Coastal Adaptation Study &
Coastal Adaptation Strategy

MCCRACKEN-HAYBOUROUGH

Study purposes:

- 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 region.
- Bring all previous work into one place of reference.
- Provide a basis for ongoing adaptation planning.

Cell
Fleurieu 10

For City of
Victor Harbor

Integrated Coasts

TABLE OF CONTENTS

PART 1 - COASTAL ADAPTATION STUDY

PART 2 - COASTAL ADAPTATION STRATEGY

Project team:

Mark Western, Project Leader, Integrated Coasts.

Professor Patrick Hesp, Profile line analysis, Flinders University.

Professor Robert Bourman, Geomorphology and inherent risk assessment.

Mike Hillman, Profile line analysis, Integrated Coasts.

Joram Downes, Storm water study, flood modelling, Integrated Coasts.

Engineering review and inputs:
Magryn and Associates, Terry Magryn, Will Souter

Front cover picture: Coast Protection Board, oblique photograph, 2014

Integrated Coasts

markwestern@integratedcoasts.com
www.integratedcoasts.com
1300 767 333 (free call)

PART 1

COASTAL ADAPTATION STUDY

Part 1 of this project has established a baseline understanding of how the coast has been performing over the last century, and the sea-flood modelling has provided 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.

Project Note: This section of work adopts terms and definitions from the glossary found at www.coastadapt.com.au

1. Introduction

This document is to be read in conjunction with the main report, *Coastal Adaptation Study for City of Victor Harbor,* that explains more fully the underpinning methodology. The digital files (GIS) used in this study can be accessed for further investigation or to repeat the assessments conducted in this project.

Definition of terms within this work are adopted from www.coastadapt.com.au (Glossary).

PROJECT SCOPE

Climate Variables

Managing projected climate change impacts involves dealing with 'deep uncertainty'[1]. 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[2]. 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[3]. 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 increasing inundation of lower lying areas, or increasing erosion, especially on landforms that are more erodible. 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[5]. These more indirect impacts may increase the rate of erosion. Increased intensity of rainfall events may increase the erosion and 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 level on the fabric of the coast. Different areas of coast will be vulnerable to different risks. Low lying areas will be more likely to be vulnerable to inundation and soft sediment backshores more vulnerable to erosion. In this study we evaluate the direct impact of *inundation* and *erosion* in four main receiving environments. These are listed below and explained later in the project:

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

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 the decision makers act in ways the communities do not support.

Project focus

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

1. Introduction

ASSESSMENT FRAMEWORK

This coastal assessment tool adopts a simple and intuitive framework. Coastal hazards experienced along a section of a coastline can be categorised and assessed in three main ways:

- **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). This assessment tool categorises coastal geology in four main ways:

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

- **Coastal modifiers (human intervention)**

In some locations there are additional factors that modify this core relationship between fabric and exposure. For example, an extensive rock revetment has been installed from Brighton to Glenelg along the Adelaide coastline. This installation has modified the fabric of the coast from dunes to rock.

- **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

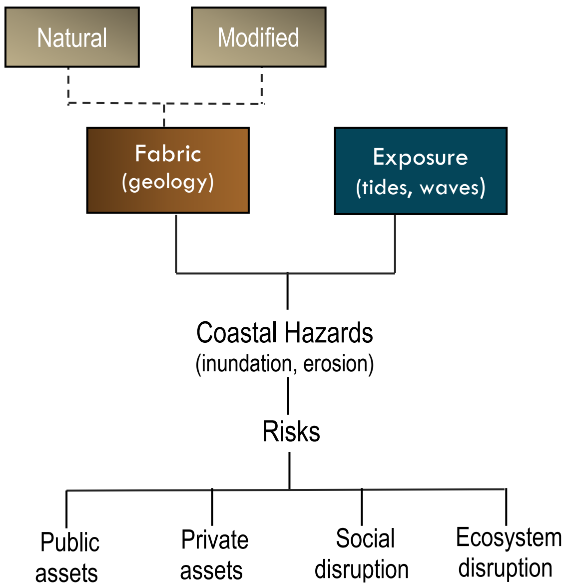
CHANGES IN THE RELATIONSHIP

Finally, in a coastal scoping 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 recent times, the rate of sea level rise has escalated. Last century, sea levels rose at ~1.4mm per year. Since 1990, seas are rising on average at ~4-5mm per year in our region. 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 (~10-15mm per year). These projections are based on sound physics, 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.

Figure a: Conceptual framework



©Integrated Coasts

What we aim to do in this project is to evaluate the relationship between the ***fabric*** of the coastline and its current ***exposure*** to actions of the sea and how this relationship may change over time in the context of rising sea levels. We conduct this evaluation within the regional setting of secondary coastal cell, **Fleurieu** (CoastAdapt) and within tertiary cell, Coastal Conservation Cell, **Fleurieu 10**.

McCracken-Hayborough is reviewed in this report.

1. Introduction

Regional Setting

Fleurieu 10

Secondary Cell: Fleurieu

Tertiary Cell: McCracken-Hayborough

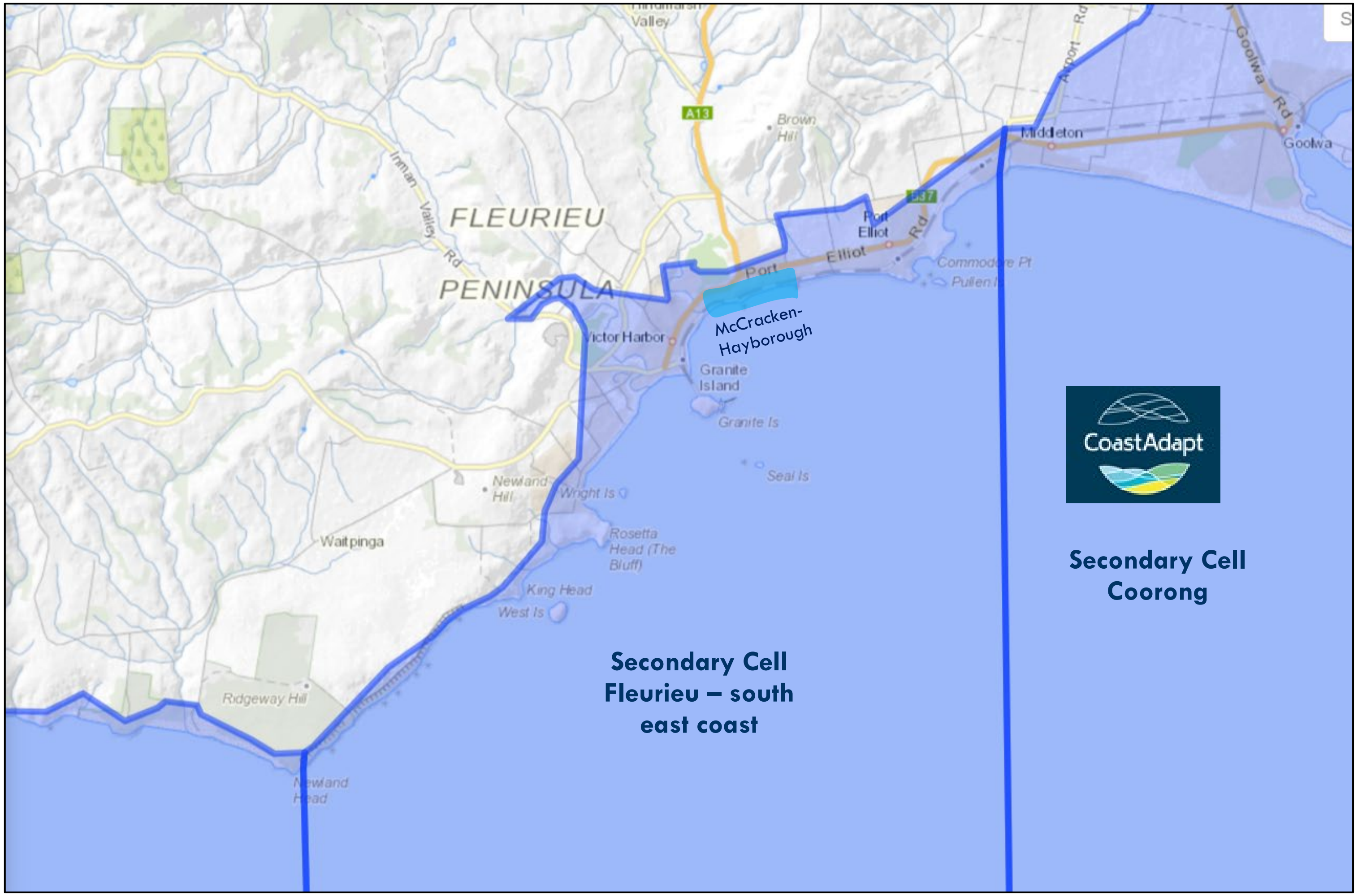
Australian regional setting

McCracken-Hayborough is situated within the Fleurieu secondary cell.

Geomorphology of the cell:

This is a mostly rocky coast facing ESE, comprising granitic (e.g. The Bluff and Wright Island) and Kanmantoo metasediments (e.g. Newland Head), with sandy beaches to the northeast on either side of Port Elliot. Encounter Bay is a limestone reef protected coast, with narrow beaches and no backing dune sediments. There is sand accumulation at Police Point spit, in the lee of Granite Island.

Parts of the cliffed coasts are stable, but elsewhere, the supply of sediment to embayed beaches is predicted to decline.



Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

The dominant regional processes influencing coastal geomorphology in this region are the Mediterranean to humid cool-temperate climate, micro-tides, high energy south-westerly swells, westerly seas, carbonate sediments with interrupted swell driven longshore transport, and the Southern Annular Mode (driving dominant south-westerly swells and storms). Regional hazards or processes driving large scale rapid coastal changes include: mid-latitude cyclones (depressions), storm surges and shelf waves.

Source: https://coastadapt.com.au/sites/default/files/docs/sediment_compartments/SA01.03.01.pdf

1. Introduction

Regional Setting

Fleurieu 10
Secondary Cell: Fleurieu
Tertiary Cell: McCracken-Hayborough

Cell 10.1 - McCracken
Relative Exposure
Moderate
Wave energy
Low
Shoreline class
Low tide terrace
Sand rating
Fine-medium sand beach

Cell 10.2 - Hayborough
Relative Exposure
Moderate
Wave energy
Moderate
Shoreline class
TBR +Low tide terrace + Rock
Sand rating
Fine-medium sand beach

Source: NatureMaps

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

2. SETTLEMENT HISTORY

A historical review ensures that the circumstances in which the settlement was founded are understood, identifies how actions of the sea have interacted with the settlement, and builds appropriately on previous study. In this section we:

- Give a brief history of the settlement
- Review archives at Coastal Management Branch
- Identify key coastal studies
- Record the circumstances of any storms (if known)

2. Settlement history

The first purpose of this section is to identify the key factors of settlement history in the context of the coastal environment[6]. In particular, we identify human interventions, ocean impacts, and past protection and management strategies. The second purpose is to identify key studies and plans so that we build appropriately upon previous work. The name, *Victor Harbor*, has been employed throughout this review with acknowledgement that Port Victor was also used. The word *Council* relates to the various names and entities of local government that were historically employed.

BRIEF HISTORY

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[7].

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 (Britian) 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.

[6]Page, M. Victor Harbor, District Council of Victor Harbor, 1987.

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. Settlers arrived from 1840 onwards and District Council of Encounter Bay was founded in 1853.

Construction of coastal infrastructure

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 required in Victor Harbor.

By 1862, the jetty stretched out 195m but was not connected to Granite Island. The railway line to Victor Harbor 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 bigger ships built with steel were beginning to traverse the oceans. In 1872, it was proposed to build a breakwater 305m to the north east from granite island to provide shelter to the ships and to extend the jetty to the island to act as a causeway. Lessons were learned from the Port Elliot breakwater that suffered displacement of rock in one of the first major storms after it was built, and larger rocks were utilised for this breakwater. A 'working jetty' was established about 200m south of the causeway.

[7] Page, M. p. 14

Figure a: View of Victor Harbor from current day McCracken, 1866, (State Library of SA, B-45839).

Figure b: Hindmarsh River bridge, 1885, (State Library of SA, B-1174).

2. Settlement history

Urban settlement

The area that is now known as McCracken and Hayborough (Cell 10) was utilised for farming and therefore development in this time period was limited to a few farm buildings. At a very early stage in history this area of land was dissected by the State Government owned railway line that opened in 1864 (Figure a).

Project note: In the context of coastal adaptation that relates to the impact of rising sea levels, the trainline provides a separation between the coast and residential development. The State Government will likely be responsible to manage its asset while on the coastal side of the trainline the Council's responsibility will likely be limited to managing the beach access points.

End of port era

Hopes faded for Victor Harbor as a commercial port with the installations of wharves and train links further up the Murray River which reduced the need for produce to be shipped through Victor Harbor. The droughts and depressions of the 1890s and the 1920s ended the era. By end of 1880, South Australia had enjoyed 30 years of boom time and had an emerging middle class who travelled to Victor Harbor for recreation and holidays. The Council increasingly sought ways to increase the attractiveness of Victor Harbor such as introducing horse drawn trams in 1895.

Recorded storms – 1860s to 1920.

A review was undertaken to identify significant storms with a particular focus on any impacts to the urban environment. However, in this elevated location, which is set well back from the beach, no impact of actions of the sea would have impacted any development.

Project note: To review the impact of storms within the Victor Harbor region refer to reports for Cell 11 (Victor Harbor Central) and Cell 12 (Encounter Bay).

Figure a: Railway line to Goolwa to the North of Hindmarsh River, 1928, (State Library of SA, B-4908).

Figure b: Aerial view of McCracken and Hayborough, 1936 (State Library of SA, B-9513).

2. Settlement history

Victor Harbor – tourist town (1920 to1970)

While the Victor Harbor township was increasingly developed in this era, the McCracken and Hayborough area remained largely untouched until the 1950s and 1960s (Figure a). After World War 2, it became increasingly popular for people to establish holiday homes in places such as Victor Harbor. However, it is likely that this area was also settled by permanent residents. By the 1970s, the areas now known as McCracken and Hayborough were established (Figure b).

Victor Harbor – modern era (1970 to 2020).

The establishment of the SA Coast Protection Board in 1972 ushered in a new era of coastal management which in its early stages focussed in restricting human activity in coastal dunes and backshores. Examples include boardwalks established at Dump Beach in 1978 and formalisation of beach access points, dune fencing and vegetation programs (19780904, 1979000).

Coastal management strategies (1970 to 2020)

Coastal management strategies within this cell relate primarily to the preservation of the dune system:

- Maintaining limited access ways to the beach.
- Restricting pedestrian movement through dune areas using fencing and signage.
- Vegetation and weed management programs.

Figure a: Coastal areas of McCracken and Hayborough in 1949 (Aerial Photograph, City of Victor Harbor).

Figure b: Aerial view of McCracken and Hayborough, 1975 (SA Coast Protection Board).

2. Settlement history

Training of Hindmarsh River outlet.

The original survey (1857) did not locate the specific outlet but did indicate that it travelled parallel to the coast for approximately 300m (1000 feet).

The written archives are quiet relating to the decision to train the Hindmarsh River into its current position. Photographs from 1984 provide a pictorial review.

- Photograph a. Periodic riverine flows eroded the dune system to the east. Note the absence of the dunes that are currently positioned in front of the Hindmarsh River outlet.
- Photograph b. The proposed location for the rock training is drawn on the photograph
- Photograph c. Rocks installed in the current position of the outlet
- Photograph d. Additional rock was added over time and in 2004 a sandbag training wall was added to the rock.

The purpose of training the river mouth may have been two-fold. The first reason was to protect the dunes that were positioned under the trainline. The second reason may have been to facilitate greater control over the opening of the mouth.

Council advises that the mouth is mechanically opened on an 'as needs' basis to lower water levels within Hindmarsh River when these become too high.

Figure a: Hindmarsh River outlet, 1984. Periodic riverine flows caused erosion to the dunes to the east. Note the absence of dunes in the location of the current outlet. (Coast Protection Board).

Figure b: Hindmarsh River outlet, 1984. The proposed location of the rock training is drawn on the photograph (Coast Protection Board).

Figure c: Hindmarsh River outlet, 1984. Rock training installed (Coast Protection Board).

Figure d: Hindmarsh River outlet, 2004. Sandbags were added to the rock training wall. (Coast Protection Board).

2. Settlement history

COASTAL STUDIES

Fleurieu Coast Protection District produced by SA Coast Protection Board, 1977.

One of the first priorities of the SA Coast Protection Board was to introduce management plans for the coast. Increasing population and mobility (using cars and motorcycles) saw increased traffic into sensitive coastal areas and resulting degradation.

The purposes of the report were to:

- Obtain an understanding of the natural characteristics and the current activity in the Fleurieu area.
- Provide concepts for development.
- Identify recommendations for management.

One of the key principles adopted for development in the Fleurieu region was that natural beauty and ruggedness of the coastline should be preserved (p. 5). This foundational report spawned local coastal plans.

Chiton Rocks – Hayborough Coastal Plan, Neill Wallman, 1979

This report produced for District Council of Victor Harbor and Coast Protection Board was a coastal plan with objectives to:

- Improve vehicle access to the foreshore
- Discourage unnecessary vehicular movement thought residential streets.
- Rationalise and upgrade existing car parking arrangements.
- Promote safe and convenient pedestrian access to the beach.
- Provide a range of appropriate coastal facilities.
- Promote erosion control measures.
- Protect existing vegetation and upgrade the visual amenity.

The legacy of the implementation of this plan is the current layout of the coastal areas of McCracken and Hayborough.

Southern Fleurieu Coastal Action Plan, Brian Caton, ~1998.

The District Councils of Yankalilla, Victor Harbor, Goolwa and Port Elliott commissioned the study which identified the following priorities:

- Maintain the integrity of sand dune areas.
- Extend and maintain a coastal reserve system.
- Establish a system of marine protection.
- Manage land-based discharges to the coastal and marine environment.
- Manage the demands of recreation and population growth.
- Conserve places of high conservation and heritage values.
- Manage impacts of global warming.

Figure a. Dune vegetation and pedestrian control measures have been implemented since the 1970s.

Key findings

McCracken and Hayborough were established as residential areas in 1950s and 1960s.

The residential area is set back from the coastline behind the State Government owned railway line and elevated well above sea level. In the context of rising sea levels, this means that the main focus of coastal adaptation will be to manage the railway.

The coastal issues managed over time include reducing the impact upon dunes and vegetation by formalising pedestrian access to the beach.

Current management strategies include weed control, vegetation management, and beach access management. On occasions when storms reduce sand levels around beach access points to the beach, Council uses a loader to push sand back to the base of the access point.

2. Settlement history

Southern Fleurieu Coastal Action Plan and Conservation Priority Study, Caton et al., 2007

This project was a comprehensive review of the conservation values and condition of the coast from the Murray Mouth to Myponga.

Purpose

The goal of the study was to understand and facilitate the conservation, protection and maintenance of the Southern Fleurieu natural coastal resources. The report identified priorities and outlined suggested actions to address threatening processes at specific locations within the region.

Methodology

Twenty-seven coastal cells were defined on the basis of physical parameters: landform, coastal wind and wave energy levels. This current study has adopted three cells – McCracken-Hayborough (Cell 10), Victor Harbor Central (Cell 11), and Encounter Bay (Cell 12).

In the context of coastal adaptation

As the main focus of this project is coastal adaptation within the urban environment of Victor Harbor and Encounter Bay the relevance to this project is limited. The issues identified for McCracken – Hayborough (Cell 10) are detailed within the table on this page.

Action Summary Table – Cell 10, Watson Gap to Hindmarsh River (p. 6)

F10. Watson's Gap to Hindmarsh River Dunes	F10.1 Target residences with educational materials, with regard to weeds.	High (Soc / Econ)
	F10.2 Implementation of management plan by Taylor (2003).	High (Soc / Econ)
	F10.3 Improvement of signage at path entrances and by railway reserve. Strategic use of sand drift fencing	High (Soc / Econ)
F10. Stormwater outlets	F10.4 Erosion control at outlets. Review of stormwater catchments, to slow peak runoff.	Medium (Threat)
F10. Watson's Gap	F10.5 Revise zoning provisions to reflect appropriate hazard standards.	Low (Hazard)

Climate change assessment

Section 4.8 of the report deals with climate change matters, noting that beach erosion and foredune erosion will occur over the next 50 years, depending on beach topography, sand supplies, and littoral sediment movement. 'Medium energy beaches protected by reefs and islands near Victor Harbor will be much more variable in their response, depending again on sand supply, rate of sea level rise in relation to sheltering reefs, but more critically on storm frequency and magnitude under change climatic regimes' (p. 119).

Adaptation to changed climatic conditions

Plans are necessary so that development now does not compromise adaptation in the future. Ongoing sea level rise underlines the value of many coastal reserves as buffers against coastal erosion and providing space for floodwall protection in some urban areas. Many of Victor Harbor's reserves fall into this category (p. 120). In particular, the action table saw beaches, dunes and coastal reserves as 'buffer zones' for future coastal adaptation.

2. Settlement history

Seagrass Condition Monitoring – Encounter Bay and Port Adelaide, 2014, Tanner, Theil, Fotheringham.

