Coastal Adaptation Study &
Coastal Adaptation Strategy

VICTOR HARBOR CENTRAL

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 11

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 clifftops thereby increasing the potential for increased rates of recession and instability. In the context of a coastal study the impact of rising sea levels can be quantified through sea flood modelling within digital models. The impact of vegetation loss cannot be easily quantified and as noted above, is based upon less certain projections. Attempting to incorporate too many impacts into a coastal study is likely to compound the level of uncertainty and deliver less clear outcomes.

Direct and indirect risks

Direct risks relate to the impact of rising sea level on the fabric of the coast. Different areas of coast will be vulnerable to different risks. Low lying areas will be more likely to be vulnerable to inundation and soft sediment backshores more vulnerable to erosion. In this study we evaluate the direct impact of *inundation* and *erosion* in four main receiving environments. These are listed below and explained later in the project:

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

Associated with these direct risks are a range of indirect risks. For example, the potential loss of a beach from erosion is a potential social and economic risk (if the beach is related to economic activity such as tourism). A political risk may occur when the decision makers act in ways the communities do not support.

Project focus

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

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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

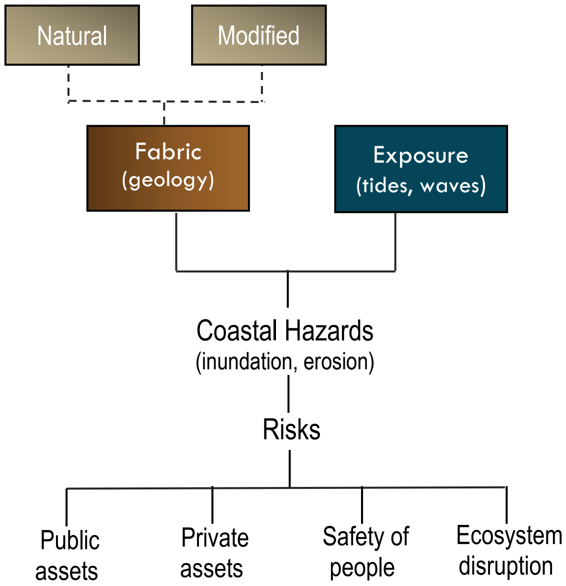
CHANGES IN THE RELATIONSHIP

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** (CoastAdapt) and within tertiary cell, Coastal Conservation Cell, **Fleurieu 11**.

Victor Harbor Central is reviewed in this report.

1. Introduction

Regional Setting

Fleurieu 11
Secondary Cell: Fleurieu
Tertiary Cell: Victor Harbor Central

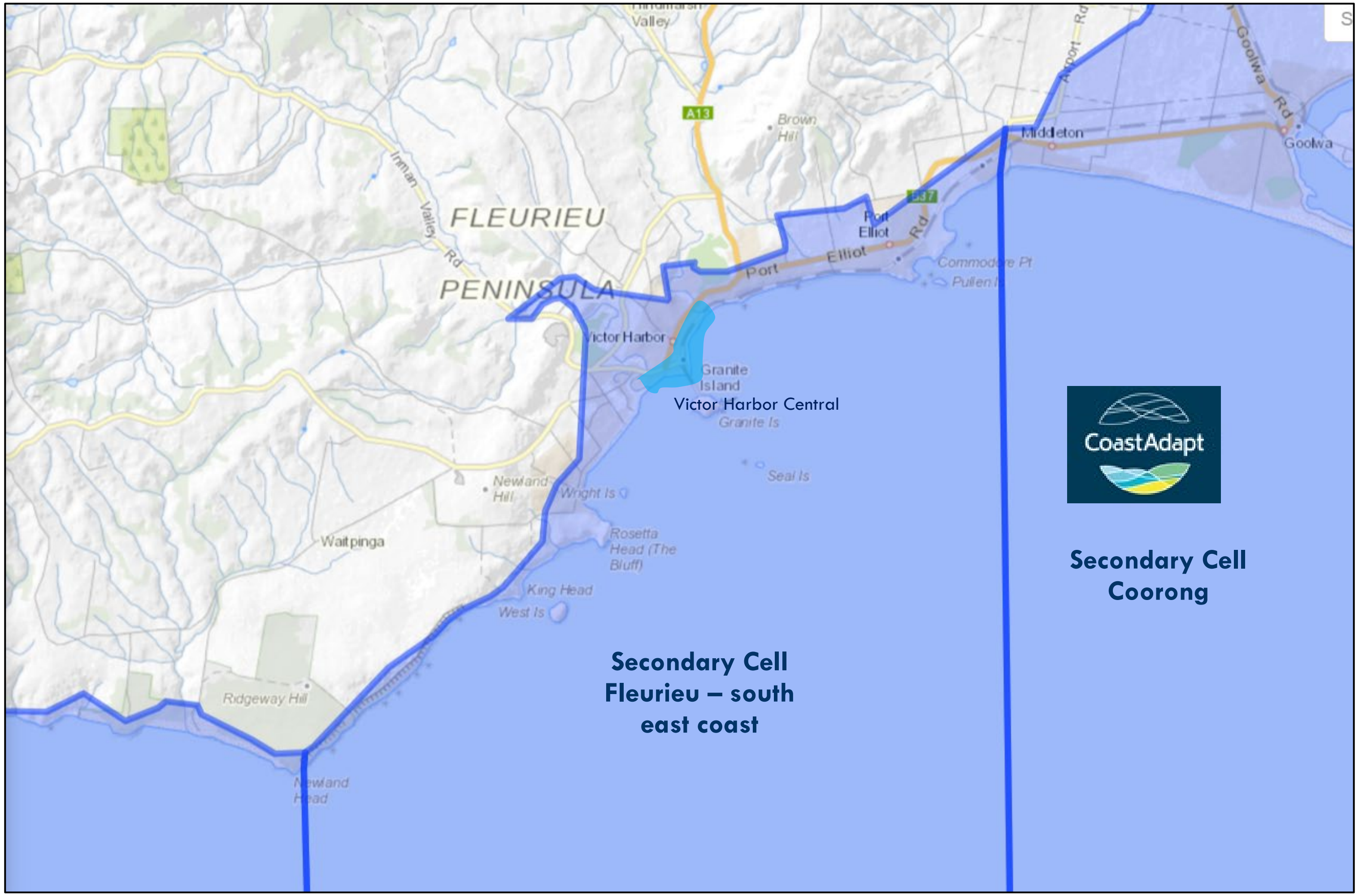
Australian regional setting

Victor Harbor Central 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.



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

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1. Introduction

Regional Setting

Fleurieu 11

Secondary Cell: Fleurieu

Tertiary Cell: Victor Harbor Central

11.1 – The Esplanade

Relative Exposure
Sheltered

Wave energy
Low

Shoreline class
Reflective

Sand rating
Coarse sand

11.2 – Flinders Parade - Bridge Tce

Relative Exposure
Moderate

Wave energy
Low

Shoreline class
Low Tide Terrace

Sand rating
Fine-medium sand

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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)

2. Settlement history

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

BRIEF HISTORY

Prior to European settlement, the region of Victor Harbor was inhabited by the Ramindjeri clan which shared the cultural life of the Ngarrindjeri. The Ramindjeri lived 'in one of the richest and most easily accessible areas in Australia' and their territory provided them with bountiful food from the land, the rivers and the sea[7].

Victor Harbor – seaport (1830s to1920).

First European interaction with the Encounter Bay region was in the form of explorers or whalers. The meeting of explorers Mathew Flinders (Britain) and Nicolas Baudin (France), who were both charting the Australian coastline in 1802, gave Encounter Bay its name. Whaling stations were established at Rosetta Head and Police Point (the causeway) about the same time as the royal navy ship 'Victor' visited the shores in 1837.

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

The early years of settlement were dominated by disputes about where the capital of South Australia should be located. Frequent storms and the wrecking of boats provided arguments against the location of Victor Harbor as the capital. Colonel Light held the view that Victor Harbor's position as 'open to the Southern Ocean' was not a suitable location. Settlers arrived from 1840 onwards and District Council of Encounter Bay was founded in 1853.

Construction of coastal infrastructure

Regionally, steamer trade through the mouth of the River Murray had faded due to the difficulty of navigating through the river mouth. Produce was transported from Goolwa by horse drawn train, first to Port Elliot and then to Victor Harbor. Bridges were required over Watson Gap and Hindmarsh River and a new jetty required in Victor Harbor.

By 1862, the jetty stretched out 195m but was not connected to Granite Island. Workers found it increasingly difficult to drive the pylons through the limestone reef below the surface between the island and the mainland. The contractor (Gouge) suggested forming an embankment between the jetty and the island and then to build a wharf on the island. This recommendation was refused because it was feared that the embankment may cause silting of the port facilities. The railway line was opened in 1864 and Port Elliot was closed as a port two years later.

[7] Page, M. p. 14

However, ships were exposed to any storm from the south-east and bigger ships built with steel were beginning to traverse the oceans. In 1872, it was proposed to build a breakwater 305m to the north east from granite island to provide shelter to the ships and to extend the jetty to the island to act as a causeway. The granite for the breakwater were sourced from granite island by blasting with dynamite. From 1879 to 1891, 192,000 tons of granite were quarried from the island. Lessons were learned from the Port Elliot breakwater that suffered displacement of rock in one of the first major storms after it was built, and larger rocks were utilised for this breakwater. A 'working jetty' was established about 200m south of the causeway (see figure next page). The seabed under the jetty was covered with a hard cap of limestone and holes were blasted in the limestone.

Figure a: Victor Harbor, 1867, jetty constructed for commercial purposes. (State Library of SA, B-282).

2. Settlement history

Construction of coastal infrastructure (cont.)

Then wooden piles capped with a steel screw were screwed into the sea floor by sheer manpower and the holes filled with concrete. A few years later another jetty was built subsequently closer to the breakwater using the same technology and the name 'screw pile jetty' remains today.

Construction of urban settlement

The South Australian Act (1836) reserved 100 feet (~30m) from the high-water mark for road or other public purposes and private interests were to be positioned behind this space. The early planners of Victor Harbor took a conservative view and place the landward edge of the road reserve of Flinders Parade and The Esplanade ~180 feet (54m) from the high-water mark.

Project note: This early planning practice means public land, usually under the control of Council, is at the forefront of coastal adaptation and not private land.

End of port era

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

Recorded storms – to 1920.

A review was undertaken to identify significant storms with a particular focus on any impacts to the urban environment.[8] It is understood in this earlier time that less urban infrastructure was built near the coast and therefore reporting of storm damage to infrastructure may be low. However, in an era when reporting of incidents such as 'one or two chimneys blown over' made the news, it is unlikely that a major storm which inundated the town would not have been reported. 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, 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'.

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

Urban legend: flood story

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).

Figure a: Victor Harbor, 1910, causeway constructed to the island and 'working jetty' established (State Library of SA, B-17978).

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

2. Settlement history

Victor Harbor – tourist town (1920 to1970).

The key focuses of this section relate to the development of the foreshore, in particular in relation to protection works, storms and urban expansion.

Foreshore development.

The impetus for foreshore development in Victor Harbor came from two directions. In 1917, the State Government passed the Victor Harbor Foreshore Act which declared the land between Flinders Parade and the coast as a reserve. The second impetus was the end of the First World War and the people of Victor Harbor desired a place to remember their fallen.

Soldiers Memorial Gardens – Seawall (1920-1921)

Charles Reade, South Australia's first government Town Planner, laid out the design[9]. The main interest for this study is the proposal for the 'construction of a sea wall 3 to 4 feet high above the existing high-water mark' which was needed to 'redress the recurrent problem of high tides and strong winds which affected the suitability of the foreshore as a public recreation space and damaged the newly planted gardens'. In a public lecture Reade stated that 'everything in the foreshore scheme, including the Gardens of Honour, was dependent upon securing protection against high tides and storms, which the proposed wall and promenade would provide'[10]. The wall was built in 1920-21.

It is difficult to now identify if the level of the location for the promenade was already raised by virtue of a natural mound adjacent the coast, or it was raised as part of the work (Figure b). It is likely that both occurred with importing of fill that had been on roads for the path and soil from elsewhere for the slope[11].

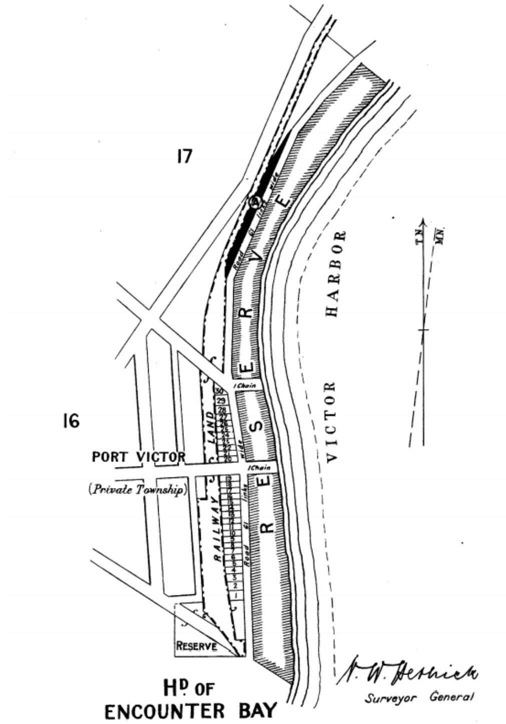

Figure a: Public reserve established by Victor Harbor Foreshore Act 1917 (SA Government).

Figure b. View of Victor Harbor foreshore reserve, 1908. This area of land was likely a gentle slope up to Flinders Parade with a small mound just above the high-water mark (SA State Library, B-17465-3).

Figure c. The promenade area was likely raised and the slope behind backfilled (SA State Library, 1937, B-23718).

[9] For a full review, see Soldiers' Memorial Gardens Management Plan, 2011, McDougall and Vines.

[10] Victor Harbor Times, 21 March 1919.

[11] Victor Harbor Times, 11 June 1920.

2. Settlement history

Esplanade – Seawall (1925-1926)

Shortly after completing the first sea wall it was proposed to install a seawall in a westerly direction from the jetty to 'primarily to protect the Crown Reserve, which is hoped to further improve'[12]. The wall was built in 1925-1926 costing about £500 for 10 chains (~100m)[13].

Groynes near Hindmarsh River – early 1950s.

Two 'experimental groynes' were installed in the early 1950s near Hindmarsh River by SA Harbors Board as a means to capture littoral sand drift. The results were described as 'encouraging' by those assessing how to manage the erosion of the Adelaide coastline but appear to have little current functionality[14].

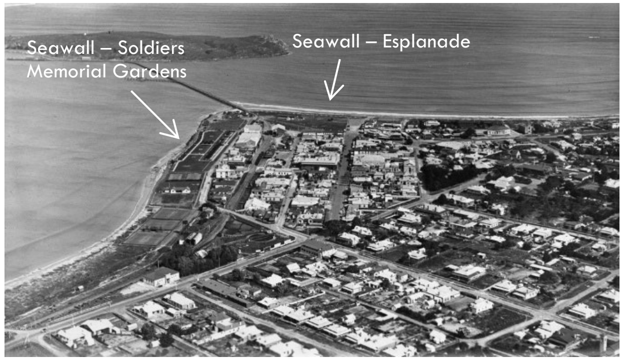

Figure a: Aerial photograph (1928) showing the layout of the reserve (SA State Library, B-4964).

[12] Victor Harbor Times, 1 May 1926.
[13] Victor Harbor Times, 12 March 1926
[14] Advertiser, 16 July 1953

Storm action upon coastal structures.

The newspaper records appear replete with storm stories, especially in the period 1920s to1940s. Events that damaged the seawalls (usually the Soldiers' Memorial Gardens) include, August 1923[15], March 1928[16], April 1932[17]. A storm on 2 October 1928 was described in various newspapers of the time[18]:

- Sleet and heavy rain fell today, and mountainous seas are running. Mr. George Woodward…says he has never seen such a bad sea since 1877.
- Water is washing over the causeway, making the structure quiver. High seas thundered against the seawall, poured over the esplanade, and washed away about 15 yards of the embankment.
- There is none of the esplanade visible, and only a little of the seawall.
- The brush wood fence from the jetty to the tennis courts near the Hotel Victory has been destroyed, in some cases the posts being washed right out of the ground.
- Foreman J. C. Joy expects if the sea still rages that more of the seawall will be destroyed.

Figure b: Two experimental groynes were installed by Harbors Board in early 1950s (Victor Harbor Times, 31 July 2014).

[15] Victor Harbor Times, 24 August 1923
[16] Barrier Miner, 22 March 1928
[17] News, 11 April 1932

The storm of April 17, 1938 appears to be one of the largest in this time period but with little damage. 'One of the biggest seas experienced here for the last 50 years prevailed today, and but for the wonderful resistance offered by the concrete sea wall the damage would have been great…Mountainous breakers hurled themselves at the wall, and waves 20 feet high carried tons of water and seaweed into the lawns and gardens. The croquet lawn and women's bowling green were inundated with water 18 inches deep, and the men's bowling green was partly covered with seaweed and water'[19].

The Mail reported a storm on 24 April 1943 which covered the tennis courts with water, sand, and seaweed[20]. On 15 March 1946, big seas swept up into the bowling green and Soldiers Memorial Gardens along the foreshore…some shelter sheds along the beach have been blown down or washed away.

[18] Chronicle, Victor Harbor Times, News, 1928
[19] Advertiser, 18 April 1938
[20] The Mail, 24 April 1943

2. Settlement history

Storms - Key points:

Storms were more predominant in the 1920s to 1940s. The 1950s to 1970 was relatively quiet.

Some sea storms were reported in the context of **heavy rainfall** (contrary to findings within St Vincent and Spencer Gulfs where large sea storm events are not normally accompanied by heavy rain).

Only **one storm** appears to have gone over The Esplanade (1928).

The Soldiers' Memorial Gardens were inundated prior to the installation of the sea wall, and **multiple times** after the installation of the sea wall.

Urban expansion between the rivers (1920 – 1970)

From 1920 onward, areas of public foreshore and areas of private land were clearly defined, with land under private ownership situated behind esplanade roads (Bridge Road, Flinders Parade and The Esplanade). Development along the foreshore was primarily residential, consisting of one house on a large allotment, or hotel and tourist accommodation. This pattern of development persisted until 1970s. Residential expansion occurred away from the foreshore to the west and to the north.

Figure a. The pattern of development was formed by 1920 and persisted to 1970s. Predominantly single houses on large allotments, Hotel and tourist accommodation set behind esplanade roads (Photograph: City of Victor Harbor, aerial photograph, 1949.).

2. Settlement history

Figure a. The Esplanade. Pattern of development was formed by 1920 and persisted to 1970s. Predominantly single houses on large allotments, Hotel Victor and Warland Reserve, set behind The Esplanade (Photograph: Coast Protection Board, 1975).

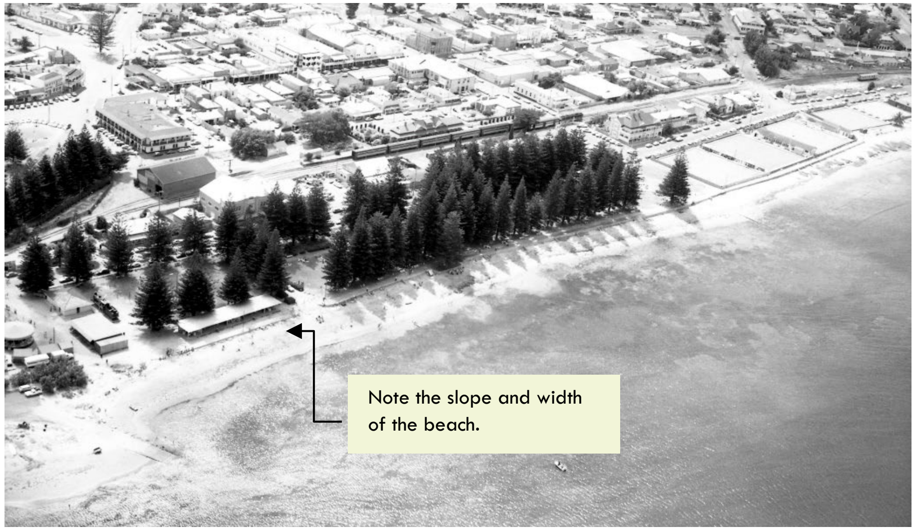

Figure b. Flinders Parade. Pattern of development was formed by 1920 and persisted to 1970s. Reserve formed in 1917 in which various clubs and playing fields are situated. Seawall installed 1920. (Photograph: Coast Protection Board, 1975).

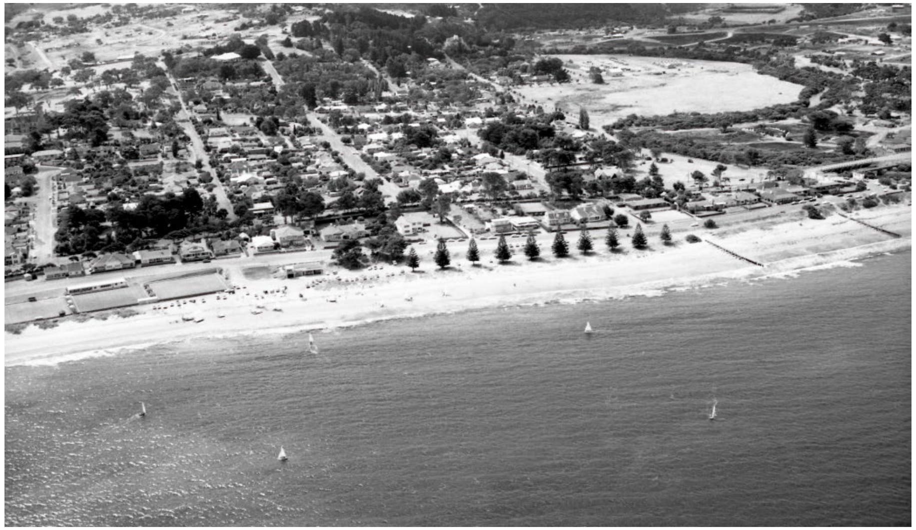

Figure c. Bridge Street. Pattern of development was formed by 1920 and persisted to 1970s. Predominantly single houses on large allotments, situated behind Bridge Road (CPB, 1975).

Figure d. Bridge Street. Pattern of development was formed by 1920 and persisted to 1970s. Predominantly single houses on large allotments, situated behind Bridge Road. Groynes installed as an 'experiment' in the 1950s by Harbors Board. (Photograph: Coast Protection Board, 1975).

2. Settlement history

Victor Harbor – modern era (1970 to 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 Coast Protection Board which was established in 1972 and less on newspaper reporting, especially after 2000. References to scans from Coast and Marine Branch are indicated by the relevant date in brackets. Matters relating to Hindmarsh and Inman rivers which specifically intersect with the coast are also recorded in this section.

Interventions in the foreshore area.

Interventions in the foreshore area that were unrelated to coastal protection or management strategies were few in this time period.

- The boat ramp and rock groyne just north of the causeway was installed in 1972.
- Car parks along The Esplanade that were orientated close to the beach were progressively removed between 1976 and 1990 and returned to vegetated dune.
- A pedestrian bridge over the Inman River was referred to the Coast Protection Board and installed in 2005 (20041202).
- Walking and cycling paths were installed to connect the foreshore along The Esplanade to the foreshore of Encounter Bay via the new bridge (2005).
- Walking and cycling paths were installed through the Memorial Gardens circa 2010 and a new path installed between the dunes and the Mini-golf centre in 2016.
- A concrete ramp was installed on the western side of the causeway circa 2012, presumably to provide efficient means for vehicles to access the beach (perhaps in relation to sand nourishment strategies).

Impacts of storms and erosion.

1970 to 2000

The Victor Harbor Times continued its practice of detailed reporting on storms from 1970 to 2000[21]. Twenty-two storms were reported that included a combination of either all or some of these factors: high winds, torrential rain, thunderstorms, and hail. The storm that seems to be stamped in community memory is the storm of October 1978 when ~75% of houses within Victor Harbor suffered some damage[22]. Storm water flooding was reported on a number of occasions, the worst event on 28 March 1984 where the dam on Richardson Road did not cope with the torrential rain.

Events that recorded damage to infrastructure or dunes by erosion include the following:

<u>Soldiers Memorial Gardens, circa 1974-1975.</u>

Damage to the sea wall was first identified by Coast Protection Board in January 1975. This damage is likely to have been caused over longer period of time and may relate to significant increase in tide levels in 1971.

Figures a-b: Damage to seawall – note the intention to retain the tree and to provide a 'planter box' edge (19750101, CPB).

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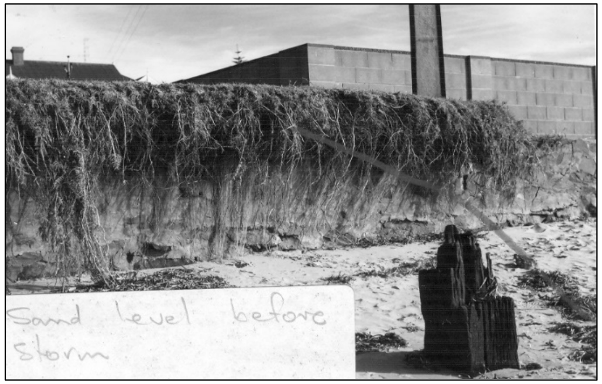
[21] After 2000 the paper went to digital and there is no archival online search function available (email February, 2021).

[22] Victor Harbor Times, October 1978

2. Settlement history

Storms in May 1975 caused damage along the foreshore, including a partial collapse of the tennis courts' fence and damage to the seawall[23]. The wall was repaired, or sections rebuilt in September 1975. One section of wall was 'boxed out' to so that the Norfolk Pine could be retained.



Figures a-b: Damage to seawall – note the drawing on the photograph to indicate the profile of the embankment prior to the storm (19750521, CPB).

[23] Victor Harbor Times, 22 May 1975.

Project note: It is likely that the integrity of the wall was undermined over a longer period of time. A spike in very high tidal events occurred in period 1971 to 1972 which may have contributed to the undermining and then ultimate collapse of the wall.

Figures c-d: The seawall was repaired or rebuilt with a section boxed out to maintain the Norfolk pine (19750901, CPB).

[24] Victor Harbor Times, 17 October 1979.

<u>Erosion of frontal dune system at Inman River, 1979.</u>

In August 1979, a combination of high tides, heavy rains and south-westerly winds caused the river mouth to move further east where it caused rapid erosion of the dunes (Figure e). Continued erosion was deemed likely to impact the road at the corner of Inman Street and The Esplanade. Emergency works were carried out with permission of Coast Protection Board to open the mouth of the river to the west (19791029).

