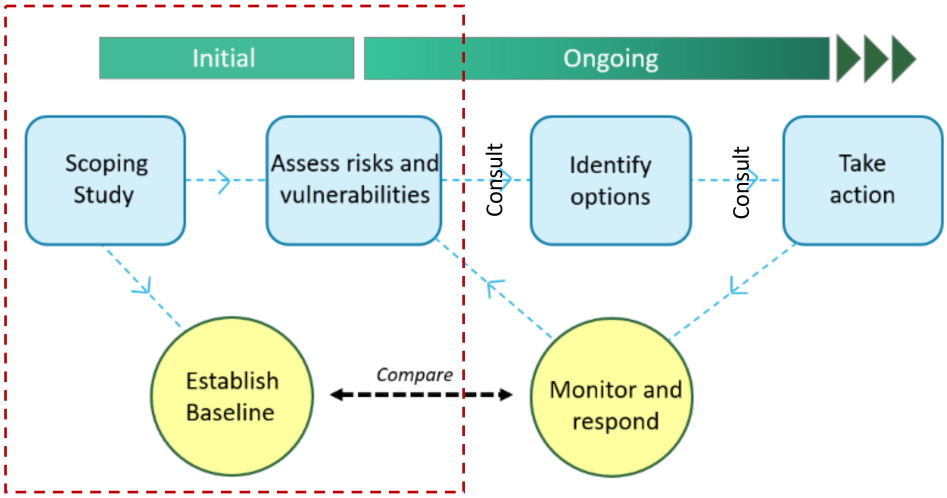
[3] https://coastadapt.com.au/pathways-approach.
[4] https://coastadapt.com.au/sites/default/files/factsheets/CoastAdapt_Glossary_2017-02-06_FINAL.pdf.

Figure 4: Coastal adaptation model (the dotted inset represents Stage 1 of the study)



Integrated Coasts (2017)

1.2 Purposes of the study

Considering the model for coastal adaptation, the general purposes of this coastal adaptation study (Stage 1) are to:

- Create a baseline upon which to monitor future changes,
- Conduct scenario modelling from which to identify plausible futures,
- Identify key coastal issues and vulnerabilities,
- Provide a risk assessment for each coastal cell,
- Bring all previous work into one place of reference,
- Provide a basis for ongoing adaptation planning.

Specifically, this study is to form the basis upon which to produce the second part of this project, Coastal Adaptation Strategy 2021-2031.

1.3 Previous study

The City of Victor Harbor has completed previous coastal studies or studies that relate to decisions within the coastal zone, and these have been reviewed and incorporated into this current study. These studies include:

- Foreshore Protection Study, Magryn, 2006.
- Coastal Engineering Report (Erosion) – Victor Harbor, Coastal Management Branch, 2009.
- Victor Harbor Coastal Management Study, Australian Water Environments, 2013.
- Climate Change Adaptation Plan for Adelaide Hills, Fleurieu Peninsula and Kangaroo Island, Seed Consulting and URPS, 2016.
- Victor Harbor Foreshore Coastal Park – Open Space Plan, Bechervaise and Associates, 2003.
- Urban Stormwater Management Plan, Kellogg Brown and Root, 2005
- Southern Fleurieu Coastal Action Plan and Conservation Priority Study, Caton et al., 2007
- City of Victor Harbor Recreation and Open Space Strategy, Suter Planners, 2017.

1.4 Project Scope

Climate Variables

Managing projected climate change impacts involves dealing with 'deep uncertainty'[5]. This uncertainty is primarily related to the nature of long-term projections which are based on climate models. These models are computer-based simulations of the Earth-ocean-atmosphere system, which use equations to describe the behaviour of the system. Models are effective at simulating temperature, but their accuracy is much less for the simulation of rainfall[6]. Overall rainfall is expected to decline in our region over the coming century and the intensity of rainfall events is expected to increase, but these projections are not assigned with as much confidence as for temperature or sea level rise. Furthermore, the climate is a complex system and the variables interdependent. For example, on the one hand we might predict that declining rainfall would produce a more arid climate and therefore less vegetation, but a recent study by NASA has found that over the last 35 years the planet has been greening, and that increased carbon dioxide in the atmosphere is 70% responsible[7]. As we learn more about the climate system and obtain more data over time, observable trends and projections will also become more certain.

Direct and indirect impacts

Some climate change impacts are more direct than others. Rising sea levels will directly impact the landforms adjacent the coast, either through inundation of lower lying areas, or increasing erosion. Other impacts will be less direct. For example, projections for a drier climate are often associated with less vegetation in dunes, and the increased cracking of cliffs[8]. These more indirect impacts may increase the rate of erosion. Increased intensity of rainfall events may increase the gullying of clifftops thereby increasing the potential for increased rates of recession and instability. In the context of a coastal study the impact of rising sea levels can be quantified through sea flood modelling within digital models. The impact of vegetation loss cannot be easily quantified and as noted above, is based upon less certain projections. Attempting to incorporate too many impacts into a coastal study is likely to compound the level of uncertainty and deliver less clear outcomes.

Direct and indirect risks

Direct risks relate to the impact of rising sea levels and associated erosion on the fabric of the coast. In this study we evaluate the direct impact of *inundation* and *erosion* in four main receiving environments:

- Public assets
- Private assets
- Social disruption
- Ecosystem disruption

[5] https://coastadapt.com.au/pathways-approach.
[6] https://coastadapt.com.au/how-to-pages/how-to-understand-climate-change-scenarios
[7] https://www.nasa.gov/feature/goddard/2016/carbon-dioxide-fertilization-greening-earth
[8] Resilient South (2014) Regional Climate Change Adaptation Plan, URPS and Seed Consulting, p.22 (technical report p.3)

The context for analysing 'social disruption' within this project is derived from Risk Management Framework for City of Victor Harbor using two main concepts:

- Public safety
- Reputation (community concern)

The term 'ecosystem disruption' is used to describe the situation where changes in a coastal region might bring about larger scale changes that may threaten to disrupt an entire ecological system, for example seawater flooding into freshwater ecologies.

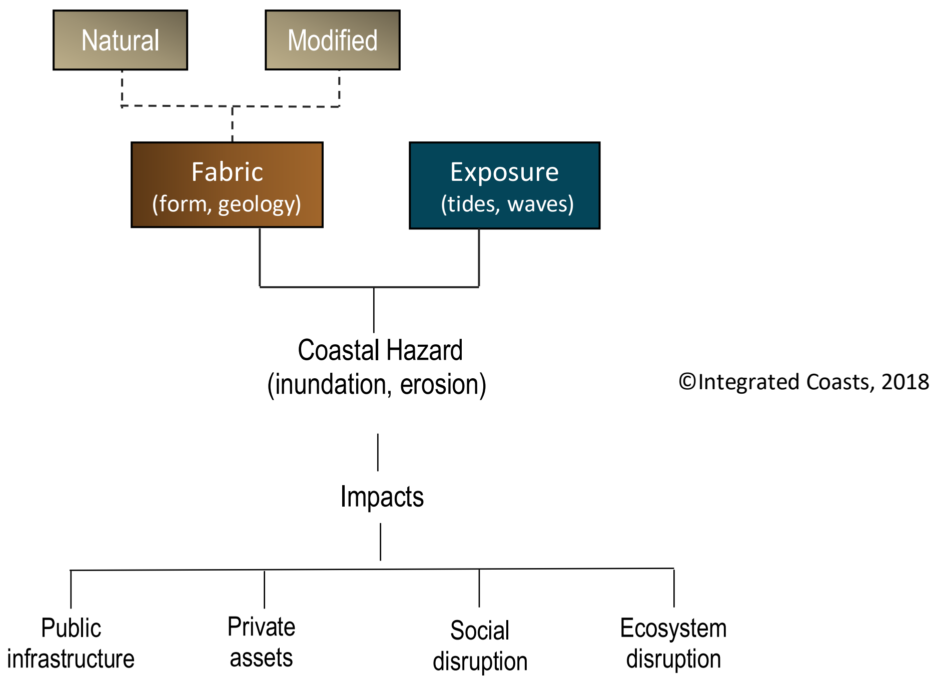
Associated with these direct risks are a range of indirect risks. For example, the potential loss of a beach from erosion is a potential social and economic risk (if the beach is related to economic activity such as tourism). A political risk may occur when decision makers act in ways the communities do not support. A legal risk may occur from not disclosing or responding to risks, or building adaptation structures that fail. However, all of these are indirect risks are derived from the direct risks to the coastline from inundation or erosion.

In summary, in a bid to increase certainty, this project evaluates the *direct impacts* of inundation and erosion in the context of *rising sea levels*. In a bid to contain focus, this study assesses the *direct risks* to assets, people and ecosystems that are positioned within coastal regions.

1.5 Conceptual assessment framework (overview)

Integrated Coasts has developed this assessment tool that adopts a simple and intuitive framework. Adopting a conceptual framework ensures that the study is accessible to all stakeholders. Coastal hazards experienced along a section of a coastline can be generally framed in terms of the nature of the 'fabric' (the nature of the geology and form) in the context of the nature of the 'exposure' (the impact of wind, tides, waves) (Figure 4).

Figure 5: Conceptual assessment framework



Coastal Hazards

South Australian Coast Protection Board considers three main coastal hazards: inundation, erosion, and sand drift. Due to the nature of the Victor Harbor coastline, only the first two are under consideration in this project.

Inundation and erosion hazards experienced along a section of a coastline can be assessed by considering three main coastal features:

- **Coastal fabric (geology)**

Intuitively we understand that if we are standing on an elevated coastline of granite that the coast is not easily erodible. Conversely, we understand if we are standing on a low sandy dune that erosion may indeed be a factor. It is the geology of the coast upon which our settlements are situated that determines one side of the hazard assessment in terms of elevation (height above sea level), and the nature of the fabric of the coasts (how resistant it is to erosion). We assess coastal geology in four categories of erodibility:

(1) Low erodibility
(2) Moderate erodibility
(3) High erodibility
(4) Very high erodibility

Assignment of erodibility classes to each location were completed by experienced coastal geologist[9] taking account of the various geological layouts within the region (See Appendix 1).

- **Coastal modifiers (human intervention)**

In some locations there are additional factors that modify this core relationship between fabric and exposure. For example, rock revetment and concrete blocks have been placed along the shoreline of Flinders Parade. These installations have modified the fabric of the coast from sand to 'rock'. However, such installations sometimes alter the natural processes of the coast. For example, new erosion problems can emerge either side of the installation, or in the context of rising sea levels, sand levels can decline on the beach, and the protection items become increasingly undermined.

In this study we identify how the coast has been modified and the implications (if any).

- **Coastal exposure (actions of the sea)**

If we find ourselves on the shore of a protected bay, or in the upper reaches of a gulf, we intuitively know that the impact from the ocean is likely to be limited. On the other hand, if we are standing on a beach on the Southern Ocean and listening to the roar of the waves, we understand that we are far more exposed. This assessment tool categorises coastal exposure in four main ways:

(1) Very sheltered
(2) Moderately sheltered
(3) Moderately exposed
(4) Very exposed

[9] Dr. Robert Bourman and Mark Western in workshop of March 2021.

The south facing coastline of City of Victor Harbor coastal region which is protected by The Bluff, Wright Island and Granite Island is generally categorised by Nature Maps (SA) as 'sheltered' and as having 'low' wave energy. The eastern facing coastline is generally categorised as 'moderate exposure' and 'low' wave energy[10]. In this study we also investigate how exposed a section of coast is by modelling routine tidal and storm surge events within the digital elevation model.

Hazard risk assessment

Each section of the coast is then assessed to determine how inherently at risk it is to the coastal hazards of inundation or erosion. For example, areas of land that are elevated are not at risk from inundation, whereas low lying land is more inherently vulnerable to inundation. Landforms that are highly erodible are assigned as higher risk because they are inherently more vulnerable to erosion, and the converse applies. In this project we have employed the expertise of two coastal geologists to make hazard risk determinations for each section of the coastline.

Changes in the relationship

In a coastal adaptation study, we are also interested to know how this relationship between ***fabric*** and ***exposure*** may change over time, and what this may mean in the context of our coastal settlements. Our sea levels have been quite stable for several thousand years. However, in the last century sea levels rose on average at ~1.7mm per year. The largest rates of rises have occurred since 1993 (4-5mm in our region), but similar rates of rises also occurred in the time period 1920 to 1950[11]. The general consensus of the scientific community is that the rate of sea level rise will continue to escalate towards the end of this century, but the exact rate is uncertain. What is certain is that if seas rise as projected then the relationship between fabric and exposure will change significantly in some coastal locations.

In this study, we model routine high-water events and storm surge events that take into account sea level rise projections for 2050 and 2100.

Risk assessment

Taking into all of the above, impacts of erosion and inundation hazards are then considered within four receiving environments:

- Public infrastructure
- Private assets
- Social disruption
- Ecosystem disruption

Each of these are assessed for current risk (2020) and future risk (2100). The structure of reporting within each of the cell reports generally follows the flow of the conceptual framework. We use Council's risk assessment framework that utilises a 'likelihood – consequence' matrix to allocate risk.

These concepts are explained more fully within this document and within each of the cell reports.

[10] South Australian Government, 2021, viewed at https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx
[11] CSIRO, 2015, Climate Change in Australia, Technical Report, p.143.

1.6 Study outputs

The project is divided into two stages with a community consultation stage at the conclusion of both stages:

Stage 1 – Coastal Adaptation Study
Stage 2 – Coastal Adaptation Strategy (2021-2031)

The outputs which represent Stage 1 of this project include:

Summary report (this report)

This document provides the overall context of the study and reports the general findings. Appendix 1 reports the process and findings of the community engagement.

Cell reports

Three cell reports which represent three coastal regions within City of Victor Harbor and coincide with the Coastal Conservation Cells utilised by the State Government[12]. These cells broadly coincide with City of Victor Harbor's planning precincts as noted in the list below. Most of the research and investigation is conducted within the cell reports for the three regions:

- McCracken-Hayborough (Cell 10) (Planning Precincts 1 and 2)
- Victor Harbor Central (Cell 11) (Planning Precinct 3)
- Encounter Bay (Cell 12) (Planning Precinct 4)

Companion reports

Two companion reports are included in the project:

- Dr. Robert Bourman has produced an excellent report for this project, *Geology and geomorphology of the Victor Harbor coastline from Rosetta Head (The Bluff) to Chiton Rocks*. The key findings from the report have been included in the summary report and the cell reports and the full report provided as a companion report.

- City of Onkaparinga commissioned and paid for Integrated Coasts to prepare the report, *Liability issues relating to coastal adaptation*. The report is a review of key documents written by duly qualified legal personnel, and some application to case studies within South Australia. The purpose of the report is not to provide legal advice but rather as an 'in house' resource from which to consider the main issues associated with coastal adaptation.

[12] South Australian Government, 2021, viewed at https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx

1.7 Methodology

The study adopts definitions from CoastAdapt[13] and coastal assessment concepts from OzCoasts[14]. The study adopts the national secondary coastal cells from CoastAdapt and utilises 3 tertiary cells that are similar to South Australian Coastal Conservation Cells[15]. A standard review process for each of the three cells and this summary report was adopted, as follows:

Settlement history

- Provide a brief history of the settlement.
- Review archives at Coastal Management Branch.
- Review coastal studies.

Geomorphology

- Provide a brief overview of how the coast was formed to provide a context from which to understand the coast today.

Coastal fabric

- Identify the nature of the coastal fabric.
- Analyse changes to the coastal fabric over the last 100 years.
- Identify human intervention.

Coastal exposure

- Review the impacts of previous storms.
- Model the impact of storm surges upon the backshores.
- Model the impact of routine high-water events upon the backshores.
- Analyse these impacts within time frames: 2020, 2050, and 2100.

Storm water runoff

- Photograph each stormwater outlet along the coast.
- Survey the height of each outlet.
- Analyse storm water impact on beaches and backshores.

Hazard risks and impacts

- Assign an inherent hazard rating to each cell (or minor cell, if applicable).
- Describe the likely impact upon the public and private infrastructure, social cohesion, and ecosystems.
- Conduct a risk assessment utilising the risk framework of City of Victor Harbor.

Cell summary

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[13] https://coastadapt.com.au/sites/default/files/factsheets/CoastAdapt_Glossary_2017-02-06_FINAL.pdf
[14] CoastAdapt's Shoreline Explorer is based upon the work completed by OzCoasts and found within Sharples et al, 2009, Australian Coastal Smartline Geomorphic and Stability Map Manual.
[15] https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx

2. Settlement history

The purpose of reviewing settlement history is to identify the circumstances surrounding the installation of coastal infrastructure and protection items, and to identify previous actions of the sea upon coastal settlement. In some circumstances, the timing of the implementation of coastal development is relevant in the context of legal liability. For example, as a general principle, it is unlikely that Councils will be held responsible for decisions made in the coastal zone in the absence of any knowledge of sea level rise or a policy context that required any assessment.

2.1 Establishment of urban settlement

Prior to European settlement, the region of Victor Harbor was inhabited by the Ramindjeri clan which shared the cultural life of the Ngarrindjeri. The Ramindjeri lived 'in one of the richest and most easily accessible areas in Australia' and their territory provided them with bountiful food from the land, the rivers, and the sea[16].

Victor Harbor – seaport (1830s to1920).

First European interaction with the Encounter Bay region was in the form of explorers or whalers. The meeting of explorers Mathew Flinders (Britain) and Nicolas Baudin (France), who were both charting the Australian coastline in 1802, gave Encounter Bay its name. Whaling stations were established at Rosetta Head and Police Point (the causeway) about the same time as the royal navy ship 'Victor' visited the shores in 1837. The early years of settlement were dominated by disputes about where the capital of South Australia should be located. Frequent storms and the wrecking of boats provided arguments against the location of Victor Harbor as the capital. Colonel Light held the view that Victor Harbor's position as 'open to the Southern Ocean' was not a suitable location.

<u>Construction of coastal infrastructure</u>

Regionally, steamer trade through the mouth of the River Murray had faded due to the difficulty of navigating through the river mouth. Produce was transported from Goolwa by horse drawn train, first to Port Elliot and then to Victor Harbor. Bridges were required over Watson Gap and Hindmarsh River and a new jetty was constructed in Victor Harbor. The railway line was opened in 1864 and Port Elliot was closed as a port two years later. However, ships were exposed to any storm from the south-east and by 1891, a 305m breakwater was constructed to the north east from granite island. The jetty was extended to the island to act as a causeway. At some time prior to 1949, a retaining wall ~150m in length was installed at the base of the train embankment at Hayborough.

<u>Construction of urban settlement</u>

The South Australian Act (1836) reserved 100 feet (~30m) from the high-water mark for road or other public purposes and private interests were to be positioned behind this space. Franklin Parade in Encounter Bay was constructed at ~30m from the high-water mark, but Flinders Parade and The Esplanade within Victor Harbor Central we set ~50-60m from the high-water mark.

16 Page, M. Victor Harbor, District Council of Victor Harbor, 1987. p. 14

Victor Harbor – tourist town (1920 to 1970).

Foreshore development

The viability of the Soldiers Memorial Gardens depended on the construction of a seawall as seawater was already flowing into the garden area in storm events. It is likely that the promenade behind the seawall was raised with imported fill and the slope backfilled, making a swale in which the gardens and playing fields were constructed. Shortly after completing the first sea wall in 1920, a second seawall was installed in a westerly direction from the jetty to 'primarily to protect the Crown Reserve'[17]. These two seawalls and the causeway provide the basic layout of the foreshore region established in this time period. In 1947, a seawall was installed in the Yilki area likely as a result of damage to Franklin Parade from a storm a few years earlier. The wall was washed away in a storm two years later and was reconstructed. Two 'experimental groynes' were installed in the early 1950s near Hindmarsh River by SA Harbors Board as a means to capture littoral sand drift, but these appear to have little current functionality[18].

Residential expansion

From 1920 onward, areas of public foreshore and areas of private land were clearly defined, with land under private ownership situated behind esplanade roads. Development along the foreshore was primarily residential, consisting of one house on a large allotment, or hotel and tourist accommodation. This pattern of development persisted until 1970s. The suburbs of Encounter Bay, McCracken and Hayborough were expanded in this era, first with holiday homes and then permanent residences. Storm water infrastructure that drained to outlets positioned on the backshores of beaches were mostly constructed in this era.

Victor Harbor – modern era (1970 to 2020).

Foreshore development

Foreshore development that was unrelated to coastal protection implemented in this era included:

- The boat ramp and rock groyne just north of the causeway was installed in 1972 and the adjacent carpark formalised.
- Carparks installed at Fell Street and Yilki shops in coastal backshores in the 1990s.
- The Encounter Bikeway was progressively installed from 2004.
- A concrete ramp was installed on the western side of the causeway circa 2012.
- The Bluff boat ramp facility was constructed in 2008.

Residential expansion

This era was characterised by urban expansion as more people moved into the region. However, no new residential areas were initiated on coastal backshores. Encounter Lakes was established in this era and is connected to the sea by way of a tidal pipe but is not situated in the immediate backshore where it could be impacted by sea level rises projected for this century. Urban consolidation policies

[17] Victor Harbor Times, 1 May 1926.
[18] Advertiser, 16 July 1953

implemented by the South Australian Government in 1993 had less impact upon the Victor Harbor region, but subsequent to the adoption of the *30 Year Plan for Greater Adelaide*, urban consolidation has become more prevalent. For example, Waterfront Policy 24 allows for allotments to be divided to accommodate semi-detached, group dwellings, residential flat dwellings, and row dwellings and development up to three storeys in height[19].

2.2 Coastal studies and associated reports.

One of the purposes of this study is to 'bring everything into one place'. The following is a list of studies and reports that are either focussed on coastal issues or where subject matter intersects within coastal issues. These reports have been individually reviewed within the cell reports accompanied by an assessment of their contribution to coastal matters.

- Fleurieu Coast Protection District report, Coast Protection Board report, 1977.
- Chiton Rocks – Hayborough Coastal Plan, Neill Wallman, 1979.
- Foreshore Protection Study, Magryn, 2006.
- Coastal Engineering Report (Erosion) – Victor Harbor, Coastal Management Branch, 2009.
- Victor Harbor Coastal Management Study, Australian Water Environments, 2013.
- Climate Change Adaptation Plan for Adelaide Hills, Fleurieu Peninsula and Kangaroo Island, Seed Consulting and URPS, 2016.
- Victor Harbor Foreshore Coastal Park – Open Space Plan, Bechervaise and Associates, 2003.
- Urban Stormwater Management Plan, Kellogg Brown and Root, 2005.
- Southern Fleurieu Coastal Action Plan and Conservation Priority Study, Caton et al., 2007.
- City of Victor Harbor Recreation and Open Space Strategy, Suter Planners and City of Victor Harbor, 2017.
- Urban Stormwater Management Plan, Kellogg Brown and Root, 2005.
- Southern Fleurieu Coastal Action Plan and Conservation Priority Study, Caton et al., 2007
- City of Victor Harbor Recreation and Open Space Strategy, Suter Planners and City of Victor Harbor, 2017.

Reports are available that concern the ecology of the two rivers, but these have not been formally reviewed in this project:

- Hindmarsh River Action Plan, Sinclair Knight Merz, prepared for Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2010.
- Inman River Action Plan, Sinclair Knight Merz, prepared for the Adelaide and Mount Lofty Ranges Natural Resources Management Board, 2010.

Archives were reviewed in hardcopy at Coastal Management Branch (Department of Environment and Water) in January 2021. Approximately 90 scans were obtained and the findings from these incorporated into each of the three cells as appropriate. The purpose of this review aligns with the project purpose to 'bring everything into one place of reference'. In particular this review bridges between the paper-based era to the digital era.

[19] City of Victor Harbor Development Plan, South Australian Government.

2.3 Implications in the context of coastal adaptation

The implications from the above findings in the context of coastal adaptation include:

1. The practice of laying out urban settlements with an esplanade road between coastal open space and private assets means that a buffer has been created between the coastline and private property. Therefore, the main focus for coastal adaptation will be for Council to manage its own assets in the context of rising sea levels.

2. Irrespective of (1), there is unlikely to be any legal requirement for Council to protect private assets. Furthermore, it has been the State Government's policy since 1980 not to fund the protection of private property.

3. Councils were only required to consider actions of the sea in planning decision after ~1990. Before this time, the implications of sea level rise were generally unknown and therefore Councils are unlikely to be liable for decision making in the absence of knowledge or policy.

When considering the liability Council may incur from previous decision making, Councils were only required to consider actions of the sea in planning decisions after 1993:

- The main esplanade roads were all established over sixty years ago and the residential settlements established by 1970s.
- Zoning changes to allow increased density in coastal areas have been implemented since 1993.

Several key principles that provide context to legal liability are listed in Table 1 below from the companion report, *Liability issues relating to coastal adaptation*[20]. Project note: the purpose of this report is not to provide legal advice but rather to provide a resource from which to begin to build a broader understanding of potential legal issues in coastal adaptation.

	Table 1: Key legal principles in the context of coastal adaptation
1	The nature of reasonable knowledge at the time a decision is made, or an action taken is a critical aspect in determining any legal decisions. Knowledge that has come to light since the decision or action will carry no weight in determining whether a decision or action was reasonable at the time.
2	Decision made on the best currently available information are likely to be upheld in court. In the case of South Australia, Councils can rely on advice from Coast Protection Board and this is likely to be a defence.
3	Government is not under a legal obligation to provide infrastructure to protect against climate change. Lack of resources to construct such infrastructure forms a legal defence.
4	If a Council does provide protective infrastructure it is obliged to maintain it. Failure to do so may constitute negligence.
5	High level strategic policy tends to be exempt from negligence actions.
6	Local decisions on individual developments that do not take known risks into account may expose councils to legal risk.
7	Litigation must commence within six years of the cause of action accruing.

[20] Integrated Coasts 2019, Liability issues relating to coastal adaptation, p.5.

3. Geomorphology

Geomorphology, in its most basic definition, is the study of the earth's physical features and the processes in which those features are formed. Geomorphology comes from the Ancient Greek words *Ge*, *morphe*, and *logos* which mean "Earth", "change", and "study" respectively[21]. In this project we consider the geomorphology of the coastline to provide an understanding of the changes that have occurred over long periods of time, so as to provide a context from which to consider future changes. In particular, we are interested in the nature of the physical forms and their susceptibility to change in the context of rising sea levels. Dr. Robert Bourman is the contributor for this section of work. An abridged version is provided below, and the full report can be found in Appendix A.

3.1 Geological setting

The Victor Harbor Embayment (Figure 5), which covers a distance of approximately 10 km, is a segment of the much larger Encounter Bay, which extends from Newland Head to Kingston in the South East. The Encounter Bay coast displays a great variety of coastal features, that include spectacular cliffs, granite headlands and islands, sand spits, sand bars, barrier shorelines, terraces, intertidal shore platforms, reefs, low lying coastal plains, modern and fossil dunes and former shorelines now stranded above sea level.