Project aims

The purpose of the study was to provide important baseline information about sea grass habitat for future monitoring of the condition of these sites. In this study, the eastern part of Encounter Bay was evaluated (i.e. Hayborough to Ratalang-Basham Beach).

Findings

The eastern part of Encounter Bay was dominated by reef and sand habitats, with seagrasses primarily located in the southwestern part of the area (I.e. near Hindmarsh River). The study found that there was no clear indication of recent changes in habitat distribution and seagrass condition, than that modelled within Nature Maps, but some areas were mapped differently.

Recommendations

Recommendation was made for resurvey every 3-5 years, but if decline of seagrass was identified then more intensive research may be required.

Key findings

The seagrass baseline project undertaken between Hindmarsh River and Ratalang-Basham Beach found there was no clear indication of recent changes in habitat distribute and seagrass condition.

Climate Change Adaptation Plan for Adelaide Hills, Fleurieu Peninsula and Kangaroo Island, Seed Consulting and URPS, 2016.

This adaptation plan is a regional plan that takes into account projected climate change impacts and contextualises these into regions, land types (e.g. coastal, hills), and usage types (e.g. urban, rural). In relation to this study, the two most relevant sections of the report are:

- Coastal ecosystems
- Built coastal assets

Coastal Ecosystems (p. 44-46)

Climate change impacts

Based on the Integrated Vulnerability Assessment, coastal ecosystems will be most influenced by increasing sea levels, increasing rainfall intensity (causing run-off), and increasing ocean acidity.

Soft coastal ecosystems like beaches have high exposure to climate change due to low topographic variability, high realised sensitivity and little or no adaptive capacity because of barriers that impede coastal migration, especially in townships.

Adaptation options

- Ensure planning systems provide adequate approval processes to reflect projected sea level rise increases.
- Restoration and enhancement of dunes, including reduce storm water discharge.

Triggers

Triggers (selected) for greater implementation of adaptation options in the coastal zone are likely to include:

- Major storm surge-induced flooding events resulting in damage to coastal systems.
- Court decisions resulting from damage by storm or sea level rise events.
- Threats to private property.
- Reduced accessibility to beaches because of high sea levels or damaged beach infrastructure.

To determine the timing of such events, monitoring and modelling of the retreat of sand dunes in response to sea level rise needs to be improved.

Built Coastal Assets (p. 62-64).

Climate change impacts

Based on the Integrated Vulnerability Assessment conducted for the region the greatest impact from climate change on built coastal assets will be sea level rise, though increasing rainfall intensity is also important in some locations susceptible to erosion.

Adaptation options

Responding to sea level rise in the coastal zone typically involves a combination of options that aim to defend, retreat or abandon natural or built assets. The initial focus of adaptation for built coastal assets in the Adelaide Hills and Fleurieu Peninsula is on **defence.**

2. Settlement history

Climate change adaptation plan (cont.)

General adaptation options include:

- Ensure planning systems provide adequate approval processes to reflect projected sea rise.
- Increase sand replenishment to maintain beaches (but only viable if suitable sand sources are available and budget permits). The study estimates that sand replenishment will only be viable for a further two decades.
- Protecting and enhance dunes, which includes planting appropriate vegetation in some locations to reduce sand erosion.

This study notes that transformational options such as relocating or abandoning assets or establishing new hard protection infrastructure such as seawalls are not considered as priorities for certain councils for at least another one or two decades.

Climate Change Adaptation Plan (cont.)

<u>Triggers</u>

Triggers for decision making regarding public coastal assets will be linked to sea level rise when:

- There is sustained damage to built assets such as paths, walls, boat ramps and stormwater infrastructure due to storms and erosion.
- Key regional assets such as coastal bowling clubs and Granite Island are regularly flooded.
- Tourism numbers decline because of impacts on natural features such as the Lower Lakes.

Enablers and barriers to adaptation

Adaptation of coastal ecosystems will be greatly facilitated by the high value that people place on the coastal zone. For example, people value being able to access clean, sandy beaches even if they are not engaged by matters relating to climate change.

It is also true that community values over time may change in response to evolving climate change impacts. Although such community-held human values may directly or indirectly facilitate adaptation of coastal ecosystems, they may also present a barrier if there is considered to be little recognition of the role that ecosystems play (or beach/ sand systems). For example, without a clear understanding of the importance of coastal ecosystems, people may operate under a strong entitlement mindset, and advocate access and use of coastal areas unimpeded by environmental rules and regulations.

Additional barriers to protecting coastal ecosystems (and beach/sand systems) are likely to be the cost of enabling inland migration, especially where this would require relocation of existing infrastructure.

Adaptation pathway

<u>Current</u>

- Raise awareness about impacts of sea rise on coastal assets.
- Utilise modelling and mapping to identify assets at risk and incorporate into decision making.
- Increase sand replenishment
- Protect and enhance coastal dunes, planting and maintaining vegetation.
- Trial impact reducing measures.

<u>Ten years</u>

- Establish hard protection infrastructure
- Amend planning regulations to ensure approval processes reflect sea level increases.
- Improve development controls/ zoning of sensitive coastal areas to allow migration of ecosystems.

<u>Twenty years</u>

- Provide space for landward migration.
- Relocate coastal assets (e.g. beach access, cafes, clubs) to enable coastal system to retreat.
- Abandon assets.
- Acquire land in high-risk area.

Key reports

- Fleurieu Coast Protection District produced by SA Coast Protection Board, 1977.
- Chiton Rocks – Hayborough Coastal Plan, Neill Wallman, 1979
- Southern Fleurieu Coastal Action Plan, Brian Caton, ~1998.
- Southern Fleurieu Coastal Action Plan and Conservation Priority Study, Caton et al., 2007
- Seagrass Condition Monitoring – Encounter Bay and Port Adelaide, 2014, Tanner, Theil, Fotheringham
- Climate Change Adaptation Plan for Adelaide Hills, Fleurieu Peninsula and Kangaroo Island, Seed Consulting and URPS, 2016.

3. GEOMORPHOLOGY

The study of coastal geomorphology analyses how the coast was formed and how the coast has changed over time. The study provides the 'bigger picture' for understanding how sea level rise may interrelate with the coastline in the future. Inputs for this section of work are provided from:

- Dr Robert Bourman, contributor to this project, 2021

3. Geomorphological context

COASTAL FORMATION

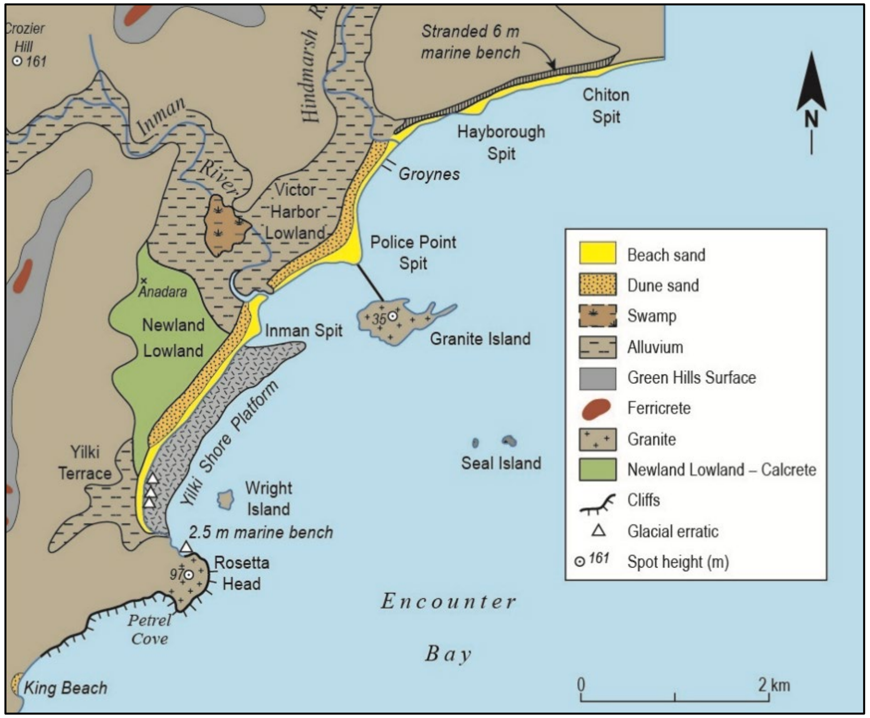
Introduction

The Victor Harbor Embayment (Figure a), 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.

Geological setting

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 outcrops of Encounter Bay Granites have exerted important influences on the shape of the modern shoreline, protecting headlands from erosion and determining the direction of wave approach to the shoreline (Figure b). 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.



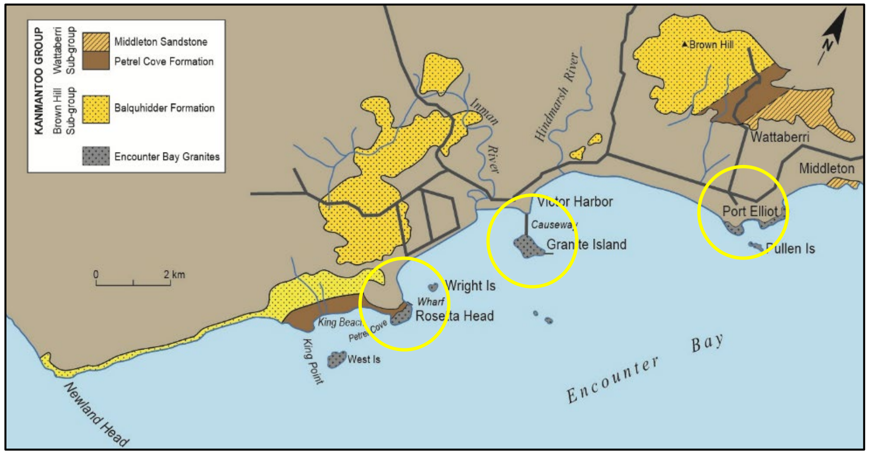


Figure a. Major geomorphic features of the Victor Harbor coastline. Bourman et al. (2016)

Figure b. Map showing the bedrock geology backing the Victor Harbor coastline highlighting the strong structural influence of the resistant Encounter Bay Granites and the Kanmantoo Group of metasedimentary rocks on the shape and orientation of the coastline. The section of coast extending from Rosetta Head to the granite outcrops of Port Elliot has developed essentially on more easily eroded deposits. Source: Bourman et al. (2016)

3. Geomorphological context

COASTAL PROCESSES

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 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 (a) 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.

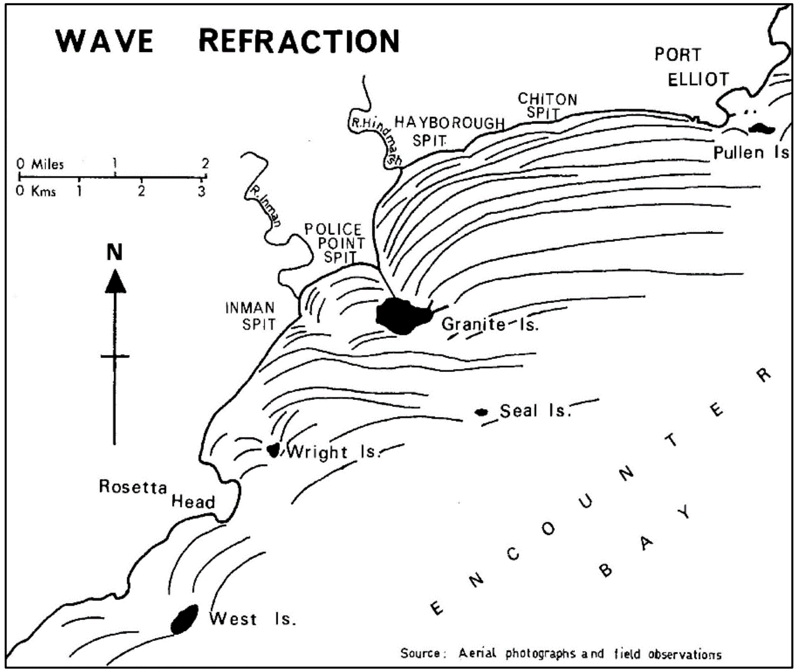


Figure a. Wave refraction and diffraction pattern of the Victor Harbor coastline. Note the Inman, Police Point, Hayborough and Chiton spits and their relationships to the wave patterns. Source: Bourman (1969)

3. Geomorphological context

By Dr Robert Bourman
See full version in Part 1 of the report

Bathymetry and associated impact on wave energy

The submarine topography impacts both on the direction and on the severity of wave attack, with a shoaling topography retarding wave action. The contours are tightly spaced seaward of the granite headlands of Rosetta Head and Port Elliot as well as the granite islands of West Island, Wright Island, Seal Island and Pullen Island, indicating steep slopes where water depths of up to 18 m occur, explain the size of the breakers at these locations. In contrast, offshore from the majority of the Victor Harbor shoreline slopes are much gentler, especially where protected by the islands or headlands. For example, the sea floor is relatively flat and shallow in the region between and landward of Granite Island and Wright Island, which is occupied by a sandstone reef. This reduces the impact of wave heights at the shore zone. Here the water depth rarely exceeds 2.7 metres.

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.

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

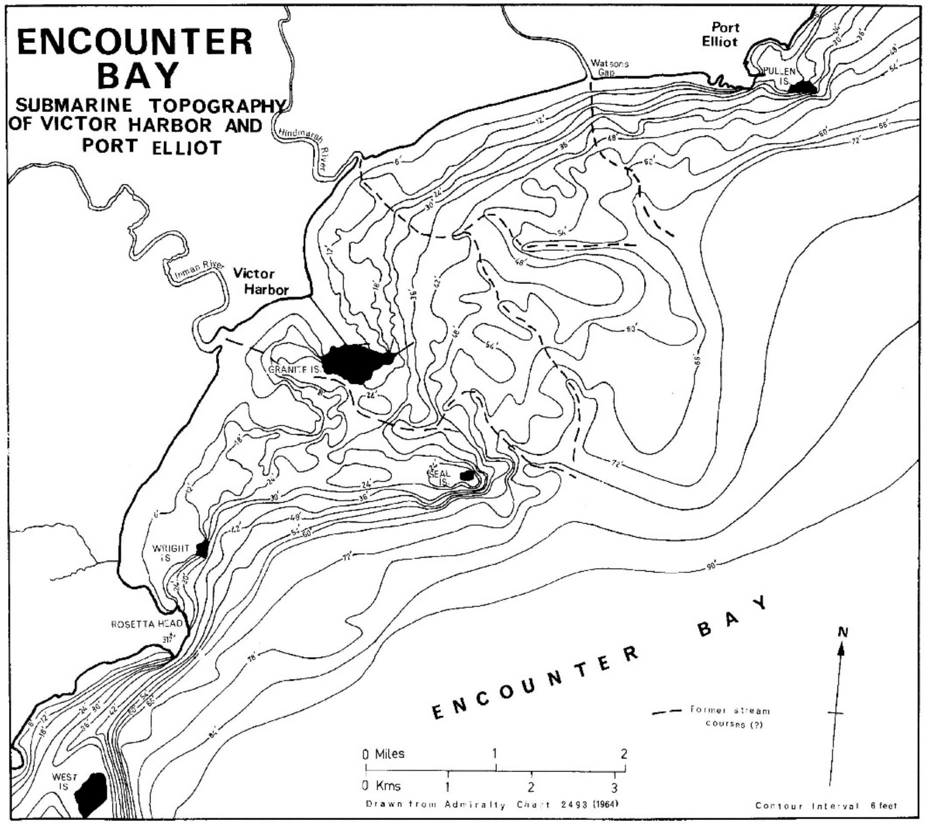


Figure a. Submarine topography of the Victor Harbor section of Encounter Bay produced from Admiralty Chart 2493, originally produced in 1869 and updated in 1958, 1959 and 1964. Source: Bourman (1969)

3. Geomorphological context

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 Franklin 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 roads and houses 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, infilling the channels, overtopping the banks, burying the floodplains 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. (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).

Summary of sea level and tectonic movement of land over 125,000 years

<u>High last interglacial sea level 125,000 years ago</u>

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/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.

<u>Low sea level of Last Glacial Maximum (i.e. Ice age)</u>

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.

<u>Mid-Holocene high sea level</u>

During the Holocene period, about 5,000 years ago, sea level rose to ~+1 m asl, 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. Geomorphological context

COASTLINE FROM THE HINDMARSH RIVER TO CHITON

This ~2.5 km long, steep cliffed section of the Victor Harbor coastline from near the mouth of the Hindmarsh River to Chiton is formed on easily eroded Permian glacial sediments, which have contributed to the local beach sand. Even though longshore transport is towards the east the coast from Hayborough to Chiton to Knight Beach is essentially a self-contained beach compartment (in other words, it is less likely to lose sand).

Erosion of a prominent cliff line and bench, now followed by the Goolwa to Victor Harbor railway line, occurred about 125,000 years ago when the global sea level was at least 2 m higher than now. The bench is up to 70 m wide, while the backing cliff line is up to 30 m high. The marine bench, originally at ~2 m above sea level now stands at 6 m above sea level (Figure a). The bench was stranded both by tectonic uplift of the land and a fall in sea level. Evidence of the age of the former marine platform is provided by the presence of shell beds discovered following railway construction. The shells are exposed in railway cuttings to the east of the Hindmarsh River mouth and west of Watson Gap. In particular the shell, Anadara trapezia is particularly useful in reconstructing the environmental conditions when the cliff and bench were formed because it is a sub-fossil no longer living locally. It is a reliable indicator of a last interglacial age (125,000 years ago) and is also associated with warmer temperatures and wetter climatic conditions.

In the context of projected sea level rise, there could be a potential problem associated with erosion, as Permian glacial sediments, which are typically easily eroded, back this coastal sector.

The rocks exposed in the intertidal zone at Chiton Rocks are Permian glacial sediments, but uncharacteristically in this location, they are quite resistant to erosion and they partially protect the coast at this location and cause the formation of a small protruding sand spit. They broadly resemble the outcrops of aeolianite (consolidated sand dunes), which occur in the shore zone at Knight Beach, as they display some crossbedding, which is typical of dune deposits. However, their mineralogical composition is quite different from the aeolianite: the Chiton Rocks consist of dolomite (magnesium carbonate, $MgCO_3$), whereas aeolianite is made up of calcium carbonate ($CaCO_3$), derived from shell fragments. Moreover, the rocks at Chiton have pronounced circular structures, which do not occur in aeolianite.

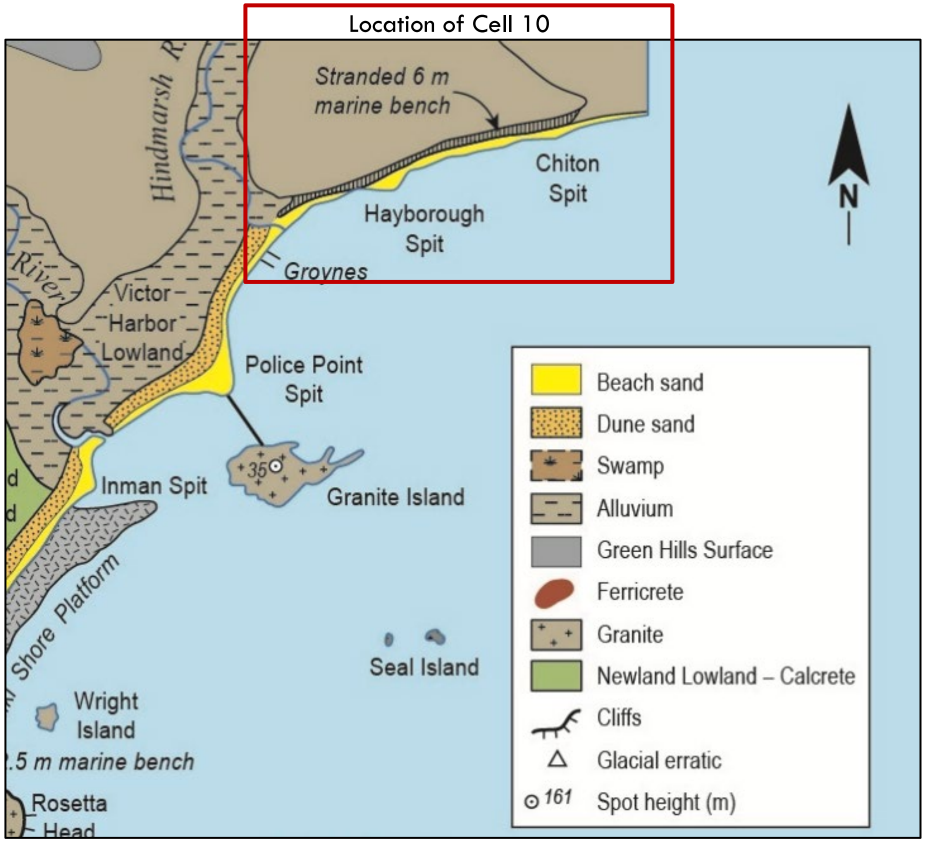


Figure a: Geological layout of Victor Harbor region with Cell 10 depicted within the red rectangle.

Key findings

The beach from Hayborough to Chiton is likely to be an equilibrium in regard to sand supply and erosion.

The reefs and rocky outcrops at Hayborough and Chiton provide stability and protection from actions of the sea.

In the context of projected sea level rise, the sediments of the backshore are easily eroded and recession would undermine the platform upon which the trainline sits.