A letter to the editor and signed by eight signatories reveal that residents held the view that the diversion of the mouth should have occurred sooner to save the erosion of the sand dunes[24]. This letter demonstrates that at this time there was some community support for the action to relocate the river mouth further west.

Figure e: Severe erosion of embankment which left unchecked may have threatened road infrastructure on corner of Inman Road and the Esplanade (Photograph: Coast Protection Board, 1 Sept 1979).

2. Settlement history

Storm event of 25 May 1985

The Victor Harbor Times described the storm as 'perhaps the worst storm in the history of Victor Harbor…accompanied by a record high tide and beautiful rains. Right through Saturday the winds blew with hurricaine force from the southwest and the result was that a very heavy sea was running. This fact combined with a record high tide, caused the tennis courts to be washed over several times during the day while the new croquet ground was partly under water'.

Storm event of 17 April 1986

Approximately 240m of the wall collapsed or was severely undermined. Applications were made for funding to the Treasury by Coast Protection Board as emergency works (19860424). Options considered were to either rebuild the seawall or install a sloping rock wall.

Figure a: Storm event of 17 April 1986 caused collapse or serious undermining of 240m of the seawall (Photograph: Coast Protection Board, 1 May 1986).

Rock revetment was installed in March 1987. It is likely that the promenade was raised to accommodate the appropriate height for the top of the sea wall.

Figure b: Storm event of 17 April 1986 caused collapse or serious undermining of 240m of the seawall (Photograph: Coast Protection Board, 1 May 1986).

Figure c: Rock revetment installed (Photograph: CPB, 1 March 1987)

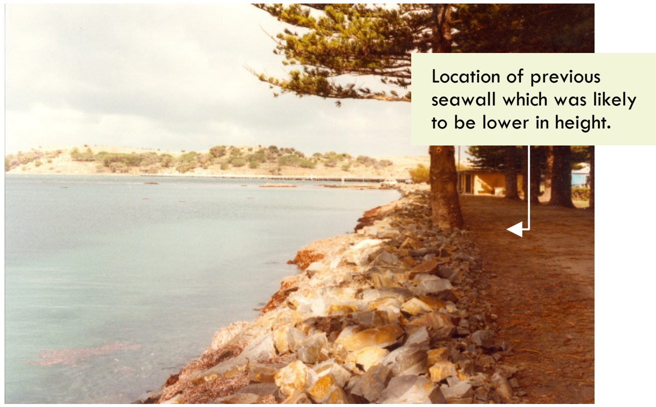


Figure d: Completed wall with line depicting the approximate location of the top of the previous seawall (Photograph: Coast Protection Board, 14 May 1987).

2. Settlement history

Storm events of 10-11 September 1989

These storm events laid the wall of the Victor Harbor bowling green flat and waves eroded the sea wall south of rock revetment constructed in 1987. Rock from the quarry was installed as emergency works (Tide gauge reading of 1.83m CD and 1.80m CD). It was also in this time period when the earthen levee was installed at the caravan park to protect from flooding (presumably riverine)[25].

Figure a: Rock protection installed as emergency works after storms of 10-11 September 1989 (19890912, CPB).

Figures b: Wave over-topping at Soldiers Memorial Gardens (Photograph: Coast Protection Board, 12 September 1989).

Project notes:

The original land upon which Soldiers Memorial Gardens were formed was likely a gentle slope up to Flinders Parade. There may have been a small bund or remant of a dune just above high water mark. In 1920, a seawall was constructed and a raised promenade formed using imported fill. The viability of the gardens depended on these works to prevent incrusions of the sea. The wall was over-topped frequently, especially in time period 1920s to 1940s. The wall failed in places in 1975 and was repaired. The wall failed completely in 1986 and the promenade was raised again and a sloping rock wall constructed with the toe of the wall ~5m seaward of the original seawall. In summary, the profile of this beach was altered from a gently sloping beach with a flexible backshore which would enable natural erosion and accretion over time.

Storm toll — $10,000

Recent storm damage would cost the Victor Harbor Council at least $10,000 in repairs according to consulting engineer, Mr B.E. McKay.

In a report to the last meeting of council, Mr McKay said inclement weather on September 10, 12, 17 and 18 resulted in council suspending all construction projects.

"Resources were diverted on to urgent maintenance and essential repairs and work of lasting benefit has been performed in many areas," he said.

The engineer said storm damage repair and necessary maintenance had been undertaken:

- Extension of the rip rap wall at the sea front to beyond the bowling club building.
- Repairs to the old stone wall along the Bluff jetty road.
- Construction of the earth bund wall at the caravan park.
- Reconstruction of the dump access road.
- Construction of an all weather access to the Encounter Lakes spoil heap (this material is most suitable for rural road maintenance).

Figure b: News article from Victor Harbor Times, 29 September 1989.

25 Victor Harbor Times, 15 September 1989.

2. Settlement history

Storms and erosion: 2000 to 2020

The era from 2004 to 2012 was dominated by concerns of erosion to The Esplanade beach between Inman River and the causeway. Residents and Council report that increases in erosion occurred from about 2000[26], especially in the vicinity of King Street.

Figure a: Foreshore in vicinity of King Street in 2000. (CPB, 20000101).

Correlation with tidal data

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

Figure b: Foreshore in vicinity of King Street in 2004 (CPB, 20041008).

Figure c: Foreshore in vicinity of King Street in 2007 (CPB, 20070724).

Figure d: Foreshore in vicinity of King Street in 2012, reverse angle from 2004, 2007 (CPB, 20120604).

Figure d: Foreshore in vicinity of King Street in 2012, after sand nourishment (see next pages) (CPB, 20140430).

[26] Council, Magryn 1997, AWE, 2000.

2. Settlement history

Coastal management strategies (1970 to 2020)

Listing the coastal management strategies in order of location from north to south:

Hindmarsh River outlet

A rock groyne was installed in 1992 to control the position of the outlet, and sandbag extension installed (at least prior to 2004). The mouth of the river is opened either by rain events or by Council on an 'as needs' basis to ensure that levels inside the sand bar do not become too high (199210010).

Flinders Parade – Bowling club to boat ramp (450m).

- Bowling Club - rock revetment installed in front of the 1920 seawall in 1989, replaced with concrete blocks 2018 (see analysis inset panel this page).
- Soldiers Memorial Gardens – the 1920 seawall repaired in 1977, rock revetment installed in 1986.
- Five sandbag groynes installed 2009.
- Sand nourishment (3000m^3) was undertaken between boat ramp and gardens in 1976 due to undermining of the sea wall (Figure b) (19760301). Note most of the sand was gone four months later (Figure c).

The causeway

Eastern side of the causeway – cement blocks installed adjacent the causeway. Storm uncovered these in summer of 2020, sand was pushed up the beach and the blocks recovered with sand.

Figure a: Hindmarsh River – training groyne (CPB, 20040810).

Figure b: Sand nourishment (CPB, 19760301).

Figure c: Comparison – 4 months later (CPB, 19760701).

Concrete block trials

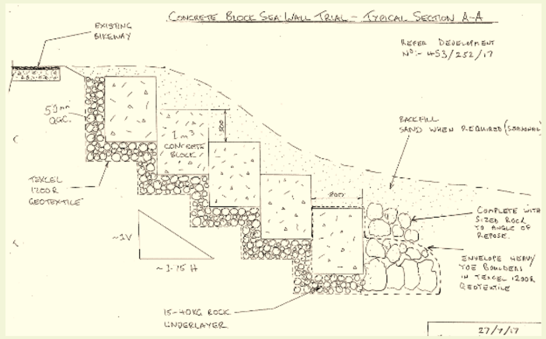
Council has trialled the installation of concrete blocks in tiers of 4 or 5 levels, accompanied with a rock toe for stability, at three locations in Victor Harbor Central and one location in Encounter Bay:

- The Esplanade, near King Street (2014)
- Fell Street, Encounter Bay (2015)
- Bowling Club and the causeway (2018).

The concept has been approved by Coast Protection Board as a trial noting that the design is 'non-standard', and that the concept requires testing under various storm and erosion conditions.

Coastal Environmental Solutions reviewed the plans for the bowling club in 2018 and concluded:

- The wall appeared stable for the intended purpose.
- Sand may be washed from the upper blocks (which has occurred in this location)
- The previous concrete block installations have remained stable with no erosion of the toe.



Concept – not working drawings. The rock sizes at the toe were increased to 0.5m (Email_CMB_20210217).

2. Settlement history

The Esplanade – Causeway to Inman River

- Sand 'sausage' installed along the beach in the vicinity of Wills Street in 2004.
- Beach nourishment (2009) – imported sand, 2500m^3 to head of the causeway and 1900m^3 to stabilise the sand dunes to east of the Inman River (including 2 rows of drift fencing and planting) (20091004).
- Eight sandbag groynes installed to the beach in 2009 for the purpose of trapping north drifting sand, including initial supply of sand ~1000m^3 per groyne (20091004) (Figure a).
- Sand sausage installed in the vicinity of King Street in 2012 (Figure a).
- Sand nourishment – transport 2000m^3 from Kent Reserve to beach in vicinity of King Street (20120621)
- Installation of concrete blocks, then covered by sand, 2015 (email_20210217) (Figure b).

Inman River

- Mouth realigned east from near the corner of The Esplanade and Inman Road in 1979 (19791029).
- Mouth realigned to its current position in 1997 and a rock training wall installed (20091118).
- The mouth of the river is opened either by rain events or by Council on an 'as needs' basis to ensure that levels inside the sand bar do not become too high.

Figure a: Sand sausage installed along the beach near King Street; sandbag groynes installed perpendicular to the beach (CPB, 20120604).

Figure b: Concrete blocks installed in backshore near King Street, covered with sand and vegetated (Email_CMB_20210217).

Figure c: Mouth of Inman River realigned, and rock training wall added in 1997. (CPB, 20070724).

General coastal management strategies

General coastal management strategies on an ongoing basis include:

- Controlling pedestrian access to the beach with fencing, walkways, and stairs.
- Ongoing dune and foreshore vegetation programs and drift fencing (if required).
- Regular inspection of access ways and storm water outlets.
- Volunteer program to measure sand heights along The Esplanade and Flinders Pde beaches.

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

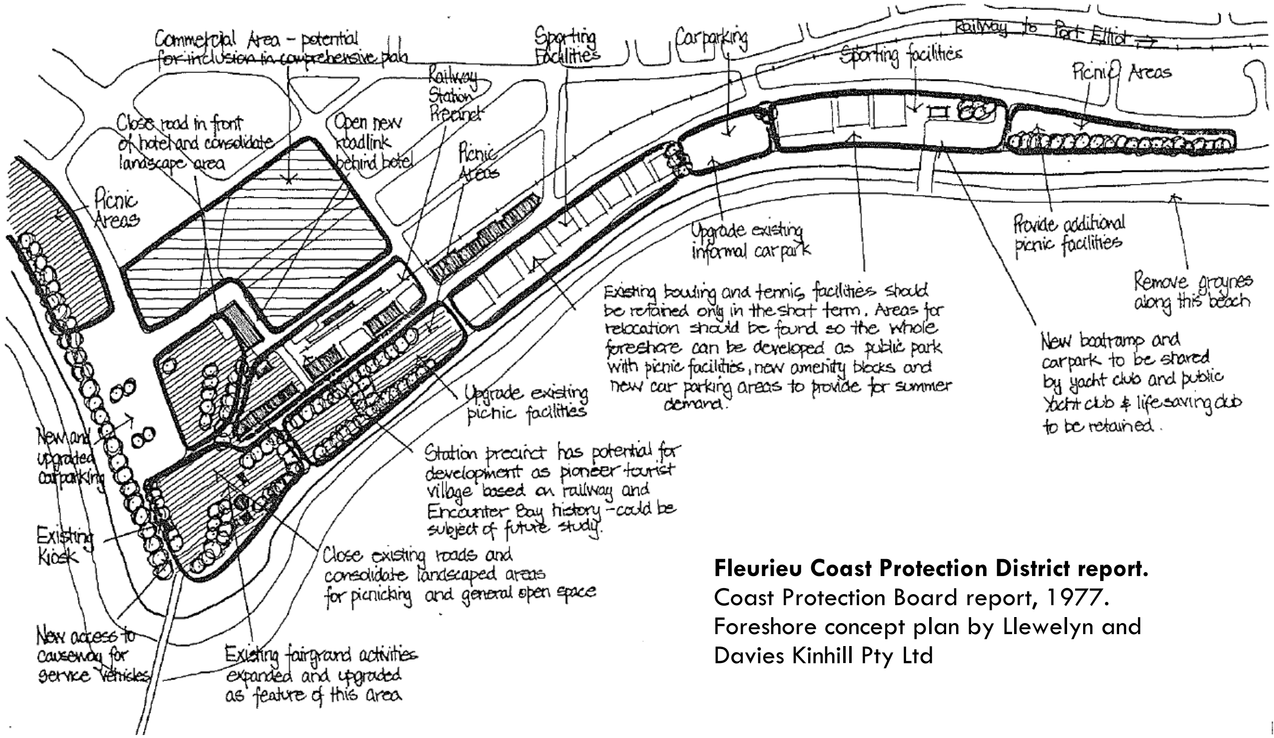
Fleurieu Coast Protection District produced by SA Coast Protection Board, 1977.

The purposes of the report were to:

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

Particularly in relation to the beach along Flinders Parade the Victor Harbor Times quoted, 'tennis courts and bowling greens built on the beach's primary dunes have robbed the beach of what would normally have been a reserve of sand, moving down to the water and then back as tides, winds and other natural forces shifted sand to other parts of the bay'. The report recommended that the boat ramp near the causeway be removed as this was also likely restricting sand into this beach area. Community consultation was undertaken at the time by way of public meeting (s)[27].

[27] Victor Harbor Times, 17 January 1979. Note, it is not clear from which report this quotation was obtained.



Fleurieu Coast Protection District report. Coast Protection Board report, 1977. Foreshore concept plan by Llewelyn and Davies Kinhill Pty Ltd

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

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

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

2. Settlement history

Foreshore Protection Study, Magryn, 2006.

The study area for this project was between the Inman and Hindmarsh Rivers (Cell 11). The catalyst for this study appears to be the increasing concern about erosion since 2000 (residents say 1997) and 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 adjacent beaches. This may or may not be true or may be only partially true. Long term accretion occurred at Kent Reserve starting in the 1970s which has reversed in the last decade. 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". Allow 5000m^3.
- Replenishment of sand to the sand lobe under the causeway, which acts as a sand bank for the beaches either side. Allow 5000m^3.
- 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. The proposal was to install a retaining type wall at 1.0m high.

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.

The specifications for the works are located within scanned report 20090200 and plans from 20090000 are included on the following page.

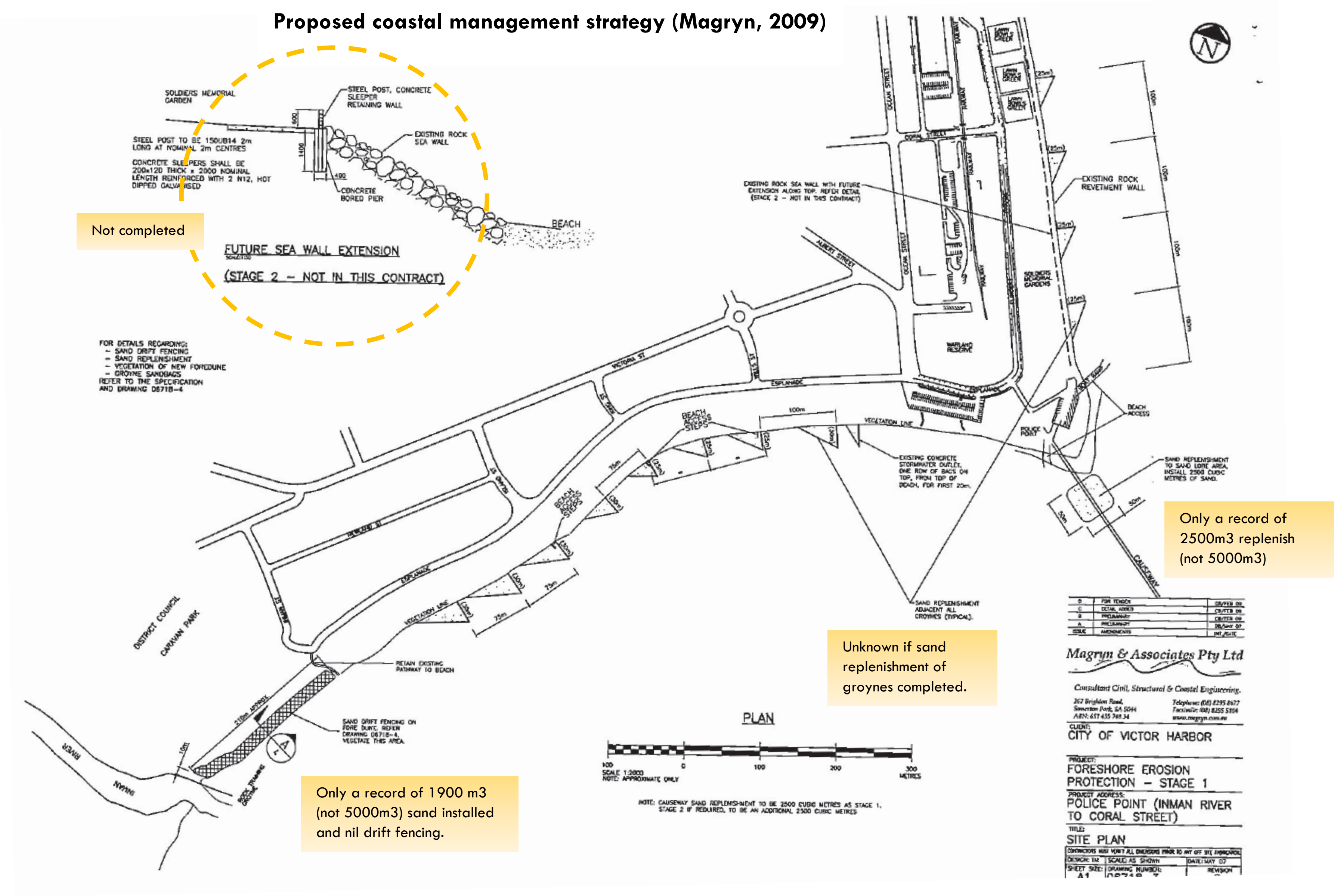
Installation of works

The works were installed progressively over years due to budget constraints (20091004):

- Install 11 of the 13 groynes and partial sand nourishment of 2500m^3 to the causeway and 1900m^3 to dunes adjacent Inman River (2008-2009).
- It was proposed apply the sand nourishment adjacent to the sandbag groynes in 2009-2010 but no archives exist to demonstrate this work was completed.
- In 2010-2011, It was proposed to install the drift fencing and a 400m seawall at the back of the existing rock revetment to Soldiers Memorial Gardens to prevent overtopping. This work was not completed.

2. Settlement history

Proposed coastal management strategy (Magryn, 2009)



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 (Victor Harbor Central to the causeway, not Flinders Pde).

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, i.e. the town beach).

Project note: the main impetus for the study came from coastal issues between Inman River and the Causeway.

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 Victor Harbor Central (Cell 11) 1 in 100-year scenario mapping depicted:

- 2050 scenario – inundation of the caravan park, minor encroachment through the dunes at The Esplanade at King Street.
- 2100 scenario – inundation on a much larger scale indicated in Figure a.

Note: This study universally applied a 0.3m wave runup, including to inland areas which are unlikely to be impacted by this aspect of sea-flooding.

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

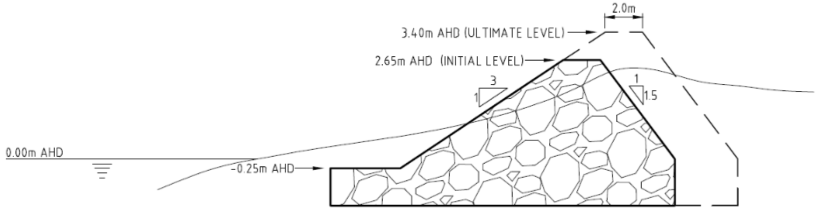
The study also noted that the sheltering effect of the offshore reef would diminish with rising sea levels and erosion would be severe causing significant recession of the shoreline with resulting damage to infrastructure. However, no estimate was made in regard to the rate of erosion.

Adaptation options

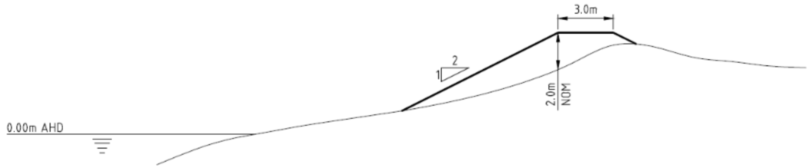
The study reviewed numerous options (p. 47) but recommended soft management approaches for the shorter term but suggested hard protection items would be required in future. Engineering options were described as the following:

1. Sloping rock revetment seawall located adjacent foredune as landward as possible to 2.65m AHD with ability to increase with height to 3.4m AHD if seas rise further (ultimate treatment)
2. Vertical concrete sea wall located behind the foredune within the reserve to 3.4m AHD with rock protection on coastal side.
3. Sloping rock revetment sea wall located adjacent foredune as landward as possible to 2.65m AHD with a parapet wall on top to 3.4m AHD to reduce wave overtopping.
4. Sand replenishment to build up dune at high-risk areas.
5. Rock armoured earthen levee located adjacent to foredune as landward as possible at 2.65m AHD with possibility of raising to 3.4m AHD if seas rise further.

The preferred engineering approach appears to be Option 1 or Option 4 (but noted as Option 3 on the cross-sectional plans in the report).



Option 1: Rock seawall (ultimate treatment) – Section A-A



Option 3: Sand Nourishment (short-medium term treatment) – Section A-A

Figure a. Location for coastal adaptation treatments.

2. Settlement history

Asset management options:

Beach access

1. Reduce the number of beach access points.
   Update: Four access points closed.
2. Close off the informal beach access point for maintenance work.
   Update: Break in dunes halfway between Inman Street and Island Street (not closed).

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: it is not known 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, 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.

Sand replenishment at King Street

The sand replenishment program has been effective at minimising erosion of the foredunes.

Update: The last sand replenishment occurred in 2014. Since that time the rate of erosion has diminished.

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 beach is scraped at end of summer, combined with seaweed and deposited to the back of the beach.

Dredging of the Inman River

The effectiveness of the excavation of the sandbar to allow water to flow out to sea needs review.

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 (i.e. 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.17).
- 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 trialling 'impact reducing measures' (such as concrete blocks, see p. 17) 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.

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.

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

The abovementioned study was located within the archives of Coast Protection Board (Department of Environment and Water). As the majority of the identified issues have been dealt with over time or have become irrelevant this report was not reviewed for Cell 11. The plan has also been superseded by the City of Victor Harbor Recreation and Open Space Strategy, 2017 which is reviewed below.

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.

<u>Purpose</u>

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.

<u>Methodology</u>

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.

<u>In the context of coastal adaptation</u>

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 11, Victor Harbor Central, are detailed within the table on the next page.

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

F11. Hindmarsh R. to Inman R. Granite Island	F.11.1 Continue implementation of Granite Island Recreation Park Vegetation Management Plan 2004-2008.	Medium (KP cell; Cons)
	F11.2 Support research to clarify causes of population decline. As an interim measure, fence the causeway against foxes, dogs and cats. Implement a rat control program.	High (Soc / Econ)
F11. Beaches and Dunes	F11.3 Support Council and Coastcare campaigns to eradicate red alert weeds. Review access control.	Medium (Threat)
	F11.4 Continue beach pole observations. Analyse and report back on existing record as a matter of urgency. Complete engineering study.	High (Hazard)
	F11.5 Maintain and analyse profile records. Initiate photopoint monitoring of beaches. Ensure the strongest possible protection within the development plan for coastal reserves (recreation now, buffer zones in the future). Where possible, seek to extend coastal reserves.	Low (Hazard)
	F11.6 Detailed high resolution mapping of topography.	Low (Hazard)
	F11.7 Community monitoring of Hooded Plover nesting sites on beach and dunes.	High (Cons / Threat)

Action Summary Table – Cell 11, Victor Harbor Central (p. 6-7)

F11. Hindmarsh River Estuary banks and floodplain	F11.8 Significance of small areas of native vegetation within the river floodplain needs recognition through proactive management: assess opportunities to establish buffers; signage.	High (Cons / Threat)
	F11. 9 Develop an estuary entrance management support system (1), to investigate other options and reasons for making opening / closing decisions.	Medium (Cons / Soc / Econ)
F11. Coastal reserves	F11.10 Maintain reserves as buffer areas (see beaches and dunes above).	Low (Hazard)

Climate change assessment

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

Adaptation to changed climatic conditions

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

2. Settlement history

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, 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

Priorities related to the foreshore within Cell 11:

- Further enhance Warland Reserve as a major events and recreation space (Item 1).
- Redesign GT Fisher Playground (south of Soldiers Memorial Gardens) with new equipment and improved spatial design and landscape as a major regional destination (Item 2).
- Redesign and upgrade the outdoor court and beach volleyball areas (the courts are in a prime location and either require upgrade or removal) (Item 3).
- Replace existing amenities and change facilities at Bridge Point with a new small amenity building.
- Upgrade and widen the foreshore pathway between Causeway Plaza and the Yacht Club facilities (Item 12).

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.

Project note: the assumption in this study is that protection (especially rock walling) will be the option that will be pursued for this cell.

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

2. Settlement history

Key findings: Victor Harbor Central (Cell 11)

1. The urban layout of Victor Harbor has been to install esplanade roads (and associated public facilities) between private assets and the beach. 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. Early infrastructure such as the railway line and jetty/ causeway would have had minimal impact upon the coastal zone. The construction of the 305m breakwater completed in 1891 would have had a major impact on the way the waves refracted around Granite Island. Dr Bob Bourman suggests that this may have caused the angle of waves approaching the Soldiers Memorial Gardens to change therefore increasing erosion in this area.

3. In early times, the sand spit at Police Point (near the causeway) was essentially characterised by sand dunes which fanned out along the shore to the river mouths (including into the Warland Reserve and areas now covered by gardens and sporting facilities along Flinders Parade). By 1937, these were all removed or flattened, even in the location of the existing dunes along The Esplanade Beach.