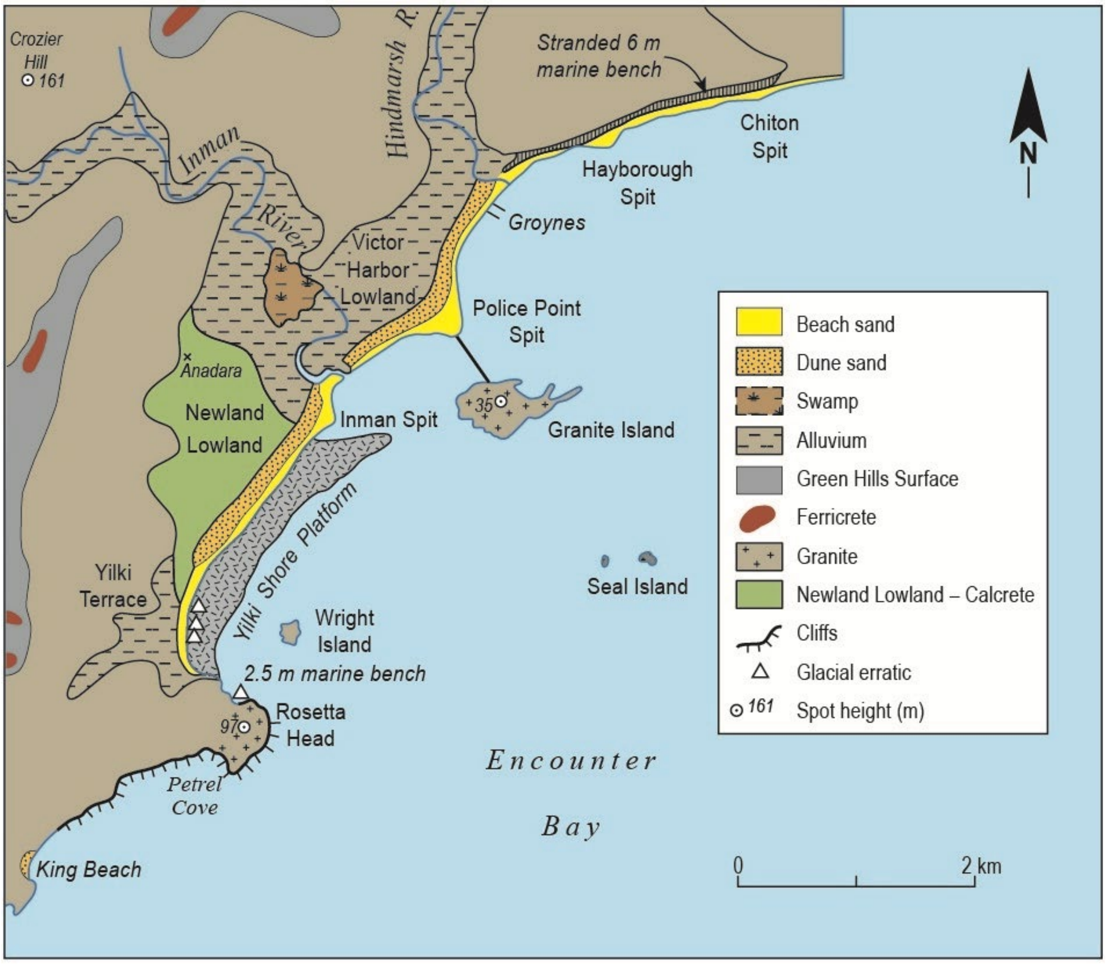


Figure 6. Major geomorphic features of the Victor Harbor coastline. Bourman et al. (2016)

21 https://www.worldatlas.com/articles/what-is-geomorphology.html

Granite islands and headlands

Until 43 million years ago the coast of Victor Harbor did not exist, as up until that time Australia and Antarctica were welded together as part of the ancient super-continent of Gondwana. They were the last of the continents to separate allowing the development of a seaway between them. Subsequently, Australia has drifted towards the north at a rate of approximately 7 cm/yr. Various geological processes (uplifting, folding, glaciation) over millions of years before and after the separation of the continents has produced the hard, metamorphic bedrock underlying the present coastline of Victor Harbor at various depths. Along the Encounter Bay coast, they are known as the Kanmantoo Group of metamorphic rocks (named after the township of Kanmantoo) and form the >100 m high cliffs between Newland Head and Kings Beach, and the shore platforms either side of Rosetta Head (The Bluff).

The present distribution of the islands and headlands was established some 300 million years ago by Permian ice, which removed less resistant parts of the granite mass or pluton. The outcrops of Encounter Bay Granites have exerted important influences on the modern shoreline, protecting headlands from erosion and determining the direction of wave approach to the shoreline: the islands and headlands slow down wave approach, but wave speed is maintained in deeper water causing the waves to bend or refract as they approach the shoreline, which they shape (Figure 6).

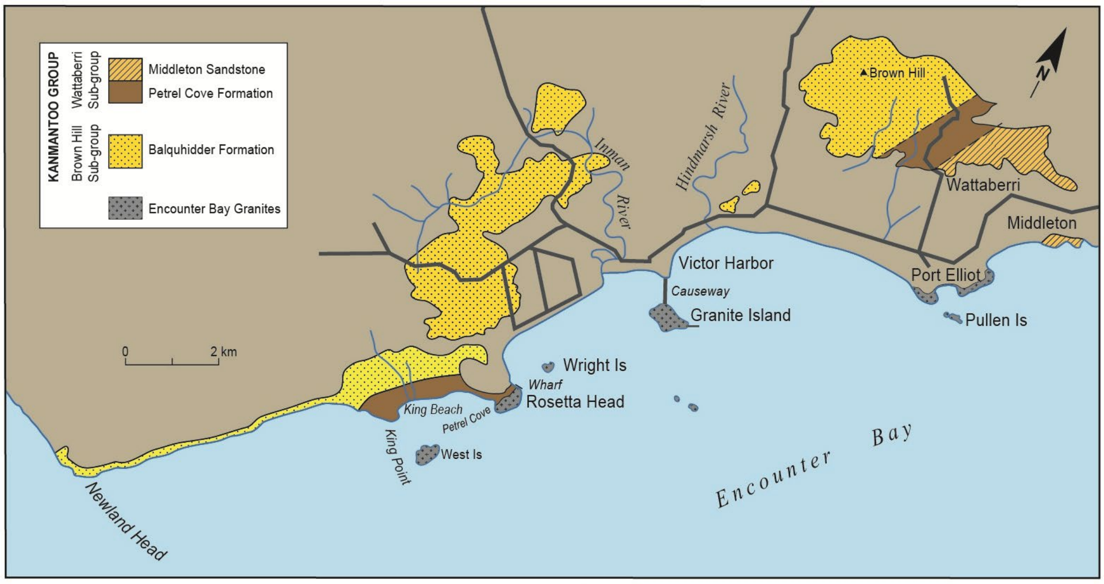


Figure 7. The bedrock geology backing the Victor Harbor coastline shows the strong structural influence of the resistant Encounter Bay Granites and the metasedimentary rocks on the shape and orientation of the coastline. The coastline has developed essentially on easily eroded glacial, marine and alluvial deposits.

Tectonic behaviour of the Victor Harbor coastline

The Victor Harbor coastline lies within the Mount Lofty Ranges, which have been tectonically uplifted relative to the Murray Basin to the east and the Gulf of St Vincent to the west. A major fault line, the Encounter Fault Zone, separates the Mount Lofty Ranges from the Murray Basin; it extends to the southwest, offshore from the coast near Middleton and runs broadly parallel to the coastline seawards of the granite islands (Figure 7). Ongoing tectonic uplift has occurred of the Victor Harbor coastline since the last inter-glacial (i.e. when the earth was last free of ice).

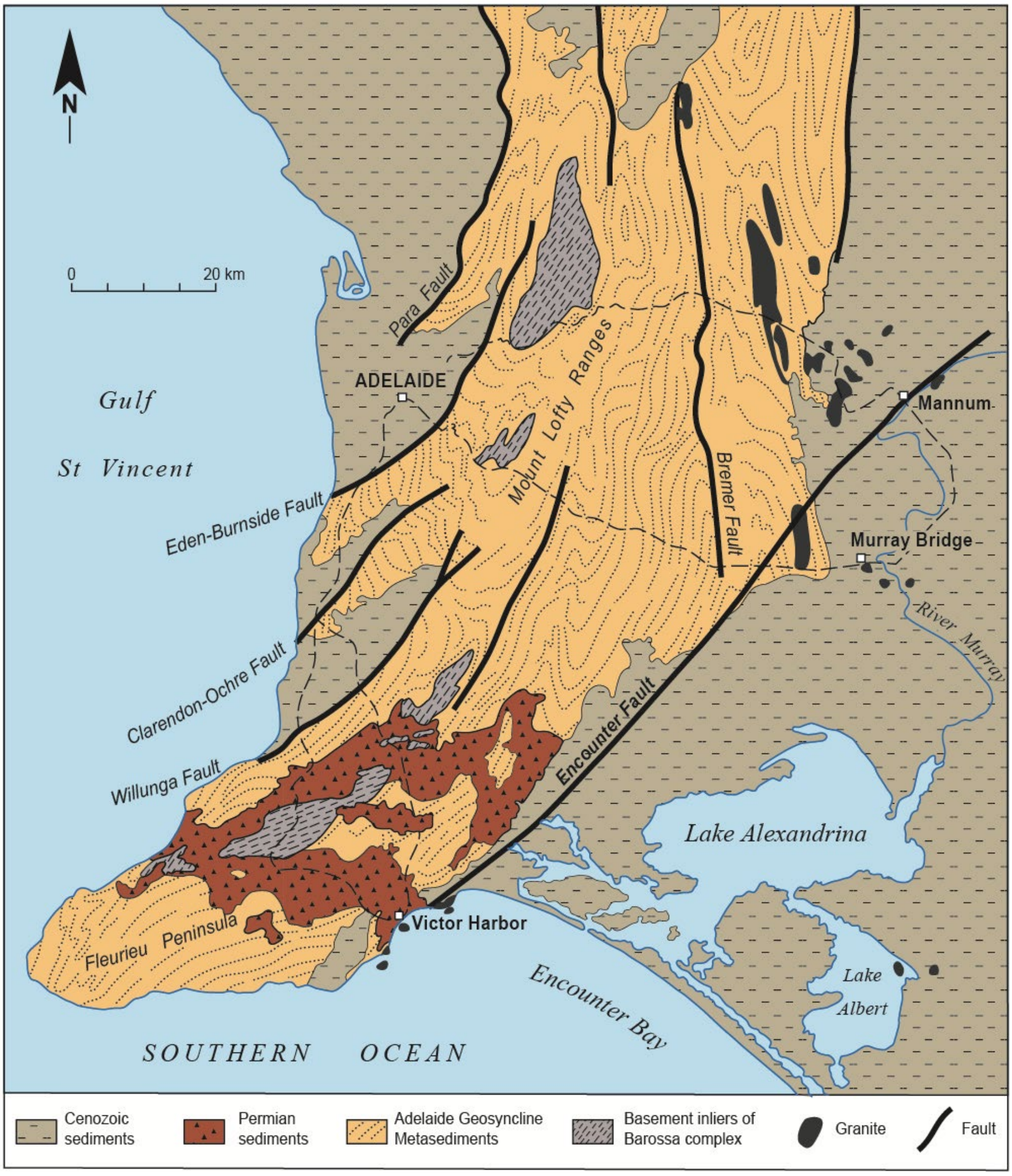


Figure 8. Geology map showing the location of the Encounter Fault Zone, the submarine extension of which runs parallel to the coastline offshore from the granite islands. Note the presence of the easily erodible Permian glacial sediments backing the Victor Harbor coastline. Source: Bourman et al. (2016)

At Victor Harbor the last interglacial shoreline now reaches up to an elevation of ~6 metres above sea level, having been uplifted by 4 m over the past 125,000 years at an average rate of uplift of 0.05 mm/yr. While this rate of uplift may appear to be insignificant, it is important to bear in mind that the uplift does not occur continually, but in separate tectonic events, some of which may have been dramatic. For example, an earthquake in 1897 centred on Beachport was reported as a severe tremor in Goolwa, where it cracked some of the buildings. At Kingston, tremors continued for several months. The same earthquake caused subsidence of the Middleton coast which led to rapid coastal erosion of >200 m over a few decades.

3.2 Summary of sea level over last 125,000 years

High last interglacial sea level 125,000 years ago

During the Last Interglacial of 132,000 – 118,000 years ago, when there was very little ice on the earth and sea levels were high, red coloured alluvium of the Pooraka Formation in-filled the lower reaches of the Inman and Hindmarsh river valleys, while cliffs were eroded at the backs of the current Newland and Victor Harbor Lowlands, and marine sediments were deposited across them. The shoreline from that time now reaches up to an elevation of ~6 metres above sea level, having been uplifted by 4 m over the past 125,000 years at an average rate of uplift of 0.05 mm/year (see also previous page).

Low sea level of Last Glacial Maximum (i.e. Ice age)

During the Last Glacial Maximum, about 18,000 years ago, sea level fell to -125 m causing streams to erode the older alluvial deposits, cutting valleys into them and forming terraces. From about 16,000 years ago the ice melted, and sea levels rose at a rate of ~10mm/yr, much faster than current rates of sea level rise, to near the current shoreline about 7000 years ago. This marked the beginning of the Holocene period.

Mid-Holocene high sea level

During the Holocene period, about 5,000 years ago, sea level rose to ~+1 m above current sea level, leading to the accumulation of alluvial deposits in channel bottoms with marine shells deposited in inland in former estuaries and on shore platforms. A subsequent fall in sea level to its present level followed, forming marine terraces and stranding the floodplains as low river terraces. Thus, in geological terms, the Victor Harbor coastline is considered to be young.

3.3 Sand supply for the coastline

The Victor Harbor coastline has had multiple sources of sand for its beaches, but nevertheless it is running out of sand, for which there are various causes.

1. As sea level rose quite rapidly between about 18,000 to 7,000 years ago it swept before landwards sediments exposed on the continental shelf. However, when sea level stabilised no new sand from offshore sources was being added to the coast; the previously ongoing sand source was stopped. Sand sources from pre-existing marine shells and sands have become quite limited.

2. Former sand dunes, which acted as a buffers to provide beach sand during storms, have now been removed, levelled, or built over. For example, the dune along Flinders Parade is now covered in roadways, housing, and community facilities, as they are in many other areas.

3. Before urban settlement, sediments generated from rainfall runoff were important sources of beach sediment. These sediments are now locked under settlements and no longer feed the beaches.

4. There is no significant input of sand from longshore drift, which is dominantly from the west to the east. Little sand from King Beach and Petrel Cove bypasses Rosetta Head (The Bluff). Sand derived by

erosion of the Permian deposits near Hayborough and Chiton contribute to the immediate shoreline, which is relatively stable, but it is possible that sand is lost to the Victor Harbor shoreline by drift to the east from Chiton.

5. The main supply of Permian sand to the coast was from the Inman River, which in its upper reaches flows through extensive areas of Permian sediments. Early farming practices caused increased erosion in the upper reaches of the river and the eroded sediments were carried downstream, burying parts of the topography and infilling much of the Inman estuary. Sand supplies formerly delivered to the coast by the Inman River are now bound up in a huge sand slug in the former estuary of the Inman[22].

3.4 Implications for Coastal Adaptation

The implications from the above findings in the context of coastal adaptation include:

1. The geomorphology of the coastline has been framed around the granite outcrops of The Bluff, Port Elliot and the islands, and largely influenced by sea level that has eroded the softer sediments between. Sea levels have been largely stable for ~2-3000 years, but if they rise as projected then the rate of change on these softer landforms can be expected to increase but the harder outcrops will continue to maintain the general shape of the shoreline.
2. The lowlands of Victor Harbor and Encounter Bay and the sand spit at Police Point were likely formed when seas were 1m higher than present about 4-5000 years ago. The foreshore areas of The Esplanade Beach, Flinders Parade and Bridge Terrace were underwater at this time and were moulded into their current shape as sea levels decreased. This recent geomorphological history is relevant to consider in the context of projected sea level rises of 1m over the course of this century and beyond.
3. The coastline is generally sheltered by The Bluff and Granite Island. Rock platforms and reefs are situated in the intertidal zone, and the water is shallow. This has a dissipating effect on the energy of the waves generated in the Southern Ocean. However, this dissipating effect may be reduced if seas rise by 1m as projected and waves with higher energy than present may impact the shoreline.

[22] Department of Environment and Water add reasons for decline of river flow as: reduction in rainfall, increased flows into the Wastewater Treatment Plant, construction of dams and use of groundwater (20080800).

4. Coastal Fabric

4.1 Introduction

As we noted in the introduction, it is the geology of the coast upon which our settlements are situated that determines one side of the hazard assessment in terms of form (height above sea level), and the nature of the fabric of the coasts (how resistant it is to erosion).

Why use the term 'fabric'?

The use of the word 'fabric' is adopted from *Smartline* developed by OzCoasts[23]. The stability of a landform depends primarily on its fabric (hard or soft constituents) and secondarily on its form (e.g. low lying, steep slope etc). Using the word 'fabric' also encompasses the study of human interventions in backshores that are not related to natural geology.

In common usage, the word 'fabric' is used to denote both *form* and *fabric*. Oxford's online dictionary www.lexico.com lists the synonyms for 'fabric' as: *structure, frame, form, make-up, constitution, composition, construction, organization….essence*. The word 'fabric' is therefore deemed suitable to convey coastal concepts as it has relevant technical meaning but is also readily accessible to all stakeholders.

Why analyse beach changes?

The first reason to analyse beach changes is to identify the normal cycles of accretion and erosion which may occur on a beach over time measured in decades. These cycles can be observed in two main ways: the position of the shoreline changes, and the levels of sand change on the beach. In times of erosion, the shoreline tends to recede, and sand levels become lower. In times of accretion, the opposite is true. The second reason to analyse beach changes is to identify the impact that sea level rise may be having on the coast. Caton (2007) noted that 'all geomorphological models of beach and dune change show recession in response to sea level rise'[24]. Therefore, analysing beach changes provides the opportunity to identify any impact that accelerating sea level rise may be having along the coast.

In summary, the purpose of evaluating the historical changes to the beach is to formulate a baseline understanding of how the coast has been operating in the past. This understanding will assist us to identify if sea level rise is currently having an impact on beaches, and if not, then it will assist us to identify when sea level rise is making a difference in the future.

[23] Sharples et al 2009, Australian Coastal Smartline Geomorphic and Stability Map Manual, University of TAS. Note that CoastAdapt adopted OzCoast methodology into Shoreline Explorer which classifies each section of beach firstly in relation to 'fabric' (composition, constituency) and secondly on 'form' (topography). However, Shoreline Explorer does not utilise the word 'fabric'.

[24] Caton, 2007, The Impact of Climate Change on the Coastal Lands of City of Onkaparinga, p.3.

4.2 Methodology

To evaluate the nature of the fabric of the coastal cells we utilised the following procedure:

1. Provide an overview of each cell,
2. Analyse changes to the shoreline,
3. Analyse changes to beach profiles,
4. Identify human intervention in backshores.

4.2.1 Overview of each coastal cell

An overview of the fabric of each cell is provided in terms of its form (topography), benthic (nature of the seafloor), and geology (classification of landforms). The benthic map for Encounter is provided below as an example (Figure 8). The information from these three map types provides an overview of the characteristics of Encounter Bay including:

- The blue lines designate the extent of the cell,
- The dotted white lines indicate the location of minor cells.
- Encounter Bay has a rock shore platform close to shore and a low-profile reef offshore, interspersed with sand patches, some containing seagrass of medium cover.

This procedure is undertaken for all of the three cells in the study.

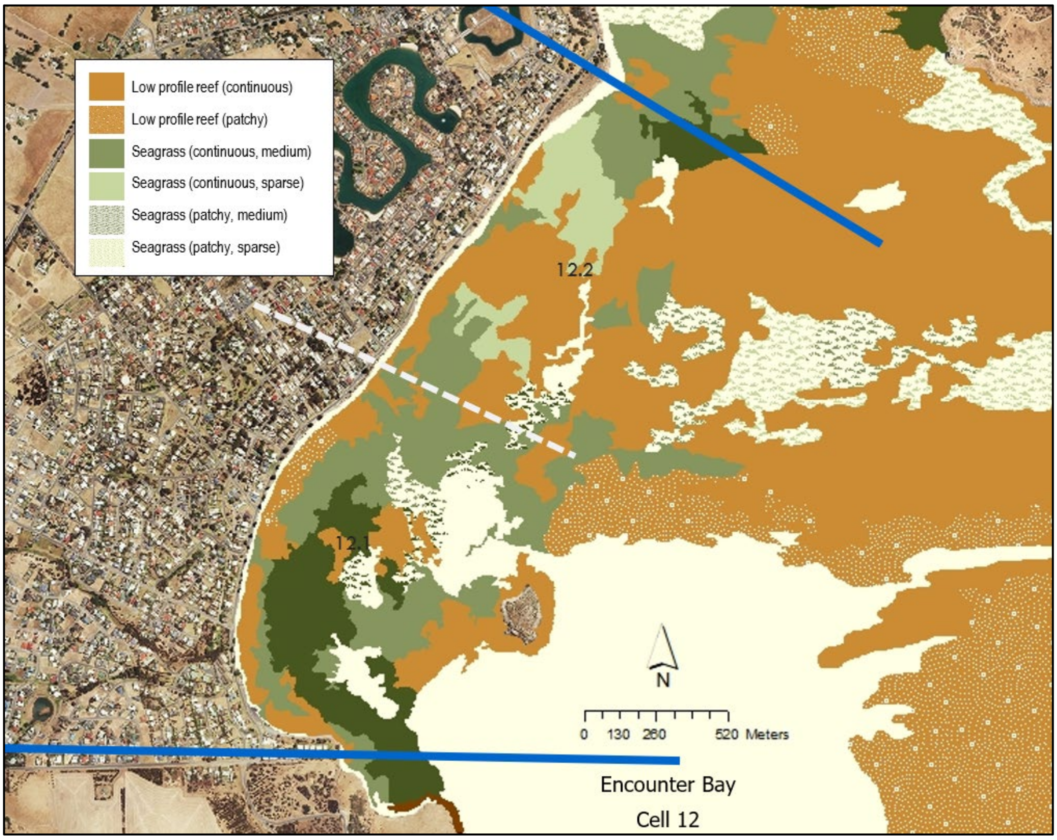


Figure 9. Example of benthic survey of Encounter Bay (Source: Nature Maps SA).

4.2.2 Analyse changes to the shoreline.

What is the shoreline?

The shoreline is the position of the land-water interface at one instant in time. But in reality, the shoreline position changes continually through time because of the dynamic nature of water levels at the coastal boundary. The best indicator of shoreline position is the location of the vegetation line closest to the area on the beach where waves end their journey. In other circumstances the shoreline may be the base of a cliff, an earthen bank at the toe of a slope, or a seawall in locations where humans have intervened (Figure 9).

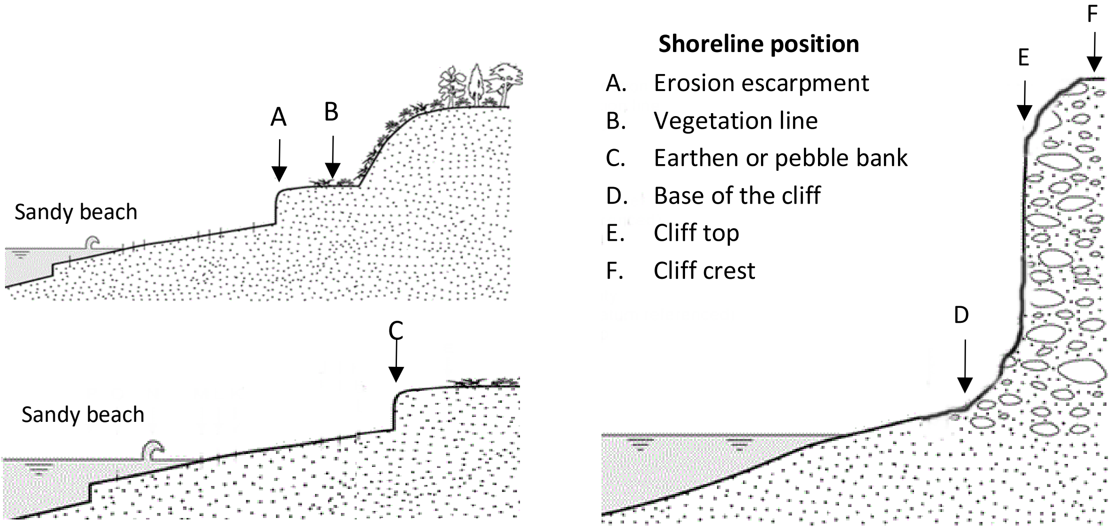


Figure 10. Adapted from Boak and Turner (2005), Shoreline definition and detection.

Evaluating shoreline change

The prime methodology for evaluating shoreline change is to utilise aerial photographs that are georeferenced so that they can be compared within geographic information systems (GIS). This means that they can be accurately aligned within computer software and changes to the shoreline measured. Depending on the clarity of the photograph, measurements should usually be accurate to plus or minus 1m, but this may vary with older photographs. The methodology includes:

- Comparing aerial photography from 1949, 1976, 1989, 1999, 2004 to 2018.
- Referencing all photography to 2018 because this year coincided with the capture of the digital elevation model for the Victor Harbor coastal region.
- Referencing the 1949 photograph into each location of analysis as it was not possible to reference this photograph using broader digital processes.

A secondary method was employed to analyse shoreline changes before the introduction of aerial photography. Where available, comparisons were made using land-based photography. This analysis tended to be more qualitative but provided a bridge between the 1850s and 1940s to evaluate shoreline changes. In locations such as Encounter Bay and the coastal regions near Police Point (i.e. the causeway), these photographs also provided an insight into the nature of the coast before significant modifications were installed. Examples of each methodology are provided below.

Example 1: A comparison of shoreline position in 2018 with photography from 1976 shows that the shoreline has accreted (built out) by 25m to 35m at the point. Also note the position of the SA Coast Protection Board survey profile line 620007 which we will review on the next page.

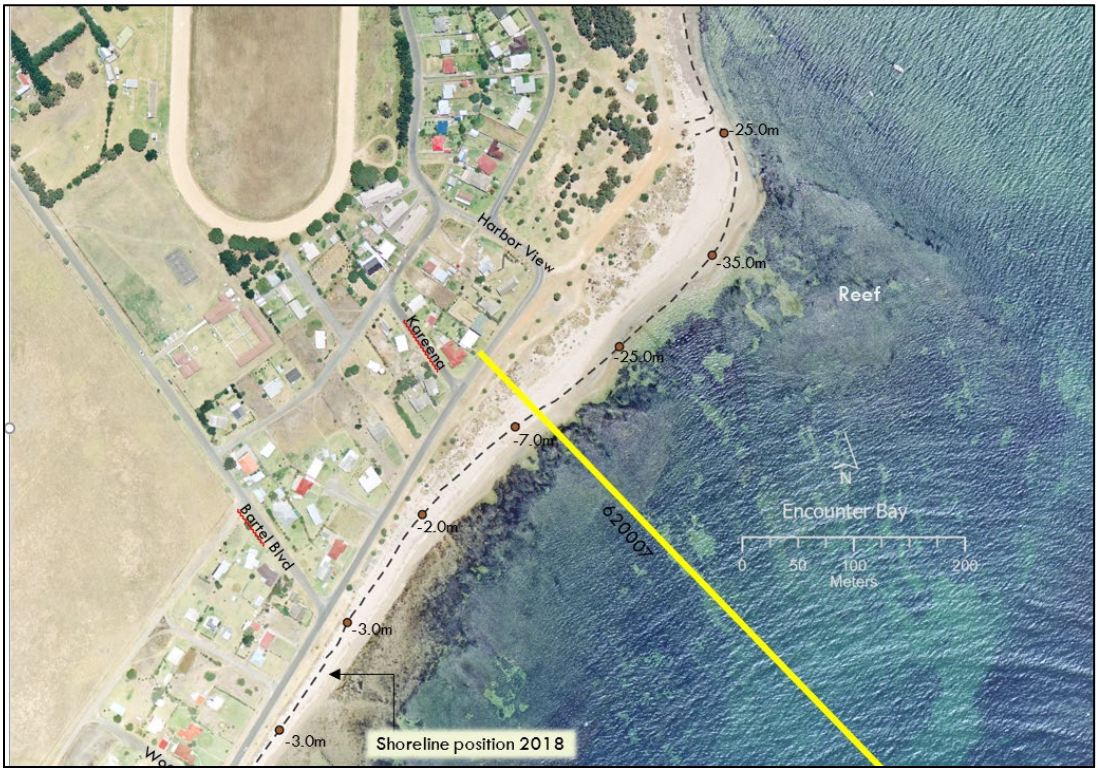


Figure 11. Comparison of shoreline position between 2018 and 1976 (M. Western,2021)

Example 2: A photograph from 1866 of the sand spit upon which the current foreshore is built upon provides an improved understanding of the coastline in its natural state. The locations upon which the current roads, carparks and buildings are located were formerly active sand dunes that were laid down when seas were 1m higher than present. This is relevant in the context of considering the impact of projected rises of 1m rise by end of this century, or sometime after this.

