Coastal Adaptation Study &
Coastal Adaptation Strategy

ENCOUNTER BAY

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 12

For City of
Victor Harbor

Integrated Coasts

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

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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 cliff-tops 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

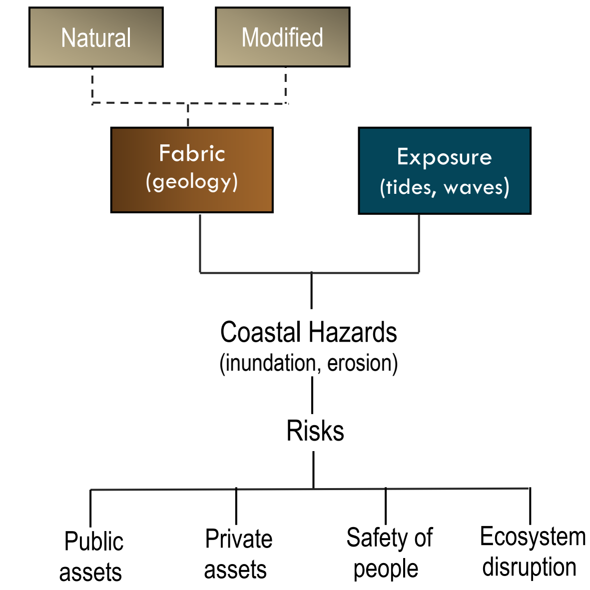
CHANGES IN THE RELATIONSHIP

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



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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 - south east** (CoastAdapt) and within tertiary cell, Conservation Cell, Fleurieu 12.

Encounter Bay (Cell F12) is reviewed in this report.

1. Introduction

Regional Setting

Fleurieu 12

Secondary Cell: Fleurieu

Tertiary Cell: Encounter Bay

Secondary Cell

Australian regional setting

Encounter Bay 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.

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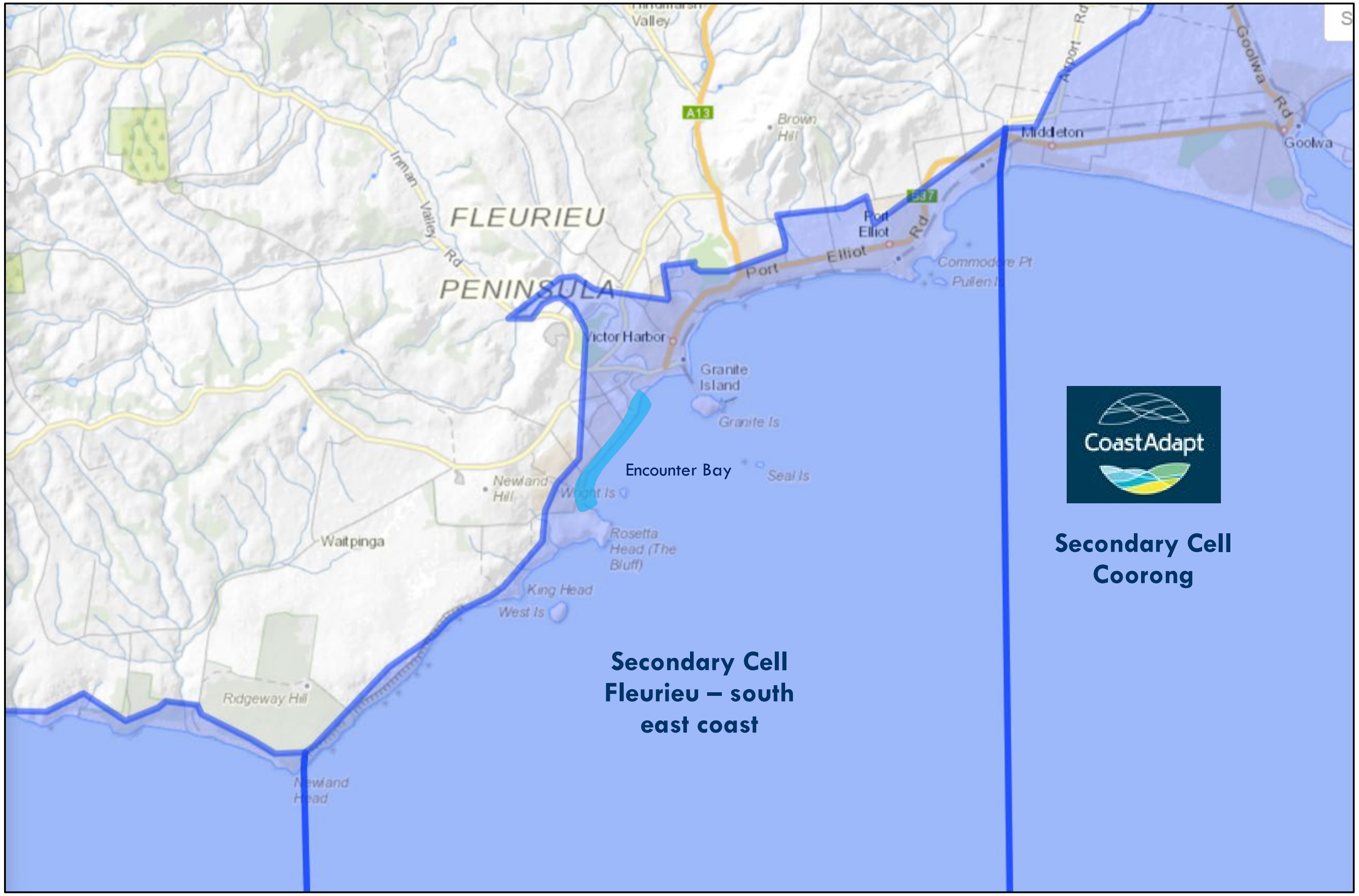

The dominant regional processes influencing coastal geomorphology in this region are the Mediterranean to humid cool-temperate climate, micro-tides, high energy south-westerly swells, westerly seas, carbonate sediments with interrupted swell driven longshore transport, and the Southern Annular Mode (driving 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 12

Secondary Cell: Fleurieu

Tertiary Cell: Encounter Bay

Tertiary Cell

Nature Maps (SA)

Relative Exposure
Sheltered

Wave energy
Low

Shoreline class
Reflective (with rocky platform)

Sand rating
Coarse sand beach

Notes:
Minor cells represent areas where geomorphologic factors are different from neighbouring areas and require independent analysis.

Nature Maps SA assigns this cell as Fleurieu 12.

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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)

Project note: Historically, the term Encounter Bay has been used to denote a region as well as the suburb west of the Inman River. Context will generally identify usage but primarily in this report we are dealing with Encounter Bay as the portion of the coast between Inman River and The Bluff.

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 utilised in the early stages of the settlement.

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].

Encounter Bay – 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] This historical narrative relies on 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.

Construction of coastal infrastructure

Settlers arrived from 1839 onwards and District Council of Encounter Bay was founded in 1853. The South Australian Government instructed the Council in 1854 to construct the Lilliputian jetty and seawall (Figure b) on the eastern side of The Bluff and to build a road from the jetty to Yilki. However, it was not known that Governor Hindmarsh owned the land and he claimed damages. The South Australian Government argued that the South Australian Act (1836) reserved 100 feet from the high-water mark all around the coast for road or other public purposes. The matter was resolved when the Government purchased the land in 1858.

Project Note: The early adoption by the South Australian Government of the planning principle that the land immediately above the high-water mark was reserved for public purposes means that as a general rule, private assets are positioned landward of public land. In the context of coastal adaptation and projected rising sea levels, this means that unlike other places in the world, private assets in Victor Harbor are provided with a land buffer and the likely focus of initial adaptation will be for Council to manage its own assets.

[7] Page, M. p. 14

Figure a: Encounter Bay, 1838, View of the Company's fishing station, William Light (State Library of SA, B9396).

Figure b: Encounter Bay, 1920, Bluff jetty and seawall constructed 1850s (State Library of SA, B-7735).

2. Settlement history

Residential settlement

In this era the land was primarily used first as a whaling station and then for farming. Ridgway Newland, a Congregational clergyman, and about 30 other relatives and friends established a settlement at Yilki, about halfway between the Inman River and The Bluff. The area was later connected to the Victor Harbor township by virtue of a bridge over the Inman River, constructed in 1863.

Recorded storms – to 1920.

A review was undertaken to identify significant storms with a particular focus on any impacts to the urban environment.[8] Understandably, none of the archives specifically mentions the impact of storms into Encounter Bay area but storms reported for Victor Harbor would also have been experienced in Encounter Bay. Storms described as 'great', 'severe' and sometimes accompanied by descriptions of 'wind, rain, and thunderstorms' include: 28 September 1867, 13 September 1880, 3 September 1887, 22 August 1888, 2 February 1903, 8 April 1905 and 27 February 1914.

Events that included descriptions of the sea or coastal damage include:

- 16 September 1902, 'Victor Baths damaged – southeast corner collapses'.
- 21 September 1903,'A gale set in with considerable amount of damage. On the coast heavy seas have broken continuously'.
- 31 July 1905, 'A very rough sea on Saturday and Sunday. Waves going over breakwater'.
- 21 March 1906, 'The wind blew fiercely, and rain fell in torrents. Extraordinary high sea'.
- 20 July 1916, 'Great storm – little damage to the town but fishing boats were not so fortunate'.

It is understood in this earlier time that very little urban infrastructure was built near the coast and therefore reporting of storm damage may be low. However, in an era when reporting of incidents such as 'one or two chimneys blowing over' made the news, it is highly unlikely that a large storm that inundated the urban environment and damaging buildings would have gone unreported.

Project note: This list demonstrates that most storms were experienced between March and September.

Urban legend:

One story was recounted in The Mail, 19 September, 1925 of an incident in the late 1880s when a 'huge sea broke over the town' on a 'calm day', with the result that 'every house in the vicinity had its floor covered'. The unnamed person telling the story rowed his boat around town until the flood water subsided within two hours. He judged that it must have been caused by an earthquake.

It was not possible to corroborate this story and even if true, it is not relevant to this study.

Figure a: Road to The Bluff, 1900, (State Library of SA, B63092).

Figure b: Road to The Bluff, 1900, and Yilki settlement in the distance (State Library of SA, B63092).

[8] Newspaper reports at trove.nla.gov.au and review of book, Victor Harbor, by M. Pace (1987).

2. Settlement history

Encounter Bay - suburb (1920 - 1970)

The key focuses of this section relate to foreshore development, impact of actions of the sea, and residential expansion.

Foreshore development

By this stage, Victor Harbor township had been established as the main commercial centre and very few mentions are made of Encounter Bay in the newspapers.

Seawall – Yilki (1947-1951)

The exact date for the installation of the sloping seawalls in the Encounter Bay region (Yilki) is unknown but these are likely to have been installed in period 1947 to 1951 (Figure a)[9].

Figure a. Franklin Parade (Yilki). A sloping stone wall was installed in this region in 1949-1951. (M. Western, 2021)

[9] Victor Harbor Times, 17 June 1949
[10] The Mail, 24 April 1943

Storm action upon coastal structures.

The newspaper records from both Victor Harbor and Adelaide are replete with storm stories, especially in the period 1920s to1940s. The main focus of the stories was upon the impact of the township of Victor Harbor with records of storms for, August 1923, March 1928, October 1928, April 1932, April 1938, and March 1946 (See Cell 11, Victor Harbor Central).

Only two mentions are made of storm impact to the Encounter Bay area. The Adelaide Mail reported a storm on 24 April 1943 which stated, 'at Encounter Bay the heaviest sea seen for many years was witnessed. Franklin Parade was undermined and had to be closed to traffic'[10]. It is likely that this event was the impetus for the construction of the seawall in 1947.

However, it is likely that most of the wall was washed away in the winter of 1953. In 1954, The Progress Association requested that the Council rebuild the 'foreshore stone wall which was washed away….and where the sea has now encroached in places up to three and four yards[11].

Council had completed two-thirds of the repair by 26 March 1954 which included, 'quarrying and carting of stone and filling for the sea wall at Yilki'[12].

[11] Victor Harbor Times, Progress Association Report, 29 January 1954.

Repairs to seawall at Bluff jetty

In a similar time period, 1947 to 1949, repairs were made to the Bluff Jetty seawall which had been constructed in the 1850s.

Key points:

The first coastal structures installed in the Encounter Bay region were the Bluff jetty and the road between Yilki and the jetty (1850s).

It is understood that when storms impacted Victor Harbor township these would also have impacted Encounter Bay. Only two references specifically mention Encounter Bay (1943, 1953). In both instances these relate to the undermining or erosion of the road.

A sea wall was installed at Yilki circa 1947 to 1951 but was washed away two years later and was rebuilt in 1954.

In the storm event (s) of 1953, residents noted that erosion had occurred in places up to three and four yards.

[12] Victor Harbor Times, Council report, 26 March 1954

2. Settlement history

Residential expansion

The Encounter Bay area was largely untouched by residential subdivision until the 1950s. After the Second World War demand for holiday houses grew and Encounter Bay was subdivided to meet that demand. By the close of the period, most of the sea front had been developed with housing (Figures a,b,c).

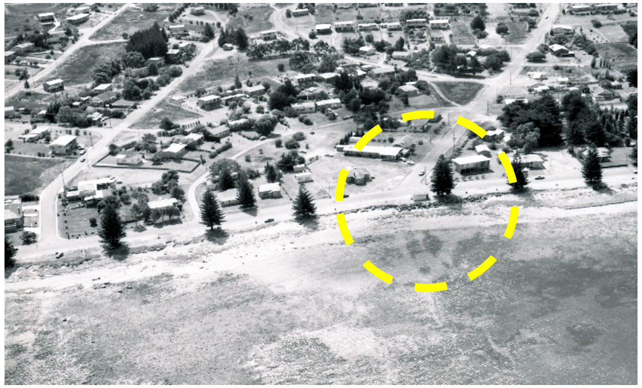
Protection works

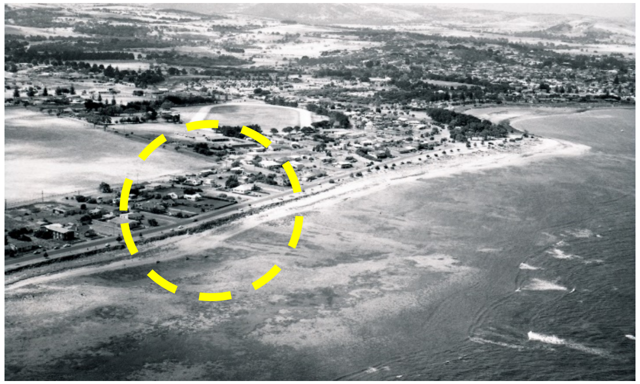
The aerial photography from 1975 provides a context from which to identify protection structures installed in this era. The South Australian Coast Protection Board was formed in 1972, and up until this time protection was usually a matter for Council and sometimes the public also took matter into their own hands and installed ad hoc protection works.

Protection works in Encounter Bay include:

a. Formal rock protection to foreshore toilet block (Figure a).
b. Informal (ad hoc) minor protection works to the road embankment (Figure b).
c. A combination of the stone wall from 1950s (including the work at the corner of Tabernacle Road) and newer installation of rock.

In summary, from 1940s to 1970s actions of the sea impacted the road reserve requiring repairs to works or installation of new protection.





Figures (clockwise).

a. Rock protection to toilet block.

b. Minor protection (ad hoc?) to base of road embankment.

c. Old stone walling, rock protection.

Encounter Bay, 1975, Oblique photography, Coast Protection Board.

2. Settlement history

Encounter Bay – modern era (1970 - 2020)

The key focuses of this section relate to human intervention in the coastal zone, the impact of storms, and the nature of residential expansion. This section of work relies more on the archives from SA Protection Board (Coast and Marine Branch) which was established in 1972 and less on newspaper reporting that increasingly diminishes in this time period. References to scans from Coast and Marine Branch are indicated by the relevant date in brackets.

Interventions in the coastal zone

- **Encounter Lakes subdivision (1987-1988)**

Kinhill Engineers lodged application for Encounter Lakes Subdivision for a subdivision that included a lake system connected to the ocean by pipe to the ocean floor 400m offshore. The height of the rip rap walls for the lake were designed at 0.6m AHD allowing for a mean level of the lakes to be 0.00m AHD and a high tide of 0.2m AHD. There appears to be some intent that the lakes become accessible from the sea in the future by way of an open channel, but this option was not pursued (19870908, 19871118). Issues raised by various Government departments relevant to this study include (19871118):

  - Was the height of rip rap wall appropriate to cater for 1 in 100-year storm event?
  - Was there a possible problem with confluence of a high tide event and a storm water event?
  - What allowance has been made for increases in sea level rise?
  - How would the lake system manage pollution from storm water runoff?

Answers were not found within the archives, but it is likely that the design of the flushing pipe at 1.5m diameter to operate 400m offshore at depth -2m AHD controlled the level of water within the lakes irrespective of actions of the sea. A condition of approval (19871224) that the lake was not to receive storm water flows apart from those generated by the subject land (i.e. the proposed development).

In 1988, approvals were obtained to reduce the length of the flushing pipe from 400m to 260m (19881214).

Figure a. Installation of pipe to ocean floor by way of temporary rock and earthen structure, pipe installed in the middle (Photograph - Coast Protection Board, 19860319).

- **Yilki – increased parking 1999- 2001**

Increased demand for parking in Yilki shopping area resulted in the introduction of a ‘slip lane’ and parallel parking. Community opinion varied with some calling for a larger car park which would necessitate encroaching into the beach area while others called this proposal ‘neither ecologically nor economically sustainable’[13]. The matter was referred to Coast Protection Board, and while approval was not located in the archives, it was likely approved (20011004).

The overall encroachment of the road and parking development towards the coast was ~3m.

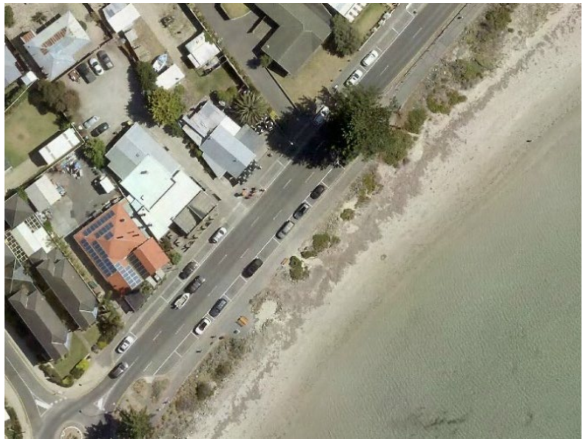


Figure b. Slip lane and parallel parking formed at Yilki, 2001, (Aerial photography, 2018)

[13] Victor Harbor Times, 29 July 1999.

2. Settlement history

- **Encounter Bay boat ramp**

The boat ramp facilities at Encounter Bay were first upgraded in 1987 (Figure c). Prior to the work the channel was dredged, and the spoil used to raise the area under which the current car park is situated.

Figure a, b. Dredging of Encounter Bay boat ramp (Photographs - Coast Protection Board, 19860319).

[14] Victor Harbor Times, 8 April 1999.

[15] www.cordellconnect.com.au

In time period 1996 to 2000, significant consideration by Council and the community was given in time period 1996 to 2000 to a proposed boat ramp and breakwater facility at Bridge Street near the Yacht Club. Despite this location being favoured by Coast Protection Board, opposition to the site appears to have grown by 2000[14]. Subsequent to 2000, Council moved its attention to upgrading the boat ramp at The Bluff and facilities were completed circa 2008 at cost of $350,000[15].

In 1999, the channel was dredged again, and the spoil was deemed appropriate for use along the beach and was deposited in the backshore along Franklin Parade between Battye Road and Fell Street[16].

Figure c. Boat ramp constructed in 1987, jetty added in 1998 (Photograph – Coast Protection Board, 20061205)

[16] www.victor.sa.gov.au

[17] Victor Harbor Times, 15 September 1989.

Storm impacts on coastal structures (1970-2020)

- 10-18 September 1989. Storms caused damage to the 'old stone wall' at Yilki requiring repairs[17].
- August 1992. Erosion of 200m section of coast near Whalers Road of up to 1.5m - 2.0m, with roots of Norfolk pines exposed. Figure (d) shows minor storm after placement of rock.
- 3 August 2004. 1.925CD. Storms caused erosion to rock protected backshore near Nevin Ave (Figures a,b, next page) and Whalers Road toilets.
- July 2011. Erosion of embankment between Fell St and Fountain Ave (Figures c,d, next page)
- 4 June 2012. Storm caused minor erosion at Franklin Parade.
- October 2013. Erosion of ~100m of embankment in vicinity of Ridgeway Street (20131002).

Figure d. Storm in Encounter Bay 1st October 1992 (Photograph - Coast Protection Board, 19921001).

2. Settlement history

Storm action on coastal structures (cont.).

Figure a. Erosion damage near Nevin Ave, 3 August 2004, 1.925CD (Photograph - Coast Protection Board, 20040810).

Figure b. Erosion damage near Nevin Ave, 3 August 2004, 1.925 CD (Photograph - Coast Protection Board, 20040810).

Figure c. Erosion damage between Fell Street and Fountain Ave, June 2011 (Photograph - Coast Protection Board, 20110616).

Figure d. Erosion damage between Fell Street and Fountain Ave, June 2011 (Photograph - Coast Protection Board, 20110616).

Figure e. Storm impact between Fell Street and Fountain Ave, 4 June 2012 (Photograph - Coast Protection Board, 20120604).

Correlation with tidal data

2003 – tide data was over 1.60m CD 15 times. This only occurred **twice** in 37 years of data (1971, 1981).

Between 2007 and 2011 tides were over 1.60m CD:

- 2007 – 20 times.
- 2009 – 17 times.
- 2011 – 15 times.

Tide heights for pictured events 4 June 2012 was 1.353m CD and 30 April 2014 was 1.458m CD. The likely cause of erosion was increased storminess in this time period. (See also exposure section for analysis).

2. Settlement history

Coastal management strategies (1970-2020).

The protection strategies employed in Encounter Bay are as follows:

Stone walling.

Installed in 1950s, repaired 1989 (Yilki region).

Rock revetment (from Nevin to ~Tabernacle Road)

- Rock revetment was installed in front of the toilet block near Whalers Rd prior to 1975.
- Installed in 1992 as 'temporary rock protection' to the north-east of the toilet block using free supplies from a local development (19920130).
- Installed either in late 1992 or early 1993, 150m of rock revetment to the north-east of the toilet block with assistance of $25,000 grant from Coast Protection Board (19921006).
- Rock revetment upgraded in vicinity of toilet block and extended in 2005 after storms of 2004 (Photo 20040810).
- Rock revetment installed in front of Yilki shops after more rapid erosion ~2020.

Sand nourishment (Fell Street)

Subsequent to storm event in 2011, sand was imported in August 2011 and installed adjacent to the embankment. The source of this sand is unknown and may have been completed as emergency works (Figure b). However, the storm of 4 June 2012 removed most of this sand and a further 1500m3 was transported from Kent Reserve (20120605).

An additional 400m3 in 2013 for sand nourishment of the 100m of the embankment between Fell and Ridgeway Road (20131002).

Cement blocks (Fell Street)

It is likely that the sand nourishment was not deemed a longer-term solution and cement blocks were installed in 2019 to the embankment between Fell Street and Ridgeway Road in a tier formation 5 levels high (Figure b).

Vegetation and fencing

Council has employed dune vegetation and pedestrian control using fencing over a long period of time (especially between Inman River and Bartel Blvd.).

Figure a. Rock revetment extended Jan 2005 (after storms in 2004). (Photograph - Coast Protection Board, 20050101).

Figure b. Cement blocks 5 tiers high, in vicinity of Fell Street (Photograph – M. Western, 2021).

Summary: 1970 to 2020

Interventions in the coastal zone included:

- Outlet pipe to the ocean for Encounter Lakes development (1988).
- Parking at Yilki and Fell Street (1999).
- Upgrade of boat ramp facilities (2008).

Increasing erosion due to increased storminess from the 1990s onward resulting in protection to:

- Nevin Ave to Whalers Rd (1990s)
- Upgraded & extended to Fountain Ave (2005)
- Sand nourishment to Fell Street (2011)
- Fell Street – cement blocks (2019)
- Yilki Shops – rock revetment ~2020.

2. Settlement history

COASTAL STUDIES AND REPORTS

The purpose of this section is to identify and review previous studies that have focused on coastal matters within this cell. Studies that deal more specifically with coastal adaptation are reviewed first and in more detail. Other studies that may just intersect with coastal matters are reviewed more briefly.

Coastal Studies

Foreshore Protection Study, Magryn, 2006.

The study area for this project was between the Inman and Hindmarsh Rivers but is related to Encounter Bay (Cell 12) in that it evaluates sand supply in the region. The catalyst for this study appears to be the increasing concern about erosion since 2000 (residents say 1997). There were also two storm events in 2004 and 2005.

Shoreline Analysis

The beaches fronting Victor Harbor onto Encounter Bay between the outlets of Inman River and the Hindmarsh Rivers, including Police Point, have remained reasonably stable during the period 1949 to 1997, and have accreted and built out in some areas.

In 1997 training groyne walls were built to the mouth of the Inman River, cutting off a loop of the river adjacent to the beach. This area of some 15,000 square metres has stabilized, vegetated and built up since this time, trapping sand and acting as a "sand sink" to the beach system. It is estimated that this area has trapped in the vicinity of 15,000 to 45,000 cubic metres of sand. Since 1997 changes to the beach system have occurred. These can be summarized as:

- A narrowing of the beach in front of the Esplanade.
- Large reduction in the size of the sand lobe under the causeway at Police Point, in the order of 75m.
- Narrowing of the beach in front of the Soldiers Memorial Gardens and storm wave overtopping of the wall, narrowing of the beach further east to the yacht club.

The report summaries that 'all of these changes are symptomatic of a reduction of sand supply to the beach system, while also acknowledging that the area is a 'low sand budget area'.

Project note: The inference in this analysis is that the construction of the groyne at Inman River has caused reduced sand supply to beaches to the east/north. This may or may not be true, or may be only partially true. Since 2012, the beaches along The Esplanade to the causeway have accreted.

Recommendations of this study include:

- Installation of sand drift fencing to the foredune in front of the "sand sink" area and replenishment of sand and vegetation to the beach in this area, to build and stabilize the foredune and limit further sand being lost to the "sand sink".
- Replenishment of sand to the sand lobe under the causeway, which acts as a sand bank for the beaches either side.
- Installation of sandbag groynes to beaches in front of the Esplanade and Bridge Terrace in critical areas, and filling of the adjacent beach with a supply of sand. It is important that these groynes be filled with sand, or the sand they trap from the beach system will cause further downdrift erosion.
- Modification or extension of the seawall in front of Soldiers Memorial Gardens to prevent wave overtopping in the case of a storm.

These recommendations form a three-pronged attack to:

- Reduce further loss of sand into the "sand sink"
- Restore the sand lobe at the causeway
- Provide protection and nourishment at critical areas of concern along the beach. Any of these can be undertaken alone, but maximum benefit will be achieved from undertaking all three recommendations.

Summary:

The main focus of this report is erosion to the town beaches and not Encounter Bay (Franklin Parade). However, the report affirms that sand had been collecting at Kent Reserve (inferring sand movement from Encounter Bay). See also Cell 11.

2. Settlement history

Coastal Engineering Report (Erosion) – Victor Harbor, Coastal Management Branch, 2009.

The reason of this study was a request by City of Victor Harbor for management advice concerning erosion at Fell Street that threatened a walking and cycling path (see photographs p. 12).

Coastal Processes

This study reviewed the Magryn report (2006) and noted the accumulation of sand at Kent Reserve. The study concluded that 'there appears to be a northerly littoral drift along Franklin Parade' noting:

- The rocky beaches south of The Bluff boat ramp would provide no sand supply.
- The sandy beach likely to be formed by successive boat ramps acting as a groyne.

Project note: The area appears to have always been a sandy beach. Some sediment supply for the beach may have come from natural rain water runoff from the hills.

- A rock seawall constructed in 2005 extends from Nevin Ave to 150m south of Fell Street with sand levels lowering in front of the wall.

Project note: A sea wall was first installed at Whalers Road prior to 1975. In 1992, 1993 the wall was extended south to Nevin Street. After the storms of 2004, the wall was upgraded (but not extended north). Therefore, sea walling had been in this location for at least 15 years.

- The beach profiles at Tabernacle Road (300m north of Fell Street) and Kent Street (Kent Reserve) indicate a period of erosion between 1989 and 2006 but no further erosion to 2009. There appeared to be a 0.5m increase in sand levels 300m offshore in both locations.

Possible causes of the erosion

The study notes the timing of the erosion as winter 2009.

Project note: However, it has been demonstrated above that the area from Nevin Street to Fell Street had suffered numerous episodes of erosion since 1992. The fact that in 2009 there was only erosion to the back shore at Fell Street may relate to other areas of this shoreline already having protection. In other words, if there was no protection to this area, then all of the back shores may have been eroded.

The study lists the possible cause of erosion at Fell Street as:

- Reef structure – Nature Maps depicts this section of coast as 'patchy low-profile reef' and either side as 'continuous low-profile reef'.
- Seagrass loss – it was reported by Coastal Management Branch that seagrass was lost in the region in 2006.
- The seawall from Nevin Ave to Fountain Ave (seawall concludes 150m south of Fell Street, see previous project note on this page).
- Noted in the conclusion, the study suggests that the erosion could be related to one storm event in 2009 (and may have been multiple events).

Response options

The report noted that the Council practice of using a loader to push sand up the beach may cause decline in sand levels on the beach.

1. It was suggested to import 1500m3 of sand to cover a distance of 300m from the end of the seawall, 5m wide and 1m high to be installed adjacent to the wall to allow for northerly littoral drift. It is anticipated this northerly drift may see sand accumulate at Kent Drive where it can be harvested and returned to the south. Cost for initial nourishment was estimated at $35,000 to $50,000 and then $3,000 every 2 to 3 years to bring sand back from Kent Reserve.

2. Relocate the pathway (but not preferred by Council and would still need protection options).

3. Seawall of 300m to connect the two seawalls north and south of Fell Street. Estimated cost $750,000.

The report recommended that Option 1 was utilised and the impact monitored through profile lines.

Project note: there doesn't seem to be any analysis whether this project was effective, and no record of sand being transported back to the south. As a general observation there appears to be a much larger weighting on sand supply (in a 'low sand budget area') than the possibility of the impact of greater actions of the sea in this time period.

2. Settlement history

Victor Harbor Coastal Management Study, Australian Water Environments, 2013.

The study area for the project extended from the Bluff boat ramp to the causeway and therefore intersects with Cell 12 (Encounter Bay) and also Cell 11 (Central).

The impetus for the study is stated as:

1. Perceived increase in the intensity of storm damage and erosion since 1990s which is now impacting on Council infrastructure.
2. Concerns about the impacts of the training groynes at Inman river and the impact of sand supply to the Esplanade Road beach.
3. Concerns about increased sand and seaweed deposition in the Inman River (and odour).
4. Beach access made difficult due to groynes and other infrastructure (but the nature of the infrastructure is not spelled out).
5. Concerns about increasing erosion of dune system near King Street (in other places of the report it also states that there was concern about the dune system on the Esplanade, ie the town beach).

Project note: the main impetus for the study came from coastal issues between Inman River and the Causeway and not within this cell.

Methodology

The methodology employed in the study was to analyse aerial photographs and Coast Protection Board survey lines, describe the geomorphology of the coastal cell, and describe the coastal processes.

The study also provided flood mapping for the 1 in 100-year ARI event for sea level rise scenarios for 2050 and 2100. No flood mapping was provided for current day 1 in 100-year events. The project utilised the 1 in 100-year sea flood risk of 1.75m AHD as set by Coast Protection Board, but also added 0.6m to this figure for wave setup (0.3m) and wave runup (0.3m).

Project note: The preferred method for modelling sea flooding that flows inland is to omit wave runup as this energy would be dissipated a short distance inland.

The study also noted the various strategies that Council has employed over time to manage coastal issues: sand nourishment (with minimal explanation of the procedures and locations), and rock protection, which the study suggests may be at least 30 years old.

The study noted the deficit of data to adequately analyse sediment movement, wave characteristics, and the nature of the geology that underpins the landforms upon which Victor Harbor is situated. The study therefore concluded that applying methodology of the Bruun Rule to ascertain possible rates of erosion was not appropriate.

Findings of the study

The study found that the coastal area had been largely stable over a long period of time (70 years) with shorter term fluctuations of erosion (that occurred quickly in the context of storms) and accretion (that occurred more slowly over weeks, months, years). However, the study also found that the coast presented as a slowly receding coastline starved of sediment. The only data that supported the latter statement was that beach widths appeared to be a 'few metres' narrower.

Based on the sea flood mapping for 2050 and 2100 which incorporated sea level rise of 0.3m and 1.0m respectively, the study found that inundation would be significant (including the possibility of flooding the current Council chambers and private caravan park to the west). Within Encounter Bay (Cell 12) sea-flood modelling (this also includes 0.3m wave runup) showed impact for:

- 2050 scenario – inundation into area between Whalers Road and Nevin Ave, minor inundation south of Tabernacle Road, and Kent Reserve.
- 2100 scenario – inundation on a much larger scale indicated in Figure a.

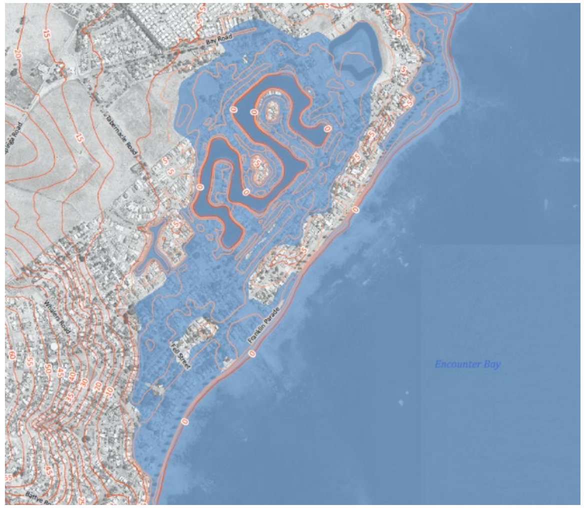


Figure a. Pattern of flooding for scenario 2100 with sea level rise of 1.0m. However, wave runup (0.3m) has been included.

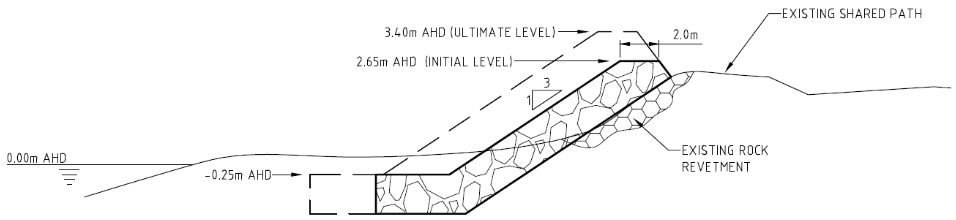
2. Settlement history

The study also noted that the sheltering effect of the offshore reef would diminish with rising sea levels and erosion would be severe causing significant recession of the shoreline with resulting damage to infrastructure. However, no estimate was made in regard to the rate of erosion.

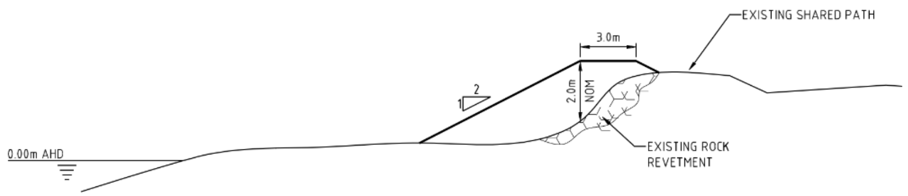
Adaptation options

The study reviewed numerous options (p. 47) but recommended soft management approaches for the shorter term but suggested hard protection items would be required in future. Engineering options were described as the following and analysis of each option can be found within the report (p. 53):

1. Sloping rock revetment sea wall seaward side of Encounter Bikeway where no wall present and upgrade or replace existing rock wall in stages initially to 2.65m AHD with ability to increase to height to 3.4m AHD if seas rise further.
2. Vertical concrete sea wall in front of bikeway to 3.4m AHD in high-risk inundation areas.
3. Place larger rock in front of current rock revetment wall with parapet wall to 3.4m AHD in low lying breach area on coastal side of Encounter Bikeway and construct new rock wall where none are currently present.
4. Raise Encounter Bikeway shared path in high inundation risk areas to 2.65m AHD with associated retaining wall to 3.4m AHD with some rock protection on coastal side.
5. Sand replenishment to build up height of fore dune at high-risk areas (and also continue with burying a mixture of sand and seagrass wrack at the back of the beach).



Option 1 Rock seawall (Ultimate Treatment) – Section B-B



Option 3 Sand Nourishment (Short-Medium Treatment) – Section B-B

Taking into account that soft options are recommended for the shorter term, the preferred engineering approaches appear to be Option 1 or Option 5 (but noted as Option 3 on the cross-sectional plans in the report).

Figure a. Location for adaptation options from the boat ramp to Kent Reserve (Source: AWE, 2013).

2. Settlement history

Asset management options:

Beach access

1. Reduce the number of beach access points.
   Update: this recommendation related more to area east of Inman River. Unknown if access points have been reduced in Encounter Bay (Cell 12).