4. At the time of the establishment of the Soldiers Memorial Gardens, a seawall and raised promenade was considered necessary for the viability of the gardens. Storm accounts repeatedly record sea water flowing over this wall, especially in the vicinity of the bowling club and tennis courts. In 1989, it was necessary to increase the height of the promenade and replace the seawall with rock revetment, and more recently with concrete blocks in front of the bowling club.

5. Storm accounts record only one incident where overtopping occurred from the south (1928). There are anecdotal accounts that tell of water flowing over the Esplanade Beach and flowing down the street to the Crown Hotel. These accounts are likely to be in the era where there were no dunes on the Esplanade Beach.

6. The mouth of the Inman River was first diverted to the west in 1979 and then permanently to its current position in 1997. The mouth of the Hindmarsh River was normally further east but broke through the dunes in 1933. It was permanently trained into its current position in 1984.

7. Analysis of the tide gauge data from 1965 to 1999 revealed a correlation of a period of increased storminess with high levels of erosion along The Esplanade Beach from 2004 to 2011 (by this time the shoreline along Flinders Parade was protected by rock to the bowling club).

8. 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).

9. A summary of protection works and nourishment strategies include:

- Soldiers Memorial Gardens – the 1920 seawall repaired in 1977, rock revetment installed in 1986.
- Bowling Club - rock revetment installed in front of the 1920 seawall in 1989, replaced with concrete blocks 2018.
- Sand 'sausage' installed along The Esplanade beach in the vicinity of Wills Street in 2004.
- Thirteen sandbag groynes installed 2009 to The Esplanade Beach and Flinders Parade beach.
- Sand 'sausage' installed in the vicinity of King Street in 2012.
- Installation of concrete blocks in vicinity of King Street, then covered by sand, 2015.
- Eastern side of the causeway – concrete blocks installed adjacent the causeway. Storm uncovered these in summer of 2020, sand was pushed up the beach and the blocks recovered with sand.
- Sand nourishment:
    - Along seawall on Flinders Parade (3000m^3) in 1976 due to undermining of the sea wall.
    - To causeway area, 2500m^3 (2009).
    - To sand dune area east of Inman River mouth (1900m^3) in 2009, including 2 rows of drift fencing and planting.
    - From Kent Reserve to beach at King Street (2000m^3) in 2012.
- Ongoing vegetation and weed control programs.

2. Settlement history

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 and the installation of groynes and sand nourishment. It is likely that increased erosion is primarily related to increased periods of storminess, which naturally does take sand from the beach. When stormy continues for an extended period of time, there is no time for the beaches to recover.

3. GEOMORPHOLOGY

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

- Dr Robert Bourman, contributor to this project, 2021

3. Geomorphological context

COASTAL FORMATION

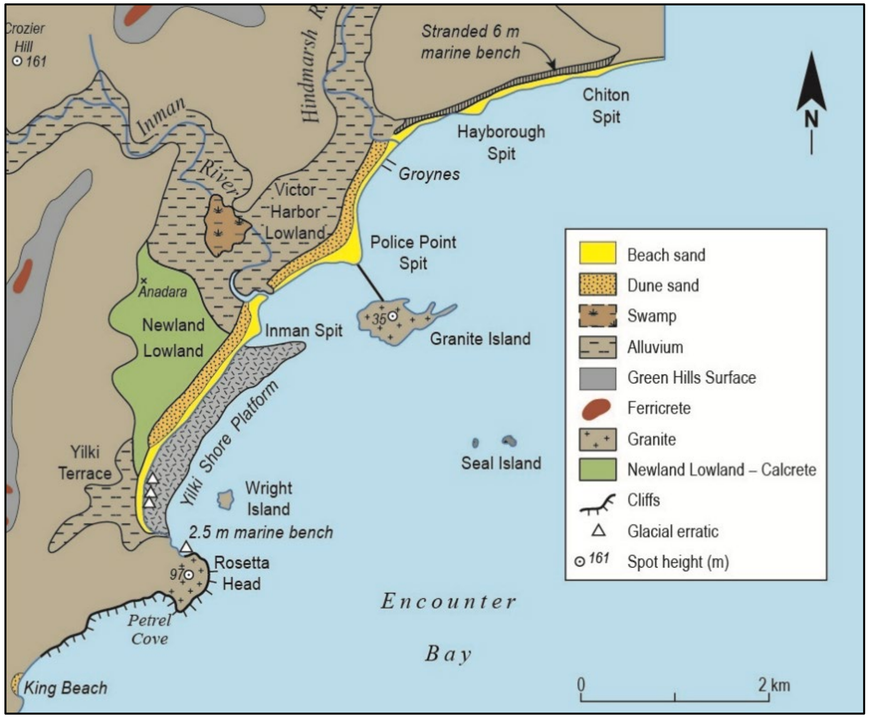
Introduction

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

Geological setting

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

The outcrops of Encounter Bay Granites have exerted important influences on the shape of the modern shoreline, protecting headlands from erosion and determining the direction of wave approach to the shoreline (Figure b). The islands and headlands slow down wave approach, but wave speed is maintained in deeper water causing the waves to bend or refract as they approach the shoreline, which they shape.



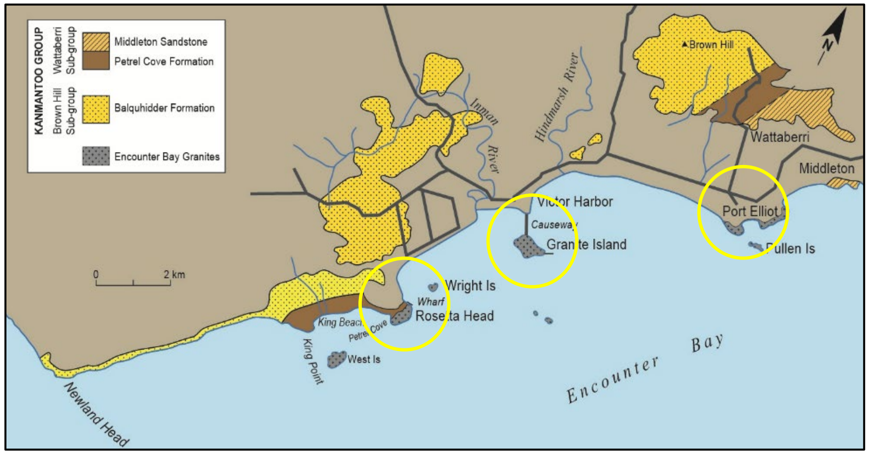


Figure a. Major geomorphic features of the Victor Harbor coastline. Bourman et al. (2016)

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

3. Geomorphological context

COASTAL PROCESSES

Wave action on the Victor Harbor coastline

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

The Victor Harbor shoreline is impacted by both swell and storm waves which dominantly approach the coast from the south and southwest. The swell waves are generated by storms in the Southern Ocean. They have long wavelengths, approach the coast with a wave period of 14-16 seconds, a relatively short wave-height, and generally push sand landwards as they approach the coast. Storm waves, on the other hand are generated by local storms, have shorter wavelengths, steeper wave fronts and have a wave period of 6-8 seconds. These waves plunge when they reach the shore, scouring the beach and moving sand seawards to form sandbars.

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

Wave refraction and diffraction

Figure (a) shows how waves are refracted around granite islands and headlands on the direction of swell and storm waves approaching the coast. There can be variations in the patterns of refracted waves depending on changes in wind strength and direction. Both swell and storm waves approach from the south and southwest, but hard rock outcrops slow down the wave approach in some locations, bending the wave fronts as they do so.

Waves are refracted when they strike the shoreline at an angle causing the wave to slow down in the shallowing water but to continue at a faster rate in the open water. Waves are diffracted when both ends are slowed down while the central part of the wave advances at a faster rate, as between Rosetta Head and Wright Island. Thus, the wave patterns of refraction and diffraction, which affect local directions of longshore drift, are the products of interaction with the resistant granite headlands and islands as well as with shore platforms, shoals, and reefs.

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

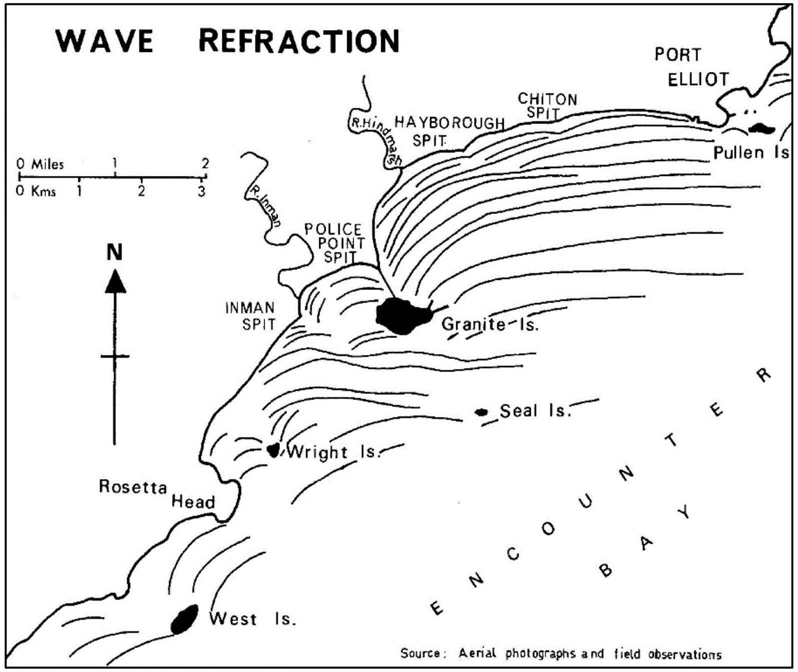


Figure a. Wave refraction and diffraction pattern of the Victor Harbor coastline. Note the Inman, Police Point, Hayborough and Chiton spits and their relationships to the wave patterns. Source: Bourman (1969)

3. Geomorphological context

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

Bathymetry and associated impact on wave energy

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

The direction of longshore sand drift

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

Analysis of the wind regime for Victor Harbor supplied from the Bureau pf Meteorology has been undertaken, supporting the notion of a dominant drift from the west to the east. In using wind data to demonstrate drift direction, only onshore winds are taken into account, and it is only wind speeds greater than 28.8 km/hr, which are effective in generating longshore drift. The resultant of winds capable of generating longshore transport trends at 227o (or from the south-west).

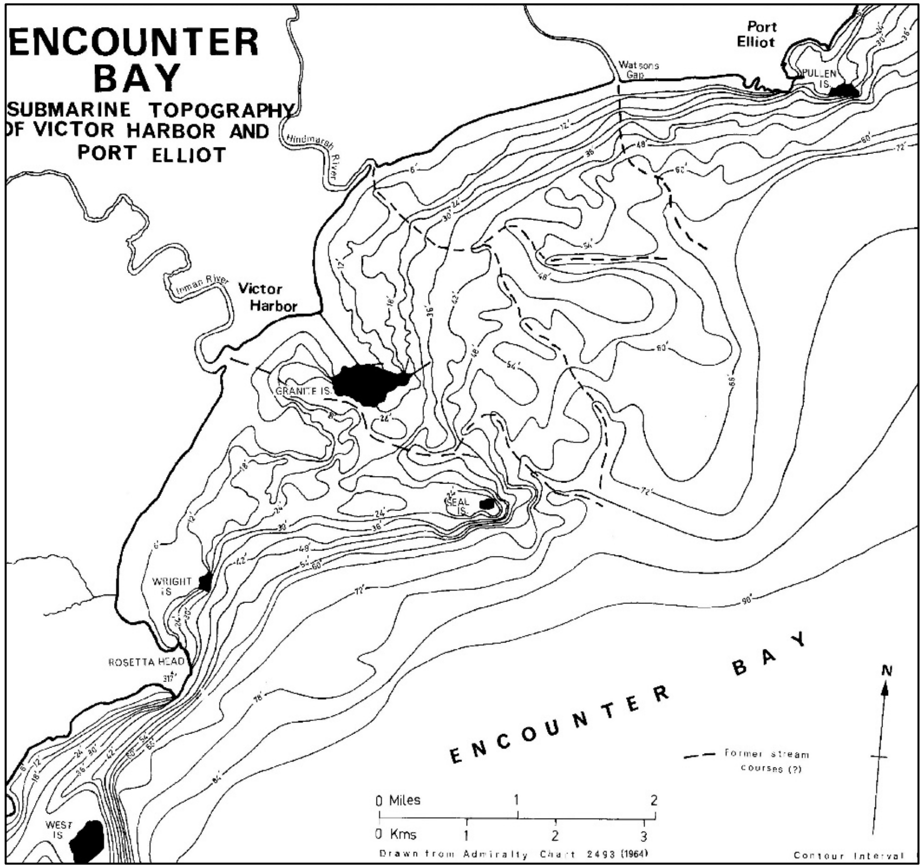


Figure a. Submarine topography of the Victor Harbor section of Encounter Bay produced from Admiralty Chart 2493, originally produced in 1869 and updated in 1958, 1959 and 1964. Source: Bourman (1969)

3. Geomorphological context

Sand supply for the coastline

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

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

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

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

4. There is no significant input of sand from longshore drift, which is dominantly from the west to the east. Little sand from King Beach and Petrel Cove bypasses Rosetta Head (The Bluff). Sand derived by erosion of the Permian deposits near Hayborough and Chiton contribute to the immediate shoreline, which is relatively stable, but it is possible that sand is lost to the Victor Harbor shoreline by drift to the east from Chiton.

5. The main supply of Permian sand to the coast was from the Inman River, which in its upper reaches flows through extensive areas of Permian sediments. Early farming practices caused increased erosion in the upper reaches of the river and the eroded sediments were carried downstream, burying parts of the topography, infilling the channels, overtopping the banks, burying the floodplains and infilling much of the Inman estuary. Sand supplies formerly delivered to the coast by the Inman River are now bound up in a huge sand slug in the former estuary of the Inman. (Department of Environment and Water add reasons for decline of river flow as: reduction in rainfall, increased flows into the Wastewater Treatment Plant, construction of dams and use of groundwater (20080800).

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

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

During the Last Interglacial of 132,000 – 118,000 years ago, when there was very little ice on the earth and sea levels were high, red coloured alluvium of the Pooraka Formation in-filled the lower reaches of the Inman and Hindmarsh river valleys, while cliffs were eroded at the backs of the current Newland and Victor Harbor Lowlands, and marine sediments were deposited across them. The shoreline from that time now reaches up to an elevation of ~6 metres above sea level, having been uplifted by 4 m over the past 125,000 years at an average rate of uplift of 0.05 mm/yr. While this rate of uplift may appear to be insignificant, it is important to bear in mind that the uplift does not occur continually, but in separate tectonic events, some of which may have been dramatic. For example, an earthquake in 1897 centred on Beachport was reported as a severe tremor in Goolwa, where it cracked some of the buildings. At Kingston, tremors continued for several months. The same earthquake caused subsidence of the Middleton coast which led to rapid coastal erosion of >200 m.

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

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

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

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

3. Geomorphological context

VICTOR HARBOR CENTRAL – BETWEEN THE RIVERS

Victor Harbor Lowland

The Victor Harbor Lowland encompasses the area between the lower Hindmarsh and Inman Rivers, and the base of a pronounced backing escarpment, which is roughly coincident with the 10 m contour above present sea level. The break in slope between lowland and escarpment, marking the position of a former shoreline, is very noticeable when travelling to the west along Seaview Road and Crozier Road.

The backing bluff may have been partly moulded by the meandering Inman and Hindmarsh Rivers, but its form is dominantly due to coastal erosion when seas were higher the last time the earth was free of ice. Marine shells of last interglacial age have been found to underlie the lowland in various localities. A detailed topographic map of the Victor Harbor Lowland reveals complex sand dune topography on the foreland of Police Point Spit. Wings of these dunes extend along the coast to both the Inman and Hindmarsh Rivers.

The lowland is developed primarily on sand dunes, alluvium and Pleistocene marine sands and shells. These sediments rest on Permian glacial sands and clays, which also form the backing escarpment, a former but now degraded cliff line, which also backs the Newland Lowland. There are no hard, resistant rocks near to the surface on the Victor Harbor Lowland; they are all buried at depth.

The following section is typical of the lowland with soil types at the following depths:

0 - 90 cm	Grey, sandy soil
90 - 1.5 m	Red clay (possibly washed down from Greenhills)
1.5 -2.75 m	Calcrete (white hard crust formed on calcareous materials when exposed to the atmosphere)
2.75 - 3.6 m	Beach sand with nodules of calcrete and small cockle shells at ~3.0 m
3.6 - 4.3 m	White sand

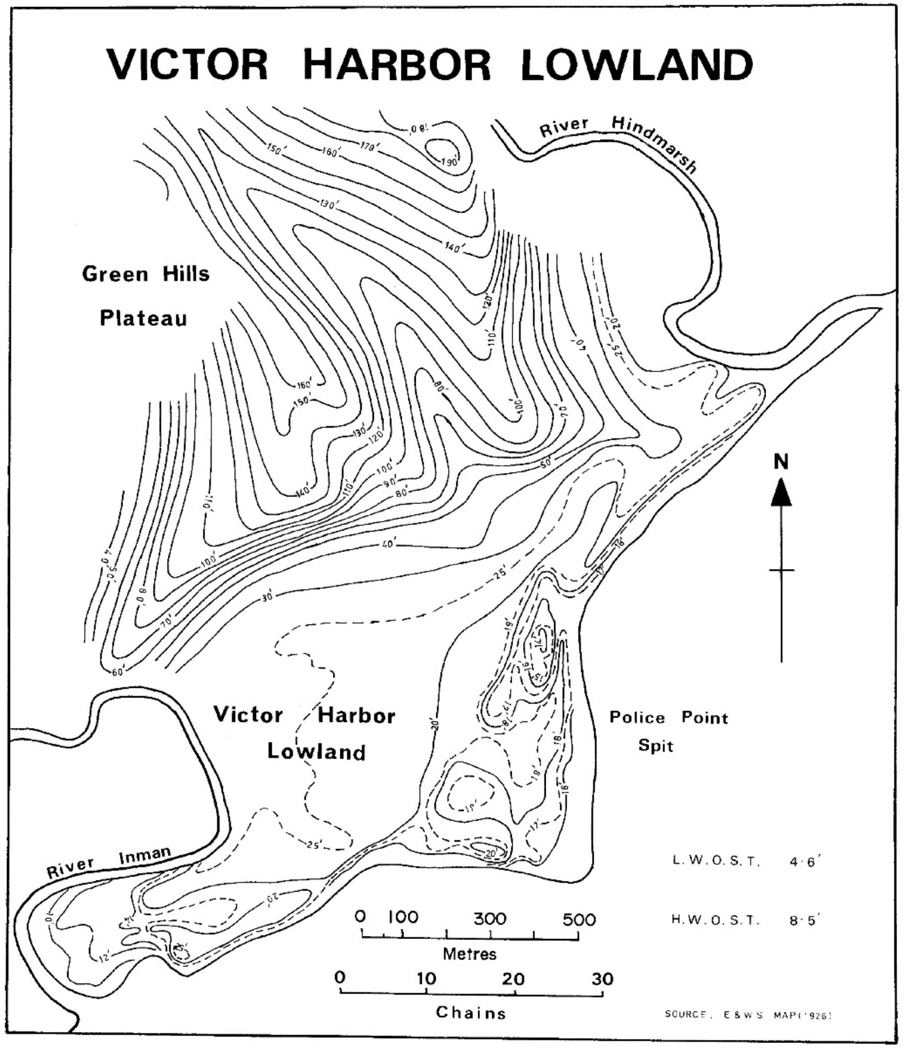


Figure a. Topographic map of the Victor Harbor Lowland and its backing escarpment. Note the complex sand dune topography on Police Point Spit. Sand dunes, which have been exposed by the Hindmarsh River along The Parkway, extend more than 200 m inland. The dunes have now largely been flattened and/or built over. Source: EWS, 1926.

3. Geomorphological context

Victor Harbor Lowland (cont.)

The 1926 topographic map produced in 1926 by the E&WS Department (previous page) highlights the character of the Victor Harbor Lowland, revealing complex sand dune topography on the foreland of Police Point Spit (Figure a). These dunes, which also extended along the coast to both the Inman and Hindmarsh Rivers have now largely been flattened and transformed by urban development. A stranded coastal dune system inland from the present shoreline lies under urban development. An example of this can be seen in the 1967 photograph taken along the Parkway near Hindmarsh Road, now the site of the Wintersun Motel (Figure b). The dune extends greater than 200 metres from the shore.

Police Point Spit

Police Point Spit is a sandy cuspate foreland or triangular spit situated between the Inman and Hindmarsh Rivers that protrudes towards Granite Island. A causeway completed in 1867, links the apex of the spit to Granite Island. The area underlain by Police Point Spit is part of a former bedrock depression excavated by the Permian ice mass, which approached from the southeast some 300 million years ago. Bore log evidence reveals that the bedrock depression is filled with glaciogenic and marine deposits. Bores near the mouth of the Inman River have reached almost 45 m below sea level without encountering local basement rocks. Below a depth of 21 m the sediments were logged as glacial. Bores sunk along the line of the causeway at 100 yard (91.44 m) intervals in 1919, intersected fine sand, coarse sand, gravels, yellow clay and blue clay, as well as some limestone. The blue clay probably consists of glacial sediments.

During the Last Interglacial of 125,000 years ago when the earth was free of ice, the site of Police Point Spit would have been at least 2 m below sea level. There was another sea level about 1m higher than present about 4-5,000 years ago when Police Point Spit would have been much less extensive than at present. The current day spit would have developed progressively as the sea regressed to near its present level. Hence the modern Police Point Spit has only been in existence for the last few thousand years. Early photographs of the area also reveal that sand dunes covered much of the spit inland, but have now been flattened or removed (Figure a).

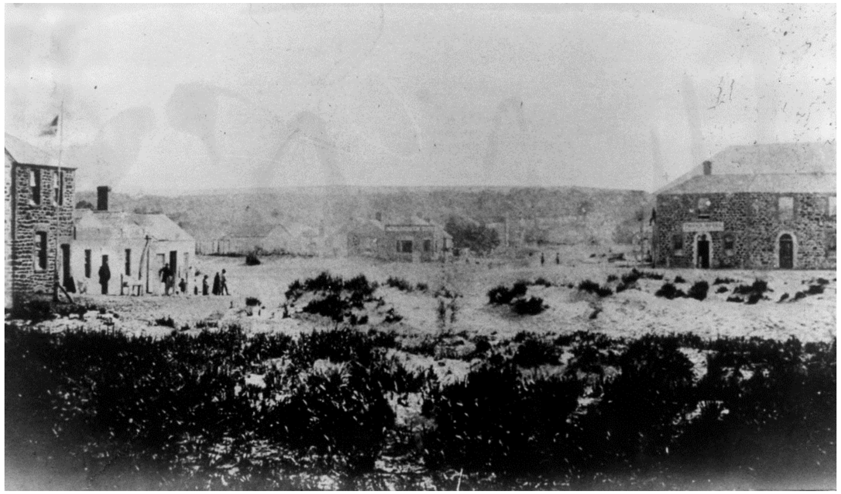


Figure a. Photograph taken in 1868 looking towards the main street of Victor Harbor. Hotel Victor on left, Crown Hotel on the right. Sand dunes in foreground now levelled and/or removed. These sand dunes would have been part of the Police Point Sand Spit.

Figure b. Photograph taken in 1967 of a coastal dune exposed in a road cutting along The Parkway near Hindmarsh Road. The area on top of the dune is now the site of the Wintersun Motel. The dune extends inland > 200 m inland from the shore

3. Geomorphological context

Police Point Spit (cont.)

Aerial photography and observations show that ocean swell waves, and local storm waves which both commonly approach from the southwest wrap around Granite Island causing the convergence of longshore drift and sand accumulation to form Police Point Spit (Figure a).

<u>Potential causes for increased erosion</u>

Police Point Spit has been the focus of much human activity since European settlement, with various activities having impacted on the spit. Possibly the greatest impact has been the construction of the breakwater on Granite Island. The breakwater extends at least 300 m into the sea and was built by 1882. The breakwater has affected the diffraction of waves, causing storm waves to approach the east-facing side of the spit at a steeper angle, leading to erosion of the spit in this location. The orientations of sandy coastlines are fashioned by the approach of waves over long periods of time and any alteration in the approach of wave fronts will alter the orientation of the coastline.

Another factor influencing the eastern side of Police Point Spit relates to variable differences in the direction of longshore drift. In the south eastern section of the spit longshore transport is generally to the south, building out the spit, while in the north the drift is towards the northeast. Consequently, in the intermediate area there is a zone deficient in sand, leading to the natural tendency to erosion in this area.

The south-facing side of the spit is in a more natural condition than the east-facing side where roads, boat ramps, sea walls, shelter sheds, tennis courts and bowling greens have been built over the sandy deposits of the spit and dunes, thus effectively sealing them off from the shore environment. Thus, the coastline has been denied a potential source of sand for its maintenance, especially in times of storms where sand would normally move offshore and then slowly rebuild the beaches and dunes over time.

Figure a. Oblique aerial view of Victor Harbor in 1933. Note the waves approaching from opposite directions thereby building out Police Point Spit. Note also the wave attack focussed on the eastern side of Police Point Spit, probably due to the impact of the breakwater causing a steeper wave approach (South Australian State Library, B-8697)

Figure b. View of the beach along Flinders Parade in 1910. This shoreline may have eroded due to the installation of the breakwater (However, the location of this picture is likely the tennis court area and not Soldiers Memorial Gardens where most of the erosion has taken place). Source: R. Bourman from the Victor Times newspaper.

3. Geomorphological context

Key findings: Victor Harbor Central (Cell 11)

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 predominant direction of sand drift (littoral) is from the south-west to the east under influence of strong winds from the south-west. However, the spit at Police Point (the causeway) is formed by waves refracting around Granite Island which also pushes sand to the south in this location.

4. In its pre-urban form, a significant dune field occupied the lowland area of Victor Harbor, most prominent at Police Point but also fanning out towards each river mouth. These dunes were flattened or mostly removed from backshores.

5. The cell has become more deprived of sand over time due to less sand coming from the off-shore shelfs, less sediment flowing down from the two rivers, and the loss of dunes from backshores which would have fed the beaches in times of storms.

6. The lowland is developed primarily on sand dunes, alluvium and Pleistocene marine sands, glacial sands and clays. There are no hard, resistant rocks near to the surface on the Victor Harbor Lowland, they are all buried at depth.