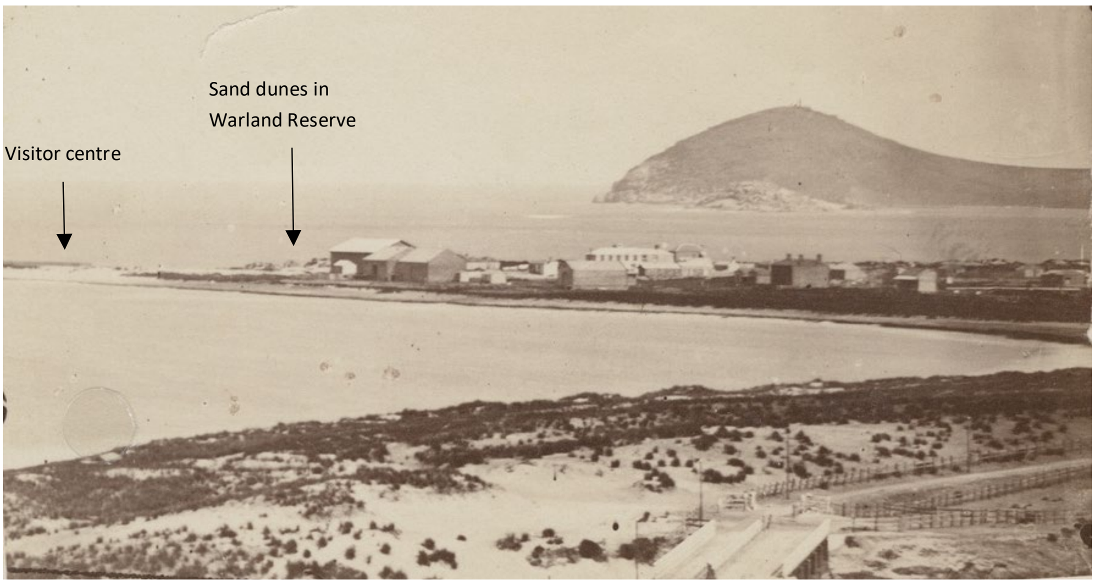


Figure 12. Victor Harbor sand spit, 1866 (Source: SA State Library, M. Western)

4.2.3 Analyse changes to beach profiles

Department for Environment and Water (DEW) has been surveying ~10 profile lines within the region, some as far back as the 1970s and some initiated more recently. These profile lines run perpendicular to the shoreline and represent survey height levels of the backshore, intertidal and subtidal zones. Evaluating changes to these profiles provides a way to identify the erosion and accretion trends over time. Three different types of analysis were performed at each profile line and the profile line from Kent Reserve is provided below as an example.

Using the same location as in Figure 10 (and noting the approximate position of the shoreline in 1949 based on an aerial photograph) we can tell the 'story' of this part of coastline. The coastline accreted (built out) over a long period of time, but after 2009, the shoreline went into retreat.

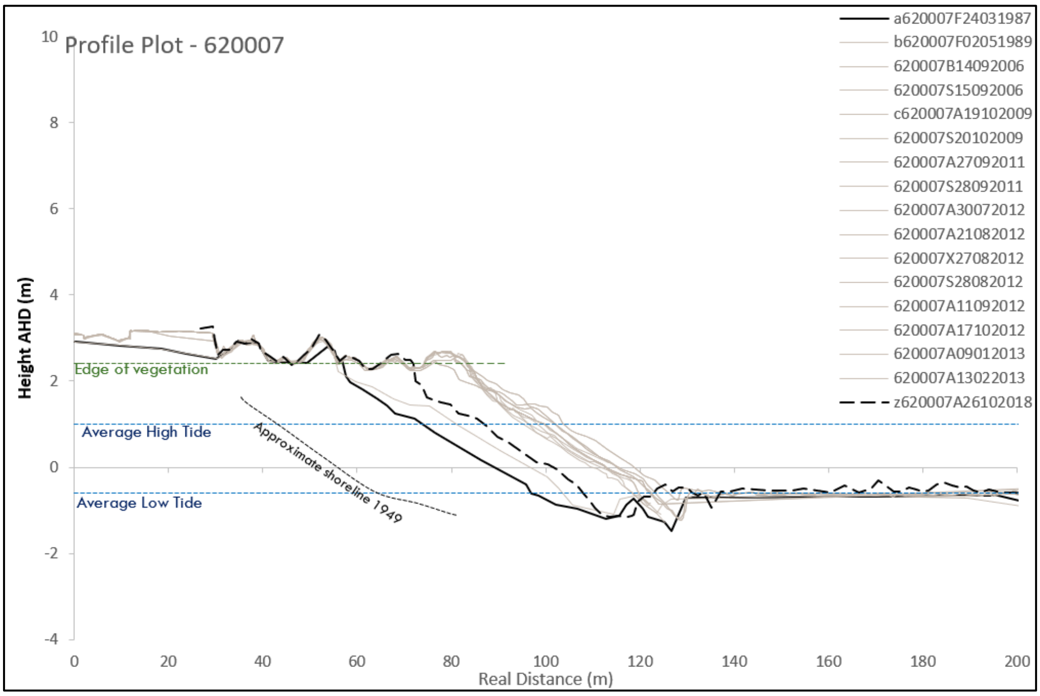


Figure 13. Analysis of profile line 620007 with the position in 1987 compared with 2018 in the context of all the profile lines (Source: SA Coast Protection Board).

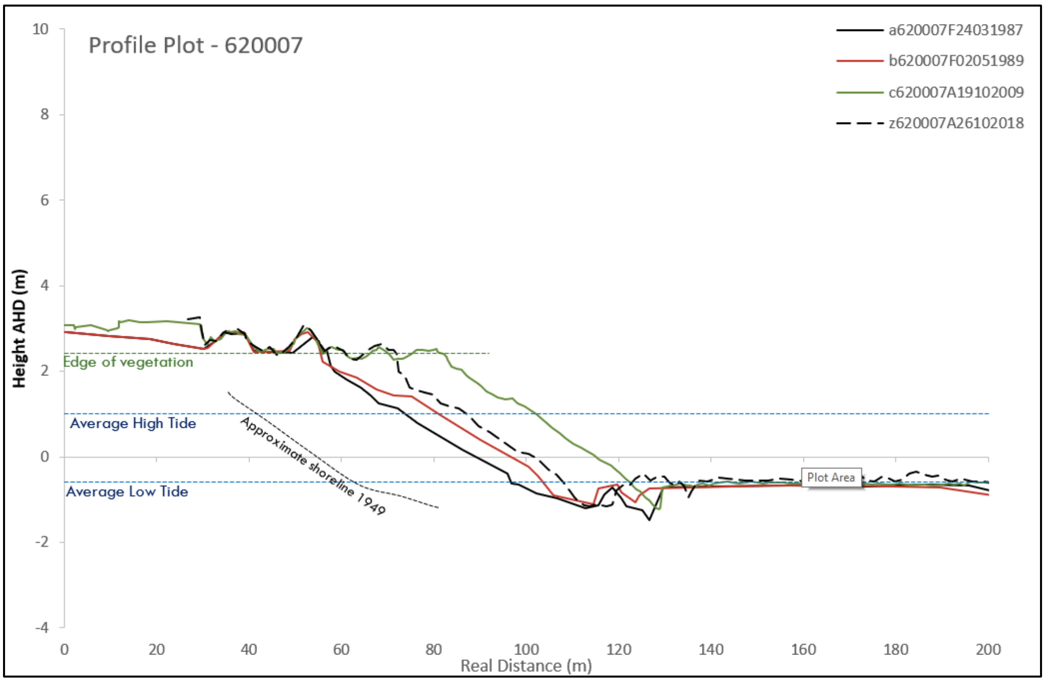


Figure 14. Analysis of profile line 620007 displayed in the context of five surveys from five decades that correlate approximately with the aerial photography. (Source: SA Coast Protection Board).

4.2.4 Identify human intervention in backshores

Urban settlements placed too close to shorelines impose rigidity in the backshore, which was formerly flexible and could cope with natural cycles of accretion and erosion. If sea levels rise as projected, then beach shorelines will recede. Those beaches that have room to recede will tend to maintain their existing profile and sand levels, those that cannot recede will tend to lose sand levels from their beaches. Within cliff locations, sea level rise brings increased action of the sea to the base of the cliff and causes it to be undermined. In natural situations, the slope of the cliff would increase, and then slides and falls would cause the top of the cliff to recede until a new equilibrium was reached. When urban infrastructure is placed too close to the top of cliffs, then cliff tops cannot recede, and the slope of the cliff tends to increase until it becomes unstable.

In some locations, protection items may be installed when backshores come under threat. In other instances, the desire to create urban spaces in close proximity to the beach results in the installation of a seawall to create a promenade. If sea levels rise, the shoreline will be unable to recede and the increased energy of the waves, now acting in closer proximity to the seawall, will tend to remove sand from the vicinity of the seawall, and sand levels are likely to decline on the beach.

Case study – One hundred years of history on Flinders Parade

The shoreline upon which the gardens and playing fields were positioned was formed as a sand spit 4-5000 years ago when sea levels were 1m higher than present. Harder rocks in this area are a long way below the surface. It is likely that the breakwater installed approximately 20 years prior to the photograph below (Figure 13) changed the angle of refraction of waves around the island which continued to change the shape of the beach along Flinders Parade over time[25].

Figure 15. Victor Harbor foreshore, 1908. Note the nature of the beach and backshore upon which the gardens and playing fields were constructed. State Library of SA. B-77156-175.

[25] See the companion report on geomorphology of the Victor Harbor region by Dr. Robert Bourman.

Figure 14 depicts the beach with a small dune to the north of Soldiers Memorial Gardens in 1910. The promenade was constructed along this dune with imported fill in 1920.

Figure 16. Victor Harbor foreshore, 1910. Note the nature of the beach and the location upon which the promenade and seawall was constructed in 1920. (Source: R. Bourman, from Victor Times ~1975).

A seawall was deemed necessary for the viability of the gardens and a raised promenade was installed behind the seawall (note the slope of the land away from the promenade). One Norfolk Pine is situated forward of the seawall (Figure 15).

Figure 17. Seawall installed in 1920. The promenade area was likely raised with imported fill and the slope behind backfilled (SA State Library, 1937, B-23718).

Storm accounts from the 1920s to 1940s report frequent overtopping of the wall or the promenade into the bowling club and tennis courts. There is little mention of any other impacts until the 1970s. Damage to the sea wall was first identified by Coast Protection Board in January 1975 and the wall was repaired. The Norfolk Pine was retained by 'boxing' out the concrete wall.

Figure 18. The seawall was undermined and repaired in 1975. The Norfolk Pine was retained by 'boxing out' the wall.

Council requested permission from SA Coast Protection Board to sand nourish the beach to improve sand levels adjacent the wall so as to protect the wall from actions of the sea.

Figure 19. Sand nourishment of $3000m^3$ in March 1976 because sand levels were dropping on the beach and the seawall undermined and damaged (Scan: CPB, 19760301).

Figure 20. Four months later, most of the sand was gone (Scan CPB, 19760701).

The storm event of 17 April 1986 caused 240m of the wall to collapse or was seriously undermined.

Figure 21. Storm event of 17 April 1986 (Photograph CPB, 19860501).

Rock revetment was installed to the Soldiers Memorial Gardens in 1987, and in September 1989 was extended to include the bowling club when the wall in front of the bowling club was threatened by storm action. The Norfolk Pine was retained behind the rock revetment. Council reports that overtopping with storm debris (seaweed) is a common event along the promenade.

Figure 22. Debris from storm event 1989. Council reports that seaweed debris is often deposited from moderate storm action in this location (Photograph CPB, 19890912).

The purpose here is not to be critical of decisions made in the past because often these were made in ignorance of coastal processes. We should also consider that increasing sea levels in the order of 200-250mm since the installation of the wall may have contributed to sand loss on the beach. (Sand monitoring by volunteers of Coastcare shows that sand levels continue to decline on this beach whereas other monitoring sites have been recording a recent accreting trend.) The case study does demonstrate the tendency for humans to increasingly protect public spaces that may have been created a long time ago, and in this case, to protect a tree which may have been wiser to remove.

4.3 General findings

4.3.1 Overview

Each cell has been evaluated in regard to its form (topography), benthic characteristics (nature of the seafloor), and geology (nature of landforms). Understandably, there is variation between cells in relation to these characteristics which can be analysed in the cell reports. Most of the coastline as we know it today was formed recently in the Holocene (last 7000 years) as waves refracted around the highly resistant granite outcrops of The Bluff, Wright Island, Granite Island and Port Elliot (See also geomorphology section above). The general layout of the Victor Harbor coastline is depicted by Nature Maps (Figure 21) and is characterised by:

- A coarse sand beach or medium-fine sand beach present in most locations,
- The intertidal zone is generally dominated by a rock shore platform and/or low-profile reefs and dense seagrass beds,
- Backshores vary from coastal lowlands (Encounter Bay, Victor Harbor Central) to soft rock sloping shores (Encounter Bay in the vicinity of the Bluff, McCracken and Hayborough).

In summary, the erodibility of the Victor Harbor coastline can be generally characterised as *low-medium erodibility* in Encounter Bay, *medium* to *high erodibility* in Victor Harbor Central (the lower rating relates to protection works along Flinders Parade), and *low-medium erodibility* in McCracken and Hayborough. As a general rule, although the backshores are generally of softer sediments the lower erodibility rating relates to the sheltered nature of the coastline due to the presence of The Bluff, islands, and rock platforms and reefs.

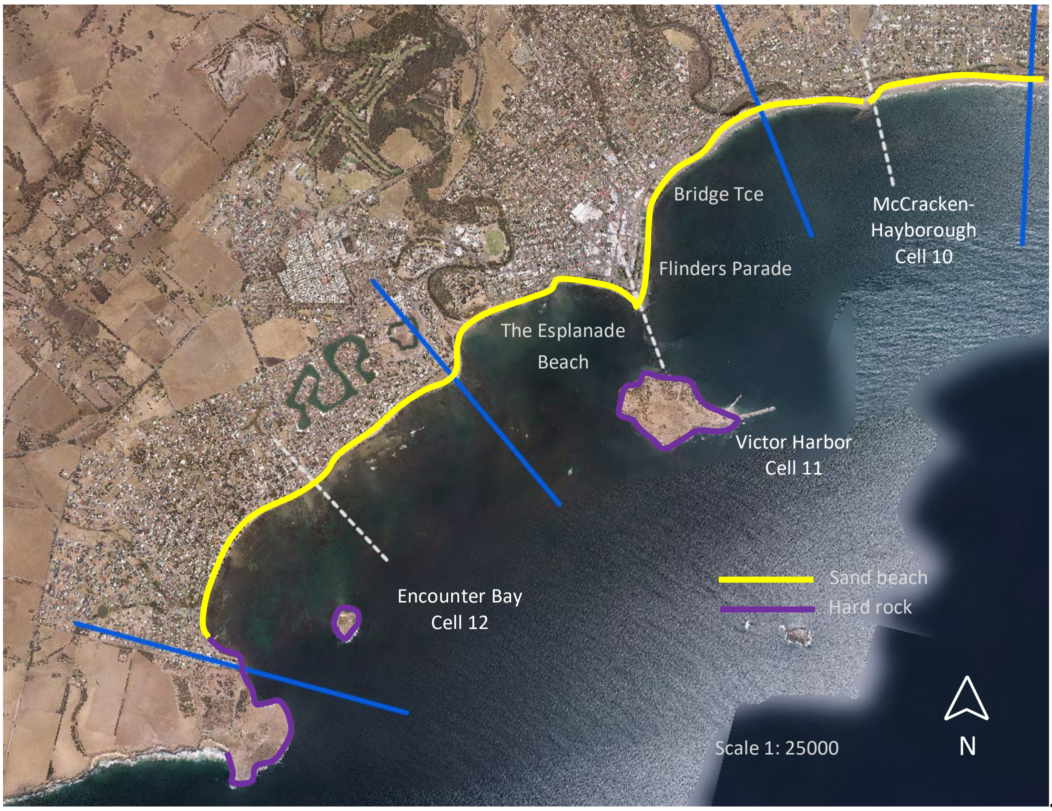


Figure 23. The general layout of the coastline of City of Victor Harbor (Adapted from Nature Maps, Department of Environment and Water).

4.3.2 Analysis of shoreline and profile line changes

The findings of the shoreline analysis within beach environments revealed:

McCracken-Hayborough

Overall, this section of coastline has been stable over at least 70 years. The shoreline has moved slightly seaward in places and the dunes have become increasingly vegetated. Urban development has been set well back from the trainline and is therefore setback >40m from the shoreline. The position of the mouth of the river was trained in 1984 and dunes and vegetation have now built in this area.

Victor Harbor Central

The backshores have been extensively modified with the removal or flattening of significant dune fields. These have been replaced by parks, playing fields and roads. Esplanade roads are set back ~60m which means the main issue in the context of sea level rise will be for Council to manage its own assets. Most of Victor Harbor has been built on softer sediments of sand and glacial deposits. In particular:

- The Esplanade Beach has been largely stable since 1949 but suffered significant erosion in a period of increased storminess between 2004 and 2011.
- The installation of the breakwater may have changed the angle of refraction of waves around Granite Island and increased erosion in vicinity of the gardens/bowling club. From 1920s onward this region has been protected but remains subject to overtopping, and currently sand levels continue to decline from the beach.
- The coast along Bridge Terrace has remained stable or accreted.

Encounter Bay

The surface on which the esplanade road is located was formed 4-5000 years ago when seas were +1m than present. In a low sand environment that is dominated by offshore reefs, the location of the current backshore, was formed in the context of recent actions of the sea. In particular:

- Increasing structures in the backshore necessitated the introduction of an embankment which is now predominately protected from Nevin Street to Yilki.
- The coast at Tabernacle Rd is at lower elevation and the former sloping shore has been replaced with an embankment and dunes which periodically accrete and erode.
- The section of coast between Tabernacle Road and Kent Reserve is naturally set at higher elevations, portions of which are now protected with rock.
- The coast at Kent Reserve accreted over a long period of time (+60m) but recently has eroded back ~10m.

4.3.3 Human intervention

Urban structures

The main human interventions that are likely to impede the natural adaptation and recession of the coastline in the context of rising sea levels are:

- The Encounter Bikeway and pedestrian pathway is positioned in the immediate backshore in most locations along the coast from Hindmarsh River to the Bluff boat ramp. In many locations the distance between the high-water mark and the path is less than 5m.
- At McCracken and Hayborough a trainline is set on a former marine bench at 6.50m AHD to 9.00m AHD (rising in elevation toward Chiton Rocks).
- Along Flinders Parade and Bridge Terrace, playing fields, formal gardens, and a playground are set within areas that were dunes prior to settlement.
- At Police Point (the causeway) a carpark, roads and paths and buildings are situated.
- Immediately landward of The Esplanade Beach dune system is the main carpark or the Memorial Gardens. The reserve between the road and the beach further to the west will be more easily adaptable.
- Within Encounter Bay, Franklin Parade is generally set within 30m of the high-water mark, with carparks at Fell Street and Yilki set closer (10-20m).

Protection and management strategies

To manage the close proximity of urban development many coast protection strategies have been implemented since 1920.

<u>Hindmarsh River outlet</u>

A rock groyne was installed in 1992 to control the position of the outlet, and a sandbag extension was installed (at least prior to 2004).

<u>Flinders Parade – Bowling club to boat ramp (450m).</u>

- Soldiers Memorial Gardens – in 1920 a seawall and promenade were constructed, replaced by rock revetment installed in 1986, and extended in front of the seawall at the bowling club in 1989. Concrete blocks are now positioned in vicinity of the bowling club.
- Five sandbag groynes were installed in 2009 along the beach.

<u>The causeway</u>

On the eastern side of the causeway, concrete blocks were installed adjacent the causeway. Storm uncovered these in summer of 2020, sand was pushed up the beach by earth-moving equipment and the concrete blocks recovered with sand.

<u>The Esplanade – Causeway to Inman River</u>

- A sand 'sausage' was installed along the beach in the vicinity of Wills Street in 2004.
- Beach nourishment (2009) – imported sand, 2500m^3 to head of the causeway and 1900m^3 to stabilise the sand dunes to east of the Inman River (including 2 rows of drift fencing and planting) (20091004).

- Eight sandbag groynes installed to the beach in 2009 for the purpose of trapping north drifting sand, including initial supply of sand ~1000m^3 per groyne.
- A 'sand sausage' installed in the vicinity of King Street in 2012.
- Installation of concrete blocks in the vicinity of King Street, these covered by sand, 2015.

Inman River

- Mouth realigned west from near the corner of The Esplanade and Inman Road in 1979.
- Mouth realigned to its current position in 1997 and a rock training wall installed.

Encounter Bay

Protection items within Encounter Bay often followed closely behind storm events:

- In 1948 a rock wall was installed at Yilki and was rebuilt after it was washed away in 1951.
- Ad hoc rock protection to the backshore at various locations between 1970s to 1990s.
- Rock or concrete protection was then added in a formal way from Nevin to Whalers Road (1992), the same section upgraded and extended (2005).
- Concrete blocks adjacent the bikeway at Fell Street (2019).
- Rock protection installed to Yilki shops area (~2020).

4.4 Implications for coastal adaptation

The implications from the above findings in the context of coastal adaptation include:

1. As an overview, the erodibility of the Victor Harbor coastline can be generally characterised as *low-moderate* due to the sheltered nature of the coastline or the presence of protection items (Flinders Parade) or *high erodibility* assigned to The Esplanade Beach.

2. Some areas of the coastline have been stable over a long period of time (Encounter Bay near The Bluff boat ramp, the coast along Bridge Terrace, and the coastline from Hindmarsh River to Chiton Rocks). The Esplanade Beach and the beaches within Encounter Bay undergo cycles of accretion and erosion. However, erosion has been the greater tendency since the 1990s, especially within a stormy period from 2004 to 2011. Kent Reserve has accreted substantially since 1949 but is currently in an erosion trend.

3. Generally, the backshores in the Victor Harbor region have been heavily modified by urban settlement with the installation of roads, carparks, playing fields, and a trainline that runs above the beach at McCracken and Hayborough. All of these structures act as 'hold points' preventing the shoreline from adapting naturally in the context of rising sea levels.

4. Protection items have been progressively added to backshores to protect urban infrastructure, especially within Encounter Bay (Nevin Street to Kent Reserve) and Flinders Parade (Soldiers Memorial Gardens and bowling club).

5. Coastal Exposure

As we noted in the introduction, the other side of the hazard assessment is evaluated in terms of exposure. In this study we are primarily concerned with the exposure of coastal landscapes to wave energy and ocean swell. However, coastal landforms can also be vulnerable to exposure from rainfall run-off or from the impact of wind which increase the erosion of coastal landscapes, especially in regions of softer constituency. The degree of vulnerability of a coastline to actions of the sea is related to the degree of exposure of the coast to wind, current, and wave attack, especially during storms.

Why use the term 'exposure'?

The term 'exposure' has a narrower technical sense within coastal study and refers to the degree to which a section of coastline receives swell wave energies that impinge on that section of coast[26]. In common usage, the word is often used in relation to a person being 'exposed to weather', and it is generally understood that people can die from 'exposure'. The word 'exposure' is therefore deemed suitable to convey coastal concepts as it has relevant technical meaning but is also readily accessible to all stakeholders.

5.1 Conditions of exposure in the Victor Harbor region.

Most of the Victor Harbor coastline is sheltered by The Bluff and Granite and Wright Islands. Nature Maps (SA) allocates exposure ratings as shown in the table below.

Table 2: Exposure ratings for the coastline of City of Victor Harbor

Location	Exposure rating	Wave energy
Encounter Bay	Sheltered	Low
Esplanade Beach	Sheltered	Low
Flinders Parade/ Bridge Terrace	Moderate	Low
McCracken	Moderate	Low
Hayborough	Moderate	Moderate

Wave action on the Victor Harbor coastline

The degree of susceptibility of a coastline to wave erosion is related to the degree of exposure of the coast to wind, current and wave attack. There are two main types of waves which fashion beaches: storm (forced waves); and swell (free or constructional waves). Forced waves scour the beach, erode sand from beach faces and form offshore bars. When storms subside, constructional waves tend to push sand back onto the beach. Fetch, the distance of open water over which waves can build, influences wave dimensions: over longer distances larger waves can build; over shorter distances, smaller waves.

The Victor Harbor shoreline is impacted by both swell and storm waves which dominantly approach the coast from the south and southwest. The swell waves are generated by storms in the Southern Ocean. They have long wavelengths, approach the coast with a wave period of 14-16 seconds, a

[26] Sharples et al 2009, Australian Coastal Smartline Geomorphic and Stability Map Manual, University of TAS, p. 7

relatively short wave-height, and generally push sand landwards as they approach the coast. Storm waves, on the other hand are generated by local storms, have shorter wavelengths, steeper wave fronts and have a wave period of 6-8 seconds. These waves plunge when they reach the shore, scouring the beach and moving sand seawards to form sandbars.

The susceptibility of coasts to erosion by storm waves is heightened by coincidence of the storm with high tides, strong onshore winds and low barometric pressures. Although facing the open Southern Ocean, wave attack on the Victor Harbor coastline is ameliorated somewhat by the granite headlands, near-shore granite islands and reefs, the orientation of the coastline and its micro-tidal (0.8 m) character. The shallow depths of water progressively dissipate the wave energy as it nears the coast.

Wave refraction and diffraction

Figure 22 shows how waves are refracted around granite islands and headlands on the direction of swell and storm waves approaching the coast. There can be variations in the patterns of refracted waves depending on changes in wind strength and direction. Both swell and storm waves approach from the south and southwest, but hard rock outcrops slow down the wave approach in some locations, bending the wave fronts as they do so. Waves are refracted when they strike the shoreline at an angle causing the wave to slow down in the shallowing water but to continue at a faster rate in the open water. Waves are diffracted when both ends are slowed down while the central part of the wave advances at a faster rate, as between Rosetta Head and Wright Island. Thus, the wave patterns of refraction and diffraction, which affect local directions of longshore drift, are the products of interaction with the resistant granite headlands and islands as well as with shore platforms, shoals, and reefs.