4. COASTAL FABRIC

In this section we evaluate coastal fabric in more detail:

- Overview of the current coastal fabric
- Changes to shoreline over seventy years
- Human intervention (coastal modifiers)

Viewing instruction:

View the coastal fabric section utilising full screen mode within your PDF software (Control L). Then use arrow keys to navigate.

4.1 Coastal fabric - overview

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 elevation (height above sea level), and the nature of the fabric of the coasts (how resistant it is to erosion).

In some locations, humans have intervened and changed the nature of the coastal fabric. For example, a construction of a seawall changes the fabric from sand to rock. The construction of an esplanade road or carpark too close to the shoreline can install a rigidity in the backshore, which was once flexible and able to naturally adapt to cycles of erosion and accretion. Some interventions change the way in which the beach operates, and new erosion problems are created.

Why evaluate shoreline change?

Beaches undergo normal cycles of accretion and erosion which may span time measured in decades. These changes 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. If sea levels rise as projected, then shorelines are likely to go into longer term recession (Caton 2007).

The purpose of evaluating the historical changes to the shoreline is to formulate a baseline understanding of how the coast has been operating in the past. In the context of rising sea levels, identifying future shoreline recession trends will assist us to identify when the beach begins to operate outside its normal historical range.

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 a).

How will we analyse the shoreline?

The analysis includes:

- Comparisons of aerial photography from 1949 (if available) to current day. This requires very fine-grained georeferencing of photography to ensure that comparisons are accurate.
- Comparison of surveyed profile lines which have been conducted by SA Coast Protection Board since the 1970s (if these are located within the cell).
- Evaluation as to how humans may have intervened in the coastal fabric and how this intervention may have changed the natural operation of the coast.

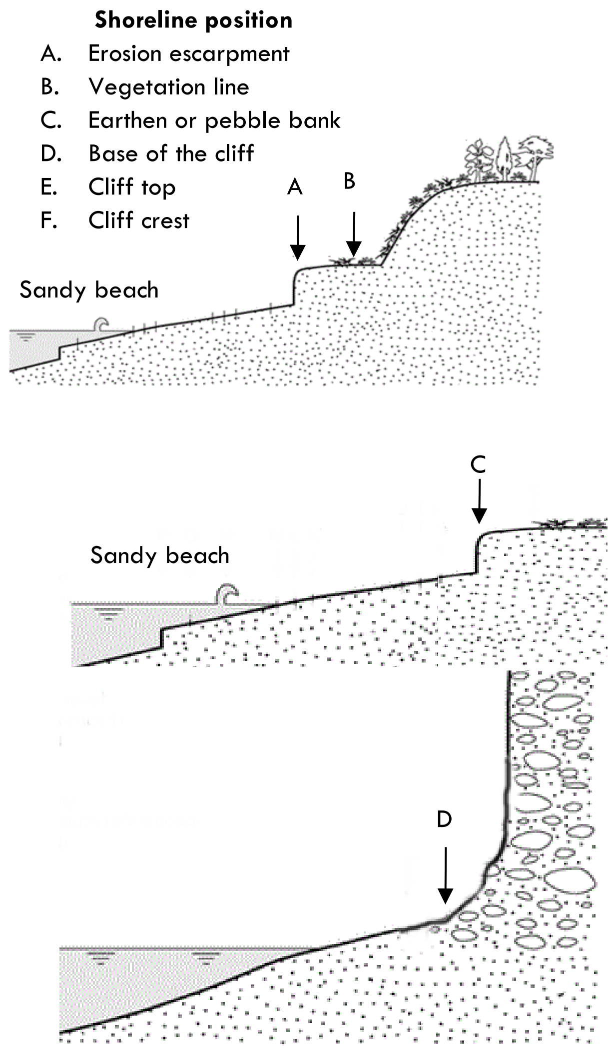


Figure a. Adapted from Boak and Turner (2005), Shoreline definition and detection.

4-1 Coastal fabric - overview

Overview

Fleurieu 10
Secondary Cell: Fleurieu
Tertiary Cell: McCracken-Hayborough
Form

Beach
Fine to medium sand beach with areas of rock and exposed low tide reef.

Backshores
Dune system of varying width (17m at its narrowest) on a steep slope up to the trainline bench at 6.50m AHD in McCracken rising gradually up to 9.50m at edge of Council boundary.

Backshore 2: Trainline (and associated reserve) behind dunes, then generally Council reserve 25m to 50m wide (then residential).

Bathymetry
Overall slope of ocean floor:
-10m at distance ~800m from beach (overall slope ratio ~1:80).

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-1 Coastal fabric - overview

Overview

Fleurieu 10
Secondary Cell: Fleurieu
Tertiary Cell: McCracken-Hayborough
Geology

Geology

Beach and backshore 1:

Semaphore Sand - The beaches and immediate backshores of McCracken-Hayborough were formed recently.

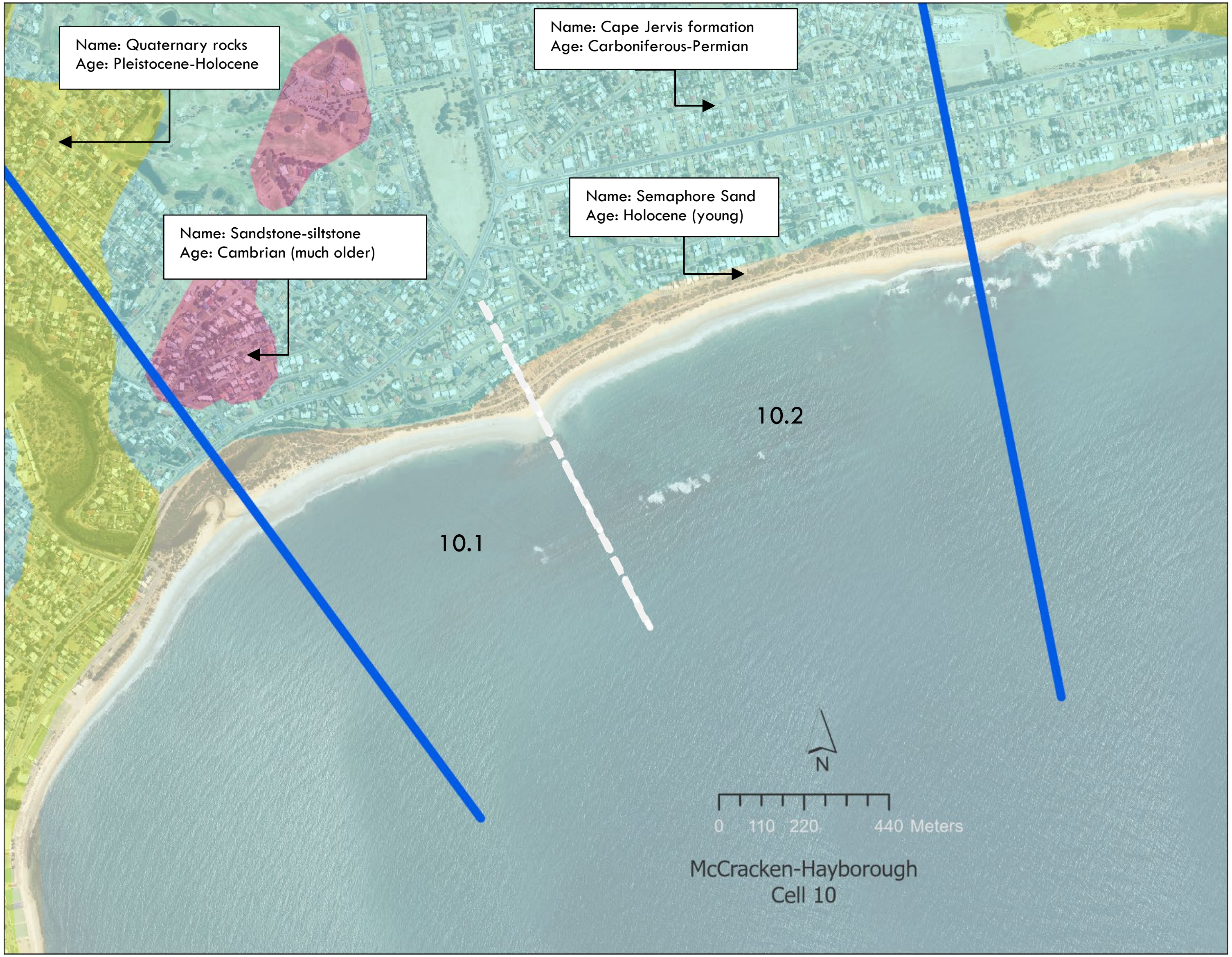
Age: Holocene ~10k BP

Backshore 2

Predominantly Cape Jervis formation (rocks left over from Carboniferous-Permian glaciation period)

Age: Carboniferous-Permian (300m B.P.)

Map opposite sourced and adapted from www.sarig.gov.au



Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-1 Coastal fabric - overview

Overview

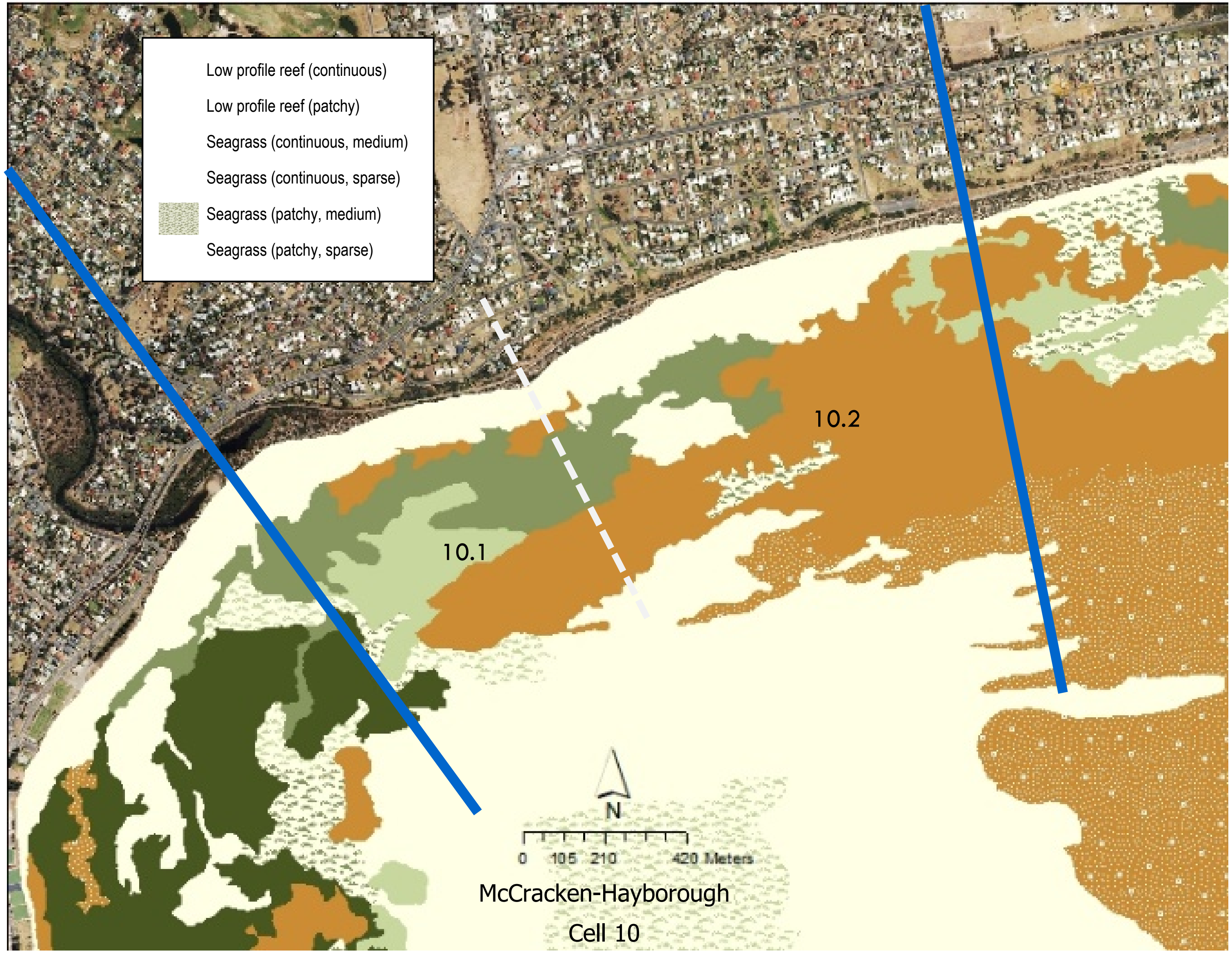
Fleurieu 10
Secondary Cell: Fleurieu
Tertiary Cell: McCracken-Hayborough
Benthic

Benthic

Nearshore and surf-zone dominated by sand, with offshore low profile continuous reef. Seagrass beds (medium/sparse) near Hindmarsh River outlet.

Map sourced from Nature Maps (SA).

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



4-2 Coastal fabric – shoreline changes (Cell 10.1)

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough
Historical comparison

Shoreline

Location:
McCracken

Aerial Photograph from 2018 provides the basis for comparison of coastal change over the last 70 years. Comparisons are made with aerial photography from:

- 1949
- 1976
- 1989
- 1999
- 2006
- 2010
- 2014
- 2018

In this location the shoreline position is the vegetation line at the toe of the coastal slope.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough
Historical comparison

Shoreline

Location:
McCracken
Year 1949

In this location the shoreline position is the vegetation line in 2018 at the toe of the coastal slope.

The location of the vegetation line in this minor cell was greatly influenced by the position of the mouth of the Hindmarsh River which periodically moved from west to east.

Allowing the river to exit to the east meant that river waters flowed around the base of the trainline.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough
Historical comparison

Shoreline

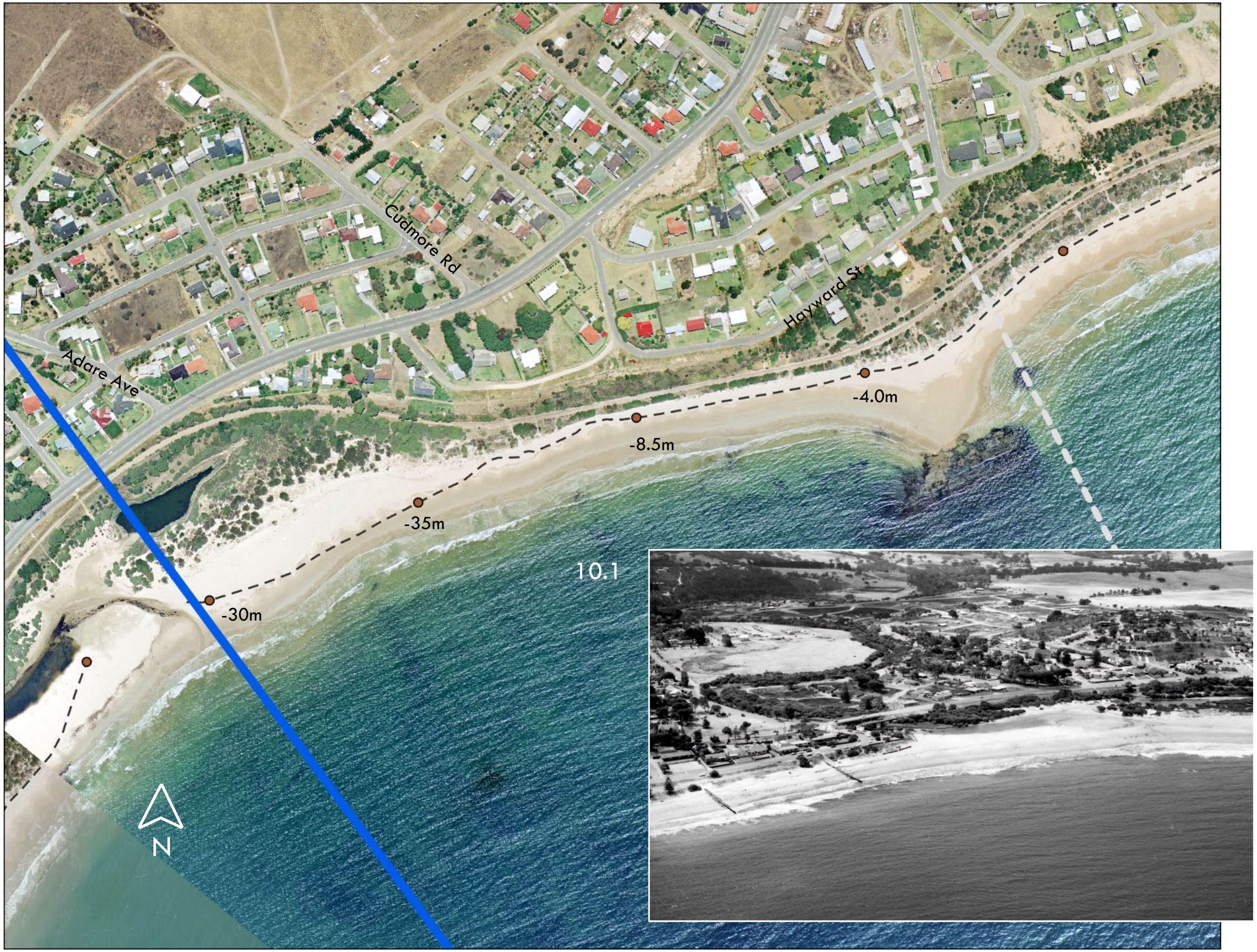
Location:
McCracken
Year 1976

In this location the shoreline position is the vegetation line in 2018 at the toe of the coastal slope.

By 1976 the outlet was more firmly established in its current position. The shoreline to the east accreted accordingly.

Note, there were no frontal sand dunes to Hindmarsh River in this era which may indicate higher levels of water flowing down the Hindmarsh River.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough
Historical comparison

Shoreline

Location:
McCracken
Year 1989

In this location the shoreline position is the vegetation line in 2018 at the toe of the coastal slope.

The shoreline is in a similar position to 1976 but the vegetation cover in the former river area increased in cover and density.

In 1984, rock training was established at the mouth, presumably to stop erosion of the dunes to the east (and perhaps potentially the train line).

Photograph: Coast Protection Board, 1984.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough
Historical comparison

Shoreline

Location:
McCracken
Year 1999

In this location the shoreline position is the vegetation line in 2018 at the toe of the coastal slope.

The shoreline continues to accrete towards its current position. Vegetation cover increasing.

By 1976 the outlet was more firmly established in its current position. The shoreline to the east accreted accordingly.

The mouth of the river began to be opened mechanically by Council when water levels become too high within the river.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough

Historical comparison

Shoreline

Location:
McCracken
Year 2010

In this location the shoreline position is the vegetation line in 2018 at the toe of the coastal slope.

A sandbag training wall was added in 2004 to manage the water flow more effectively than the 1984 installation.

The shoreline continues to accrete towards its current position. Vegetation cover increasing.

The mouth of the river began to be opened mechanically by Council when water levels become too high within the river.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough
Historical comparison

Shoreline

Location:
McCracken
Year 2014

In this location the shoreline position is the vegetation line in 2018 at the base of the coastal slope.

The shoreline continues to accrete towards its current position. Vegetation cover increasing.

The mouth of the river was held in position by the rock and sandbag training wall and the mouth began to be opened mechanically by Council when water levels become too high within the river.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough

Historical comparison

Shoreline

Location:
McCracken
DEM comparison:
2011 and 2018

The level of the digital elevation model of 2011 was compared with 2018:

- Yellow indicates stability,
- Green areas indicate accretion or increased sand levels,
- Red areas indicate erosion, or lower sand levels.

The area within Cell 10.1 has been stable with some areas of increased sand levels.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – summary (Cell 10.1)

Medium Term Changes

Fleurieu 10.1

McCracken-Hayborough

Historical comparison

Shoreline

Location:
McCracken
Summary

70 years

The shoreline in this location accreted significantly due to the establishment of the river mouth to the east.

10 years

No change to shoreline position. Vegetation cover continued to increase in the former river mouth.

Notes:

Location has been very stable over 70 year period with long term accretion and increasing vegetation cover. Minimal evidence of wave attack from storms.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes (Cell 10.2)

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough
Historical comparison

Shoreline

Location:
Hayborough

Aerial Photograph from 2018 provides the basis for comparison of coastal change over the last 70 years. Comparisons are made with aerial photography from:

- 1949
- 1976
- 1989
- 1999
- 2006
- 2010
- 2014
- 2018

In this location the shoreline position is the vegetation line at the toe of the coastal slope.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough
Historical comparison

Shoreline

Location:
Hayborough
Year 1949

In this location the shoreline position is the vegetation line in 2018 at the base of the coastal slope.

In 1949 the vegetation line was generally 2-4m further landward but on the western side was 8.5m landward (as the shoreline becomes closer to Hindmarsh River).

The circled location was a cross over point of the trainline in 1949.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough

Historical comparison

Shoreline

Location:
Hayborough
Year 1976

In this location the shoreline position is the vegetation line in 2018 at the base of the coastal slope.

The vegetation line in 1976 is generally in the same position as 2018.

An informal carpark was created at what is now known as Investigator Carpark. Studies and plans generated by Coast Protection Board provided the impetus to introduce management practices.