7. In the last ice age, the Victor Harbor lowland was under ~2m of water which was subsequently uplifted when ice melted. About 4-5000 years ago, sea levels were 1m higher than present and therefore the lowland area of Victor Harbor is very young. Since settlement in the1850s, sea levels have risen globally by ~250mm and are projected to rise up to 1m by the end of this century.

8. The introduction of the breakwater may have changed the angle of refraction of waves which caused the coastline along Flinders Parade to realign (erode).

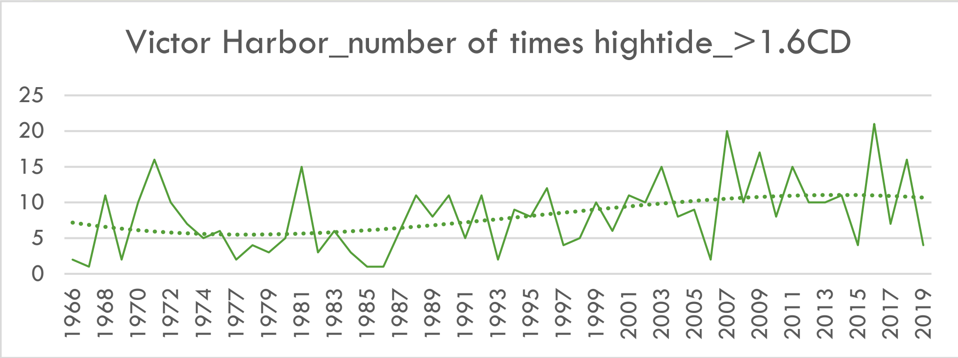
Reflections:

The tendency in past study 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 main 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 Flinders 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.



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.

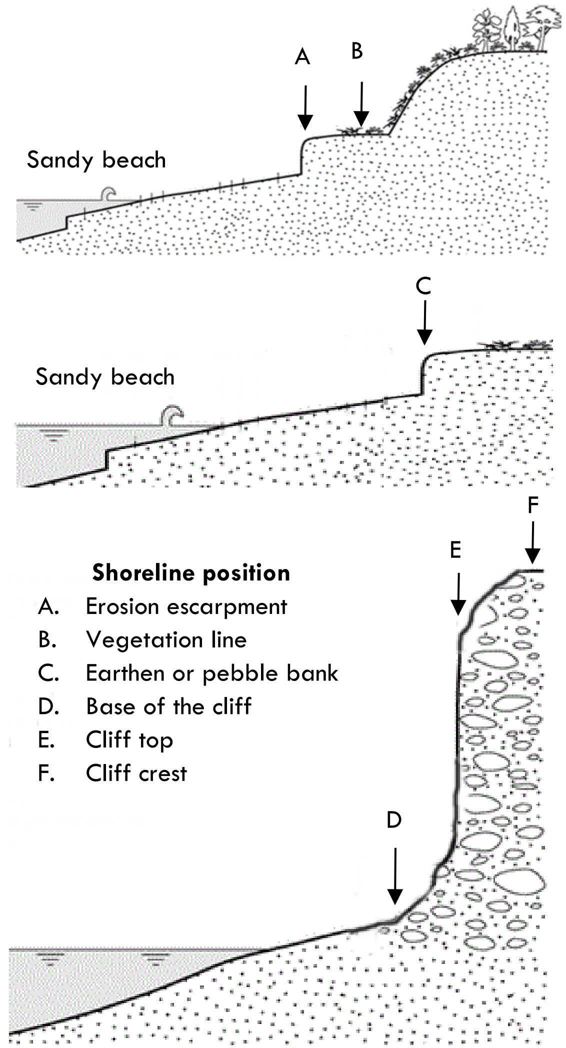


Figure a. Adapted from Boak and Turner (2005), Shoreline definition and detection.

4-1 Coastal fabric - overview

Overview

Fleurieu 11

Secondary Cell: Fleurieu

Tertiary Cell: Victor Harbor Central

Form

Beach
Fine to medium sand beach.

Backshores
11.1 – Esplanade Road. Narrow low height vegetated dunes 3.5m -4.5m AHD, behind which reserve/car park positioned and esplanade road at 3.5m to 4.5m AHD.

11.2: Flinders Parade. Rock or concrete seawall from causeway to bowling club, then very narrow, low height dune (7m to 8m wide) backed by walking path and playing fields.

Bathymetry
11.1 Overall slope of ocean floor: -5m ~1500m from beach (overall slope ratio 1:300).
11.2 Overall slope of ocean floor: -10m ~1000 from beach (1:100)

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4-1 Coastal fabric - overview

Overview

Fleurieu 11

Secondary Cell: Fleurieu

Tertiary Cell: Victor Harbor Central

Geology

Geology

Beach and backshore 1:

Semaphore Sand - The beaches and immediate backshores of Victor Central were formed recently.

Age: Holocene ~10k BP

Backshore 2

Quaternary rocks (much younger than Granite Island).

Age: Pleistocene – Holocene. Less than 2.5m B.P.

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

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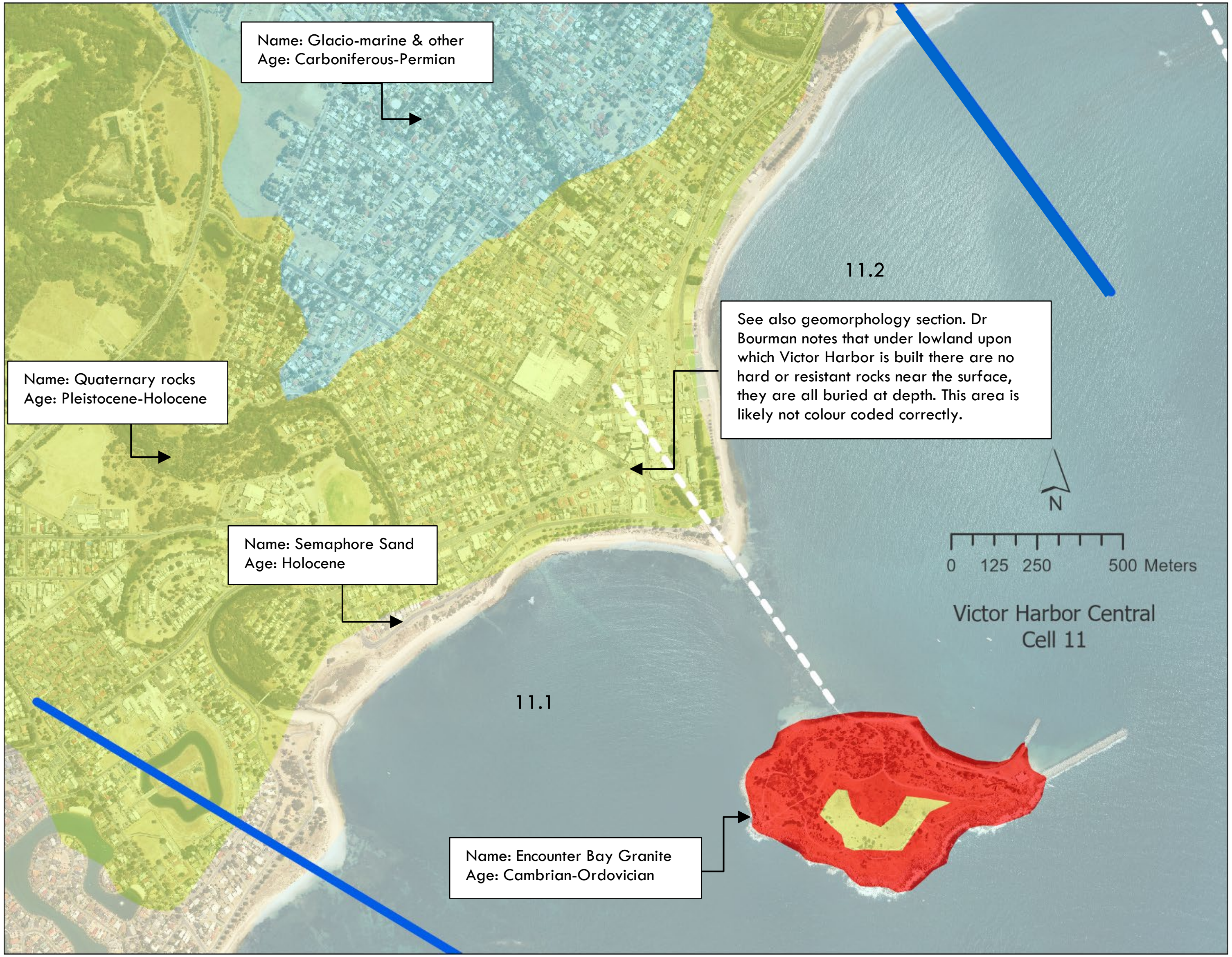


4-1 Coastal fabric - overview

Overview

Fleurieu 11

Secondary Cell: Fleurieu

Tertiary Cell: Victor Central

Benthic

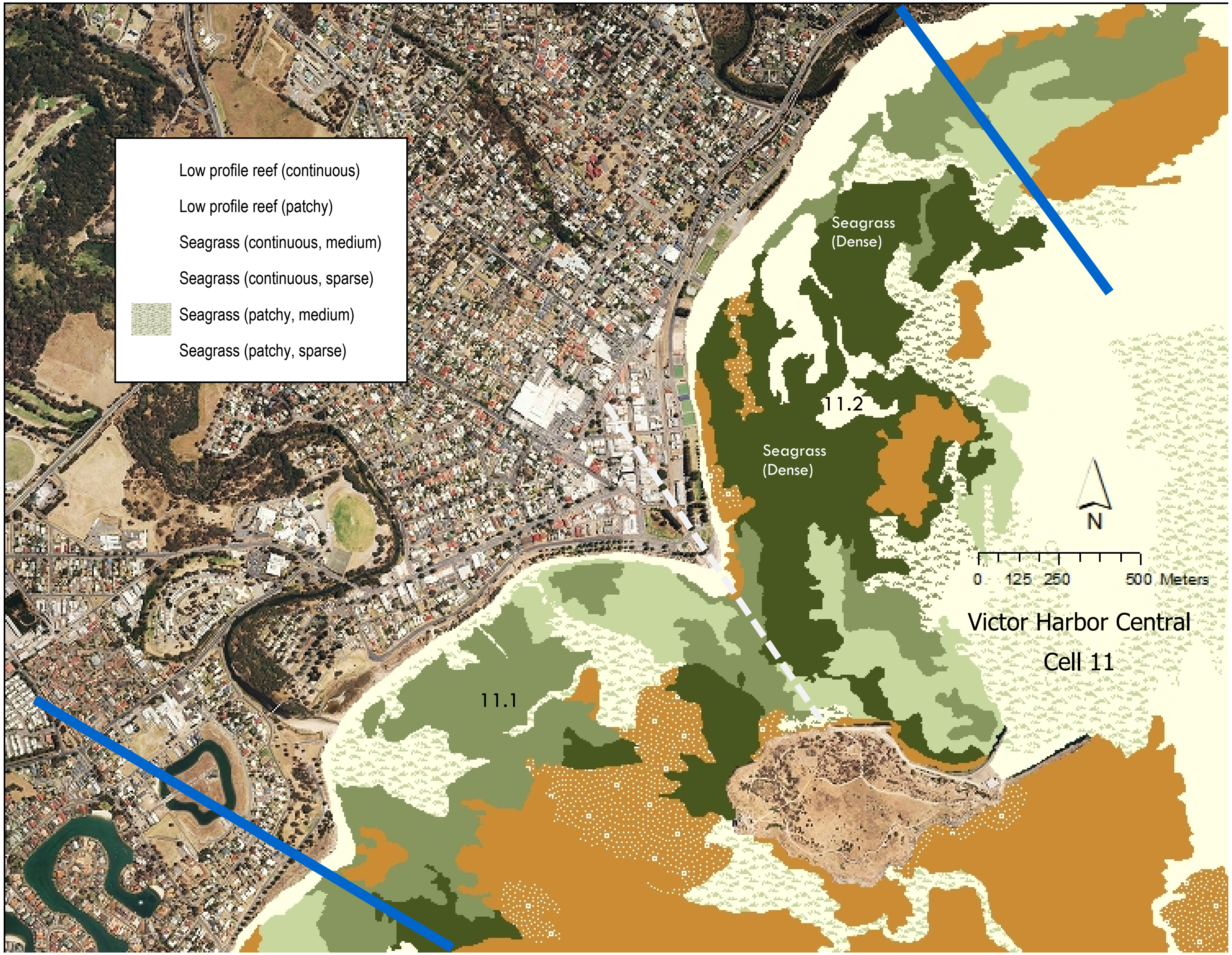
Benthic

11.1 The Esplanade Beach

Nearshore and surf-zone dominated by sand, covered by continuous and patchy seagrass beds. Offshore is a low profile continuous or patchy reef.

11.2 Flinders Parade -

Nearshore and surf-zone dominated by sand, covered by dense seagrass beds. Offshore is dominate by sand with patchy seagrass cover.



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4-2 Coastal fabric – shoreline changes

Comparison with photographs 1860s to 1930s

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 an insight to coastal change from the 1860s.

The Esplanade Beach (1866-1879)

Observations:

Observe the nature of the sand dunes in the foreshore area of The Esplanade Beach in 1866-1867.

- These sand dunes appear a height of ~6m and are well vegetated (Figure a).
- The view of the causeway is to the right of the main dunes observed in Figure a. It appears as if the low height dune field extended some distance back from the beach. (Figure b).
- By 1879, the dunes near the causeway had been removed.

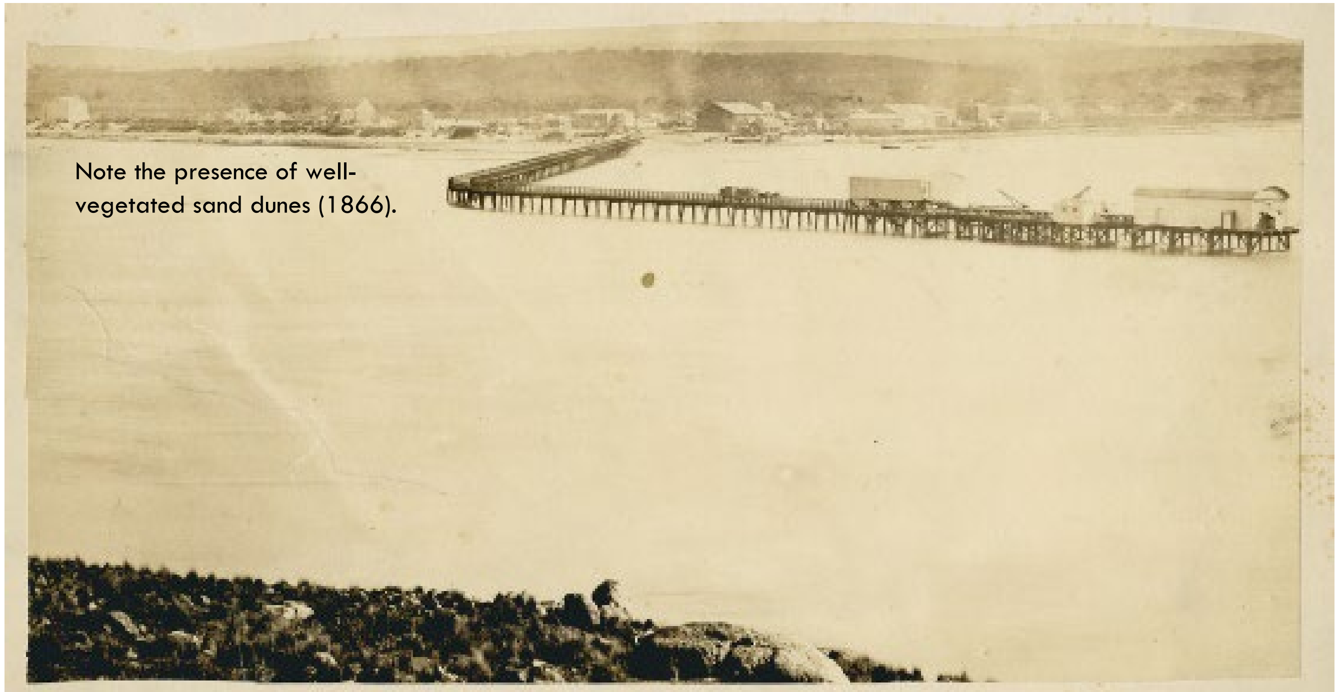

Figure a: Victor Harbor foreshore, 1866. Note the vegetated sand dunes along The Esplanade Beach. State Library of South Australia, B-45837.

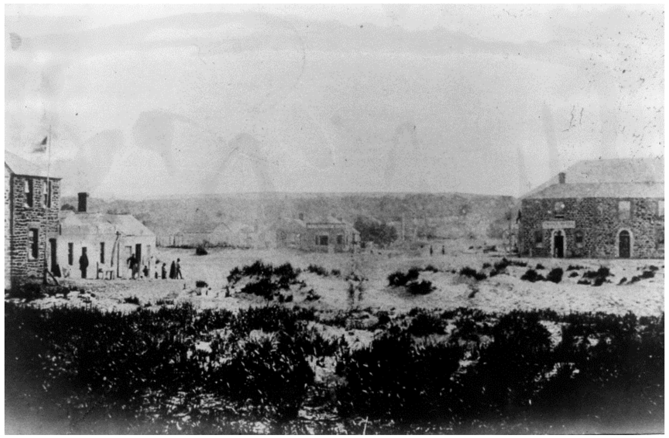

Figure b: Victor Harbor foreshore, 1867. Low height dune field extended back some distance from the beach. State Library of SA. B-282.

Figure c: Victor Harbor foreshore, 1868. The dune field extended landward into the area that is now utilised as Warland Reserve (note Victory Hotel on left, the Crown Hotel on the right). Source: Bob Bourman (original source unknown).

4-2 Coastal fabric – shoreline changes

The Esplanade Beach

(1890 compared to 1937)

Observations:

Observe the nature of the sand dunes in the foreshore area of The Esplanade Beach in 1890 compared with 1937.

- Well-vegetated sand dunes existed in the backshore of The Esplanade Beach in 1890 (Figure a).
- By 1937, the sand dunes had been completely removed. (Figure b).
- It is likely that the flood anecdote recorded below relates to this time period.

Flood anecdote:

In 1979, at the release of the Coast Protection Board report for the region, one yacht club member recalled that the 'foreshore had undergone considerable change since the second world war' and recalled that, 'on occasions when the ocean swell was particularly high and the winds strong, waves would wash past the Hotel Victor and into the drains near the Hotel Crown' (Victor Times, 1st February 1979).

Note that in older pictures the depth of field is rendered with higher appearance of vertical dimensions.

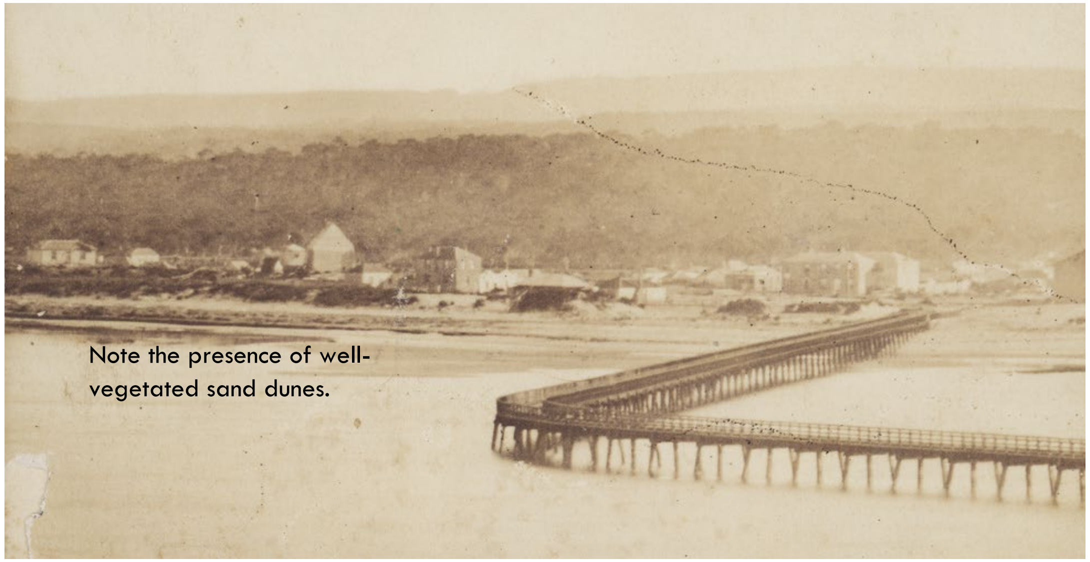

Figure a: Victor Harbor foreshore, 1890. Note the vegetated sand dunes along The Esplanade Beach. State Library of South Australia, B-27476-2 (cropped from the original).

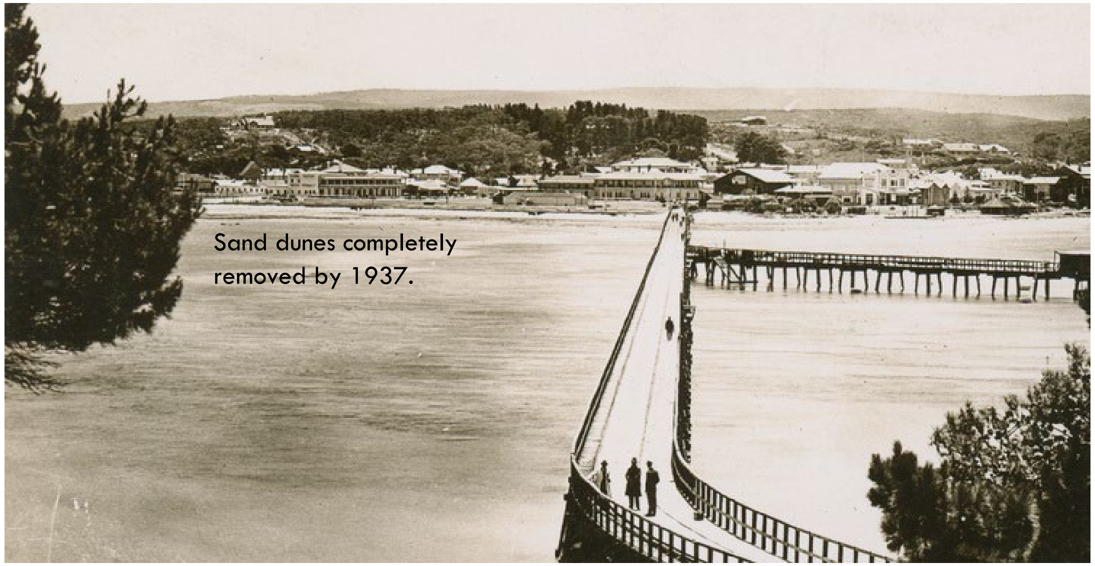

Figure b: Victor Harbor foreshore, 1937. Low height dune field extended back some distance from the beach. State Library of SA. B-282 (cropped from the original).

4-2 Coastal fabric – shoreline changes

Flinders Parade

(1866 compared to 1908)

Observations:

Observe the nature of the sand dunes in the foreshore area of The Esplanade Beach in 1866 and 1908 before the installation of the Soldiers Memorial Gardens and the various playing fields.

- The area towards the current day causeway was essentially a sand dune (Figure a).
- Note the height of the sand dunes on the Esplanade Beach visible behind the buildings (Figure a).
- The profile of the shore appears to slope gently up to what is now Flinders Parade. (Figure a).
- By 1910, the position of Flinders Parade is established in its current position. The area immediately above the high-water mark is now vegetated.

Note that in older pictures the depth of field is rendered with higher appearance of vertical dimensions.

Figure a: Victor Harbor foreshore, 1866. Note the nature of the beach and backshore. The area towards the causeway was originally a sand dune. State Library of South Australia, B-45839 (cropped from the original).

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

4-2 Coastal fabric – shoreline changes

Flinders Parade (1910)

<u>Observations:</u>

Observe the nature of the sand dunes in the foreshore area of The Esplanade Beach in 1910 before the construction of the Soldiers Memorial Gardens and the various playing fields.

- The profile of the shore appears to have a vegetated raised section just above the high-water mark, and then a lower swale before rising up to Flinders Parade (Figure a).
- In 1920, the vegetated section was raised and made into a promenade protected by a seawall. Soldiers Memorial Gardens and the playing fields were constructed in the swale.

Note that in older pictures the depth of field is rendered with higher appearance of vertical dimensions.

4-2 Coastal fabric – shoreline changes

Hindmarsh River outlet (1910-1933)

Observations:

The aerial photographs in 1949 and 1976 show no sand dunes in the vicinity of the Hindmarsh River outlet. Earlier photographs reveal:

- The Hindmarsh River originally followed the course of the trainline. (Figure a).
- Photographs from 1890 to 1933 show a large dune system where the river bends to the north (Figure b).
- In 1933, there appears to be a gap through the sand dunes in direct line with the upstream river. It is not known if this formed naturally or was purposefully cut. There may have been concern relating to erosion of the bank underneath the trainline (Figure c).
- This gap through the dunes may be the reason that the sand dunes were completely removed by 1949.

Note that in older pictures the depth of field is rendered with higher appearance of vertical dimensions.

Figure a: Hindmarsh River, 1920. The original course of the Hindmarsh River flowed in parallel to the trainline. State Library of SA. B-26875.

Figure b: Hindmarsh River, 1928. A vegetated dune existed at the last bend of the river seen in photographs from 1890 to 1933. State Library of SA. B-77156-175.

Figure c: Hindmarsh River, 1933. Note the gap between the sand dunes in line with the upstream river. State Library of SA. B-77156-175.

4-2 Coastal fabric – shoreline changes (Cell 11.1a)

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Inman River

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
- 2010
- 2014
- 2018

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Inman River
Year 1949

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

In 1949, the outlet of the mouth of the Inman River was to the east of the current day outlet.

A historical analysis completed by Coast Protection Board found that the river mouth changed its position over time (19791001).

The area to south and west of the river mouth has changed significantly. To the south the coast around Kent Reserve has accreted by 30m to 55m since 1949.