These refracted and diffracted waves have moulded the shape of the Victor Harbor coastline, which has developed on relatively easily erodible sediments. The Inman, Police Point, Hayborough and Chiton spits have been shaped by the waves refracted by the granite headlands and islands, as well as some slightly harder outcrops of coastal rocks in these locations. The patterns are also affected by water depth as the waves approach the coastline.

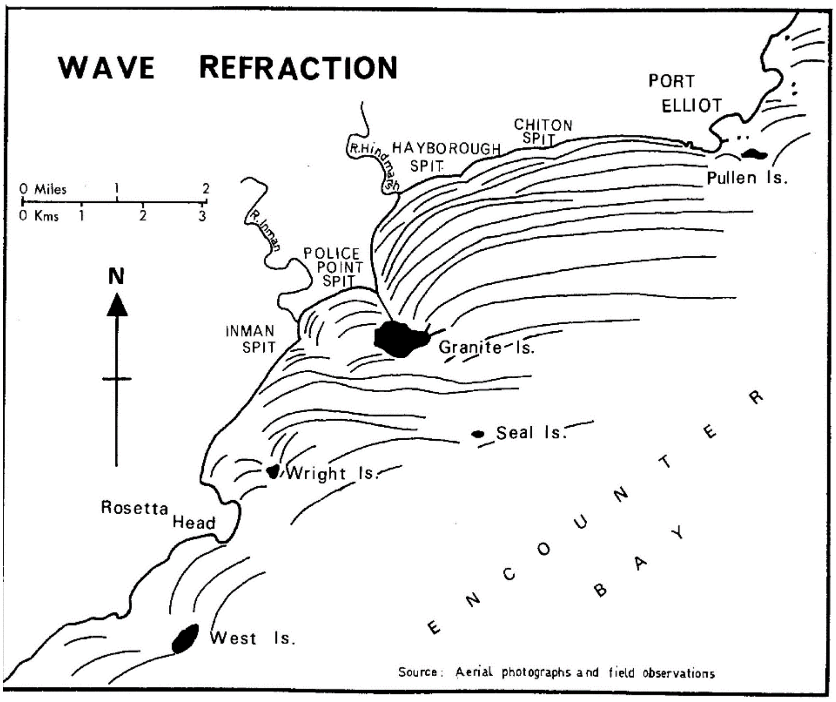


Figure 24. Generalised wave refraction and diffraction map of the Victor Harbor coastline drawn from aeriall photographs and field observations. Note the Inman, Police Point, Hayborough and Chiton spits and their relationships to the wave patterns. Source: Bourman (1969)

Tidal Range

The ranges between low and high tides are categorised world-wide as micro-tidal (<2m), meso-tidal (2-4m) and macro-tidal (>4m). The tidal range within the Victor Harbor region is categorised as micro-tidal and is presented in the table below both in chart datum (i.e. using the same measurement as local tidal charts) and Australian Height Datum (i.e. using the same measurement system as a surveyor would use to measure heights in Australia).

Table 3: Tidal range in Victor Harbor region

Level	Chart Datum (m)	AHD (m)
Lowest astronomical tide	0.021	-0.564
Mean sea level	0.705	0.120
Australian Height Datum	0.585	0.000
Mean higher, high water	1.177	0.592
Highest recorded (9 May 2016)	2.220	1.635

Source: Australian Water Environment (2013) p. 23 (amended to include updated highest recorded tide).

Along the coast of Encounter Bay, it is anticipated that tidal currents would be low and predominantly shore normal, having negligible impact on sediment transport at the beach face or in the near shore region. While these tidal currents may have the potential to entrain and move bare sand on the seabed which is stirred by waves, they do not contribute significantly to the along shore sediment transport rates at the shoreline[27].

The direction of longshore sand drift

The dominant direction of drift is from the southwest and west to the east, under the influence of strong winds from the south-westerly quarter. Historically, the mouths of both the Inman and Hindmarsh Rivers have been deflected to the east, supporting the view of west-east drift. Despite the dominant drift direction being towards the east, the direction of longshore drift along the Victor Harbor coastline is variable. For example, opposed drift directions are required to explain the formation of Police Point Spit. In other words, to form the spit on the eastern side of the causeway, the longshore drift must tend to the south.

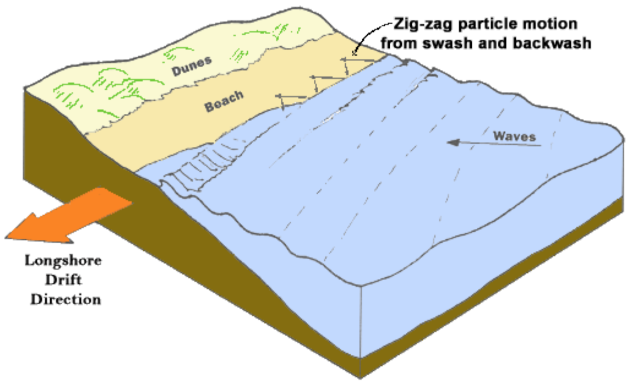


Figure 25. The diagram explains how long shore drift operates along a coastline. Waves meet the coastline obliquely and move sediment along the shore.

Analysis of the wind regime for Victor Harbor supplied from the Bureau of Meteorology has been undertaken, supporting the notion of a dominant drift from the west to the east. In using wind data

[27] Australian Water Environments, 2013, p. 23.

to demonstrate drift direction, only onshore winds are taken into account, and it is only wind speeds greater than 28.8 km/hr, which are effective in generating longshore drift. The resultant of winds capable of generating longshore transport trends at 227o (or from the south-west).

Storm surge

Estimates of storm surge at particular locations are based on historical occurrence and calculated from highest astronomical tide, storm surge height, and wave effects (wave setup and wave runup). The concept of storm surge is illustrated at Figure 23 and the components explained below:

- **Storm surge** (storm tide) refers to the combined effect of barometric setup and wind setup. Barometric setup of the coastal water level during storms is commonly in the range of 0.1 to 0.4m. Wind setup is due to the stress of the wind blowing over the ocean surface and piling water up against the coast. A unique aspect of storm surges within Gulf St Vincent is that the narrowing of the gulfs towards the north tends to increase the height of the storm surge in the upper reaches of both gulfs. In the upper regions of the gulf there is less volume in the ocean basin and therefore water is increasingly piled up against the narrowing coastlines.
- **Wave setup** occurs in the surf zone after the breaking of the waves. The water surface inside the surf zone raises up above the still water level and the water encroaches further up the beach than would occur in the absence of waves. Wave setup levels are typically around 20% of the offshore significant wave height.

- **Wave runup** refers to the way waves surge up the beach after breaking. The factors that determine the distance and impact of wave runup include the slope of the beach and the energy of the wave. The point where the energy of the wave is finally dissipated is the height of wave runup. Wave runup can cause erosion to the base of dunes or earthen shorelines.

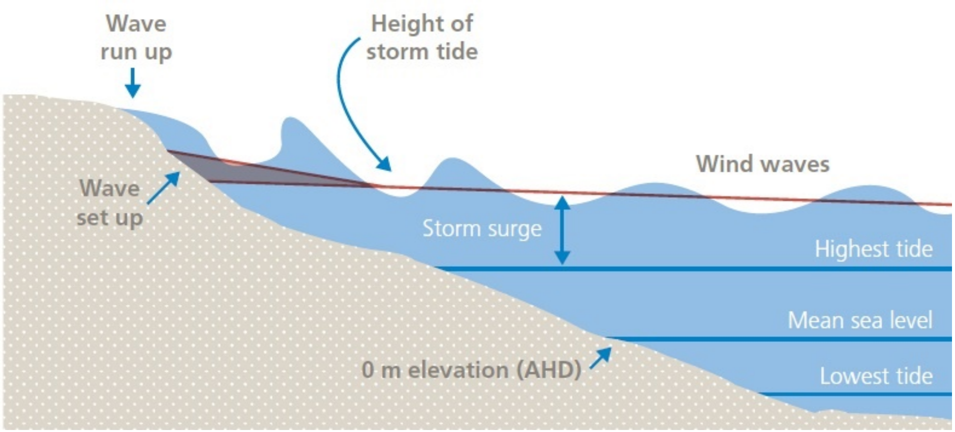


Figure 26. The components of storm surge which use the highest astronomical tide as the starting point for calculating storm surge heights and impacts (Source: CoastAdapt.com.au)

5.2 Trends and projections for sea level rise

In the context of a coastal adaptation study, it is recognised that increases in sea level rise will also increase the exposure of the coastal fabric to actions of the sea. The purpose here is not to undertake a full review of matters relating to climate change and sea level rise. Readers requiring further information are encouraged to refer to resources developed by National Climate Change Adaptation Research Facility (NCCARF) at the website https://coastadapt.com.au/.

Global and regional sea levels

Global sea levels reflect the state of the climate system. During ice ages a large volume of water is stored on land in the form of ice sheets and glaciers, leading to lower sea levels, while during warm interglacial periods, glaciers and ice sheets are reduced and more water is stored in the oceans. Regional changes also occur in sea level, but these do not change the overall mass of the ocean. For example, regional sea levels change in accordance with the climate variability associated with El Nino and La Nina cycles. During El Nino years sea level rises in the eastern Pacific and falls in the western Pacific, whereas in La Nina years the opposite is true[28]. Sea levels also change in relationship to the vertical movement of land. If an area of land is falling, then in relative terms, sea levels will rise, and vice versa. Dr Bob Bourman has calculated the average rate of uplift in the Victor Harbor region as 0.05mm per year which can be disregarded for the purposes of calculating sea level rise (see also geomorphology section).

Short-term to medium-term historical sea-level rise

Global sea levels have varied greatly over long time periods but have been largely stable over the last 2-3000 years[29]. One of the outcomes from global warming is sea level rise, caused by thermal expansion and melting of ice caps and glaciers. Over the period 1901 to 2010, global mean sea level rose by around 0.19m, or an average 1.7mm per year.

CoastAdapt states that sea levels have risen at a faster rate around Australia since 1993 (partly due to natural variability), and that the rates of rises are similar to that measured globally. There is some variability in the trend around the Australian coastline with greater increases observed in the north, north-west and south-east than in the southern and mid-eastern regions[30]. In our region the rate of sea level rise since ~1990 has been on average 4.3mm per year based on SEAFRAME gauges at Port Stanvac[31] and at Thevenard[32] and satellite measurements.

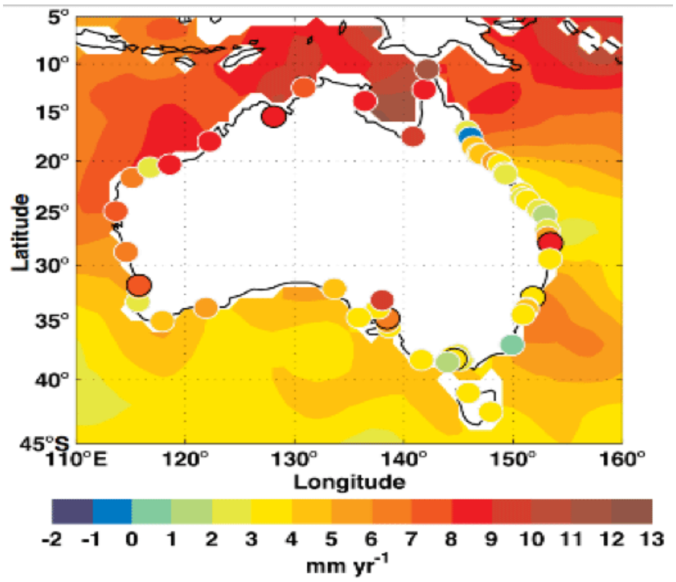


Figure 27. Sea-level trends from January 1993 to December 2010 from satellite altimeters (colour contours) and tide gauges (coloured dots). Source: CSIRO and BoM 2015 © Commonwealth of Australia.

[28] CSRIO (2020) Sea level, waves and coastal extremes.
[29] https://coastadapt.com.au/how-climate-and-sea-level-have-changed-over-long-term-past.
[30] https://coastadapt.com.au/how-to-pages/how-to-use-national-mapping-to-understand-recent-climate-trend
[31] This tide gauge decommissioned in 2010.
[32] CSIRO and Bureau of Meteorology 2015, Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia, p. 145

Sea level rise projections

Sea level rise projections for the 21st century are based on computer based simulations of the climate system and the likely impact of increased greenhouse emissions on temperature (and therefore, sea level). The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) identified four emissions scenarios to frame projected climate futures. These are known as Representative Concentration Pathways (RCPs) and are framed in the following manner:

RCP 8.5 Very high emissions pathway
RCP 6.0 High emissions pathway
RCP 4.5 Moderate emissions pathway
RCP 2.6 Low emissions pathway

CSIRO and Bureau of Meteorology have utilised the IPCC findings and provided sea level rise projections for locations around Australia, including Victor Harbor (Table 4)[33].

Table 4: Projections of sea level rise for Victor Harbor based upon various RCP scenarios.

STATIONS	SCENARIOS	2030 (m)	2050 (m)	2070 (m)	2090 (m)
VICTOR HARBOUR	rcp25	0.12	0.21	0.32	0.43
	RCP4.5	0.12	0.22	0.35	0.50
	RCP6.0	0.11	0.21	0.34	0.51
	RCP8.5	0.13	0.25	0.44	0.69

2005

South Australian Coast Protection Board

In 1991, South Australian Coast Protection Board (CPB) adopted sea level rise policy standards of 0.3m rise by 2050 and 1.0m by 2100 (compared to 1990 levels), and these standards were written into South Australian Development Plans in 1994. These policy standards are based on modelling by the Intergovernmental Panel on Climate Change (IPCC) which has modelled global climate and produced scenarios of accelerated sea level rise that relate to the various rates of projected accumulation of Greenhouse gas emissions in the atmosphere. CPB believes it has taken the best advice available in resolving to base the sea level rise aspects of its hazards policy on the IPCC sea level rise projections[34]. Figure 25 depicts sea level rise projections based on the adoption of scenario RCP 8.5 and how CPB policy levels relate.

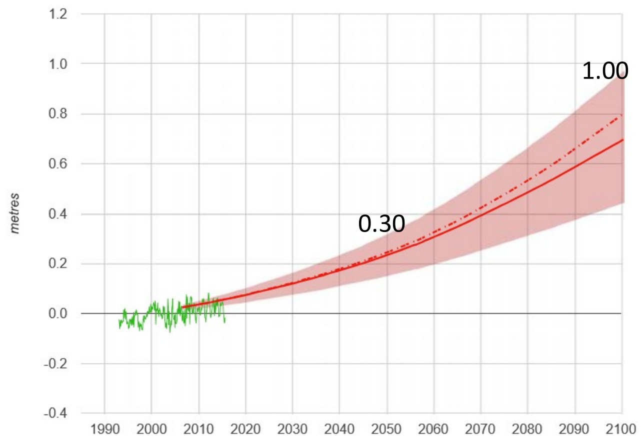
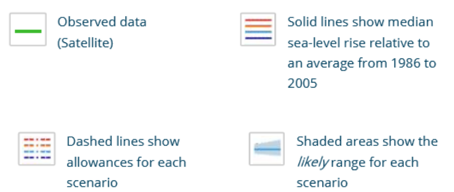


Figure 28. Sea level rise projections based on scenario RCP 8.5 from IPCC accessed from Shoreline Explorer, CoastAdapt, August 2017, The figure is adapted to show the relationship to CPB sea level rise policy standards for South Australia.



[33] CSIRO and Bureau of Meteorology 2015, Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia, p. 156.
[34] Coast Protection Board Policy Document: revised 29 July 2016, p. 16.

5.3 Methodology

To evaluate the nature of the exposure within the coastal cells we utilise the following procedure:

1. Identify the impact of previous storms,
2. Use scenario modelling to analyse the impact of storm surge events,
3. Use scenario modelling to analyse the impact of routine high-water events,
4. Assess these impacts in the context of scenarios for 2050 and 2100,
5. Estimate possible shoreline recession for 2100 taking into account sea level rise projections.

5.3.1 Identify the impact of previous storms

The analysis of previous storms provides a window into the past to assist us to identify where the coast is most vulnerable. In some ways, storms are 'natures' vulnerability assessment of how resilient our coast currently is, and how it may respond in the future. Brian Caton (2007) also encapsulated the importance of studying the impact of storms when he noted, 'recession of the [shoreline] will not be regular over time but will occur with the failure of the beach and foredune to fully recover from individual storms or a series of storm episodes'[35].

The procedure included:

- Identify significant storm events from the past,
- Locate storm accounts and photographs from the community, Council and Department of Environment and Water (SA),
- Analyse the impact of the storm and where possible, identify sea-flood heights.

5.3.2 Analyse the impact of current 1 in 100-year storm surge scenario.

This project analyses the impact of storm events within the digital elevation model captured in 2018 that takes into account: storm surge height, wave setup, and wave runup (See Figure 23 above). South Australian Coast Protection Board has assigned sea-flood risk ratings for the Victor Harbor coastline using three categories of storm dynamics: storm surge height, wave set-up, and wave run-up (Table 5). Specific wave setup and wave runup allowances have not been set for McCracken-Hayborough and therefore these are extrapolated from the findings of the Coastal Adaptation Study for Alexandrina Council completed by Integrated Coasts in 2019[36].

Table 5: Coast Protection Board sea-flood risk level for Victor Harbor coastal region.

AHD	*Encounter Bay – Victor Harbor*	*McCracken*	*Hayborough*
Storm surge (1 in 100 ARI)	1.75m	1.75m	1.75m
Wave setup	0.30m	0.40m	0.40m
Wave run-up	0.30m	0.80m	1.20m
Total risk height	2.35m	2.85m	3.35m

Source: Email Jason Quinn, Department of Environment and Water, 8 January 2021.

[35] Caton, B (2007), The impact of climate change on the coastal lands of City of Onkaparinga.
[36] Western, Hesp and Bourman (2019) Coastal Adaptation Study for City of Alexandrina by Integrated Coasts.

Coast Protection Board uses 1 in 100-year average return interval methodology which means in terms of probability, the event described would only occur one time in every 100 years. However, nature does not read our probability charts and this event could occur in shorter time scales. For example, the fifth and sixth highest events on the all-time record for Outer Harbor occurred within the months of June and July in 1981.

5.3.3 Identify the impact of routine highwater scenarios

While storm surges can have a significant impact on the coast, these by their very nature are rare events. Routine tidal action is likely to have a greater impact on the general form of the beach and backshore over time, especially in the later part of the century if seas rise as projected. In this project, routine high-water events are currently expected to occur a few times a month from April to September. Any rise in sea levels will increase the frequency of the impact. Inputs are based upon:

- Calculation of a tidal event that is likely to occur a few times per month from April to September based on tide gauge data from Victor Harbor (see graph below),
- Adopting Coast Protection Board wave setup allowances from the storm surge modelling,
- Modelling these within the digital elevation model and an aerial photograph for 2018 and identifying wave runup allowances.

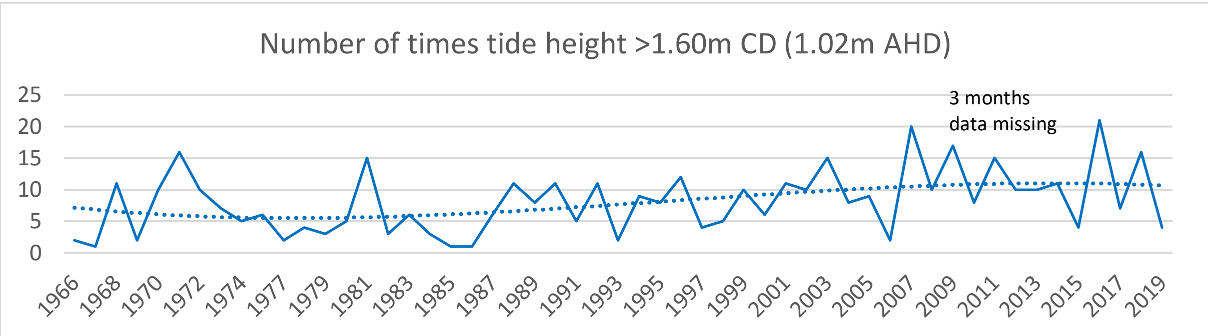


Figure 29. Assessment to identify a routine highwater event that would occur on average a few times per month from April to September.

The modelling inputs for the various coastal locations around City of Victor Harbor for routine high-water events are in Table 6. When modelling storm surge events or routine highwater events within the Inman River or the Hindmarsh River, wave run-up is not included as the energy from waves would be dissipated not too far from the shoreline.

Table 6: Inputs for modelling of routine highwater events.

AHD	*Encounter Bay – Victor Harbor*	*McCracken*	*Hayborough*
Routine high-water event	1.00m	1.00m	1.00m
Wave setup	0.30m	0.30m	0.30m
Wave run-up	0.30m	0.70m	1.10m
Total risk height	1.60m	2.00m	2.40m

Source: Estimations from tidal and seaweed strand study (Integrated Coasts).

5.3.4 Assess these impacts in the context of scenarios for 2020, 2050 and 2100.

Using the inputs as described in the previous section, 0.30m for scenario 2050 and 1.00m for scenario 2100 were added to the modelling for storm surge and routine high-water events. Scenario modelling of 1 in 100-year events for Flinders Parade for 2100 are included below as examples.

Figure 30: Modelling for 2100 scenario for routine highwater events for Flinders Parade. These routine events are expected to occur a few times month from April to September (M. Western).

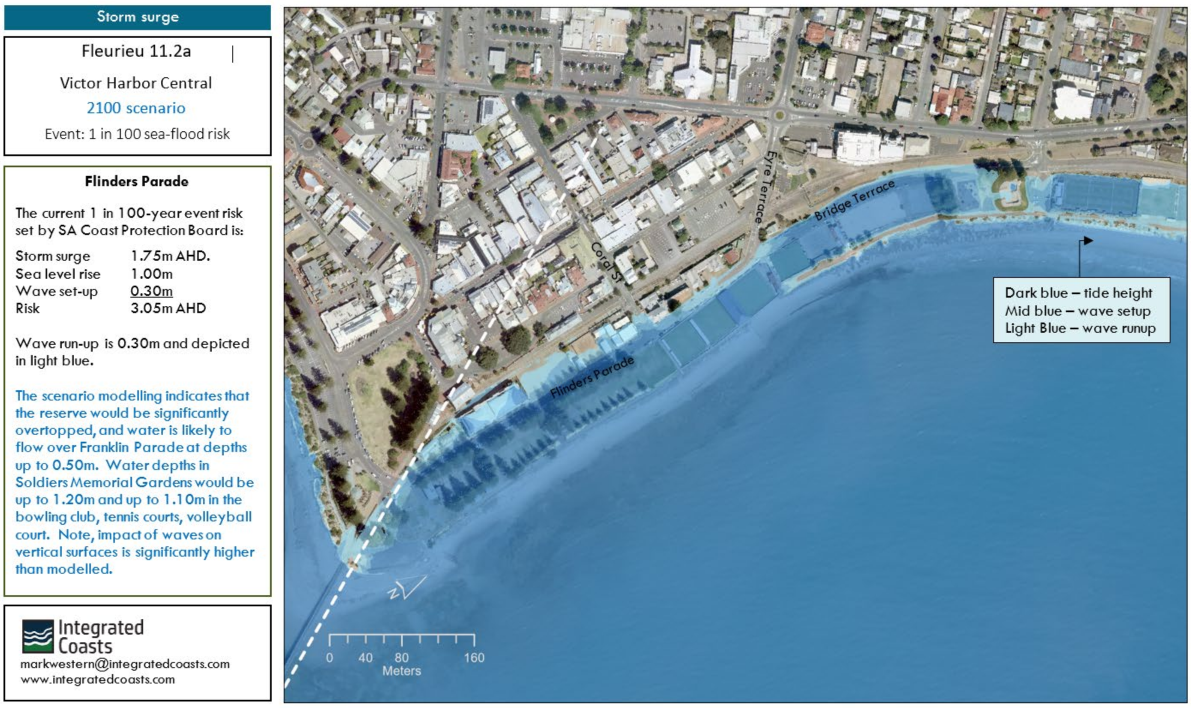


Figure 31: Modelling for 2100 scenario for 1 in 100-year sea-flood for Flinders Parade (M. Western).

5.3.4 Estimate shoreline recession due to sea level rise projected for 2100

Methodology

Estimation of shoreline recession was estimated using three methods[37]. The first method utilised the Bruun Rule, which is the standard method to estimate shoreline retreat, but which has several implicit assumptions, and ignores the possibility of dune translation. The second is a method which assumes the beach and dune system can translate upwards and landwards as sea level rises, and estimates shoreline change based on assumptions that the coastal system can actually do this, and that there is sufficient sediment in the system for this to occur. The third method is to consider the recent geomorphology of the coast which was formed when seas were ~1m higher than present 4-5000 years ago known as the mid-Holocene high stand. This is particularly relevant in the context of projected rises of ~1m by 2100.

Assessment context

Backshores of urban environments are often altered from their original states with the installation of protection works in the immediate backshore, or the construction of roads, parks, and buildings further back from the shoreline. It is not possible to factor in these interventions in the assessment of shoreline retreat in any meaningful way. Therefore, the assessment of shoreline recession assumes that the coast is in its natural state before interventions took place. The assessment question is, 'if seas rise as projected, what would the coastline naturally do?'. This provides a context to consider what the intensity of the likely impact of sea level rise will be upon urban settlement and a context to consider appropriate adaptation strategies over time.

Shoreline Change indicated by the Bruun Rule

The Bruun Rule is an equation developed by Per Bruun (1962). While it has subsequently been modified (e.g. Dean and Houston, 2016), the modified equations require more data than available for this coast. The original equation is the most widely used method for determining shoreline response to sea level rise.

$$S = -Sp\,(W/dc + B) \qquad (1)$$

Where
- *S* is Erosion due to sea level rise
- *Sp* is Sea level rise projection
- *W* is Width of the beach profile
- *dc* is Depth of closure
- *B* is Foreshore/Dune crest height

The depth of closure is estimated from equation *(2)* where *h* is the closure depth in the inner portion of the surfzone-nearshore, and *Hs* is mean annual significant wave height following Hallermeier (1981) as modified by Houston (1995):

$$h = 8.9\overline{Hs} \qquad (2)$$

[37] The first two methods were utilised by Professor Patrick Hesp, the third method was applied from the geomorphological study by Dr Robert Bourman.

Equation (1) applies to the upper shoreface (Cowell et al., 2003a). It assumes that the upper shoreface keeps the same profile and translates seaward or landward depending on the sediment budget, and ignoring alongshore and across-shore changes in sediment supply (Le Cozannet et al. (2016). Obviously this is a huge assumption in the case of many coastal tracts in South Australia. This is particularly so for the Victor Harbour beaches, since the surfzone-nearshore is characterised by significant areas of subtidal reef and seagrass beds which may restrict sand movement and alter the ability of the nearshore-surfzone profile to translate landwards. In addition, the small foredunes and dune system present along this coast indicate that it has never had more than a small sediment supply in the past.

There is extremely limited information available for the Victor Harbor beaches to determine alongshore and across shore sediment exchanges These are the contributions of other processes causing losses or gains of sediments in the active beach profile. However, as Le Cozannet et al. (2016) note, there is currently no better model or "rule" to use. Recent results regarding the global impact of sea-level rise on shoreline change are largely based on the Bruun rule and it is commonly utilised to provide at least a rough estimate of shoreline migration in relation to sea level rise. Alternative approaches exist, but they are more complex, and they require more data.