Stormwater outlets

1. Repair and rock protect existing stormwater outlet structures and headwalls from wave energy and erosion and provide headwalls and erosion control on all outlets.
   Update: unknown which outlets have been upgraded or repaired.
2. Provide GPTs along all stormwater outlets along the Esplanade, Franklin Parade, and the Inman River Estuary.
   This project has photographed all outlets and a current storm water project by others is underway.
3. Replace existing low point drainage outfall swale near King Street with underground pipe.
   Update: Completed.
4. Provide upgrade tidal flap gate or Tideflex valves on all storm water outlets along the Esplanade, Franklin Parade, and the Inman River Estuary.
   This project has photographed all outlets and a current storm water project by others is underway.
5. Review existing storm water outfall drainage from Council Caravan Park.
   A storm water project by others is underway.
6. Survey all storm water outlets to confirm whether adequate discharge and fall arrangements from the outlet invert to the beach.
   This project has surveyed the height of all coastal storm water outlets and riverine outlets ~200m upstream from the coast.

Vegetation along foreshore between Bartel Boulevard and Police Point.

An active protection and revegetation program to maintain the integrity and stability of the foredune.

Update: within Cell 12, this relates to the area of Kent Reserve which has ongoing vegetation program.

Use of sand and seagrass mixture

Continue to combine sand and seagrass at ratio of 1:1 and monitor for any adverse impacts (relating to the use of seaweed) and deposit at the back of the beach, upon the dune crest, or landward of the dune scarp.

Update: The intention of this recommendation appears to relate to all beaches. The beach between Inman River and the causeway is scraped at end of summer, combined with seaweed and deposited to the back of the beach. It is unknown if this practice is also undertaken within Encounter Bay (Cell 12).

Note: the study identified the area around Kent Reserve as an important location for Hooded Plovers.

Other recommendations

- Council to support and encourage ongoing soft management strategies for the beach areas and the fragile dune buffers through volunteer environmental groups
- Sand renourishment, continued use of the sand and seaweed mix (monitor to identify any undesirable effects); and vegetation replanting;
- Commence ongoing dialogue with local community and stake holders (including State Government).
- Prepare a climate adaptation strategy to minimise the worst future impacts taking into account the recommendations of the project (ie protection).
- Promote and support a focussed data collection and monitoring program;
- Identify funding needs into the future and identify and secure funding sources (consider a special rate under provisions of Local Government Act);
- Review the coast and management strategies every five years.

2. Settlement history

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

This adaptation plan is a regional general 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

The section on 'built coastal assets' is the most relevant due to the predominantly urban nature of Victor Harbor coastline.

Coastal Ecosystems (p. 44-46)

Climate change impacts

Based on the Integrated Vulnerability Assessment (Resilient Hills and Coasts, 2016), coastal ecosystems will be most influenced by increasing sea levels, increasing rainfall intensity (causing localised 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 (landward) migration, especially in close proximity to 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.

- Ensure planning systems provide adequate approval processes to reflect projected sea level rise increases.
- 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.

2. Settlement history

Climate Change Adaptation Plan (cont.)

Triggers

Triggers for decision making regarding public coastal assets will be linked to sea level rise and the extent to which:

- 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
- Foreshore vegetation in public parks dies back due to salt leaching into the soil.

Enablers and barriers to adaptation

Project note: enablers and barriers have been combined from pages 45 and 63.

Adaptation of coastal ecosystems will be greatly facilitated by the high value that people place on the coastal zone even if these human values are not directly related to the ecosystem values they will still have beneficial implications. For example, people value being able to readily access clean, sandy beaches

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

Project note: The adaptation pathway has been combined from p. 44 and 65 with an emphasis on the latter due to the urban nature of Victor Harbor.

Current

- 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.

Ten years

- 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.

Twenty years

- 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.

Project notes: While recognising that the plan is general and regional, in the context of Victor Harbor:

- Proposed sand replenishment proposed by Magryn (2006) proved to be very expensive. The benefits of sand nourishment are not always easy to quantify. See example from 1976 (p.xx).
- The consideration for relocating assets should be more related to the immediate impact of actions of the sea upon an asset ***and*** in the context of the remaining life cycle of the asset.
- The concept of trailing 'impact reducing measures' (such as concrete blocks, see p. x) should be embraced. However, the current tendency is not to conduct research on the possible drivers of localised erosion (which may be regional, or local).

2. Settlement history

Other studies

The studies reviewed in this section are not specifically related to coastal adaptation in the context of rising sea levels but intersect with coastal issues. The purpose is to identify the studies and assess what relevance the studies have to coastal adaptation.

Victor Harbor Foreshore Coastal Park – Open Space Plan, Bechervaise and Associates (2003)

The study objectives were to bring together within one overall plan, an outline of future development and management objectives for the foreshore reserves that balances access for human use, recreation and leisure, with long term conservation and maintenance.

Findings in relation to Encounter Bay

Encounter Bay foreshore from The Bluff to Kent Reserve is a low-lying rocky foreshore which provides visual outlook across relatively protected waters to The Bluff, Wright Island, Seal Rock and Granite Island.

The main usages for the area were identified as:

- Cycling and walking.
- Offshore used for snorkelling, reef walking.
- Picnic and recreational activities at Kent Reserve (high volume in holidays/summer).

The main issues were identified as:

- Loss of dune and frontal vegetation.
- Vehicle and pedestrian impact (Kent Reserve).
- Kent Reserve was the last known camping ground used by the Ramindgeri.
- The area around Kent Reserve was utilised as a bird habitat (including the hooded plover).

Opportunities identified for the region included:

- Increase natural planting wherever possible
- Increasing landscaping along Franklin Parade
- Control vehicle and pedestrian access within dune and vegetation (apart from direct cross over to utilise boat launching at Kent Reserve.
- Reinstate the estuary as a wetlands system.
- Install interpretive signage (including relating to Ramindgeri people).

Project note: this study was completed in 2003 and most of the recommendations have been adopted in the Encounter Bay region.

Urban Stormwater Management Plan, Kellogg Brown and Root, 2005

Overview of the study

This project was conducted in two stages. The focus of the first stage (not reviewed) was to analyse the capacity of the current system (i.e. in 2005). The study noted that current methodology was to view capacity for 5-year ARI event in the context of the minor system (pipes, inlets) and 100-year ARI event in the context of the major system (rivers, creeks, roads, gutters).

The study recognised that most areas have adequate capacity to manage 5-year ARI flows and 100-year ARI flows with biggest inadequacy relating to inlet capacity. The study also noted that most vulnerable area was around the Inman River catchment (Catchment 11) near Council offices and library. One of the aims of the studies was to identify areas that may be suitable for new development or increased density of development.

In the context of coastal adaptation

This study does not specifically address the method or volume of outflows to the ocean apart from in the conclusion where it states, 'stormwater quality will become even more important considering Encounter Bay and Victor Harbor coastline are set to become a marine protected area'. The study provides some general strategies that may assist with volume and quality of flows to the coast:

- Flow control measures – onsite retention and detention opportunities, but only limited opportunity for larger schemes.
- Storm water quality improvements – gross pollutant traps grease arrestors, wetlands and bio-infiltration measures. These can be at-source controls or end-of-line applications.
- Storm water harvesting and use – likely to be on a smaller scale through use of rainwater tanks plumbed to the house. Limited scope is likely to be available for using aquifers.

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, and to establish conservation priorities for places and areas within the region. The report also outlines suggested actions to address threatening processes at specify 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).

Within each of these cells analysis of conservation values and condition was undertaken.

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 Cell 12, Encounter Bay are detailed within the table on this page.

Action Summary Table – Cell 12, Encounter Bay (p. 7)

F12. Inman R. to The Bluff. Reefs	F12.1 Development of interpretive signage relating to biota of platform reef. Development of educational materials in conjunction with Victor Harbor High School.	High (Cons / Threat)
	F12.2 Support setting up of community Reefwatch intertidal monitoring group (data collection, kits, methodology).	High (Cons / Threat)
F12. Lower Inman floodplain	F12.3 Continue re-vegetation program of the Lower Inman floodplain, and habitat management to improve vegetation patch connectivity.	High (Cons / Threat)
F12. Dunes near Kent Reserve	F12.4 Continued weed control and access management within the dune area adjacent Kent Reserve. Pursue opportunities for signage.	Medium (Cons)
F12. Estuary Entrance	F12.5 Develop an estuary entrance management support system for the Inman, (1), to investigate other options and reasons for making opening / closing decisions.	Medium (Cons)

2. Settlement history

City of Victor Harbor Recreation and Open Space Strategy, Suter Planners and City of Victor Harbor, 2017.

Project aims

Council has developed this strategy to ensure open spaces and recreation opportunities continue to be provided and enhanced for the benefit of the community and visitors. The study was broken into six main areas:

- The foreshore
- Natural areas
- Non-foreshore recreation
- Connections and corridors
- Sporting facilities
- Community wellness.

This focus of this review is primarily where the study touches on the first item – the foreshore.

Key findings (in relation to the foreshore)

The theme goal for the foreshore is, 'quality foreshore destinations with distinctive recreation and natural spaces'. The strategic directions identified for the foreshore are:

- Strengthen the quality and uniqueness of foreshore destinations.
- Improve provision, location and quality of recreation and sport facilities and related amenities.
- Manage and where appropriate reduce the dominance of buildings, structures and car parking.
- Protect, and strengthen coastal vegetation, estuaries and natural foreshore settings.
- Continue to respond to risk of climate change through rock walls and other initiative that will protect the foreshore from sea level rise.

Priorities

Only two priorities related to the foreshore within Cell 12, Encounter Bay:

- Continue to undertake path and landscape improvements along Encounter Walkway focussing on connectivity (item 11).
- Support major and local events in larger parks (such as Kent Reserve) (item 19).

Actions in relation to climate change:

Continue to maintain and upgrade rock walls and adopt other environmentally sensitive response that will help protect the foreshore from sea level rise and erosion. A particular focus should be placed on protecting the area between GS Read Reserve (which is near Kent reserve) and Bridge reserve and adopting other recommendations in the Victor Harbor Coastal Management Strategy and the Climate Change Adaptation Plan developed from the region.

Figure a. Plan of priorities for recreation and open space use for Encounter Bay, Suter Planners and City of Victor Harbor, 2017.

Project note: the assumption in this study is that protection (especially rock walling) will be the option that can be pursued for this cell. In particular, the study recommends that the foreshore from GS Read Reserve (near Kent Reserve) around to the Bridge Reserve (near Hindmarsh River) should be protected from sea level rise. This study will assist in quantifying what options may be viable over the short and longer terms.

2. Settlement history

Key findings: Encounter Bay (Cell 12)

1. The road from Tabernacle Road (Yilki) to The Bluff jetty was installed in 1854 and likely to have been positioned 30m (100 feet) above the high-water mark. The road was extended to the east to Kent Reserve in the 1960s. The implication in the context of projected sea level rises is that the main emphasis of coastal adaptation will be for Council to manage its own assets.

2. While the position of the current road is similar to that of 1854, the width of the constructed road reserve has widened to accommodate a wider road, cycle track and increased car parks (Fell Street, Yilki). To create the necessary flat surfaces, an embankment has been formed which is now situated closer to the high-water mark. The implication is that higher storm events interrelate with the backshore in ways that would be less likely to occur prior to the installation of infrastructure.

3. In regard to the storm record there is unlikely to have been a significant event of which we are unaware in the past 150 years in a social environment where a 'chimney blown over' or a 'chicken loses an eye to a hailstorm' made the news.

4. In regard to the storm record generally:

- In the era of 1920s to1940s were frequent storm accounts.
- The era of 1970s erosion seems to have been a problem.
- After the 1990s, the incidents of erosion generally increased.

5. In particular, only two storms made the news in the Encounter Bay (suburb) region. The first was in 1943, after which a wall was constructed at Yilki. The second was in 1953 when the wall was washed away and rebuilt. Residents noted that erosion had occurred in places 'up to three and four yards'.

6. Analysis of the tide gauge data from 1965 to 1999 revealed a correlation of a period of increased storminess with high levels of erosion 2007 to 2011.

7. The records from newspapers indicate that sea storm events can be accompanied by significant rain events. This is a different finding than for locations within Gulf St Vincent where the meteorological conditions that produce the most severe storm surges are not accompanied by heavy rain (See Kemp, Tonkin).

8. Periods of protection tended to follow periods of erosion:

- Installation of rock wall at Yilki (1948, 1953).
- Rock to toilet block at Whalers Road, parts of The Esplanade between Tabernacle Road and Kent Reserve (often begun as ad hoc) (1970s).
- Rock protection from Nevin to Whalers Road (~1992).
- Rock protection upgraded from Nevin to Whalers and extended to Fountain Ave (2005).
- Sand nourishment to Fell Street (2011)
- Installation of concrete blocks adjacent the bikeway at Fell Street (2019)
- Rock protection to Yilki shops after rapid erosion (~2020).

Key Reports

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

Generally, the emphasis in coastal studies in the context of erosion was to focus on sand supply, particularly in the context of littoral drift. It is likely that increased erosion was a direct result of increased storminess in particular time periods (for example 2007 to 2011).

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 are provided from:

Dr Robert Bourman, contributor to this project, 2021

3. Geomorphological context

COASTAL FORMATION

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.

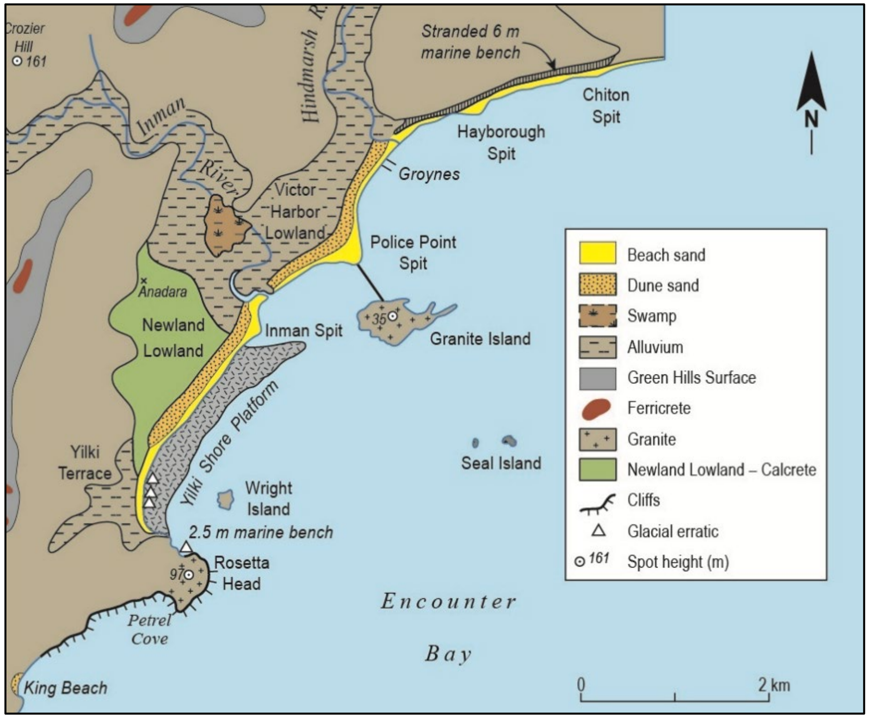


Figure a. Major geomorphic features of the Victor Harbor coastline. Bourman et al. (2016)

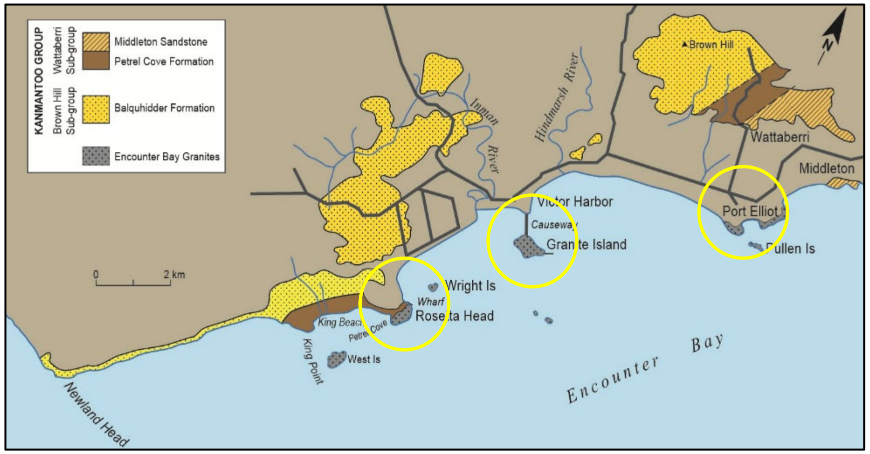


Figure b. Map showing the bedrock geology backing the Victor Harbor coastline highlighting the strong structural influence of the resistant Encounter Bay Granites and the Kanmantoo Group of metasedimentary rocks on the shape and orientation of the coastline. The section of coast extending from Rosetta 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.

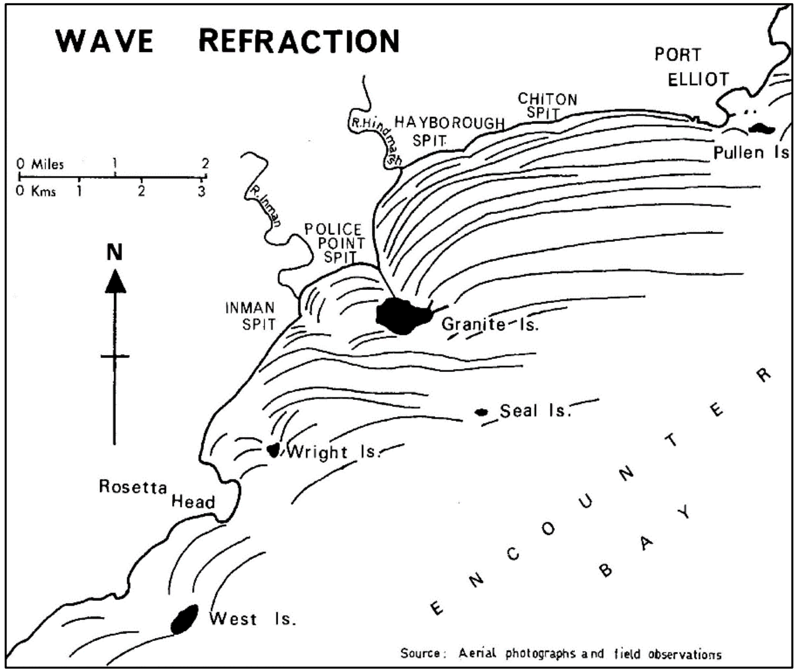


Figure a. Wave refraction and diffraction pattern of the Victor Harbor coastline. Note the Inman, Police Point, Hayborough and Chiton spits and their relationships to the wave patterns. Source: Bourman (1969)

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 of 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).

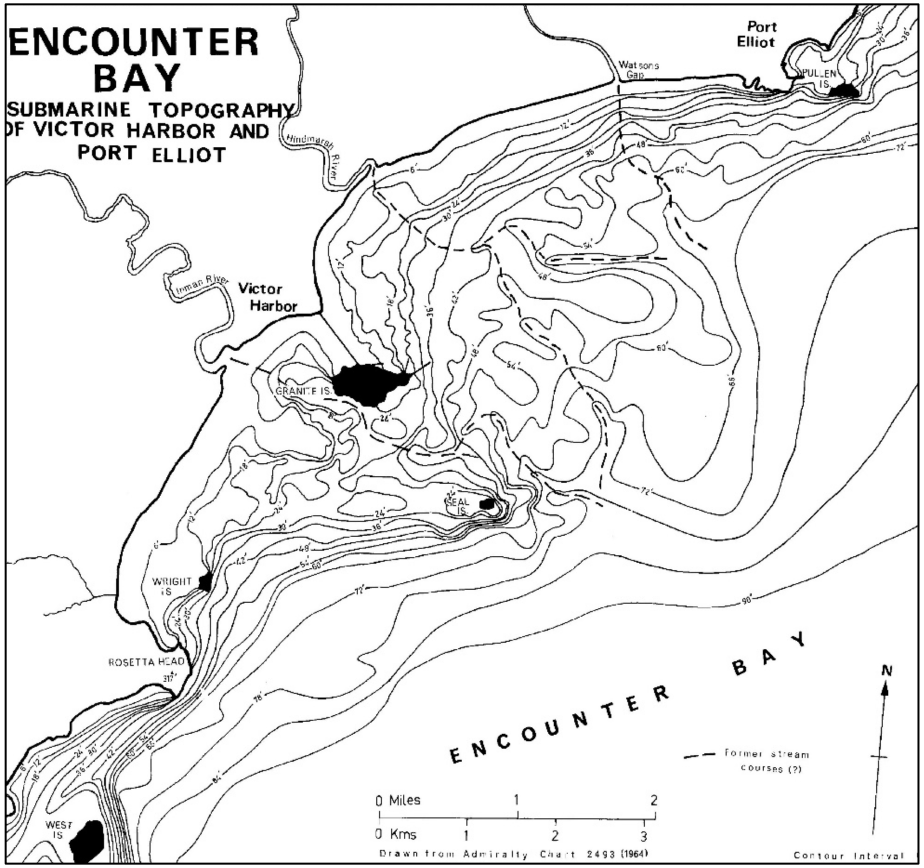


Figure a. Submarine topography of the Victor Harbor section of Encounter Bay produced from Admiralty Chart 2493, originally produced in 1869 and updated in 1958, 1959 and 1964. Source: Bourman (1969)

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

High last interglacial sea level 125,000 years ago

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

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

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

Mid-Holocene high sea level

During the Holocene period, about 5,000 years ago, sea level rose to ~+1 m 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 BOAT RAMP TO KENT RESERVE

The area known as the suburb of Encounter Bay (Cell F12) is located between the Bluff boat ramp at Rosetta Head and Kent Reserve, just south of the Inman River mouth.

Rosetta Head

Rosetta Head, locally called 'The Bluff', is a prominent, resistant granite headland over 100 m high, which forms the important role of buffering the Victor Harbor coastline from wave attack (Figure a). In fact, the large bay, which extends from Rosetta Head to the granite outcrops of Port Elliot, has developed in relatively easily eroded glacial, marine and alluvial deposits, and if the granite headlands did not exist the coastline would have a very different configuration.

The Bluff acts as a barrier to the transport of sand at King Beach and Petrel Cove, from which minimal passes the headland. Limited Permian and Pleistocene sediments north of the Bluff make insignificant contributions to the Victor beaches. A shore platform cut across resistant metamorphic rocks follows the roadway from the boat launching facility to the Inman Spit at Kent Reserve.

Yilki Terrace

The Yilki Terrace (Figure a,b) consists of red-coloured alluvial deposits known as the Pooraka Formation, which is of last interglacial (125,000 years) age, infilling a valley cut into underlying Kanmantoo bedrock and Permian glacial deposits. Two main gullies dissect the terrace surface, exposing bedrock in several places where it forms minor rapids and falls. Although now covered by housing, photographs taken during the 1960s (Figures 26 and 27) reveal its pronounced terrace morphology, the seaward edge of which is about 9 m above sea level, sloping inland up to about 45 m.

The alluvial soil was deposited 125,000 years ago when sea level was +2m higher than present, and it was subsequently tectonically uplifted a further 4m to its present position. The steeper slope at the base was formed about 4-5000 years ago when sea levels was ~1m higher than present in the Mid-Holocene period. Thus, the Yilki Terrace records the existence of two former sea levels higher than present (Figure b).

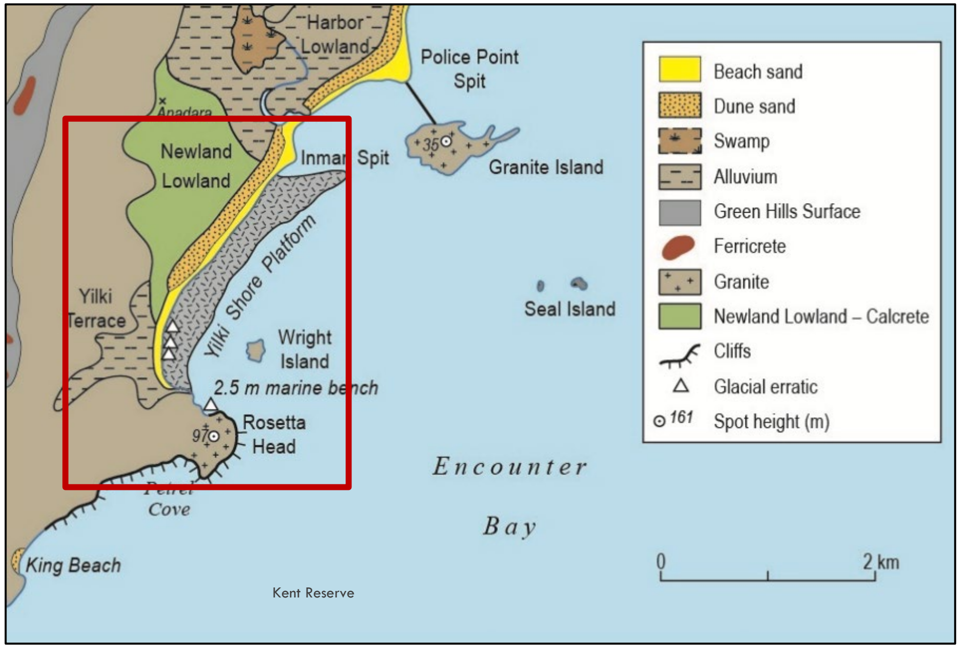


Figure a: Geological layout of Victor Harbor region with Cell 12 depicted within the red rectangle.

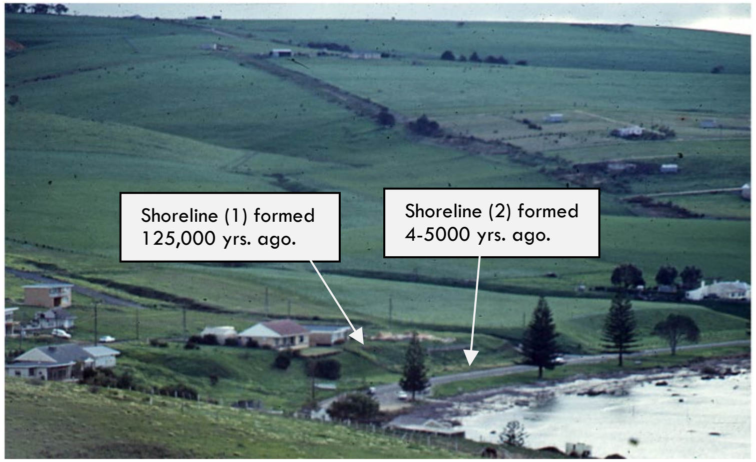


Figure b: Shoreline (1) was formed 125,000 years ago when sea levels were +2m. It was then tectonically uplifted +4m. Shoreline (2) was formed 4-5000 years ago when sea levels were +1m higher than present. Therefore, the surface upon which the road sits was formed when seas were +1m than this present time.

3. Geomorphological context

Yilki Shore Platform

An intertidal shore platform and reef extend along the shoreline from the Bluff almost to the mouth of the Inman River (See Figure a, previous page). The Yilki Shore Platform has been cut across three different types of rocks: resistant Kanmantoo Group metasediments, Permian glacial deposits and Pleistocene calcareous sandstone.

From the Bluff jetty to near the boat-launching area the shore platform has developed on hard Cambrian (500 million years old) Petrel Cove Formation rocks of the Kanmantoo Group, where they form a resistant serrate shore platform. There are also granite boulders on parts of the bedrock shore platform, some of which have been locally derived from the granite outcrops but some may be erratics, the result of transport from distant sources by the Permian ice sheet 300 million years ago (Figure c).

As well as forming a nearshore intertidal shore platform, the calcareous sandstone forms a reef up to 800 m offshore from the Newland Lowland. The sediments underlying the shore platform are calcareous sandstones containing small shell fragments and are eroded remnants of the last interglacial marine and coastal dune sediments which infill the Newland Lowland (Figure a,b).

Newland Lowland

The Newland Lowland is a low-lying littoral zone between the coast and approximately the 7 m contour line, extending from the Yilki Terrace to the alluvial deposits of the Inman River (See Figure a, previous page). Primarily, coastal and marine sediments underlie the lowland.

Calcrete occurs extensively throughout the lowland, and although it is soluble, the tough capping impedes water infiltration so that before housing developments much of the area was inundated during winter months. Poor natural drainage of the area is accentuated by its low-lying nature, and by coastal dunes, which prevent easy drainage to the coast. The Holocene coastal sand dune several hundred metres across at its widest point parallels the coastline from the Yilki Terrace to the Inman River, where it forms part of the riverbank. In places along the coastal dune, such as at Oakham Street, the dune is higher than the backing Newland Lowland.

Figure a: Granite boulders incorporated into the last interglacial dune sandstone on the Yilki shore platform.

Note the embankment installed in the backshore under the road and cycle track. In the context of sea level rise or periods of increased storminess this will come under attack.

Figure b: View over the calcareous sandstone Yilki shore platform with Granite Island in the background. The reef has formed on last indurated interglacial age calcareous dune sediments.

3. Geomorphological context

Key findings: Encounter Bay (Cell 12)

1. The granite formations of Rosetta Head (The Bluff), Wright Island, Granite Island and Port Elliot maintain the shape of the bay. Waves refract around these formations in generally consistent ways and form the shape of the softer sediment beaches and backshores.

2. A combination of the sheltering effect of the Bluff and the shallower water between the line of the Bluff and Granite Island dissipates wave energy from the Southern Ocean by the time the waves reach the shore.

3. The surface under which the road to The Bluff (Franklin Parade) was constructed in the 1850s was formed about 4-5000 years ago when seas were ~1m higher than present. This means the coastline is very young in Encounter Bay.

4. Sea levels have risen globally by ~250mm since the 1850s and are projected to rise up to 1m by the end of this century.

5. The area is inherently a low sand environment dominated by a rock shore platform, offshore reefs, and seagrass beds. Historically there were no sand dunes south of Yilki. Sand dunes existed in the Kent Reserve area, but urban structures now cover most of these. Sand supply is expected to continue to decline.

6. In a coastal environment dominated by rock shore platform with little flexibility in the backshores, increasing sea levels or increasing periods of storminess will have a direct erosive impact on the backshores.

Reflections:

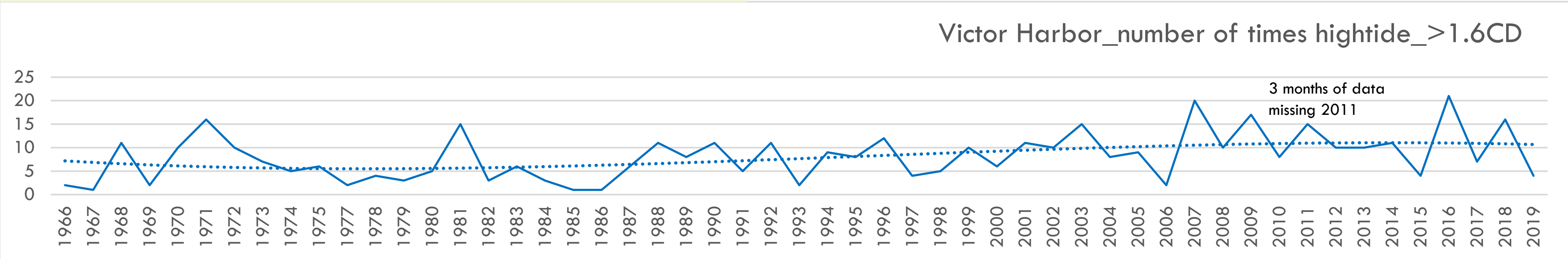
The tendency in the past was to focus on sand supply/ littoral drift issues as reasons for increased erosion in Victor Harbor region (i.e. installation of sand bag groynes etc.). However, in a low sand environment where offshore reefs and rock platforms dominate, and there is limited flexibility in the backshores, periods of increasing storminess may be the sole reason for increased erosion.

There have been three main time periods of increased storminess:

- 1920s to 1940s – the storm record is numerous, but quiet in 1950- 1960s.
- Early 1970s when protection was installed to Fountain Ave., sand nourishment to the beach on Franklin Parade (failing wall). There is some correlation in the tidal record at the Victor Harbor gauge.
- More recently, 2007 to 2011 was a period of erosion in vicinity of Yilki, The Esplanade Beach which is correlated strongly in increased sea levels at the tide gauge.

More work could be undertaken in the future to ascertain what might be the drivers of these patterns of erosion. For example, globally, we know that rates of sea level rise were similar in 1920s to 1940s as for 1990s to 2000s. Are climate patterns such as El Nino Southern Oscillation (ENSO) associated with certain drivers that increase erosion? Do prevailing wind directions change? If we can understand these climate drivers more clearly, we may be able to predict the impacts we expect upon the Victor Harbor shoreline and respond accordingly.

Erodibility Rating: Moderate (2) (due to current levels of protection already installed in the backshores.



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 car park 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.

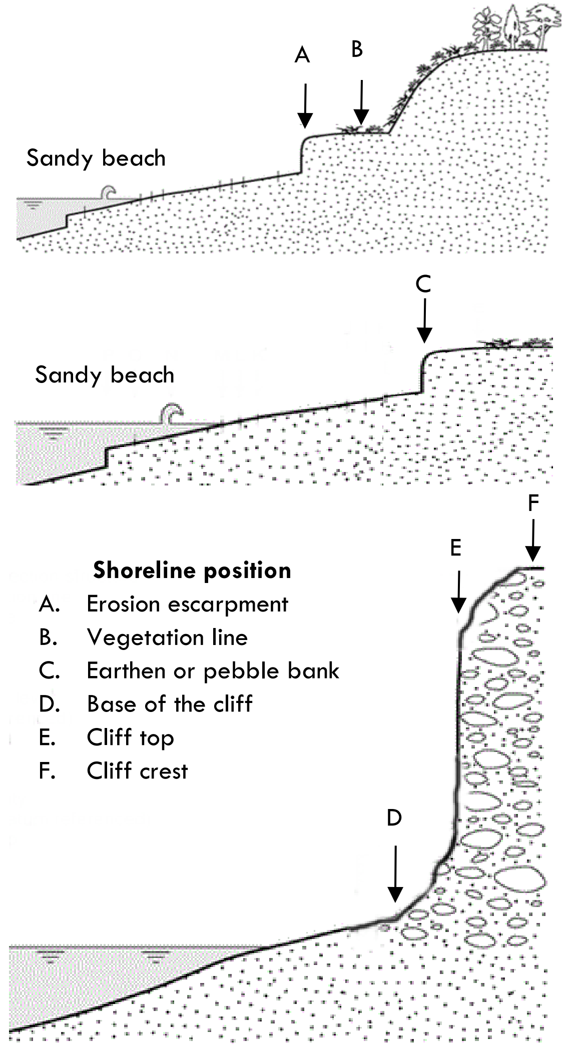


Figure a. Adapted from Boak and Turner (2005), Shoreline definition and detection.

4-1 Coastal fabric - overview

Overview

Fleurieu 12

Secondary Cell: Fleurieu

Tertiary Cell: Encounter Bay

Form

Beach
Narrow coarse sand beach with offshore intertidal rocky shelf. Increasing volume of sand and low height dune near Kent Reserve

Backshores
12.1 A steep earthen embankment to the road reserve at ~2.5m to 3.0m AHD

12.2 In southern portion – a steep earthen embankment to the road reserve, but nearing Kent Reserve, increasing width of low height dunes, road reserve at 3.0m – 4.5m AHD.

Bathymetry
Overall slope of ocean floor:
-5m ~700 to 1000m from beach
(overall slope ratio ~1:150).

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4-1 Coastal fabric - overview

Overview

Fleurieu 12

Secondary Cell: Fleurieu

Tertiary Cell: Encounter Bay

Geology

Geology

Beach and backshore 1:

Semaphore Sand - The beaches and immediate backshores of Encounter Bay were formed recently.

Age: Holocene ~10k BP

Backshore 2

12.1 – Sandstone-siltstone/ Carboniferous-Permian (very old rocks)

Age: Pleistocene – Holocene.

12.2 – quaternary rocks (younger rocks than in 12, less than 2.5m B.P.)

Age: Pleistocene – Holocene.