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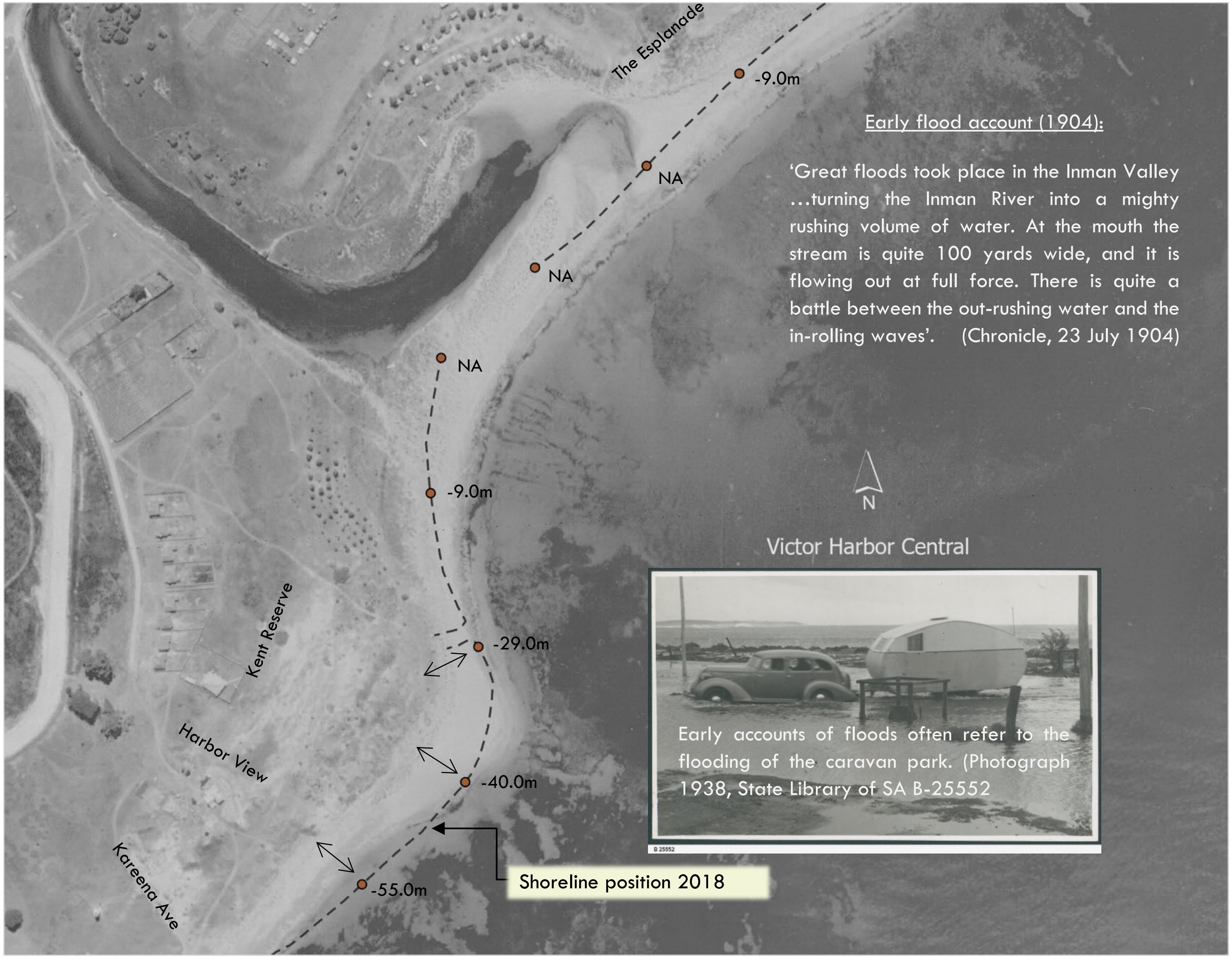

Early flood account (1904):

'Great floods took place in the Inman Valley …turning the Inman River into a mighty rushing volume of water. At the mouth the stream is quite 100 yards wide, and it is flowing out at full force. There is quite a battle between the out-rushing water and the in-rolling waves'. (Chronicle, 23 July 1904)

Early accounts of floods often refer to the flooding of the caravan park. (Photograph 1938, State Library of SA B-25552

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Inman River
Year 1976

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

Between 1949 and 1976 the coastline to the south of Inman River accreted between 10-20m (especially in the section of coast in line with Harbor View Drive).

Inset photograph provides oblique view from 1975 (Coast Protection Board).

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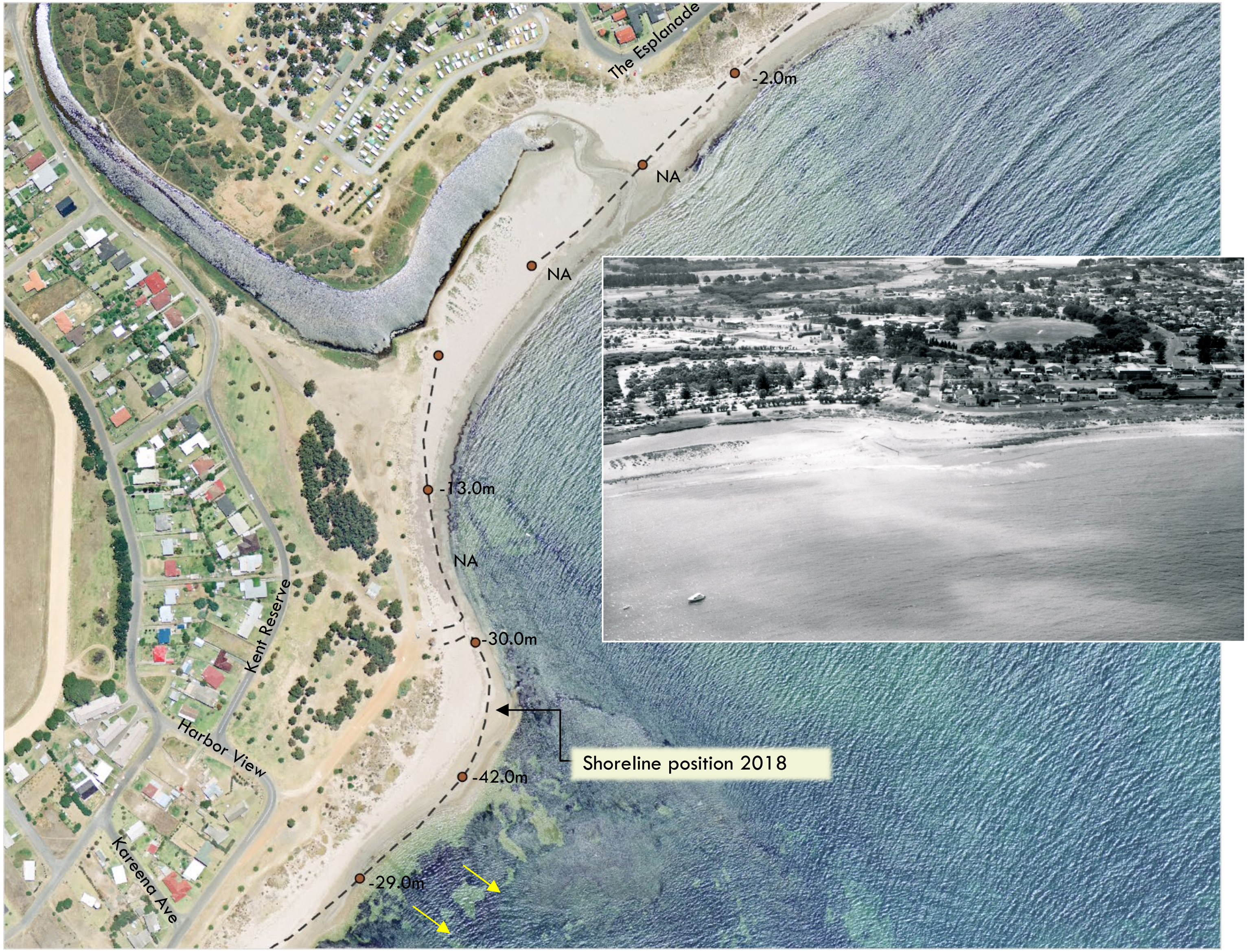

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Inman River
Year 1989

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

Between 1976 and 1989 the coastline to the south of Inman River accreted between 10-15m.

In 1979, due to flooding that was threatening the road and car park at the corner of The Esplanade and Inman Street, the mouth of the river was mechanically opened about 100m to the east.

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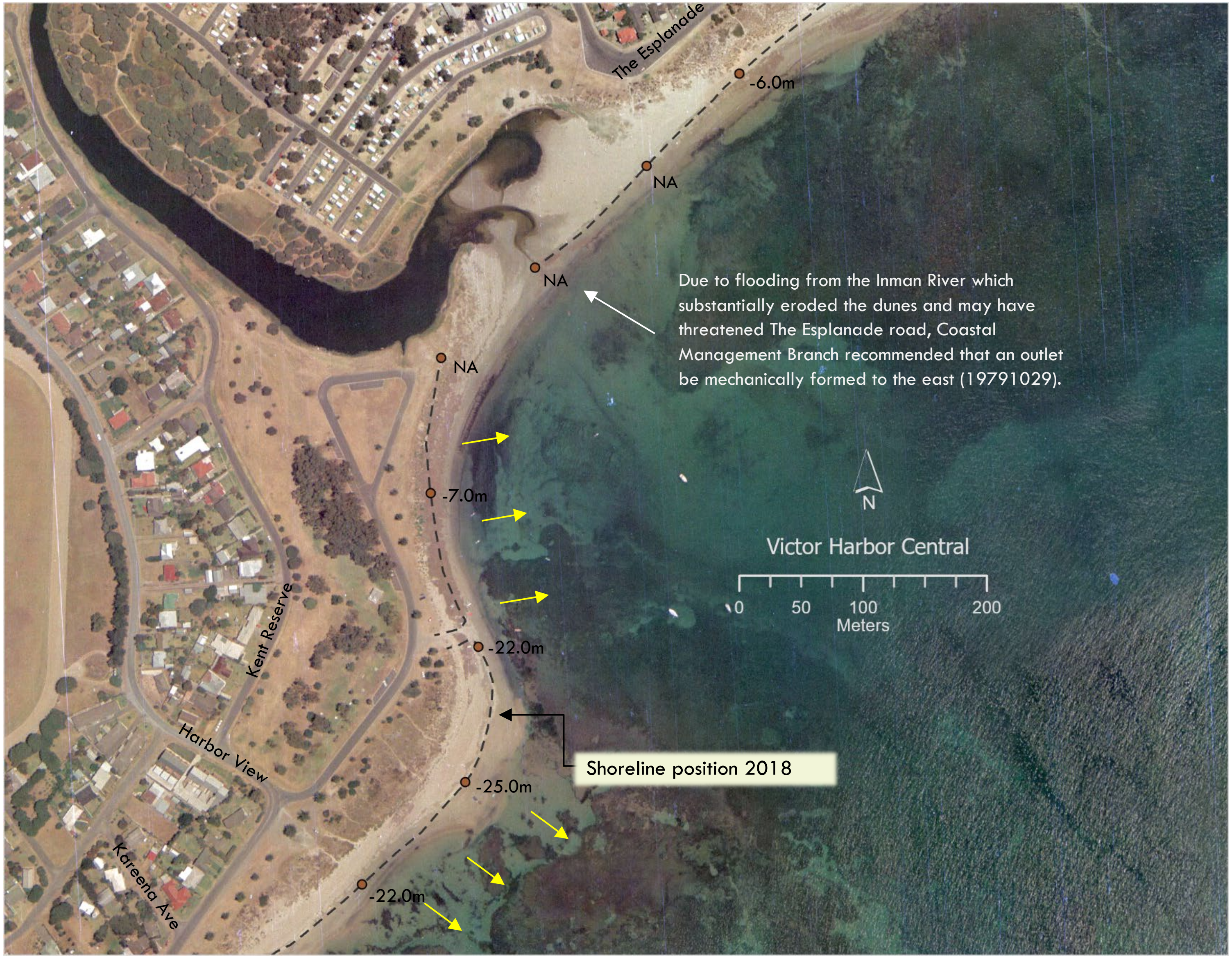


4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central

Historical comparison

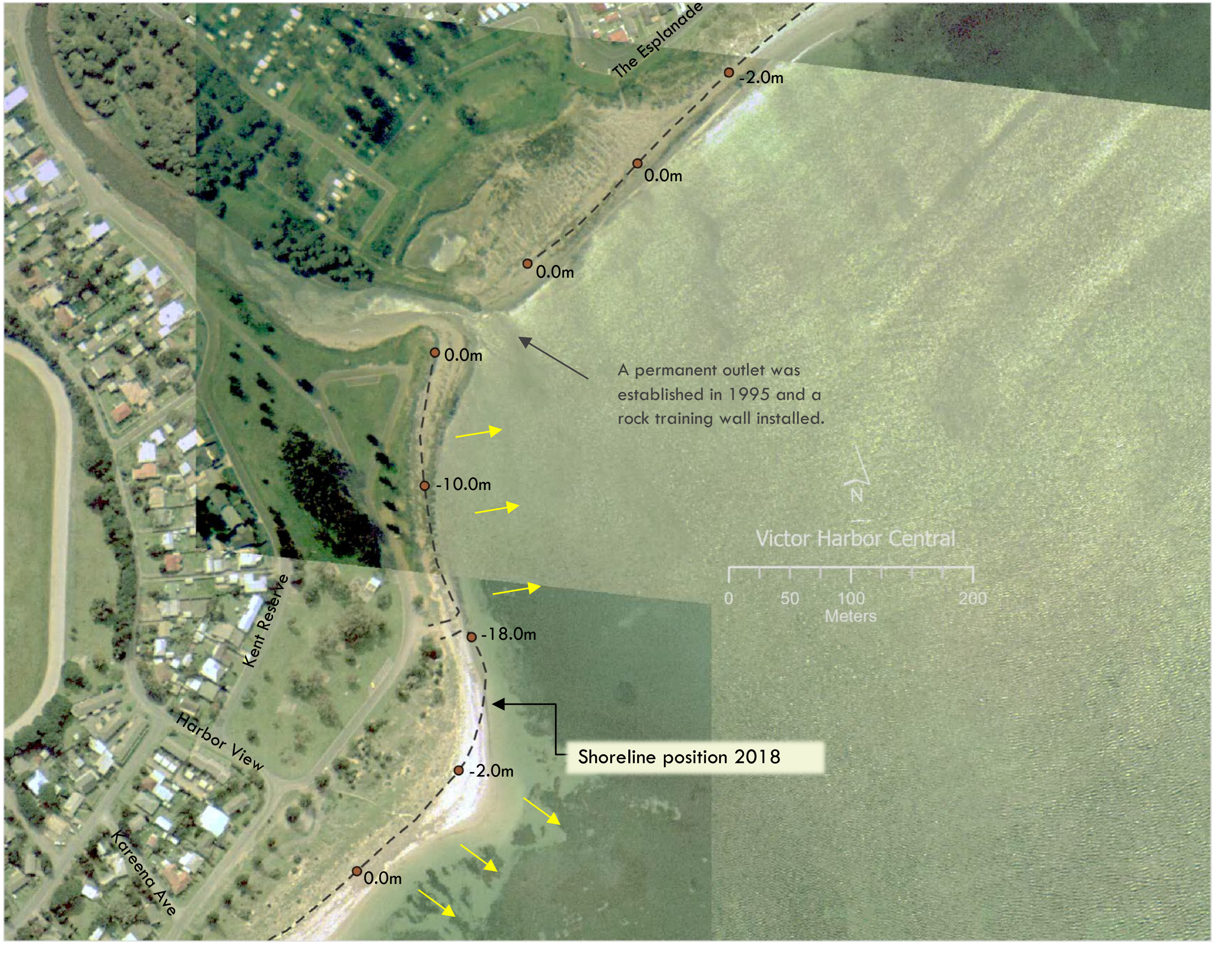
Shoreline

Location:
Inman River
Year 1999

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

A permanent outlet for the Inman River was established in 1995 and a rock training wall installed.

Between 1989 and 1999 the coastline to the south of Kent Reserve accreted a further 22m and the coastline on the east side of Kent Reserve accreted 3-4m.



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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Inman River
Year 2008

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The period 2004, 2007 to 2011 was an era of above average high tides which caused considerable erosion at King Street (The Esplanade Beach) and some areas of Encounter Bay.

Despite this prevailing trend, between 1999 and 2008 the coastline to the south of Kent Reserve accreted a further 14m to be in a seaward position of current day. The coastline east of Kent Reserve eroded 2-7m.

The dunes to east of the river mouth were formed in this time and vegetated (see Magryn, 2006).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Inman River
Year 2012

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The period 2004, 2007 to 2011 was an era of above average high tides which caused considerable erosion at King Street (The Esplanade Beach) and some areas of Encounter Bay.

By 2012, the coastline was beginning to stabilise.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Inman River
Year 2016

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The year 2016 was a year of above average high tides and the coastline to the south of Kent Reserve eroded into its current position.

To the east of Kent Reserve the shoreline accreted ~4m.

To the east of the mouth of the Inman River, the coastline eroded slightly.

From 1999 to 2018 the point circled in yellow does not alter whether the coastline is accreting or eroding north or south.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Inman River
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 shoreline analysis above shows that in the period 2011 to 2018 the shore-line recedes and accretes simultaneously at different locations along this section of coast.

Overall, the coast has accreted within Cell 11 and some erosion has occurred within Cell 10 (Encounter Bay).

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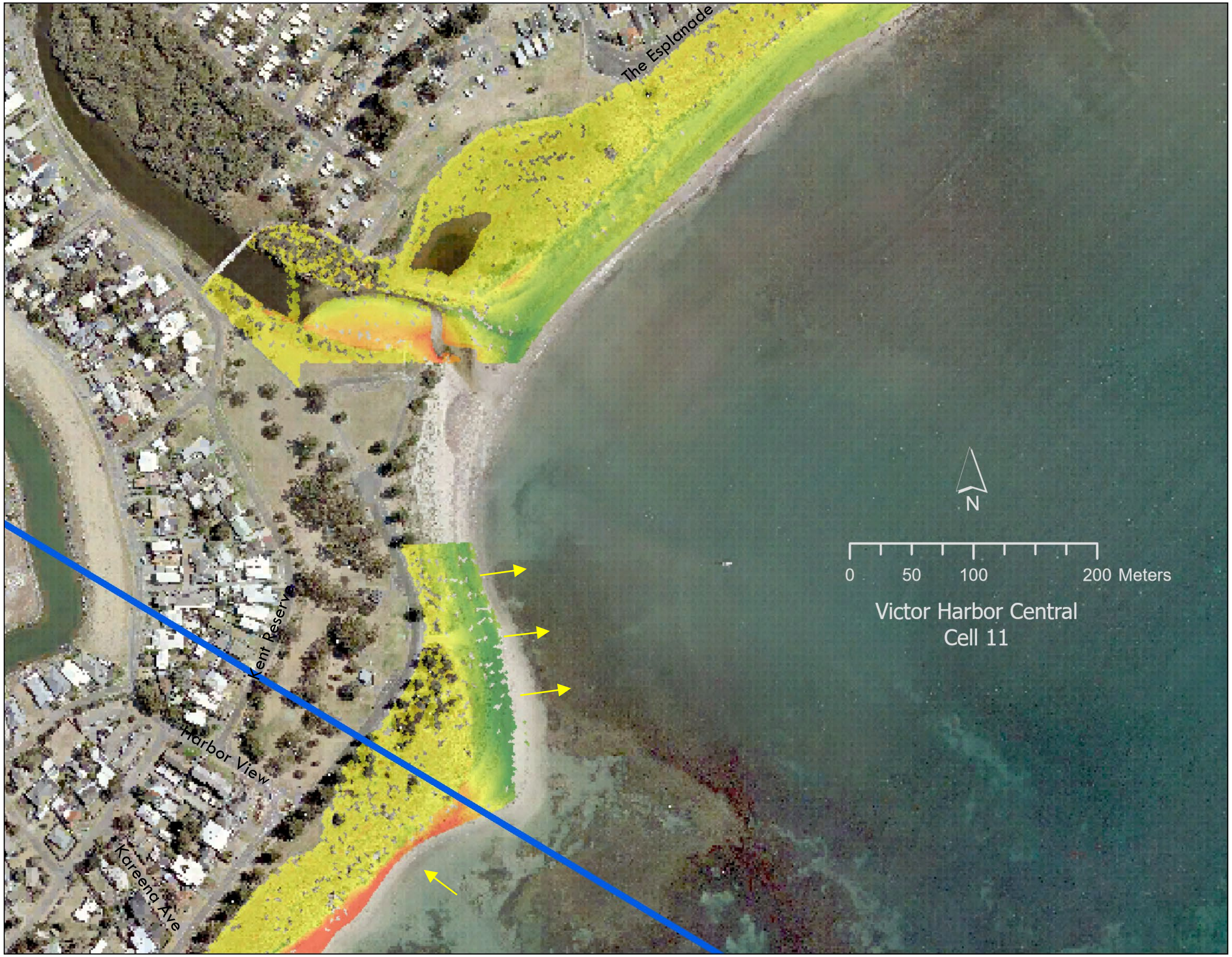

4-2 Coastal fabric – summary (Cell 11.1a)

Medium Term Changes

Fleurieu 11.1a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Inman River
Summary

70 years
The coastline in the vicinity of Inman River outlet changed significantly. To the south and east of Kent Reserve the shoreline accreted by up to 55m. The outlet of the Inman River was opened first 100m to the west (1979) and then permanently trained with rock into its current position in 1995.

10 years

The period 2007 to 2011 was an era of above average high tides which caused considerable erosion at other locations. To the south of the river outlet the coast underwent cycles of accretion and erosion. The dunes were formed to the east of the outlet and vegetated.

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4-2 Coastal fabric – shoreline changes (11.1b)

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central
Historical comparison

Shoreline

Location:
The Esplanade Beach

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

The shoreline position is toe of the rock protection installed in 1989.

The locations of Coast Protection Board profile line 620006, 620008 and 620024 is shown to provide a context for later analysis.

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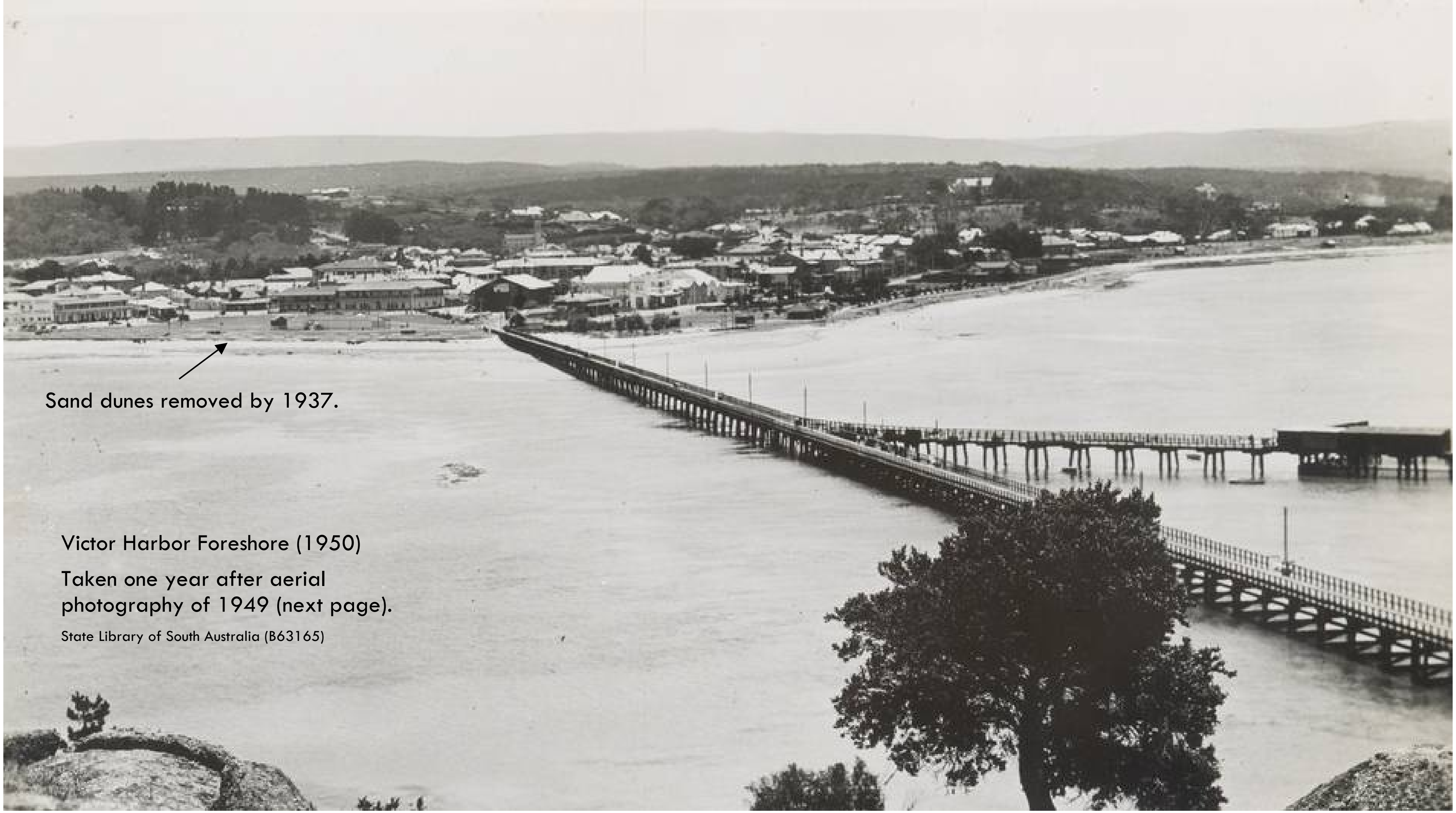
4-2 Coastal fabric – shoreline changes

Medium Term Changes



Victor Harbor Foreshore (1950)

Taken one year after aerial photography of 1949 (next page).

State Library of South Australia (B63165)

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central

Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 1949

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

In 1949, there were no dunes in the backshore (removed by at least 1937).

Generally, the shoreline on the western side of the photograph is further seaward than current day and the shoreline on the eastern side of the photograph is further landward than current day.