The 'closure depth' is the depth where most sediment transport due to waves and wave induced currents terminates (Hesp and Hilton, 1996). This closure depth cannot easily be determined along Victor Harbor coastline due to the fact that the nearshore region is dominated by complex three-dimensional geomorphology and includes sand, possible bedrock outcrop, and reef. Onshore/offshore sediment transport processes are therefore not operating in a straightforward manner, and application of the Bruun Rule is likely not easily applicable here. Note, in addition, there is no wave data for the region and thus, any estimate of significant wave height ($\overline{Hs}$) is also based on local observations, and possibly incorrect.

While extreme caution is urged in using the results provided in this report, for the purposes of obtaining some estimate of shoreline change driven by sea level rise, the Bruun Rule is first utilised.

Shoreface-Beach and Dune Translation Model

The utility of the Bruun Rule has been the subject of debate over the last decades, because the "rule" takes no account of longshore sediment transport, the possibility that the foredune or dunes existing behind the beach can translate upwards and landwards with sea level rise, and it is not supposed to be utilised where surfzone-nearshore reefs exist.

It is now a known fact that beaches and dunes can easily translate upwards and landwards as either shoreline erosion occurs or sea level rises (Davidson-Arnott, 2005). Therefore, another way to estimate the degree of shoreline retreat due to a given sea level rise is to take the latest topographic profile of the nearshore-beach-dune system and merely translate it entirely upwards and landwards by a given amount of sea level rise (in this case 1.0 m by 2100).

The distance that the profile is translated horizontally is determined by maintaining the distance between two topographic points (i.e. the slope of the beach-backshore) on the original profile in the projected future translated profile. For example, if the distance between zero m or AHD on the current profile and the foredune toe is, say, 15m, then that distance between those two points is maintained in the translated 2100 profile.

There is considerable shallow reef and sea grass beds existing at various places and depths along the Victor Harbor coast and it is impossible to translate this material. It is also virtually impossible to determine what will happen to this reef (and surrounding reefs) as sea level rises.

The translation method shows that the beach-foredune system will translate an estimated number of metres by 2100 depending on the nearshore-beach-dune profile or morphology. Note that this assumes there is enough sediment in the system to allow this to occur (a large assumption), and that the nearshore profile can translate adequately given all the reefs present. It also assumes that the foredune is maintained as the shoreline retreats and sea level rises and has not been destroyed, in part or fully, due to increased storminess and/or significant jumps in sea level due to meltwater pulses (very rapid rises in sea level due to massive ice retreat or ice shelf collapse) occurring in the next ~80 years.

Note that as future sea level rises over the reef dominated nearshore region, wave energy will increase due to the fact that there will be less dissipation of waves over the reefs as the water depths increase. This will increase wave energy at the beach face and impact several of the factors considered above (storm wave heights and runup, significant wave heights).

The context of recent geomorphology

The context of recent geomorphology also provides a context from which to consider the impacts of 1m of projected sea level rise. Dr Bob Bourman notes that the Police Point sand spit upon which much of the original Victor Harbor settlement was constructed, was formed in the Mid-Holocene period about 4-5000 years ago when seas were ~1m higher than present. Likewise, the surface upon which Franklin Parade is positioned from Tabernacle Road to the Bluff is a former marine 'bench' which was formed as seas receded in height by ~1m. The key issue in the context of this project is an assessment of the likely impact of a future rise of 1m in sea level. Therefore, former tides at 1m higher than present would have interacted with a shoreline that would have been more in line with the position of current-day Flinders Parade and Bridge Terrace, and the base of the coastal slope within Encounter Bay near The Bluff. The understanding of the geomorphology of the region assists in providing a possible picture of the future under higher tidal action.

5.4 General findings

5.4.1 Identify the impact from previous storms

The purpose of studying the historical storm record is to identify:

- Any large storm event that may have been lost from community memory,
- Any locations along the shoreline that have been impacted more than others,
- Whether storm action was more prevalent in some eras than others,
- Whether sea-storm events are accompanied by significant rain events.

The methodology employed was to research online newspaper articles at Trove[38], to review archives at Coast and Marine Branch at Department of Environment and Water, and to seek anecdotes and photographs from the community.

Findings from archives and newspaper articles

In the context of the four study areas mentioned above:

1. No evidence was found of a significant storm event that overtopped the coastline in ways that are not currently known.
2. From the 1920s onwards, storms often produced overtopping at Soldiers Memorial Gardens and the playing fields. The backshore of Encounter Bay in the vicinity of Whalers Road to Tabernacle Road appears to have suffered repeated erosion episodes. Only one record exists of overtopping along The Esplanade (1928) which is likely to coincide with the era when all the sand dunes had been removed from the foreshore.
3. The records indicated that storms may have been more prevalent in some eras than others. The storm record was active in 1920s to 1940s, the early 1970s, and then increased erosion in the period 2004 to 2011. In regard to the latter era, evidence was found within the tidal record to suggest that this era was accompanied by increased storminess.
4. While recognising that this area of assessment is more qualitative, early storm records do indicate that larger sea storms can be accompanied by significant rain events. This is a different finding to Gulf St Vincent where the meteorological conditions that produce high sea levels are not accompanied by significant rainfall.

Findings from the community

Input from the community was sought by way of the Your Say Victor Harbor website from 22 February to 19 March 2021 at the same time that Integrated Coasts was completing this stage of the project. Five submissions were received of a general nature which covered various coastal issues, including:

- Incidents of erosion (and sand levels from beach pole data collected by Coastcare).
- Past management strategies (some regarded as effective and others ineffective).
- Concerns and recommendations regarding the hooded plover conservation program.
- Issues relating to storm water drains along the coast.

[38] Trove, viewed at https://trove.nla.gov.au/

- Comments and concerns about two proposals: a marina in the vicinity of Bridge Terrace and the extension of the bikeway through McCracken and Hayborough.
- A general recommendation for structures along the coast (groynes and jetties) to create improved amenity for beach goers.

The submission by **Coastcare** noted the following issues. Photographs that provide additional insight to the photographs already used in this project are included.

Yilki

- The escarpment at Yilki has been subject to erosion for many years.
- Informal paths down to the beach are creating gullies.
- Specifically, storm events of June 2012 and June 2014 eroded the escarpment in the vicinity of 69 to 75 Franklin Parade.

June 2014 Opposite house numbers 74/75.
Erosion very close to the footpath

June 2012 Opposite house numbers 69 to 71.
Severe erosion

The Esplanade, King Street

- Erosion was prevalent 2008 to 2010 in which time 10 sets of steps were damaged[39].
- Management strategies of sandbag groynes and sand 'sausage' were ineffective.
- Construction of a block wall 2015 and extended in 2017 was successful.

The causeway (west)

- Winter gales of 2010 caused erosion which caused erosion of the escarpment in the vicinity of the visitors' centre and mini-golf.
- The strategy of mixing sand and seagrass and placing this at the back of the beach has proved effective[40].
- Some erosion is occurring adjacent the concrete ramp adjacent the causeway.

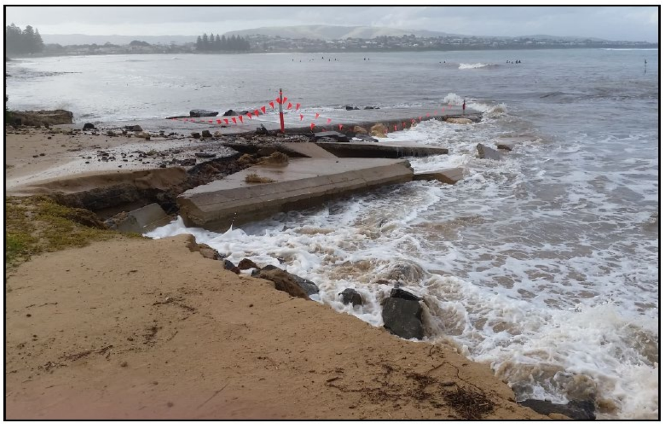
[39] See also section 5.3.3 above which demonstrates that the coastline of Victor Harbor was subjected to increased 'storminess' from 2004, 2007 to 2011. The effectiveness of the block walls may still come under scrutiny if a stormy period returns.

[40] Footnote 40 is relevant to consider in this context. Additionally, currently three storm water outlets are placed at the back of the beach in front of which sand and seagrass mix cannot be placed. Therefore, in the context of future stormy periods, or increased sea level rise erosion will occur rapidly in these locations.

The causeway (east)

- Severe erosion of the dune between the causeway and the boat ramp (2017)
- Construction of a concrete block wall in 2017, but sand and vegetation removed in 2019.
- Unsure if this concrete block wall will remain effective.

November 2019
Storm damage next to the causeway



January 2019
Storm damage next to the boat ramp.

March 2017 and November 2019
A gentle slope from car park level down to the beach was severely eroded all the way along between the causeway and the boat ramp. A block wall, topped with a sand dump and revegetation was built.

Flinders Parade

- This area is low and storm events cause masses of seaweed to be dumped on the pathway[41].
- Storms of June 2014 and Oct 2009 caused undermining of the wall adjacent the bowling club.
- A block wall has been installed in this location, but the perception is that this will be inadequate over time.

[41] See also history section within Cell 11, Victor Central that details the nature of this area prior to intervention and the storm record that shows that this area has been overtopped since installation in 1920.

June 2014 The Bowling Club wall was damaged and had to be rebuilt after a storm

October 2009
Bowling Club showing severe erosion back to foot path wall and showing old red brick wall prior to the construction of the yellow wall.

Inman River

- The diversion of the river in the last 20th century has allowed seaweed to travel further up the river and can cause an unpleasant odour.

Hindmarsh River

- The mouth of the river has been controlled by rip rap rock and sandbags, but the river still sometimes goes around the end (presumably the top end).

Other submissions relevant to this stage of the project:

Two submissions noted the problems associated with the diverting and training of the river mouths.

Anthony Milnes provided a number of older photographs, most of which had already been reviewed as part of this project. One photograph of particular interest is the nature of the coastline in 1930 in the vicinity of the tennis courts[42].

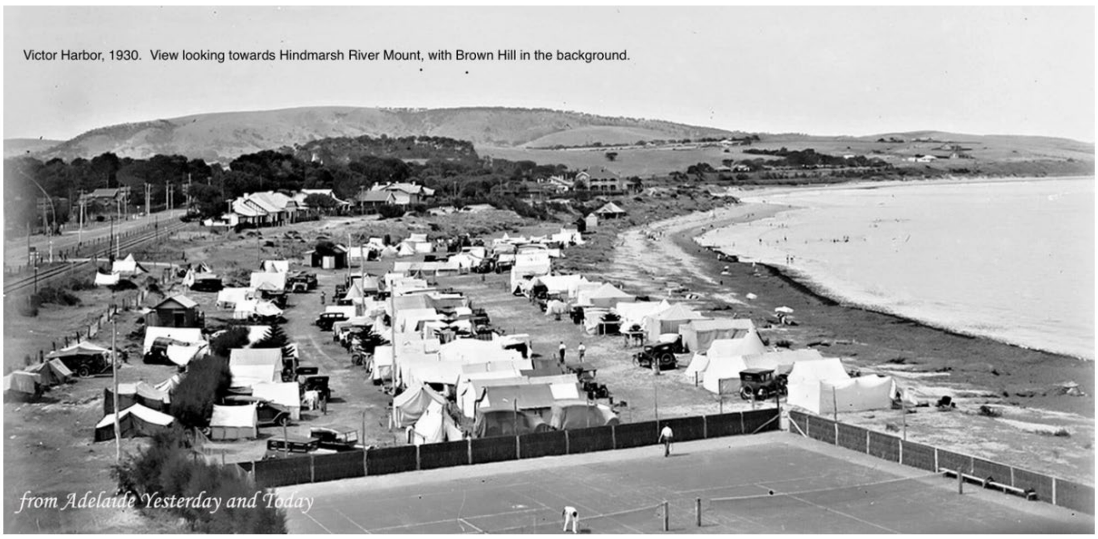


Figure 32: Beach scene adjacent trainline, 1930, Anthony Milnes, Adelaide, Yesterday and Today.

[42] Note: historical records indicate that the tennis court was often overtopped in storms.

5.4.2 Analyse the impact of the various storm surge and routine high-water events

The impact of the various scenarios depends largely on the nature of the beach and backshores and these impacts are analysed in a fine-grained manner within the cell reports. It is acknowledged that for scenarios 2050 and 2100 that we are superimposing 'future exposure' upon 'existing fabric' in the current digital elevation model. In reality, if seas rise as projected, then the fabric will change more slowly over time.

Current scenarios

- The modelling of routine high-water events reveals virtually no impact which is an expected finding because it is the routine actions of the sea that have formed the current beach and backshores.
- The modelling of 1 in 100-year storm surge suggests that the Soldiers Memorial Gardens and playing fields would be significantly overtopped with wave effects, and it is likely that Franklin Parade would also be overtopped in places of lower elevation (Fountain Ave to Tabernacle Road). The erosion impact is likely to be significant in locations which are not protected, but as this is a rare event, beaches would likely rebuild in locations of larger sand supply. However, in locations where only an embankment exists, or low sand levels, the impact is expected to be more permanent.

2050 scenarios

- The combination of routine high-water events and the rarer storm surge events at 0.30m higher than present will cause some recession in softer sediment backshores (beaches along The Esplanade, Bridge Terrace, McCracken and Hayborough). The embankment in the backshore of Encounter Bay would suffer erosion and sand levels are likely to drop at locations where rock protection is positioned (Encounter Bay, Flinders Parade).
- Significant overtopping of waves into Soldiers Memorial Gardens and the playing fields would occur more regularly. Franklin Parade would also be overtopped more frequently.

2100 scenarios

- If seas rise as projected, then the scenarios for 2100 would be significant for many areas of the coastline. Recession in soft sediment backshores is likely to be measured in decametres (at least 2-3 in most locations) and areas such as the Soldiers Memorial Gardens and the playing fields are not likely to be viable later in the century.

Generally, it is also relevant to consider that the shallow water which effectively dissipates the wave energy as it flows over reefs, rock platforms and seaweed beds would become less effective and therefore wave energy to the shoreline could increase.

5.5 Implications for coastal adaptation

The implications from the above findings in the context of coastal adaptation include:

1. South Australian Coast Protection Board has adopted sea level rise policy standards of 0.30m sea level rise by 2050 and 1.0m sea level rise by 2100 compared to sea levels in 1990. These policy standards are based on the assessments of the Intergovernmental Panel on Climate Change (IPCC) and are congruent with IPCC sea level rise projection scenario for RCP 8.5.
2. Nature Maps (SA) assesses the exposure of City of Victor Harbor coastline within the context of South Australian marine waters as: *sheltered* with *low wave energy,* for the coastline from The Bluff boat ramp to the causeway and *moderate* with *low-moderate wave energy,* for the coastline from the causeway to the eastern border of Council. This general assessment, and in the context of more fine-grained analysis within the coastal cells, provides a general input for the assignment of the inherent hazard risk rating conducted below.
3. The storm of 9 May 2016 almost coincided with 1 in 100-year risk level, but this event did not have a significant impact on the coast. This finding suggests that swell size, wind speed and direction may have greater influence on wave energy and related impacts along specific sections of the coastline rather than a general storm surge (although both are likely to be contributing factors).
4. Routine high-water events and the rarer storm surge events are likely to have the following impacts on the coastlines by 2050:
    - Increased overtopping of roads (Franklin Parade) and playing fields and reserves (Flinders Parade).
    - Soft sediment plains and slopes – recession of the shoreline (measured in metres).
    - Human intervention – where backshores have been changed to hard surfaces (rock and seawalls), sand levels are likely to decline on the beach.
    - The scenario modelling suggests that the impact within the estuaries may not be significant enough to cause major disruption. The levee around the caravan park is likely to be high enough (but this requires surveying to confirm) and the levee and retaining wall on the northern side of Hindmarsh River is likely to prevent incursion of water into residential areas (but this also requires surveying to confirm).
5. Routine high-water events (occurring at much higher rates than current) and storm surges (occurring at higher sea levels and with more frequency) are likely to have the following impact on the coastline by 2100 if seas rise as projected:
    - Significant and regular overtopping of Franklin Parade (and some inland flows between Fountain Ave and Tabernacle Road) which is likely to make this road unviable without intervention. Significant and regular overtopping into Soldiers Memorial Gardens and the playing fields, with water flows over Flinders Parade in some locations. It is unlikely that the gardens and playing fields would be viable if seas rise as projected (or at least without major intervention along the shoreline).

- Soft sediment plains and slopes (McCracken, Hayborough, Bridge Terrace, Kent Reserve, the sand dunes at the mouths of rivers) would suffer significant recession (likely to be measured in decametres).
- Human intervention – where backshores have been changed to hard surfaces (i.e. rock and seawalls), sand levels are likely to decline so that some beaches are lost in some locations.
- Seawater flows into estuaries would overtop the caravan park levee and likely flow into residential areas adjacent the Hindmarsh River (but surveying is required to confirm the latter). The modelling suggests that seawater may not flow over Bay Road into the area in which the City of Victor Harbor and library is situated but sea water would likely flow over some riverbanks causing disruption to ecologies.

6. Storm water runoff from urban settlements

The purpose of this study is to evaluate the impact of storm water that flows from urban areas to the coast. Large volumes of rainwater can quickly accumulate and flow from the impervious surfaces of urban settlements. Storm water flowing over softer cliffs can cause gullying and instability at the top of the cliffs. Storm water rushing out to the beach can cause gullying of the dunes or embankments and scouring of the beach. Over time cliffs, embankments and dunes break down and sand levels are likely to drop on the beach. In the context of sea level rise, the locations where storm water is impacting beach and backshores are likely to be the first points along the coast that become vulnerable. Additionally, as noted by Caton (2007), if shorelines recede, then storm water infrastructure is prone to be left forward of the coastline.

6.1 Scope of the assessment

The scope of this assessment is limited to answer three questions. Are storm water flows from urban environments adequately controlled so that:

- Storm water flows do not flow over coastal backshores (dunes, slopes or cliffs) in an uncontrolled manner that is likely to cause gullying and/or erosion?
- Storm water flows do not cause detrimental scouring or lowering of beach levels?
- Outlets are not positioned too low or too close to the shoreline so that rises in sea level will impact the operation of these in the future[43]?

The following limitations apply to this study:

- The assessment is concerned only with water flowing from urban environments because this is the responsibility of the Council to control and therefore a liability also exists.
- The project is not concerned with assessing the adequacy of the current storm water system in terms of matters relating to volume, velocity, current sediment and pollution controls, unless observations on beaches and backshores indicated a potential problem.
- The project recognises that in some cases, draining storm water to the coast is unavoidable and that some scouring of beaches will occur. The question here is to what degree and how permanent is the scouring.
- In the context of a broad scoping project the assessment tends to be qualitative and based only on direct observations.

6.2 Methodology

1. An inspection of each outlet was conducted on 29 January 2021. The height of the storm water outlet was surveyed, and photographs captured at the beach level to assess:

- The nature of the outlet,
- The condition of the outlet,
- Evidence of scouring or other effects on backshores.

[43] Caton, 2007, observed that erosion caused by sea level rise could leave storm water outlets stranded forward of a receding coastline and that it was important to control storm water flows in backshores.

In relation to the last point, it is recognised that the assessment took place in the summer months. However, follow-up inspections of selected locations are expected to be undertaken over the course of this project after an appropriate rainfall event. The timing of the inspection is deemed appropriate to analyse how beaches rebuild after rain events. It was assumed from the selected inspection points that the findings would be applicable to other locations[44].

2. Review the storm water system within Geographic Information System (GIS) software to:

- Identify the approximate catchment and the scheme of the general flow of storm water,
- Identify any areas of low beach levels in the vicinity of storm water outlets that may be caused by storm water outflow, but also may be vulnerable to sea-flooding in storm events.
- Identify which storm water outlets will be the most vulnerable to rising sea levels by comparing the height of the sea-flood with the height of the outlet.

3. Inspection from the crest of coastal backshores to identify any areas of the coast where storm waters may be flowing from urban environments into backshores. This inspection was relatively easy to complete due to the predominant urban layout of an esplanade road positioned between the coast and urban development.

6.3 General Findings

1. In general, Council is effectively managing the flow of stormwater from urban environments to prevent uncontrolled flows through coastal backshores.
2. Storm water outlets are set at very low levels along Flinders Parade, and these are regularly interacting with tidal flows. If seas rise as projected, then these outlets, and others set at only slightly higher current levels (The Esplanade Beach, and some in Encounter Bay) will increasingly be hindered in their operation in times of heavy rainfall. This is likely to increase the flooding potential within the township.
3. Locations where storm water outlets are set at low elevation and where storm water outflow lowers sand levels on the beach, will be threatened first in the context of rising sea levels and the backshores broken down more rapidly in these locations. In the case of The Esplanade Beach, the position of the storm water outlets at the back of the dunes prevents the dune system from being consolidated so that it forms a protective barrier between the beach and the backshore.

6.4 Implications for coastal adaptation

In general, City of Victor Harbor is managing the stormwater run-off from urban environments so that erosion in backshores is avoided. However, in the context of projected sea level rise, two issues are relevant. In some locations (The Esplanade Beach) storm water outlets are situated at the back of the dune system. This means that the dune system cannot be built up and consolidated with vegetation. Additionally, many storm water outlets are set at low elevation. Therefore, as sea levels rise these will increasingly be impeded in their operation and the potential for inland flooding may be exacerbated.

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[44] Yet to be completed if a rain event occurs within the time frame of this project.

7. Hazard impacts and risks

7.1 Overview

South Australian Coast Protection Board considers three main coastal hazards: inundation, erosion, and sand drift. Due to the nature of the City of Victor Harbor coastline, only the first two are under consideration in this project.

It is the combination of the characteristics of the coastal fabric and the nature of the exposure that determines the degree of hazard risk (Figure 29). This reality is most simply understood when considering inundation risk. Whether a coast is at risk from inundation depends entirely on the topography of the coast. If we explain this another way, a low-lying coast is *inherently* more at risk to flooding whereas an elevated coast is *inherently* not at risk from flooding.

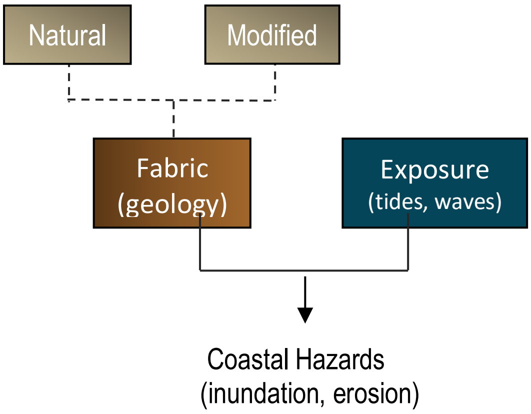


Figure 33. Conceptual framework for assessment (Integrated Coasts)

The assessment of the erosion hazard is more complex, but it is still the relationship of *fabric* to *exposure* that determines whether a coast is *inherently* more at risk from erosion or less at risk. A coastal fabric of granite is less at risk from erosion than a coast backed by sand dunes. In some locations the natural fabric of the coast has been altered by human intervention. For example, the Adelaide metropolitan beaches were once backed by sand dunes, but installation of rock revetment has changed the nature of the fabric to rock.

The application of an inherent risk rating does not suggest that areas rated as 'low' are entirely free from vulnerability, nor conversely that areas rated more highly are necessarily vulnerable now. The aim is to assess the underlying inherent vulnerability of the fabric of the coastal location.

The output from the assessment has been designed so that it is easily accessible to all stakeholders.

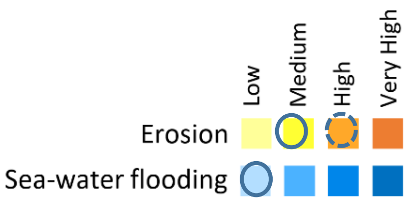


Figure 34. Example output from inherent hazard risk assessment that has meaning within South Australian coastlines.

7.2 Methodology

The assessment of hazard impacts and risks is undertaken in three main steps.

7.2.1 Assign an inherent hazard rating

Erosion

Inherent hazard ratings for erosion were applied in a workshop on 17 March 2021 December with Dr Robert Bourman who is regarded as an expert geologist and geomorphologist for the coastline of South Australia[45]. The assessment was undertaken for each cell (or minor cell if applicable) using a worksheet that followed a set process:

1. Assign an erodibility rating
2. Is any amendment required due to human intervention?
3. Apply an exposure rating
4. Assess historical impacts on backshores
5. Assess any influence from benthic characteristics
6. Assess the sediment balance
7. Assess any other factors that may warrant a change to the rating.

Inundation

Inherent inundation ratings are much easier to apply as these depend on the topography of the land in the coastal region. The assessment is applied from the chart below which takes into account any historical flooding as well.

Table 8: Inherent hazard rating assessment for inundation

Inundation Hazard Rating	Scenario modelling	Other Criteria
No risk	Modelling for 2100 scenarios depicts no risk (with allowance 0.5m freeboard)	
Low	Modelling for 2100 scenario depicts flooding of settlements	
Medium	Modelling for 2050 depicts flooding of settlements (but not current scenario).	
High	Modelling of 1 in 100 ARI year event depicts minor flooding of settlements	Experienced flooding in past events (water over roads to depth of 0.1m)
Very High	Modelling of past events depicts flooding or modelling of 1 in 100 ARI year event depicts substantial flooding.	Experienced significant flooding in past events (water over roads above 0.1m)

The aim of the assessment is to provide an assessment that has meaning within the entire State of South Australia. We therefore expect to see some commonality within the inherent hazard ratings

[45] Dr. Bourman has worked in the Victor Harbor and Alexandrina region since 1970s and is lead author for the book, Coastal Landscapes of South Australia (2016), Adelaide University Press.

in a particular region. For example, we would expect to generally see higher inundation hazard ratings in the upper regions of the gulfs where land elevations are low, and we would expect to see higher inherent erosion ratings in locations along the Southern Ocean.

7.2.2 Describe hazard impacts upon urban settlements.

In this study we are primarily concerned with the way that coastal hazards may impact urban settlements over the coming century. How inundation and erosion impact human settlement will vary according to location. For example, the impact of sea level rise will be experienced in the McCracken – Hayborough region as increased erosion to the base of the embankment which may threaten major infrastructure such as the trainline, but this area will not be subject to inundation. On the other hand, low lying areas such as Kent Reserve will experience increased inundation from seawater which will change the ecology but is not likely to threaten significant infrastructure apart from carparking and internal roads.

To bring appropriate focus, hazard impacts are described within four main receiving environments:

- Public infrastructure
- Private assets
- Social disruption
- Ecosystem disruption

The context for analysing 'social disruption' within this project is derived from the Risk Management Framework for City of Victor Harbor using two main concepts:

- Public safety
- Reputation (community concern)

The term 'ecosystem disruption' is used to describe the situation where changes in a coastal region might bring about larger scale changes that may threaten to disrupt the entire ecological system, for example seawater flooding into freshwater ecologies.

7.2.3. Conduct risk assessment using the risk framework of City of Victor Harbor.

The final step is to conduct a risk assessment using Council's Risk Management Framework which utilises 'likelihood' and 'consequence' methodology in the context of the various risk categories[46]. Risk assessment is completed for current outlook, but also for the future outlook at 2100. It is recognised that values and parameters of risk assessment will have changed by 2100, but the procedure does produce meaningful outputs. In particular, the two risk eras provide a useful context to understand the trend of a coastline. For example, in one area of coast the immediate backshore may be high enough that inundation is not a risk in this current era and all of the risk indicators are assigned as low. However, the scenario modelling may demonstrate that a tipping point is reached sometime in the future and inundation may flow over the immediate backshore and flood lower lying areas behind. A relevant examples is the levee at the caravan park which protects against flooding until after 2050, but then is likely to be significantly inundated thereafter.