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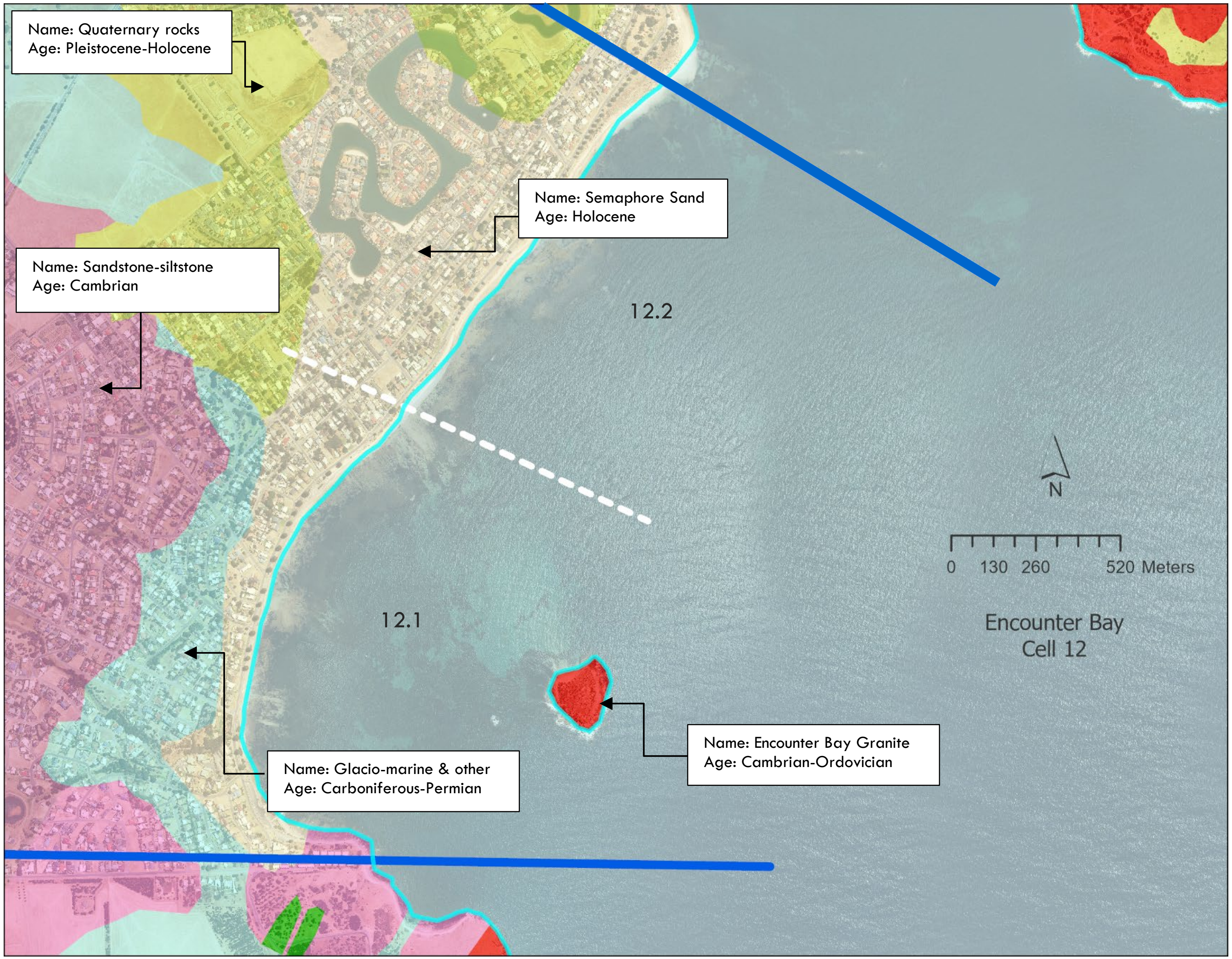


4-1 Coastal fabric - overview

Overview

Fleurieu 12

Secondary Cell: Fleurieu
Tertiary Cell: Encounter Bay

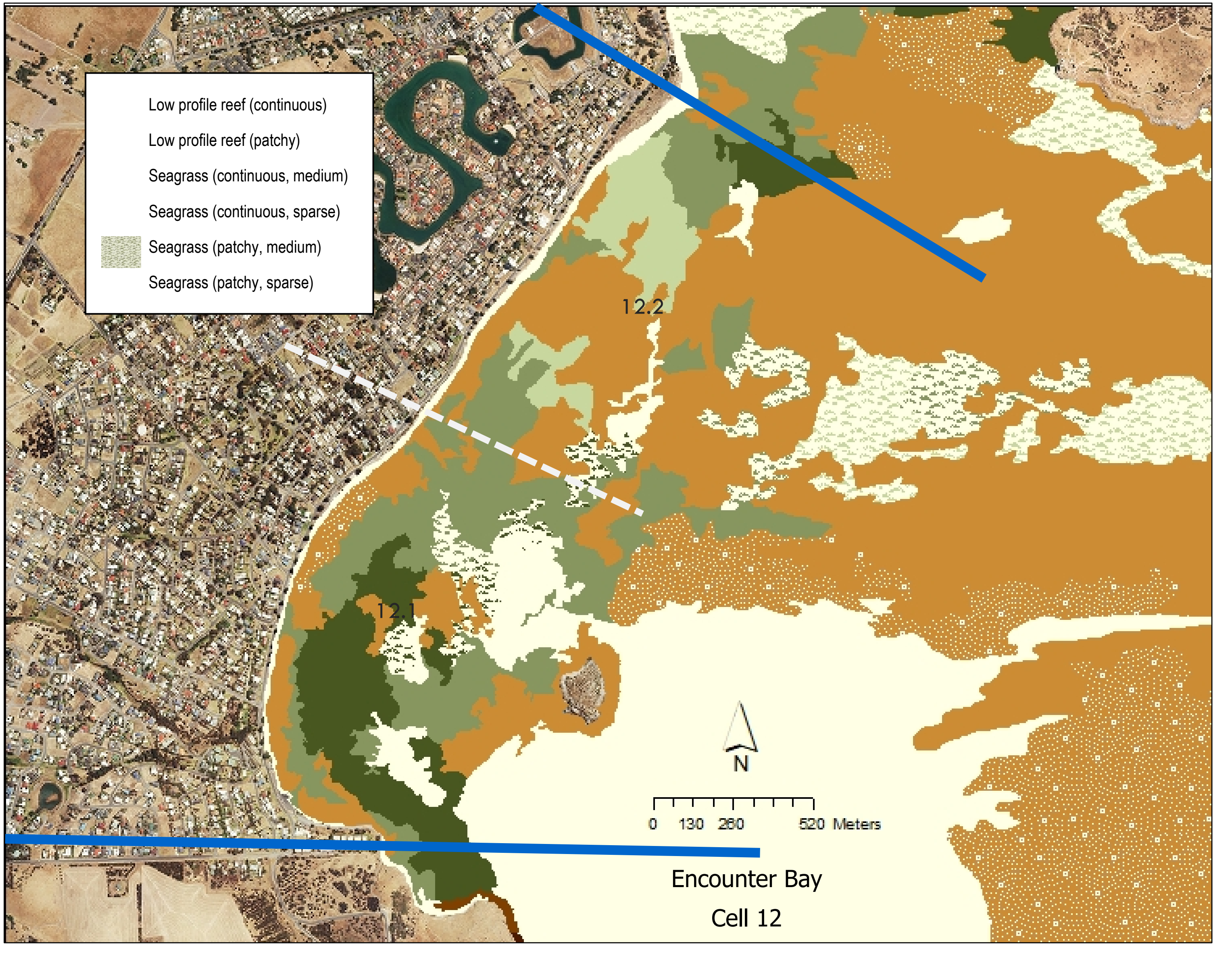
Benthic

Benthic

Nearshore and surf-zone dominated low profile reef and continuous seagrass beds.

Large sand bed around The Bluff and Wright Island.

Map sourced from Nature Maps (SA).



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4-2 Coastal fabric – shoreline changes

Comparison with photographs 1900 to 1940

This section of work provides a comparison of the coastline from periods that pre-date aerial photography. The comparison is less definitive but still provides and insight to coastal change from the early 1900s.

View of Encounter Bay ~1900

Observations:

1. The road was constructed in 1854 and likely positioned ~30m (100 feet) from the high-water mark. The landward edge of the road surface in 1949 was positioned ~2m further inland than the current road (which is now likely to be the footpath).

2. The beach towards the Bluff appears sandier and the profile of the beach and immediate backshore is lower than current day (note the boats lying on upper beach).

3. To the east, note the larger portion of land left between the road the sea, and the low profile of the shore at what is now current day, Fell Street. This area has now been raised and a carpark and walking trail positioned. It is very likely that periodically higher storms encroached into this area and washed up toward the former road.

Figure a: View of Encounter Bay (1900), State Library of SA, B-63092.

Figure b: View of Encounter Bay (1900), State Library of SA, B-63093. The inset picture shows the position of the current carpark in the vicinity of Fell Street.

4-2 Coastal fabric – shoreline changes

View of Encounter Bay 1938.

Observations:

1. The Norfolk Pines were planted in this era along some of the Encounter Bay coast.

2. The backshores above the beach are becoming more consolidated but still would have provided a buffer for larger storms which seem to periodically impact the bay (as has occurred in time period 2008 to 2012).

3. In 1943 a large storm undermined the road so that it had to be closed. In 1947 seawall was constructed at Yilki which was washed away in early 1950s and was rebuilt.

Summary:

- The road was positioned 30m above high-water mark in 1850s, since which time the seas have risen globally ~250-300mm.
- The land between the road and the water appears to be a gentle slope and in places the road was placed further inland to allow for higher storm action (e.g. in vicinity of Fell St).
- Even so, the road came under threat in 1940s and rock protection was installed at Yilki.
- Progressively over time, the back shore has become more formalised and raised to create the necessary level surface for roads, carparks and walking trails. This has created the modern embankment we see today, and which has required increasing amounts of protection.

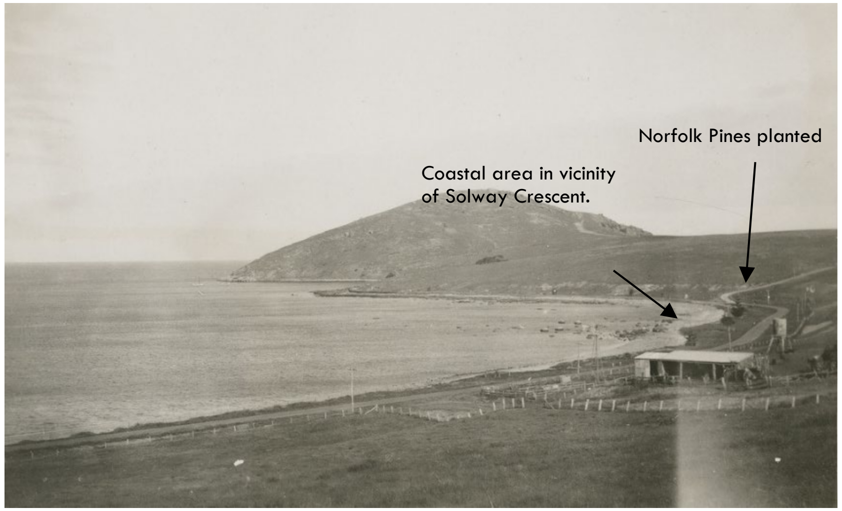

Figure a: View of Encounter Bay (1938), State Library of SA, PRG-287-1-6-42.

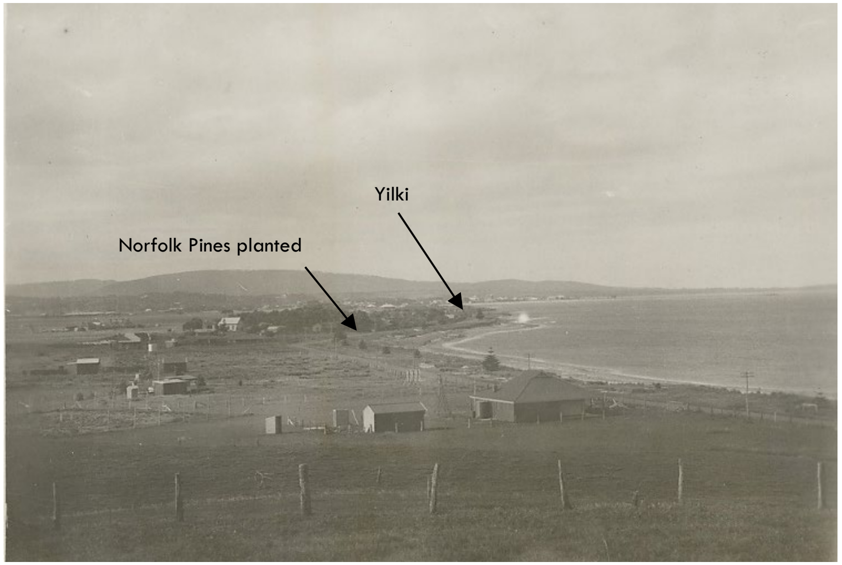

Figure b: View of Encounter Bay (1938), State Library of SA, PRG-287-1-6-44.

4-2 Coastal fabric – shoreline changes (12.1a)

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp

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
- 2008
- 2012
- 2016
- 2018

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
Year 1949

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

Land based photographs from the time show that the beach sloped up to the road. The minor vegetation in the backshore was set ~3m to 6m back further than the current toe of the embankment.

Storm water flowed down a natural gully to the sea.

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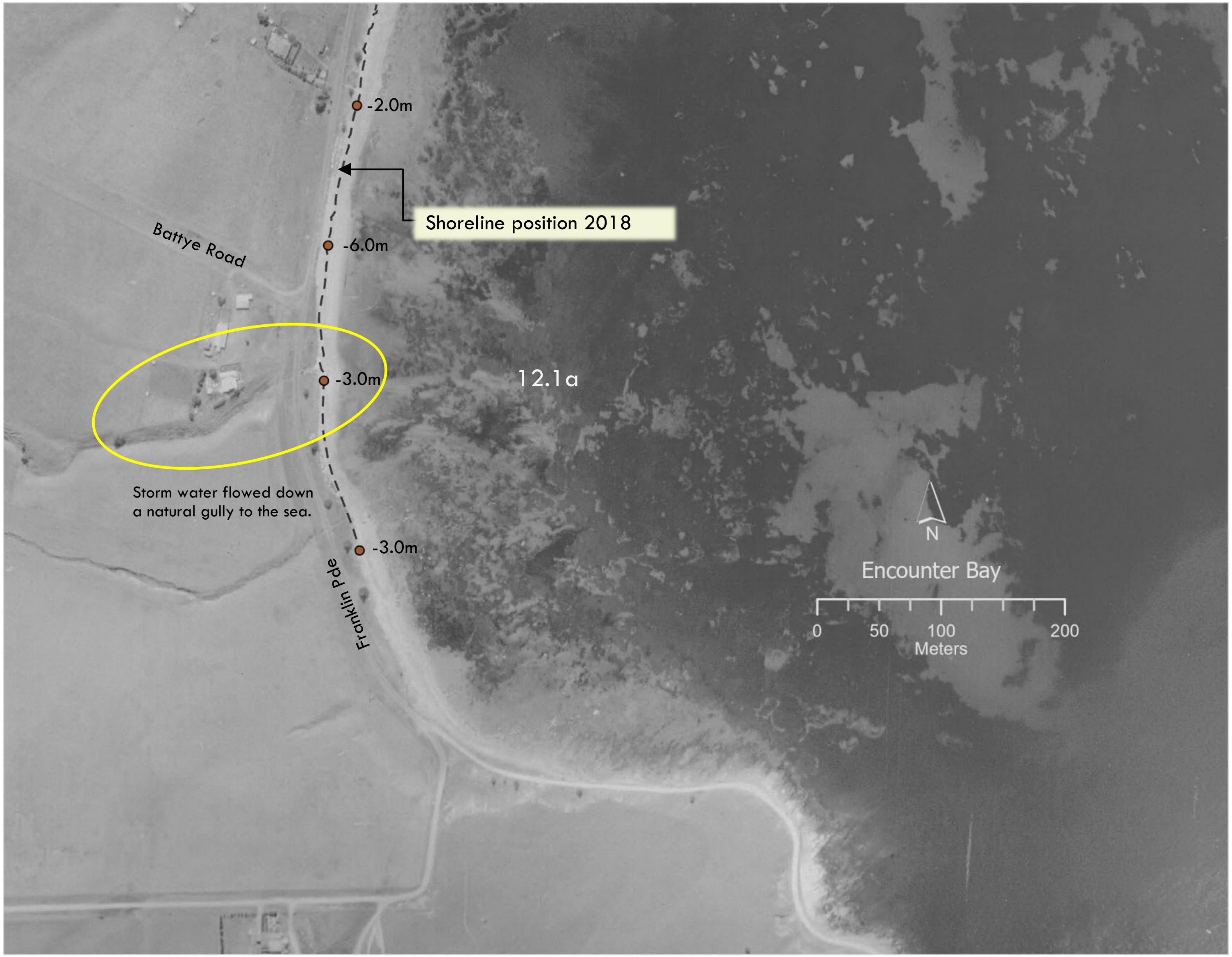

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay
Historical comparison

Shoreline

Location:
The Bluff boat ramp
Year 1976

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

In this time period, the beach had a gentle slope up to the road (see inset photograph, 1975). The minor vegetation in the backshore was set ~2m to 4m back further than the current toe of the embankment.

Storm water flowed down a natural gully to the sea (piped under the road).

Photograph: Coast Protection Board,1975

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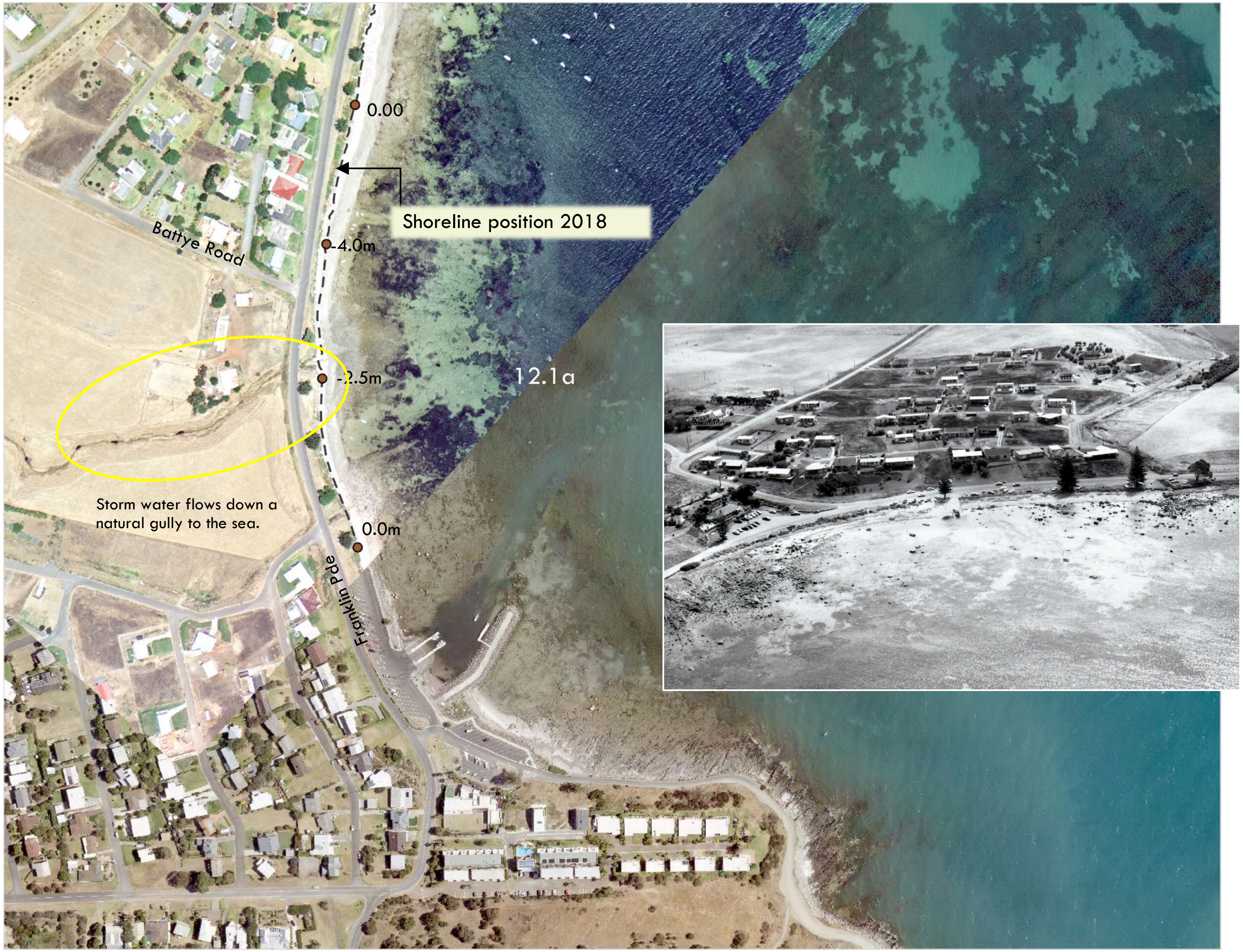

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
Year 1989

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

By 1989 the shoreline was in a similar position to current day.

Storm water flowed down a natural gully to the sea (piped under the road).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
Year 1999

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The shoreline in 1999 was in a similar position to current day.

Storm water flowed down a natural gully to the sea (piped under the road).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
Year 2008

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The shoreline in 2008 was in a similar position to current day. However, to create the space for the Encounter Bikeway the slope of the embankment was increased.

Storm water flows down a natural gully to the sea (piped under the road).

Photograph: Coast Protection Board,2008

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
Year 2012

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The shoreline in 2012 was in a similar position to current day. However, to create the space for the Encounter Bikeway the slope of the embankment was increased.

Storm water flows down a natural gully to the sea (piped under the road).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
Year 2016

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The shoreline in 2016 was in a similar position to current day. However, to create the space for the Encounter Bikeway the slope of the embankment was increased.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
DEM compare:
2011 with 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 coast has been stable in this location.

The green section in the south of the photograph is a new carpark installed in the backshore since 2011.

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4-2 Coastal fabric – summary (Cell 12.1a)

Medium Term Changes

Fleurieu 12.1a

Encounter Bay

Historical comparison

Shoreline

Location:
The Bluff boat ramp
Summary

70 years
The beach in it is natural state sloped up to road without an embankment. Minor vegetation in the backshore was positioned about 4-6m landward of the current shoreline. Increasing the width of the road and installation of bikeway required more space and post ~2000 an embankment was installed.

10 years

Recession over last decade is nil.

Notes:

Location has been very stable over 70-year period in what is a sheltered part of the bay.

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4-2 Coastal fabric – shoreline changes (Cell 12.1b)

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki

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
- 2008
- 2012
- 2016
- 2018

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

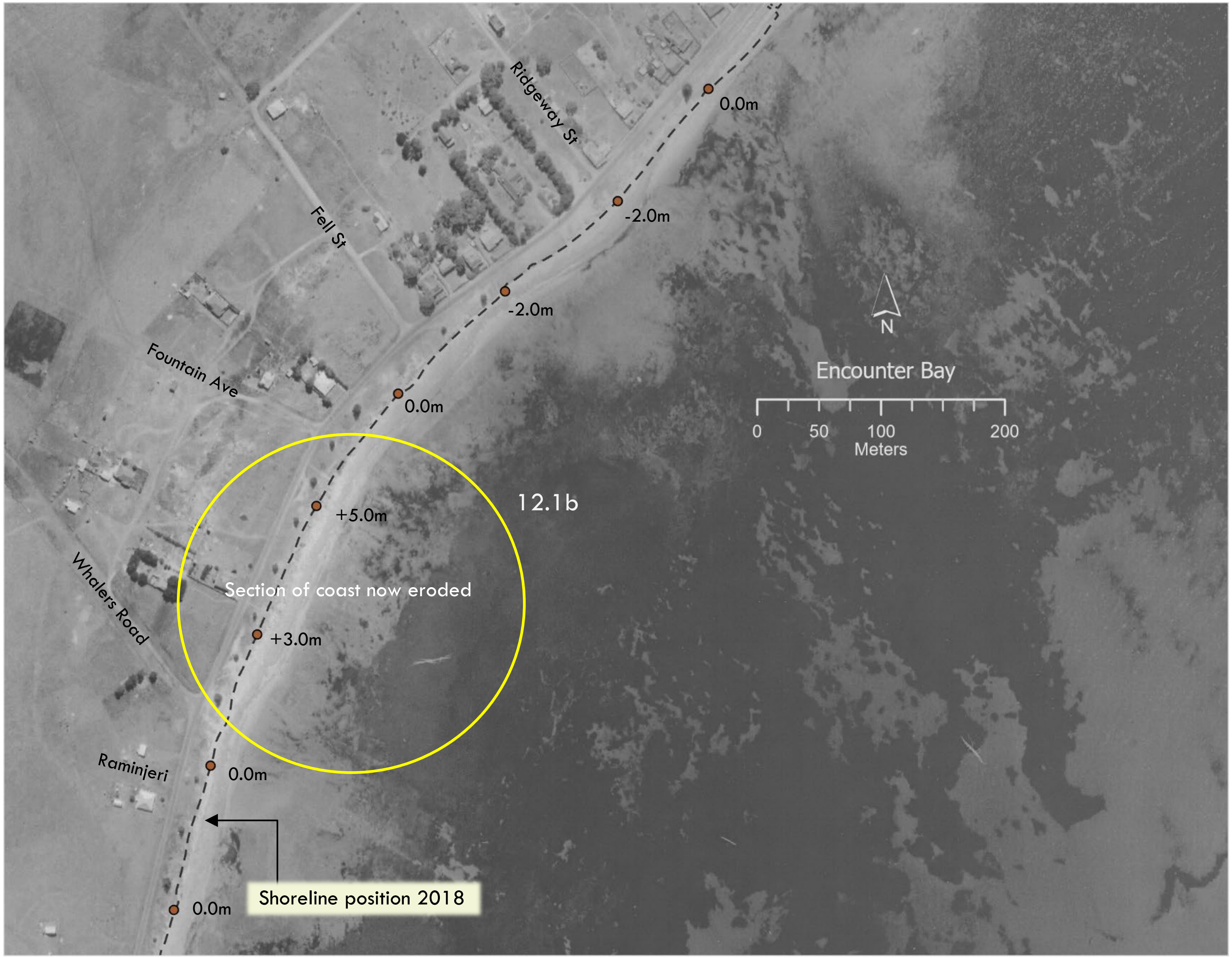
Shoreline

Location:
Yilki
Year 1949

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

Photographs from the time show that the beach sloped up to the road which had no embankment on the seaward side.

In most locations the shoreline in 1949 is in a similar position as 2018 apart from an area between Whalers Road and Fountain Ave.



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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
Year 1976

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

In this time period, the beach sloped up to a small embankment or grass verge to the road. Erosion appears to be prevalent in some sections (yellow circles), with the beach becoming close to the road. Rock protection was introduced at end of Whalers Road (see also inset photo).

The circle on the right also indicates the location of the Yilki shops.

Photograph: Coast Protection Board,1975

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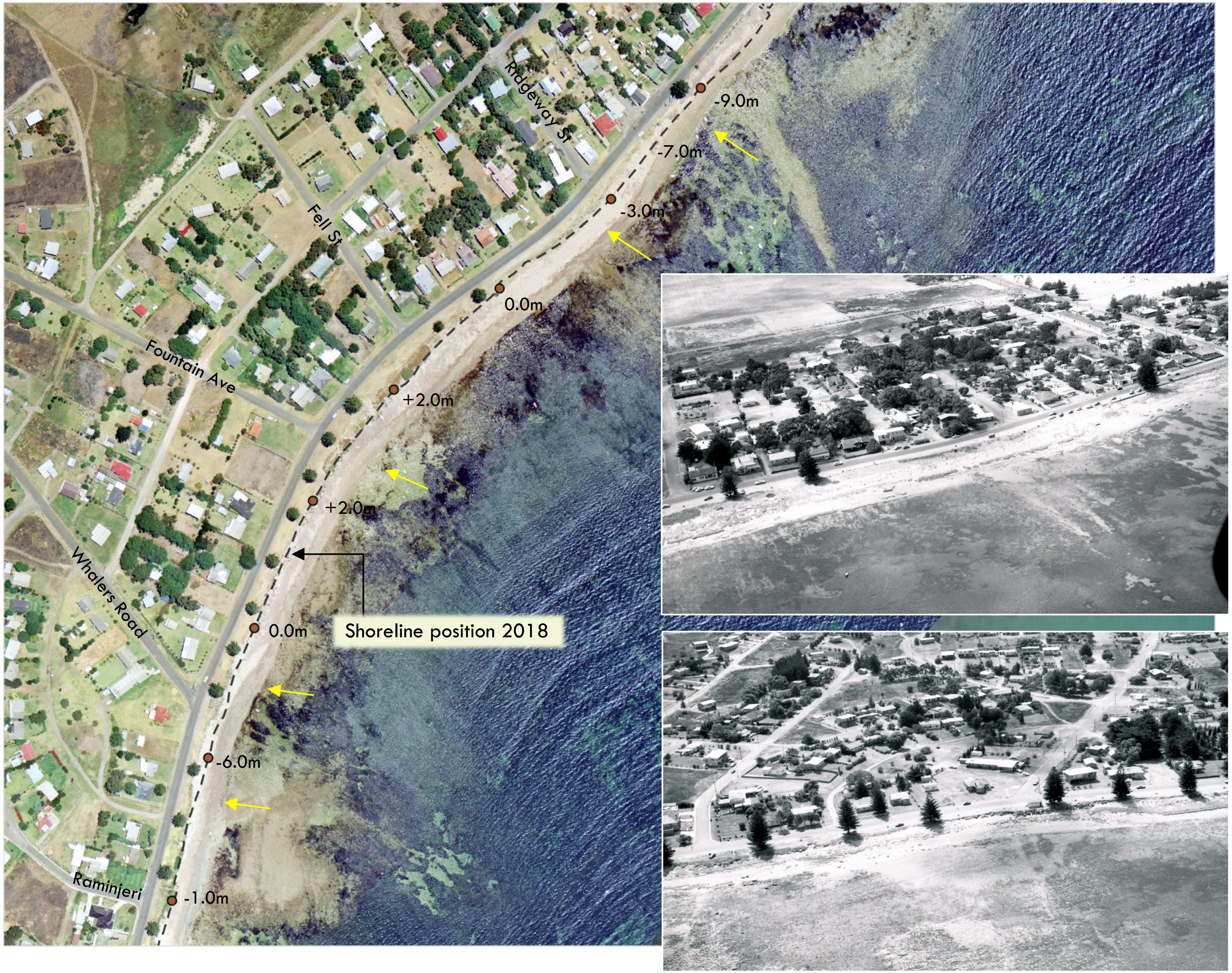

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
Year 1989

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

In this time period, the beach sloped up to the vegetated backshore on a small embankment or a grassed verge at the edge of the road.

In this era, accretion appears to be prominent, especially from Fountain Ave to the Yilki Shops. This may have been an era of Council management to install a dune in this location (see also minor cell 12.2a in the vicinity of Tabernacle Road).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
Year 1999

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The Encounter Bikeway was installed in this era meaning that a level area between the road and the beach was required. In some places this is likely to have involved the installation of a higher embankment.

Most of the shoreline is in a similar position to the current era apart from the area in front of the Yilki shops which was further seaward.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
Year 2008

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

Most of the shoreline is in a similar position to the current era south of Fountain Ave but rock protection was first installed here in the 1990s and upgraded and lengthened in 2005.

Inset picture: Rock protection installed between Whalers Road and Fell Street carpark.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
Year 2012

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

Most of the shoreline is in a similar position to the current era south of Fountain Ave but rock protection was first installed here in the 1990s and upgraded and lengthened in 2005.

The area in front of the Yilki shops accreted further in this era. The area in front of the carpark receded 4m.

The period 2007 to 2011 was characterised by higher-than-average high tides which caused considerable erosion in other locations (e.g. King St).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
Year 2016

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

Most of the shoreline is in a similar position to the current era apart from a minor section of coast in front of the Yilki shops.

However, rock protection has been progressively installed from 1990s from Raminjeri Crescent to Fell Street.

Since 2018, concrete block protection has been installed between Fell Street and Ridgeway St (see inset photo).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
DEM compare:
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.

The coastline around Fell Street has undergone minor accretion. This area was sand nourished in 2012 (but suffered further storm impact and is now protected by concrete blocks).

The erosion at Yilki shops is observed in the shoreline analysis above and occurred 2016- 2018.

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4-2 Coastal fabric – summary (Cell 12.1b)

Medium Term Changes

Fleurieu 12.1b

Encounter Bay

Historical comparison

Shoreline

Location:
Yilki
Summary

70 years
The shoreline in 1949 was in a similar position to the current era apart from an area between Whalers Road and Fountain Ave. Rock walling was installed in front of Yilki ~1948 and progressively added to the coast between Raminjeri to Fell Street.

10 years
The period 2007 to 2011 was characterised by higher-than-average high tides. Protected areas remained unchanged as did the shoreline at Yilki. The shoreline at Yilki eroded significantly in the last few years (after the erosion period) and is now protected by rock. However, this position is not significantly different to 1975 (inset photograph).

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4-2 Coastal fabric – shoreline changes (Cell 12.2a)

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle Rd to Oakham Rd

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
- 2008
- 2012
- 2016
- 2018

In this location the shoreline position is the toe of the embankment or the vegetation line in 2018.

The location of Coast Protection Board profile line 620002 is shown to provide context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Year 1949

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

Photographs from the time show that the beach sloped up to the road without an embankment to the edge of the road.

In vicinity of Tabernacle Road, the shoreline was much further inland and was likely a low area in which storm water exited in former times from the lower lying area that is now Encounter Lakes.

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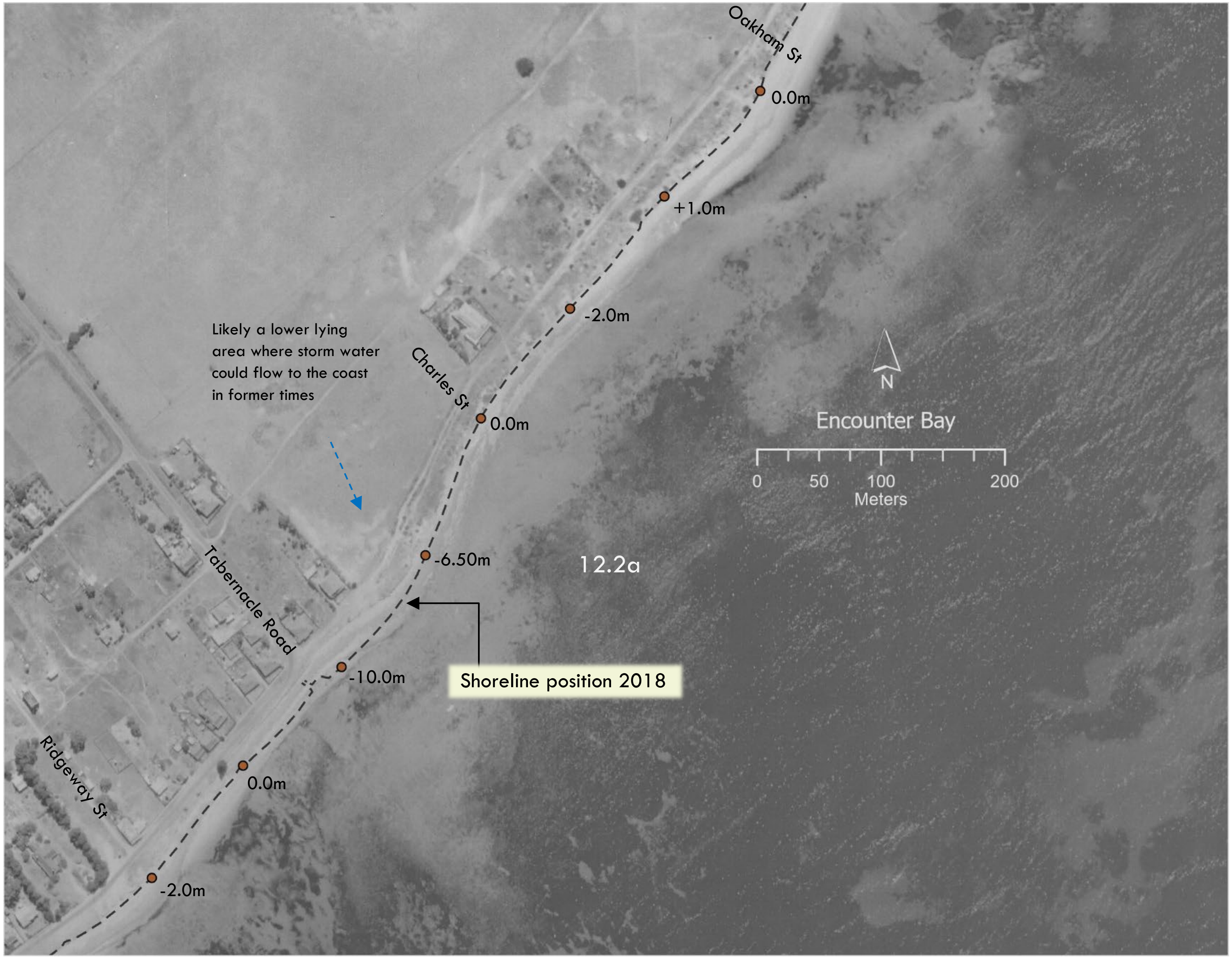

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Year 1976

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

Photographs from the time show that the beach sloped up to the road. The seawall pictured is likely the seawall installed in early 1950s.

In this era, the beach receded back to the road (or near to the road) along Franklin Parade between Tabernacle and Oakham Street. In the vicinity of Tabernacle Road, the shoreline was 20m landward of the current position of the shoreline.

Photo: Coast Protection Board, 1975

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Year 1989

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The period between 1976 and 1989 was marked by accretion. For example, by 18m the area in vicinity of Tabernacle and Charles Street. Note, this may have also been a result of Council management.

The location of Coast Protection Board profile line 620002 is shown to provide context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Year 1999

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The Encounter Bikeway was installed in this era meaning that a level area between the road and the beach was required. In some places this is likely to have involved the installation of a higher embankment.

The shoreline in 1999 was in a similar position to 1989.

The location of Coast Protection Board profile line 620002 is shown to provide context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Year 2008

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

This period is marked by erosion. Analysis of the tidal record shows increased height of high tides at Victor Harbor gauge. The records indicate that from 2007 to 2011 Council was dealing with ongoing erosion in Encounter Bay, and especially along The Esplanade Beach.

The location of Coast Protection Board profile line 620002 is shown to provide context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Year 2012

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

This period is marked by erosion. Analysis of the tidal record shows increased height of high tides at Victor Harbor gauge. The records indicate that from 2007 to 2011 Council was dealing with ongoing erosion in Encounter Bay, and especially along The Esplanade Beach. However, this beach appears to be recovering by 2012.