Also note the circled location – this was a cross over point of trainline in 1949.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough
Historical comparison

Shoreline

Location:
Hayborough
Year 1989

In this location the shoreline position is the vegetation line in 2018 at the base of the coastal slope.

The vegetation line in 1989 is receded a little in the eastern end of this minor cell, but accreted 4.5m in the west as it nears Hindmarsh River.

Also note the circled location – this was a cross over point of trainline in 1949.

The Investigator carpark was installed and roads and access ways to the beach formalised.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough
Historical comparison

Shoreline

Location:
Hayborough
Year 1999

In this location the shoreline position is the vegetation line in 2018 at the base of the coastal slope.

The vegetation line in 1989 is in a similar position to 1999.

Also note the circled location – this was a cross over point of trainline in 1949.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough
Historical comparison

Shoreline

Location:
Hayborough
Year 2010

In this location the shoreline position is the vegetation line in 2018 at the base of the coastal slope.

The vegetation line in 1989 is receded a little in the eastern end of this minor cell, but accreted 4.5m in the west as it nears Hindmarsh River.

Also note the circled location – this was a cross over point of trainline in 1949.

Note increasing vegetation cover and density due to management practices.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough
Historical comparison

Shoreline

Location:
Hayborough
Year 2014

In this location the shoreline position is the vegetation line in 2018 at the base of the coastal slope.

The vegetation line in 2014 is in a similar position to 2018.

Also note the circled location – this was a cross over point of trainline in 1949.

Note increasing vegetation cover and density due to management practices.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 10.2

McCracken - Hayborough
Historical comparison

Shoreline

Location:
Hayborough
DEM comparison:
2011-2018

The level of the digital elevation model of 2011 was compared with 2018:

- Yellow indicates stability,
- Green areas indicate accretion or increased sand levels,
- Red areas indicate erosion, or lower sand levels.

Most of this minor cell has been stable.

Some loss of sand is observed on the western side of the photograph. The Shoreline has receded by 2m in this location since 2014.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-2 Coastal fabric – summary (Cell 10.2)

Medium Term Changes

Fleurieu 10.2

McCracken-Hayborough

Historical comparison

Shoreline

Location:
Hayborough
Summary

70 years

Overall, the vegetation line at the base of the coastal slope under the trainline has moved seaward. Management practices introduced in the 1970s improved dunes and vegetation cover.

10 years

Recession or accretion over last decade is nil.

Notes:

Location has been very stable over the 70-year period. Coastal management practices are maintaining a well vegetated dune that does not appear to be under wave attack.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 10

McCracken-Hayborough

Historical comparison

Profile line

Analysis

The Coast Protection Board has been surveying seafloor and coastal backshores since the 1970s around South Australia.

Profile line:

- 615001

This profile is located just to the South of the study boundary and is in a higher energy wave environment than all other profiles in this study.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 10

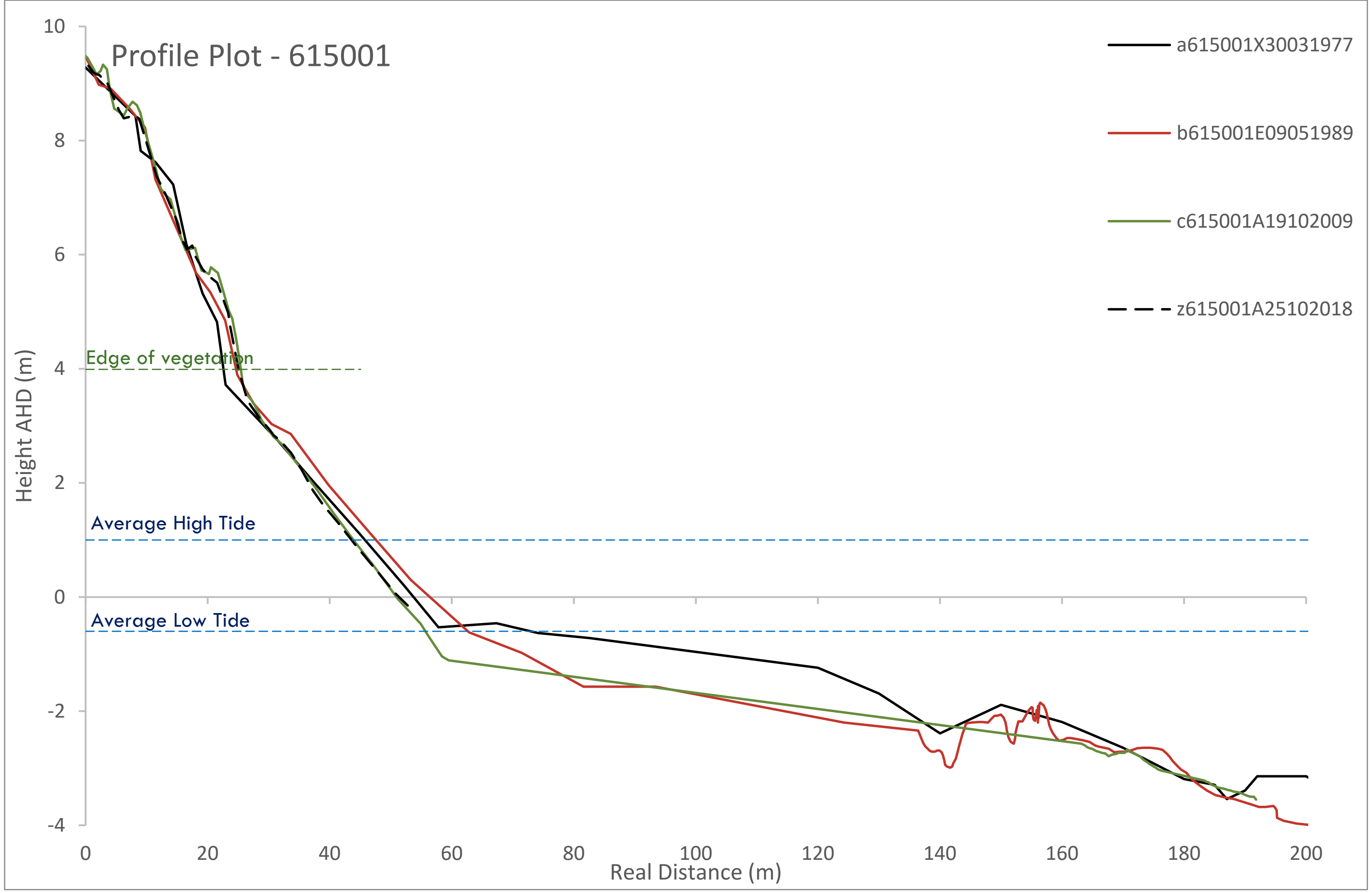
McCracken-Hayborough
Historical comparison

Beach Profile

Analysis:
Profile line 615001
Chiton Rocks

The profile is located east of the Victor Harbor council area and is utilised for the purpose of nearby comparison.

Between 1989 and 2009 there was ~3m of horizontal accretion in the dunes at ~5m elevation, which remains stable in 2021. This may be related to the walkway and vegetation accumulation of sand. The edge of vegetation is recorded at ~4.12m elevation and ~25m chainage in 2009 and 2018 indicating a stable dune toe. The beach profile for the subaerial zone has receded landwards by ~5m between 1989 and 2018.



Project note: This profile line is to the east of the Victor Harbor council area and is included for comparison purposes.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

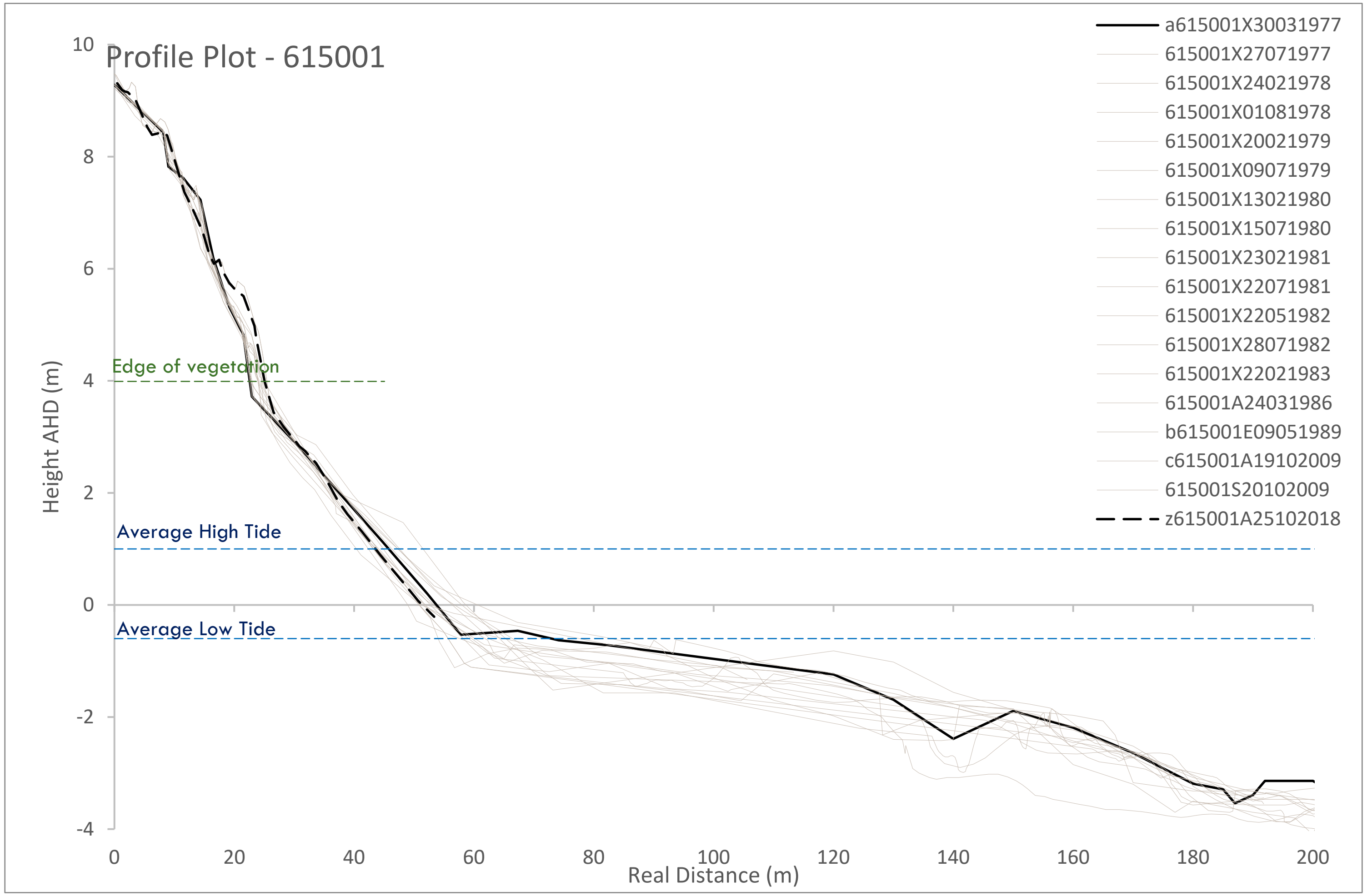
4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 10

McCracken-Hayborough Historical comparison

Beach Profile



Analysis:
Profile line 615001
Chiton Rocks

The indicator lines for average tides and the edge of vegetation are indicated for 2018.

The range of movement in the subaerial zone is relatively small and within the range of typical beach fluctuation.

There does appear to be a trend toward less sediment in the intertidal zone and additional study into beach width fluctuations may be warranted.

The general trend is one of slight accretion in the dune which is supported by established vegetation, and minor erosion of the beach face. There is also apparent erosion between 0m AHD and ~-2m AHD to ~100m offshore. While erosional, this beach profile is in the range of expected fluctuation. Project note: This profile line is to the east of the Victor Harbor council area and is included for comparison purposes.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

4-4 Coastal fabric – human intervention (Cell 10.1)

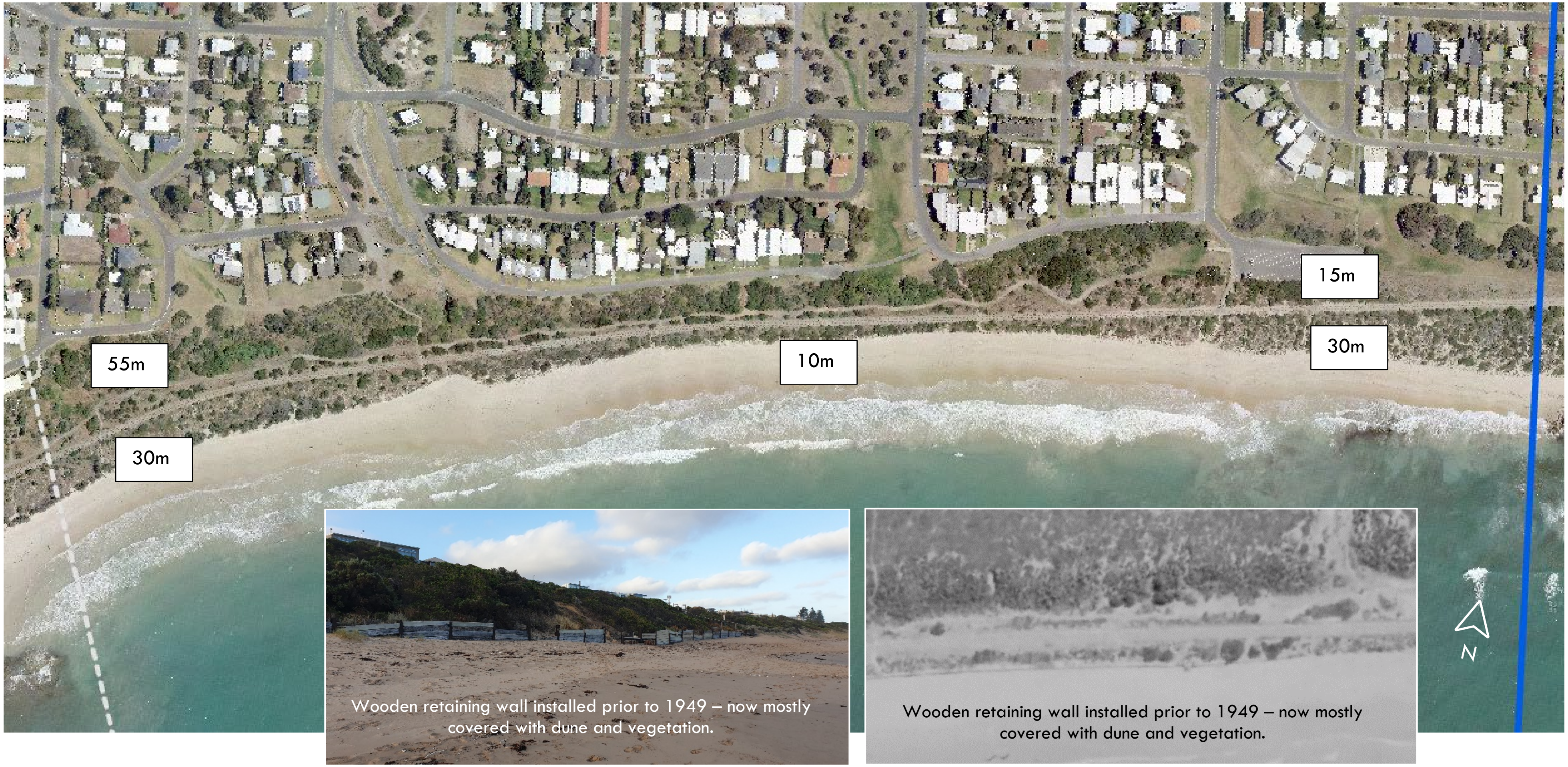
MODIFIED COASTS

Urban settlements placed too close to shorelines impose rigidity in the backshore, which was formerly flexible and could cope with the 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. Furthermore, when coastal settlements become threatened, protection items may be installed that alter the nature of the coastal fabric, and potentially also alter the natural operation of the beach.

4-4 Coastal fabric – human intervention (Cell 10.2)

MODIFIED COASTS

Urban settlements placed too close to shorelines impose rigidity in the backshore, which was formerly flexible and could cope with the 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. Furthermore, when coastal settlements become threatened, protection items may be installed that alter the nature of the coastal fabric, and potentially also alter the natural operation of the beach.



Wooden retaining wall installed prior to 1949 – now mostly covered with dune and vegetation.

Wooden retaining wall installed prior to 1949 – now mostly covered with dune and vegetation.

4-4 Coastal fabric – human intervention

LAND USE ZONING

In the context of sea level rise and the likelihood of increased rates of erosion, future consideration may be required as to the preferred nature of urban development. The urban planning controls are described on this page to provide a context for future assessment. However, within Cell 10, infrastructure and private development is set well back from the shoreline, and universally set back behind the State Government owned trainline.

Zoning and policy areas:

<u>Coastal Open Space</u>

Coastal Open Space zoning controls all development in the foreshore area. For most development proposals in this zone, referrals are required to SA Coast Protection Board.

<u>Residential Zoning</u>

The areas designated as Residential Zone are also governed by Policy Area 14, Hayborough. The desired form of housing in the foreshore region is low density detached or semi-detached housing. Quantitative density controls are governed by lot sizes at 420m2 for detached housing and 300m2 for semi-detached housing.

Referrals:

Under current Development Plan there is no requirement to refer development to Coast Protection Board situated behind the Coastal Conservation Zone.

Figure a. Land use zoning for the foreshore areas of McCracken and Hayborough. (Source: State Government of SA.

4-4 Coastal fabric – human intervention

WORKS AND STRATEGIES

Council has implemented the following coastal works and coastal management strategies:

- Car parks and beach access points formalised. Vegetation protected by dune fencing and board walks (in places) (1970-1980s),
- Ongoing weed control,
- Fencing and signage to control pedestrian and vehicular movement,
- When larger storm events erode sand from around the base of access stairs to the beach, Council uses a loader to push sand back to an appropriate level for pedestrian use.
- Access stairs are checked periodically,
- The mouth of Hindmarsh River is mechanically opened on an as needs basis when water levels become too high within the estuary.

Figure a. Council has implemented pedestrian and vehicle control measures that minimises impacts to dune systems and backshores.

Figure b (top right). Board walks and stairs provide a non-invasive way access to the beach.

Figure c (middle right). Vegetation has increased substantially in the dunes since the 1970s.

Figure d (bottom right). Periodically storms reduce sand levels around the base of the stairs. The current strategy is to use a loader to push sand back up around the base of the stairs.

4. Coastal fabric – summary table

McCracken-Hayborough (Cell Fleurieu 10)

McCracken-Hayborough		Coastal context - natural				Modified	Coastal changes			
Cell	Location	Bathymetry	Benthic	Beach	Backshore	Human	70 years	10 years	**Erodibility**	**General notes**
10.1	McCracken	Slope 1:85 (10m deep at 850m offshore).	Nearshore dominated by sand and seagrass beds. A low-profile reef runs parallel ~400m offshore.	Fine-medium sand beach	A dune system has built in the former mouth of the river. The trainline is positioned behind the dune system at ~6m AHD.	Trainline in the backshore ~6m AHD. Urban settlement set well back from shoreline >40m.	The shoreline has accreted significantly due to the realignment of the river mouth and increase of vegetation.	No change to shoreline position. Vegetation cover increasing in former river mouth region.	High (sandy beaches and backshores)	Backshore consists of 'easily erodible sediments' (Dr. Bob Bourman).
10.2	Hayborough	Slope 1:80 (10m deep at 800m offshore).	Nearshore dominated by sand. A low-profile reef becomes more substantial in 10.2 and is aligned closer to the shore (in closer proximity to Chiton Rocks)	Fine-medium sand beach	The trainline is positioned behind a dune at ~7m-10m AHD. The width of the dune system is 8m at its narrowest point. Backshore 'consists of erodible sediments' (Dr. Bob Bourman).	Trainline in the backshore ~7m to 10m AHD. Where the dune narrows, a retaining wall has been installed (likely to be > 50 years ago).	The shoreline is in a similar position to 1949. Vegetation of dunes increasing over time.	The coastal profile line at Chiton Rocks shows a trend for less sand in the intertidal and subtidal zones.	High (sandy beaches and backshores)	The retaining wall is in very poor condition. Backshore consists of 'easily erodible sediments' (Dr. Bob Bourman).

Erodibility Rating: High (3)

McCracken-Hayborough : key points

McCracken – Hayborough has four main stories. The trainline was installed in 1864 along the former 'marine bench'. A retaining wall was also constructed where the dunes are at their narrowest, presumably to protect the trainline. The position of the mouth of the river was trained in 1984 and dunes and vegetation have now built in this area. 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.

5. COASTAL EXPOSURE

To evaluate how actions of the sea currently impact the coastal fabric and how actions of the sea are projected to impact in the future in this section:

- Review impact of storms (if any)
- Apply current 1 in 100 sea-flood risk scenario,
- Analyse routine high-water impact,
- Analyse these scenarios in time frames: 2020, 2050, 2100,

Viewing instruction:
View sea-flood modelling using full screen mode within your PDF software (Control L). Then use arrow keys to navigate.

5. Coastal exposure – overview

Coastal exposure

The concept of coastal exposure is something we tend to understand intuitively. For example, if we find ourselves on the shore of a protected bay, we 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.

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. These can also increase the erosion of coastal landscapes, especially in cliff regions of softer constituency.