[46] City of Victor Harbor, 2020, Risk Management Framework.

The output is purposefully designed so that it is immediately accessible and meaningful to a wide range of personnel involved in managing the coastal environs including: politicians, elected members, policy makers in all levels of Government, coastal managers, and the general public.

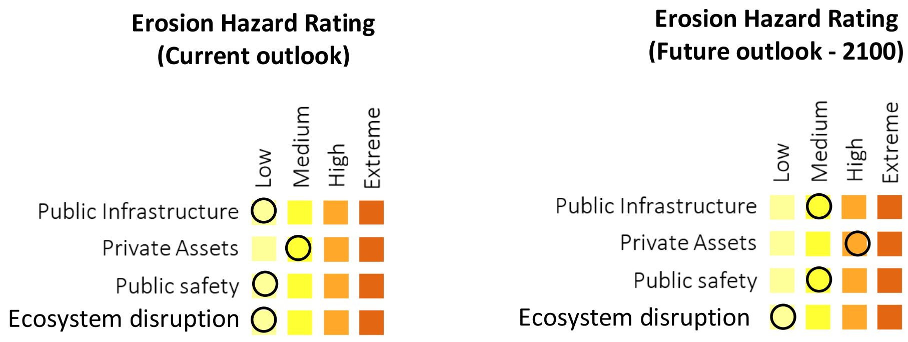


Figure 35: **Example** of risk assessment conducted within receiving environments for current and future outlook at 2100.

7.3 General findings - Hazard impacts

Specific hazard impacts are recorded within the cell reports. A summary of hazard impacts is also available for immediate review in the Cell Snapshot Summaries in Section 10 of this report.

Inundation

Generally, the coastline of City of Victor Harbor is set above current sea-flood risk apart from the overtopping of protection works in the vicinity of the reserve and playing fields on Flinders Parade. However, if seas rise as projected post 2050, seawater flows will increasingly overtop protection works along Flinders Parade and flow over Franklin Parade between Tabernacle Road and The Bluff boat ramp. Without intervention, these areas are not likely to be viable for their intended uses later in the century. It is likely that increasing levels of seawater flowing up the estuaries post-2050 will eventually overtop the levee around the caravan park and possibly flow into the residential area on the northern side of Hindmarsh River. To confirm these findings the height of the levee systems should be surveyed. The modelling suggests that seawater will overtop the banks of the rivers in places causing ecosystem disruption, but the impact upon roads and urban infrastructure may be low.

Erosion

Prior to 2050, erosion will increase around the coastline, but recession is likely to be measured in metres. Beach and dune locations are likely to suffer cyclic recession but also may rebuild over time (The Esplanade Beach, McCracken, Hayborough). Unprotected embankments are likely to experience permanent erosion damage and recession (Encounter Bay, Bridge Terrace). In locations where humans have placed hold points (protection items), sand levels in these regions are likely to drop with the possibility of the loss of some beaches (Flinders Parade, Encounter Bay).

If seas rise as projected post 2050, erosion will substantially increase with shoreline recession measured in decametres. Beach and dune locations are likely to suffer significant erosion with retreat back to esplanade roads and the trainline likely (The Esplanade Beach, McCracken, Hayborough). Locations where the backshore is an unprotected embankment are likely to experience permanent erosion damage and recession (Encounter Bay, Bridge Terrace). In locations where humans have placed hold points (protection items), sand levels in these regions are projected to drop so that beaches are completely lost and protection works continually undermined (Flinders Parade, Encounter Bay).

8. Limitations of the study

The following are recognised limitations of the study.

1. The modelling of sea level rise scenarios for 2050 and 2100, involves the superimposing of future actions of the sea (i.e. that incorporate sea level rise) over the layout of the existing fabric of the coast. It is recognised that changes in the fabric of the coast will occur over long periods of time. However, the modelling is key to assessing the risks and the visual approach will be a benefit in communicating with stakeholders.

2. SA Coast Protection Board has assigned wave effect allowances of 0.30m for wave setup and 0.30m for wave runup for Victor Harbor Central (Cell 11) and Encounter Bay (Cell 12). In an area where waves and currents are complex these allowance have proved to be not fine grained enough to apply throughout all sections of the study area.

3. Shoreline recession modelling has been conducted at four locations where South Australian Coast Protection Board profile lines have also been surveyed. At three of the four locations, offshore reefs and/or rock platforms are present and the tools to estimate shoreline recession are limited. The limitations are noted at each location.

4. It is acknowledged that utilising the risk assessment procedures and framework for City of Victor Harbor for events at 2100 has some limitation. However, the aim of the assessment is to provide an 'outlook' and in practice the methodology appears to produce meaningful outcomes when using the sea-flood modelling and erosion outlook created in the project.

5. The sea-flood modelling does not take into account the possibility of increased flooding produced by a rainfall event for which the storm water system does not effectively manage, nor the possibility of increased flows down the Inman and Hindmarsh rivers.

9. Further research

Areas that may require further research are listed here. These items are in addition to specific recommendations made within the various cell reports.

1. One area that has not been reviewed in this project is the implications of increasing residential density in locations that are in close proximity to the coastline. If rapid erosion should occur which places private dwellings, or access to those dwellings at risk, how would the legal system view the decision to increase density in coastal area.

2. Various data gaps are missing from the flood analysis for flooding within the estuaries:
    - The surveyed height levels for the levee around the caravan park. At this stage the project has relied on the digital elevation model.
    - The surveyed height level for the retaining wall and levee that protects the residential area to the north of the Hindmarsh River. At this stage the project has relied on the digital elevation model for the levee and eyewitness accounts of the likely height of the retaining wall.

3. It is recommended that a storm and tidal study be conducted for the three cells within the study area (Bluff Boat Ramp to Investigator Carpark). Two or three storms of moderate size could be surveyed and analysed in the following manner:

    - While the storm is underway, observe the highest level of wave runup and mark locations.
    - Use survey equipment to identify the location and height of the markers.
    - Identify the tidal height of the storm at the Victor Harbor tide gauge and calculate the residual. The result is the total wave effects for any particular location, but these are best averaged over the various sections of the beach.

10. Cell summaries (snap shots)

The following pages contain summary pages for each minor cell. There are three cells within the study, and in all, 6 minor cells.

McCracken-Hayborough (Cell 10.1)

McCracken

(10.1)

Coastal setting:

McCracken coastline is categorised as a fine-medium sandy beach with areas of rock in the intertidal zone and exposed low tide reef. The beach is backed by a vegetated dune that rises up to a former marine bench at 6.50m AHD upon which the trainline is situated. Urban development is situated ~25 to 50m landward of the trainline. Exposure is categorised as 'moderate', and wave energy 'low'. Historical analysis shows that the mouth of the Hindmarsh River has been moved further south and a dune system has built up at the former mouth.

Fabric - Coastal history

A retaining wall has been installed at some time in the past to protect the embankment upon which the trainline is situated. Since 1949, the coastline has generally accreted in this location (4-8m), partly due to the realignment of the mouth of the Hindmarsh River further to the south. Management practices are also likely to have contributed to shoreline stability.

Exposure - Scenario modelling

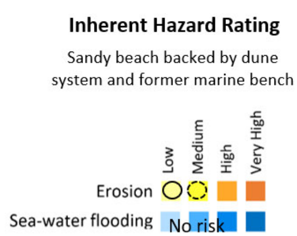
Scenario modelling demonstrates that the current 1 in 100-year ARI storm would impact the backshore, but the beach would tend to rebuild in this location. Modelling for 2050 indicates increased pressure on the backshore with recession likely (measured in metres). Modelling for 2100 indicates that both storm surge action and routine monthly highwater events are likely to cause significant recession of the dunes and embankment under the trainline (10 to 20 metres).

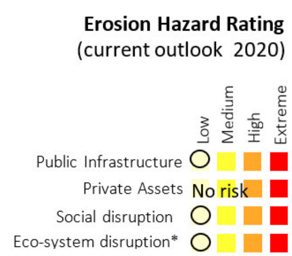
Storm water runoff

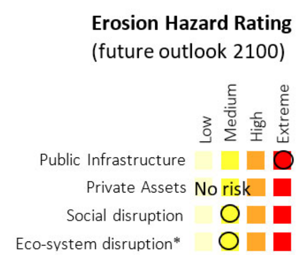
Storm water from urban settlement set landward and above the trainline only flows to the beach in one location which is set within the embankment at 3m AHD. Some lowering of sand levels on the beach is observed. Other storm water outlets appear to drain into the natural swale between the trainline and the landward slope.

Overview of Impacts

The main threat that sea level rise will bring is recession of the embankment under the trainline resulting in increasing stability over time and placing the trainline at risk. Additional risks relate to the location of storm water outlets, which in two cases may also be increasing potential for erosion of the embankment, and beach access points. *While broadscale ecosystem disruption is unlikely, shore nesting bird habitats are likely to be disturbed or lost*.







McCracken-Hayborough (Cell 10.2)

Hayborough
(10.2)

Coastal description:

The Hayborough coastline is categorised as a fine-medium sandy beach with areas of rock and exposed low tide reef. The beach is backed by a vegetated dune that rises up to a former marine bench at 6.50m AHD upon which the trainline is situated. Urban development is situated ~25 to 50m landward of the trainline. Exposure is categorised as ‘moderate’, and wave energy ‘moderate’. The position of the toe of the dune accreted seaward between 1949 and 1976 by 4 to 8m and has remained in a similar position since this time (apart from on the western end which has periodically accreted and eroded ~4m).

Fabric - Coastal history

A retaining wall has been installed in the past to protect the embankment upon which the trainline is situated. Since 1949, the shoreline has accreted by 4-8m and has been stable in this location since 1976 (with some minor cycles of accretion and erosion evident). Management practices are also likely to have contributed to shoreline stability.

Exposure - Scenario modelling

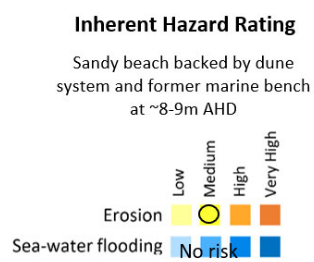
Scenario modelling demonstrates that the current 1 in 100-year ARI storm would impact the backshore, but the beach would tend to rebuild in this location. Modelling for 2050 indicates increased pressure on the backshore with recession likely (measured in metres). Modelling for 2100 indicates that both storm surge action and routine monthly highwater events are likely to cause significant recession of the dunes and embankment under the trainline (10 to 20 metres).

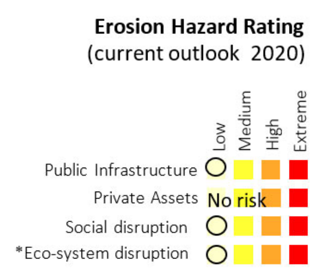
Storm water runoff

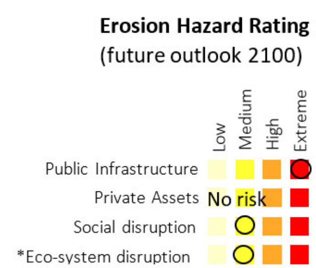
Storm water from urban settlement set landward and above the trainline only flows to the beach in one location which is set within the embankment at 3m AHD. Some lowering of sand levels on the beach is observed. Other storm water outlets appear to drain into the natural swale between the trainline and the landward slope.

Overview of Impacts

The main threat that sea level rise will bring is recession of the embankment under the trainline resulting in increasing stability over time and placing the trainline at risk. Additional risks relate to the location of a storm water outlet which is already interacting with actions of the sea. Lower sand levels here will also increase potential for actions of the sea to erode the embankment behind. Beach access points will become more difficult to manage with lower sand levels. *While broadscale ecosystem disruption is unlikely, shore nesting bird habitats are likely to be disturbed or lost*.







Victor Harbor Central (Cell 11.1)

The Esplanade Beach

(11.1)

Coastal description:

Coarse sand beach backed by narrow low height vegetated dunes 3.5m -4.5m AHD. A reserve or car park is positioned behind the dunes and the esplanade road at 3.5m to 4.5m AHD. Nearshore and surf-zone is dominated by sand, covered by continuous and patchy seagrass beds. Offshore is a low profile continuous or patchy reef. Exposure is rated as 'sheltered' and wave energy, 'low'. Overall slope of ocean floor is 1:300. Significant seaweed rack often accumulates on the beach.

Fabric - Coastal history

In the mid-1800s a significant dune system covered the foreshore area back to Warland Reserve. The sand dunes were all removed by 1937 but since the 1970s have been re-established. Historical shoreline analysis demonstrates that the shoreline periodically undergoes erosion and accretion cycles. A particularly significant erosion cycle occurred 2004 to 2011 which was accompanied by installation of protection items and sandbag groynes. The recent trend has been for accretion.

Exposure - Scenario modelling

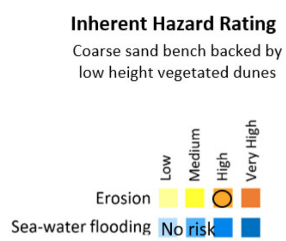
Scenario modelling for 2050 indicates increased pressure on the backshore with recession likely (measured in metres). Modelling for 2100 indicates that both storm surge action and routine monthly highwater events are likely to cause permanent recession of the soft sediment backshore that will be measured in decametres (at least 2-3). The erosion modelling suggests recession between 35m to 69m.

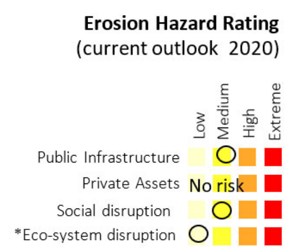
Storm water runoff

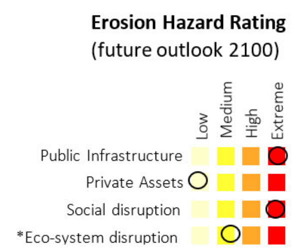
Storm water from urban settlement is being appropriately managed so that none flows to the coast in an uncontrolled manner. However, storm water outlets set in the backshore of the Esplanade Beach (x3) prevent the sand dunes from being consolidated. Increasing actions of the sea will first impact these gaps in the dunes, causing more rapid recession.

Overview of Impacts

The main threat that sea level rise will bring is the permanent recession of the sand dunes. Unless room is made landward of the sand dunes, they will be unable to retreat and will be lost to the foreshore. Overtopping of sea water into the car park and reserve will become more frequent post 2050. The reserve, car park and visitors centre will become increasingly exposed to actions of the sea and require protection. *While broadscale ecosystem disruption is unlikely, shore nesting bird habitats are likely to be disturbed or lost*.







Victor Harbor Central (Cell 11.2)

Franklin Parade – Bridge Terrace

(11.2)

Coastal description:

Fine to medium sandy beach backed by rock or concrete seawall from causeway to bowling club, then very narrow, low height dune (7m to 8m wide) backed by walking path and playing fields. Nearshore and surf-zone dominated by sand, covered by dense seagrass beds. Offshore is dominate by sand with patchy seagrass cover.

Exposure is rated as 'moderate' and wave energy, 'low'. Overall slope of ocean floor is 1:100.

Fabric - coastal history

In the mid-1800s the foreshore contained a small dune system that extended back to Franklin Parade. A promenade and seawall were installed in 1920 to provide protection to the gardens and playing fields. Storms frequently over-topped the seawall into the bowling club or tennis courts. In 1986, storm damage required the replacement of the seawall with rock revetment, extended to the bowling club 1989 (but this section now replaced with concrete blocks). Comparisons with early photography suggest that the beach is diminishing, and sand levels are dropping.

Exposure – scenario modelling

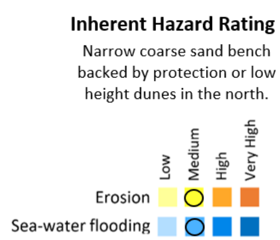
Minor overtopping occurs regularly in vicinity of gardens and bowling club. Scenario modelling for 2050 indicates increased overtopping, recession of the beach in unprotected locations, loss of sand in protected locations. Post 2050, both routine high-water events and 1 in 100-year storm surge events will significantly overtop the reserve and playing fields, with inundation flowing over Franklin Parade and up to the edge of Bridge Terrace. Loss of sand and undermining is likely to occur in areas that are protected, significant recession of the shoreline where not protected.

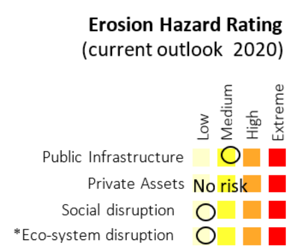
Storm water runoff

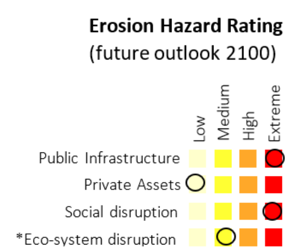
Storm water outlets in the vicinity of the gardens and bowling club are set at very low elevations. Increasing sea levels will close the tidal flaps more frequently and increase the likelihood of increased flooding from rain events.

Overview of Impacts

The main threat that sea level rise will bring is increasing overtopping of the rock/concrete protection and inundation of the gardens and playing fields making these increasingly unviable as community areas. Decreasing levels of sand on the beach will tend to undermine protection works and the beach will become increasingly less accessible for public use. *While broadscale ecosystem disruption is unlikely, shore nesting bird habitats are likely to be disturbed or lost*.







Encounter Bay (Cell 12.1)

Boat ramp to Yilki
(12.1)

Coastal setting

The Encounter Bay coastline (boat ramp to Yilki) is categorised as a narrow coarse sand beach with offshore intertidal rocky shelf. At the back of the beach is a former marine shelf created about 4-5000 years ago when seas were ~1m higher. Franklin Parade is situated on this bench. Exposure is categorised as 'sheltered' and wave energy, low. The boat ramp area could be categorised as very sheltered. Increasing storm activity since 1990s has resulted in most of the backshore now having some form of protection from Nevin Street to Yilki.

Coastal fabric - history

The surface on which the road is located was formed 4-5000 years ago when seas were +1m than present. In a low sand environment that is dominated by offshore reefs, the location of the current backshore, was formed in the context of recent actions of the sea. Increasing structures in the backshore necessitated the introduction of an embankment which is now predominately protected from Nevin Street to Yilki.

Coastal exposure - scenario modelling

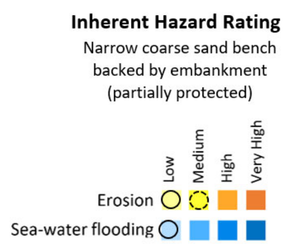
Current episodes of erosion are likely caused by periods of increased storminess. Actions of the sea at 0.3m higher will produce minor overtopping of the road and erosion of the embankment if not protected. Post 2050, overtopping would increase over the road with some flows into residential areas in Yilki region. Increasing intensity of wave action will occur on the embankment causing significant erosion in unprotected areas and increased undermining of protection.

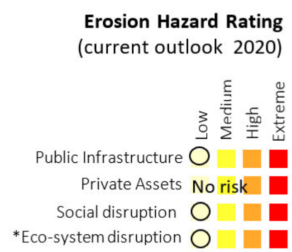
Storm water runoff

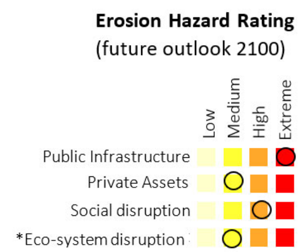
Storm water from urban settlement is being appropriately managed so that none is dispensed over the top of coastal slopes. However, many outlets are set at low elevation (especially south of Yilki) and increasing sea levels will inhibit proper function of these. Post 2050, a confluence of a rain event and a sea storm event may be exacerbated due to inability to drain to the sea.

Overview of Impacts

The main threat that sea level rise will bring increasing impact to backshores so that unprotected areas recede, but also likely to undermine protected areas. Combined with increasing overtopping post 2050, the cycle track, carparks, and road will come under increasing threat. Residential areas in the vicinity of Whalers to Yilki may be flooded in the later part of the century, especially if a sea storm event occurred at the same time as a rain event. *While broadscale ecosystem disruption is unlikely, shore nesting bird habitats are likely to be disturbed or lost*.







Encounter Bay (Cell 12.2)

Yilki to Kent Reserve
(12.2)

Coastal Setting

The Encounter Bay coastline (Yilki to Kent Reserve) is categorised as a narrow coarse sand beach with offshore intertidal rocky shelf. At the back of the beach are former sand dunes now covered over by urban settlement and roads. Exposure is categorised as 'sheltered' and wave energy, low. Rock protection has been installed in three segments between Tabernacle Road and Bartel Terrace.

Coastal fabric - history

The coast at Tabernacle Rd is at lower elevation and former sloping shore has been replaced with an embankment and dunes which periodically accrete and erode. The mid-section is naturally set at higher elevations, portions of which are protected with rock. The coast at Kent Reserve accreted over a long period of time (+60m) but recently has eroded back ~10m.

Scenario modelling

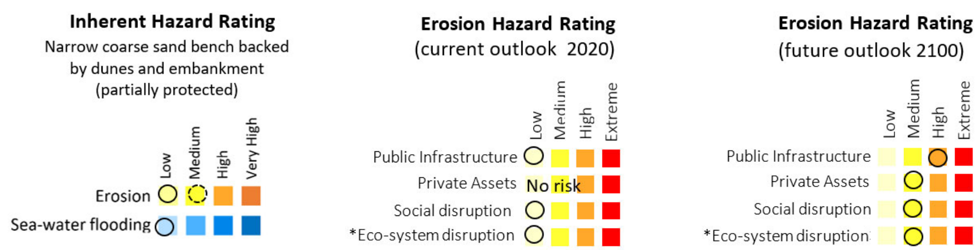
The coast is more elevated north of Tabernacle Road and therefore this area is not generally subject to inundation. Actions of the sea at 0.3m will increase erosion of unprotected embankments and likely to decrease sand levels on the beach. Some overtopping of the road may occur later in the century, but the impact will be minor. Sea levels at 1m higher will cause significant erosion of unprotected backshores, and increased intensity of wave action will tend to undermine and degrade existing protection works.

Storm water runoff

North of Tabernacle Road the area is more elevated, and the residential area has been constructed on a former dune. Most storm water drains to Encounter Lakes or Kent Reserve and therefore the catchments that drain to the ocean are small. Storm water outlets are generally set at higher elevations.

Overview of Impacts

The main threat that sea level rise will bring increasing impact to backshores so that unprotected areas recede, but also likely to undermine protected areas. Combined with increasing overtopping post 2050, the cycle track, car parks, and road will come under increasing threat. This minor cell is more elevated than 12.1 and therefore is not likely to subject to inundation from actions of the sea, but some minor over topping is possible post 2050. *While broadscale ecosystem disruption is unlikely, shore nesting bird habitats are likely to be disturbed*.



Part 2:

Coastal Adaptation Strategy

Completed June to August 2021

Part 1 of the project establishes a baseline understanding of how the coast was formed, how humans have interacted with the coast over time, how the coast has been performing over the last century. Current risks and vulnerabilities are identified, and the sea-flood modelling provides a basis to assess potential risks and vulnerabilities in the context of timeframes 2050 and 2100.

Part 2 of the project provides an adaptation strategy with a specific focus on actions and plans required for the time period 2021 – 2031. However, because assets constructed in the coastal zone usually have long life spans and because long lead times are often required to prepare for adaptation responses, in the first instance this strategy maintains a focus on sea-flood risk for 2050. Additionally, in locations of high social importance such as within Victor Central, the strategy also considers the longer-term adaptation context for 2100.

Document structure

The report is structured in two main sections. Section 1 reports the methodology utilised in the study and the coastal issues that are common to the entire coastline. Section 2 of the study creates standalone reports for the three Coastal Conservation Cells found between the Bluff Boat Ramp and the eastern border of the Council area (at Investigator Carpark). This document represents Section 1 of the study.

The coastal cell reports in Section 2 of the study are:

- McCracken-Hayborough (Cell Fleurieu 10)
- Victor Harbor Central (Cell Fleurieu 11)
- Encounter Bay (Cell Fleurieu 12)

Reading context

Readers requiring information on a particular location or region are advised to consult the relevant coastal cell report which adopt a highly visual format and are predominantly written in plain English. Readers who wish to know more about the methodology and technical aspects of the study are advised to read this report.

1. Introduction

City of Victor Harbor (the Council) engaged Integrated Coasts in January 2021 to produce a coastal adaptation study (Stage 1) and a coastal adaptation strategy (Stage 2) for the coastline from The Bluff boat ramp to the eastern border of Council. This section of the report represents Stage 2 of the project. Community engagement was managed by URPS, and Appendix 1 is a standalone report of the activities and findings from this process.

This section of work adopts the framework and understanding of adaptation options and strategies from CoastAdapt[47].

2. Coastal Adaptation Overview

2.1 Adaptation methods

What is known as 'pathways' adaptation methodology is the common way to undertake coastal adaptation. This methodology deals with uncertainty using three main ingredients: scenario planning, time, and triggers or thresholds[48]. A 'pathways' approach outlines plausible futures from which to identify key thresholds and triggers, and then considers alternative pathways when these are breached. The problem with this method is that trigger points are often arbitrarily set on very limited information and in the context of deep uncertainty, and as such provide little direction to ongoing coastal management. Integrated Coasts holds the view that in most cases, less time should be given to extensive analysis to the timing of the likely breaching of thresholds, and more time allocated to initiating monitoring programs to track change over time. The only exception to this rule is when Council is considering whether to invest in upgrading or installing infrastructure. In these cases, an analysis of the timing of impacts is useful, and the precautionary principle should apply[49]. CoastAdapt notes the emergence of 'adaptive management' that relies on inputs from monitoring for decision making and this is the method adopted in this project (Figure 36).

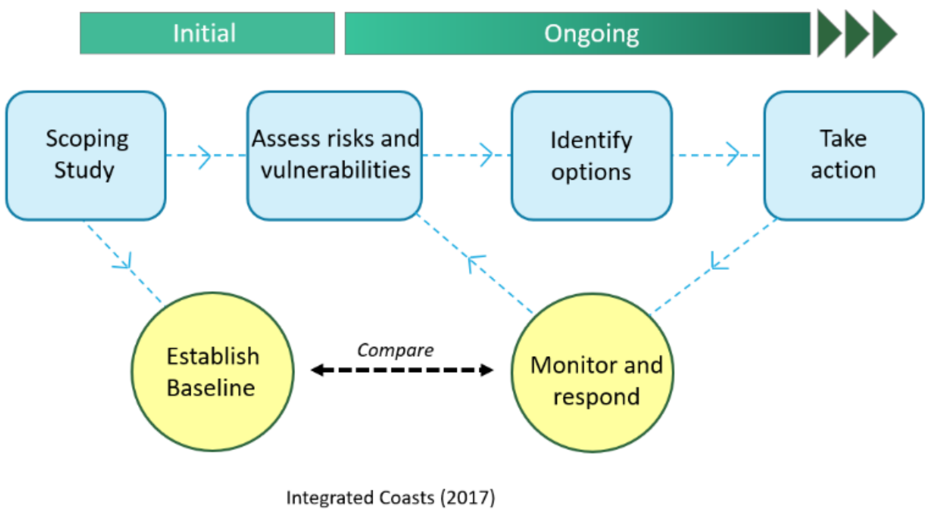


Figure 36. Coastal adaptation model

[47] Coast Adapt, coastadapt.com.au/understand-adaptation, coastadapt.com.au/adaptation-options
[48] https://coastadapt.com.au/pathways-approach.
[49] https://coastadapt.com.au/sites/default/files/factsheets/CoastAdapt_Glossary_2017-02-06_FINAL.pdf.