The location of Coast Protection Board profile line 620002 is shown to provide context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Year 2016

In this location the shoreline position is the toe of the embankment in the backshore or the vegetation line.

The year 2016 was also a year of higher-than-average high tides.

The shoreline is in a similar position to 2012 but the area in front of the Fell Street carpark eroded.

The location of Coast Protection Board profile line 620002 is shown to provide context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
DEM compare:
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.

This area has undergone accretion which is also observed in the shoreline position.

Shoreline accretion of 3-6m since 2008.

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4-2 Coastal fabric – summary (Cell 12.2a)

Medium Term Changes

Fleurieu 12.2a

Encounter Bay

Historical comparison

Shoreline

Location:
Tabernacle to Oakham
Summary

70 years

Most of the shoreline is in a similar position to 1949. The exception is between Tabernacle Rd and Charles St which was ~10m to 20m landward, which in former times may have been a drainage point from lower lying land now known as Encounter Lakes.

10 years

The region went through a period of higher high-tides and increased erosion from 2007 to 2011. Over the last few years, the shoreline has settled into its current position.

Notes:

The beach goes through cycles of accretion and erosion, most likely related to actions of the sea.

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4-2 Coastal fabric – shoreline changes (Cell 12.2b)

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve

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
- 2008
- 2012
- 2016
- 2018

In this location the shoreline position is the vegetation line in 2018.

The position of Coast Protection Board profile line 620007 is shown to provide context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
1949

In this location the shoreline position is the vegetation line in 2018.

This location has undergone large changes over a seventy-year period.

In 1949 the shoreline in the vicinity of the offshore reef was 25m to 45m landward of the current shoreline position in 2018.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
Year 1976

In this location the shoreline position is the vegetation line in 2018.

This location has undergone large changes over a seventy-year period.

In 1976 the shoreline in the vicinity of the offshore reef was 25m to 35m landward of the current shoreline position in 2018. In the period between 1949 and 1976, overall, this section of coast accreted.

Minor recession occurred at Bartel and Wood Street

Photograph: Coast Protection Board, 1975

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
Year 1989

In this location the shoreline position is the vegetation line in 2018.

This location has undergone large changes over a seventy-year period.

Between 1976 and 1989, the coastline continues to accrete (but receded at Wood Street in the south of the photograph).

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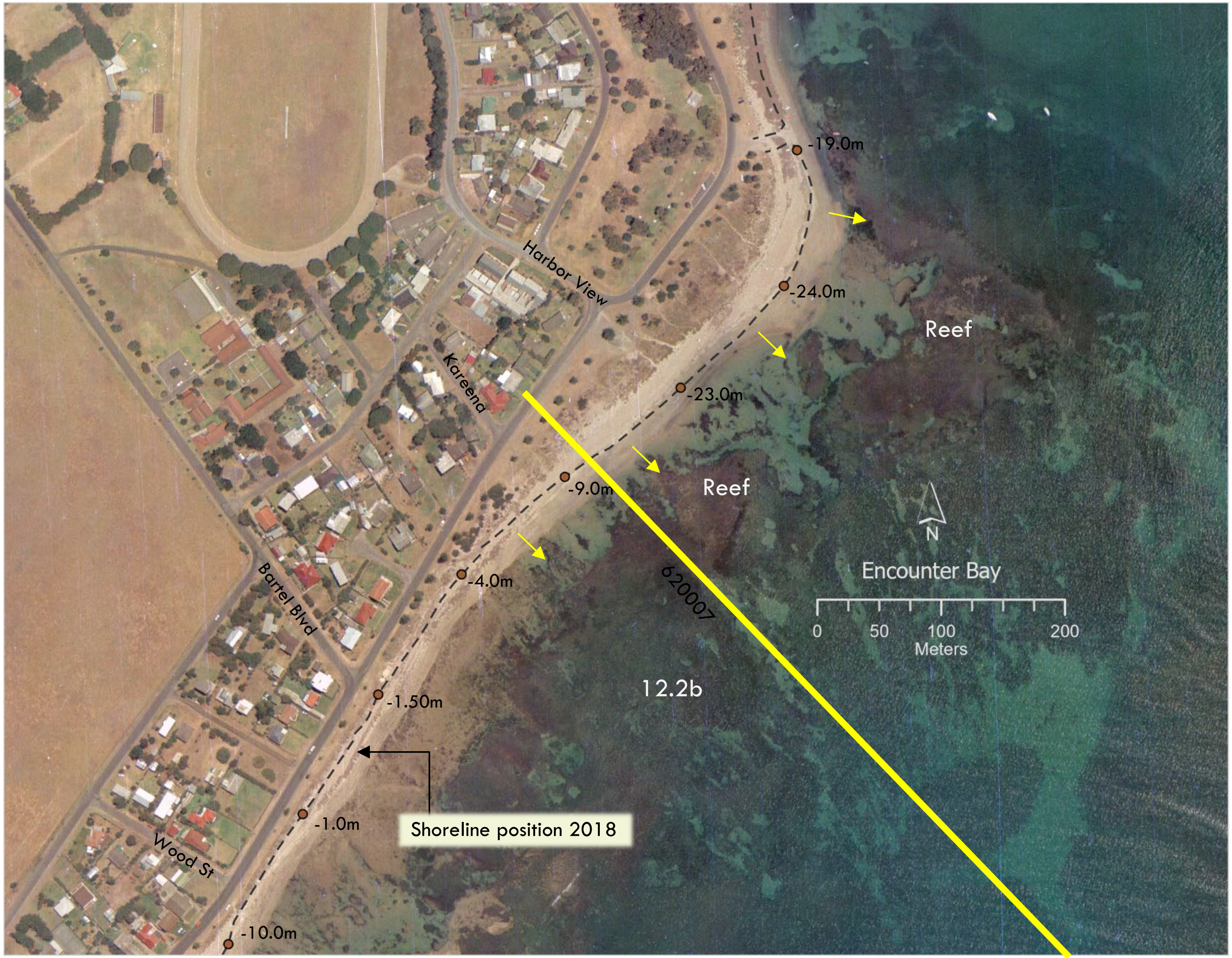

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
Year 1999

In this location the shoreline position is the vegetation line in 2018.

This location has undergone large changes over a seventy-year period.

In 1999, the shoreline position was almost the same as 2018, but further inland at the boat launching area (see top of photograph).

Note, the mouth of the Inman River was realigned to the west in 1995. This may have had an impact on sediment flow in the area. However, the Kent Reserve area **was already accreting by 1976.**

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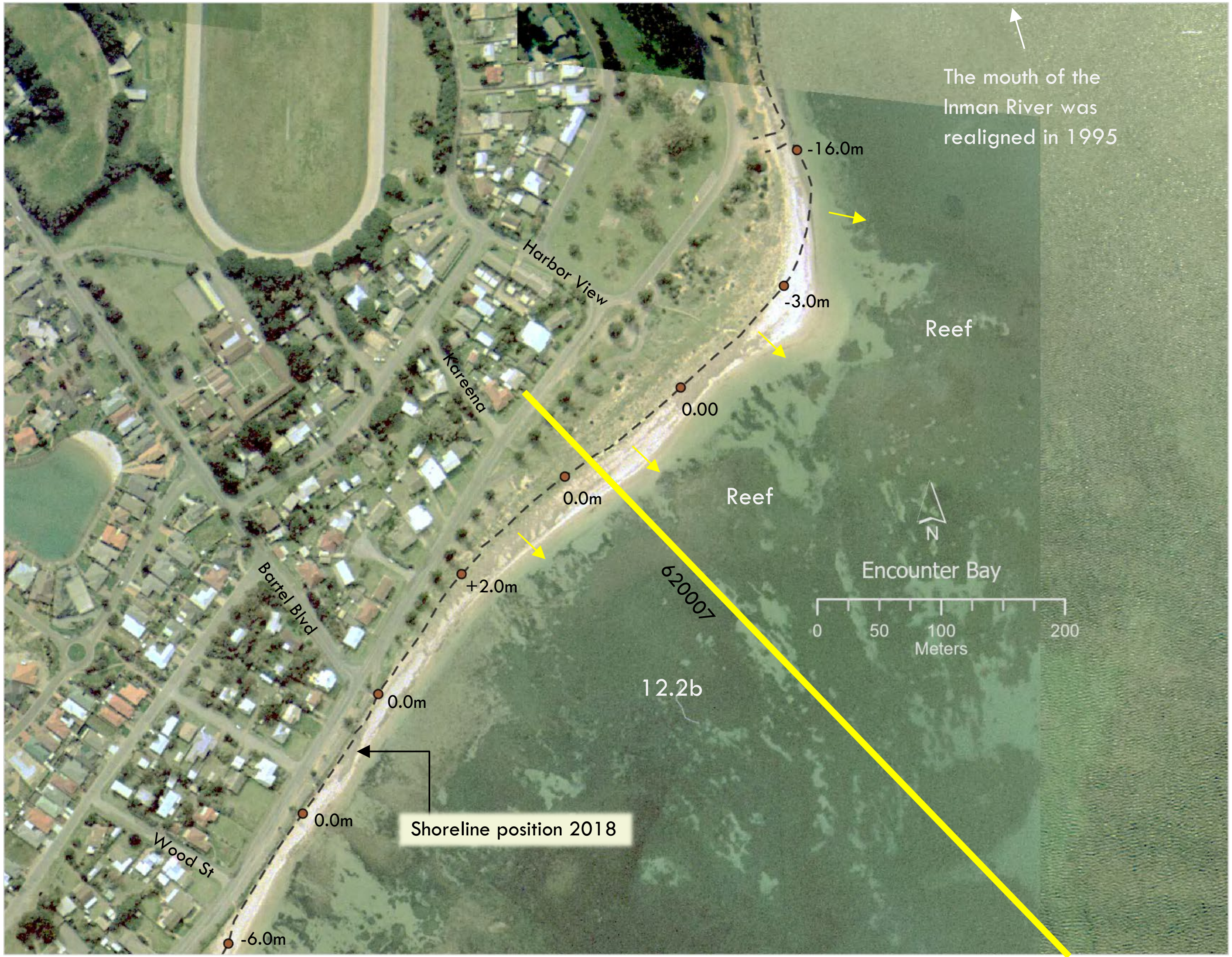

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
Year 2008

In this location the shoreline position is the vegetation line in 2018.

This location has undergone large changes over a seventy-year period.

The coastline continued to accrete adjacent the reef until it was located further seaward than 2018.

Note, the mouth of the Inman River was realigned to the west in 1995. This may have had an impact on sediment flow in the area. However, the Kent Reserve area was already accreting by 1976.

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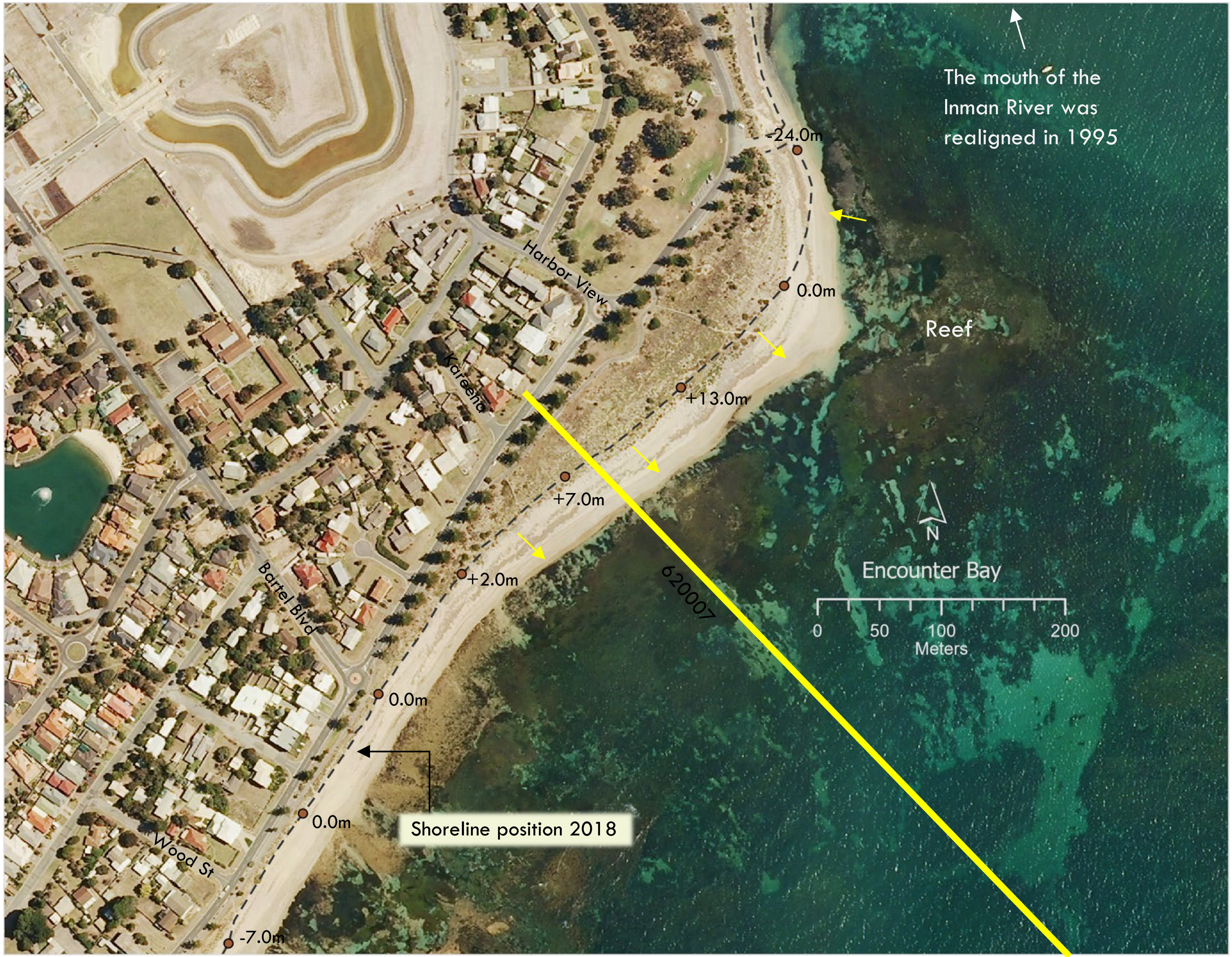

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
Year 2012

In this location the shoreline position is the vegetation line in 2018.

This location has undergone large changes over a seventy-year period.

Between 2008 and 2012 the coastline continued to **accrete** adjacent the reef until it was located further seaward than 2018. This is in contrast to other areas around the coast that were eroding. This time period was marked by higher-than-average high tides and significant erosion on the Esplanade Beach and erosion at some places around Encounter Bay (Fell Street).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
Year 2016

In this location the shoreline position is the vegetation line in 2018.

This location has undergone large changes over a seventy-year period.

Between 2012 and 2016 the coastline accreted in places and receded in others until it arrived at a similar position as 2018 (next page).

Note, the mouth of the Inman River was realigned to the west in 1995 (check). This may have had an impact on sediment flow in the area. However, the Kent Reserve area was already accreting by 1976.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 12.2b

Encounter Bay
Historical comparison

Shoreline

Location:
Kent Reserve
DEM compare:
2011-2018

The area within Cell 12 has eroded 6-12m since 2012. The shoreline in Cell 11 has accreted about the same amount since 2012.

The aerial photography from 1949 to 2018 provides a longer time period from which to identify the movement of the beach. From the period 1949 to 2012 the coastline in line with Harbor View Terrace accreted 58m. This section of beach continued to **accrete** in an era of increased storminess and higher erosion at other localities (2004-2011). When this period of erosion passed, the shoreline in this location then **receded** by ~10m.

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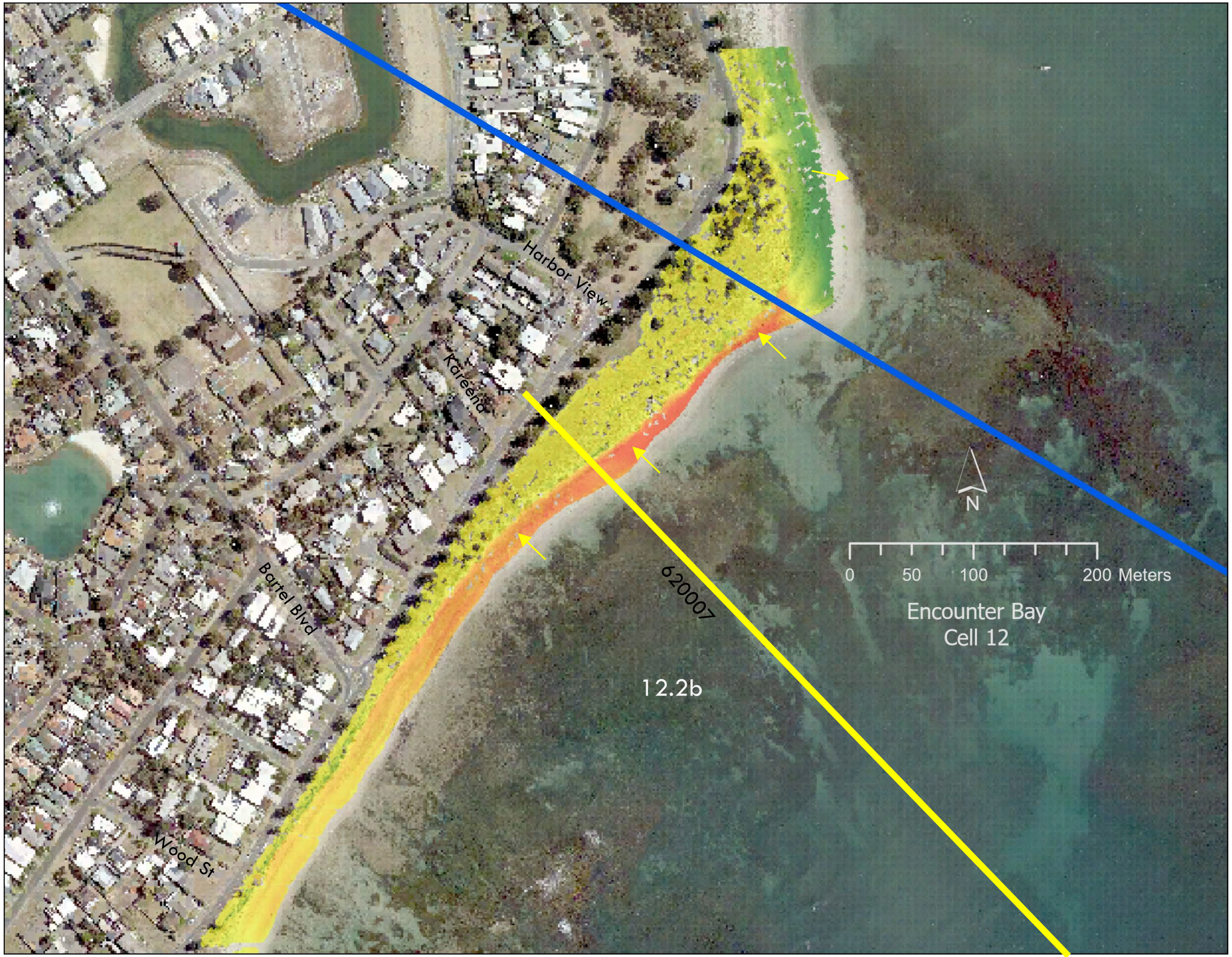

4-2 Coastal fabric – shoreline changes (Cell 12.2b)

Medium Term Changes

Fleurieu 12.2b

Encounter Bay

Historical comparison

Shoreline

Location:
Kent Reserve
Summary

70 years

Overall, this area underwent significant accretion. Between Kareena Road and the boat launching area the coast accreted 25m to 45m (and at one stage accreted further than the 2018 line).

10 years

In a period when the remainder of the coast was suffering erosion, this area accreted past the 2018 line and then receded back.

Notes:

The mouth of the Inman River was realigned in 1995 and this may have impacted sediment but this section was already accreting by 1976.

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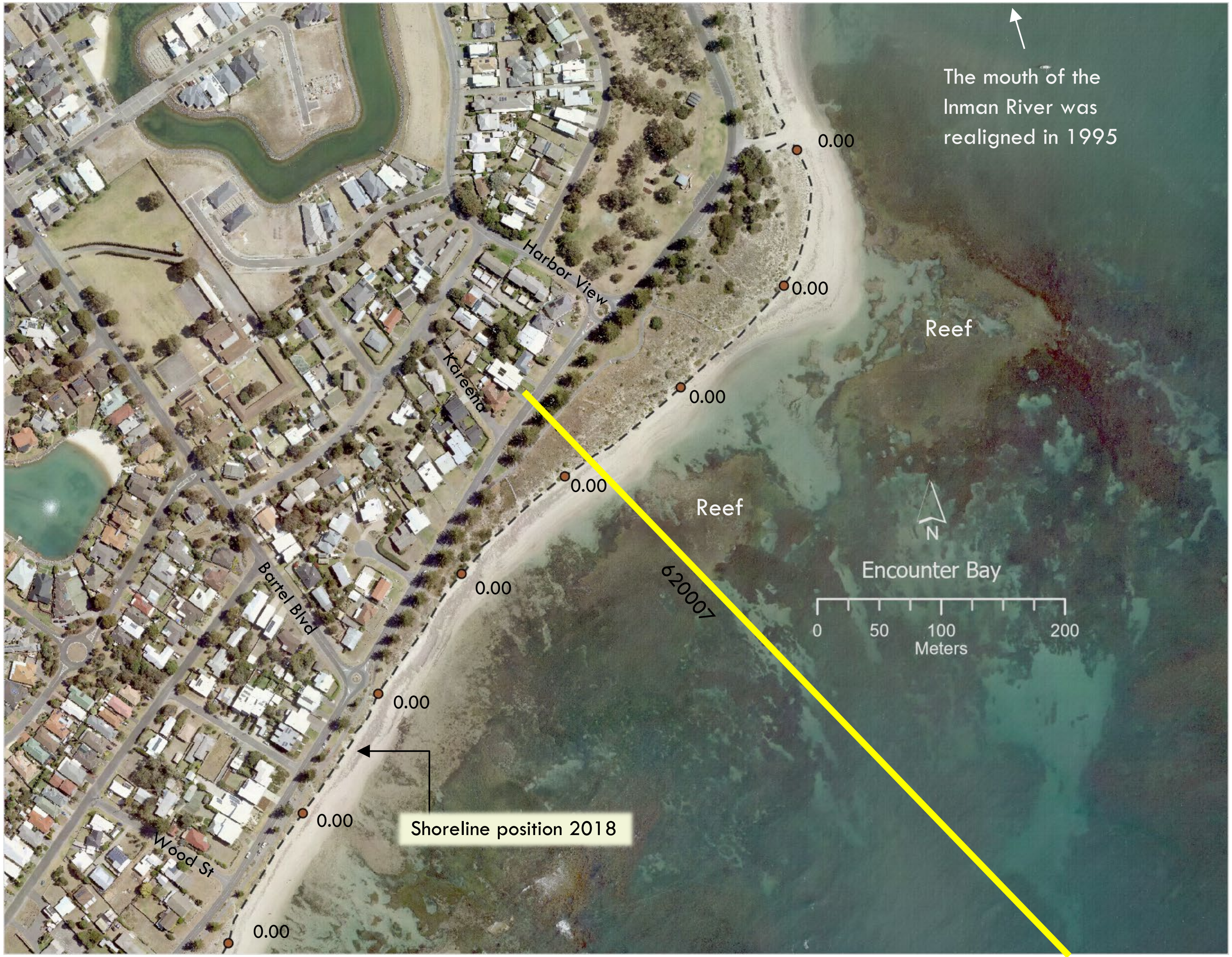

4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 12

Encounter Bay

Historical comparison

Profile line

Analysis

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

Profile lines:

- 620002
- 620007

Beach description (Nature Maps)

- Low Tide Terrace + Transverse Bar Rip
- fine-medium sand beach
- moderate exposure
- low wave energy
- Cliff, reef flats front the beach.

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4-3 Coastal fabric – beach profile changes

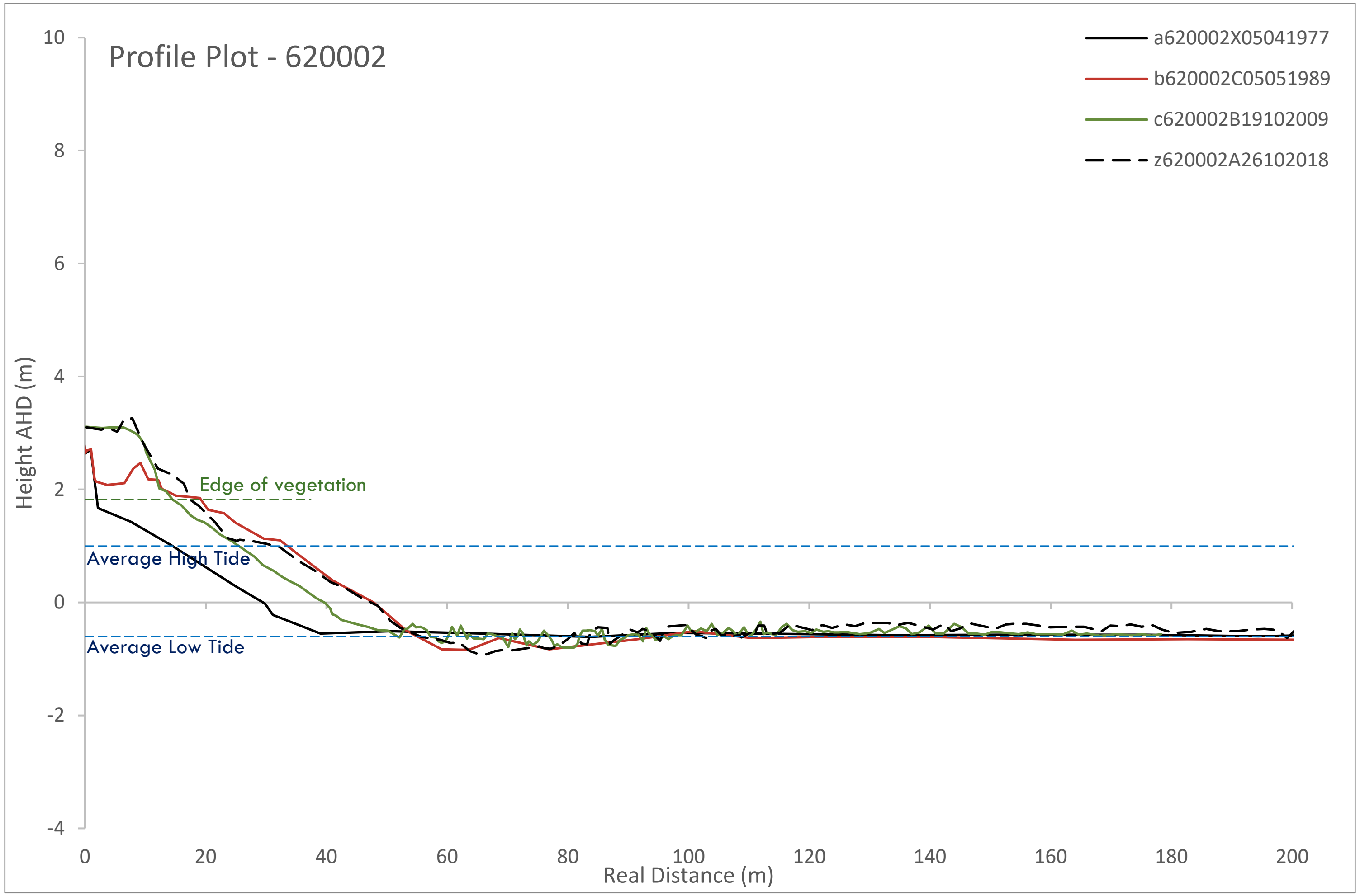
Medium Term Changes

Fleurieu 12

Encounter Bay

Historical comparison

Beach Profile



Analysis:
Profile line 620002
Tabernacle Road

Photographs from ~1975 show that the backshore of the beach at Tabernacle Road had no dune system but sloped back to the edge of the road. Higher tides at the time are likely to have flowed near to the road edge.

It is likely in the 1980s (red line) that Council implemented a program of works to install a vegetated backshore. A period of erosion occurred 2004 to 2011 and then the backshore has rebuilt to its current position in 2018.

As a general observation, below the low tide line is dominated by a low-profile reef which is reflected in the minimal amount of movement in the profile line offshore. The area below the low tide line close to the shore (where there is no reef) currently shows a lower level of sand than in previous eras, but further offshore, sand is at a slightly higher level.

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4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 12

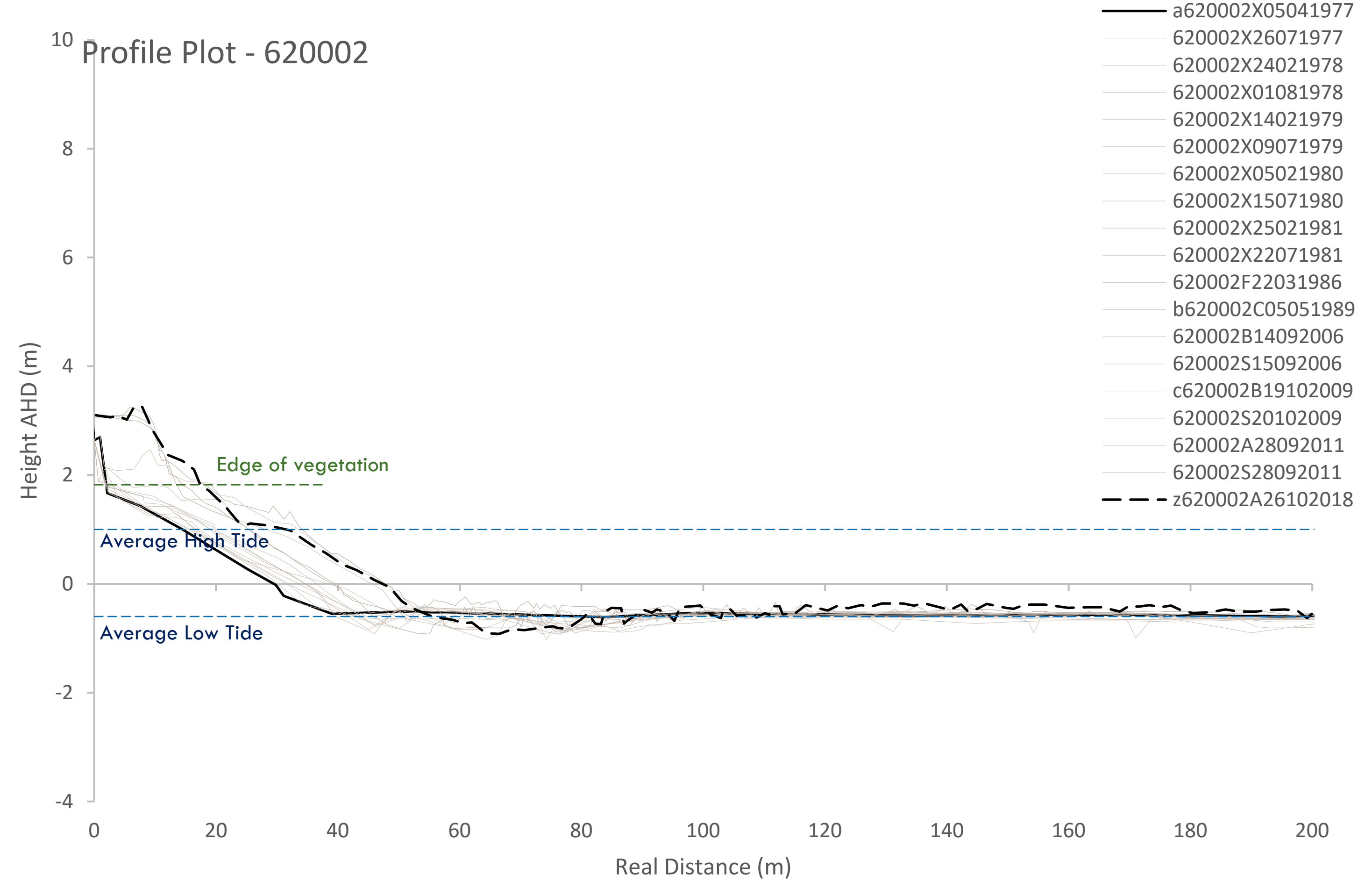
Encounter Bay

Historical comparison

Beach Profile

Analysis:
Profile line 620002
Tabernacle Road

When comparing start and finishing profiles, the current position of the whole backshore above the low tide line is ~20m seaward of the 1977 position. This may have been due to management strategies employed by Council in the 1980s.



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Notes: It is relevant to note that the position of the backshore in 1977 was formed by wave action in that time period (early 1970s were a time of increased storminess). Therefore, it could be anticipated that this section of coast is likely to come under pressure to recede in the context of increased storminess and higher than average high tides when these occur.

4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 12

Encounter Bay

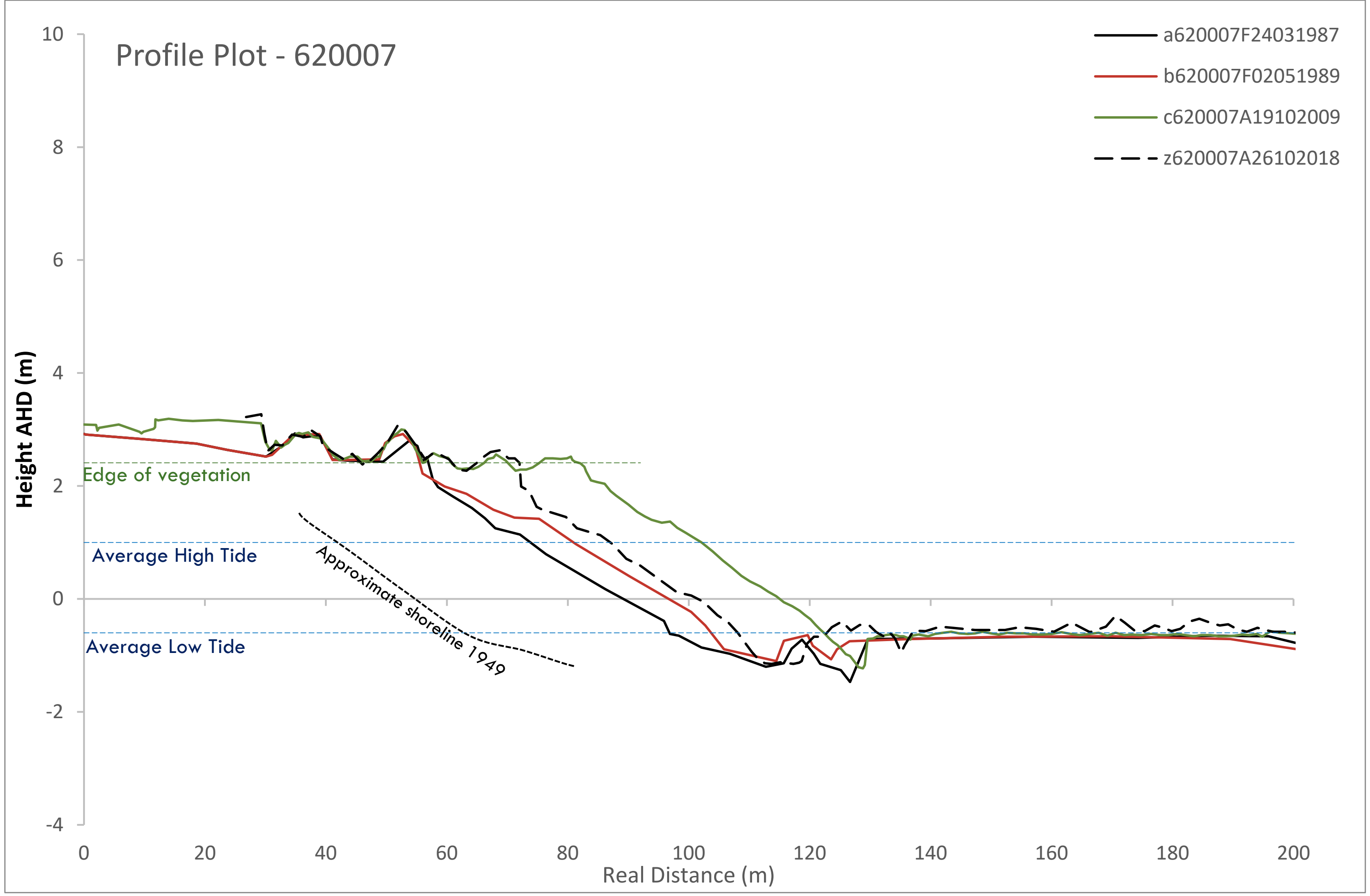
Historical comparison

Beach Profile

Analysis:
Profile line 620007
Kent Reserve

The horizontal accretion and building seaward of the dune at ~2.4m elevation has produced a vegetated relatively flat platform. This total range is ~25m over the monitoring period (1987 to 2018). The 2018 profile sits in the mid-range of this zone, consistently 10 – 12m seaward of the 1987 levels, and about the same distance landward in comparison to the most accreted profiles (2006 – 2011).

The aerial photography from 1949 to 2018 provides a longer time period from which to identify the movement of the beach (continued at bottom-right).



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From the period 1949 to 2012 the coastline in line with Harbor View Terrace further to the north of this profile line accreted 58m. In this location was 30m. The section of beach at Kent Reserve continued to **accrete** in the era of increased storminess and higher erosion at other localities (2004-2011). When this period of erosion passed, the shoreline in this location then **receded** by ~10m.