Due to its location which is also afforded protection from the Southern Ocean by Granite Island and its position within the bay, Nature Maps (SA) has assigned the exposure rating for McCracken-Hayborough as 'moderate', wave energy as 'low' – 'moderate'.

Storm surges

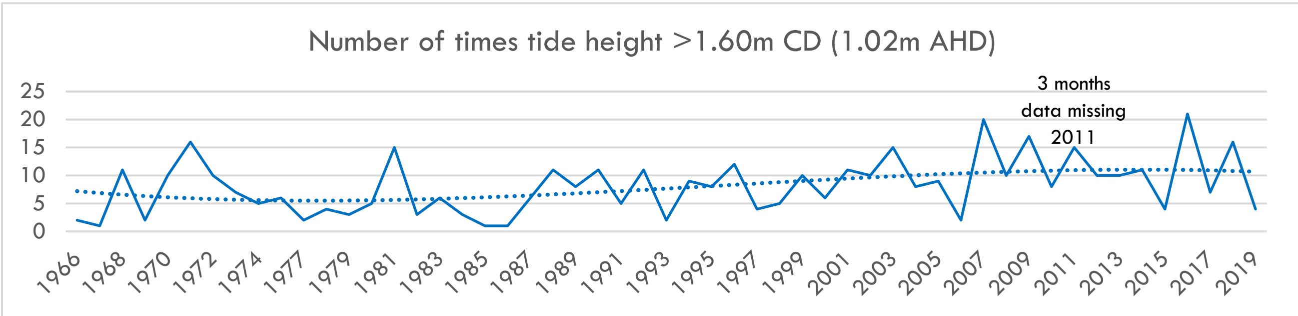
Despite this protection, when a number of meteorological conditions combine, storm surges can produce water levels up to 1.0m higher than the predicted astronomical tide. To manage the risk of these events upon human infrastructure, SA Coast Protection Board has set storm surge policy risk levels for the 1 in 100-year event. In terms of probability, this event is predicted to occur once every hundred years. However, 'nature' does not read our probability charts and there is no reason why these large events could not occur closer together, albeit less likely. While storm surges may have significant impact on the coast, these by their very nature are rare events. Over time beaches may rebuild and humans can repair the damage.

The event of 9 May 2016 was the highest event recorded at the Victor Harbor tide gauge since records began and was recorded at 2.22m CD[1] or 1.64 AHD[2]. This event came close to the 100-year event set by South Australian Coast Protection Board at 1.75m AHD.

Routine high water

Routine tidal action is likely to have a greater impact on the backshore over time, especially in the later part of this century if seas rise as projected. Using the tidal data from the Victor Harbor gauge which has been operating since 1965, we identified a routine storm event this is likely to occur a few times a month in the winter months. This event was identified as 1.60m CD (1.02m AHD). We then identified likely wave effects from seaweed strands observed within the Digital Elevation Model and Aerial Photography, both captured in 2018.

Figure a: Congruence of modelling of current routine high-water events with seaweed strands (2018).



[1] CD stands for Chart Datum and relates to tide heights recorded in the local tide charts.

[2] AHD stands for Australian Height Datum and this is the same measurement system that a surveyor would utilise.

5. Coastal exposure – overview

Long term variability of sea levels

Climate change occurs over long timescales in response to solar variations, changes in the Earth's orbit around the Sun, volcanic eruptions, movement of the continents and natural variability[3]. 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[4]. Over the last few thousand years sea levels have stabilised and this has coincided with the time that urban settlements have been established in close proximity to the coast all over the world.

Global mean sea levels

Long term tide gauges show that seas began to rise in the 19th century and this trend has continued throughout the 20th century[2] at on average rate of 1.7mm per year. The average level of the ocean is known as *global mean sea level* (GMSL). Changes in global sea level occur due to melting ice and the thermal expansion of the ocean water mass. While the average rate of rise was 1.7mm over the last century, this rate of rise was not constant. Rates of sea level rise were higher in the period 1920s to1940s[5] (in the context of higher global temperatures and melting of the Greenland ice sheets[6]). Over the following decades the rate of sea level slowed but in the 1990s sea levels again rose at a faster rate, comparable to that of the 1920s to 1940s. Since 1990, satellites have been tracking global mean sea level rise at 3-4mm per year in our region[3]. However, this shorter-term record is likely to contain an element of natural variability. It is likely that the current rate of rise is not unusual in the context of natural variability and the data record from last century[4].

Regional sea levels

Regional changes 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. Longer term changes are also associated with changes in the Trade Winds which bring increases in sea levels in the Western Tropical Pacific region[2]. Sea levels can 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.

Projected sea level rise

Projections of future climate change are carried out using climate models that use various greenhouse gas emissions scenarios. These models are computer-based simulations of the earth-ocean-atmosphere system that identify plausible futures as to how the climate will respond over the coming century[3]. Sea level rise projections are based upon these various scenarios. In 1993, South Australian Coast Protection Board (CPB) adopted sea level rise allowances into planning policy of 0.3m rise by 2050 and 1.0m rise by 2100. These sea level rise projections are similar to the high emissions scenario shown in the figure below (Figure a).

Scenario modelling

In this project we take the current storm surge risk levels and current routine high-water data and model the impact of these in a digital elevation model captured in 2018. We then take the sea level allowances set by CPB at 0.3m by 2050 and 1.0m by 2100 and model the projected impact of sea level rise upon the coast.

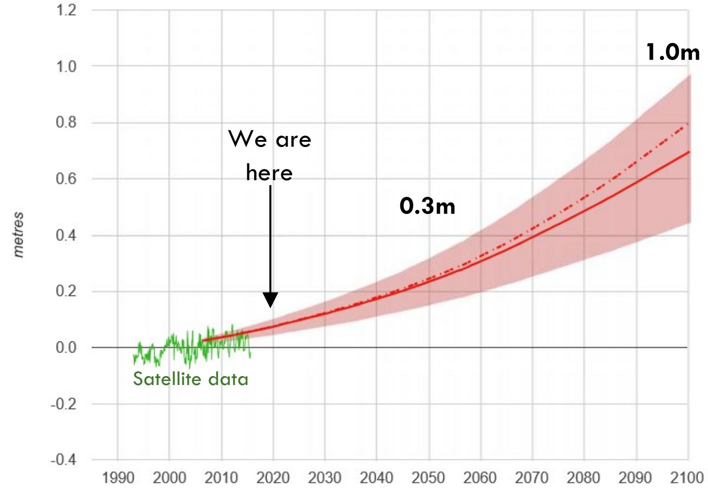


Figure a: Sea level rise high emissions scenario (RCP 8.5) and including SA Coast Protection Board sea level rise policy projections (Adapted from CoastAdapt, 2017).

---

[3] Coast Adapt (2017).
[4] CSRIO (2020) Sea level, waves and coastal extremes.
[5] IPCC, WG1AR5, Sea level change, 2014, Watson P., 2020.
[6] Curry, J., Sea level and climate change, 2019.

5. Coastal exposure – overview

Overview

Fleurieu 10

McCracken-Hayborough

Coastal Exposure

Overview

SA Classification – Nature Maps

10.1 McCracken

Relative Exposure:
Moderate
Wave energy:
Low
Shoreline class
Low tide terrace + Rock
Sand rating
Fine-medium Sand

10.2 Hayborough

Relative Exposure:
Moderate
Wave energy:
Moderate
Shoreline class
Traverse Bar and Rip + Rock
Sand rating
Fine-medium Sand

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – location map (Cell 10.1)

Location

Fleurieu 10.1

McCracken-Hayborough

Location Map

McCracken

The scenarios modelled are:

- Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur once or twice per month from April to September.
- 1 in 100-year ARI storm surge event (CPB)

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Moderate

Wave energy:
Low

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

Viewing instruction:
View the coastal exposure section utilising full screen mode within your PDF software (Control L). Then use arrow keys to navigate.

5. Coastal exposure – routine high water (2020)

Routine high water

Fleurieu 10.1

McCracken-Hayborough

2020 scenario

Event: Routine high water

McCracken

Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur a few times per month from April to September.

Inputs are based on findings of the analysis of data from the Victor Harbor tide gauge and analysis of seaweed strands using DEM (2018) and aerial photograph (2018).

The event modelled:

Routine monthly tide	1.00 AHD
Wave set-up	0.30m
Total risk	1.30m AHD

Wave run-up of 0.70m is included.

Assessment: The modelling is congruent with observations and the current impact on beach and backshore is low.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 10.1

McCracken-Hayborough

2050 scenario

Event: Routine high water

McCracken

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

The event modelled:

Routine monthly tide	1.0m AHD
Sea level rise	0.30m
Wave set-up	0.30m
Total risk	1.50m AHD

Wave run-up of 0.70m is included.

Assessment:
The scenario modelling indicates that routine highwater events at 0.30m higher than present will have minimal impact on the base of dunes although some recession is likely. Note the incursions of sea water into locations where storm water outlets are positioned.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 10.1

McCracken-Hayborough

2100 scenario

Event: Routine high water

McCracken

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

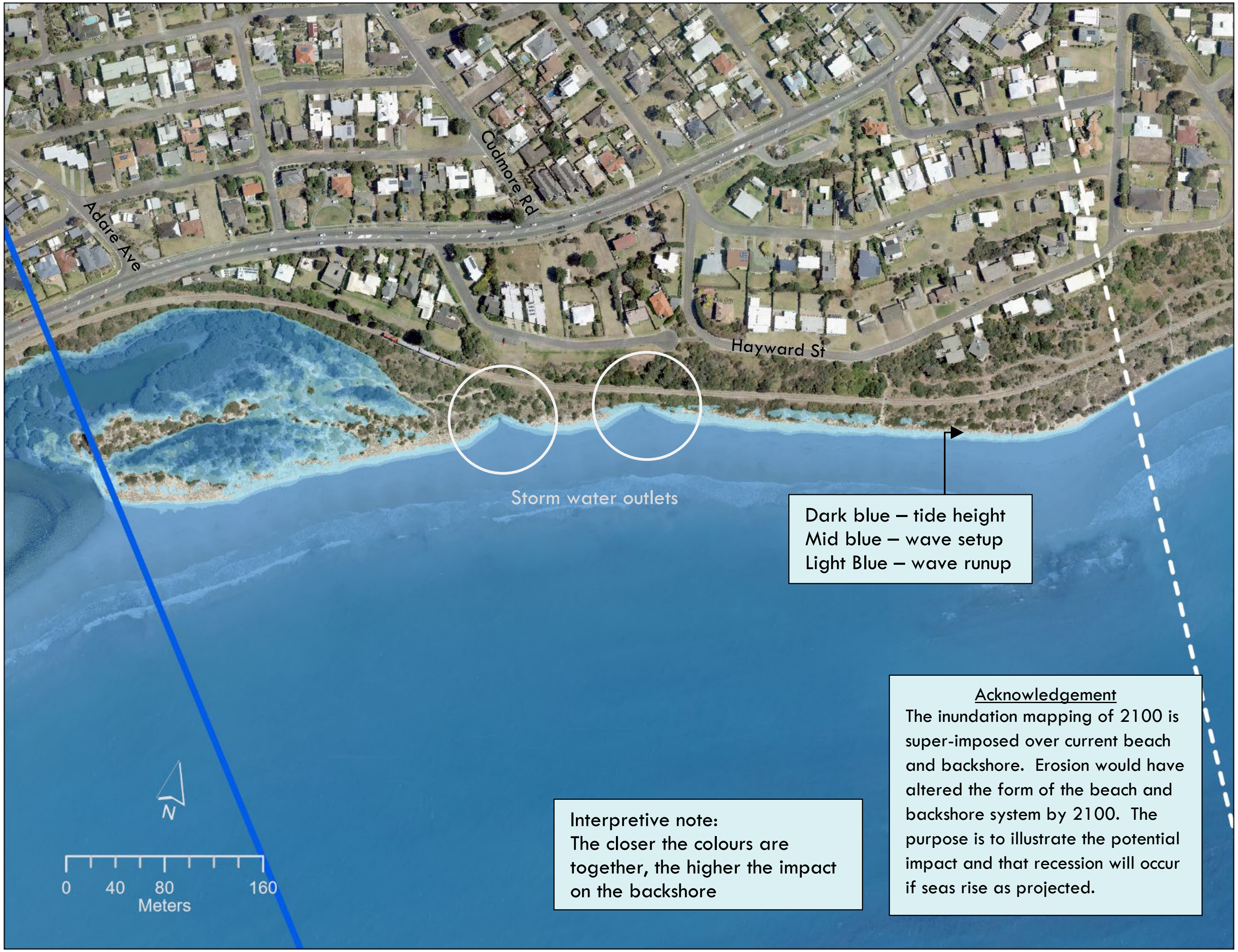
The event modelled:

Routine monthly tide	1.00m AHD
Sea level rise	1.00m
Wave set-up	0.30m
Total risk	2.30m AHD

Wave run-up of 0.20m is included.

Assessment:
The scenario modelling indicates that routine high water events at 1.0m higher than present would have a significant impact on the slope underneath causing instability and potential collapse. The dune area of the former river mouth would likely erode back to its former position. See also erosion modelling below.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



Interpretive note:
The closer the colours are together, the higher the impact on the backshore

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2020)

Storm surge

Fleurieu 10.1

McCracken-Hayborough

2020 scenario

Event: 1 in 100 sea-flood risk

McCracken

The current 1 in 100-year event risk set by SA Coast Protection Board is 1.75m AHD. Wave runup and wave setup allowances were derived from storm study in the region.

Storm surge	1.75m AHD.
Wave set-up	0.40m
Risk	2.15m AHD

Wave run-up is 0.80m and depicted in light blue.

Assessment:
This event is of similar height at the tide gauge as the event of 9 May 2016 although nothing is known of the impact of that event into this area. This event would have significant impact on the dunes/ slope underneath the trainline but as a one-off event, the beach would be expected to recover.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 10.1

McCracken-Hayborough

2050 scenario

Event: 1 in 100 sea-flood risk

McCracken

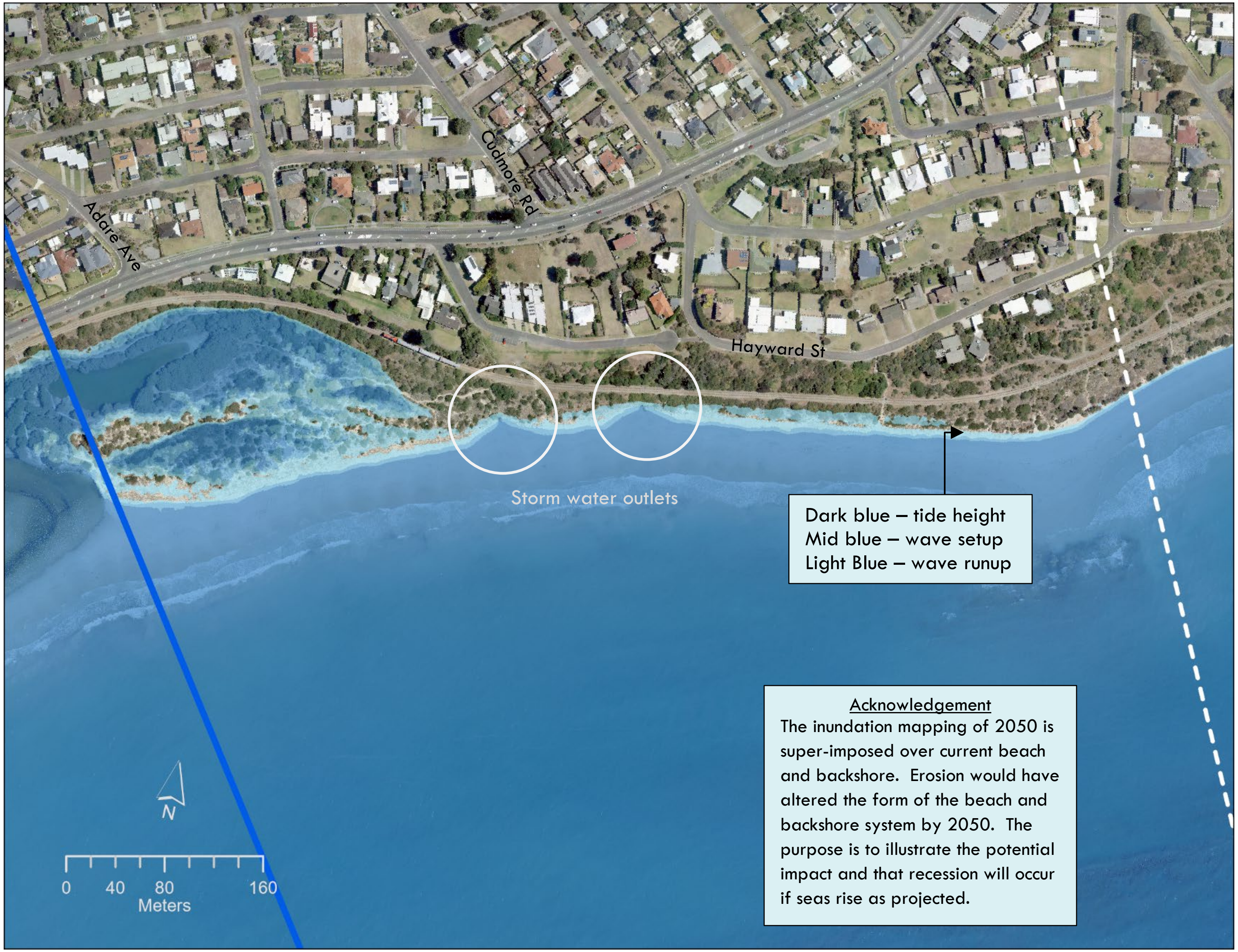
The current 1 in 100-year event risk set by SA Coast Protection Board is 1.75m AHD. Wave runup and wave setup allowances were derived from storm study in the region.

Storm surge	1.75m AHD.
Sea level rise	0.30m
Wave set-up	0.40m
Risk	2.45m AHD

Wave run-up is 0.80m and depicted in light blue.

Assessment:
The scenario modelling indicates that a storm surge with projected sea level rise of 0.30m by 2050 would have significant impact on the slope under the trainline which would likely destabilise the slope. (See also erosion modelling below)

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 10.1

McCracken-Hayborough

2100 scenario

Event: 1 in 100-year event

McCracken

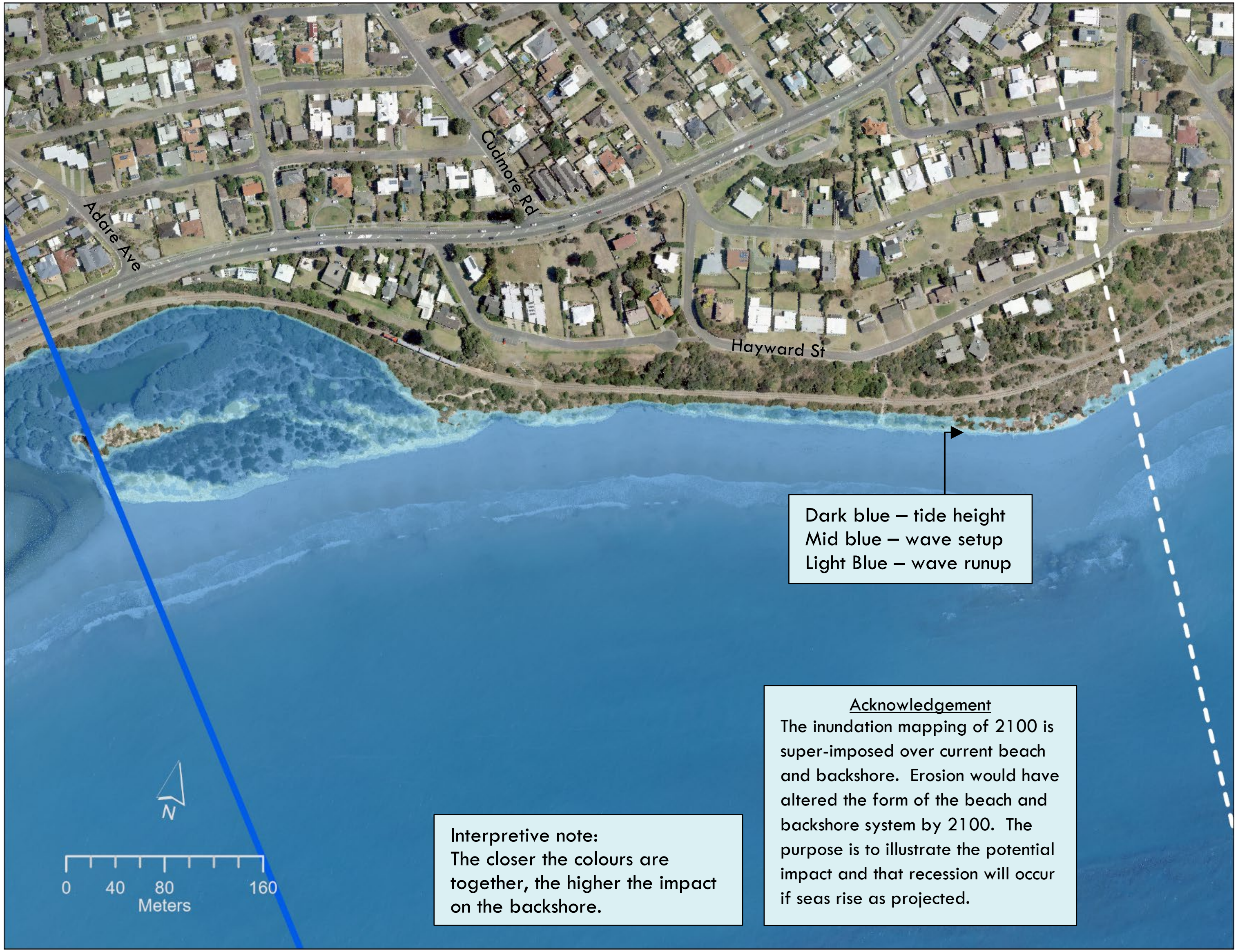
The current 1 in 100-year event risk set by SA Coast Protection Board is 1.75m AHD. Wave runup and wave setup allowances were derived from storm study in the region.