2.2 Adaptation options

There are generally five categories of adaptation responses in the coastal zone:

1. **Avoidance** - Avoid the impacts of coastal hazards by ensuring that assets are not placed in areas that could be impacted in the future.
2. **Hold the line** – Install protection infrastructure that reduces the impact of coastal hazards or use environmental practices to strengthen natural protective forms such as dunes.
3. **Accommodate** – Accept some degree of hazard and conduct limited intervention to manage the hazard (for example, in areas that may be subject to inundation, raise houses on poles).
4. **Managed retreat** – Progressively move assets or services away from areas that could be impacted by coastal hazards now or in the future.
5. **Loss acceptance** - Accept that coastal hazards will cause negative impacts on assets and services and when this occurs, they will not be replaced.

These categories are not necessarily exclusive from each other, and one locality may employ one or two of these concurrently, and over a longer period of time measured in decades, several adaptation options may be employed.

2.3 Adaptation approaches

There are two main approaches to coastal adaptations:

1. **Incremental approach** - A series of relatively small actions and adjustments aimed at continuing to meet the existing goals and expectations of the community in the fact of the impacts of climate change.
2. **Transformative approach** - In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant that they can only be addressed through more dramatic action. Transformational adaptation involves a paradigm shift: a system-wide change with a focus on the longer term. A transformative approach may be triggered by an extreme event or a political window when it is recognised the significant change could occur.

2.4 Adaptation responses

There are three main approaches to coastal adaptations[50]:

1. **Planning** – planning responses are options that use planning legislation and regulations to reduce vulnerability and increase resilience to climate change and sea-level rise. Thus, land that is projected to become more prone to flooding in future can be scheduled as suitable only for development such as light industry or warehouses, and unsuitable for housing or critical infrastructure.

2. **Engineering** - In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation. These approaches differ from other types of approaches in that they require significant commitments of financial and social resources and create a physical asset.

[50] CoastAdapt also includes 'community education' but in this project it is assumed that Council will continue to communicate with the community.

3. **Environmental management** - Environmental management includes habitat restoration and enhancement through activities such as revegetation of coastal dunes or building structures to support growth of habitat such as seagrasses. It may also include developing artificial reefs to reduce wave erosion of shorelines or engineered solutions to prevent encroachment of saltwater into freshwater systems.

3. Monitoring strategies

The purpose here is not to provide a design for a detailed monitoring program which is a separate project. The purpose here is to provide a context for understanding why monitoring is necessary and broadly, what type of monitoring actions are likely to be adopted. In most areas of Victor Harbor coastline, this study has recommended an 'incremental approach' to adaptation and therefore, a core response will be to 'monitor and respond'.

3.1 Prime response – monitor and respond

Data will be collected on an ongoing basis and compared to the baseline we have established in this study. We have established a baseline in two ways: First, the capturing of the digital elevation model in 2018 provides a point in time baseline of the current form of the coast and the aerial photograph from 2018 also provides a 'bird's eye' view of the coast in 2018. Future data captures can be compared to these over time. The second way in which this study has formed a baseline is by analysing coastal change over time. We have compared the position of the shoreline from 1949 to 2018 and identified areas of erosion and accretion. Overall, the coastline in most places appears to have been stable for 70 years. In some places it has eroded. This understanding of how a coast operates over time also forms part of the baseline understanding. Future data captures will add to the ongoing picture of what is occurring in the coastal zone. Analysing the impacts of storm activity will also form part of the monitoring strategy and ongoing assessment of Coast Protection Board profile lines will also assist in identifying trends within the coastal region.

3.2 Establishing indicators for monitoring

Indicators are things that we can measure. They help to determine whether objectives have been achieved for a specific program or project. Therefore, the monitoring plan should contain measurable objectives together with indicators for each of the objectives. Monitoring programs need to be in place so that they can collect appropriate data on each indicator and assess these against baseline conditions.

3.3 The key indicator: the shoreline

Generally, we are most interested in the position of the shoreline over time. Both coastal management and engineering design require information about where the shoreline is, where it has been in the past, and where it is predicted to be in the future. The shoreline is the position of the land-water interface at one instant in time. But in reality, the shoreline position changes continually through time because of the dynamic nature of water levels at the coastal boundary (waves, tides, storm surge, wave setup, wave runup), and because of cross-shore and alongshore sediment movement. The shoreline is a time-dependent phenomenon that may have substantial short-term variability, and this needs to be carefully considered when determining the shoreline position.

Various indicators relating to shoreline position.

A monitoring program will identify appropriate indicators and observe changes to these over time. The figures depict the various coastal indicators (Figure 37).

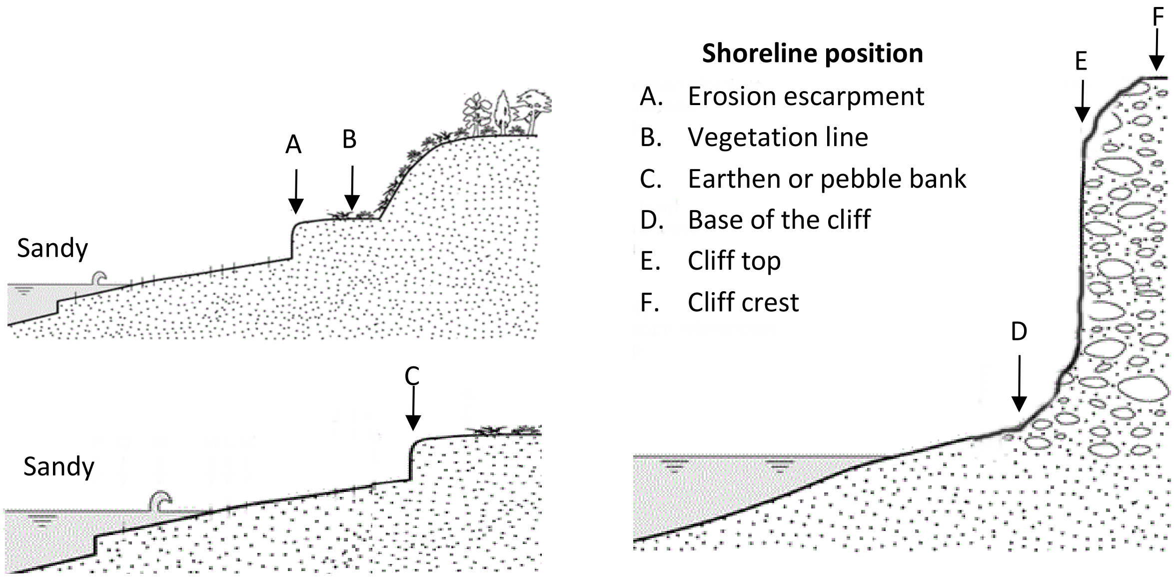


Figure 37. Adapted from Boak and Turner (2005), Shoreline definition and detection.

3.4 Typical monitoring activities.

The table below lists typical monitoring activities to provide further understanding of monitoring techniques rather than a properly designed monitoring program appropriate for Victor Harbor.

Table 9. Typical activities for a coastal monitoring program

Item	Reason	Indicators	Preferred Timing
Recapture digital elevation model	Assess shoreline change – including sand volumes	Sand volume changes, location of escarpments	Every 5 years
Aerial photography	Assess shoreline change…identify trends	Position of vegetation line, escarpments	Every 1-2 years
Coast Protection Board profile lines	Assess offshore and onshore sediment trends	Profile line change indicating accretion or erosion trends	Every 5 years (or when the profile line is captured)
Observe and analyse storm activity	Identifies impacts and any storm trends.		When storms occur.

On some occasions, more intensive monitoring programs are required. For example, the wave setup and wave runup allocations provided by SA Coast Protection Board are unlikely to be suitable for all sections of Victor Harbor Central and Encounter Bay. The monitoring of wave effects for 2 or 3 storms would likely provide the necessary inputs for the next thirty years of coastal adaptation.

4. Adaptation strategy – cell summaries

In this section of the report one-page summaries from each cell are provided that give a brief overview of:

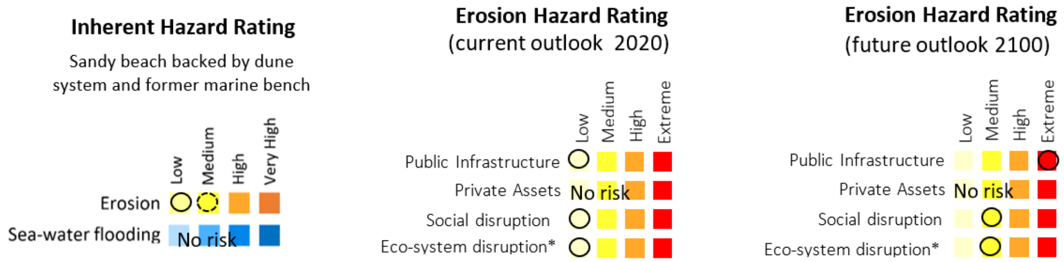
- Coastal processes
- Risk assessment
- Adaptation Strategy

This section of the report concludes with a list of adaptation tasks with a priority ranking.

Adaptation Strategy: McCracken (Cell 10.1)

Coastal processes	McCracken coastline is categorised as a fine-medium sandy beach with areas of rock in the intertidal zone and exposed low tide reef. The beach is backed by a vegetated dune that rises up to a former marine bench at 6.50m AHD upon which the trainline is situated. Urban development is situated ~25 to 50m landward of the trainline. Exposure is categorised as 'moderate', and wave energy 'low'. Historical analysis shows that the mouth of the Hindmarsh River has been moved further south and a dune system has built up at the former mouth.

Risk outlook



Adaptation overview:

The modelling for the long-term indicates that the dune system seaward of the trainline will erode away by 2100 and the embankment under the trainline will come under attack. Irrespective of whether the trainline can be protected or will need to be removed, the embankment will prevent any direct attack from the sea to the base of the coastal slope upon which the settlement of McCracken is situated. The short to mid-term strategy is to monitor and maintain the existing vegetated dune system using environmental management techniques. Storm water outlets should be designed to minimise scouring on the beach and so that they can be adapted to the cycles of accretion and recession that take place on this beach (and if seas rise as projected, then the trend is expected to be predominantly recession).

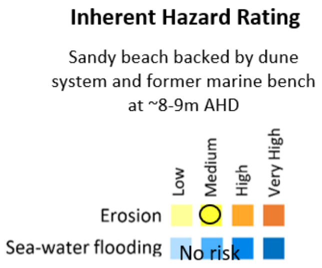
Summary table:

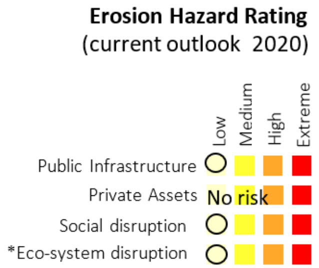
	Approach	Short-term strategy 2020	Mid-term strategy 2050	Long-term strategy 2100	Adaptation Type	Monitoring strategy
McCracken Cell 10-1	Incremental [Monitor and Respond]	[Hold the line] [Also, design storm water outlets capable of adjustment to various dune positions]	[Hold the line with vegetated dune system, adjust location of storm water outlets]	Either hold the line (protect the trainline) or managed retreat (remove the trainline)	Environmental: Maintain vegetated dune Engineering: Design and implement adaptable storm water outlets to accommodate accretion and erosion cycles.	Monitor the following: Shoreline position Storm impacts on backshores Analyse offshore profile lines..

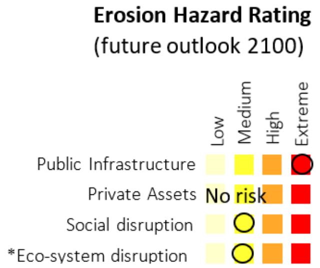
Adaptation Strategy: Hayborough (Cell 10.2)

Coastal processes	The Hayborough coastline is categorised as a fine-medium sandy beach with areas of rock and exposed low tide reef. The beach is backed by a vegetated dune that rises up to a former marine bench at 6.50m AHD upon which the trainline is situated. Urban development is situated ~25 to 50m landward of the trainline. Exposure is categorised as 'moderate', and wave energy 'moderate'. The position of the toe of the dune accreted seaward between 1949 and 1976 by 4 to 8m and has remained in a similar position since this time (apart from on the western end which has periodically accreted and eroded ~4m).

Risk outlook







Adaptation overview:

The modelling for the long-term indicates that the dune system seaward of the trainline will erode away by 2100 and the embankment under the trainline will come under attack. Irrespective of whether the trainline can be protected or will need to be removed, the embankment will prevent any direct attack from the sea to the base of the coastal slope upon which the settlement of Hayborough is situated. The short to mid-term strategy is to monitor and maintain the existing vegetated dune system using environmental management techniques. Storm water outlets should be designed to minimise scouring on the beach and so that they can be adapted to the cycles of accretion and recession that take place on this beach (and if seas rise as projected, then the trend is expected to be predominantly recession).

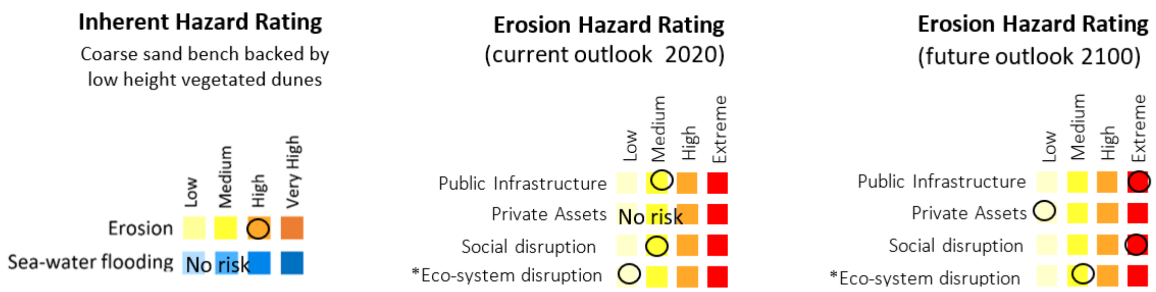
Summary table:

	Approach	Short-term strategy 2020	Mid-term strategy 2050	Long-term strategy 2100	Adaptation Type	Monitoring strategy
Hayborough Cell 10-2	Incremental [Monitor and Respond]	[Hold the line] Also, design storm water outlet capable of adjustment to various dune positions.	[Hold the line with vegetated dune system, adjust location of storm water outlets if required]	Either hold the line (protect the trainline) or managed retreat (remove the trainline)	Environmental: Maintain vegetated dune Engineering: Design and implement adaptable storm water outlet to accommodate accretion and erosion cycles.	Monitor the following: Shoreline position Storm impacts on backshores Analyse offshore profile lines.

Adaptation Strategy: Victor Central – Esplanade Beach (Cell 11.1)

Coastal processes	Coarse sand beach backed by narrow low height vegetated dunes 3.5m – 5.0m AHD. A reserve or car park is positioned behind the dunes and the esplanade road at 3.5m to 4.5m AHD. Nearshore and surf-zone is dominated by sand, covered by continuous and patchy seagrass beds. Offshore is a low profile continuous or patchy reef. Exposure is rated as 'sheltered' and wave energy, 'low'. Overall slope of ocean floor is 1:300. Significant seaweed rack often accumulates on the beach.

Risk outlook



Adaptation overview:

This beach undergoes cycles of erosion and accretion. If seas rise as projected, then the longer-term trend will be for erosion and recession of the dune. The short to mid-term strategy is to remove the gaps along this beach (storm water outlets, redesign accessways for pedestrians) and create a consolidated and well-vegetated dune system. The longer-term strategy is to maintain the dune system for as long as feasible and facilitate recession of the dune if this occurs with sand nourishment and vegetation. Harder protection works such as concrete block sea walls may prove useful within the dune system to slow recession. If the coast recedes back to the carpark, then hard protection items will be required.

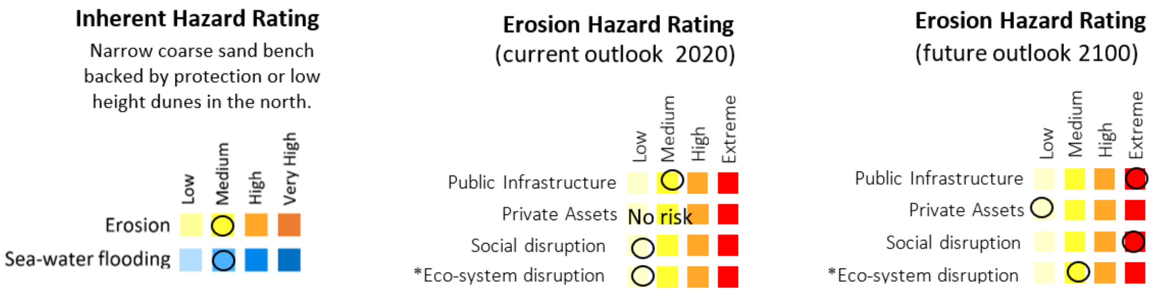
Summary table:

	Approach	Short-term strategy 2020	Mid-term strategy 2050	Long-term strategy 2100	Adaptation Type	Monitoring strategy
Victor Central Cell 11-1	Incremental [But formalise a strategy]	[Hold the line] Develop a consolidated dune from Inman River to Causeway	[Hold the line] Maintain the dune – manage any permanent recession	[Managed retreat and then hold the line] Implement hard protection works when required.	Environmental (soft): Use natural dune system Engineering: Employ hard protection works if required post 2050.	Use quarterly terrain modelling using drone technology to provide inputs for sand nourishment and vegetation growth. Then lower-cost strategies.

Adaptation Strategy: Victor Central – Flinders Parade (Cell 11.2)

Coastal processes	Fine to medium sandy beach backed by rock or concrete seawall from causeway to bowling club, then very narrow, low height dune backed by walking path and playing fields. In the mid-1800s the foreshore contained a small dune system that extended back to Franklin Parade. Larger swells from the Southern Ocean have created the curve in the bay and these swells overtop the defences in the vicinity of Soldiers Memorial Gardens and bowling club Sand has been declining on the beach.

Risk outlook



Adaptation overview:

Consideration is required as to the viability of long-term protection along Flinders Parade. If seas rise as projected, then the defences required will be of significant height which will tend to 'cut off' the community from the coast. Holding the line at its current location will also remove a useable beach. The adaptation proposal for this minor cell is for Council and the community to consider developing a master plan that will create a new layout for this section of the coast that will be designed to absorb the impact of the sea more effectively over time, remove storm water outlets from the beach, and create spaces adjacent the coast for the community to enjoy.

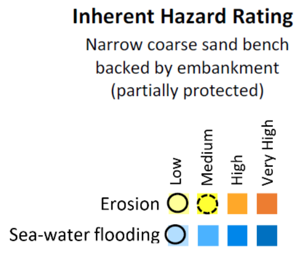
Summary table:

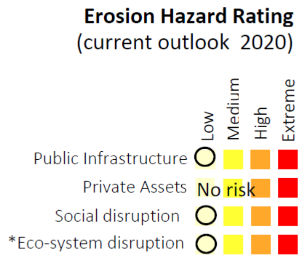
	Approach	Short-term strategy 2020-2031	Mid-term strategy 2050	Long-term strategy 2100	Adaptation Type	Monitoring strategy
Encounter Bay Cell 12-2	Transformative [Consider developing a master plan]	[Develop a master plan that considers alternative layouts]	[If alternative layouts are not implemented, raise protection works]	[If alternative layouts are not implemented, raise protection works]	Engineering: Implement new 'ridge line' adjacent Flinders Parade/ Bridge Terrace. But if new layouts are not considered, install protection works to existing coastal edge.	Storm impacts on backshores Analyse offshore profile lines

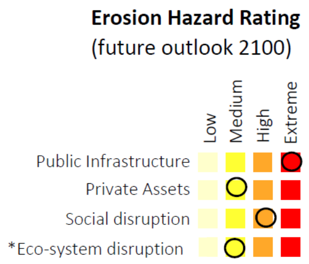
Adaptation Strategy: Encounter Bay (Cell 12.1)

Coastal processes	The coastline from the boat ramp to Yilki is categorised as a narrow coarse sand beach with offshore intertidal rocky shelf. At the back of the beach is a former marine shelf created about 4-5000 years ago when seas were ~1m higher. With increasing width required for road infrastructure, an earthen embankment has been formed seaward of the original marine bench. Exposure is categorised as 'sheltered' and wave energy, low. Increasing storm activity since 1990s has resulted in most of the backshore having some form of protection from Nevin St to Yilki. Periodic larger swells from the Southern Ocean can have significant impact.

Risk outlook







Adaptation overview:

Overtopping of the frontal defences occurs in this current time on high tides and larger swells. Sea level rise will increase the height and frequency of these events. The short to mid-term strategy is to design and implement a protection strategy that utilises the proposed bike track as the 'spine' of the defence system and to which protection works can be abutted. Storm water outlets should be designed and adapted to minimise scouring of the beach. The longer-term strategy post 2050 is harder to determine and will depend on the rate of sea level rise. The strategy is likely to involve maintaining protection works, increasing the elevation of properties (and perhaps roads) and accommodating some overtopping.

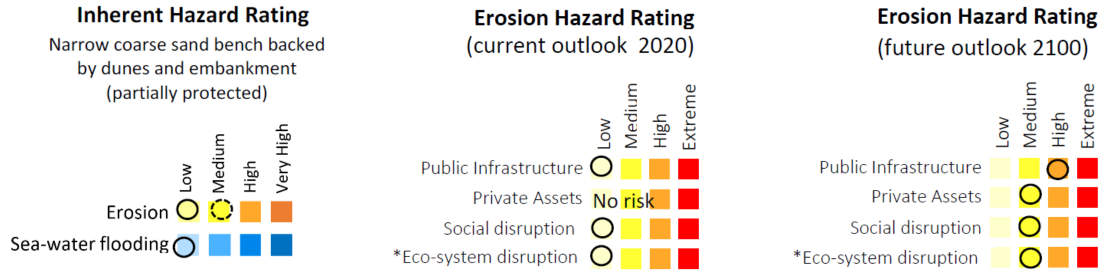
Summary table:

	Approach	Short-term strategy 2020	Mid-term strategy 2050	Long-term strategy 2100	Adaptation Type	Monitoring strategy
Encounter Bay Cell 12-1	Incremental [But formalise a strategy]	[Hold the line] Install bikeway to act as 'spine' to defence works. Add other protection as required.	[Hold the line] Ensure that the works installed now will manage 2050	Hold the line strategy will require higher protection works and some accommodation of overtopping may be required.	Engineering (hard): Concrete bikeway and rock or concrete protection. Environmental: Where possible retain natural beaches and dunes.	Initial: monitor the wave effects of 2-3 storms. Longer term: Sand levels, Dune position, offshore profile.

Adaptation Strategy: Encounter Bay (Cell 12.2)

Coastal processes	The Encounter Bay coastline (Yilki to Kent Reserve) is categorised as a narrow coarse sand beach with offshore intertidal rocky shelf. At the back of the beach are former sand dunes now covered over by urban settlement and roads. Exposure is categorised as 'sheltered' and wave energy, low. However, wave energy is generally higher in this minor cell than the section of coast from the boat ramp to Yilki. The larger swells from the Southern Ocean wrap around the Bluff and Wright Island and periodically impact the backshores. Rock protection has been installed in three segments between Tabernacle Road and Bartel Terrace.

Risk outlook



Adaptation overview:

The backshores within Cell 12-2 are generally at higher elevation than in Cell 12-1. The short to mid-term strategy is to review the current protection works and design and install rock revetment to protect from Tabernacle Road to Bartel Boulevard. In the vicinity of Kent Reserve no protection works are currently required. Storm water outlets should be designed and adapted to minimise scouring of the beach. The longer-term strategy post 2050 is harder to determine and will depend on the rate of sea level rise. The strategy is likely to involve maintaining and improving protection, while managing the retreat of beaches such as those near Kent Reserve.

Summary table:

	Approach	Short-term strategy 2020	Mid-term strategy 2050	Long-term strategy 2100	Adaptation Type	Monitoring strategy
Encounter Bay Cell 12-2	Incremental [Monitor and Respond]	[hold the line] Assess current protection/ damage. Progressively upgrade	[hold the line] Maintain protection works	[hold the line] Maintain protection is the likely strategy.	Engineering (hard): Rock revetment is likely choice. Environmental: Where possible retain natural beaches and dunes.	Initial: monitor the wave effects of 2-3 storms. Longer term: Sand levels, Dune position, offshore profile.

5. Adaptation tasks (2021-2031)

It is recommended that the following tasks be implemented. Some of these items require either further design parameters and direction, and some will require long lead times in community and stakeholder engagement.

Coastal Adaptation Tasks				
Task	**Cell**	**Reason**	**Priority**	**Timing**
1. Develop a long-term monitoring program.	Council wide	It is essential to understand how the coast operates and when it may be operating outside of its normal parameters due to sea level rise.	High	1-2 years
2. Assess storms (2-3) of varying magnitude to identify appropriate wave effect allocations for the various parts of Victor Central.	Council wide	Currently wave effects are set at 0.30m for wave setup and 0.30m for wave runup for Cells 11 and 12. These are likely either too low, or not appropriate for all sections of the coast. Identifying wave effects for defined localities will aid in design of protection items and provide a more accurate context for ongoing management. It is likely the Coast and Marine may pay half of this cost.	High	1-2 years
3. Conduct a feasibility study and cost estimates to reduce the flow of storm water to the beach from two outlets adjacent Hayward Court.	McCracken Hayborough Cell 10.1	Storm water is scouring the beach, reducing sand levels around outlets, and in some locations preventing the dune from establishing. It may be feasible to combine outlets	Low	Within 5 years
4. Upgrade storm water outlet at Yandra Terrace with design able to be adjusted for cycles of erosion / accretion.	McCracken Hayborough Cell 10.2	Storm water is scouring the beach, reducing sand levels around the outlet and preventing the dune from establishing. Council has already contracted a storm water consultant.	High	1-2 years
5. Ascertain ownership of the old retaining wall, assign a function to the structure as something other than 'retaining wall'.	McCracken-Hayborough	This asset is no longer fit for the purpose of protecting the trainline and therefore should be removed or assigned a new function such as mechanism for 'dune stabilisation'.	Low	Within 5 years

6. Survey the levee surrounding the caravan park and report suitability for protecting to 2050.	Victor Central Cell 11.1	It is not clear from the digital elevation model whether the levee system is high enough and stable enough to protect for sea-flood scenario 2050.	Low	Within 5 years
7. Design and implement a program to consolidate and vegetate the dune system from the Inman River to the causeway. Remove gaps (storm water outlets and pedestrian points)	Victor Central Cell 11.1	The distance between the esplanade road and the shoreline is sufficiently wide enough to implement a soft management approach. Storm water outlets would need to be relocated to make this proposal viable.	High	Planning: 1-2 years Implement: within 5 years
8. Consider creating a master plan for the Flinders Parade – Bridge Terrace precinct.	Victor Central Cell 11.2	It will be difficult to protect this area if seas rise as projected. The location is a significant area in the context of a historic town. It is recognised that this process will involve extensive engagement with stakeholders and therefore the first step is intentionally kept simple.	Moderate	1-2 years (master plan only)
9. Design, cost and implement bikeway (pathway) from Tabernacle Road to the tree line north of the Bluff Boat Ramp constructed at sufficient height to manage sea level rises projected to 2050.	Encounter Bay Cell 12.1	This proposal will create a 'spine' for the protection strategy in this region to which protection can be added or replaced as required.	Moderate	1-2 years (design and plan) 5 years implement (but Yilki area sooner)
10. Assess the protection works from Tabernacle Road to Bartel Boulevard and upgrade/ repair if required	Encounter Bay Cell 12.1	Very recent storms have eroded the works in vicinity of Bartel. Some of the protection works are buried under the embankment.	High	Now (repairs may be required)

References

(Project note: some of the references below may relate to the individual coastal cell reports).