4-3 Coastal fabric – beach profile changes

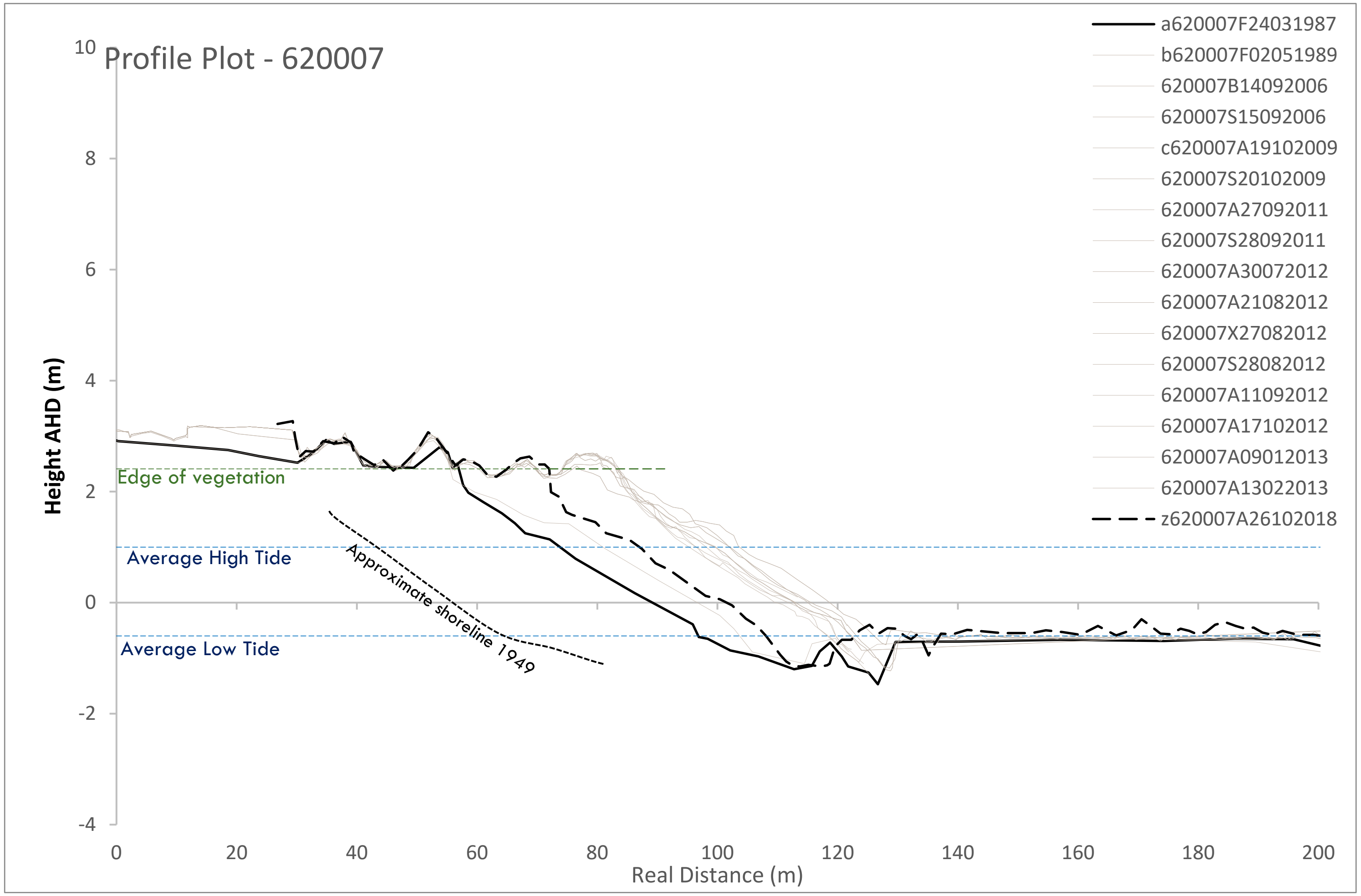
Medium Term Changes

Fleurieu 12

Encounter Bay

Historical comparison

Beach Profile



Analysis:
Profile line 620007
Kent Reserve

The area accreted significantly from 1949 to 2012 and then receded to its current position (2018).

Further monitoring is required to determine if the current position indicates a trend of ongoing retreat, or if the profile builds back toward the seaward levels of the post 2009 era.

One key observation is that this section of coast has undergone long term accretion, but also continued to accrete in a higher erosion period (2004-2011) and then receded when other parts of the coast were beginning to stabilise or accrete (for example The Esplanade). Ongoing monitoring might establish that the sand from Kent Reserve could be used as a sand nourishment source in times of erosion.

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4-4 Coastal fabric – human intervention (Cell 12.1)

MODIFIED COASTS

Urban settlements placed too close to shorelines impose rigidity in the backshores, which were 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. Human interventions for Encounter Bay from the **Bluff boat ramp** to **Tabernacle Road** are noted below.

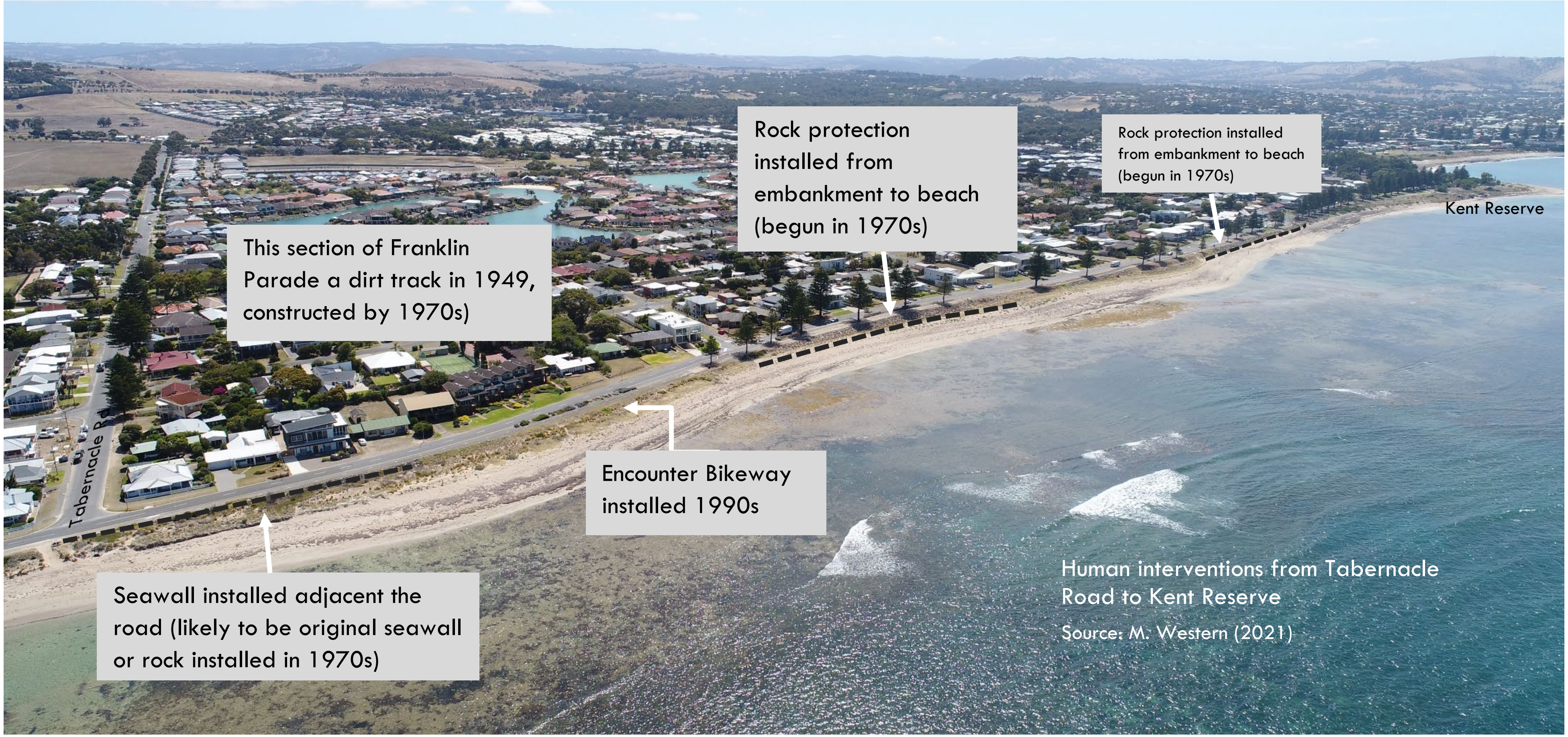
Human interventions from The Bluff boat ramp to Tabernacle Road (Yilki)

Source: M. Western (2021)

4-4 Coastal fabric – human intervention (Cell 12.2)

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. Human interventions for Encounter Bay from **Tabernacle Road** to **Kent Reserve** are noted below.



Human interventions from Tabernacle Road to Kent Reserve

Source: M. Western (2021)

4-4 Coastal fabric – human intervention (Cell 12)

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 (if required).

Zoning and policy areas:

Open Space

Open Space zoning controls all development in the foreshore area. Referrals are required to be made to SA Coast Protection Board.

Waterfront Neighbourhood

The areas designated as Residential Zone has an additional policy area known as Waterfront Policy 24. The zoning objective is to comprise a wide range of residential housing types and tourist accommodation. Envisaged dwelling types include detached dwellings, semi-detached, row dwellings, group dwellings and residential flat dwellings.

Local Activity Centre:

The role of this policy area is to develop into a fully integrated Local Centre by upgrading existing buildings through the appropriate development of under-utilised sites. Quantitative controls include 0m setback to Franklin Parade and three storeys high (12m) for any allotment that fronts Franklin Parade.

Referrals:

There is no requirement to refer any development proposal to the SA Coast Protection Board that is situated behind the Coastal Open Space Zone.

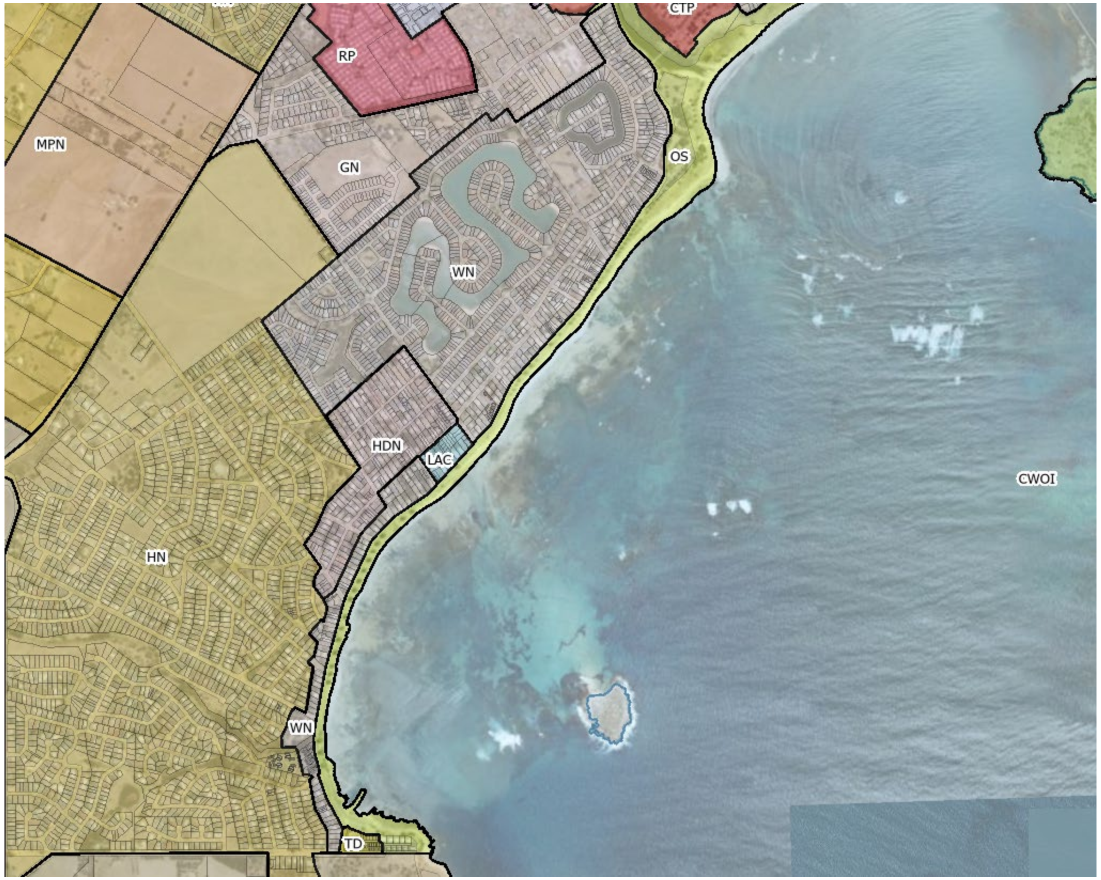


Figure a. Encounter Bay urban zoning characteristics (Source: South Australian State Government).

4-4 Coastal fabric – human intervention (Cell 12)

WORKS AND STRATEGIES

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

- It is likely that Council implemented works to install a dune and vegetated backshore in the vicinity of Tabernacle Road (compare pictures to the right).
- Council has an ongoing vegetation and weed control program.
- Controlled access ways exist in the vicinity of Kent Reserve. Access to the beach is more difficult to control south of Tabernacle Road and the impact of informal pedestrian access is observed in some places.
- Sand nourishment was trialled in the vicinity of Fell Street.
- Rock and concrete block protection has been installed from Nevin to Tabernacle, and in some sections east of Tabernacle Road (see pages above).

Project notes

Recent erosion at Yilki over the last few years may indicate a change in actions of the sea. The tidal record from 2004 to 2011 and analysis of other portions of the coast show that this era was a time of increased storminess and elevated sea levels. This may be an indication of the impact of climate change and rising seas. However, it is also relevant to note the characteristics of this location in the 1970s.

Figure a. The backshore in the vicinity of Yilki and Tabernacle Road was an unvegetated slope back to the road (which appears to have a seawall, most likely constructed in 1950s)

Figure b. The area between Yilki and Tabernacle Road were likely nourished and vegetated by Council in the 1980s. (The only other explanation is that this area accreted and was vegetated but

4. Coastal fabric – summary table (Cell 12)

Encounter Bay		Coastal context - natural				Modified	Coastal changes			
Cell	Location	Bathymetry	Benthic	Beach	Backshore	Human	70 years	10 years	**Erodibility**	**General notes**
12.1	Bluff boat ramp to Tabernacle Road (Yilki)	Slope 1:200 (-5m at 1km offshore). Slope of seabed increases seaward of Wright Is.	Nearshore dominated by low profile reef and seagrass beds. A sand bed is situated between The Bluff and Wright Island.	Coarse sand beach	The surface under the road was formed 4-5000 yrs ago when seas were +1m. Backshores from Nevin to Yilki are now mostly rock or concrete protected.	In 1850 the backshore was a gentle slope. Wider road, carparks, cycle tracks required the install of an embankment (now protected).	Close to the boat ramp the coast has been stable. Erosion increases toward Yilki (south of Tabernacle Road).	Nil change near the boat ramp. Increased erosion at Fell Street and Yilki (last few years).	Moderate. Reefs in nearshore, earthen banks, or hard protection.	Some sections of the coast are not yet protected between Nevin and Yilki. Between boat ramp and Nevin is more sheltered with little erosion evident.
12.2	Tabernacle Road (Yilki) to Kent Reserve	Slope 1:150 (-5m at 600-800m offshore). Slope increases seaward of Granite and Wright Island	Dominated by rock platform and reefs and low-profile reefs. Interspersed with seagrass beds.	Coarse sand beach	Varies – a steeper embankment/ dunes nearer Tabernacle Road. In the vicinity of Kent Reserve an elevated vegetated sand platform.	Rock protection has been installed in sections of the coast between Tabernacle Road and Kent Reserve.	The shoreline has moved seaward (accreted) at Tabernacle Road and significantly at Kent Reserve.	Minor accretion near Tabernacle Road, erosion at Kent Reserve (but after long term accretion).	High (sandy beaches and backshores, partly protected)	Understanding what causes the significant accretion of Kent Reserve may promote this area as a suitable sand source for beach nourishment.

Erodibility Rating: Moderate (2) (due to prevalence of protection structures)

Encounter Bay: key points

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

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

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 within Encounter Bay, which is also afforded protection by Rosetta Head from the Southern Ocean, Nature Maps (SA) has assigned the exposure rating for Encounter Bay as 'sheltered' and the wave height as 'low'.

Storm surges

Despite this protection, when a number of meteorological conditions combine, storm surges can produce water levels up to 0.6m 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 once or twice 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: Routine high-water modelling displays appropriate congruency 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 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]). Throughout the following decades the rate of sea level slowed. 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.

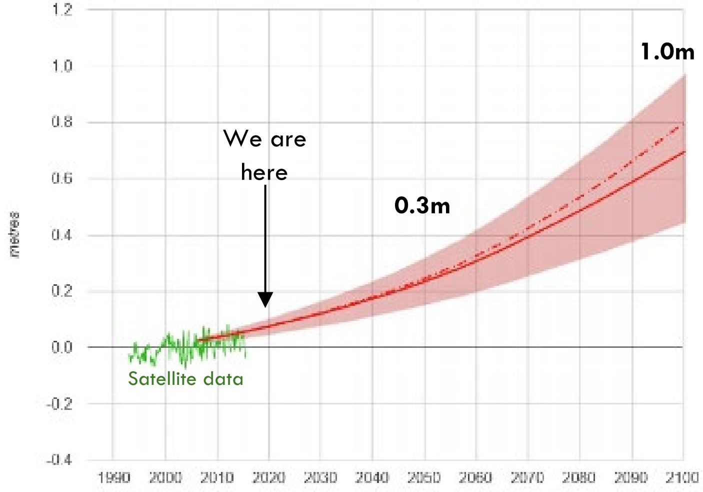


Figure a: Sea level rise high emissions scenario (RCP 8.5) and including SA Coast Protection Board sea level rise policy projections (Adapted from CoastAdapt, 2017)

[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 12

Encounter Bay

Coastal Exposure

Overview

SA Classification

Nature Maps (SA)

Relative Exposure:
Sheltered

Wave energy:
Low

Shoreline class
Rock Platform

Sand rating
Coarse Sand

Form:
Overall slope of ocean floor:
-5m ~700 to 1000m from beach
(overall slope ratio ~1:150).

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5. Coastal exposure – previous storm impact

COASTAL STORMS

The analysis of previous storms provides a window into the past to assist us to identify where the coast is most vulnerable. This analysis also provides a window into the future because it provides a context from which to consider how storms will impact the coast if seas rise as projected. In some ways, storms are 'natures' vulnerability assessment of how resilient our coast currently is, and how it may respond in the future.

Storm events

The five highest storm surges on record at Victor Harbor tide gauge occurred:

- 29 June 1972 – 2.10m CD
- 3 July 1981 – 2.16m CD
- 14 May 1987 – 2.12m CD
- 2 August 1996 – 2.09m CD
- 9 May 2016 – 2.22m CD

In this region, that is exposed to high winds and actions of the sea from the Southern Ocean, events that cause erosion to the coastline may not necessarily be accompanied by very high tides.

There are very few photographs of storm action into Encounter Bay. The two shown here (Figures a,b) were not accompanied by very high tides but do provide an insight into wave action upon the coast. Figure (c) shows erosion damage after an event that was almost 2.00m CD and caused enough erosion damage that this section of rock was upgraded and extended in 2005.

Only two early accounts refer specifically to storm action in Encounter Bay. The Adelaide Mail reported a storm on 24 April 1943 which stated, 'at Encounter Bay the heaviest sea seen for many years was witnessed. Franklin Parade was undermined and had to be closed to traffic'[7]. It is likely that this event was the impetus for the construction of the seawall in 1947. However, it is likely that most of the wall was washed away in the winter of 1953. In 1954, The Progress Association requested that the Council rebuild the 'foreshore stone wall which was washed away….and where the sea has now encroached in places up to three and four yards[8].

Figure a. Storm in Encounter Bay 1st October 1992 (Photo - Coast Protection Board, 19921001). Does not correlate with high tide.

Figure b. Storm impact between Fell Street and Fountain Ave, 4 June 2012 (Photograph - Coast Protection Board, 20120604). Does not correlate with a high tide.

Figure c. Erosion damage near Nevin Ave, 3 August 2004, 1.925 CD (Photograph - Coast Protection Board, 20040810).

[7] The Mail, 24 April 1943

[8] Victor Harbor Times, Progress Association Report, 29 January 1954.

5. Coastal exposure – location map (Cell 12.1a)

Location

Fleurieu 12.1a

Encounter Bay

Location Map

The Bluff boat ramp

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 a few times 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:
Sheltered

Wave energy:
Low

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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 12.1a

Encounter Bay

2020 scenario

Event: Routine high water

Bluff boat ramp

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	1.00m AHD
Wave set-up	0.20m
Total risk	1.20m AHD

Wave run-up of 0.20m is included.

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

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5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 12.1a

Encounter Bay

2050 scenario

Event: Routine high water

The Bluff boat ramp

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.

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
Sea level rise	0.30m
Wave set-up	0.20m
Total risk	1.50m AHD

Wave run-up of 0.20m is included.

Routine highwater events at 0.30m higher than present are likely to erode and scour the bank under the road (minor overtopping likely)

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5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 12.1a

Encounter Bay

2100 scenario

Event: Routine high water

The Bluff boat ramp

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	0.20m
Total risk	2.20m AHD

Wave run-up of 0.20m is included.

Dr Bourman notes that the surface upon which the road is situated was likely formed 4-5000 years ago when seas were 1m higher.
Routine highwater events at 1.0m higher would cause significant erosion of the road and routine overtopping (not fully depicted here as waves interacting with vertical surfaces produce higher wave action).

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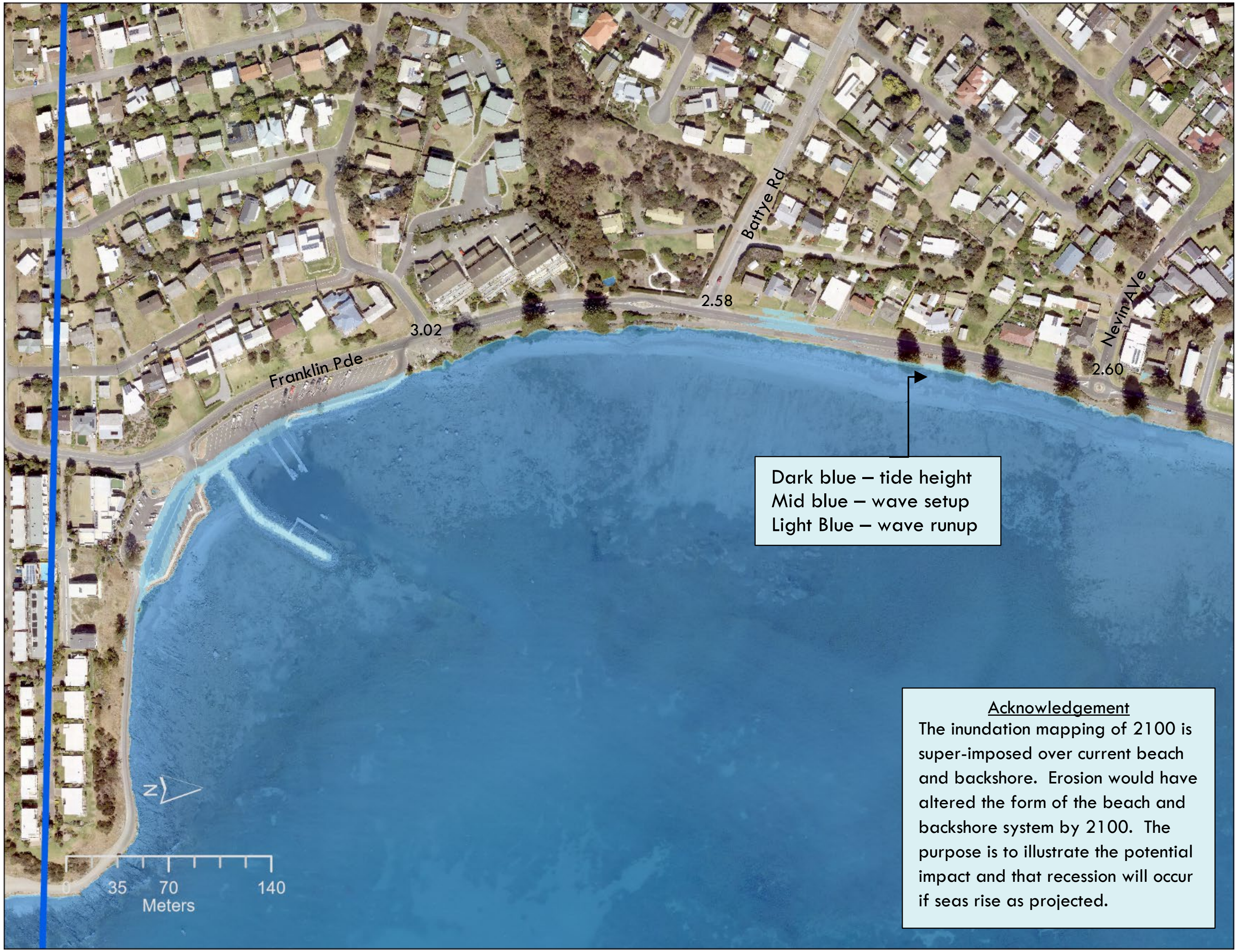

Dark blue – tide height
Mid blue – wave setup
Light Blue – wave runup

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 12.1a

Encounter Bay

2020 scenario

Event: 1 in 100 sea-flood risk

The Bluff boat ramp

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	0.30m
Risk	2.05m AHD

Wave run-up is 0.30m and depicted in light blue.

Assessment:
The impact of this storm event would similar impact as storm event 9th May 2016.
However, no known impacts were recorded from this event within Encounter Bay (impact may be associated with particular wind direction rather than the height of the tide).

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 12.1a

Encounter Bay

2050 scenario

Event: 1 in 100 sea-flood risk

The Bluff boat ramp

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	0.30m
Wave set-up	0.30m
Risk	2.35m AHD

Wave run-up is 0.30m and depicted in light blue.

Assessment.
The lighter blue is wave runup which indicates that overtopping of the embankment would be significant where indicated. Also note that wave setup would be directly impacting the embankment (some protected) and undermining and damage is likely.

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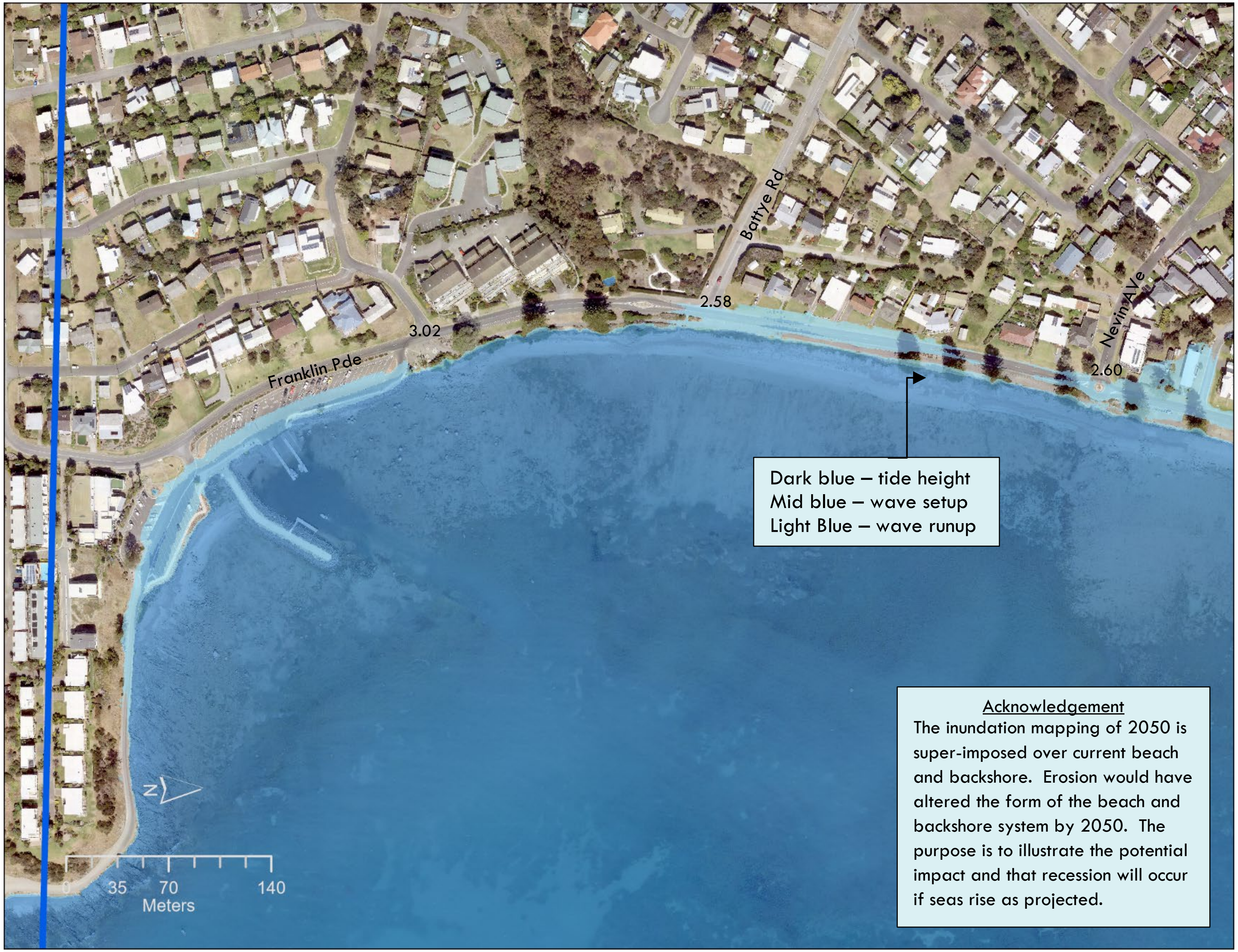

Acknowledgement
The inundation mapping of 2050 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2050. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 12.1a

Encounter Bay

2100 scenario

Event: 1 in 100-year event

The Bluff boat ramp

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.30m
Risk	3.05m AHD

Wave run-up is 0.30m and depicted in light blue.

Assessment.
Dr Bourman notes that the surface upon which the road is situated was likely formed 4-5000 years ago when seas were 1m higher. This event would overtop the road at depths up to 0.6m.

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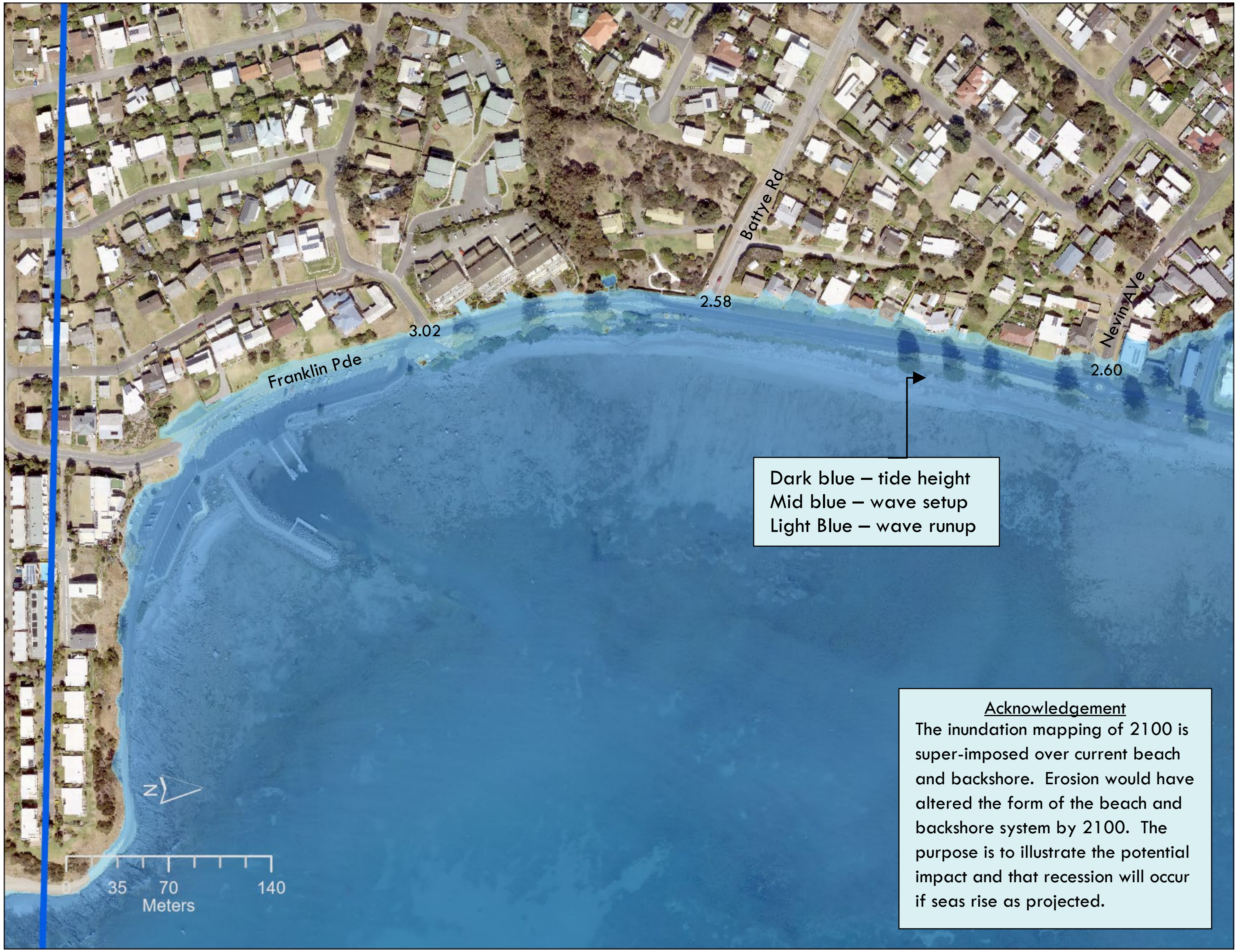

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – summary (Cell 12.1a)

Summary

Fleurieu 12.1a

Encounter Bay

Summary

The Bluff boat ramp

2020-2050

Sea levels 0.3m higher than present are likely to significantly erode the embankment or lower sand levels on the beach where protection exists. Storm surges will increasingly impact the embankment with overtopping of waves.

2050-2100

If sea levels rise as projected, in the latter half of the century the road would be significantly eroded and overtopping of the embankment would occur more often and in higher storm surges, at depths up to 0.6m.

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5. Coastal exposure – location map (Cell 12.1b)

Location

Fleurieu 12.1b

Encounter Bay

Location Map

Yilki

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 a few times 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:
Sheltered

Wave energy:
Low

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5. Coastal exposure – routine high water (2020)

Routine high water

Fleurieu 12.1b

Encounter Bay

2020 scenario

Event: Routine high water

Yilki

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	1.00m AHD
Wave set-up	0.20m
Total risk	1.20m AHD

Wave run-up of 0.20m is included.

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

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5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 12.1b

Encounter Bay

2050 scenario

Event: Routine high water

Yilki

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	0.30m
Wave set-up	0.20m
Total risk	1.50m AHD

Wave run-up of 0.20m is included.

Routine highwater events at 0.30m higher than present are likely to erode the embankment, lower sand levels on the beach where the beach is already protected.

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5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 12.1b

Encounter Bay

2100 risk:

Event: Routine high water

Yilki

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	0.20m
Total risk	2.20m

Wave run-up of 0.20m is included.

Routine highwater events at 1.0m higher than present would likely frequently overtop the embankment (waves on vertical surfaces produce higher action than modelled). The embankment in front of the cycle way would be eroded, and undermining and sand loss would result in locations where protection has been installed.