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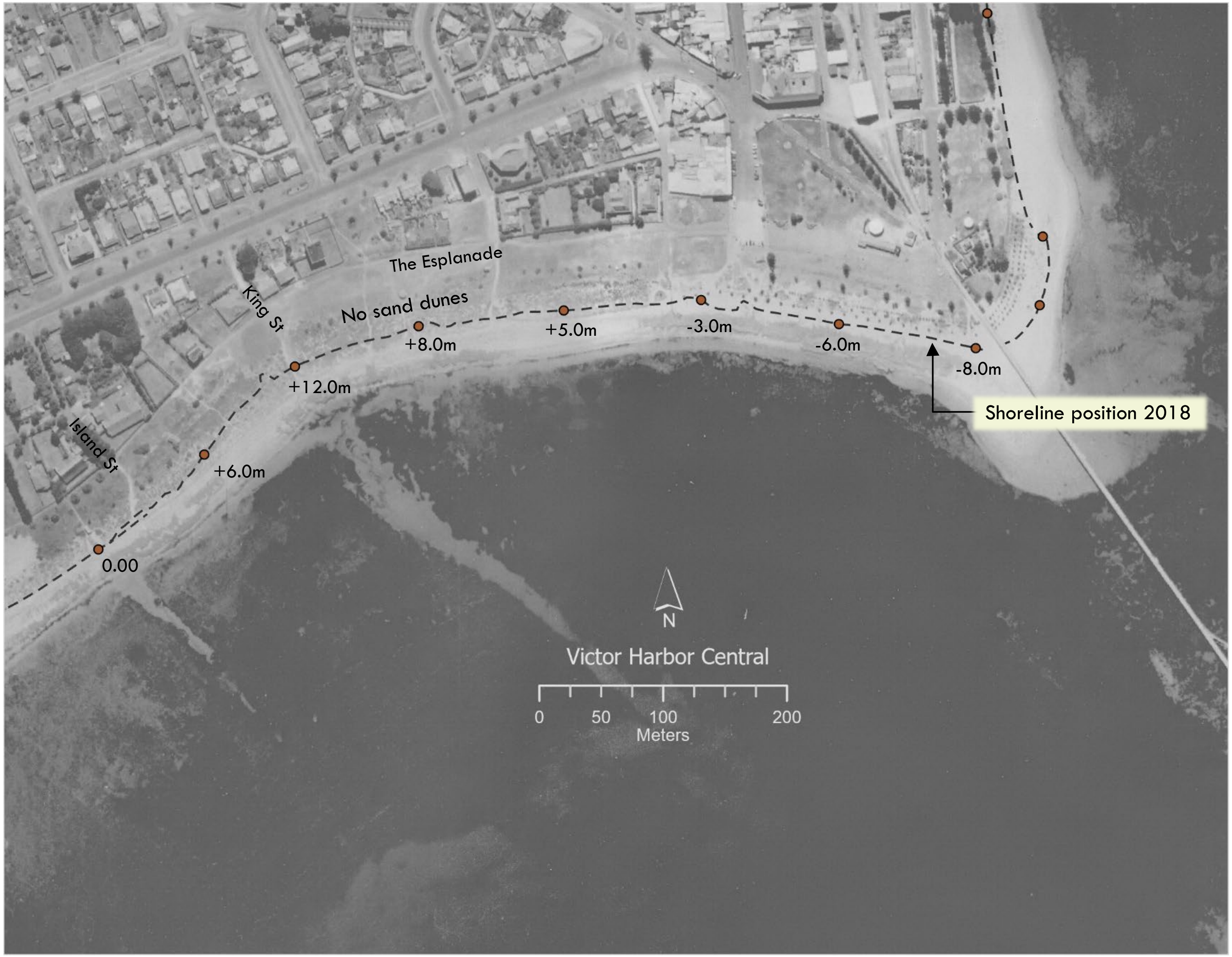

4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central

Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 1976

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The shoreline is in a similar position as 1949 (apart from minor accretion in vicinity of King Street).

The founding of the SA Coast Protection Board began a new era of coastal management with the restoration and vegetation of dune areas.

Photograph: Coast Protection Board, 1975.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central
Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 1989

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The shoreline on the western side of the picture (Island Street) eroded by 2-5m. The shoreline on the eastern side of the picture (current day car park) accreted 3-6m.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central

Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 1999

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The shoreline is in a similar position to 1989.

The locations of Coast Protection Board profile line 620006, 620008 and 620024 is shown to provide a context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central
Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 2004

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The shoreline is in a similar position to 1999.

However, 2004 is the year when higher than average high tides are experienced which begins an erosion cycle on The Esplanade Beach until 2011. Note: this picture may have been taken in summer of 2004 before the winter of higher tides.

The locations of Coast Protection Board profile line 620006, 620008 and 620024 is shown to provide a context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central
Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 2008

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The period 2004, 2007 to 2011 was an era of above average high tides which caused considerable erosion at King Street (total of 11m from 2004-2012 in vicinity of King Street).

The locations of Coast Protection Board profile line 620006, 620008 and 620024 is shown to provide a context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central

Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 2012

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The shoreline in vicinity of King Street a total of 11m since 2004 and increased erosion occurred near the causeway. Sand nourishment was carried out in the King Street area in 2012.

The curve in the bay at King Street was likely formed partly due to the nature of the wave action in this area combined with a gap between the reef (see 1949). The higher consistent storm action 2004 to 2011 had the greatest impact here. These factors also noted by Richard House (Victor Harbor Coastcare) in 2012.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central

Historical comparison

Shoreline

Location:
The Esplanade Beach
Year 2016

In this location the shoreline position is the vegetation line at the back of the beach in 2018.

The year of 2016 was another period of higher than average high tides but the lower tides between 2011 and 2016 enabled the coastline to recover.

The locations of Coast Protection Board profile line 620006, 620008 and 620024 is shown to provide a context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central
Historical comparison

Shoreline

Location:
The Esplanade Beach
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.

Sand nourishment occurred in the vicinity of King Street in 2012.

Comparing sand heights for 2011 and 2018 shows an accretion pattern to the west of the causeway which is congruent with the analysis of the shoreline position. Post 2011, the number of higher-than-average storms decreased allowing the beach time to recover (apart from 2016).

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4-2 Coastal fabric – summary (Cell 11.1b)

Medium Term Changes

Fleurieu 11.1b

Victor Harbor Central

Historical comparison

Shoreline

Location:
The Esplanade Beach
Summary

70 years
The shape of the beach changed with the western side eroding and the eastern side accreting (although the latter may be related to coastal management). The original dunes were removed by 1937. Post 1970, management practices began to restore the dune system.

10 years
The era (2004-2011) was characterised by increased storminess and a significant amount of erosion in the King Street area. The combination of the higher-than-average high tides and the gap in the reef and seagrass are likely reasons for increased erosion in this location. The beach has since recovered.

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4-2 Coastal fabric – shoreline changes (Cell 11.2a)

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Flinders Parade

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

The shoreline position is toe of the rock protection installed in 1989.

The location of Coast Protection Board profile line 620004 and 620005 is shown to provide a context for later analysis.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Flinders Parade
Year 1949

In this location the shoreline position is toe of the rock protection installed in 1989.

The seawall installed in 1920 is the shoreline position in 1949.

Note the natural sand dune on the right of the causeway into which a car park was constructed in 1970s.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Flinders Parade
Year 1976

In this location the shoreline position is toe of the rock protection installed in 1989.

At Soldiers Memorial Gardens the toe of the rock protection in 2018 is ~4.0m further seaward than the seawall that was installed in 1920.

The boat ramp was installed in the 1970s (?) and acts as a groyne preventing sand from moving northward. A car park was constructed in the former dune to the east of the causeway. (This was likely used as a 'dirt' car park for some time before construction). These two factors are likely reasons for loss of sand on the beach to the north.

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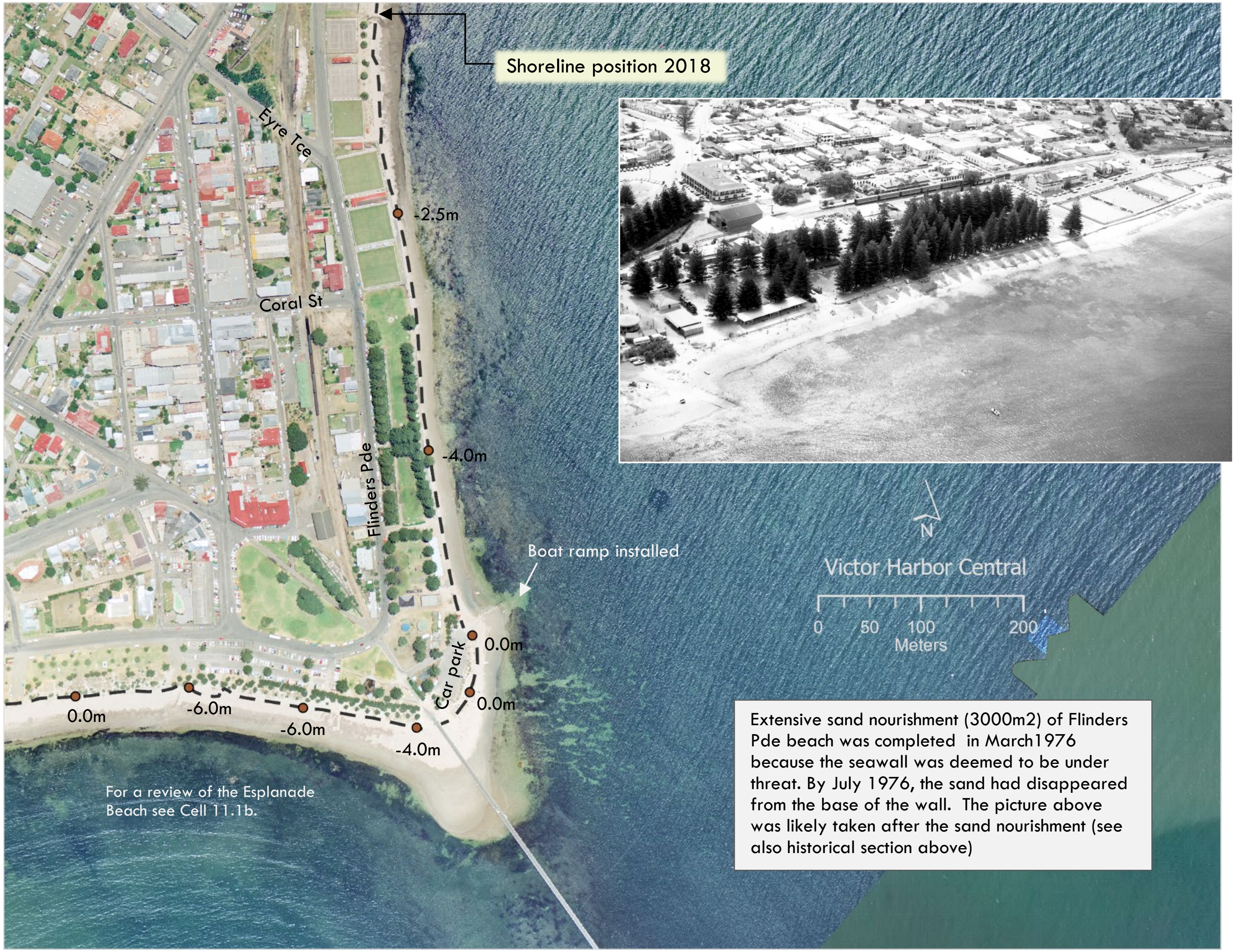


4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Flinders Parade
Year 1989

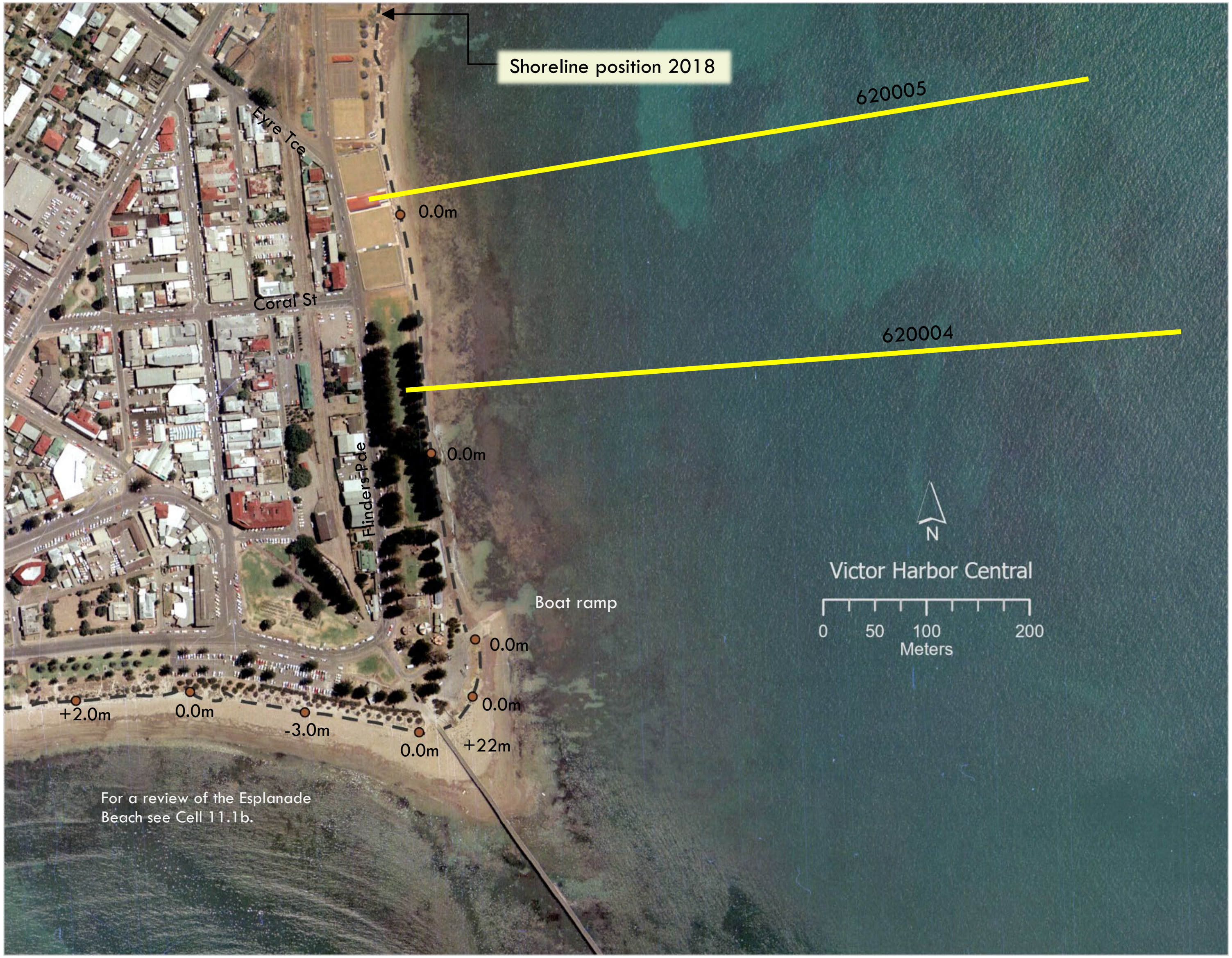
In this location the shoreline position is toe of the rock protection installed in 1989.

.

At Soldiers Memorial Gardens the toe of the rock protection in 2018 is ~4.0m further seaward than the seawall that was installed in 1920.

The boat ramp was installed in the 1970s (?) and acts as a groyne preventing sand from moving northward.

Note the lack of sand along Flinders Parade beach (but also take into account that the tide is higher in this picture).



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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Flinders Parade
Year 1999

In this location the shoreline position is toe of the rock protection installed in 1989.

No change from 1989.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Flinders Parade
Year 2008

In this location the shoreline position is toe of the rock protection installed in 1989.

No change from 1999 (tide is lower in this photograph than 1999).

Note that the sand node to the east of the causeway is seaward by 22m compared to its 2018 position.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Flinders Parade
Year 2012

In this location the shoreline position is toe of the rock protection installed in 1989.

Sandbag groynes were installed to Flinders Parade Beach in 2008 which appear to be trapping an increased amount of sand.

Note that the sand node to the east of the causeway is seaward by 19m compared to its 2018 position.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central

Historical comparison

Shoreline

Location:
Flinders Parade
Year 2016

In this location the shoreline position is toe of the rock protection installed in 1989.

The sand node under the causeway receded in this year (likely as a result of higher than average high tides).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Flinders Parade
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 sand node under the causeway receded in this year (likely as a result of higher-than-average high tides).

Sand levels in the beach area in the vicinity of the car park increased. However, the areas in the darker green at the back of the beach represent seaweed and sand scraped from the beach by Council.

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4-2 Coastal fabric – summary (Cell 11.2a)

Medium Term Changes

Fleurieu 11.2a

Victor Harbor Central
Historical comparison

Shoreline

Location:
Flinders Parade
Summary

70 years
The shoreline position along Flinders Parade has been governed by human intervention since the installation of the seawall in 1920. The wall was upgraded to rock protection in 1989, the toe of which is now ~4m further seaward. The installation of the boat ramp and car park to the east of the causeway appear to be factors that have reduced sand supply.

10 years
Sandbag groynes were introduced in 2008 which seem to have increased the volume of sand. The node of sand to the east of the causeway receded and concrete block protection was installed.

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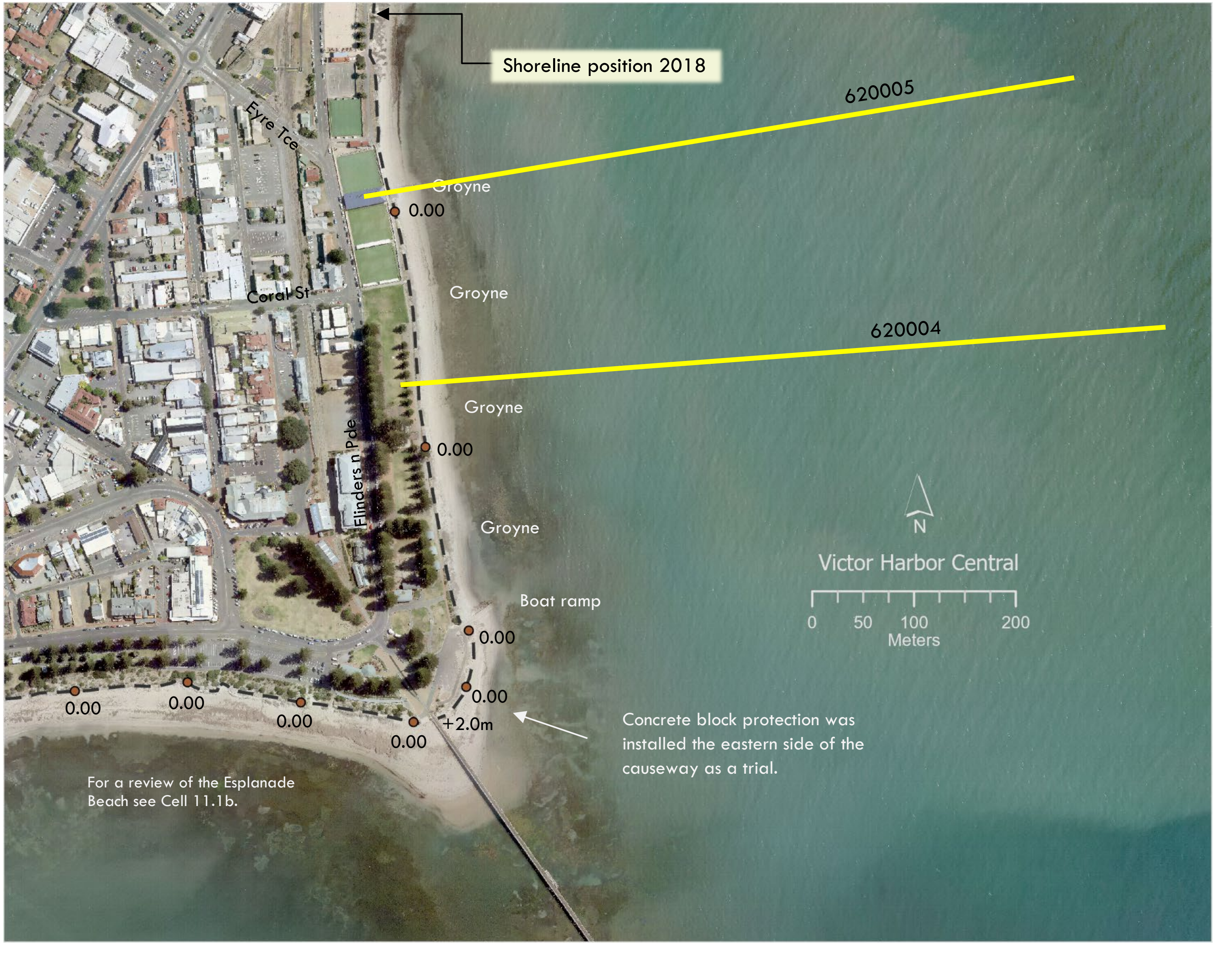

4-2 Coastal fabric – shoreline changes (Cell 11.2b)

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central

Historical comparison

Shoreline

Location:
Bridge Street

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.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central
Historical comparison

Shoreline

Location:
Bridge Street
1949

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

The shoreline position in 1949 in the vicinity of the Hindmarsh River outlet is 11-27m landward of its position in 2018. It is likely that the alignment of the outlet of the Hindmarsh River to the south has caused this area to accrete.

The sand dunes observed in photographs 1890 to 1933 have been eroded away by 1949.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central

Historical comparison

Shoreline

Location:
Bridge Street
Year 1976

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

The shoreline in the middle of the photograph is ~20m seaward of the 1949 photograph. This may be a result of coastal management with planting of trees and perhaps importing of fill (?).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central
Historical comparison

Shoreline

Location:
Bridge Street
Year 1989

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

The introduction of rock to train the mouth of the Hindmarsh River was first introduced in 1984 (Inset photograph, Coast Protection Board).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central
Historical comparison

Shoreline

Location:
Bridge Street
Year 1999

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

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central
Historical comparison

Shoreline

Location:
Bridge Street
Year 2008

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

The shoreline in 2008 is in the same position as 2018. This is despite this era being a time of higher-than-average high tides that caused erosion to The Esplanade Beach.

It is likely that rock was added to the Hindmarsh River outlet over time from 1984 onwards. In 2004, sandbag training walls were introduced (Inset photograph, Coast Protection Board).

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central
Historical comparison

Shoreline

Location:
Bridge Street
Year 2012

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

The shoreline in 2012 is in the same position as 2018. This is despite this era being a time of higher-than-average high tides that caused erosion to The Esplanade Beach.

Council informs that the river is mechanically opened periodically when water levels become too high within the river upstream.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central
Historical comparison

Shoreline

Location:
Bridge Street
Year 2016

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

The shoreline in 2016 is in the same position as 2018.

Council informs that the river is mechanically opened periodically when water levels become too high within the river upstream.

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4-2 Coastal fabric – shoreline changes

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central

Historical comparison

Shoreline

Location:
Bridge Street
Comparison DEMs:
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 section of coast has been stable with slight increase of sand levels over the period 2011 to 2018.

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4-2 Coastal fabric – shoreline changes (Cell 11.2b)

Medium Term Changes

Fleurieu 11.2b

Victor Harbor Central
Historical comparison

Shoreline

Location:
Bridge Street
Summary

70 years

This section of the coastline accreted between the period 1949 and 2004 and has remained in this position since. Rock was first installed in the river mouth in 1984 and further rock installed over time until sandbags were installed in 2004.

10 years

There has been minimal change in this period, despite this era being a time of higher-than-average tides which caused erosion at The Esplanade.