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.40m
Risk	3.15m AHD

Wave run-up is 0.80m and depicted in light blue.

Assessment:
The scenario modelling indicates that a storm surge with projected sea level rise of 1.00m by 2050 would have catastrophic impact on the slope under the trainline which would likely destabilise the slope. (See also erosion modelling below).

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



5. Coastal exposure – summary (Cell 10.1)

Summary

Fleurieu 10.1

McCracken-Hayborough

Summary

McCracken

2020-2050

Sea levels 0.3m higher than present are likely to cause recession to the toe of the slope under the trainline measured in metres by 2050. Locations of storm water outlets (x2) are likely to be the most vulnerable.

2050-2100

If sea levels rise as projected, in the latter half of the century the slope under the trainline is likely to be eroded to such a degree that the embankment would become destabilised. The area of the former mouth of the Hindmarsh River would likely recede to its former position.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – location map (Cell 10.2)

Location

Fleurieu 10.2

McCracken-Hayborough

Location Map

Hayborough

The scenarios modelled are:

- Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur once or twice per month from April to September.
- 1 in 100-year ARI storm surge event (CPB)

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Moderate

Wave energy:
Moderate

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – routine high water (2020)

Routine high water

Fleurieu 10.2

McCracken-Hayborough

2020 scenario

Event: Routine high water

Hayborough

Routine tidal action is likely to have greater impact on the backshore over time. Routine high-water events are expected to occur once or twice per month from April to September.

Inputs are based on findings of the analysis of data from the Victor Harbor tide gauge and analysis of seaweed strands using DEM (2018) and aerial photograph (2018).

The event modelled:

Routine monthly tide	1.00m AHD
Wave set-up	0.30m
Total risk	1.30m AHD

Wave run-up of 1.10m is included.

Assessment: The modelling is congruent with observations and the current impact on beach and backshore is low.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 10.2

McCracken-Hayborough

2050 scenario

Event: Routine high water

Hayborough

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

The event modelled:

Routine monthly tide	1.0m AHD
Sea level rise	0.30m
Wave set-up	0.30m
Total risk	1.60m AHD

Wave run-up of 1.10m is included.

Routine highwater events at 0.30m higher than present are likely to cause recession to the coastal slope under the trainline measured in metres.

Note the incursion of seawater into the location of the storm water outlet.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 10.2

McCracken-Hayborough

2100 risk:

Event: Routine high water

Hayborough

Sea level rise will increase the frequency of routine interactions between the sea and coastal fabric so that the impact on backshore will become greater over time.

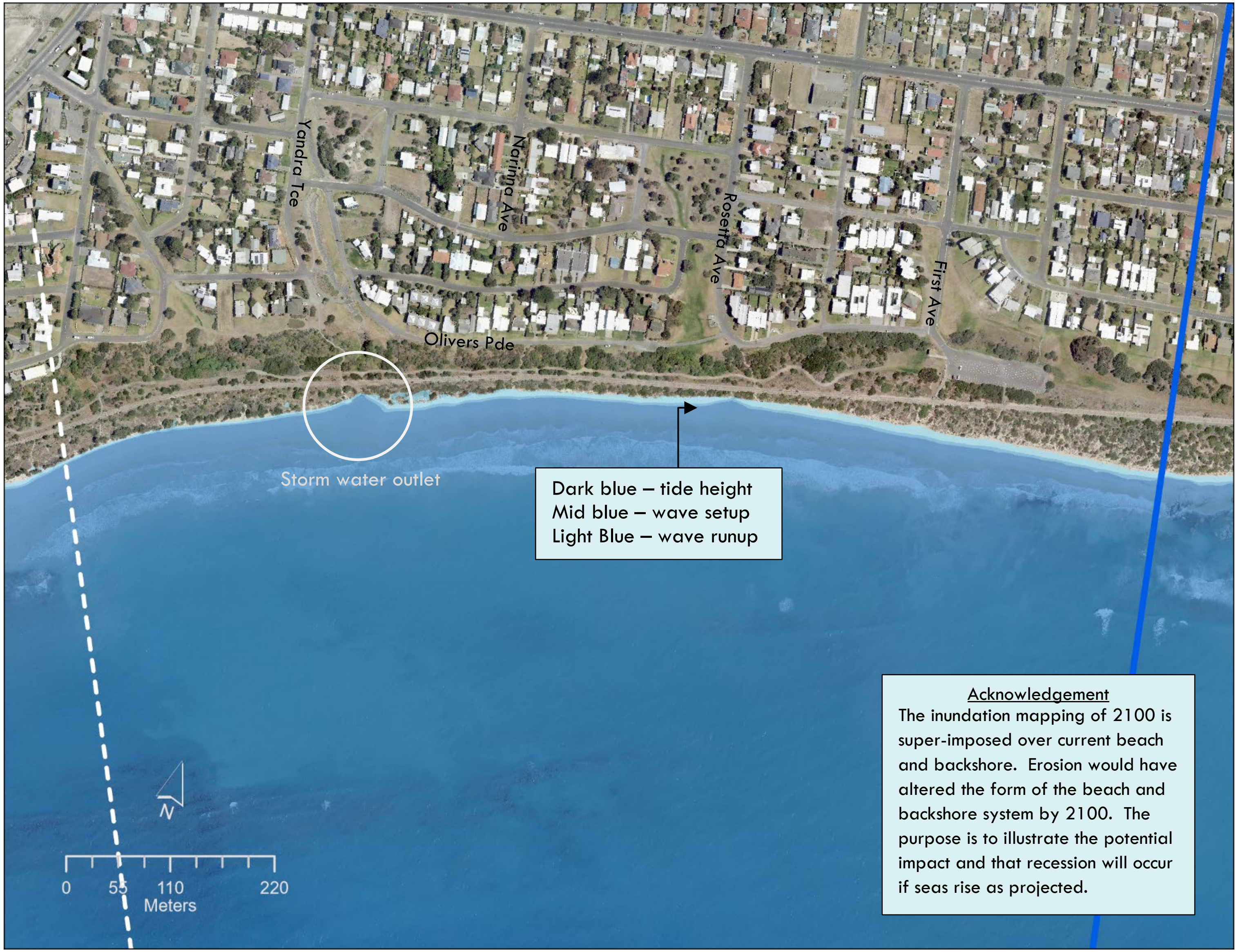
<u>The event modelled:</u>

Routine monthly tide	1.00m AHD
Sea level rise	1.00m
Wave set-up	<u>0.30m</u>
Total risk	2.30m

Wave run-up of 1.10m is included.

Assessment
Routine high water events at 1.0m higher than present would cause significant recession of the slope under the trainline which would undermine its stability. (See also erosion modelling)

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



5. Coastal exposure – storm surge (2020)

Storm surge

Fleurieu 10.2

McCracken-Hayborough

2020 scenario

Event: 1 in 100 sea-flood risk

Hayborough

The current 1 in 100-year event risk set by SA Coast Protection Board is 1.75m AHD. Wave runup and wave setup allowances were derived from storm study in the region.

Storm surge	1.75m AHD.
Wave set-up	0.40m
Risk	2.15m AHD

Wave run-up is 1.20m and depicted in light blue.

Assessment:
The impact of this storm event would have similar impact as storm event 9th May 2016. However, no impacts are currently known from this event in this region. This one-off event would cause erosion and recession of the toe of the dune but the beach and dune would likely recover.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 10.2

McCracken-Hayborough

2050 scenario

Event: 1 in 100 sea-flood risk

Hayborough

The current 1 in 100-year event risk set by SA Coast Protection Board is 1.75m AHD. Wave runup and wave setup allowances were derived from storm study in the region.

Storm surge	1.75m AHD.
Sea level rise	0.30m
Wave set-up	0.40m
Risk	2.45m AHD

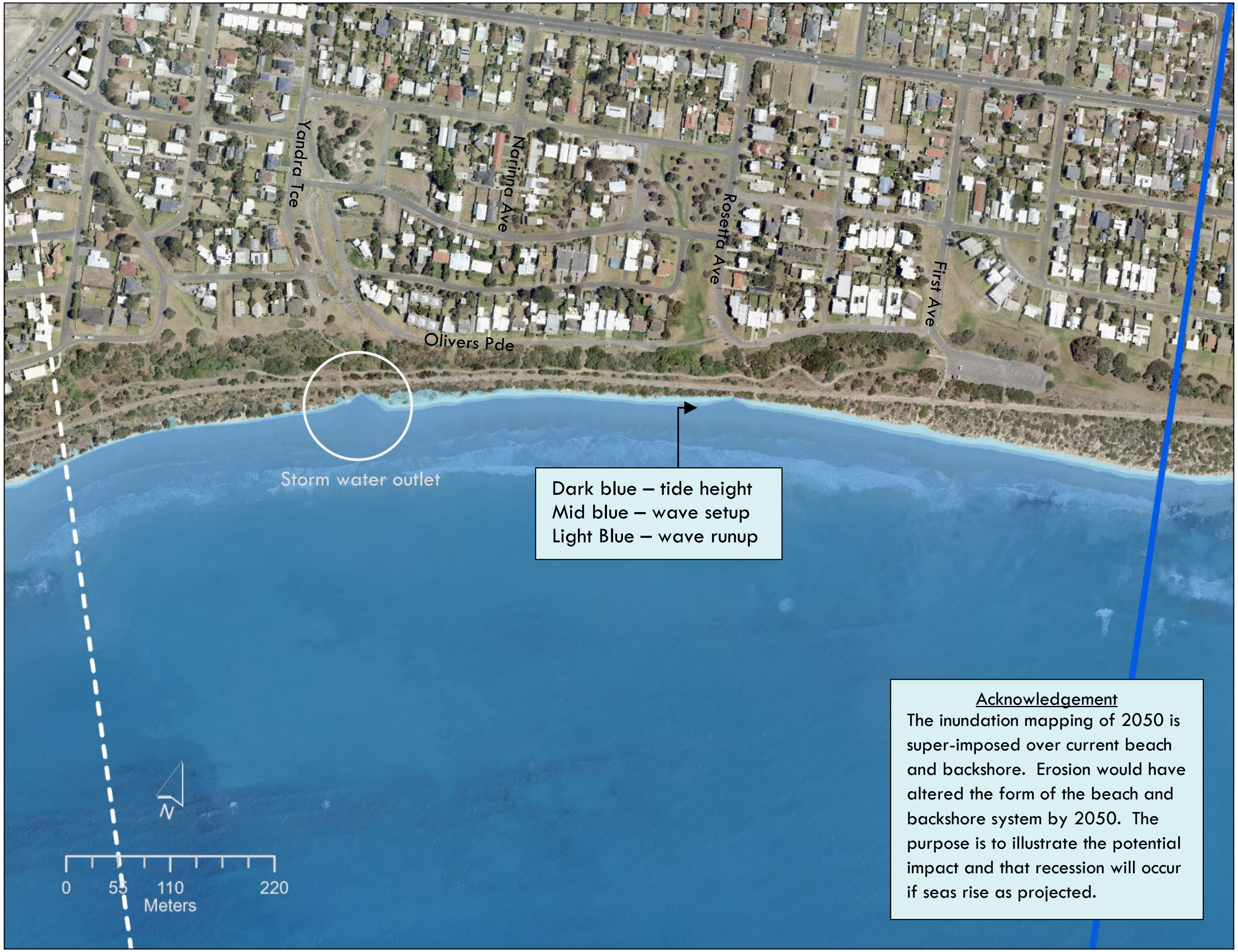
Wave run-up is 1.20m and depicted in light blue.

Assessment:

This one-off event would have significant impact on the coastal slope under the trainline and cause erosion and recession of the toe of the dune.

Integrated Coasts

markwestern@integratedcoasts.com
www.integratedcoasts.com



5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 10.2

McCracken-Hayborough

2100 scenario

Event: 1 in 100-year event

Hayborough

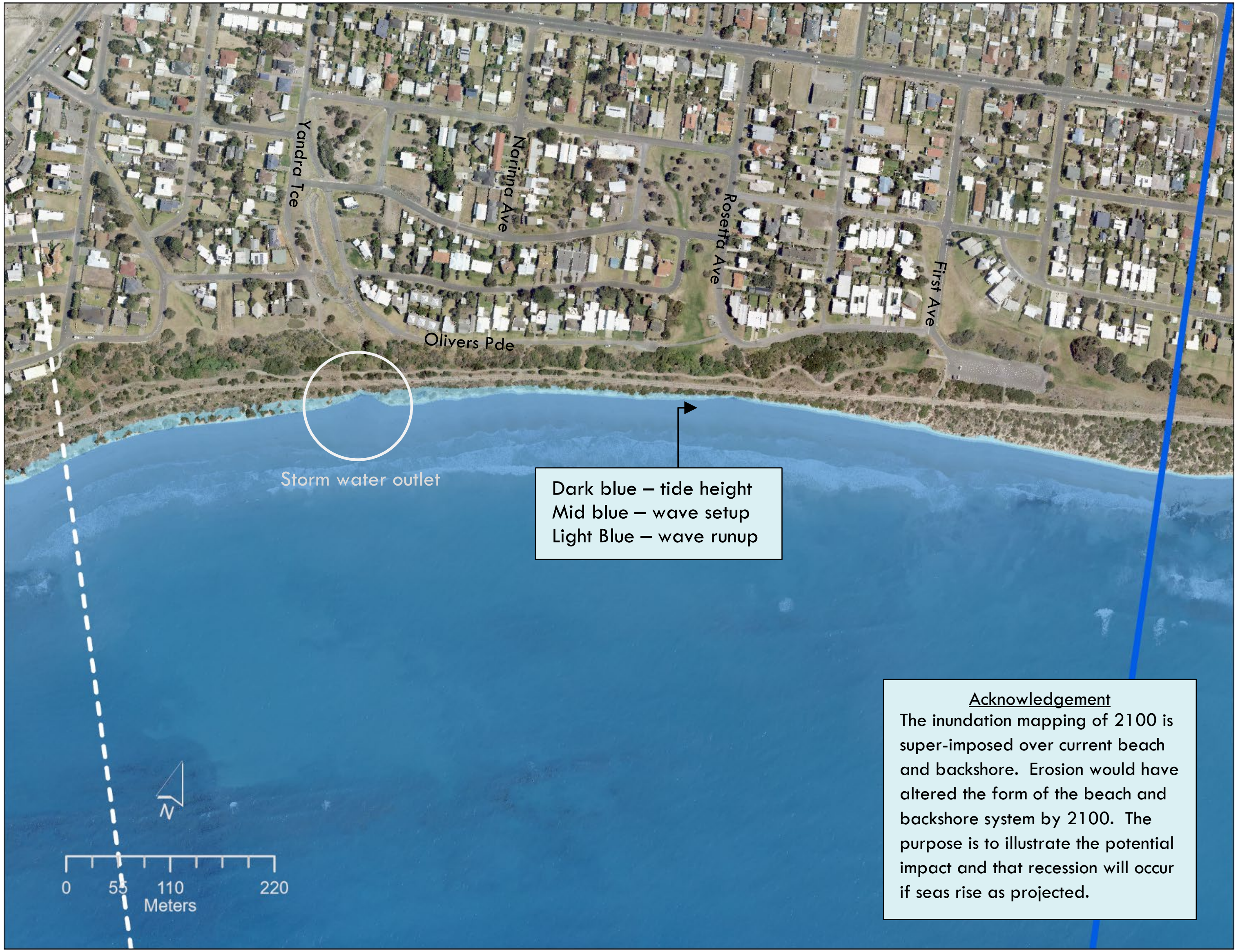
The current 1 in 100-year event risk set by SA Coast Protection Board is 1.75m AHD. Wave runup and wave setup allowances were derived from storm study in the region.

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.40m
Risk	3.15m AHD

Wave run-up is 1.20m and depicted in light blue.

Assessment:
The scenario modelling indicates that a storm surge with projected sea level rise of 1.00m by 2050 would have catastrophic impact on the slope under the trainline which would likely destabilise the slope. (See also erosion modelling below).

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com



5. Coastal exposure – summary (Cell 10.2)

Summary

Fleurieu 10.2

McCracken-Hayborough

Summary

Hayborough

2020-2050

Sea levels 0.3m higher than present are likely to cause recession to the toe of the slope under the trainline measured in metres by 2050. Locations of storm water outlets (x1) are likely to be the most vulnerable.

2050-2100

If sea levels rise as projected, in the latter half of the century the slope under the trainline is likely to be eroded to such a degree that the embankment would become destabilised.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

Methodology

In the following, we attempt to estimate shoreline retreat on the Victor Harbour beaches due to sea level rise. This is achieved by three methods, one, utilising 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.

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, this assessment 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.

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

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):

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

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 Harbour 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 at Bashams Beach 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

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

Methodology (cont.)

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 Harbour 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 X 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).

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

Assessment

SA Coast Protection Board profile lines were unavailable within the immediate area of this cell and therefore the profile line at Chiton Rocks was used as a basis for assessment. Additionally, a previous assessment has been completed for Boomer Beach in the context of Alexandrina Coastal Adaptation Study that calculated recession of 18-23m by 2100. Generally, the coastal context of McCraken-Hayborough is more sheltered than either of these locations, and specifically the exposure reduces toward Hindmarsh River even within the context of the cell under consideration in this assessment.

Chiton Rocks

Chiton Beach is characterised by a steep embankment at the rear of the beach affording this area more protection than most of the rest of the Victor Harbour coastline. However, the nearshore region is characterised by shallow reef and seagrass beds and therefore it is difficult to accurately estimate the shoreline response to sea level rise.

If one uses the Bruun Rule to estimate sea level recession (in this case, as with all the Victor Harbour shorelines, a extremely rough estimate), the amount of shoreline recession that would occur by 2100 with 1m sea level rise is ~19m (assumes a 1m significant wave height (Hs), and depth of closure of 8.9m).

If the shoreline were to translate upwards and landwards essentially maintaining the current profile, the shoreline recession is estimated at 37.6m (using -4m as the depth at which the profile would cease translating due to the presence of reef). Figure (b) indicates this translation.

This estimate ignores the geological fabric and strength of materials in the cliff/seaward slope and assumes that slope could translate landwards as a normal dune slope would. The true nature of the translation will also be strongly affected by the nearshore reefs and it is unlikely they will shift or translate. However, with a higher sea level, higher wave energy will reach the shoreline, and the degree of erosion may be greater than predicted due to this.

Taking into account the more sheltered location of McCracken-Hayborough erosion could be expected in the range of 10-20m by 2100, also taking into account the diminishing impact towards Hindmarsh River.

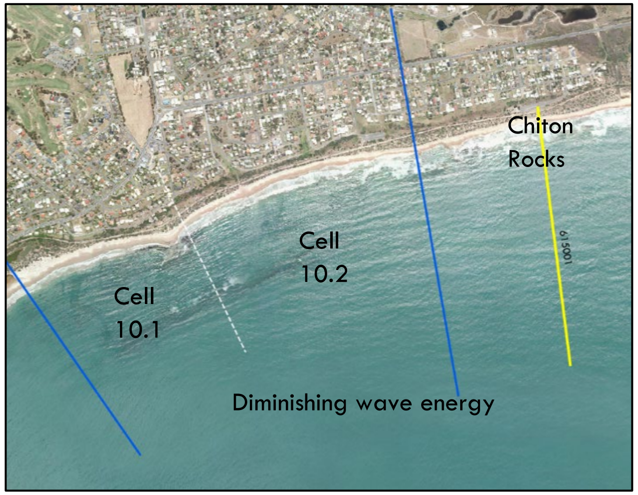
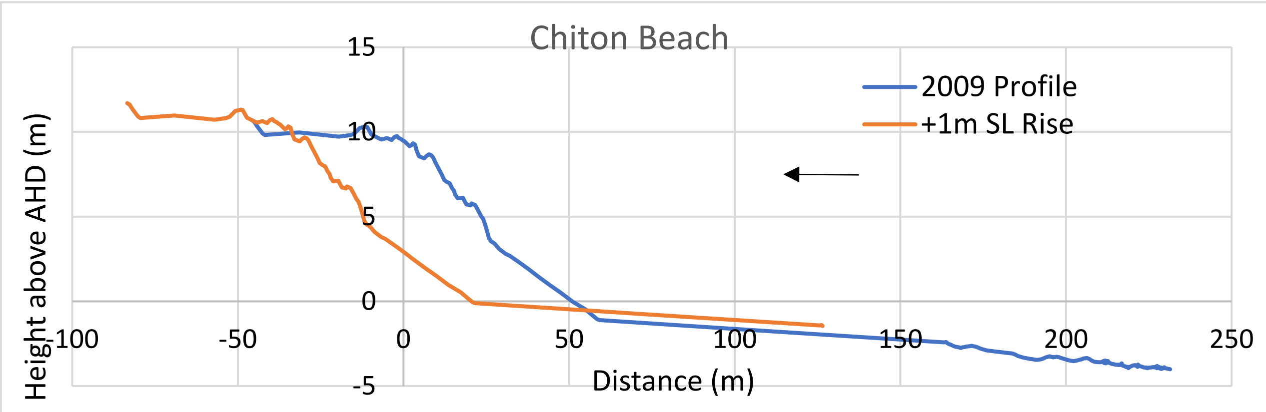


Figure a. The coastal context of McCracken-Hayborough (Cell 10)

Figure b. Translation of the 2009 beach/dune/ramp/reef profile with 1m sea level rise.