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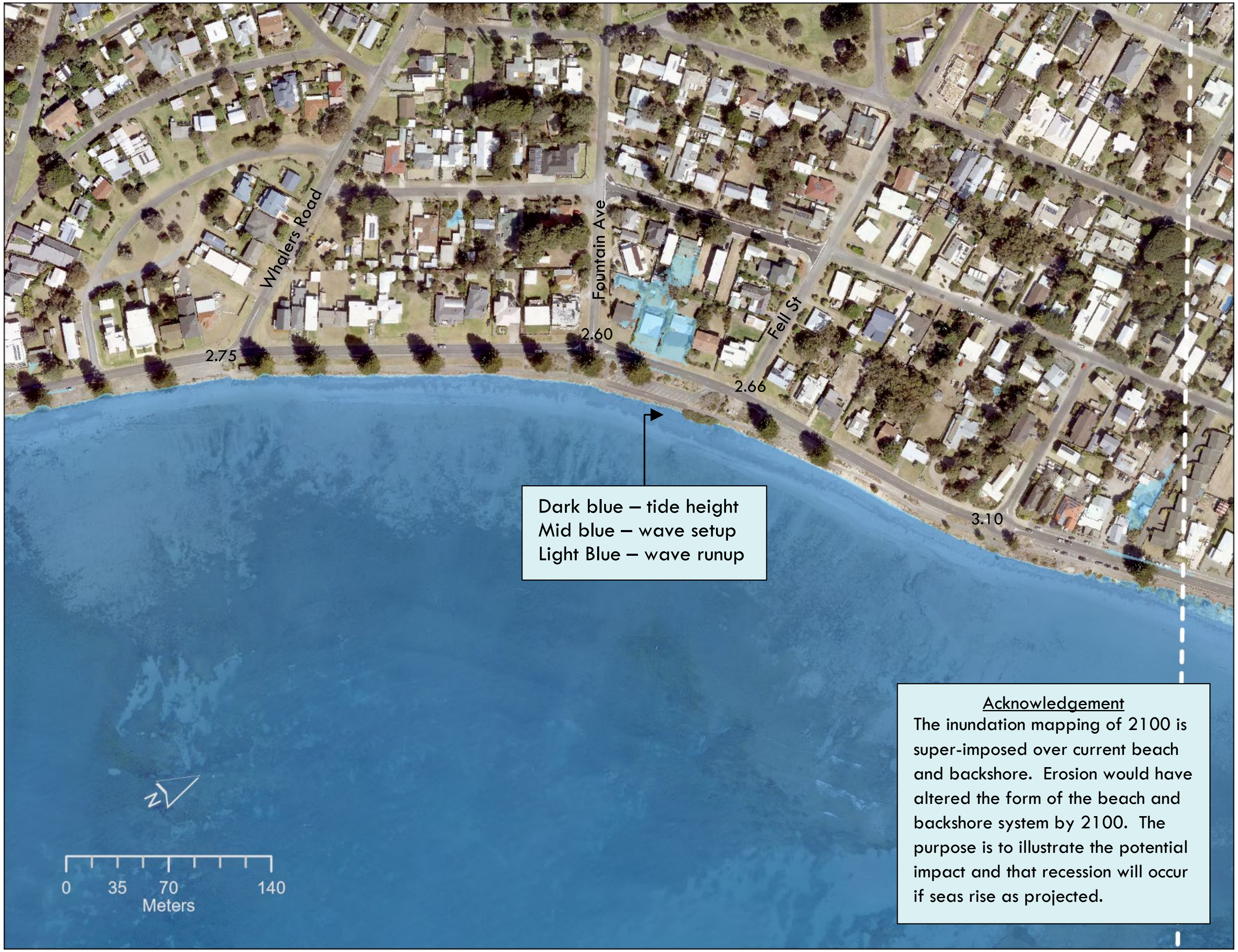

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2020)

Storm surge

Fleurieu 12.1b

Encounter Bay

2020 scenario

Event: 1 in 100 sea-flood risk

Yilki

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	0.30m
Risk	2.05m AHD

Wave run-up is 0.30 and depicted in light blue.

Assessment:
The impact of this storm event would have a similar impact as storm event 9th May 2016.
However, no known impacts were recorded from this event within Encounter Bay (impact may be associated with particular wind direction rather than the height of the tide). This event would cause significant erosion of the embankment where not protected.

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 12.1b

Encounter Bay

2050 scenario

Event: 1 in 100 sea-flood risk

Yilki

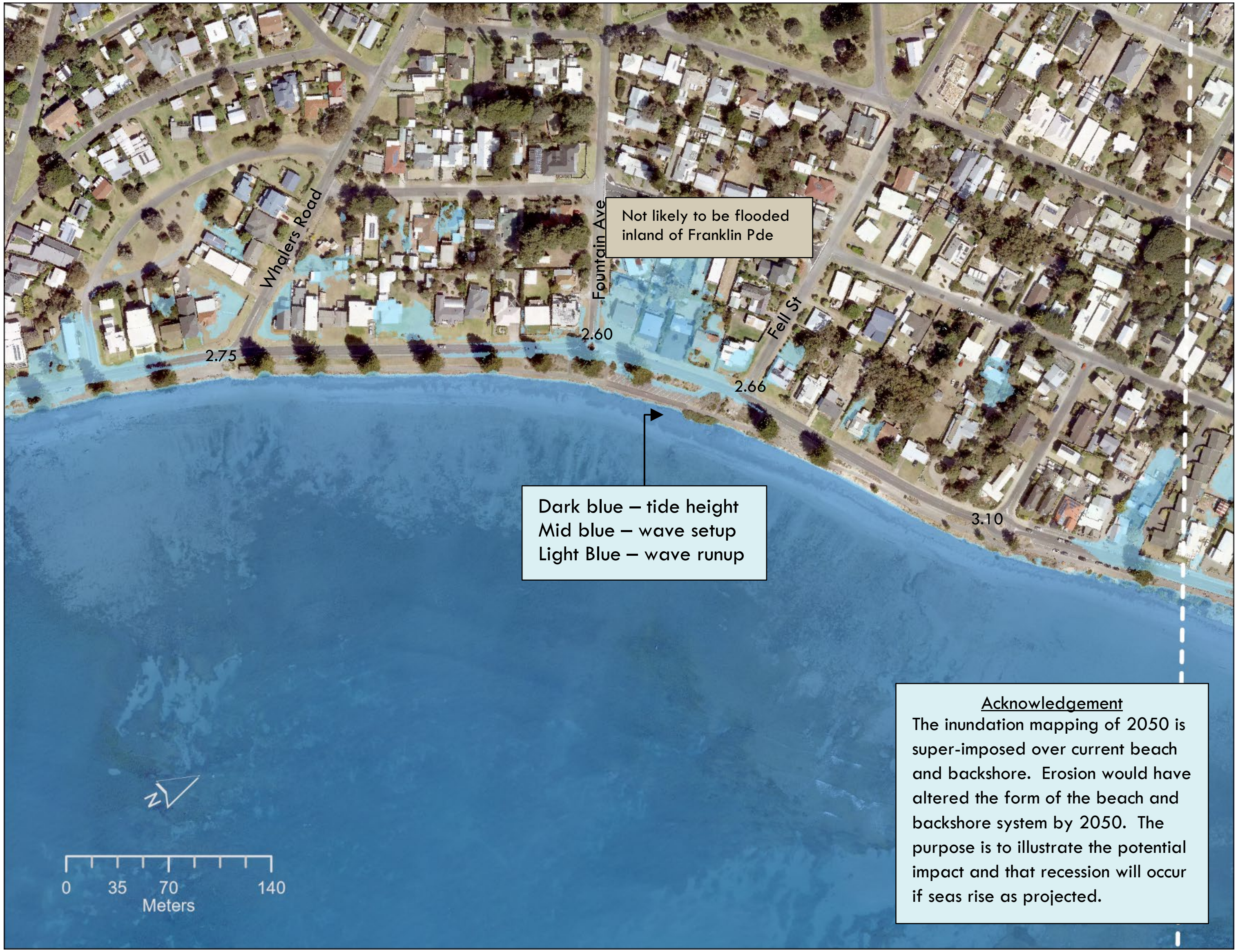
The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	0.30m
Wave set-up	0.30m
Risk	2.35m AHD

Wave run-up is 0.30m and depicted in light blue.

Assessment:

This scenario would cause overtopping of the embankment. Some of the lighter blue areas shown would be impacted, others are not sufficiently connected to the coast. The erosion of the embankment where not protected is likely.



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5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 12.1b

Encounter Bay

2100 scenario

Event: 1 in 100-year event

Yilki

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.30m
Risk	3.05m AHD

Wave run-up is 0.30m and depicted in light blue.

This scenario would bring significant overtopping of the embankment and flooding of the streets and houses. Depth of water over Franklin Parade up to 0.6m deep.

The impact on the embankment and protection works would be significant and erosion of the bank and road infrastructure likely.

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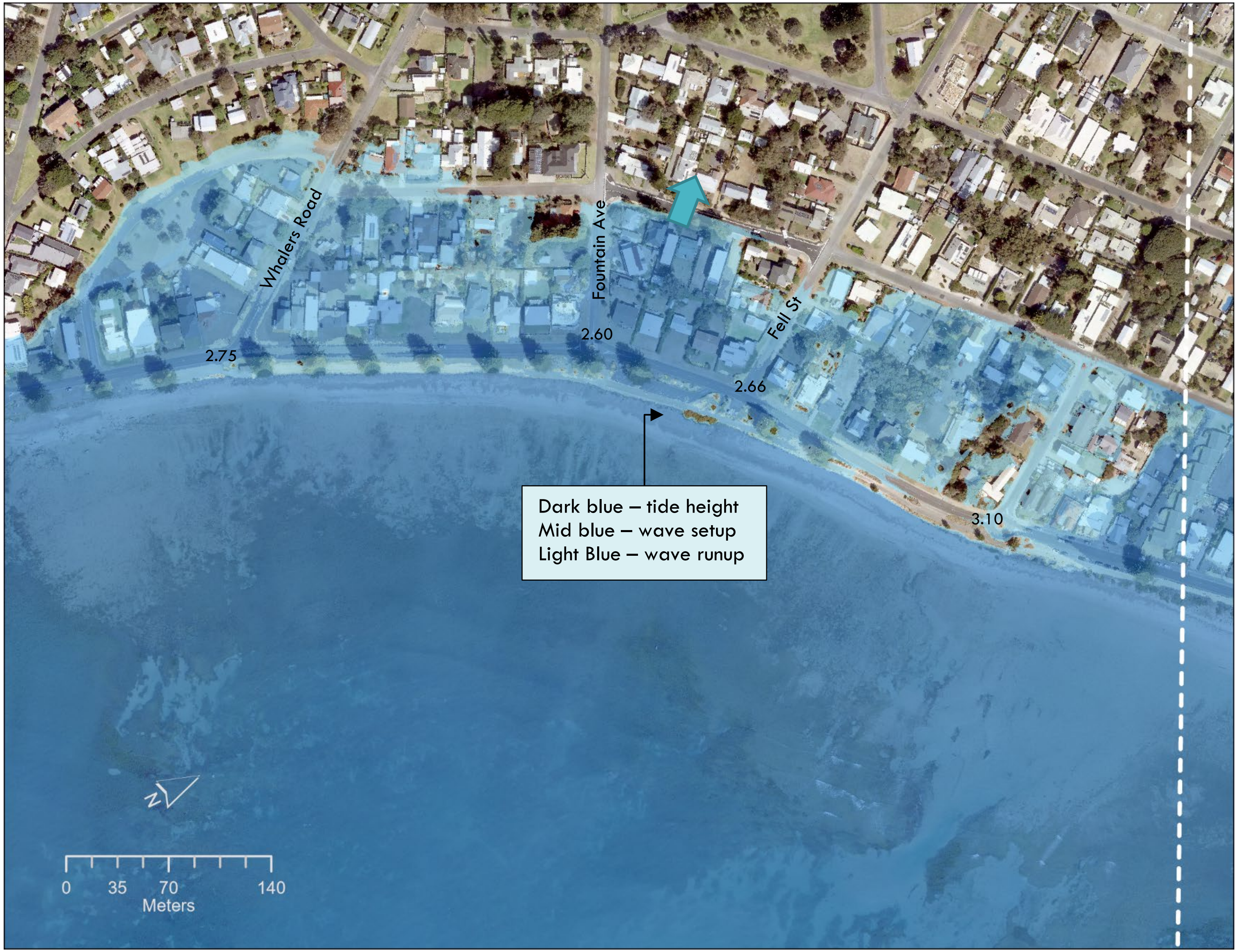

5. Coastal exposure – summary (Cell 12.1b)

Summary

Fleurieu 12.1b

Encounter Bay

Summary

Yilki

2020-2050

Sea levels 0.3m higher than present would cause significant damage to the embankment in places where no protection exists. Some over topping of the embankment would occur in higher storm events.

2050-2100

If sea levels rise as projected, in the latter half of the century over topping of the embankment would become more frequent. Larger storm events would flood the road up to depths of 0.6m and some residential areas flooded.

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5. Coastal exposure – location map (Cell 12.2a)

Location

Fleurieu 12.2a

Encounter Bay

Location Map

Tabernacle to Oakham Road

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 a few times 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:
Sheltered

Wave energy:
Low

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5. Current exposure – routine high water (2020)

Routine high water

Fleurieu 12.2a

Encounter Bay

2020 scenario

Event: Routine high water

Tabernacle to Oakham Road

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	1.00m AHD
Wave set-up	0.30m
Total risk	1.30m AHD

Wave run-up of 0.30m is included.

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

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5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 12.2a

Encounter Bay

2050 scenario

Event: Routine high water

Tabernacle to Oakham Road

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	0.30m
Wave set-up	<u>0.30m</u>
Total risk	1.60m AHD

Wave run-up of 0.30m is included.

Routine highwater events at 0.30m higher than present are likely to cause some recession to the shoreline (measured in metres) which in some places would undermine the embankment under the road and sand levels lowered on the beach.

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5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 12.2a

Encounter Bay

2100 scenario

Event: Routine high water

Tabernacle to Oakham Road

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 0.30m is included.

Routine high-water events of this nature, and in context of higher storms, will cause recession of the shoreline back to the road. The embankment would be increasingly undermined and eroded and sand levels lost from the beach.

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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 12.2a

Encounter Bay

2020 scenario

Event: 1 in 100 sea-flood risk

Tabernacle to Oakham Road

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	0.30m
Risk	2.05m AHD

Wave run-up is 0.30m and depicted in light blue.

Assessment:
The impact of this storm event would have a similar impact as storm event 9th May 2016. However, no known impacts were recorded from this event within Encounter Bay. Impact may be associated with particular wind direction rather than the height of the tide. This event would cause significant erosion of the embankment where not protected, and water would overtop the embankment.

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 12.2a

Encounter Bay

2050 scenario

Event: 1 in 100 sea-flood risk

Tabernacle to Oakham Road

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	0.30m
Wave set-up	0.30m
Risk	2.35m AHD

Wave run-up is 0.30m and depicted in light blue.

This scenario would cause overtopping of the embankment with minor flows over Franklin Parade. At locations where no protection exists, the embankment would be significantly eroded.

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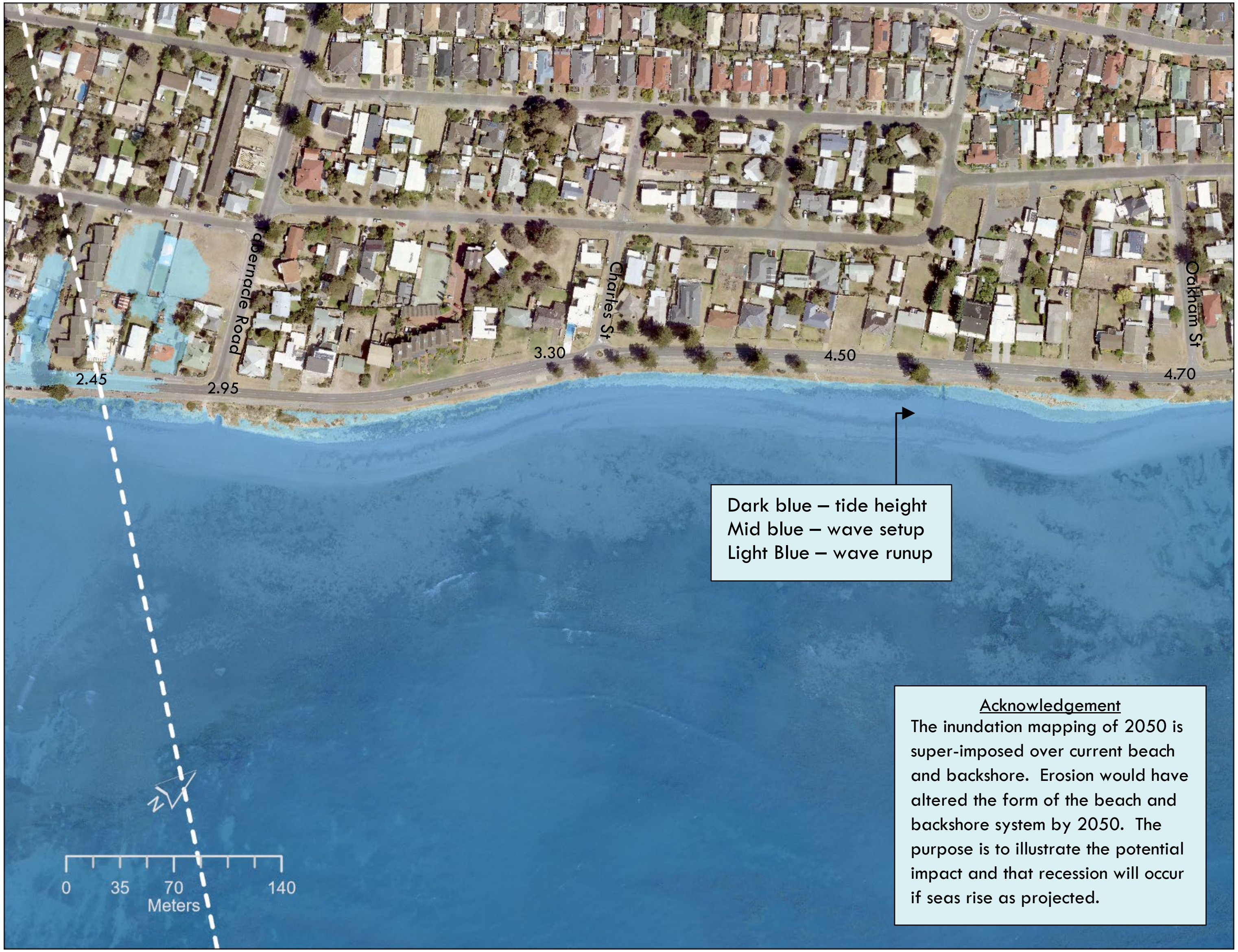

Acknowledgement
The inundation mapping of 2050 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2050. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 12.2a

Encounter Bay

2100 scenario

Event: 1 in 100 sea-flood risk

Tabernacle to Oakham Road

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.30m
Risk	3.05m AHD

Wave run-up is 0.30m and depicted in light blue.

In this scenario sea water would flow through the area to the west of Tabernacle Road and flows are likely to extend further than shown.
On vertical surfaces, wave effects are greater and therefore the flooding pattern would be greater than drawn over Franklin Parade. The erosion of the embankment would be significant and sand is likely to be lost from the beach.

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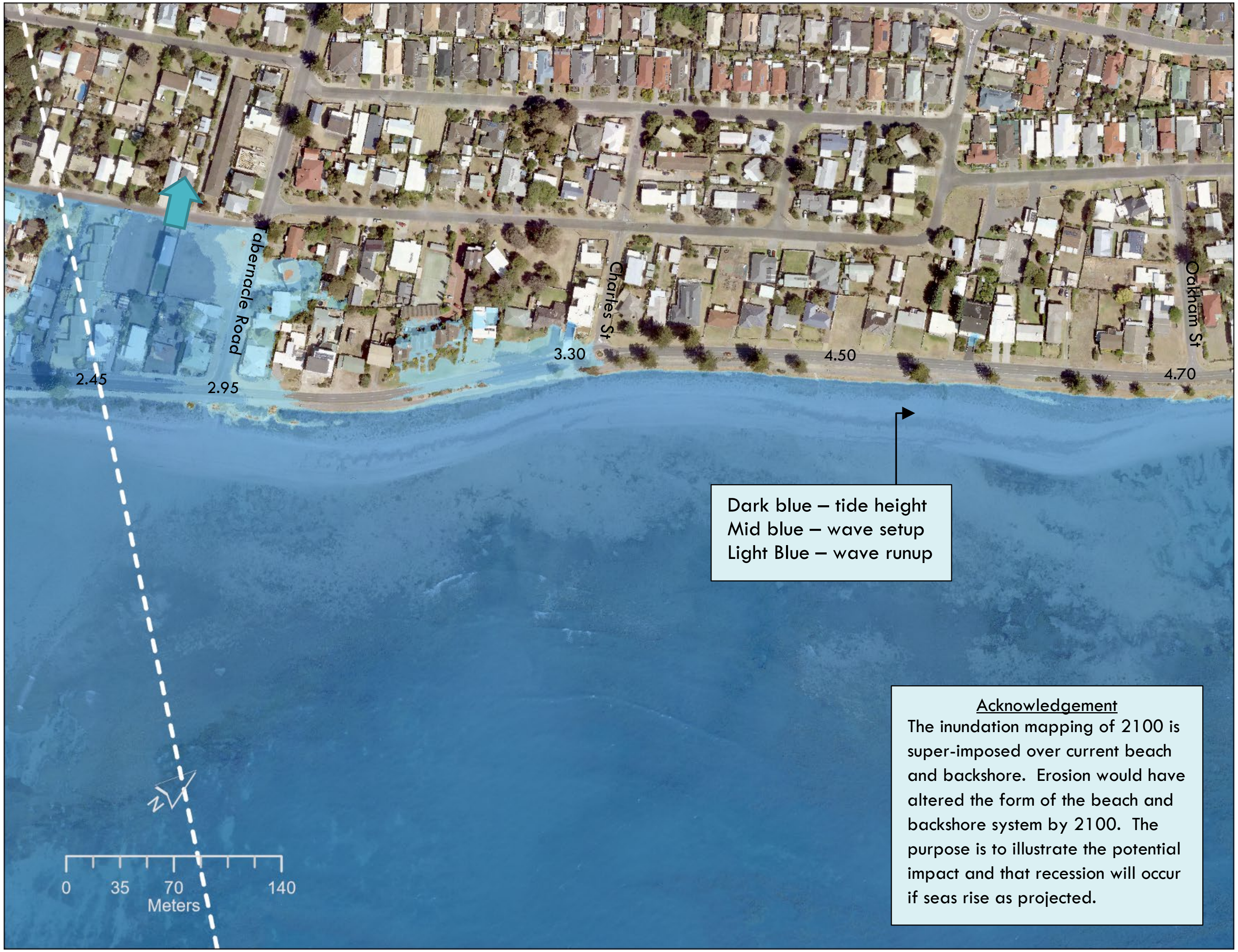

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – summary (Cell 12.2a)

Summary

Fleurieu 12.2a

Encounter Bay

Summary

Tabernacle to Oakham Road

2020-2050

Sea levels 0.3m higher than present would cause significant damage to the embankment in places where no protection exists. Some over topping of the embankment would occur in higher storm events in the vicinity of Tabernacle Road.

2050-2100

If sea levels rise as projected, over topping of the embankment would become more frequent in the vicinity of Tabernacle Road. Where not protected, the embankment would erode, and the road would be undermined. Sand levels are likely to be lost from the beach.

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5. Coastal exposure – location map (Cell 12.2b)

Location

Fleurieu 12.2b

Encounter Bay

Location Map

Kent Reserve

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 a few times 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:
Sheltered

Wave energy:
Low

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5. Coastal exposure – routine high water (2020)

Routine high water

Fleurieu 12.2b

Encounter Bay

2020 scenario

Event: Routine high water

Kent Reserve

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	1.00m AHD
Wave set-up	0.30m
Total risk	1.30m AHD

Wave run-up of 0.30m is included.

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

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5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 12.2b

Encounter Bay

2050 scenario

Event: Routine high water

Kent Reserve

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.

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
Sea level rise	0.30m
Wave set-up	0.30m
Total risk	1.60m AHD

Wave run-up of 0.30m is included.

Erosion of the dunes would occur (measured in metres) and the sand platform at Kent Reserve is likely to recede significantly.

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5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 12.2b

Encounter Bay

2100 scenario

Event: Routine high water

Kent Reserve

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 0.30m is included.

The road and residential area is more elevated in this location but routine high water events projected for 2100 would cause significant erosion of the coastline, likely to undermine the embankment under the road reserve.

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5. Coastal exposure – storm surge (2020)

Storm surge

Fleurieu 12.2b

Encounter Bay

2020 scenario

Event: 1 in 100 sea-flood risk

Kent Reserve

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	0.30m
Risk	2.05m AHD

Wave run-up is 0.30m and depicted in light blue.

Assessment:
The impact of this storm event would have a similar impact as storm event 9th May 2016. However, no known impacts were recorded from this event within Encounter Bay. Impact may be associated with particular wind direction rather than the height of the tide. This event would cause significant erosion of the embankment where not protected, and recession of the sand platform at Kent Reserve.

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 12.2b

Encounter Bay

2050 scenario

Event: 1 in 100 sea-flood risk

Kent Reserve

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	0.30m
Wave set-up	0.30m
Risk	2.35m AHD

Wave run-up is 0.30m and depicted in light blue.

In this scenario significant erosion would occur to the sand platform at Kent Reserve (but note, this may have been significantly eroded by 2050). The embankment to the road reserve would likely be eroded (where not protected) and undermined (with loss of sand from the beach).

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Acknowledgement
The inundation mapping of 2050 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2050. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 12.2b

Encounter Bay

2100 scenario

Event: 1 in 100 sea-flood risk

Kent Reserve

The current 1 in 100-year event risk set by SA Coast Protection Board is:

Storm surge	1.75m AHD.
Sea level rise	1.00m
Wave set-up	0.30m
Risk	3.05m AHD

Wave run-up is 0.30m and depicted in light blue.

In this scenario, the storm surge would flow over the lower parts of the road but not at significant depth (0.10m). Some flooding of residential area is likely but not at any significant depth.

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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 – summary (Cell 12.2b)

Summary

Fleurieu 12.2b

Encounter Bay

Summary

Kent Reserve

2020-2050

Parts of Franklin Parade in this area are more elevated and not subject to inundation. Increasing sea levels will cause erosion of the dunes and sand platform (measured in metres, and at Kent Reserve more significantly).

2050-2100

If sea levels rise as projected, then routine high-water events combined with storm events will cause significant recession of the dune and vegetation line, most likely back to the embankment to the road reserve. Where the road becomes lower in the vicinity of Kent Reserve, seawater of minor depth (0.10m) would flow over Franklin Parade and into a few residential properties.

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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. The third method is to consider the recent geomorphology of the coast which was formed when seas were ~1m higher than present 4-5000 years ago known as the mid-Holocene high stand. This is particular relevant in the context of projected rises of ~1m by 2100.

However, in Encounter Bay (Cell 12) it was not possible to use all methods due to reasons that are explained in the assessment below.

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.

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

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

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

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

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.

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

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 in the Victor Harbor region due to the fact that the nearshore region is dominated by complex three-dimensional geomorphology and includes sand, possible bedrock outcrop, and reef.

Onshore/offshore sediment transport processes are therefore not operating in a straightforward manner, and application of the Bruun Rule is likely not easily applicable here. Note, in addition, there is no wave data for the region and thus, any estimate of significant wave height $(\overline{Hs})$ is also based on local observations, and possibly incorrect.

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

Shoreface-Beach and Dune Translation Model

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

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

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

There is considerable shallow reef and sea grass beds existing at various places and depths along the Victor 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).

The context of recent geomorphology

The context of recent geomorphology also provides a context from which to consider the impacts of 1m of projected sea level rise. Dr Bob Bourman notes that the area of land between The Bluff and Yilki upon which Franklin Parade is situated was a former marine bench. This marine bench was formed 4-5000 years ago when sea levels were ~1m higher than present. In the context of projected sea level rises of ~1m by 2100 the understanding of the geomorphology of the region assists in providing a picture of the future under higher tidal action.

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

The Bluff boat ramp to Yilki (Cell 12.1)

Due to the lack of profile information in this region and the extensive rock shelf and off-shore reefs, it was not possible to apply methods 1 and 2 with any meaningful outcomes. A study of recent geomorphology (Section 3) found that the surface upon which Franklin Parade is situated was a former marine bench that was formed 4-5000 years ago when seas were ~1m higher than present. In other words, 4-5000 years ago, the shoreline was at the base of the coastal slope and the marine bench was laid down as sea levels decreased. Sea-flood mapping at 1m higher than present did provide some insight flooding evenly over-tops the former marine bench (Figure a).

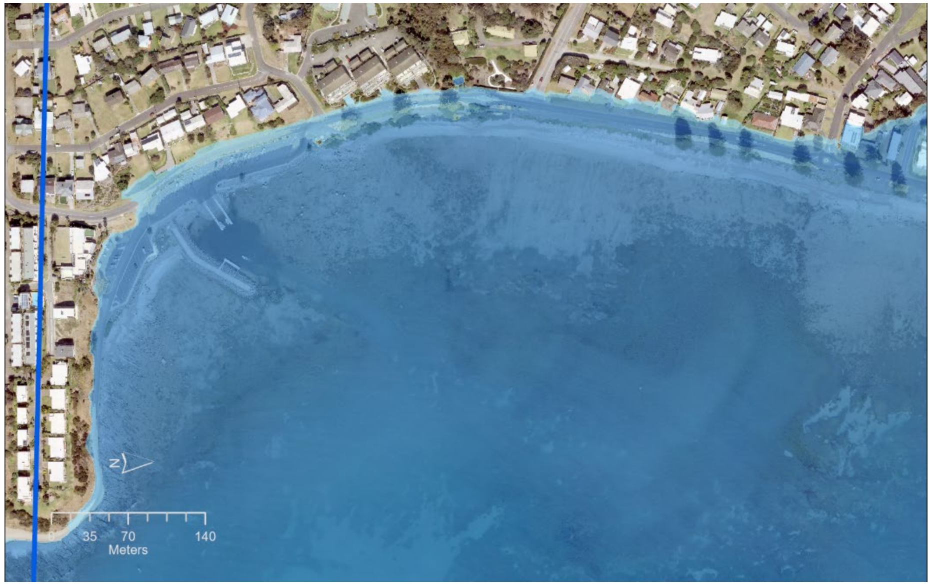

Figure a. Sea-flooding projected for 2100 provides congruence with the geomorphological context which indicates that the former marine bench upon which Franklin Parade is positioned was formed as seas receded from ~1m higher than present 4-5000 years ago. .

Tabernacle Road to Kent Reserve (Cell 12.2)

SA Coast Protection Board profile line 620002 (Figure b) illustrates the complex bathymetry that exists seaward of the base of the beach which is at only ~0.76m below AHD. The profile seawards of that is a complex of reef and (likely) seagrass beds.

The depth of closure is estimated at -4.5m for this location using a significant wave height (Hs) of 0.5m (a guesstimate). The nearshore is characterised by a highly variable reef morphology which makes an estimation of coastal recession due to sea level rise by the Bruun Rule as largely invalid. However, if the profile was all sand and all other issues (open embayment, only sandy surfzone and nearshore, no longshore transport, no reef, no seagrass) were

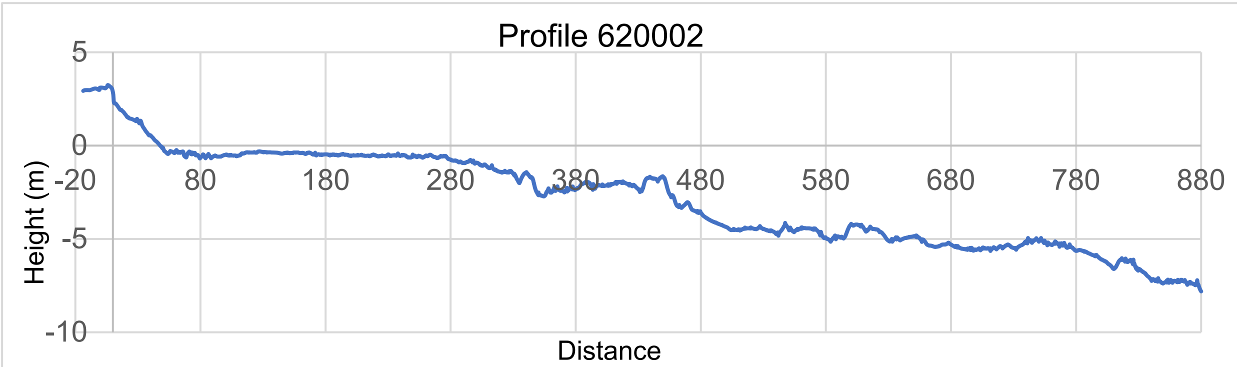

Figure b. Topographic and bathymetric profile out to 880m at DEW Profile 620002 surveyed in 2011.

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

negligible, the Bruun Rule would estimate recession at this location of ~38m with a sea level rise of 1m by 2100. The translation method indicates that the profile would retreat by 143m, which is likely excessive. This is based on using a depth of -2.0 which is ~286m offshore (measured seawards from AHD).

Comments made above about the gross uncertainty of these estimates given the presence of significant reef, the difficulty in determining the depth of closure point or a point on the profile that may be used to define a limit to the nearshore (e.g. the -2.0m depth noted above) apply here also. In summary, it is not possible to use normal methods to calculate shoreline retreat and therefore

Dr. Robert Bourman notes in Section 3 that behind Franklin Parade from Tabernacle Road to Kent Reserve is a coastal sand dune that was formed in the Holocene period. Behind the sand dune which is now known as Encounter Lakes was formerly a poorly drained coastal lowland. The approximate location of the former shoreline when seas were ~1m higher than present can be observed in the Kent Reserve area, but it is not possible to identify this elsewhere along the coast.

In summary, the assessment tools are not able to determine the likely shoreline recession in this location. However, a valid conclusion may be to state that if the coast was in its natural state, that if seas rose by 1m by the end of the century that the shoreline would recede a distance that would be measured in decametres (perhaps 2 or 3).

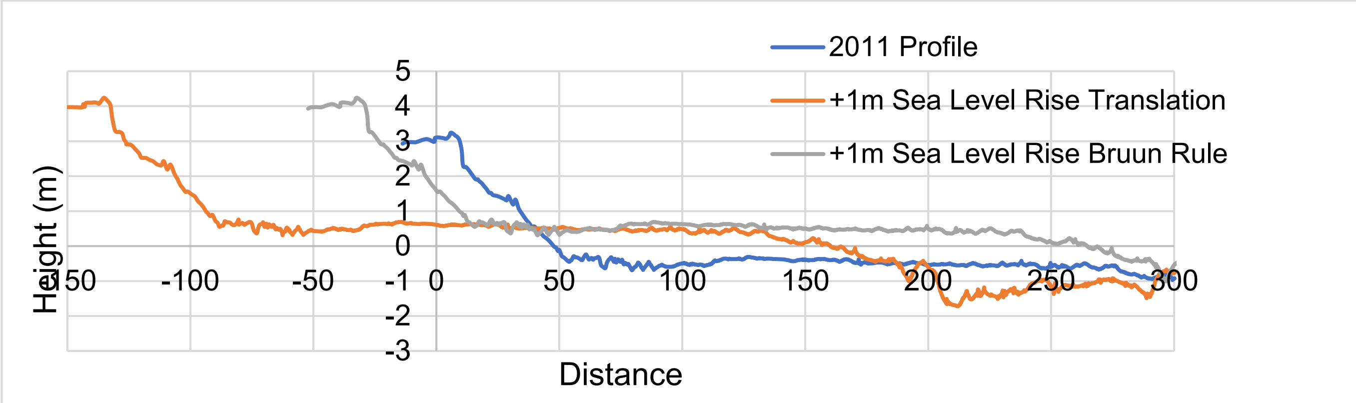

Figure a. Depicts the 2011 DEW profile, the translated profile with a sea level rise of +1m by 2100, and the Bruun Rule estimated profile with the same sea level rise.

Figure b. Depicts the likely location of the shoreline in the Kent Reserve region when sea levels were ~1m higher 4-5000 years ago. Residential settlement has been established upon a former sand dune that was formed in the Holocene period. This sand dune now separates the coast from the lowland behind which is now occupied by Encounter Lakes.

5. Exposure – erosion (2100)

Summary

Fleurieu 12.1

Encounter Bay

2100 risk:

Erosion outlook

Boat ramp to Yilki

The erosion modelling is conducted as though there was no human infrastructure present. The question this modelling answers is, what would the coastline likely do in the context of 1m of sea level rise? Only method three was appropriate in Cell 12.1

The surface upon which Franklin Parade is situated was likely formed about 4-5000 years ago when seas were 1m higher than present. In the context of projected sea level rise of 1m by 2100, and without any human infrastructure present, the shoreline would likely recede to the base of the escarpment. (approximately 20m erosion by 2100).

Erosion outlook to 2050 would more likely be in range of 4-6m without any human intervention.