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4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11

Encounter Bay

Historical comparison

Profile line

Analysis

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

Profile lines:

- 620004
- 620005
- 620006
- 620008
- 620010
- 620012
- 620024

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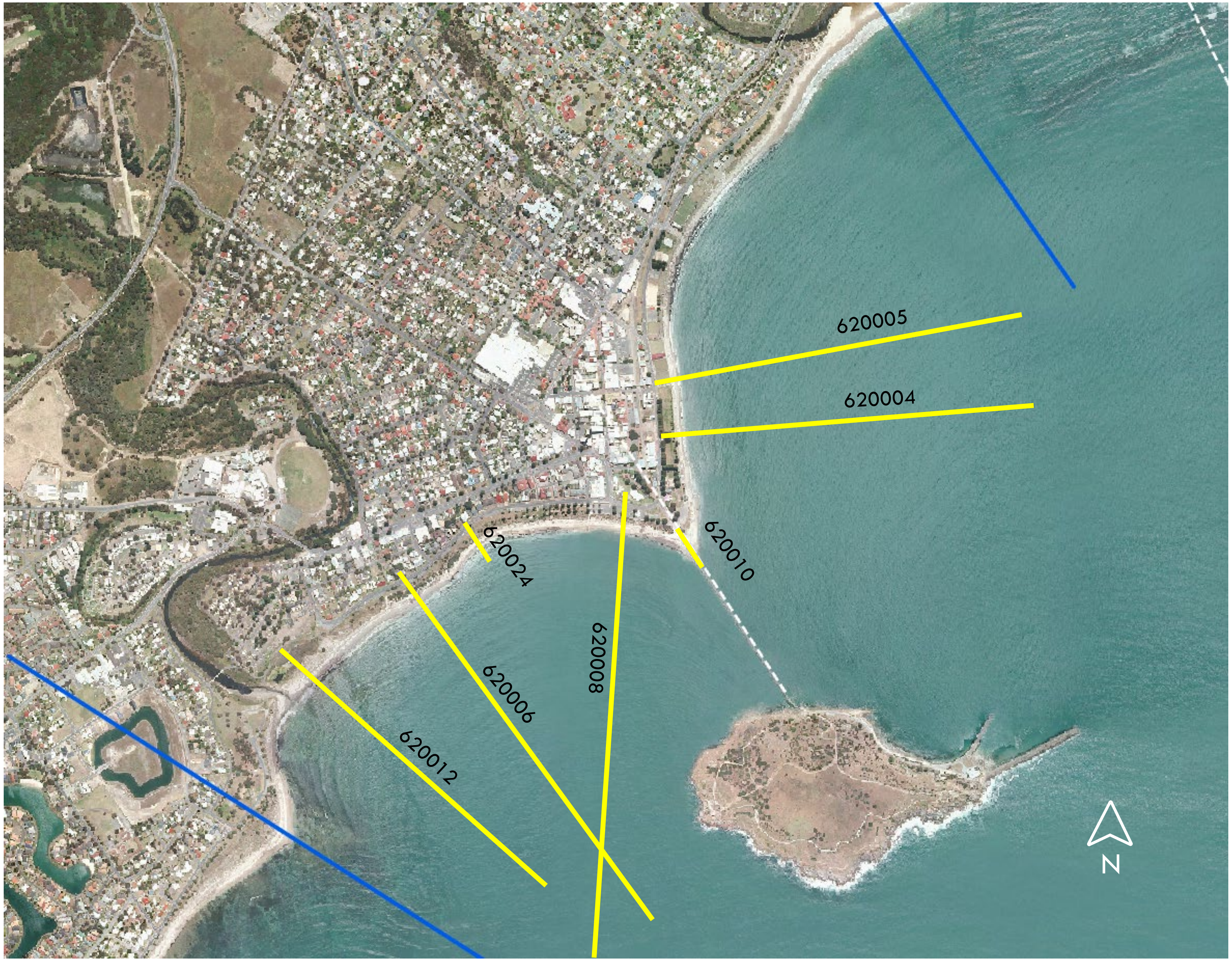


4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11
Victor Harbor Central
Historical comparison

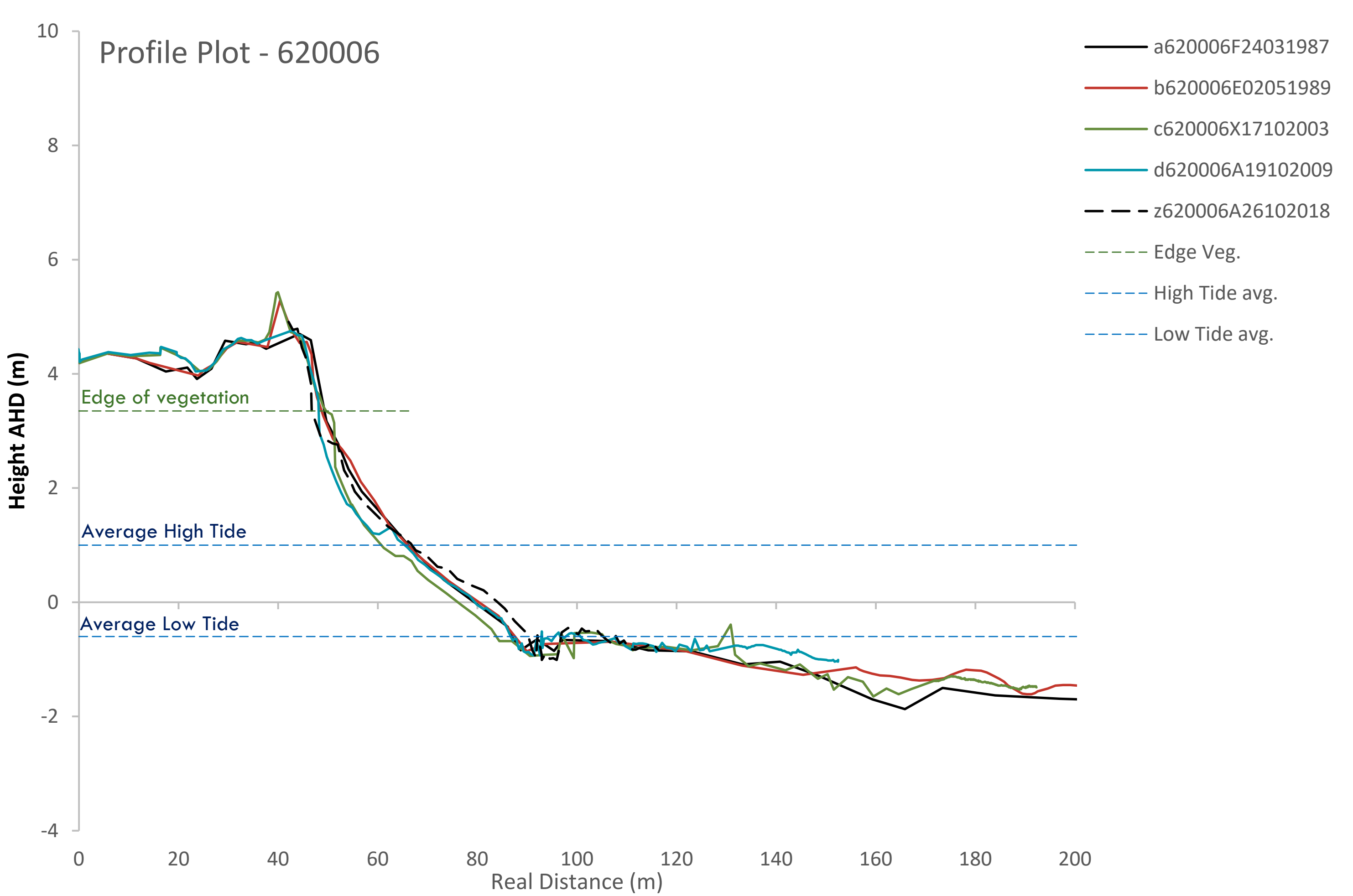
Profile line

The Esplanade Beach
(Island Street)
620006

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

The escarpment between +4.5m and +2.7m elevation has generally undergone minor erosion and has translated landward between 1987 and 2018 by a total distance of ~1m.

Sand levels in 2018 in the intertidal zone were higher than at any other historical profile.



Below the low tide line, it is difficult to ascertain any recent trend as the 2018 profile was not measured into the subtidal zone.

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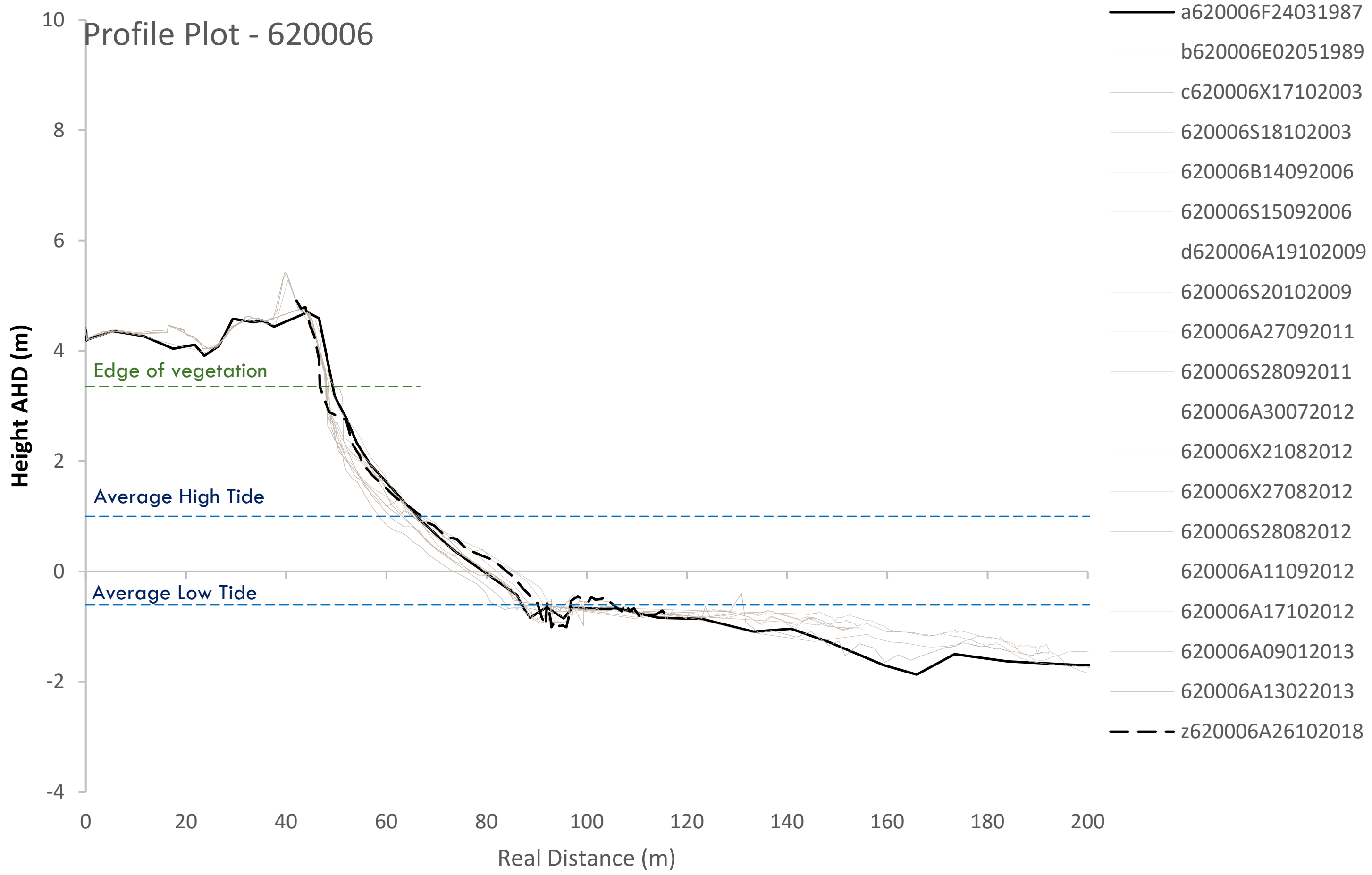
4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11
Victor Harbor Central
Historical comparison

Profile line



The Esplanade Beach (Island Street) 620006

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

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

At elevations below 2.7m the 1987 and 2018 profiles are well correlated, notably all other profiles are more eroded. This would suggest an erosional pattern has been balanced by an accretional pattern in the subaerial zone for the monitoring time period (1986 to 2018) that ranges around 5m horizontally.

The upper portion of the escarpment (above 2.5m+ AHD) is undergoing erosion and it is possible that natural beach processes will be unable to restore sediment levels to 1986 levels in this location. Below the average tide line, all profiles are above 1987. The profile of 2018 was not taken below the low tide line and therefore current comparison cannot be made.

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4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11

Victor Harbor Central

Historical comparison

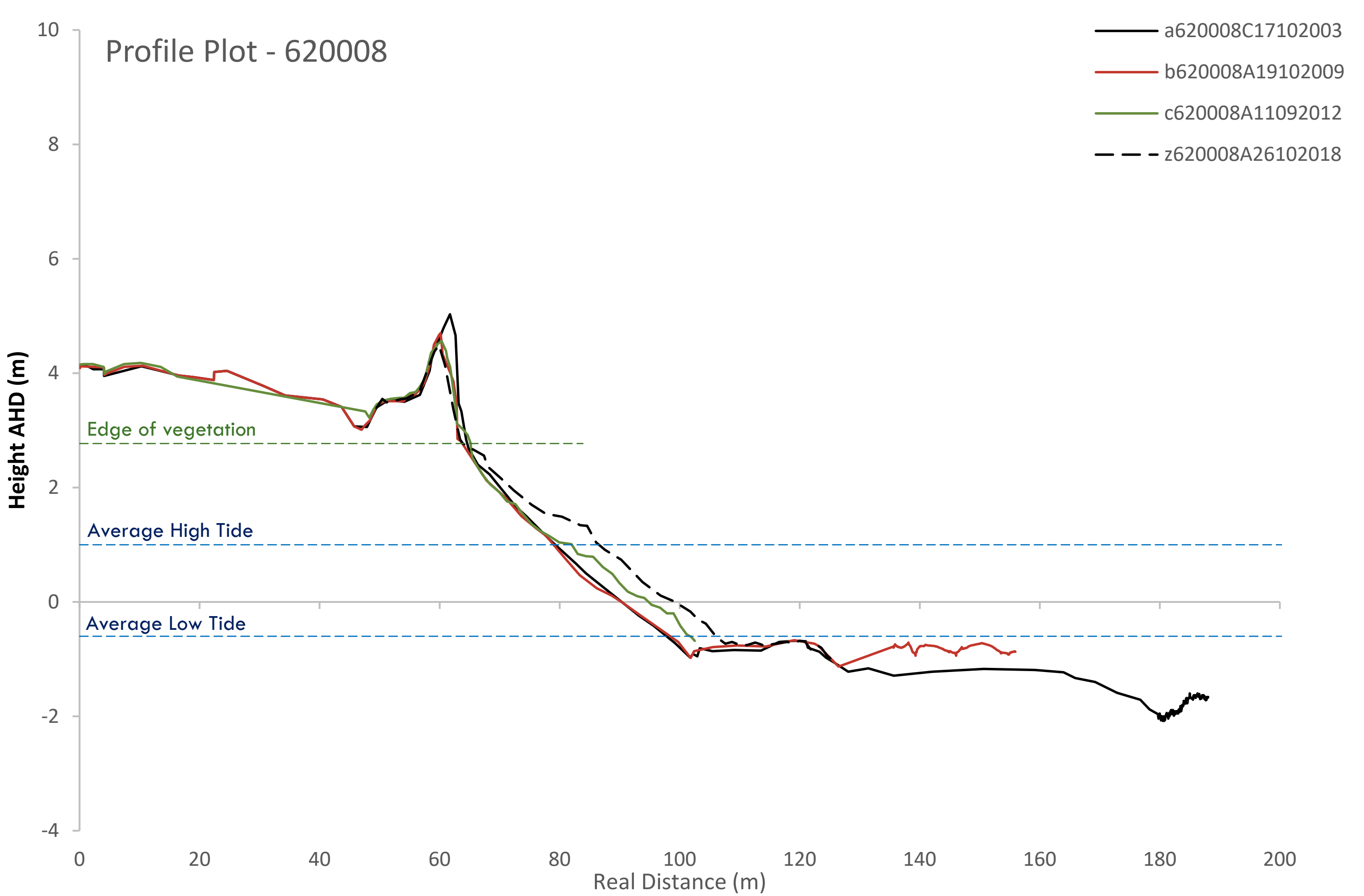
Profile line

The Esplanade Beach (Near causeway) 620008

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

This is an area where Council has been accumulating sand mixed with seaweed wrack over the last ten years.

There is a noticeable erosion of the high point of the scarp and the steep face that indicates an erosion event after 2003 which has not been repeated. The material lost has not been replaced. (Note, 2004 was a significantly 'stormy' year).



The 2018 profile is the most accretional of all of the selected profiles. However, the 2018 survey was not continued into the subtidal zone, so no comparison is possible lower than the average low tide line.

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4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11

Victor Harbor Central

Historical comparison

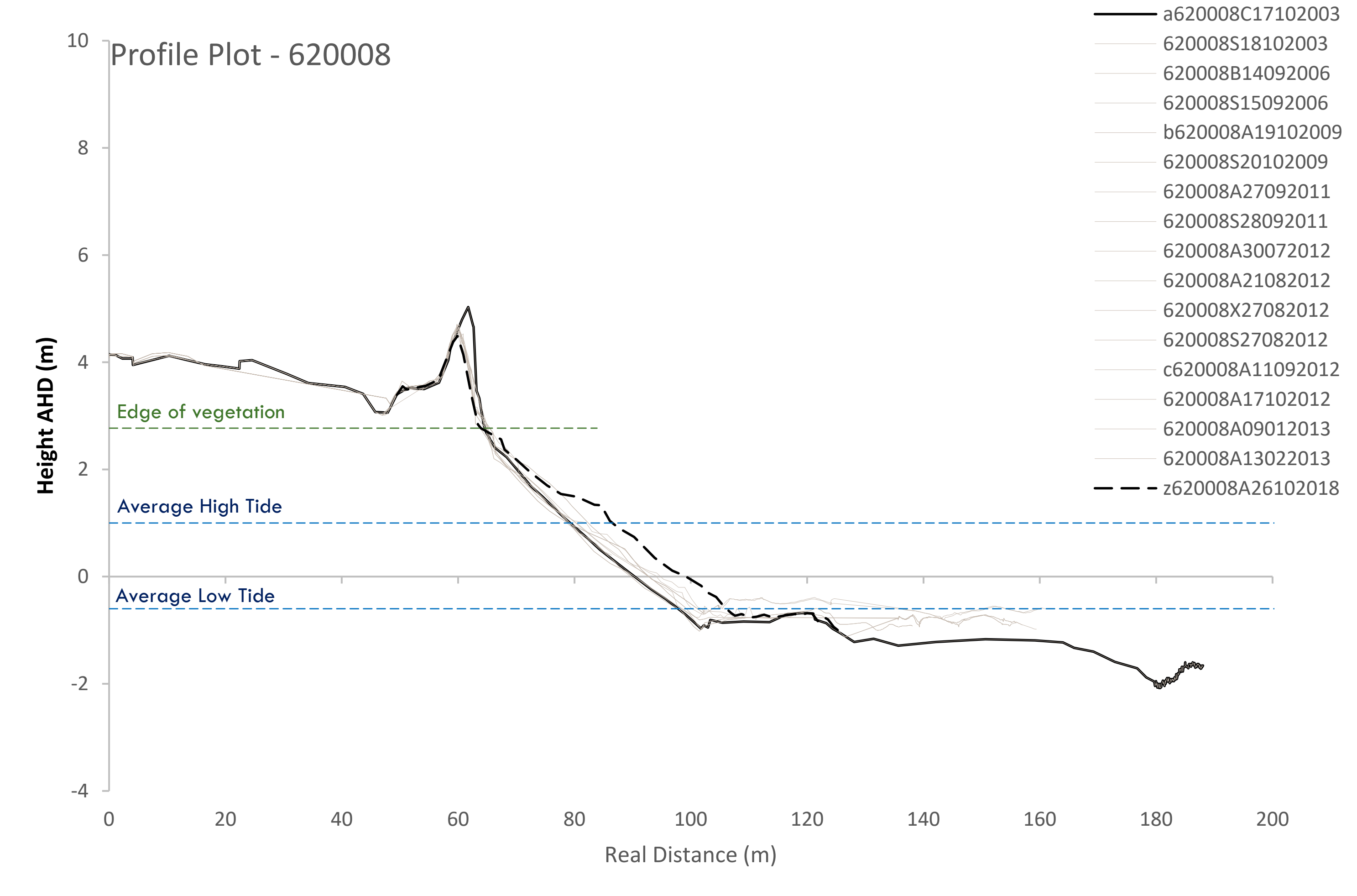
Profile line

The Esplanade Beach (Near causeway) 620008

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

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

The beach in general has moved through a horizontal range of ~5m and has steadily accreted, building seawards from 2003 to 2018.



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Note: This is an area where Council has been accumulating sand mixed with seaweed wrack over the last ten years.

4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11

Victor Harbor Central
Historical comparison

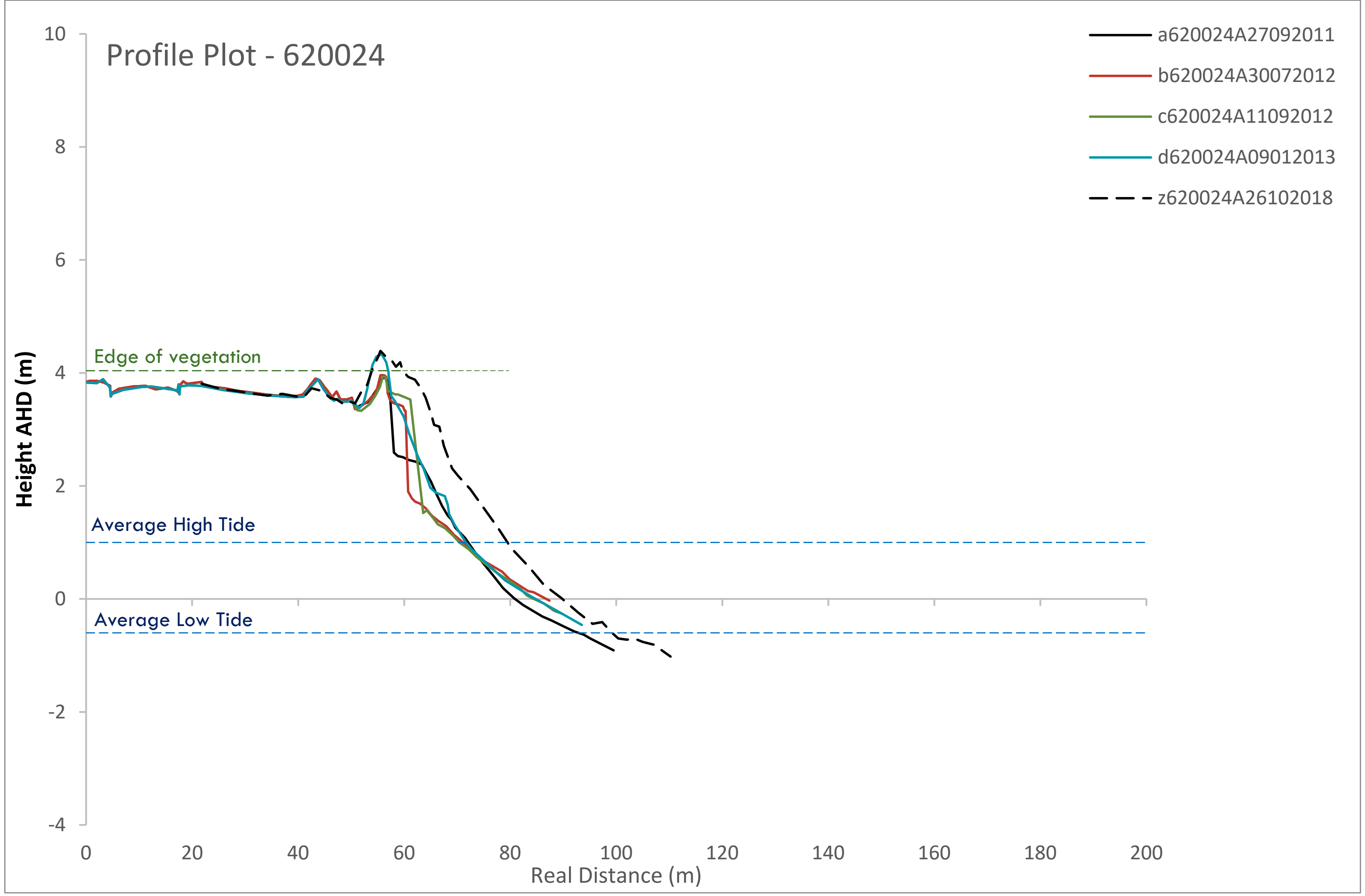
Profile line

Esplanade Beach
King Street
620024

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

This profile was initiated due to the significant erosion that occurred 2004 to 2011 (likely caused by increased storminess in this era).

This section was sand nourished in 2012 which is observed in the square edge of the 2012 profile. The beach has accreted naturally from 2013 to 2018. However, this section of coast receded ~11m in period 2004 to 2011.



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Therefore, this recent accretional pattern is mostly related to the beach recovering from a period of increased storminess (2004 to 2011), aided by the beach nourishment implemented in 2012.

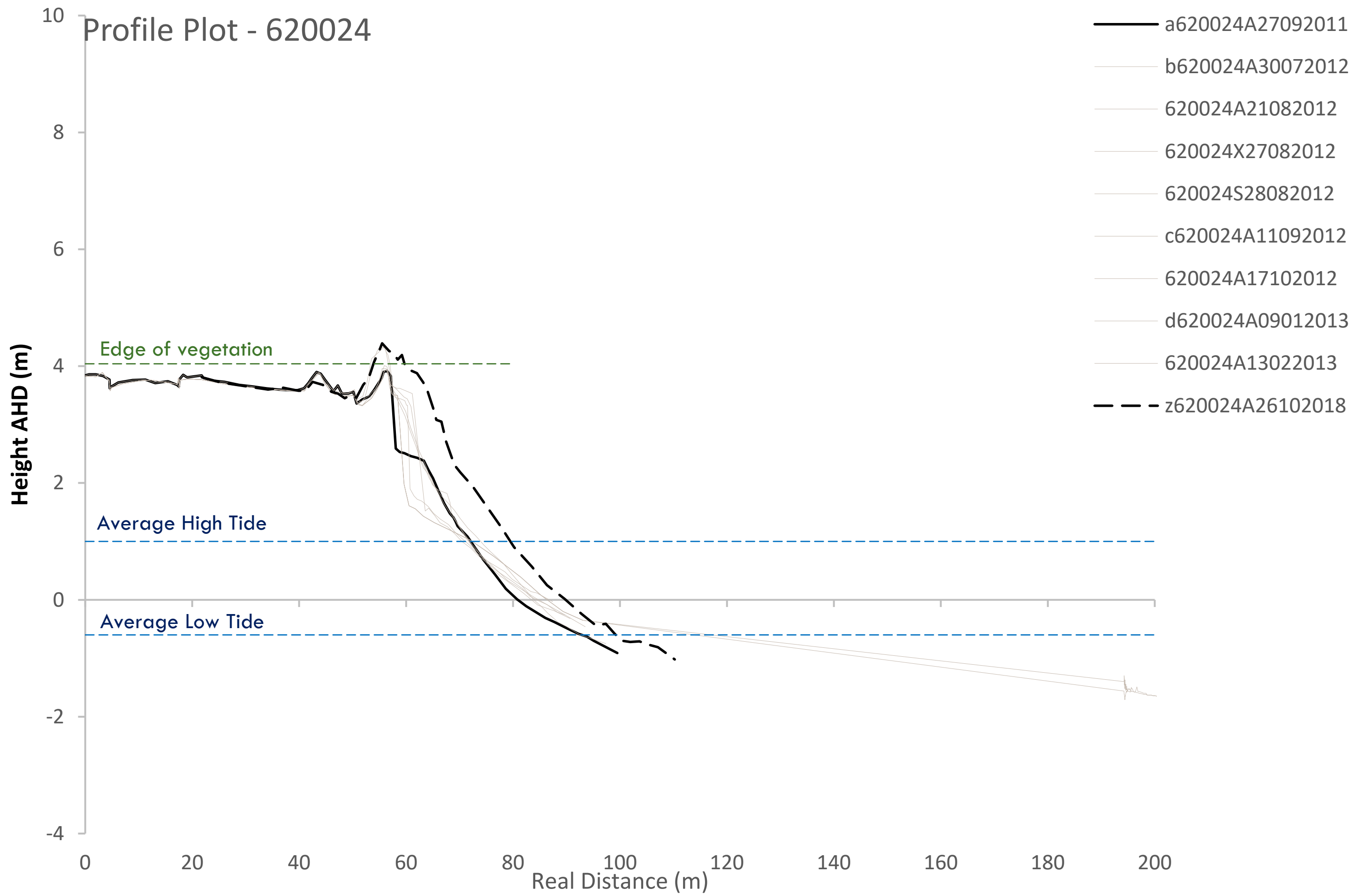
4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11

Victor Harbor Central
Historical comparison

Profile line



King Street
620024

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

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

This section was sand nourished in 2012 which is observed in the square edge of the 2012 profile. The beach has accreted naturally from 2013 to 2018. However, this section of coast receded ~11m in period 2004 to 2011.