5. Exposure – erosion (2100)

Summary

Fleurieu 10

McCracken-Hayborough

2100 risk:
Erosion outlook

McCracken-Hayborough

Based on the erosion modelling on the previous pages, shoreline recession within the McCracken-Hayborough region will have decreasing impact towards the more sheltered region of Hindmarsh River.

The trainline is situated on a former marine bench rising from 6.00m AHD at the river to 9.50m AHD towards Chiton Rocks. The width of the embankment and dune seaward of the trainline varies from 10 to 34m.

If seas rise as projected, and in the absence of any human intervention, it is likely that the shoreline would retreat 10-20m and the embankment upon which the trainline is situated eroded away in most areas.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

COASTAL EXPOSURE – Summary table

McCracken-Hayborough (Cell 10)

McCracken-Hayborough		Coastal context - natural				Modified	Exposure*	Scenario Modelling	
Cell	**Location**	**Bathymetry**	**Benthic**	**Beach**	**Backshore**	**Human**	**Waves**	**2020 - 2050**	**2050-2100**
10.1	McCracken	Slope of ocean floor is 1:80: (-10m deep at ~800m from the shore).	Nearshore and surf-zone dominated by sand, with offshore low-profile reef. Seagrass beds near Hindmarsh River outlet.	Fine to medium sand beach with rocky outcrops and exposed low tide reef.	Dune system of varying width (10m at its narrowest) on a steep slope up to the former marine bench at 6.50m AHD upon which the trainline is situated.	The training of the river mouth resulted in significant a build-up of dunes to the east. A trainline is positioned on the former marine bench.	**Moderate** exposure **Low energy** waves	Sea levels 0.3m higher than present are likely to cause recession to the toe of the slope under the trainline measured in metres by 2050. Locations of storm water outlets (x2) are likely to be the most vulnerable.	If sea levels rise as projected, in the latter half of the century the slope under the trainline is likely to be eroded to such a degree that the embankment would become destabilised. The area of the former mouth of the Hindmarsh River would likely recede to its former position.
10.2	Hayborough	Slope of ocean floor is 1:80: (-10m deep at ~800m from the shore).	Nearshore and surf-zone dominated by sand, with offshore low-profile reef.	Fine to medium sand beach with rocky outcrops and exposed low tide reef.	Dune system of varying width (10m at its narrowest) on a steep slope up to the former marine bench at 9.00m AHD upon which the trainline is situated	Trainline is positioned on the former marine bench. A retaining wall (dilapidated) ~120m long at slope toe.	**Moderate** exposure **Moderate** energy waves	Sea levels 0.3m higher than present are likely to cause recession to the toe of the slope under the trainline measured in metres by 2050. Locations of storm water outlets (x1) are likely to be the most vulnerable.	If sea levels rise as projected, in the latter half of the century the slope under the trainline is likely to be eroded to such a degree that the embankment would become destabilised.

***Exposure Rating: Low - Moderate (3)** (diminishing towards Hindmarsh River)

McCracken-Hayborough : Key Points

The shoreline is currently stable. Actions of the sea at 0.3m higher will cause some recession of the slope measured in metres (<10). If sea levels rise as projected, in the latter part of the century, the slope under the trainline is likely to be eroded to such a degree that the embankment would become destabilised. The area of the former mouth of the Hindmarsh River would likely recede to its former position under the embankment of the trainline. Locations of storm water outlets (x3) are likely to be the most vulnerable as modelling shows that sand levels are lower and dune toe most recessed.

6. Storm water runoff from urban settlement

6. Storm water runoff from urban settlement

Purpose

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 embankments can cause gullying and instability. Storm water rushing out to the beach can cause gullying of the dunes 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.

Methodology

Three basic questions are assessed in this project for Victor Harbor:

(1) Does Council manage the flow of storm water from urban settlement so that it does not flow uncontrolled over backshores (dunes and embankments)? In the context of Cell 10, we focus only on the embankment on which the trainline is positioned.

(2) What impact is occurring on the beach due to storm water runoff?

(3) What is the potential for a confluence of events where storm water flows may coincide with high sea levels and thereby increasing flooding potential.

The study is confined to evaluating storm water runoff from urban settlement and is not related to any impacts associated with natural runoff from rain events.

However, due to the slope of the backshore and the elevated nature of urban development it was concluded that a confluence of a rain event and a sea storm event that caused flooding within urban settlement was not possible. Therefore, in this cell we confined our assessment to questions (1) and (2).

This study is therefore confined to evaluating the impact of projected sea level rises upon the existing three storm water outlets. Note, many of the storm water pipes conclude on the land side of the trainline and drain into the terrain which acts as a natural detention swale.

Other storm water studies

A previous study was undertaken in 2005 by Kellogg Brown and Root. However, the scope of works for this study was confined to Victor Harbor Central (Cell 11) and Encounter Bay (Cell 12).

At the time of writing, Council is completing another storm water study although the parameters of this project are unknown.

6. Storm water runoff from urban settlement

Storm Water

Cell F10.1

McCracken-Hayborough

Storm water:

Current design

Storm water outlet assessment McCracken

Two storm water outlets are located on the beach. The preliminary assessment on this page indicates that the catchment area is reasonably large (in the context of outlet pipes to the beach).

Location 50 is set within the embankment at elevation ~3m AHD. Storm water flows decrease the height of sand levels (see modelling).

Location 51 may be an older outlet that is positioned behind the retaining wall (now dilapidated).

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Storm water runoff from urban settlement

Storm Water

Cell F10

McCracken-Hayborough

Storm water:

Current design

Storm water outlet assessment Hayborough

Only one storm water outlet is located in the foreshore region in Hayborough (Location 52). Storm water to this location flows down what was a former natural storm water gully prior to settlement (see shoreline history). This gully has gabion style rock at the base of the gully to slow the rate of storm water flow to the coast. Water flows in open channels until it is piped under the trainline. The retaining wall and outlet infrastructure is in dilapidated condition. Note the seaweed strands around the base of the pipe.

Other locations appear to drain into the natural swale between the former marine bench upon which the trainline runs and the coastal slope landwards upon which urban settlement is situated.

Integrated Coasts
markwestern@integratedcoasts.com
www.integratedcoasts.com

6. Storm water runoff from urban settlement

Three basic questions were assessed in this project:

(1) Does Council manage the flow of storm water from urban settlement so that it does not flow uncontrolled over coastal backshores and dunes?

This assessment is confined to impacts upon the embankment upon which the trainline is positioned. There are only three outlets positioned on the beach where water is piped under the trainline. There was no observed scouring of the embankment or the dunes. Storm water from other locations appears to drain into the natural swale between the trainline and the landward slope upon which urban settlement is positioned. The inspection was carried out in February in a low rainfall environment, but no adverse impacts were observed on the embankment upon which the trainline is situated from draining into this swale.

(2) What impact is occurring on the beach due to storm water runoff?

The assessment was undertaken in February at a time of low rainfall. Some scouring of the beach was observed which can also be seen in the scenario modelling (Figure a). To a certain extent this is unavoidable in locations where it is necessary to drain storm water to the coast. However, in the context of rising sea levels and higher storm action, these areas around storm water outlets will be the first areas of vulnerability. Sand levels are likely to continue to drop and erosion of the backshore to accelerate. In a location such as the trainline, this may have serious consequences if left unchecked.

(3) What is the potential for a confluence of a sea storm and a rainstorm, thereby increasing flooding potential of roads and residential areas.

Due to the slope of the terrain any confluence of a rain event and a sea storm event is unlikely.

Further assessment is required by engineers for matters relating to storm water.

Figure a. Scenario modelling demonstrates the lowering of sand levels around the outlet. In the context of rising sea levels, these areas become the first to be impacted.

Figure b. The outlet (52) is in poor condition (not the focus of this assessment). Note the lower sand levels and seaweed strands which demonstrates that actions of the sea area interacting with this location.

7. HAZARD IMPACTS AND RISKS

The purpose of this section of work is to consider the inputs from the first part of the study and undertake an assessment of hazard impacts and risks on coastal landscapes of City of Victor Harbor. We undertake this in three steps:

1. Assign an inherent hazard rating,
2. Describe the likely impacts upon coastal regions,
3. Conduct a risk assessment utilising the risk framework of City of Victor Harbor.

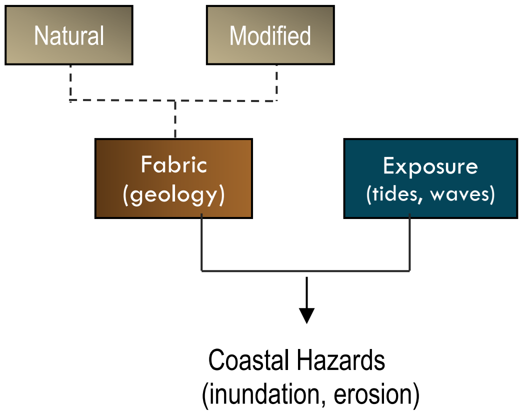
7. Hazard impacts and risks

Overview

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

1. Assign an inherent hazard rating

It is the combination of the characteristics of the coastal fabric and the nature of the exposure that determines the degree of hazard risk. 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 from flooding whereas an elevated coast is *inherently* not at risk from flooding.



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.

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, in the vicinity of The Esplanade Beach private assets are set well back from the shoreline behind the esplanade and are unlikely to be impacted by rising sea levels. However, storm water infrastructure is set within the dunes and is likely to be impacted. If seas rise as projected, then the dunes and beach may be eroded away which is likely to cause considerable social concern.

In summary, while the impact of sea level rise may be somewhat uniform on a coastal region such as the Esplanade Beach, the impact will be felt differently in the context of human experience. In the first instance, public infrastructure may be under threat, whereas in the second instance, private infrastructure will not be threatened but the human social concern may be great.

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

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

Note, 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.

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

This assessment utilises the Councils risk assessment framework and assessment is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. The risk assessment is conducted within either the inundation or the erosion risk assessment template, usually depending on the assignment of the inherent risk assessment (Step 1).

7-1 Inherent hazard risk assessment

Assessment methodology

The purpose of the inherent hazard risk assessment is to identify the inherent nature of a section of coast. This assessment takes into consideration:

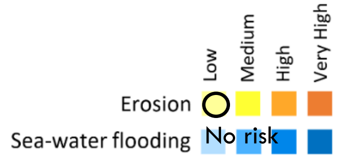
- The geological layout
- The erodibility of beach and backshores
- The historical analysis as to how the coastline has performed over time
- The exposure (set by Nature Maps)
- Whether any human intervention has altered the nature of the coastline.

The risk assignments range from 'low' to 'very high' and may include a 'no risk' category. For example, coastal land that is elevated above any inundation risk will be assigned 'no risk'. A dotted circle to the right of the main assignment indicates that the risk assignment requires intensifying due to unique factors, or to indicate a higher risk that does not qualify for an overall higher rating.

Note: Inherent risk ratings were applied by Dr R Bourman (Author, Coastal Landscapes of SA) and Mark Western (Integrated Coasts) in March 2021.

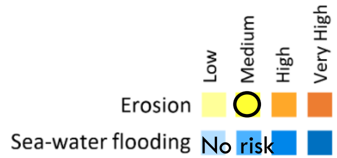
Coastal setting:

McCracken (Cell 10.1)



A fine-medium sandy beach with areas of rock and exposed low tide reef, backed by a vegetated dune that rises up to a former marine bench at 6.50m AHD upon which the trainline is situated. 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. The position of the toe of the dune accreted seaward between 1976 and 1999 by 4 to 8m and has remained in much the same position since.

Hayborough (Cell 10.2)



A fine-medium sandy beach with areas of rock and exposed low tide reef, backed by a vegetated dune that rises up to a former marine bench at 6.50m AHD upon which the trainline is situated. 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).

7-2 Description of hazard impacts

Public assets at risk

Trainline

The Goolwa to Victor Harbor trainline dissects the top of the former marine bench. The trainline is situated on Crown Land and is owned by the State Government. It is leased until 2026 to Steam Ranger to operate tourist train services. It is likely that the responsibility to protect this line will fall to the State Government. Council and private assets are set well back from the trainline.

In the context of projected sea level rises, the base of the embankment is likely to recede by 10 to 20m post 2050, with some recession likely prior to 2050. This slope will become increasingly unstable, and successive collapses will tend to make the escarpment increasingly vertical, and increasingly more unstable.

Beach access points

Beach access points are positioned along the beach. Over the longer term, if the dunes recede some of these will left stranded forward of the vegetation line and diminishing sand levels on the beach will make pedestrian access difficult (requiring redesign).

Storm water outlets (x3)

Two of the three outlets are positioned on the beach and actions of the sea already interact with these locations. In the context of rising sea levels, locations where sand levels are low will be impacted first causing further loss of sand and increased erosion of the backshore (in this case, the slope under the trainline).

The erosion modelling indicates ~10m to 20m recession of the shoreline by 2100. The trainline dissects the dune system at the top of the escarpment. As this is a fixed line, it will not be possible for the dune to translate landwards, and therefore the slope of the dune must increase. This slope will become increasingly unstable, and successive collapses will tend to make the escarpment increasingly vertical, and increasingly more unstable.

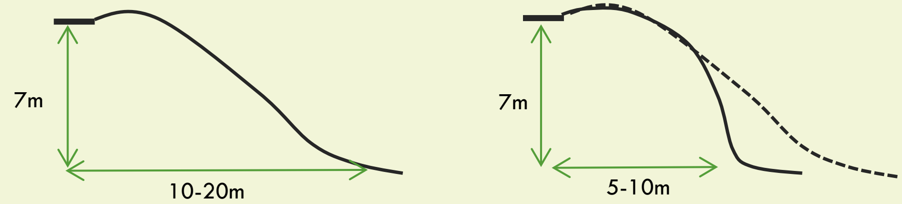


Figure a (top). Diagrammatic representation of impact of increase actions of the sea upon the slope of the trainline.

Figure b. The trainline viewed in perspective of the coast and the coastal slope on which urban settlement is positioned.

Figure c. Beach access points are positioned along the beach. In some locations where access ways exit on the beach, current storm action removes sand from the base of the stairs. Council uses front end loader to push sand back up around the base of stairs. Over the longer term, if the dunes recede some of these will left stranded forward of the vegetation line and diminishing sand levels on the beach will make pedestrian access difficult (requiring redesign and upgrade).

Description of hazard impacts (cont.)

Private assets

Private assets are set a long way back from the shoreline and positioned behind the trainline. Therefore, therefore no risk is envisaged for urban settlements positioned on the slope above the trainline.

Social disruption

The concept of social disruption is primarily concerned with issues of public safety and community concern (reputation).

In the context of safety issues, the assessment conducted within this project is only related to how impacts of the sea may <u>increase</u> the risk to people accessing the area. It is not related to any risks that the beach and backshore currently pose to the safety of people. This assessment remains with Council in its normal operation of risk. In the current era there appear to be no additional risks above those normally associated with a beach/ foreshore environment, apart from increasing difficulty accessing the beach when sand levels drop.

In the context of social concern If the dune and embankment recede and the slope becomes steeper between the railway line and the shoreline, then it may be increasingly difficult to provide beach access. However, this is unlikely to occur prior to 2050.

Ecosystem disruption

The assessment of ecology of risk in the context of this project is confined to that which may be described as 'ecosystem disruption' with the intent that this disruption would occur on a wide scale. For example, sea water flooding through to low lying land that is currently freshwater ecology would be irreversibly disrupted with incursion of saltwater.

There are no apparent risks for ecosystem disruption on a broad scale in this cell. However, coastal areas which are habitats for shore nesting birds are likely to be disturbed by retreating shorelines. The impact is likely to be the greatest in locations where shorelines are unable to retreat naturally due to human intervention. In this cell, the trainline will prevent a natural recession of the coastline and rising sea levels are likely to impact bird habitats so that they are disturbed or lost.

Summary: Hazard Impacts

If seas rise as projected, then increasingly the embankment under which the trainline is situated will recede so that the slope becomes unstable. The main hazard impact is to the viability of the trainline which is owned by the State Government. More minor risks relate to the viability of storm water outlets, and beach access points. In relation to the former, storm water lowers sand on the beach and these points become more vulnerable to attack from actions of the sea. The result of this is faster erosion of the embankment under the trainline. Broadscale eco-system disruption is unlikely, but shore nesting bird habitats are likely to be disturbed or lost.

7-3 Risk assessment using Council's risk framework.

McCracken (Cell 10.1)

Risk identification: If seas rise as projected, actions of the sea will increasingly interact with the backshore causing erosion and recession.

Coastal setting	The McCracken coastline is categorised as a fine-medium sandy beach with areas of rock and exposed low tide reef, 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. The position of the toe of the dune accreted seaward between 1976 and 1999 by 4 to 8m and has remained in much the same position since (this may be related to management practices by Council).

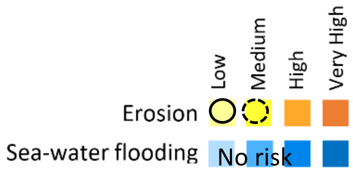
Are any strategies employed to mitigate the risk? Nil (apart from ongoing dune and vegetation management)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The trainline is positioned on top of a former marine bench at a distance from the shoreline of 10m - 30 m. Storm water outlets (x2) and beach access ways traverse the trainline. Increasing erosion will cause recession of the dune and embankment.	current	*Rare*	*Minor*	low
		2100	*Very Likely*	*Catastrophic*	Extreme
Private assets*	Private assets are mostly situated behind esplanade roads, and all private assets are situated landward of the trainline.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk
Social disruption	Increasing levels of sea level will mean that pedestrian access points will be more frequently eroded increasing safety risk. In the longer term, if the bank under which the trainline recedes it may be more difficult to maintain beach access.	current	*Rare*	*Minor*	low
		2100	*Possible*	*Minor*	Medium
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. Due to the slope of the backshore in this location, broad scale ecosystem disruption is not envisaged. *However, bird habitats may be disturbed or lost*.	current	*Unlikely*	*Minor*	low
		2100	*Possible*	*Moderate*	Medium*

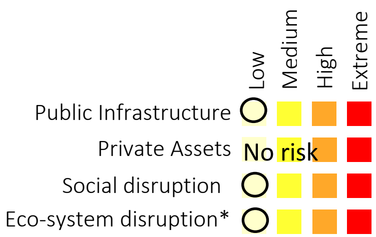
*Council not necessarily liable for private assets

Inherent Hazard Rating

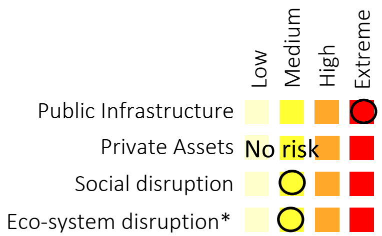
Sandy beach backed by dune system and former marine bench



Erosion Hazard Rating
(current outlook 2020)



Erosion Hazard Rating
(future outlook 2100)



Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment.

7-3 Risk assessment using Council's risk framework.

Hayborough (Cell 10.2)

Risk identification: If seas rise as projected, actions of the sea will increasingly interact with the backshore causing erosion and recession.

Coastal setting	The Hayborough coastline is categorised as a fine-medium sandy beach with areas of rock and exposed low tide reef, 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).

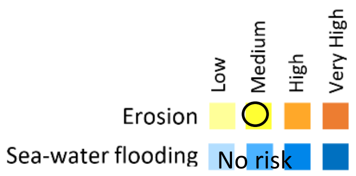
Are any strategies employed to mitigate the risk? A dilapidated retaining wall has been installed in much earlier times where the dune is at its narrowest.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The trainline is positioned on top of a former marine bench at a distance from the shoreline of 10m - 30 m. One storm water outlet and 5 beach access points traverse the trainline. Increasing erosion will cause recession of the dune and embankment.	current	*Rare*	*Minor*	low
		2100	*Very Likely*	*Catastrophic*	Extreme
Private assets*	Private assets are mostly situated behind esplanade roads, and all private assets are situated landward of the trainline.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk
Social disruption	Increasing levels of sea level will mean that pedestrian access points will be more frequently eroded. In the longer term, if the bank under which the trainline recedes it may be more difficult to maintain beach access.	current	*Rare*	*Minor*	low
		2100	*Possible*	*Minor*	medium
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. Due to the slope of the backshore in this location, ecosystem disruption is not envisaged. *However, bird habitats may be disturbed or lost*.	current	*Unlikely*	*Minor*	Low
		2100	*Possible*	*Moderate*	Medium*

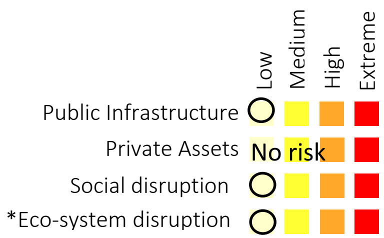
*Council not necessarily liable for private assets

Inherent Hazard Rating

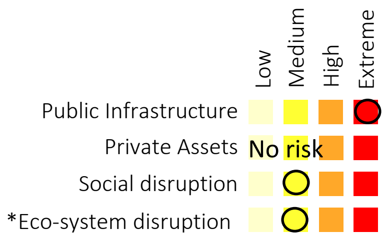
Sandy beach backed by dune system and former marine bench at ~8-9m AHD



Erosion Hazard Rating
(current outlook 2020)



Erosion Hazard Rating
(future outlook 2100)



Note: the assignment of future risk assumes that no action is taken to mitigate the risk apart from normal safety procedures.