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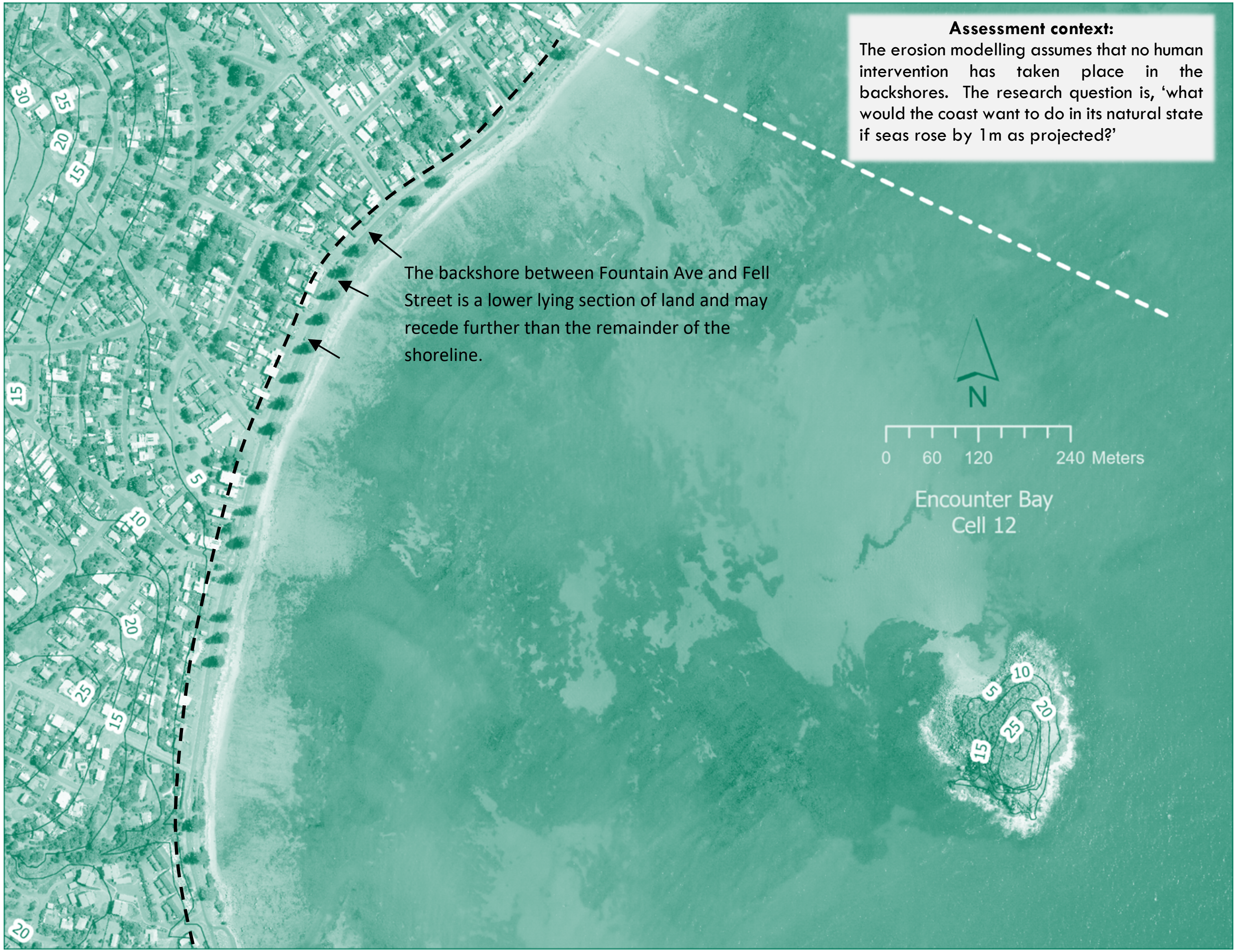

5. Exposure – erosion (2100)

Summary

Fleurieu 12.2

Encounter Bay

2100 risk:
Erosion outlook

Yilki to Kent Reserve

The elevation of Franklin Parade varies in this location – lower in the south and higher in the north towards Kent Reserve.

Applying the first two assessment methods to SA Coast Protection Board profile line 620002 resulted in a large disparity of results (38m to 143m recession by 2100). An assessment of the geomorphology did not provide an improved context from which might support a more refined conclusion.

It is likely to be a valid conclusion that if seas rose as projected by 1m at 2100, and the coastline was in its natural state, that recession would be measured in decametres, likely at least 3-4).

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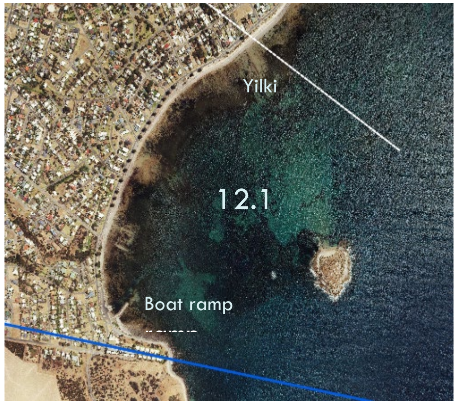
Assessment context:
The erosion modelling assumes that no human intervention has taken place in the backshores. The research question is, 'what would the coast want to do in its natural state if seas rose by 1m as projected?'

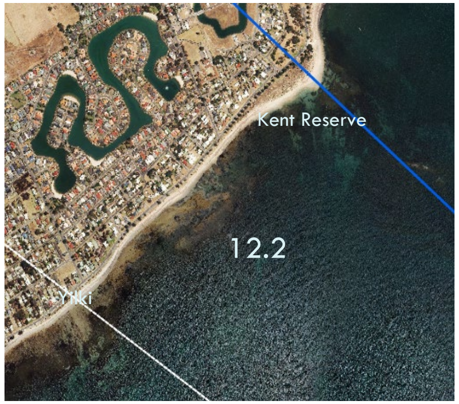
COASTAL EXPOSURE – Summary table

Encounter Bay (Cell 12)

Encounter Bay		Coastal context - natural				Modified	Exposure*	Scenario Modelling	
Cell	Location	Bathymetry	Benthic	Beach	Backshore	Human	Waves	2020 - 2050	2050-2100
12:1	Bluff boat ramp to Tabernacle Road (Yilki)	Slope 1:200 (-5m at 1km offshore). Slope of seabed increases seaward of Wright Is.	Nearshore dominated by low profile reef and seagrass beds. A sand bed is situated between The Bluff and Wright Island.	Coarse sand beach	The surface under the road was formed 4-5000 yrs ago when seas were +1m. Backshores from Nevin to Yilki are now mostly rock protected.	In 1850 the backshore was a gentle slope. Current infrastructure requires an embankment (now protected).	Sheltered exposure Low energy waves	Erosion of the backshore is likely caused by periods of increased storminess. Actions of the sea at 0.3m higher will produce minor overtopping of the road, erosion of the embankment if not protected, and lower sand levels on the beach.	Major overtopping would occur over the road with some flows into residential areas in Yilki region. In places where the embankment is not protected, erosion would undermine the cycle track and road. Beaches may be lost.
12:2	Tabernacle Road (Yilki) to Kent Reserve	Slope 1:150 (-5m at 700m offshore). Slope increases seaward of Wright - Granite Islands.	Dominated by low profile reefs that are positioned between the shore and extend to Granite and Wright Islands. Interspersed with seagrass beds.	Coarse sand beach	Varies – a steeper embankment/ dunes nearer Tabernacle Road. In the vicinity of Kent Reserve an elevated vegetated sand platform.	Rock protection has been installed in sections of the coast between Tabernacle Road and Kent Reserve.	Sheltered exposure Low energy waves	The coast is more elevated north of Tabernacle Road. Actions of the sea at 0.3m will increase erosion of unprotected embankments and likely to decrease sand levels on the beach.	Some overtopping of the road may occur later in the century but the impact will be minor. Sea levels at 1m higher will cause significant impact on protected and unprotected surfaces alike.

***Exposure Rating: Sheltered (2)** (assigned by SA Nature Maps)





Encounter Bay – Key Points

12.1 Episodes of erosion are likely caused by periods of increased storminess. Actions of the sea at 0.3m higher will produce minor overtopping of the road and erosion of the embankment if not protected. Post 2050, overtopping would increasingly occur over the road with some flows into residential areas in Yilki region. Increased wave energy will cause significant erosion to unprotected areas and undermining of protected areas.

12.2 The coast is more elevated north of Tabernacle Road and therefore this area is not generally subject to inundation. Actions of the sea at 0.3m will increase erosion of unprotected embankments and likely to decrease sand levels on the beach. Some overtopping of the road may occur later in the century, but the impact will be minor. Sea levels at 1m higher will cause significant impact on protected and unprotected surfaces.

6. Storm water runoff from urban settlement

6. Storm water runoff from urban settlement

Purpose

The purpose of this part of the 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 beaches and backshores are likely to be the first points along the coast that become vulnerable.

Three basic questions are assessed in this project:

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

(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.

Methodology

Storm water outlets were inspected, photographed and the height of the outlet was surveyed in Feb 2021.

We reviewed all references to sea storms in newspaper archives back to 1850s to identify if sea storm events were accompanied by larger rain events. While recognising the more qualitative nature of the assessment, it was concluded that large sea storm events are sometimes accompanied by significant rain events. The implication of this finding is that in the context of projected sea level rises that the potential for a confluence of events is increasingly likely when increased levels of the sea will shut storm water tidal flaps preventing or slowing the flow of storm water. By way of contrast, it has been established that the meteorological effects that produce the highest sea storm surges in Gulf St Vincent are not accompanied by significant rain events.

We sea-flood mapped routine high-water events in the context of the height of outlets.

Previous study

Urban Stormwater Management Plan, Kellogg Brown and Root, 2005

Overview of the study

This project was conducted in two stages. The focus of the first stage (not reviewed) was to analyse the capacity of the current system. The study recognised that most areas have adequate capacity to manage 5-year ARI flows and 100-year ARI flows with biggest inadequacy relating to inlet capacity. The study also noted that most vulnerable area was around the Inman River catchment near Council offices and library.

In the context of coastal adaptation

This study does not specifically address the method or volume of outflows to the ocean apart from in the conclusion where it states, 'stormwater quality will become even more important considering Encounter Bay and Victor Harbor coastline are set to become a marine protected area'. The study provides some general strategies that may assist with volume and quality of flows to the coast:

- Flow control measures – onsite retention and detention opportunities, but only limited opportunity for larger schemes.
- Storm water quality improvements – gross pollutant traps grease arrestors, wetlands and bio-infiltration measures. These can be at-source controls or end-of-line applications.
- Storm water harvesting and use – likely to be on a smaller scale through use of rainwater tanks plumbed to the house. Limited scope is likely to be available for using aquifers.

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

Fleurieu 12.1a

Encounter Bay

Storm Water

Current design

Storm water outlet assessment
Boat ramp to Whalers Road

The process is one of comparing the height of the outlet with the height of a routine tidal event which includes tide height and wave setup, but NOT wave runup. Red numbers indicate the height of water over outlets in the following routine high tide events:

- 2020 1.2m AHD
- 2050 1.5m AHD
- 2100 2.2m AHD

If a sea storm event combined with a rain event, it is likely that some of these outlets would not operate effectively. However, due to the slope of the terrain in this location, extensive flooding of roads and residential areas is unlikely due to outlets that are closed by higher levels. Storm water is likely to flow to the sea over the top of the embankment. Further assessment is required by hydraulic engineers.

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ID	OUTLET	HEADWALL	ENDCONTROL	ASSESSMENT	ELEVATION	2020	2050	2100
31	Pipe (RCP)	Yes	No	Pipe blocked	1.67	0.37	0.07	-0.63
32	Pipe (RCP)	Yes	Tidal flap	Flap immobile	1.25	-0.05	-0.35	-1.05
33	Pipe (RCP)	Yes	No	None	1.52	0.22	-0.08	-0.78
34	Pipe (RCP)	No	No	None	1.64	0.34	0.04	-0.66
35	Pipe (PVC)	No	No	None	2.38	1.08	0.78	0.08
36	Pipe (RCP)	No	No	None	1.36	0.06	-0.24	-0.94
37	Pipe (RCP)	Yes	Tidal flap	None	0.96	-0.34	-0.64	-1.34
38	Pipe (RCP)	Yes	Tidal flap	Erosion (Escarp)	1.61	0.31	0.01	-0.69
39	Pipe (RCP)	Yes	Tidal flap/ Rock	Undercut (Escarp)	0.85	-0.45	-0.75	-1.45

6. Storm water runoff from urban settlement

Storm water

Fleurieu 12.1b

Encounter Bay

Storm Water

Current design

Storm water outlet assessment Whalers Rd to Yilki

The process is one of comparing the height of the outlet with the height of a routine tidal event which includes tide height and wave setup, but NOT wave runup. Red numbers indicate the height of water over outlets in the following routine high tide events:

- 2020 1.3m AHD
- 2050 1.6m AHD
- 2100 2.3m AHD

If a sea storm event combined with a rain event, it is likely that some of these outlets would not operate effectively, especially in the context of projected sea levels for post-2050. The sea flood mapping in this location shows this location to be vulnerable post 2050. A confluence a rain event and a sea flooding event is likely to produce a higher flooding impact. Further assessment is required by engineers.

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ID	OUTLET	HEADWALL	ENDCONTROL	IMPACT	ELEVATION	2020	2050	2100
24	Pipe (RCP)	Yes	No	None	1.58	0.28	-0.02	-0.72
25	Pipe (RCP)	Yes	Tidal flap	Erosion (escarp)	1.16	-0.14	-0.44	-1.14
26	Pipe (RCP)	Yes	Tidal flap	None	0.98	-0.32	-0.62	-1.32
27	Pipe (RCP)	Yes	Tidal flap	Gullying (beach)	1.43	0.13	-0.17	-0.87
29	Pipe (RCP)	Yes	Tidal flap	None	1.39	0.09	-0.21	-0.91
30	Pipe (RCP)	Yes	No	None	1.95	0.65	0.35	-0.35
31	Pipe (RCP)	Yes	No	Pipe blocked	1.67	0.37	0.07	-0.63
32	Pipe (RCP)	Yes	Tidal flap	Flap immobilized	1.25	-0.05	-0.35	-1.05

6. Storm water runoff from urban settlement

Storm water

Fleurieu 12.2a

Encounter Bay

Storm Water

Current design

Storm water outlet assessment
Yilki to Oakham Street

The process is one of comparing the height of the outlet with the height of a routine tidal event which includes tide height and wave setup, but NOT wave runup. Red numbers indicate the height of water over outlets in the following routine high tide events:

- 2020 1.3m AHD
- 2050 1.6m AHD
- 2100 2.3m AHD

Most of the storm water east of Tabernacle Road flows into Encounter Lakes and is discharged to the sea by way of the tidal pipe. Therefore, catchments that flow to outlets are relatively small and outlets suitably elevated. The exception is Tabernacle Rd where the catchment is larger, and the outlet set at very low elevation. Should a sea storm event and rain event combine, additional flooding is likely to result, especially post 2050.

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ID	VH-ID	OUTLET	HEADWALL	ENDCONTROL	IMPACTS	ELEVATION	2020	2050	2100
22	165	Pipe (PVC)	No	No	None	2.98	1.68	1.38	0.68
23	166	Pipe (PVC)	Yes	No	Gullying (beach)	1.46	0.16	-0.14	-0.84
24	489	Pipe (RCP)	Yes	No	None	1.58	0.28	-0.02	-0.72
25	490	Pipe (RCP)	Yes	Tidal flap	Erosion (escarp)	1.16	-0.14	-0.44	-1.14

6. Storm water runoff from urban settlement

Storm water

Fleurieu 12.2b

Encounter Bay

Storm Water

Current design

Storm water outlet assessment
Oakham Street to Kent Reserve

The process is one of comparing the height of the outlet with the height of a routine tidal event which includes tide height and wave setup, but NOT wave runup. Red numbers indicate the height of water over outlets in the following routine high tide events:

- 2020 1.3m AHD
- 2050 1.6m AHD
- 2100 2.3m AHD

Most of the storm water in this location is discharged to Encounter Lakes which is then flows to the ocean by pipe or flows into Kent Reserve. Therefore, the catchment areas are relatively small. Additionally, due to the elevated nature of the terrain, storm water outlets are set above sea flood risk levels until post 2050.

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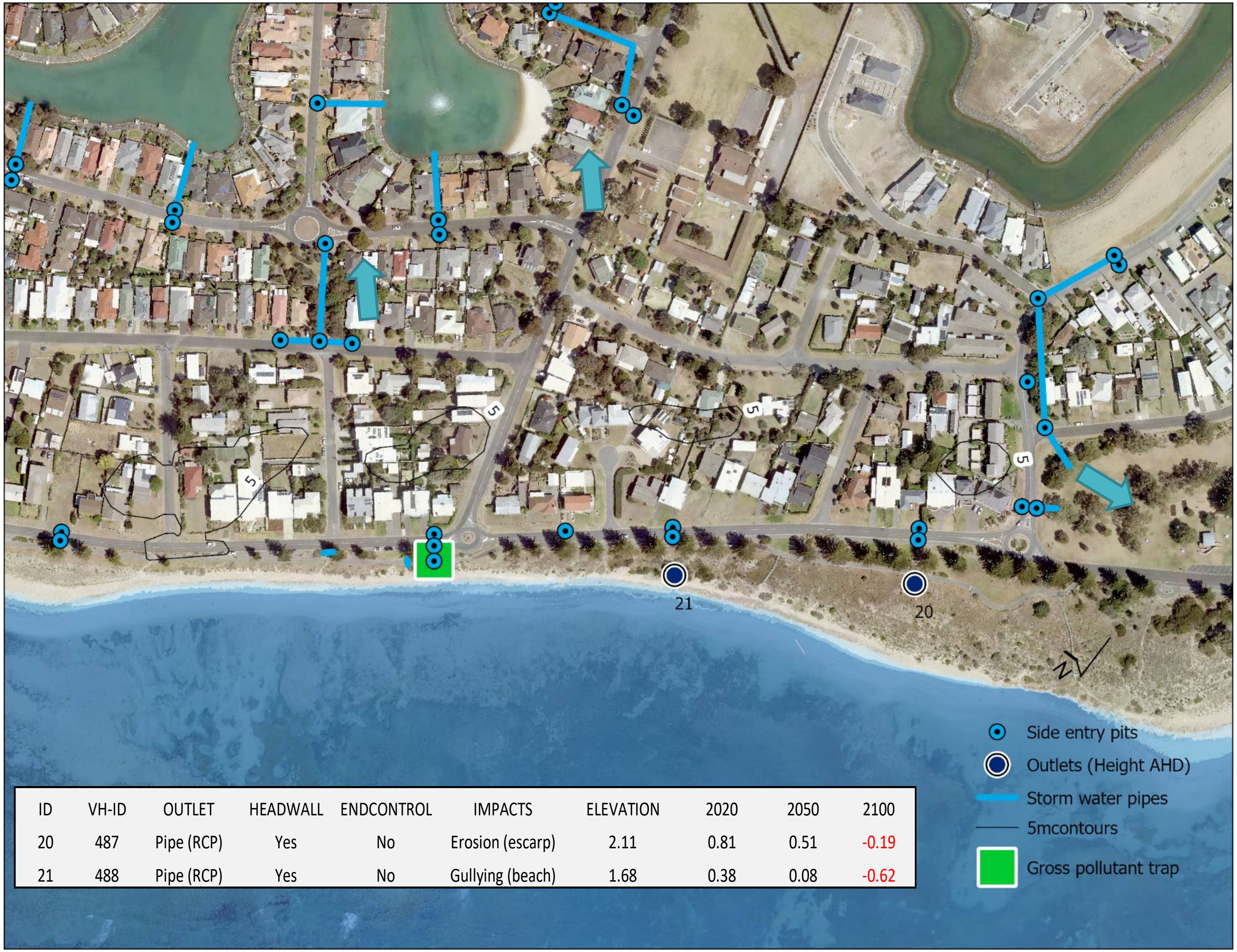


ID	VH-ID	OUTLET	HEADWALL	ENDCONTROL	IMPACTS	ELEVATION	2020	2050	2100
20	487	Pipe (RCP)	Yes	No	Erosion (escarp)	2.11	0.81	0.51	-0.19
21	488	Pipe (RCP)	Yes	No	Gullying (beach)	1.68	0.38	0.08	-0.62

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?

The assessment observed no storm water from urban settlements flowing to the coast that was not managed by way of kerb and gutter, side entry pits and pipe to the coastal outlet. Note, this does not mean that some erosion is not occurring of embankments/ dunes because of storm water runoff from specific shoreline localities because this is unavoidable.

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

The assessment found that due to elevated backshores and slopes between the Bluff boat ramp and Whalers Road, roads and residential areas are unlikely to be flooded even if the tidal flaps were closed for periods of time. (Note, Franklin Pde may be flooded at low depth, but storm water could flow over the embankment). Most of the storm water to the east of Tabernacle Road flows into Encounter Lakes, and generally tidal outlets are set above current routine tidal levels. The most likely area where a confluence of sea flooding and storm water flooding may occur is within the lower lying section of coast between Whalers Road and Tabernacle Road. The sea flooding, especially after 2050 becomes more significant into this area, and storm water flows more challenging to collect and pipe to the sea due to the lower terrain.

(3) 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 minor scouring of the beach was observed (Figure c). To a certain extent this is unavoidable and usually beaches rebuild after rainstorms. The problem in some locations is that storm water outlets prevent the dune from building and stabilising (Figure c). Headwalls installed to outlets at lower elevations appear to be effective at minimising undermining or erosion from the sides of the outlet (Figure a). Gross pollutant traps appear to be appropriately employed at outlets related to larger catchment areas. The exception may be at Tabernacle Road which does not have a gross pollutant trap.

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

Figure c. Fell Street outlet. The flow of storm water lowers sand levels on the beach making it more vulnerable to seawater impact and preventing the dune from building in this location.

Figure a. Headwall tends to prevent undermining from actions of the sea.

Figure b. Some outlets require maintenance (not the focus of this assessment)

Figure d. Fell Street outlet. Same location as Figure (a). The headwall tends to prevent undermining from actions of the sea.

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.

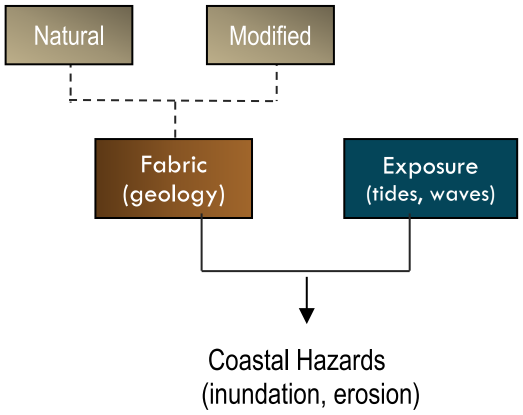
7. Hazard impacts and risks

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:

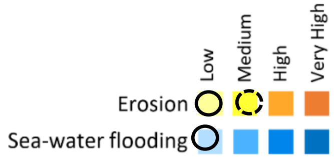
- The geological layout,
- The erodibility of beach and backshores,
- The historical analysis as to how the coastline has performed over time,
- The exposure (set by Nature Maps),
- Whether any human intervention has altered the nature of the coastline.

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) March, 2021.

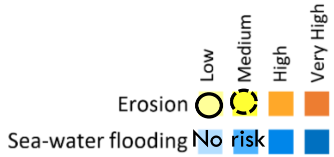
Coastal setting:

Encounter Bay (Cell 12.1)



A narrow coarse sand beach with offshore intertidal rocky shelf. At the back of the beach is a former marine shelf created about 4-5000 years ago when seas were ~1m higher. Exposure is categorised as 'sheltered' and wave energy, low. Only two storm records exist prior to 1970s, both of which impacted the road. Increasing storm activity since 1990s has resulted in most of the backshore now having some form of protection from Nevin Street to Yilki.

Encounter Bay (Cell 12.2)



A narrow coarse sand beach with offshore intertidal rocky shelf. At the back of the beach are former sand dunes now covered in urban infrastructure and settlement. Exposure is categorised as 'sheltered' and wave energy, low. Rock protection has been installed in three segments between Tabernacle Road and Bartel Terrace.

7-2 Description of hazard impacts

Public assets at risk

Since the 1990s erosion has had an increasing impact on backshores. A progressive installation of rock and concrete block protection may have produced a temporary equilibrium between actions of the sea and backshores. There remain gaps in protection between Whalers Road and Kent Reserve and time will tell whether these also become subject to erosion. While acknowledging that this is a low exposure / low wave energy environment, higher sea levels will continue to impact the backshores. After 2050, projected sea level rise will be accompanied by significant overtopping and flooding, particularly in the region between Whalers Road and Tabernacle Road.

Coastal infrastructure

The embankment that underpins walking trails, carparks and the road will come under increasing impacts from actions of the sea, including those that are already protected. Public assets include:

- Encounter Bikeway
- Franklin Parade
- Carparks (Yilki, Fell Street)
- Coastal furniture – chairs, tables
- Toilet block (Fountain Ave)
- Storm water outlets

Description of hazard impacts (cont.)

Private assets at risk

Residential housing

Private housing in this cell is all situated behind the esplanade road (Franklin Parade) and most areas are unlikely to be impacted by actions of the sea over the course of this century.

The exception is the area from Whalers Road to Tabernacle Road where the esplanade road and general terrain is lower. Sea flood mapping indicates that this area is likely to be more significantly impacted post 2050.

Social disruption

Social disruption is a category of risk that includes:

- Public safety
- Reputation, in particular, 'community concern'.

In relation to assessing 'public safety', the assessment conducted within this project is only related to how impacts of the sea may increase the risk to people accessing the area. It is not related to any risks that the beach and backshore currently and normally pose to the safety of people. This assessment remains with Council in its normal operation of risk.

In an area where wave energy and exposure is low, it is unlikely that there will be increase risk to public safety due to sea level rise. However, when impacts of the sea begin to erode shorelines or overtop protection, community concern grows. If seas begin to overtop protection and flow into residential area, community concern will escalate quickly.

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.

Due to the elevated nature and residential character of most of the area within Cell 12, it is unlikely that rising sea level will cause any broadscale level of ecosystem disruption.

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 cycleway and Franklin Parade will prevent the shoreline from retreating naturally and habitats are likely to be disturbed or lost.

Summary: Hazard Impacts

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

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

Encounter Bay (Cell 12.1)

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

Coastal setting	The Encounter Bay coastline (boat ramp to Yilki) is categorised as a narrow coarse sand beach with offshore intertidal rocky shelf. At the back of the beach is a former marine shelf created about 4-5000 years ago when seas were ~1m higher. Franklin Parade is situated on this bench. With increasing width required for road infrastructure, an earthen embankment has been formed seaward of the original marine bench. Exposure is categorised as 'sheltered' and wave energy, low. Only two storm records exist prior to 1970s, both of which impacted the road. Increasing storm activity since 1990s has resulted in most of the backshore now having some form of protection from Nevin Street to Yilki.

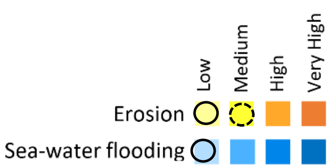
Are any strategies employed to mitigate the risk? Rock or concrete block protection installed from Nevin Street to Yilki (with minor gaps)

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Franklin Parade, Encounter Bikeway, carparking and storm water outlets are positioned in the backshore. Significant overtopping, flooding and erosive impacts to the backshores. Risk is related to financial, service delivery.	current	*Unlikely*	*Minor*	Low
		2100	*Very Likely*	*Major*	Extreme
Private assets*	Private assets are situated landward of the esplanade road. This road will come under increasing pressure if seas rise as projected and sea-flood mapping indicates that overtopping is likely to flow across the road (esp. Whalers to Yilki).	current	*No risk*	*No risk*	No risk
		2100	*Possible*	*Moderate*	Medium
Social disruption	Increasing levels of sea level will increase over topping of the embankment. Where the coast is protected, sand levels are likely to continue to drop. Public safety and enjoyment may be increasingly at risk.	current	*Rare*	*Insignificant*	low
		2100	*Possible*	*Major*	High
Ecosystem disruption	Due to the slope of the backshore in this location and the nature of infrastructure already in the backshore, broadscale eco-system disruption is unlikely. *However, bird habitats may be disturbed or lost*.	current	*Unlikely*	*Minor*	low
		2100	*Possible*	*Moderate*	Medium*

*Council not necessarily liable for private assets

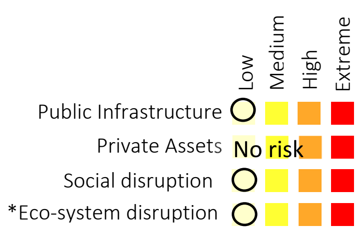
Inherent Hazard Rating

Narrow coarse sand bench backed by embankment (partially protected)



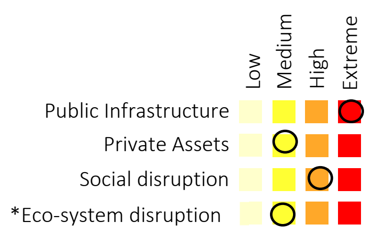
Erosion Hazard Rating

(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.

Encounter Bay (Cell 12.2)

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

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

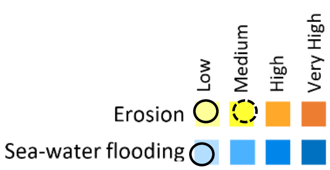
Are any strategies employed to mitigate the risk? Rock protection (three sections from Tabernacle Road to Bartel Boulevard).

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Franklin Parade, Encounter Bikeway, carparking and storm water outlets are positioned in the backshore. The area near Tabernacle road is at lower elevation but overall this area is at higher elevation and therefore not as much at risk.	current	*Unlikely*	*Minor*	Low
		2100	*Possible*	*Major*	High
Private assets*	Private assets are situated landward of the Franklin Parade. This road will come under increasing pressure if seas rise as projected and sea-flood mapping indicates some overtopping in Tabernacle Road area (but the remainder is elevated).	current	*No risk*	*No risk*	No risk
		2100	*Unlikely*	*Moderate*	Medium
Social disruption	Increasing levels of sea level will increase over topping of the embankment. Where the coast is protected, sand levels are likely to continue to drop. Public safety and enjoyment may be increasingly at risk.	current	*Rare*	*Insignificant*	low
		2100	*Possible*	*Minor*	Medium
Ecosystem disruption	Due to the slope of the backshore in this location and the nature of infrastructure already in the backshore, broadscale eco-system disruption is unlikely. *However, bird habitats may be disturbed or lost*.	current	*Unlikely*	*Minor*	low
		2100	*Possible*	*Moderate*	Medium*

*Council not necessarily liable for private assets

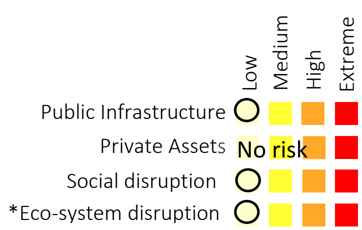
Inherent Hazard Rating

Narrow coarse sand bench backed by dunes and embankment (partially protected)



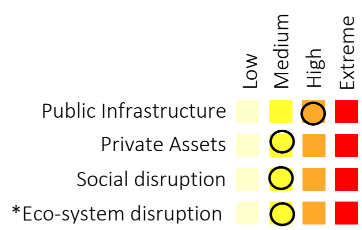
Erosion Hazard Rating

(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: Encounter Bay (Cell 12.1)

Boat ramp to Yilki
(12.1)
Coastal setting

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

Coastal fabric - history

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

Coastal exposure - scenario modelling

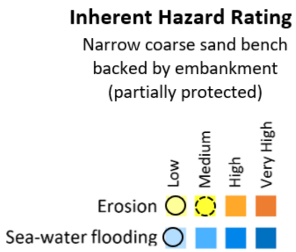
Current episodes of erosion are likely caused by periods of increased storminess. Actions of the sea at 0.3m higher will produce minor overtopping of the road and erosion of the embankment if not protected. Post 2050, overtopping would increase over the road with some flows into residential areas in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

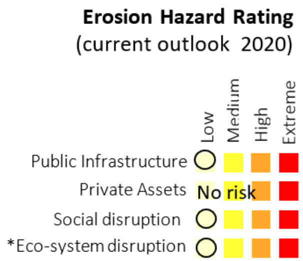
Storm water runoff

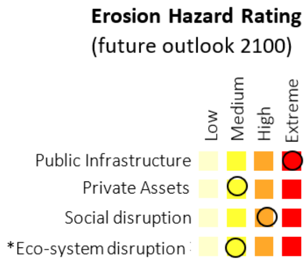
Storm water from urban settlement is being appropriately managed so that none is dispensed over the top of coastal slopes. However, many outlets are set at low elevation (especially south of Yilki) and increasing sea levels will inhibit proper function of these. Post 2050, a confluence of a rain event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

Overview of Impacts

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







8. Summary: Encounter Bay (Cell 12.2)

Yilki to Kent Reserve (12.2)

Coastal Setting

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

Coastal fabric - history

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

Scenario modelling

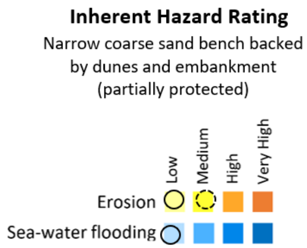
The coast is more elevated north of Tabernacle Road and therefore this area is not generally subject to inundation. Actions of the sea at 0.3m will increase erosion of unprotected embankments and likely to decrease sand levels on the beach. Some overtopping of the road may occur later in the century,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

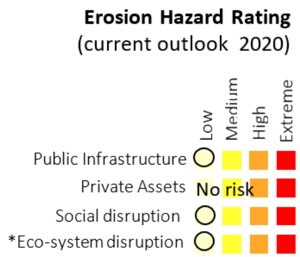
Storm water runoff

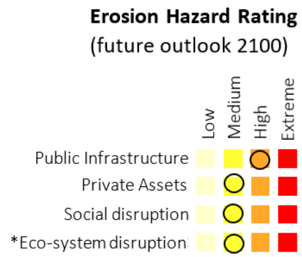
North of Tabernacle Road the area is more elevated, and the residential area has been constructed on a former dune. Most storm water drains to Encounter Lakes or Kent Reserve and therefore the catchments that drain to the ocean are small. Storm water outlets are generally set at higher elevations.

Overview of Impacts

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







PART 2

COASTAL ADAPTATION STRATEGY (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.

Adaptation responses

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

<u>Planning</u>

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.

<u>Engineering</u>

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.

<u>Environmental management</u>

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.

<u>Incremental approach</u>

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.

<u>Transformative approach</u>

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.

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

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

Adaptation strategy

2. COASTAL CONTEXT - SUMMARY

The construction of Franklin Parade in the 1850s represents a very early intervention in the backshore of this region. While storms have been recorded that impacted the backshore in times past, there are four main reasons why storms may be having a greater impact in the Encounter Bay region in current times and why this impact is likely to increase over time.

1. Sea level rise

Taking into account global sea level rises since the mid-1800s, it is likely that sea level has risen within Encounter Bay by 200 to 300mm since the installation of Franklin Parade. At the very least, actions of the sea are now experienced further landward, but in addition this increased depth of water over the reefs and the seafloor in Encounter Bay may also be facilitating swells of larger height into the bay. All of these factors mean that actions of the sea are experienced further landward.

2. Increasing swell size in Southern Ocean

Recent studies have demonstrated that the height of swell in the Southern Ocean has been increasing over the last thirty years. While the increases in height are only measured in centimetres, the effect will be to generate swells of larger size within Encounter Bay[3]. Periodically, as experienced in May 2021, larger swells from the Southern Ocean penetrate between the headlands and islands and have a significant impact on the Encounter Bay coastline.

3. Legacy issues (human intervention)

The main legacy issue within Encounter Bay is the expansion of the foreshore in a seaward direction that has occurred since the installation of Franklin Parade (Figure a). The profile of the beach and backshore in earlier times consisted of a gentle slope to the road, which occupied the same location as the north side of current-day Franklin Parade (Figure b).

Progressively, since the 1940s, items and infrastructure were placed in the backshore region that have moved the foreshore region further seaward and raised the height of the backshore in relation to the height of the beach. The Norfolk Pines were planted in the 1940s, the road was progressively widened, carparking installed, and the Encounter Bikeway installed ~2000. In the context of coastal processes, this has moved the backshore approximately 8-10m seaward where it now is more often in contact with actions of the sea.

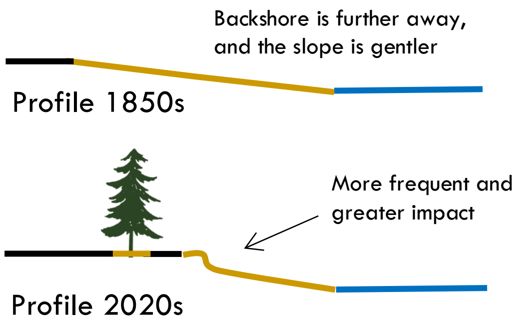


Figure a: Schematic illustration of the change of beach and backshore profile due to human intervention.

4. Periods of storminess

The coastal adaptation study found that the Victor Harbor coastline experiences periods of increased storminess from the Southern Ocean. The historical study demonstrated that the period 1920s to 1940s was strongly represented in the storm record. More recently, between 2007 and 2011 analysis of the tide gauge data demonstrated that elevated waters from the Southern Ocean were interacting with the backshores more regularly and this contributed to increased erosion, especially along The Esplanade Beach. The reason it is important to recognise these episodes is that periodically the coast is likely to come under increased pressure due to natural cycles in climate and ocean conditions. These are separate issues from sea level rise, although it is also accepted that any increases in sea level and swell size will also increase the impact of these stormy periods.

Figure b: Road to The Bluff, 1900, and Yilki settlement in the distance (State Library of SA, B63092).

[3] Hemer et al, 2008, p 651, Young and Ribal, 2019.

Adaptation strategy

3. ADAPTATION STRATEGY (2021-2031)

Adaptation approach - incremental

An incremental adaptation approach is recommended for Encounter Bay. The linear layout of the foreshore of Encounter Bay and the narrow distance between private development and the highwater mark means that a transformational approach, that may call for a complete redesign of the coastal layout, will have limited room in which to plan. Research tends to show that it is only a large event accompanied by significant damage that generates willingness to consider transformational change. An ongoing more rapid increase in the rate of sea level rise may be another impetus for broadscale change.

This project has reviewed the storm record since the 1880s for Encounter Bay and not found any storms of magnitude that are outside of the realms of current experience. Furthermore, the rate of sea level rise is not projected to accelerate until around the middle of this century and currently there is only 'very weak' acceleration observed in the tide gauge records[4].

In summary, considering the storm record and the current rate of sea level rise, an incremental approach is recommended for Encounter Bay that continues to apply incremental adaptation strategies within the current layout. This approach can be reviewed in 2031 with the advantage of another ten years of storm and sea level rise data.

Planning and implementation time frames

The time period 2021-2031 adopted for the adaptation strategy provides an appropriate time frame in which Council can make decisions and plan for the future. A coastal adaptation strategy should aim in the first instance to manage sea level rises to 2050 (0.30m) which is more certain, as well as take into consideration the longer-term threat projected for 2100 (1.00m) which is far less certain. However, in locations of higher significance, more attention should be focussed on planning for the longer-term threat.