Aagaard, T., and Sørensen, P., 2013. Sea level rise and the sediment budget of an eroding barrier on the Danish North Sea coast. *J. Coast. Res.* SI65, 434–439.

Advertiser Newspaper, 16 July 1953, accessed through Trove at https://trove.nla.gov.au/

Anderson, T. R., Fletcher, C. H., Barbee, M. M., Frazer, L. N., and Romine, B. M., 2015. Doubling of coastal erosion under rising sea level by mid-century in Hawaii. *Nat. Hazards* 78, 75–103.

Australian Government 2019, Climate Change in Australia, viewed March 2021, < https://www.climatechangeinaustralia.gov.au/en/>

Australian Government, Bureau of Meteorology, 2017, *Tide gauge metadata and observed monthly sea levels and statistics*, accessed at http://www.bom.gov.au/oceanography/projects/ntc/monthly/ on 18th February, 2021.

Water Technologies, formerly known as Australian Water Environments, 2013, Victor Harbor Coastal Management Study.

Boak and Turner 2005, Shoreline definition and detection: Journal of Coastal Research.

Bourman, Murray-Wallace, Harvey, 2016, Coastal Landscapes of SA, Adelaide University Press.

Bruun, P., 1962. Sea-level rise as a cause of shore erosion. *J. Waterway. Harbour. Div.* 88, 117–130.

Caton, B 2007, The impact of climate change on the coastal lands of the City of Onkaparinga.

Christensen et al, 2013, The Physical Science Basis, Contribution to Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Church et al 2016, Sea-level rise and allowances for coastal Councils around Australia, Guidance Material, CSIRO report.

City of Victor Harbor Development Plan, South Australian Government.

City of Victor Harbor, 2020, Risk Management Framework.

Cooper, J. A. G., and Pilkey, O. H., 2004. Longshore drift: trapped in an expected universe. *J. Sediment. Res.* 74, 599–606.

Cowell, P. J., Stive, M. J., Niedoroda, A. W., de Vriend, H. J., Swift, D. J., Kaminsky, G. M., et al., 2003a. The coastal-tract (part 1): a conceptual approach to aggregated modelling of low-order coastal change. *J. Coast. Res.* 19, 812–827.

Cowell, P. J., Stive, M. J., Niedoroda, A. W., Swift, D. J., de Vriend, H. J., Buijsman, M. C., et al., 2003b. The coastal-tract (part 2): applications of aggregated modelling of lower-order coastal change. *J. Coast. Res.* 19, 828–848.

CSIRO and Bureau of Meteorology 2015, Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report, CSIRO and Bureau of Meteorology, Australia.

CSIRO, 2020, Sea level, waves and coastal extremes, accessed August 2020 at https://research.csiro.au/slrwavescoast/sea-level/

Curry J, 2019, Sea level and climate change, Climate Forecast Application Network.

Davidson-Arnott, R. G., 2005. Conceptual model of the effects of sea level rise on sandy coasts. *J. Coast. Res.*21, 1166–1172.

Davidson-Arnott, R., Hesp, P.A., Ollerhead, J., Walker, I., Bauer, B., Delgado-Fernandez, I., Smyth, T.A.G., 2018. Sediment budget controls on foredune height: a comparison of cimulation model results and field data. Earth Surface Processes and Landforms 43: 1798-1810.

Geomarine, 1990. Umina and Ocean Beaches Coastal Development Manual. Report prepared for Gosford City Council by P.A. Hesp, 30pp.

Hayes, M, WorldAtlas, 2017, What is Geomorphology? Viewed: https://www.worldatlas.com/articles/what-is-geomorphology.html

Hesp, P.A., and M.J. Hilton, 1996; Nearshore-surfzone system limits and the impacts of sand extraction. Journal of Coastal Research 12 (3): 557-785.

Hinkel, J., Nicholls, R. J., Tol, R. S., Wang, Z. B., Hamilton, J. M., Boot, G., et al., 2013. A global analysis of erosion of sandy beaches and sea-level rise: an application of DIVA. *Glob. Planet. Change* 111, 150–158.

IPCC, WG1AR5, Sea level change, 2014.

Le Cozannet, G., Oliveros, C., Castelle, B., Garcin, M., Idier, D., Pedreros, R., & Rohmer, J., 2016. Uncertainties in sandy shorelines evolution under the Bruun rule assumption. *Frontiers in Marine Science*, *3*, 49.

McPherson, A., Hazelwood, M., Moore, D., Owen, K., Nichol, S. & Howard, F. 2015. The Australian Coastal Sediment Compartments Project: methodology and product development.

National Climate Change Adaptation Research Facility, 2021, Glossary, viewed: https://coastadapt.com.au/sites/default/files/factsheets/CoastAdapt_Glossary_2017-02-06_FINAL.pdf.

National Climate Change Adaptation Research Facility, 2021, *How to understand climate change scenarios*, viewed: https://coastadapt.com.au/how-to-pages/how-to-understand-climate-change-scenarios

National Climate Change Adaptation Research Facility, 2021, *What is a pathways approach to adaptation?* Viewed: https://coastadapt.com.au/pathways-approach.

NASA, 2019, Carbon dioxide fertilization greening earth, accessed March, 2021 at https://www.nasa.gov/feature/goddard/2016/carbon-dioxide-fertilization-greening-earth.

Nott, J. F. 2016: How climate and sea level have changed over the long-term past. CoastAdapt, National Climate Change Adaptation Research Facility, Gold Coast.

Ollerhead, J., Davidson-Arnott, R., Walker, I. J., & Mathew, S., 2013. Annual to decadal morphodynamics of the foredune system at Greenwich Dunes, Prince Edward Island, Canada. *Earth Surface Processes and Landforms 38*(3), 284-298.

Page, M. 1987, Victor Harbor - from pioneer port to seaside resort, District Council of Victor Harbor.

Passeri, D. L., Hagen, S. C., Medeiros, S. C., Bilskie, M. V., Alizad, K., and Wang, D., 2015. The dynamic effects of sea level rise on low gradient coastal landscapes: a review. *Earth Future* 3, 159–181.

Ranasinghe, R., Callaghan, D., and Stive, M. J. F., 2012. Estimating coastal recession due to sea level rise: beyond the Bruun Rule. *Clim. Change* 110, 561–574.

Ranasinghe, R., and Stive, M. J. F., 2009. Rising seas and retreating coastlines. *Clim. Change* 97, 465–468. doi: 10.1007/s10584-009-9593-3.

Resilient South (2014) Regional Climate Change Adaptation Plan, URPS and Seed Consulting, p.22 (technical report p.3)

Rhein, M et al, 2013: Observations: Ocean. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Seed Consulting and URPS (2014), Resilient South, Climate Change Regional Adaptation plan, 2014.

Sharples et al 2009, Australian Coastal Smartline Geomorphic and Stability Map Manual, University of TAS.

South Australian Coast Protection Board, Coastal erosion, flooding and sea level rise standards and protection, 26 January 1992.

South Australian Coast Protection Board. Coast Protection Board Policy Document: revised 29 July 2016.

South Australian Government 2019, South Australian Resources Information Gateway, viewed March 2021, < https://map.sarig.sa.gov.au/>

South Australian Government, 2021, viewed at https://data.environment.sa.gov.au/NatureMaps/Pages/default.aspx

Tonkin Consulting 2009, Pedler Creek – floodplain mapping study.

Watson, P.J., 2011. Is there evidence yet of acceleration in mean sea level rise around mainland Australia? Journal of Coastal Research, 27(2), 368–377. West Palm Beach (Florida), ISSN 0749-0208.

Watson, P.J., 2020. Updated mean sea-level analysis: Australia. Journal of Coastal Research, 36(5), 915–931. West Palm Beach (Florida), ISSN 0749-0208

Western, M., 2019, Liability issues relating to coastal adaptation, prepared by Integrated Coasts for City of Onkaparinga, 2019.

Western, Hesp and Bourman (2019) Coastal Adaptation Study for City of Alexandrina by Integrated Coasts.

Victor Harbor Times, 1 May 1926, accessed through Trove at https://trove.nla.gov.au/

Appendix 1 Engagement Summary Report.

Appendix 1 is a stand-alone document produced by Nicole Halsey, URPS and reports the process and findings of the community engagement for the Coastal Adaptation Study.

Integrated Coasts
21ADL-0096
9 June 2021

Engagement Summary Report

City of Victor Harbor Coastal Adaptation Study

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Engagement Summary Report

9 June 2021

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Prepared for	Integrated Coasts
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URPS Ref	21ADL-0096

Document history and status

Revision	Date	Author	Reviewed	Details
V1	09/06/21	N. Halsey	M. Western	Issued to client

Contents

1. Introduction

The City of Victor Harbor has engaged consulting team, Integrated Coasts to review and update the Coastal Management Study 2013 to provide a Coastal Adaptation Study, and, based on the findings of the Study, provide Council with a Coastal Adaptation Strategy 2021-2031.

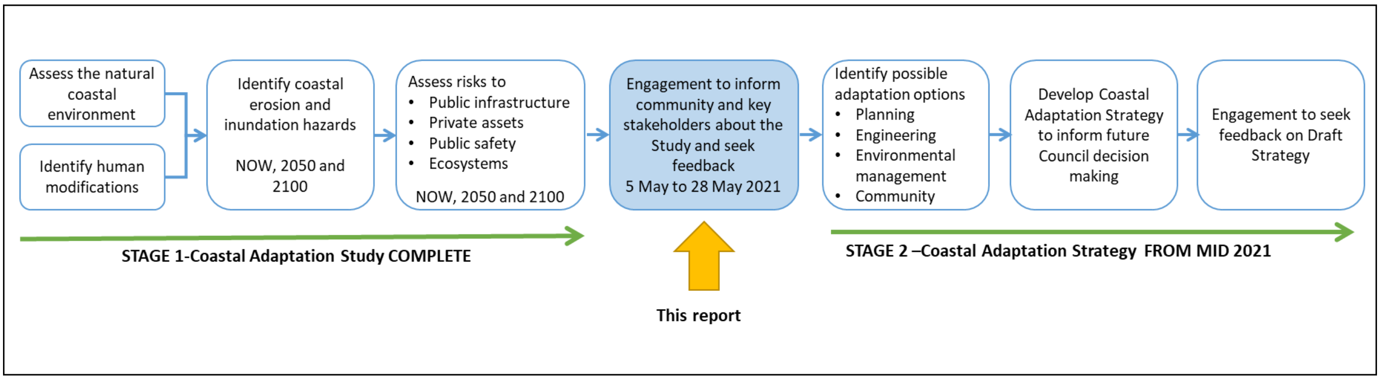
In preparing the Coastal Adaptation Study and the Coastal Adaptation Strategy, Council wishes to engage with the community and key stakeholders to gather information about local coastal issues and experiences and obtain feedback on draft documents.

Three phases of engagement are proposed, with Phases 1 and 2 completed.

This report documents the engagement implemented for Phase 2 and the feedback received. Council led the delivery of the engagement with URPS providing selected engagement services as part of implementing Phase 2.

Figure 1 shows Councils coastal adaptation planning process, and how the Phase 2 engagement fits in within the broader project context.

Figure 1 Coastal Adaptation planning process



1.1 Phase 1 engagement

Early in Stage 1 of the project, the community was invited to submit information and evidence of coastal changes and storm events in the Victor Harbor area[1]. Information provided included photographs and six written submissions. Targeted engagement was also undertaken with key stakeholders from relevant government agencies and interest groups.

The information gathered in this phase provided valuable input and was incorporated into the drafting of the Coastal Adaptation Study.

[1] URPS was not involved in the design, delivery or documentation of the engagement for Phase 1. This was undertaken by City of Victor Harbor and Integrated Coasts as per Council's Coastal Adaptation Study & Strategy Communications and Engagement Plan.

2. Engagement process

The Coastal Adaptation Study is a comprehensive and technical document that is of interest to a range of stakeholders and the community. The Phase 2 engagement therefore focussed on communicating the findings of the Coastal Adaptation Study, providing the opportunity to view information and ask questions to better understand the study findings and receiving feedback.

Council established a dedicated web page regarding the Coastal Adaptation Study on its website which provided overview information about the Study and broader coastal adaptation planning project and links to key information at Your Say Victor Harbor including:

- The full Study report
- An information pack comprising a series of Fact Sheets which summarised key findings of the Study in an easy-to-read format.

Opportunities to participate in the engagement comprised:

- Attending a community webinar, with facilitated Q&A. Integrated Coasts presented the Study findings and online participants could ask questions/make comments live throughout the presentation. Responses to questions/comments were facilitated by URPS
- Viewing a recording of the community webinar
- Completing a feedback form
- Providing written feedback (eg via email).

The engagement on the Study was promoted via:

- Public Notice in The Times newspaper
- Council's Facebook Page
- Council's Instagram
- Council's monthly e-newsletter, Victor Viewpoint
- Newsletter to Your Say database
- Posters/Information packs in Civic Centre foyer.

2.1 Participation in the engagement

Ten people attended the live community webinar. The webinar was also attended by representatives of Council, Integrated Coasts and URPS.

During the Phase 2 engagement period between 5 May to 28 May 2021, there were 65 visits to the 'Protecting Victor Harbor's Coastline' webpage and 29 document downloads.

Of these, 8 were engaged participants, 33 were informed participants and 60 were aware participants.

Eight online feedback forms were completed.

2.2 Feedback received

2.2.1 *Community webinar*

During the webinar a number of online participants asked questions or made comment. Where a question was asked, Integrated Coasts provided a response 'live'. Comments/questions related to:

- Participants providing clarification of points made during the presentation such as the correct name for the Victor Harbor Coastcare group and who owns the trainline
- Raising concerns about other projects or initiatives in the Victor Harbor area such as pressure from some members of the community to build a marina and Council's proposal for a possible path/bikeway between the railway line and dunes at McCracken.
- Querying how the Study findings can be used to inform decision making in the future regarding the type and location of development along the coast, the opportunity to inform development assessment for development in flood prone areas and enabling coastal retreat
- Understanding how different infrastructure impacts erosion along the coast eg the causeway, jetties and boat ramps
- Understanding about the interaction between storm events and the Hindmarsh River outflow
- Identifying that the sand sausage at King Street was too low and needed to be much higher to have served any purpose
- Identifying that the erosion along The Esplanade will be much worse when sea level rise makes the reef less effective as a wave calmer.

2.2.2 *Online feedback form*

Eight online feedback forms were completed. Respondents described themselves as residents and/or property owners and/or a business owner in the City of Victor Harbor area and were all aged over 55.

What do you value about the coast?

Respondents were asked what they valued about the coast. Comments related to two key aspects:

- Accessibility in terms of the ability to access the coast easily and via walking and cycling trails. Comments included:

  Access, cycling pathways, vegetation, open spaces

  It's current walking trails and accessibility

  Easy access to sea views, the sea and whales

  Accessible

- The natural look and feel of the coast and its unique features. Comments included:

  It's naturalness, uniqueness and ruggedness

  The beautiful beaches and walking trails

  The mostly calmish sea

The natural look of the coast with its three islands it's sometime rough white caped see and strong south & west winds the seabirds, penguins & rocky outcrops

Peaceful atmosphere

Clean beaches

Key findings and lived experience

Respondents were asked if they felt the key findings of the study fit with their lived experience of what is happening along the City of Victor Harbor coastline. Responses were mixed with four identifying yes, one no and two were unsure.

What is important when managing the coast?

Respondents were asked to identify what they considered to be most important when considering the management of the City of Victor Harbor's coastline. The following aspects were ranked in order of importance (highest to lowest):

1. Maintaining access to the beach
2. Managing incompatible development along the coast
3. Protection of homes and private property
4. Protection of public built assets such as roads, car parks, beach stairs and pathways
5. Protecting the natural environment eg dunes, plants and animals
6. Managing erosion of the coast
7. Other
8. Limiting built protection infrastructure along the coast eg sea walls, groynes

Other feedback

Other feedback provided by respondents comprised:

- A desire to see the section of road from 'whalers to the jetty' closed to traffic and turned into a walkway. This section of road has been damaged in the past by storm events
- A desire to see the coastline remain in a 'natural' state
- The view that a bike path from the yacht club to Bridge Point is a waste of money
- The desire to see sea views from main roads entering Vitcor Harbor
- Locate walkways and cycle paths along the coast
- The need to acknowledge the local volunteer group as Victor Harbor Coastcare in the study report and not Coastcare as it currently reads
- A desire to see Granite Island as natural as possible and prevent further damage
- Comment that the study contained interesting information that was well explained. It was also noted that although the images were confronting, you "can't argue data or stats".

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Appendix 2 Engagement Summary Report – Coastal Adaptation Strategy 2021-2031 (Stage 2)

Appendix 2 is a stand-alone document produced by Mark Western (Integrated Coasts) and reports the process and findings of the community engagement for the Coastal Adaptation Strategy 2021-2031 (Stage 2 of the project).

Engagement Summary Report

City of Victor Harbor Coastal Adaptation Strategy 2021-2031

This report represents the findings of the community engagement for Stage 2, Coastal Adaptation Strategy 2021-2031.

By Mark Western

Integrated Coasts

20 October 2021

Engagement Summary Report (Stage 2)

20 October 2021

Report

This report was written by Mark Western, Integrated Coasts and represents the findings of the community engagement for Stage 2, Coastal Adaptation Strategy 2021-2031 which was conducted from 15 September to 1 October 2021.

Nicole Halsey from UPRS managed and hosted the webinar on 15 September 2021.

Permissions

This document the output from the project *Coastal Adaptation Study and Coastal Adaptation Strategy (2021-2031) for City of Victor Harbor* and incorporated into the main report as Appendix 2.

Front Cover

City of Victor Harbor coastline, photographed by Coastal Management Branch, Department for Environment and Water in 2008.

Document Control

Report number	Version	Released	Approved
20211020_engagement_Stage_2	Draft	26 October, 21	MW

Contents

1. Introduction

City of Victor Harbor engaged consulting team, Integrated Coasts to review and update the Coastal Management Study 2013. The project was completed in two stages. Stage 1 provided the Coastal Adaptation Study and formed the basis for Stage 2 of the project, the Coastal Adaptation Strategy 2021-2031.

In preparing the Coastal Adaptation Study and Coastal Adaptation Strategy 2021-2031, Council wished to engage with the community and key stakeholders to gather information about local coastal issues and experiences to obtain feedback on reports and proposals.

Due to the uncertainties associated with Covid 19, it was decided that no engagement would be undertaken in public forums and would be restricted to online communication and participation.

Three phases of engagement have now been completed.

Phase 1 : Invitation to contribute local knowledge (February-March 2021)

Early in Stage 1 of the project, the community was invited to submit information and evidence of coastal changes and storm events in the Victor Harbor area. Information provided included photographs and six written submissions. Targeted engagement was also undertaken with key stakeholders from relevant government agencies and interest groups. The information gathered in this phase provided valuable input and was incorporated into the drafting of the Coastal Adaptation Study.

Phase 2 : Presentation and feedback for the Coastal Adaptation Study (May 2021)

The Coastal Adaptation Study is a comprehensive and technical document that is of interest to a range of stakeholders and the community. Phase 2 of the engagement process was therefore focussed on communicating the findings of the Coastal Adaptation Study, providing the opportunity to view information and ask questions to better understand the study findings and receiving feedback. Council led the delivery of the engagement with URPS providing selected engagement services as part of implementing Phase 2. These services included the management of the webinar, assessing the feedback, and providing a stand alone report for the findings of Phase 2. This report is included in the main study report as Appendix 1.

Phase 3 : Presentation and feedback for the Coastal Adaptation Strategy 2021-2031 (Sept. 2021)

The Coastal Adaptation Strategy 2021-2031 built on the findings of the Coastal Adaptation Study and provided proposals to manage coastal risks associated with projected sea level rise both in the short term and the long term. Specifically, the strategy was then focussed on priorities for the next ten years.

This report documents the engagement implemented for Phase 3 and the feedback received. Council led delivery of the engagement with Integrated Coasts and URPS providing various engagement services as part of completing Phase 3.

This report is included in the main study report as Appendix 2.

2. Engagement process

The Coastal Adaptation Strategy 2021-2031 built on the findings of the Coastal Adaptation Study and provided proposals to manage coastal risks associated with projected sea level rise both in the short term and the long term. Specifically, the strategy was then focussed on priorities for the next ten years.

Phase 3 of the engagement therefore focussed on communicating the specific proposals for coastal adaptation for each of the three coastal cells: Hayborough-McCracken, Victor Central, and Encounter Bay and provided opportunities for the community to view the information, ask questions, and to provide feedback as to their view of the proposals.

Council established a dedicated web page regarding the coastal adaptation project on its website which provided overview information about the coastal adaptation planning project and links to key information at Your Say Victor Harbor including:

- The main study report and three cell reports that included adaptation proposals,
- An information pack comprising a series of fact sheets which summarised the key findings of the study and the strategy in an easy-to-read format.

Opportunities to participate in the engagement comprised:

- Attending a community webinar, with facilitated Q&A. Integrated Coasts presented the Study findings and online participants could ask questions/make comments live throughout the presentation. Responses to questions/comments were facilitated by URPS,
- Viewing a recording of the community webinar uploaded to the Council website and You Tube for period 15 September to 1 October,
- Completing a feedback form that specifically sought responses to the particular proposals,
- Providing written feedback (eg via email).

The engagement on the coastal adaptation project was promoted via:

- Public Notice in the Times newspaper,
- Council's Facebook page,
- Council's Instagram,
- Council's monthly e-newsletter, Victor Viewpoint,
- Newsletter to Your Say database,
- Posters/ information packs in Civic Centre foyer.

2.1 Participation in the engagement

Six people attended the live community webinar which included representatives of Council, Integrated Coasts and URPS. The webinar was recorded and uploaded unedited to the Council website and YouTube.

During Phase 3 of the engagement period between 15 September and 1 October 2021, there were 76 visits to the 'Protecting Victor Harbor's Coastline' webpage and 24 document downloads. Of these visitors, 3 were categorized as engaged participants, 31 were informed visitors, and 63 were aware participants. Three online feedback forms were completed that gave specific responses to each of the adaptation proposals. Eight views were undertaken of the presentation on YouTube, but none on the Council website.

2.2 Feedback received

2.2.1 Community webinar

The webinar was presented in three parts that related to the three coastal cells within the Victor Harbor region. Opportunities were provided at the close of each section for comments or questions. There were no comments or questions from the participants of the webinar.

2.2.2 Online feedback form

The feedback forms were designed for participants to give a direct response to each of the proposals that related to each of the coastal cells. Five responses were possible which ranged from 'strongly disagree' to 'strongly agree'. Respondents described themselves as residents and/or property owners in the City of Victor Harbor area and were aged 40 to over 75.

The specific responses to each of the proposals are included on the following pages.

Generally, the participants either agreed or strongly agreed with the proposals. The exceptions were all within the Encounter Bay coastal cell where one participant was opposed to prioritizing protection works, raising the bikeway or a preliminary review of the planning parameters within Encounter Bay. The questions and results are included in the tables below.

Encounter Bay (Cell 12)	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
Undertake short term assessment of coastal impacts of storms (2-3) to identify appropriate wave effect allocations for the various parts of Encounter Bay.	2	1			
Develop a long-term coastal monitoring program that monitors sand levels, dune position and offshore profiles.	2	1			
Increase the height of the Encounter Bikeway along Franklin Parade to act as a barrier to waves, overtopping, storm surge and sea level rise.		2		1	
Prioritise protection works along Franklin Parade to protect properties from future flooding risk associated with sea level rise.	1	1		1	
Conduct a preliminary review of the planning parameters for Whalers Road to Tabernacle Road to identify Council's responsibilities in providing protection in the context of higher density zoning.	1	1			1

Victor Central (Cell 11)	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
Undertake short term assessment of coastal impacts of storms (2-3) to identify appropriate wave effect allocations for the various parts of Encounter Bay.	2	1			
Develop a long-term coastal monitoring program that monitors sand levels, dune position and offshore profiles.	2	1			
Survey and inspect the levee surrounding the caravan park which is generally high enough to cater for current risk.		3			
Design and implement a program to consolidate and vegetate the dune system from the Inman River to the causeway.		2	1		
Create a master plan to guide decisions for the Flinders Parade/ Bridge Terrace precinct.	2	1			
Prioritise the creation and retention of the beach by allowing the existing beach to retreat to the edge of Flinders Parade/ Bridge Terrace (SEE NOTE BELOW).	1	2			

Important note: the last question was not framed in accordance with the proposal. The proposal is not to allow 'the existing beach to retreat' but to create a much larger beach / dune system which can be consolidated and sand nourished as required over the course of this century. Furthermore, this proposal is subordinate to the proposal above which is to 'create a master plan to guide decisions'. Within this process it is anticipated that further research would be conducted to ensure that the proposal for 'the beach' is viable.

Hayborough - McCracken (Cell 10)	Strongly agree	Agree	Unsure	Disagree	Strongly disagree
Undertake short term assessment of coastal impacts of storms (2-3) to identify appropriate wave effect allocations.	2	1			
Develop a long-term coastal monitoring program that monitors sand levels, dune position and offshore profiles.	2	1			
Conduct a feasibility study and obtain cost estimates to reduce the flow of storm water to the beach from two outlets adjacent Hayward Court.	2	1			
Upgrade storm water outlet at Yandra Terrace with design able to be adjusted for cycles of erosion and accretion.	2	1			
Ascertain ownership of the old retaining wall and assign a function to the structure other than 'retaining wall', e.g. dune stabilization[1].	1	1	1		

[1] The reason for this proposal is due to the age of the structure and no longer being capable of acting as a retaining wall.

2.2.3 Written submission

One written submission was received from Emma Stephens, Birdlife Australia dated 30 September 2021 which noted that for 13 years staff and volunteers have been monitoring, recording, and protecting Hooded Plovers along the City of Victor Harbor coastline. The issues raised in the submission are summarized below:

- City of Victor Harbor's coastline provides suitable habitat for Hooded Plover breeding pairs, but their available nesting space is often 'squeezed between the high tide mark and the dunes which are often covered with an unsuitable weed type which the group is hoping to replace with native Spinifex.
- The submission encourages City of Victor Harbor to incorporate appropriate management of the Hooded Plover breeding habitat into future coastal adaptation management, including minimizing disturbances should any coastal works occur.
- The submission agrees that Kent Reserve is an important breeding site, but also would include Encounter Bay in general, nesting sites either side of the causeway, Hindmarsh River and Oliver's Reef. In general, the entire coastline of Victor Harbor provides important non-breeding habitat for flocks during the winter months.
- Birdlife agrees that City of Victor Harbor should develop a long-term monitoring program that monitors sand levels, dune position and offshore profile.