Rain intensity and storm water impacts not assessed in this risk assessment.

8. Cell Summary

8. Summary: 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

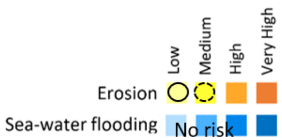
Storm water from urban settlement set landward and above the trainline only flows to the beach in one location which is set within the embankment at 3m AHD. Some lowering of sand levels on the beach is observed. Other storm water outlets appear to drain into the natural swale between the trainline and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

Overview of Impacts

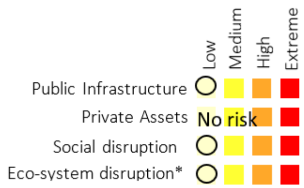
The main threat that sea level rise will bring is recession of the embankment under the trainline resulting in increasing stability over time and placing the trainline at risk. Additional risks relate to the location of storm water outlets, which in two cases may also be increasing potential for erosion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

Inherent Hazard Rating

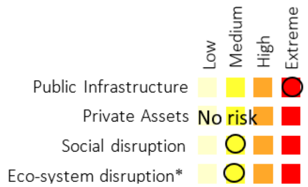
Sandy beach backed by dune system and former marine bench



Erosion Hazard Rating
(current outlook 2020)



Erosion Hazard Rating
(future outlook 2100)



8. Summary: 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

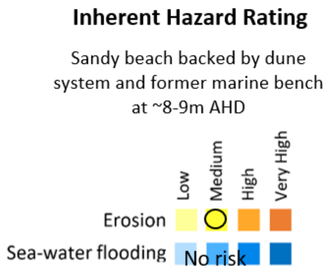
Scenario modelling demonstrates that the current 1 in 100-year ARI storm would impact the backshore, but the beach would tend to rebuild in this location. Modelling for 2050 indicates increased pressure on the backshore with recession likely (measured in metres). Modelling for 2100 indicates that both 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).

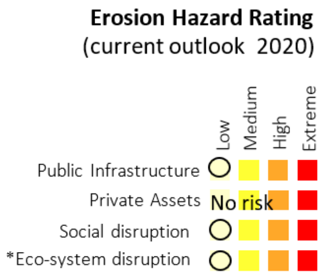
Storm water runoff

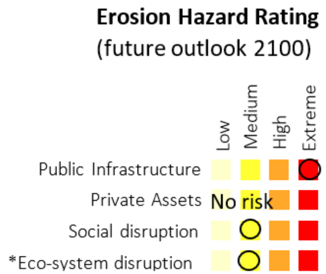
Storm water from urban settlement set landward and above the trainline only flows to the beach in one location which is set within the embankment at 3m AHD. Some lowering of sand levels on the beach is observed. Other storm water outlets appear to drain into the natural swale between the trainline and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







PART 2

COASTAL ADAPTATION STRATEGY (2021-2031)

Part 1 of this project has established a baseline understanding of how the coast has been performing over the last century, and the sea-flood modelling has provided 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.

Project Note: This section of work adopts the framework and understanding of adaptation options and strategies from CoastAdapt. Further reading is available at:

Coastadapt.com.au/understand-adaptation
Coastadapt.com.au/adaptation-options

Adaptation strategy

1. COASTAL ADAPTATION - OVERVIEW

This section of work adopts the framework and understanding of coastal adaptation options from CoastAdapt[1] which notes that 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.

CoastAdapt notes two general forms of adaptation strategies. The first is known as 'adaptation pathways' where the emphasis is placed on laying out likely scenarios, action pathways, and identifying trigger points for action. The second is known as 'adaptative management' where decision making finds its foundation in ongoing monitoring[2]. The problem with the first 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. This project adopts the second method. The rate of future sea level rise and associated changes to the coast are unknown, and therefore ongoing monitoring of the coast will provide the basis for timely decision making.

[1] Coast Adapt, coastadapt.com.au/understand-options

[2] Coastadapt.com.au/understand-adaptation

Adaptation responses

Within the adaptation response categories there are a range of potential adaptation responses.

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.

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.

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.

Adaptation timing

There are two broad ways in which adaptation can occur in relation to timing.

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 face of the impacts of climate change.

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.

Adaptation strategy

2. COASTAL CONTEXT - SUMMARY

Legacy issues (human intervention)

The main legacy issue within McCracken-Hayborough is the installation of the trainline in the 1860s upon the former marine bench that sits at the base of the coastal slope in this region. If seas rise as projected, then this coastline will recede and the trainline will act as a hold point that will either need protection or removal. However, as noted previously, this is unlikely to occur until the latter part of this century.

A retaining wall was installed seaward of the trainline before 1949 which was regarded at the time as necessary to protect the trainline from actions of the sea (Figure a). However, this coastal region has accreted over the last 70 years and the retaining wall has been mostly buried (Figure b). It is likely to be several hundred metres in length. It is recommended that the ownership of this retaining wall be established, and its current function formally quantified. The retaining wall is unlikely to be in a condition to protect from actions of the sea if the accretion trend reversed and this section of coast went into recession, but it is likely to perform an ongoing function as a dune stabiliser and sand trap if the coast were to undergo future recession.

Finally, there are three storm water outlets in this region that are set further back from the main vegetation line due to the ongoing accretion that has occurred over the last seventy years. In two of these locations the retaining wall is visible at the beach level because the storm water outlets have prevented the vegetation line/ dunes from accreting (Figures c, d).

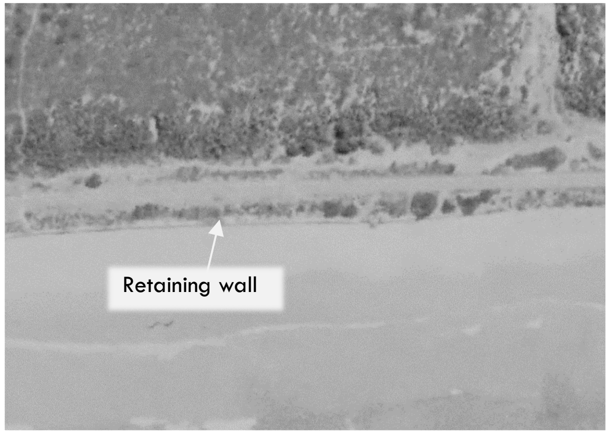


Figure a: Aerial photograph 1949 shows the position of the retaining wall forward of the dune line.

Figure b: Since 1949 the dunes have accreted and most of the retaining wall is buried.

Figures c, d: The retaining wall is visible at two locations where storm water outlets have prevented the dunes from accreting.

Adaptation strategy

3. ADAPTATION STRATEGY (2021-2031)

Summary of the strategy

An **incremental** adaptation approach is recommended for McCracken – Hayborough. While this section of beach undergoes natural cycles of erosion and accretion which can be measured in decades, it has been largely stable over the last seventy years and has accreted from its position in 1949.

Initially, a **'hold the line'** approach should be employed using **environmental management** techniques. This represents a continuation of the existing strategy that includes maintaining and establishing vegetation within the sand dunes, pedestrian control using established pathways and weed control.

The modelling indicates that if the rate of sea level rise increases in accordance with projections, then longer-term recession of the beach will result, and eventually the embankment under the trainline will come under threat. However, this is more likely to occur in the second half of this century when the rate of sea level rise is projected to accelerate.

Because there is unlikely to be any immediate threat, the approach should be to **monitor** this beach over time, with special attention given to changes or impacts to the backshore. Monitoring over time will enable decision makers to determine when the beach is operating within its normal parameters, and when it has moved out of its range due to sea level rise. It is recommended that a monitoring program be designed and implemented within 1-2 years.

Storm water outlets

Council advises that a storm water consultant has been contracted to review the storm water management system for City of Victor Harbor. Therefore, the role of this current project is to provide ancillary input from the perspective of coastal management in the context of long-term sea-level rise. The locations of storm water outlets are:

- Two storm water outlets are located in the vicinity of Hayward Court. On the western side, the outlet is ~400mm pipe positioned within the sand dunes and appears to cater for a smaller catchment. On the eastern side the outlet contains two pipes at ~400mm which are positioned within the retaining wall (Figure a).
- Yandra Terrace outlet is a single 675mm pipe set within the retaining wall. The outlet is set further landward than the current vegetation line of the dunes (Figure b).

<u>General observations</u>

The outlets were observed on 20 June 2021, three days after substantial rain occurred at Victor Harbor (~50mm). In this location which is dominated by sand and low – medium energy waves, the sand quickly rebuilds after being scoured by storm water outflow.

However, the modelling shows that sand levels in the vicinity of the outflows are lower and therefore in the context of sea level rise will be the locations that are most vulnerable (Figures a, b).

Figure a: Two storm water outlets in the vicinity of Hayward Court lower sand levels on the beach.

Figure b: Storm water outlet in the vicinity of Yandra Tce lowers sand levels on the beach.

Adaptation strategy

Review by Magryn and Associates

The adaptation strategy proposed relates to management of existing stormwater. There are several stormwater outlets that currently discharge to the beach, causing erosion. Magryn and Associates do not consider this to be an urgent concern, however the upgrades outlined below should be considered for the near future.

Hayward Court (2 outlets)

In relation to the two outlets in the vicinity of Hayward Court, Magryn and Associates consider it to be feasible to redirect the storm water from the eastern outlet (Figure a) to the western outlet. It will likely be required to upgrade the size of the pipe for the eastern outlet. Rock scour protection will be required at the outlet.

A detention basin may be included on the landward side of the trainline, to reduce the flow rate and velocity discharging to the beach at the outlet. The feasibility of this is subject to space and financial constraints.

Adaptation Proposal:

To conduct a feasibility study and calculate the cost for redirecting the storm water from Hardy Street into the storm water outlet further to the west so that the storm water can be managed further back from the beach. Consider the feasibility of a detention pond on the landward side of the trainline.

- Recommended timing for the study: 1-2 years
- Recommended implementation: within 5 years.

Figure a: Storm water outlet from Hardy Street drains on to the beach causing scouring. Consider diverting to outlet further west which is capable of draining higher up the coastal slope. Add rock scour protection.

Adaptation strategy

Review by Magryn and Associates

There are several stormwater outlets that currently discharge to the beach, causing erosion. Magryn and Associates do not consider this to be an urgent concern, however the upgrades outlined below should be considered for the near future.

Yandra Terrace (1 outlet)

In relation to the outlet in the vicinity of Yandra Terrace (Figure a), Magryn and Associates recommend to 're-establish the dune system and install a pipe extension to discharge stormwater to the edge of the dune. A sandbag headwall and rock scour protection would be required.

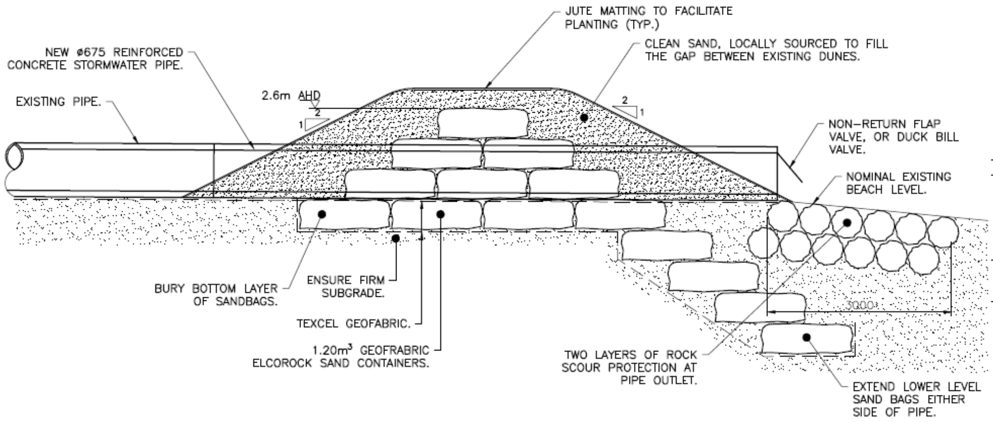
A detention basin may be included on the landward side of the trainline, to reduce the flow rate and velocity discharging to the beach at the outlet. The feasibility of this is subject to space and financial constraints'.

Adaptation Proposal:

Install a pipe extension, establish the dune system in line with the main vegetation line and provide a sandbag headwall and scour protection. This is item is for consideration by the storm water consultant.

Undertake feasibility study and cost estimates for installation of detention swale on the landward side of the trainline.

- Recommended timing of study 1-2 years.



YANDRA TCE OUTLET

N.T.S.

MAGRYN

ENGINEERING CONSULTANT

267 BRIGHTON ROAD
SOMERTON PARK, SA 5044
TELEPHONE: (08) 8295 8677
www.magryn.com.au

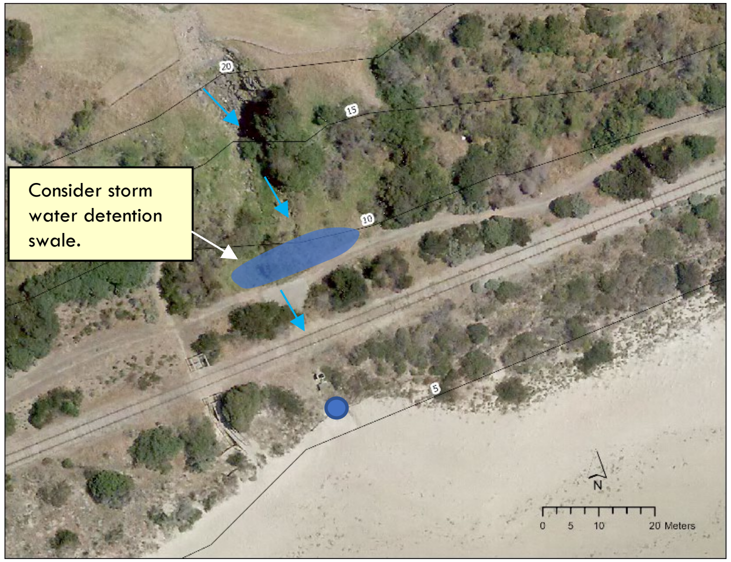


Figure a: Storm water outlet currently drains directly on to the beach and prevents the dune from forming in this location. Recommendation to extend the outlet pipe and form the dune to the main vegetation line but using construction methods that can reduce the length of the pipe in the future if the coast goes into an erosion cycle.

Adaptation strategy

Monitoring strategies

The purpose here is not to provide a design for a detailed monitoring program but to provide a context for understanding why monitoring is necessary, and broadly, what type of monitoring actions are likely to be required. In this coastal region an 'incremental approach' to coastal adaptation is recommended. In this current era, the coast is not at risk from erosion or inundation. In fact, this section of the coastline has continued to accrete over the preceding decades.

Prime response – monitor and respond

Therefore, in this cell, the prime adaptation response will be to 'monitor and respond'. Data should be collected on an ongoing basis and compared to the baseline we have established in this study. A baseline has been established in two main ways. First the digital elevation model (DEM) and the aerial photograph captured in 2018 provides a point in time baseline of the current form of the coast. Future captures of photography or digital elevation models can be compared, and analysis undertaken as to coastal behaviour. 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 to identify how the coastline has performed over decades. In summary, we have both a point in time capture, and an understanding of how the coastline has behaved over time. This baseline understanding will be invaluable to assist in determining when the coastline is operating outside of its normal parameters due to sea level rise.

Monitoring actions

As this coastline has been largely stable, monitoring actions should be kept simple and cost effective. The next stage of the adaptation strategy should be to design and implement a cost-effective monitoring program. Monitoring activities may include:

1. When new aerial photography is obtained by Council (usually every 2 years), compare the position and changes in the dunes and vegetation line.

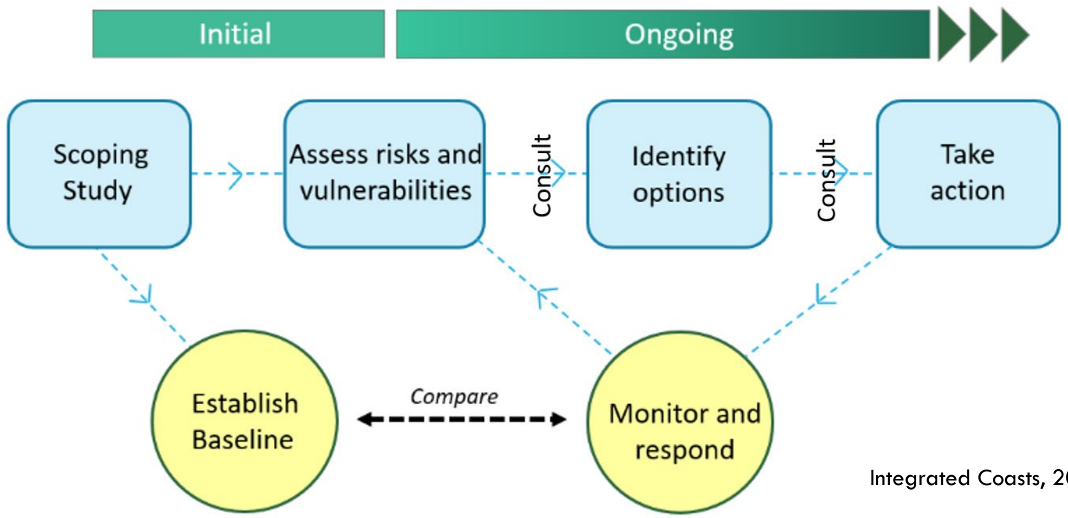
2. When a new digital elevation model is obtained (usually 5-10 years), compare the data points to determine whether the coast is accreting or eroding.

3. In the event of a severe storm, identify the damage to the dune system and track recovery. This is likely to be most effectively managed with drone photography. At the outset of the monitoring program define the parameters of a 'severe' storm.

4. When SA Coast Protection Board (Coast and Marine Branch) captures profile data for the profile lines in this cell (or adjacent), identify trends in bathymetry.

5. Periodically (every 2 years) analyse the data from the tide gauge to identify sea level rise trends and storm activity.

Coastal Adaptation Strategy – Monitor and Respond

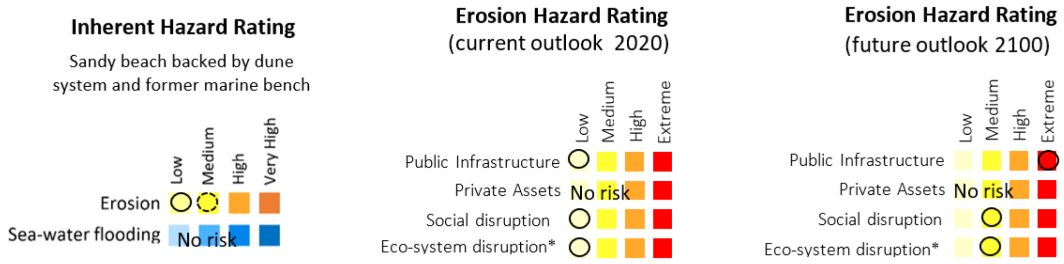


Integrated Coasts, 2017

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).

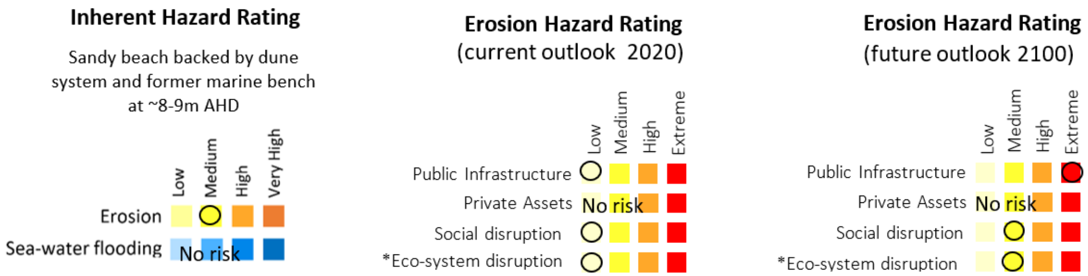
Summary table:

	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 tasks: McCracken – Hayborough (Cell 10)

	Task	Reason	Priority	Timing
1	Develop a long-term monitoring program.	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	Conduct a feasibility study and cost estimates to reduce the flow of storm water to the beach from two outlets adjacent Hayward Court.	Storm water is scouring the beach, reducing sand levels around outlets, and in some locations preventing the dune from establishing.	Low	Within 5 years
3	Upgrade storm water outlet at Yandra Terrace with design able to be adjusted for cycles of erosion / accretion.	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
4	Ascertain ownership of the old retaining wall, assign a function to the structure as something other than 'retaining wall'.	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