In dealing with longer term projections, the Coastal Management Study, 2013 noted that it is 'prudent to limit initial costs while utilising available time to gather additional site data, obtain better estimates of the likely climate impacts. It is not sound management practice to implement major infrastructure spending on protection structures that may not be required for 50 or 100 years into the future. However, it is essential that the strategy to be implemented is identified now and the planning for that implementation is put into place'[5]. The reason why it is essential to have a long-term strategy is that urban infrastructure and housing have long asset lives. The advantage of having a long-term strategy is that every new proposal can be assessed within the strategy and cost savings are likely to be achieved over the longer term.

Adaptation response – 'hold the line'

The current coastal adaptation strategy has been to **'hold the line'**, although as noted previously, this line has been continually pushed seaward over time. The further the line is pushed seaward; the greater will be the impact from actions of the sea, and the greater the defences will be required to manage the impact. Therefore, any proposals in the foreshore region should resist moving the backshore any further seaward.

Protection items designed to protect for sea flood risk for 2050 should have a design life of 30 to 40 years and at heights set by Coast Protection Board as:

1 in 100-year storm surge	1.75m AHD
Wave setup and runup	0.60m
Risk (current)	2.35m AHD
Plus SLR	0.30m
Risk (2050)	2.65m AHD

However, protection items designed at this height are unlikely to prevent overtopping in some sections of Encounter Bay where protection items have been installed. Therefore, some allowance in protection height should be added to manage overtopping. However, at this stage we do not have the data to make this determination and therefore we have adopted 0.40m additional height to protection proposals to manage anticipated overtopping.

[4] Watson P.J. 2020, Updated mean sea-level analysis: Australia noted a 'weak acceleration' in sea level rise but statistically equal to zero (in other words, statistically meaningless).

[5] AWE, 2013, Victor Harbor Coastal Management Study, p. 50.

Adaptation strategy

Coastal Management Study, 2013 - strategy

The Coastal Management Study (2013) generally recommended a 'hold the line' approach for Encounter Bay noting in the first instance that soft environmental responses are preferred such as sand nourishment and dune vegetation (Figure a) but that by 2030 the rock revetment wall should be extended and upgraded along Franklin Parade focussing on higher risk and low-lying areas first[6]. In regard to hard protection items the Coastal Management Study provided concepts for protection to 2050 (initial level, 2.65m AHD) and a concept of protection for 2100 (ultimate level, 3.40m AHD) (Figure b).

Since the Coastal Management Study in 2013, the historical review in this project found that:

- Sand nourishment was trialled in 2011 and 2013 between Fell St and Ridgeway Rd but this does not seem to have been successful. The larger swells that periodically impact this coast would tend to remove the sand where the beach is narrow.
- A concrete block seawall was installed in this same location in 2019 as a trial (Figure c).
- A rapid period of erosion occurred in the Yilki region between Fountain Avenue and Tabernacle Road after 2012, and rock revetment was installed to this region in 2020, but these are showing signs of failure after recent storms.

Concrete block seawall - discussion

The concrete block seawall proposal was reviewed from the perspective of coastal geomorphology and from an engineering perspective. From a geomorphological perspective, the advantage of the concrete block seawall approach is that it is less intrusive in the backshore, it can be covered with sand and vegetated, and a more natural beach profile maintained.

However, from an engineering perspective, Magryn and Associates advised:

'Where wave effects are higher, the rock revetment wall is the preferred protection solution. Randomly stacked rock armour is more effective to dissipate wave energy and has been utilised in other nearby locations. The concrete block wall option may be suitable in sheltered areas with minimal wave action. A more detailed wave analysis is required during the design phase, to confirm viability. The intent is for sand to be backfilled over the concrete blocks, establishing a more natural beach/dune. However, if wave action erodes the sand, the concrete block may be exposed to wave action. Waves tend to reflect off vertical faces such as this, which may lead to further erosion'.


Figure c: Concrete block seawall installed as a trial 5 tiers high, covered with sand and vegetated in the region of Fell Street.

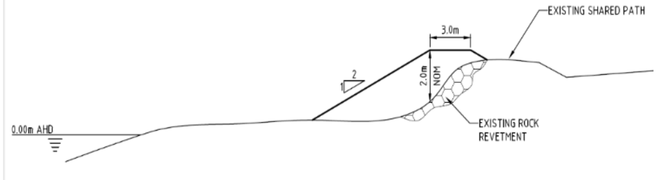


Figure a: Sand nourishment – a short to medium treatment, AWE, 2013.

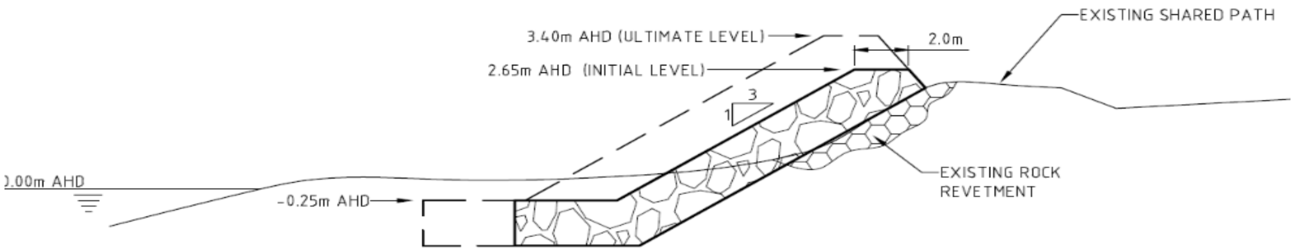


Figure b: Rock revetment – designed to for 2050 sea level rise projections at 2.65m AHD, with capability of being raised to 3.40m, presumably for 2100 projections. AWE, 2013.

6 AWE, 2013, Victor Harbor Coastal Management Study, p. vi, 57.

Adaptation strategy

Adaptation response parameters

In summary, there are three 'hold the line' strategies that may be employed within Encounter Bay.

1. Environmental strategies that consolidate natural dune systems with sand nourishment and/or vegetation. However, as noted previously, sand nourishment may have limited usefulness in locations where the backshore has been moved seaward and the beach width is narrow. Larger swells from the Southern Ocean that sometimes penetrate Encounter Bay are likely to remove this sand quickly before a dune has had time to be established.

2. Concrete block seawalls which are effective in locations where a pedestrian pathway is to be constructed in close proximity. This strategy also allows for backfilling of sand and installation of vegetation which enables a more natural beach to be retained. However, this strategy is caveated by the need for site specific wave analysis to ensure that the structure will manage impacts over a sufficient length of time.

3. Rock revetment, which has a proven track record with dissipating wave energy, as has been installed in the vicinity of Whalers Road.

The application of these strategies will be determined on site specific analysis of coastal profile and wave analysis and designs completed by appropriately qualified engineers and consultants.

Since completing Part 1 of this project, some doubt has emerged regarding the suitability of the current allocation of wave setup at 0.30m and wave runup at 0.30m which is currently assigned to the whole of Encounter Bay. In particular, recent correspondence with Coast and Marine Branch (Department of Environment and Water) suggests that an allowance for overtopping is likely to be required where protection works are to be installed. These matters will require further research and analysis.

Encounter Bay has been divided into two minor cells for the purpose of ongoing adaptation management.

Cell 12.1 – the Bluff Boat Ramp to Tabernacle Road

This section of coast is characterised by:

- A backshore of low elevation (especially from Nevin Avenue to the Bluff Boat Ramp,
- Narrow beach width (partially due to backshores having been moved seaward over time),
- An earthen embankment in the backshore rather than a dune system (some of which is protected),
- The area between Whalers Road and Tabernacle Road is subject to overtopping on moderate events, and/or erosion in the backshore.
- The land adjacent Franklin Parade between Whalers Road and Tabernacle Road is at low elevation (2.20 to 2.40m AHD).

The unifying strategy for Cell 12.1 is the installation of a concrete pathway at 3.00m wide set at elevation 3.10m AHD. However, this elevation has been set based on the incorporation of an allowance for wave overtopping at 0.40m which is subject to review. The path will provide a 'spine' for the coastal adaptation strategy at consistent height and design to which new protection works or replacement protection works can be butted as required.

These works are likely to be either concrete block seawalls or rock revetment sea walls, depending on the beach profile and the nature of the waves, and are unlikely to be sand nourishment strategies alone.

The option for an additional plinth was reviewed by Magryn and Associates and it was recommended that this is installed at the time of the pouring of the concrete. Due to safety concerns for pedestrians and cyclists, a handrail will be required which can be bolted to the plinth.

The recommended design life is 30-40 years so that the impacts of projected sea level rise may be managed to 2050-2060.

Cell 12.2 – Tabernacle Road to Kent Reserve

This coastal stretch is generally more elevated than the southern portion and not at risk from inundation. The exception is to the north of the boat launching area within Kent Reserve.

The predominant protection strategy in this region is rock revetment and this is likely to remain the preferred option between Charles Street and Bartel Boulevard due to the higher profile of the beach and backshore and the greater distance between the backshore and the bikeway.

A long-term accretion trend has occurred in the vicinity of Kent Reserve. If this trend was to reverse, then protection may be required adjacent the path.

Adaptation strategy

Preliminary protection concepts

Cell 12.1 The Bluff Boat Ramp to Tabernacle Road

Magryn and Associates has provided two preliminary design concepts for protection in conjunction with the proposed bike way.

Option 1 includes the concrete plinth, but this can also be applied to Option 2.

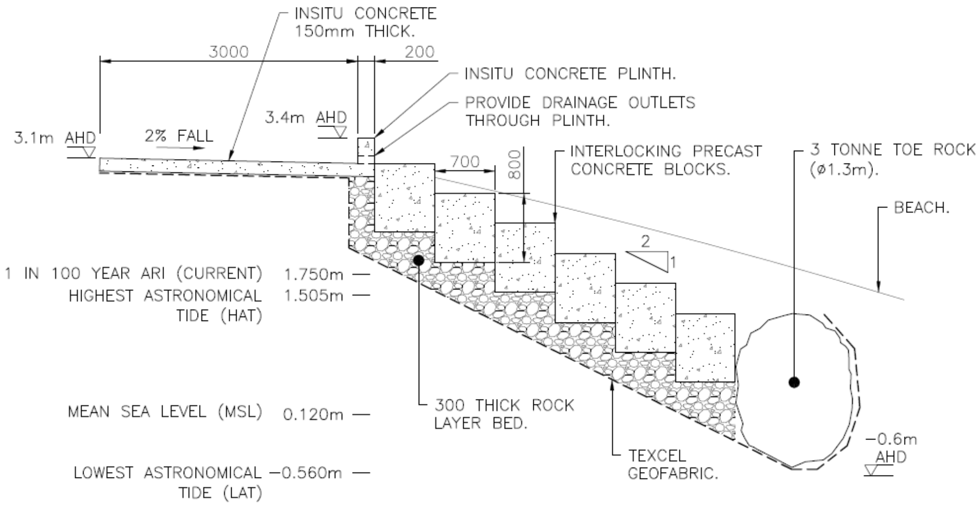
A handrail will be required for both designs where the path is placed in close vicinity of the protection works.

The selection of either option will depend on the beach and backshore profile, the energy of the waves in a particular location, and preferences as to whether a more natural beach is desired.

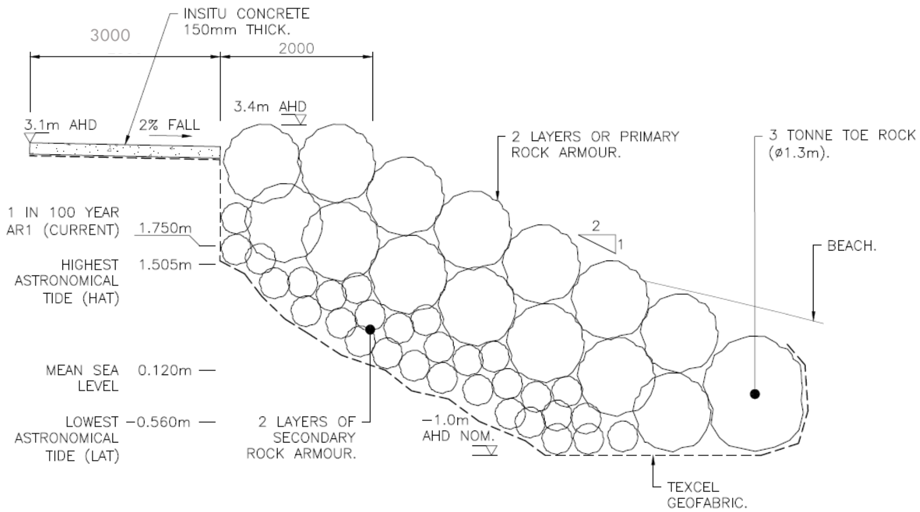
Magryn and Associates estimated the cost for the concrete block seawall at $900 per lineal metre (based on a previously constructed Victor Harbor project). The estimated cost for the rock revetment wall is $1,000 per lineal metre (based on a previously constructed project in South Australia)'. Based on this information, Magryn and Associates concluded that 'the costs are similar and, in our opinion, should not factor into the decision making'.

Cell 12.2 Tabernacle Road to Kent Reserve

In this minor cell, east of Charles Street the preferred protection concept is Option 2, rock revetment as this is the existing form of protection, the bikeway is not set in close proximity, and the height and the slope of the backshore is likely to be more suited to this type of protection.



OPTION 1



OPTION 2

MAGRYN
ENGINEERING CONSULTANTS
CLIENT: INTEGRATED COASTS
PROJECT: SEAWALL

Adaptation strategy – Bluff Boat Ramp to Nevin Avenue

Adaptation Strategy

Fleurieu 12.1
Encounter Bay
Bluff Boat Ramp to
Nevin Avenue

Coastal setting

This section of the coast is the most sheltered part of the bay.

Existing protection:

No protection in backshore.

Exposure

The sea-flood risk projected for 2050 is 2.65 (including wave runup. An allowance of ~0.40m has been added for potential overtopping*.

The boat ramp area and section of the pathway from the boat ramp to the end of the treed section of the pathway are set above 2050 risk.

The modelling indicates approximate pattern of sea-flood projected for 2050 and illustrates that wave runup would overtop the backshore and flood the road at low depth. The road is at 2.40m AHD.

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*It is recommended that wave and tidal studies be carried out within Encounter Bay to enable more site-specific allowances for wave setup, wave runup and wave overtopping to be allocated. For example, it is likely that wave impacts and the potential for overtopping is less in this section of the bay than further to the east due to the sheltering effect of The Bluff.

Adaptation strategy - Bluff Boat Ramp to Nevin Avenue

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Bluff Boat Ramp to Nevin Avenue

Strategy 2021-2031

Install concrete bikeway with top at 3.10m AHD, depth 0.150m, at desired width where space allows. It is preferable to keep any advancement seaward of structures to a minimum as this will increase the impact of the sea on backshores and make it harder to retain a natural beach. Install a handrail to manage safety concerns.

The path will create an edge against which to place future protection works when required.

The three Norfolk Pines near Nevin Avenue are on the seaward side of the path and would require removal.

The desired design life is 30-40 years for the path to ensure that it manages sea level rises to 2050-2060.

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Strategy in brief – Install concrete path at 3.10m AHD to cope with sea-flood projected for 2050, including wave over topping. Provide an edge against which future protection can be installed.

Adaptation strategy – Nevin Avenue to Fell Avenue

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Nevin Ave to Fell Ave

Coastal setting

The land north of Franklin Parade is the lowest in this cell and is the most vulnerable to flooding after 2050.

Existing protection:

The shoreline is completely protected at varying height.

- Rock revetment (Nevin - Fountain) Poorer quality near Nevin.
- Concrete block (Fountain to Fell)

Exposure

The sea-flood risk projected for 2050 is 2.65 but some allowance is required to manage overtopping on sea walls*.

The modelling indicates some overtopping near Nevin Street. Residents report overtopping at the Whalers Road toilets. The modelling indicates wave overtopping at Fell Street possible.

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*It is recommended that wave and tidal studies be carried out within Encounter Bay to enable more site-specific allowances for wave setup, wave runup and wave overtopping to be allocated. For example, it is likely that wave impacts and the potential for overtopping is less in this section of the bay than further to the east due to the sheltering effect of The Bluff.

Adaptation strategy – Nevin Avenue to Fell Street

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Nevin Ave to Fell Street

Terrain review

The importance of establishing an effective protection system in the immediate backshore is underscored by the terrain model for this region.

Parts of Franklin Parade are as low as 2.40m AHD. Some housing allotments are as low as 2.20m AHD.

Planning context

The road reserve and foreshore region are zoned Open Space.

The first block landward of Franklin Parade is zoned Waterfront Neighbourhood which allows for three storey buildings setback 5m from the front boundary of the allotment. Development implemented in this current era will have a lifespan of 60+ years. Consideration should be given to how these will be protected.

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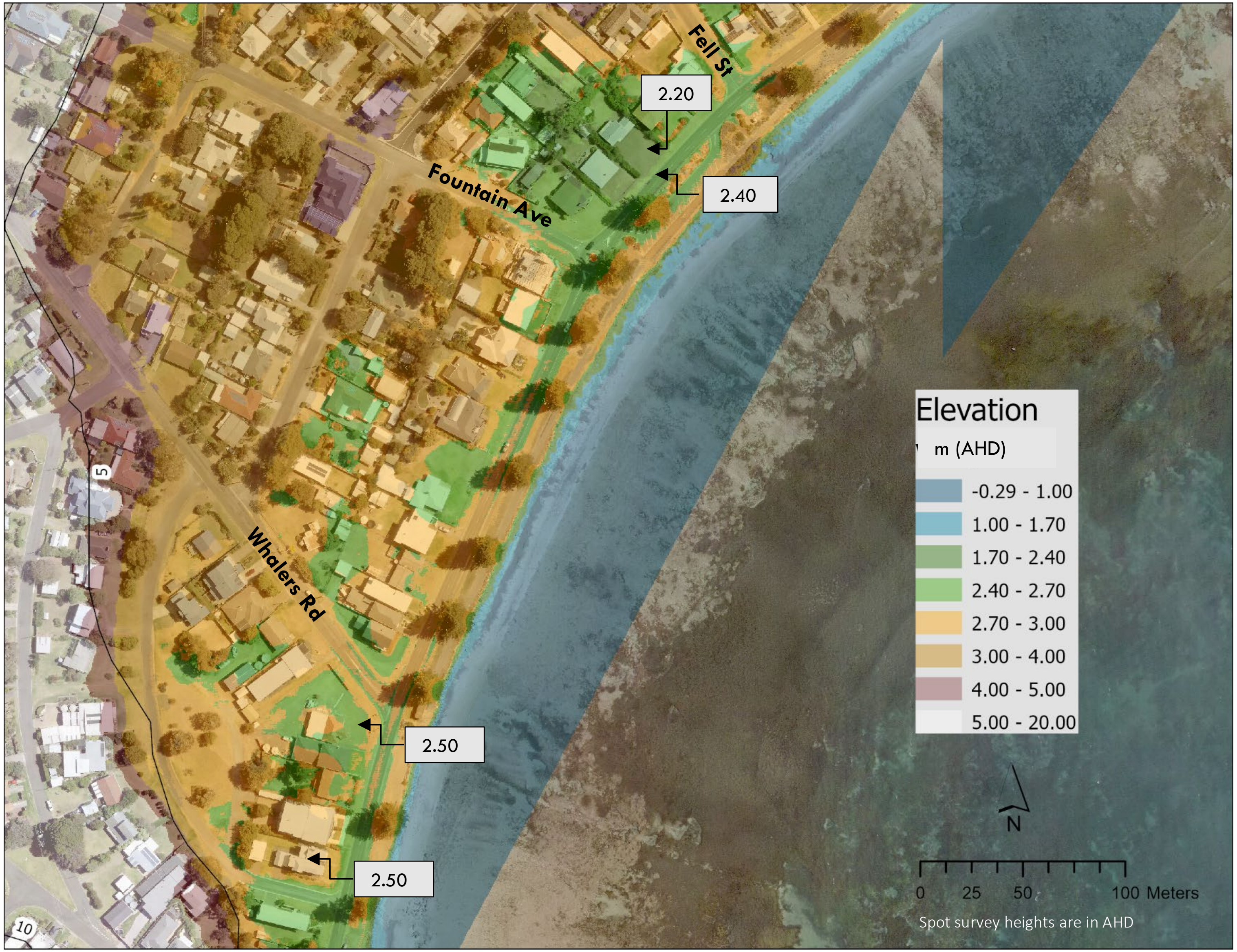

Adaptation strategy - Nevin Avenue to Fell Street

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Nevin Ave to Fell Street

Strategy 2021-2031
Install concrete bikeway with top at 3.10m AHD, depth 0.150m, at desired width where space allows. It is preferable to keep any advancement seaward of structures to a minimum as this will increase the impact of the sea on backshores and make it harder to retain a natural beach.

The existing protection works should be butted up to the edge of the bikeway.

Install a hand rail to the seaward side of the pathway to manage safety concerns.

The desired design life is 30-40 years for the path to ensure that it manages sea level rises to 2050-2060.

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Strategy in brief – Install concrete path at 3.10m AHD to cope with sea-flood projected for 2050, including wave over topping. Provide an edge against which current protection and/or future can be butted.

Adaptation strategy – Fell Street to Tabernacle Road

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Fell Street to Tabernacle Road

Coastal setting

This coastal region undergoes cycles of accretion and erosion. It appears the area in front of Yilki shops is now in an erosion cycle.

Existing protection:

This shoreline can be broken into five sections (left to right):

1. Concrete block (Fell Street)
2. No protection
3. Concrete rock wall (1950s)
4. Rock revetment (poor condition)
5. Rock walling (behind bank/dune).

Exposure

The sea-flood risk projected for 2050 is 2.65 (including wave runup). In the Yilki region, moderate events overtop the rock revetment (see following page).

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Concrete block seawall – installed 2015 as a trial.

Rock and concrete seawall – installed in 1950s (condition poor)

Rock revetment – in poor condition. Install date unknown.

Rock revetment (buried in embankment) – poor condition.

Adaptation strategy – Fell Street to Tabernacle Road

Yilki issues

Overtopping (Photographs 1,3)

A recent example of overtopping occurred at Yilki on 25 June 2021 which coincided with the highest astronomical tide for the year. The bikeway height is 2.90m AHD in this location. This overtopping is due partly because the coast has eroded in this vicinity but also because additional road space has been added in ~2000 that has pushed the shoreline seaward. Wave action is now directly interacting with the defences rather than dissipating its energy by running up the beach as in former times.

Loss of beach (Photograph 5)

Further evidence that this section of backshore is further seaward is the constant interaction with tides. This is leading to loss of beach in this area.

Protection works (2,5)

The protection works are in poor condition and not engineered in accordance with current practice. The profile appears almost 1:1, rock sizes are small, and there doesn't appear to be a toe. Subsequent to recent tides, the rocks have slipped, and the edge of the pathway is exposed.

Recent erosion (6)

Recent events have scoured the embankment in the vicinity of Tabernacle Road.

Adaptation strategy – Fell Street to Tabernacle Road

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Fell Street to Tabernacle Road

Terrain review

The Yilki terrain is difficult to manage:

- The bikeway is narrow and elevated above terrain on both sides.
- The road is low (2.40m AHD) and an internal retaining wall makes the elevation of the foreshore possible at 2.90m AHD.
- The Norfolk Pine is situated in between the bikeway and the roadway.

Planning context

The Yilki block – bordered by Ridgeway and Tabernacle is zoned Local Activity Centre with 3 storey buildings permitted at 12.5m high and positioned directly on the front boundary of the allotments. Planners should consider longer term risk of sea level rise in this location.

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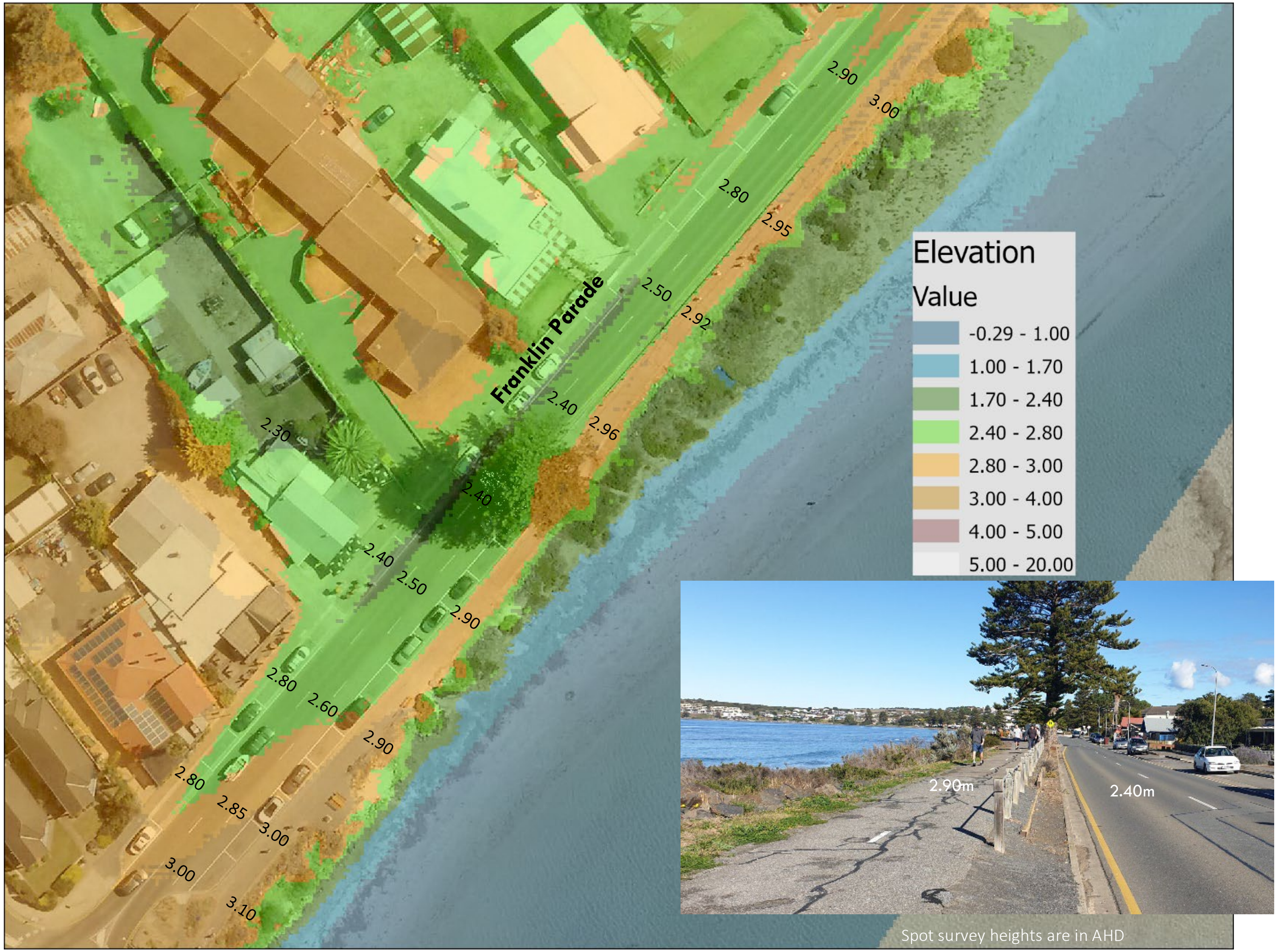

Adaptation strategy – Fell Street to Tabernacle Road

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Fell Street to Tabernacle Road

Strategy 2021-2031

Option 1

If the imperative is to be able to maintain a viable beach, then the aim should be to retreat the location of the toe of the protection works.

- Relocate the parking bays into the slip lane (remove the slip lane)
- Remove the Norfolk Pine
- Remove the rock revetment
- Install a 3.0m wide concrete bikeway at 3.20m with a plinth at 3.40m and a handrail.
- Remove the roundabout and either close Ridgeway Terrae or convert to T-junction.
- Remove the two Norfolk Pines in the vicinity of Ridgeway Terrace.
- Install either rock revetment or concrete block seawalls (depending on outcome of wave analysis).
- Sand nourish – a dune did exist here, may be possible to establish.

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Adaptation strategy – Fell Street to Tabernacle Road

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Fell Street to Tabernacle Road

Strategy 2021-2031

Option 2

If the current layout is to remain then the only other option is 'push' the line of the coast seaward to allow for the desired path width of 3.5m in this location. Council advises that some consideration is being given to creating a public space in this location which will push the line of the coast even further seaward.

This would mean certain loss of a useable beach and the inability to create a natural dune system. As the toe of the protection would be pushed further seaward, the potential for overtopping would be greater and the height of the defences required to be higher.

Consideration could be given to creating public spaces by way of a wharf type structure. This proposal would allow the line of the coast to remain in its more natural position.

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Adaptation strategy – Fell Street to Tabernacle Road

Adaptation Strategy

Fleurieu 12.1

Encounter Bay

Fell Street to Tabernacle Road

Strategy 2021-2031

The wider extent on this page demonstrates the required length for the proposed pathway and protection items.

Pathway – 410m

Protection - either concrete block or rock revetment seawall – 320m.

Survey spot heights of the existing path are provided in Australian Height Datum to provide design and planning context.

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Adaptation strategy – Tabernacle Road to Bartel Blvd

Adaptation Strategy

Fleurieu 12.2

Encounter Bay

Charles Street to Bartel Blvd

Coastal setting:

This coastal region is the most elevated within Encounter Bay. The beach undergoes cycles of erosion and accretion (over last ten years, predominantly accretion, but recent storm action has caused some erosion).

Existing protection:

This shoreline can be broken into four main sections (left to right):

1. Rock walling behind embankment installed in 1970s (?) (not pictured)
2. Rock revetment in sound condition
3. Gap in protection works
4. Rock revetment – recent erosion, rocks sliding on to the beach.

Exposure

The sea-flood risk projected for 2050 is 2.65 (including wave runup). This area is elevated above inundation, but subject to erosion.

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2. Rock revetment – well constructed and in sound condition

3. A gap in the protection works – but not under immediate threat.

4. Rock revetment – recently eroded so that rocks are sliding on to the beach.

Adaptation strategy – Tabernacle Road to Bartel Blvd

Adaptation Strategy

Fleurieu 12.2

Encounter Bay

Bartel Blvd to Charles St.

Strategy 2021-2031

Recent storms on 18 July 2021 have damaged the embankment for ~100m south of Bartel Boulevard. This storm damage occurred too late in the project to be reviewed by the engineer.

The adaptation proposal for this section of coast is to:

- Conduct an inspection of section (1) to ascertain the nature of the protection structures that appear buried under the embankment.
- Design and install rock revetment to section (3). Low priority.
- Conduct an inspection of the recently damaged section (4) and repair or replace rock revetment.

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Adaptation strategy – Bartel Blvd to Kent Reserve

Adaptation Strategy

Fleurieu 12.2

Encounter Bay

Bartel Blvd to Kent Reserve

Coastal setting:
Long term accretion occurred (30-40m) between 1949 and 2012, recently eroded leaving access forward of the dune line (now removed).

Existing protection:
Nil.

The bikeway/ path has recently been upgraded in this location and is constructed at height 3.10m AHD and runs along the road on the left of the photograph and on the seaward side of the Norfolk Pines on the right side (see inset photograph).

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Notes.

Adaptation strategy – Bartel Blvd to Kent Reserve

Adaptation Strategy

Fleurieu 12.2

Encounter Bay

Kent Reserve to Bartel Blvd.

Strategy 2021 to 2031:
Monitor the position of the dune and maintain vegetation.

Outlook 2050 - 2100:
Increases in sea level may cause the dune to recede. Keep vegetated but allow recession to occur. If/when required modify the bikeway (raise) and protect using concrete block seawall. Modelling for 2100 indicates major intervention required to protect Kent Reserve and Franklin Parade or managed retreat.

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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

Ongoing monitoring provides the context for decision making but 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.

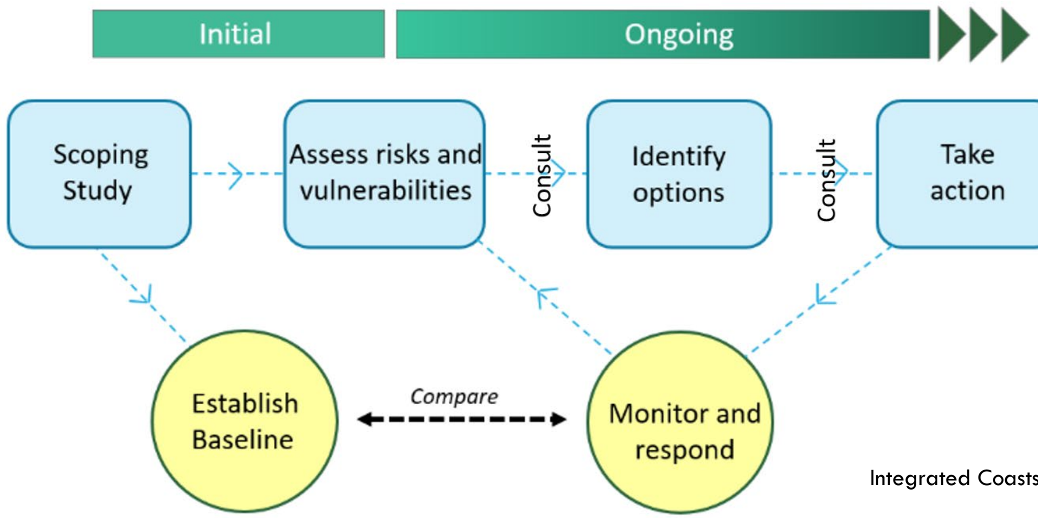
2. When a new digital elevation model is obtained (usually 5-10 years), compare the data points to determine whether the coast is accreting or eroding.

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

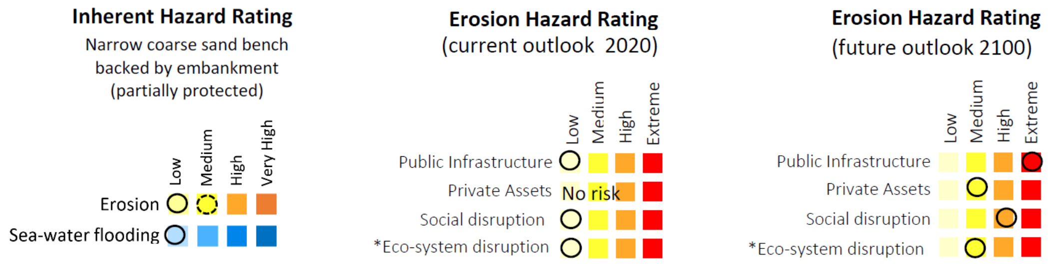


Integrated Coasts, 2017

Adaptation Strategy: Encounter Bay (Cell 12.1)

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

Risk outlook



Adaptation overview:

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

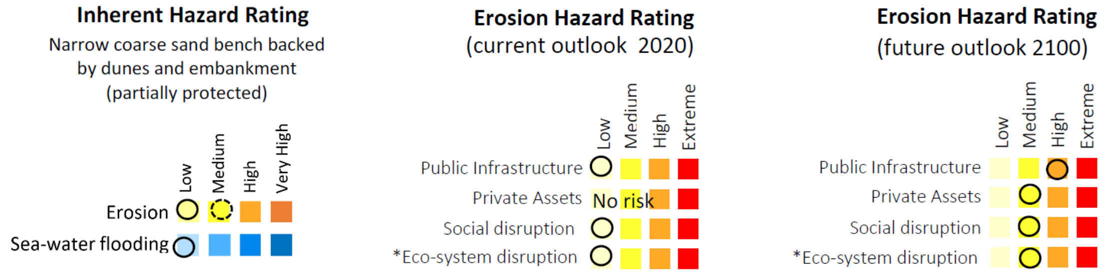
Summary table:

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

Adaptation Strategy: Encounter Bay (Cell 12.2)

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

Risk outlook



Adaptation overview:

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

Summary table:

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

Adaptation tasks: Encounter Bay (Cell 12)

	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 an assessment of storms (2-3) of varying magnitude to identify appropriate wave effect allocations for the various parts of Encounter Bay.	It is likely that the current allocation of 0.30m for wave setup and 0.30m for wave runup are too low for some parts of the bay. At the moment there is no allowances for overtopping behaviour on protected backshores. Identifying specific wave effects for specific locations will feed into the design of future protection items.	High	Now
3	In Cell 12.1, design and construct the bikeway at 3.10m with optional plinth to protect against overtopping (or at height determined by the wave effects study).	An appropriately designed bikeway will act as the 'spine' to the protection system for Cell 12.1. New or replacement protection items can then be abutted to this spine when required over the course of the next 30 to 40 years.	Moderate	5 years
4	In Cell 12.2, review the recently damaged section of rock revetment in the vicinity of Bartel Boulevard.	Recent storms have eroded the embankment and rock protection has been dislodged.	High	Now
5	In Cell 12.2 review the nature and condition of the rock revetment in locations where it is buried behind the embankment and the vulnerability of the gap in protection.	The areas of rock wall which are buried and the current gap in the system are in locations where the coast appears stable and the dune system in sound condition.	Low	Review now, install within 5 years (subject to monitoring).
6	Conduct a preliminary review of the planning parameters for Whalers Road to Tabernacle Road to identify Council's responsibilities in providing protection in the context of higher density zoning.	The land to the north of Franklin Parade in the area between Whalers Road and Tabernacle Road is lower than immediate backshore to the beach. Later in this century, the flood modelling depicts this area as being impacted by inundation.	Moderate	1-2 years