Therefore, this recent accretional pattern is mostly related to the beach recovering from a period of increased storminess (2004 to 2011), aided by the beach nourishment implemented in 2012.

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4-3 Coastal fabric – beach profile changes (CPB)

Medium Term Changes

Fleurieu 11

Victor Harbor Central

Historical comparison

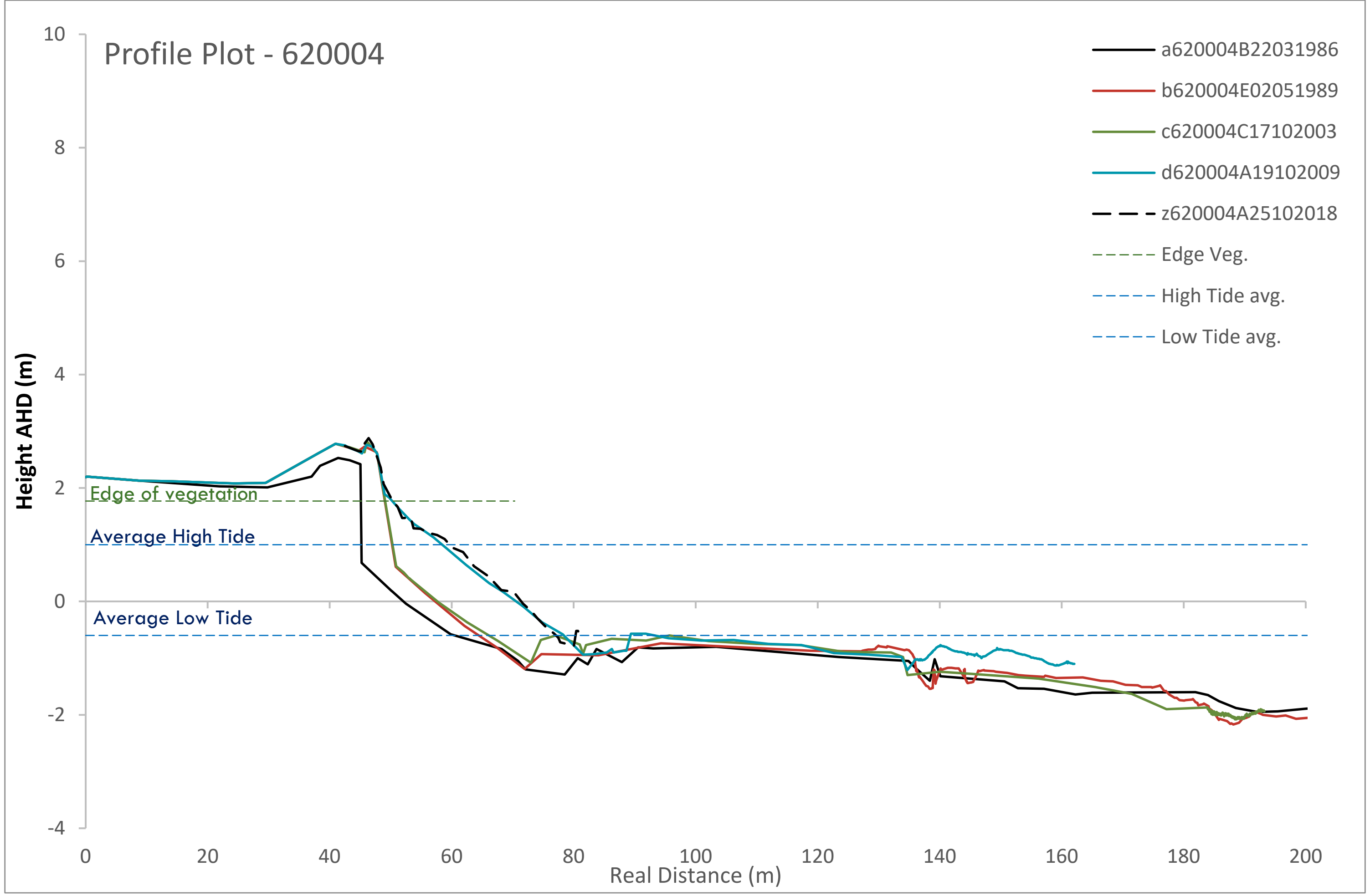
Profile line

Flinders Parade
Memorial Gardens
620004

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

Seawards of ~75m, the shoreface is seagrass/reef dominated and appears to be relatively stable.

The vertical face of in the 1986 profile relates to the presence of a seawall in this location (installed in 1920 and repaired ~1975. Subsequent to a significant storm event in 1989, rock revetment was installed. The exact correlation of the 2009 and 2018 in the intertidal zone relate to the presence of rock protection.



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Review note: in this context, the profile of 2003 does not make any logical sense. Did surveyors use upper level of 1989 and just start at the base?

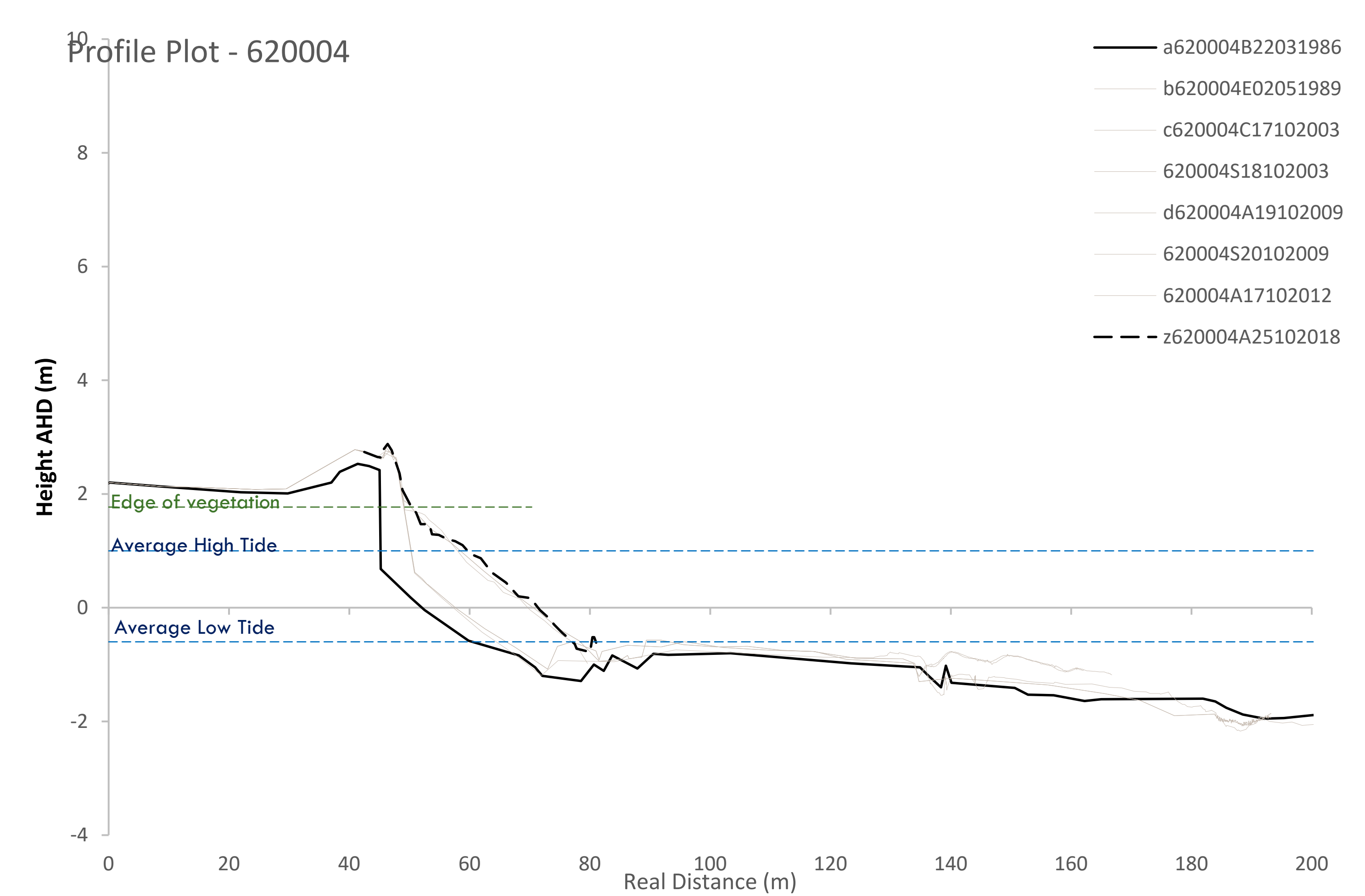
4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 11

Victor Harbor Central
Historical comparison

Profile line



Memorial Gardens
620004

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

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

Overall, the subaerial zone shows the 2009 to 2018 survey lines as almost identical.

Below the 0m AHD water line, the profiles are very similar as per the reef dominated nearshore platform.

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Summary note: The profile line above the low tide mark is now determined by rock revetment installed in 1989.

4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 11

Victor Harbor Central
Historical comparison

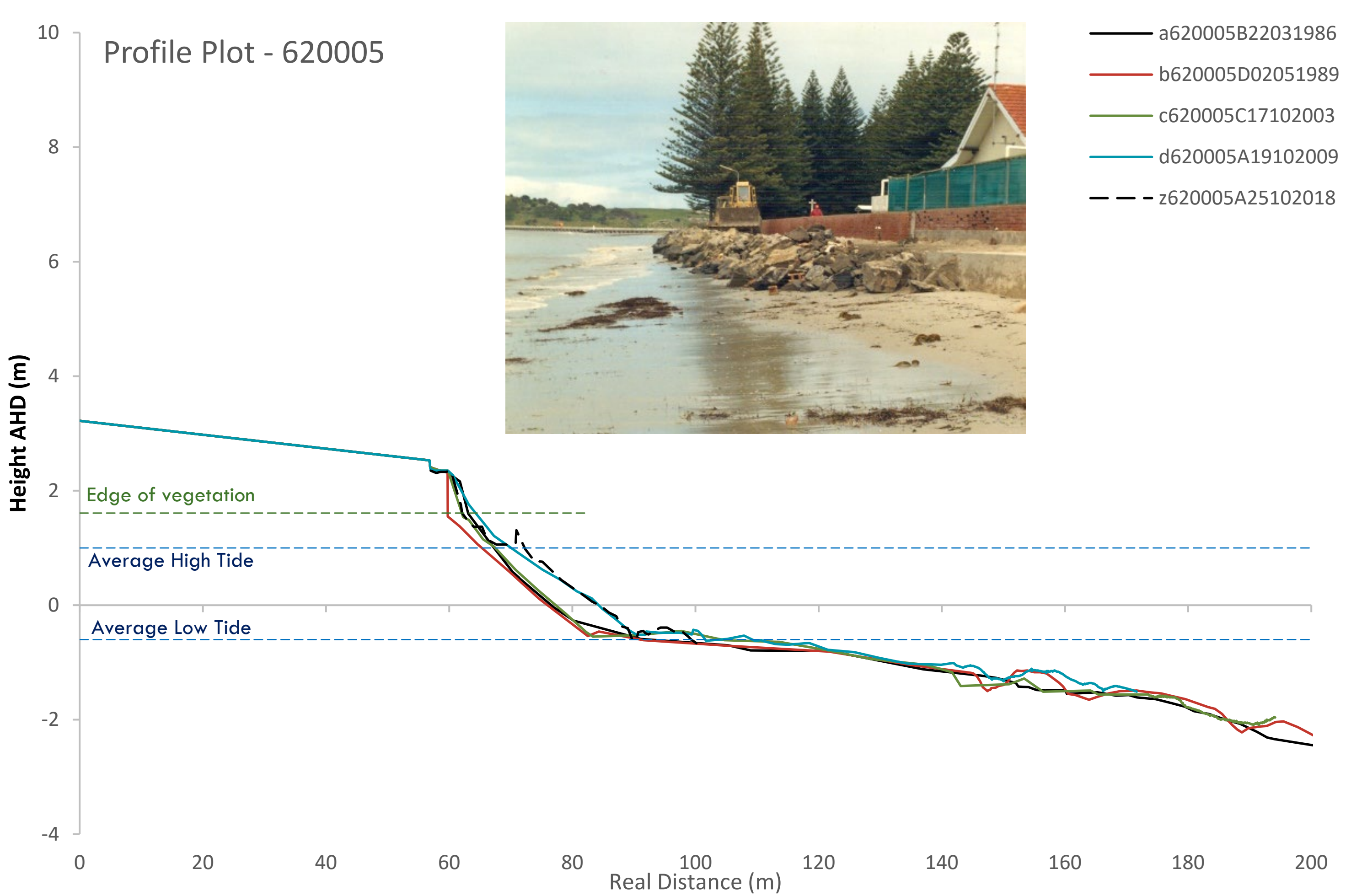
Profile line

Bowling Club
620005

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

This region has been impacted by human intervention. First in maintaining a bank under the walking path (seen as a small horizontal line at the top of the coastal slope). Rock protection was first installed in 1989 (inset picture).

More recently, since 2018, concrete blocks have been installed. Therefore, the anomaly in the 2018 line at the high tide mark is likely to relate to former rock protection.



Notes:

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4-3 Coastal fabric – beach profile changes

Medium Term Changes

Fleurieu 11

Victor Harbor Central

Historical comparison

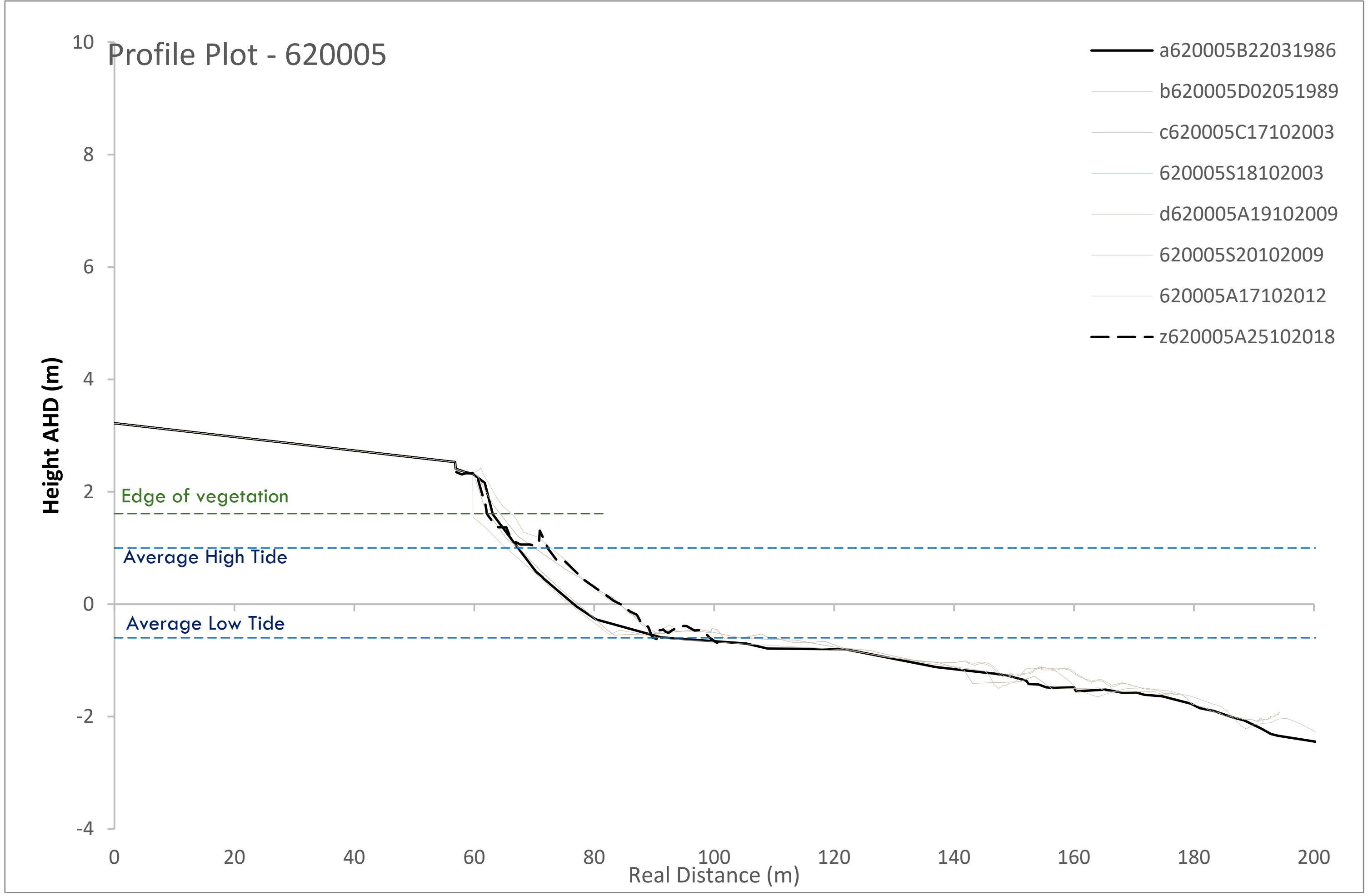
Profile line

Bowling Club
620005

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

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

This beach appears to have been very stable in the subaerial zone since 2009 and is likely related to engineering works.



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This region has been impacted by human intervention. First in maintaining a bank under the walking path (seen as a small horizontal line at the top of the coastal slope). Rock protection was first installed in 1989 (inset picture). More recently, since 2018, concrete blocks have been installed. Therefore, the anomaly in the 2018 line at the high tide mark is likely to relate to former rock protection.

4-3 Coastal fabric – beach profile changes (Coastcare)

Medium Term Changes

Cell F11

Victor Harbor Central

Historical comparison

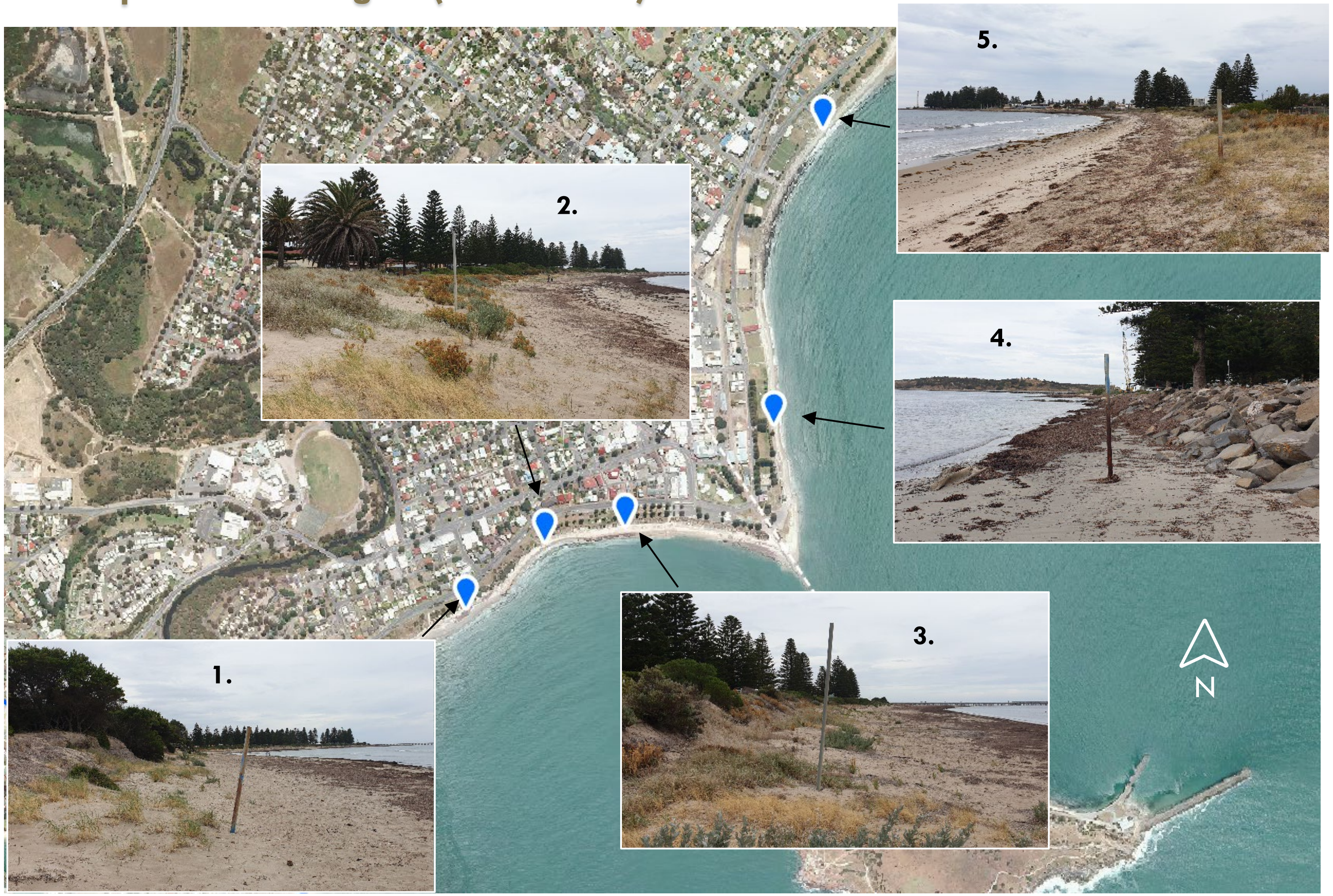
Beach poles

Coastcare

Volunteers from the community (Coastcare) have been recording sand levels at four to five beach pole locations since 2011. Measurements have been taken weekly in relationship to a designated mark on the pole. This project has identified the height of the mark in the context of Australian Height Datum (AHD) and the recorded heights have been converted to AHD. The poles may have risen or fallen slightly in height over this time.

The locations of beach poles are on the beach in the vicinity of:

(1) Island Street (Esplanade Beach)
(2) King Street (Esplanade Beach)
(3) Wills Street (Esplanade Beach)
(4) Memorial Gardens (Flinders Pde)
(5) Yacht Club (Bridge Terrace).



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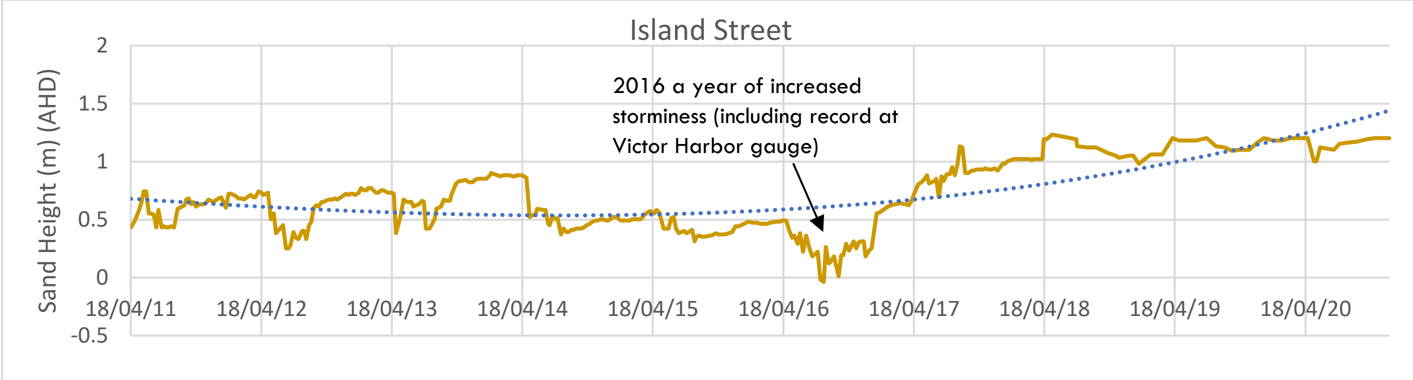
Background: The period from 2004 to 2011 was a characterised by increased storminess and increased erosion of beaches. Therefore, this monitoring program was instituted in 2011and managed very effectively by volunteers. However, since 2011 the storminess has subsided, and the beach levels have progressively recovered. The exception to this trend is the pole at Soldiers' Memorial Gardens where sand levels have continued to decline. Note, this beach pole is set lower on the beach profile than all others.

4-3 Coastal fabric – beach profile changes (Coastcare)

Esplanade Beach

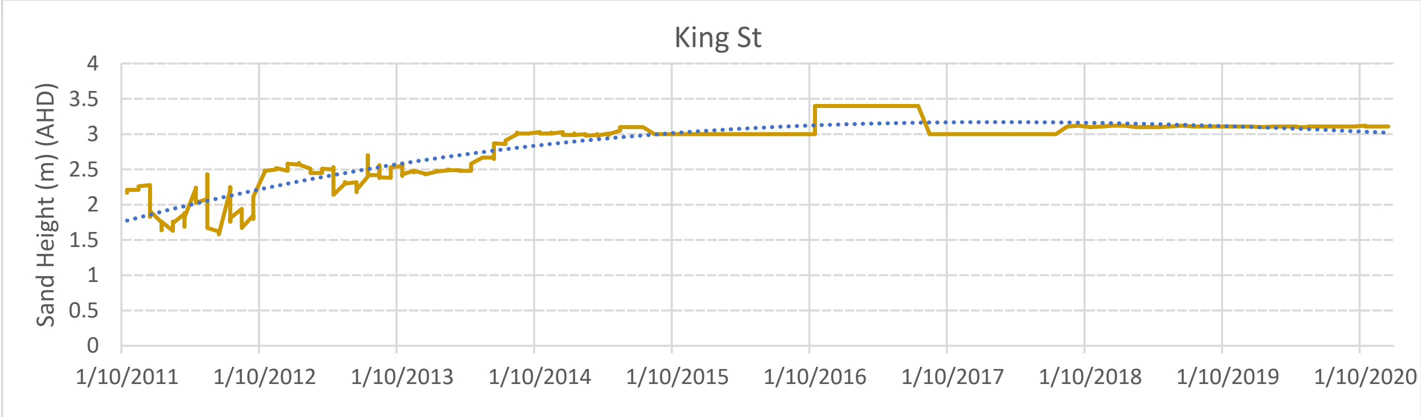
Island Street

This pole is positioned on the beach several metres seaward of the vegetation line (see photo previous page). This section of beach underwent some erosion 2004 to 2011. Sand levels have stabilised since 2011 and increased after 2016 (which was a year of increased storminess). The winter cycles of lower sand levels are observed up until 2016.



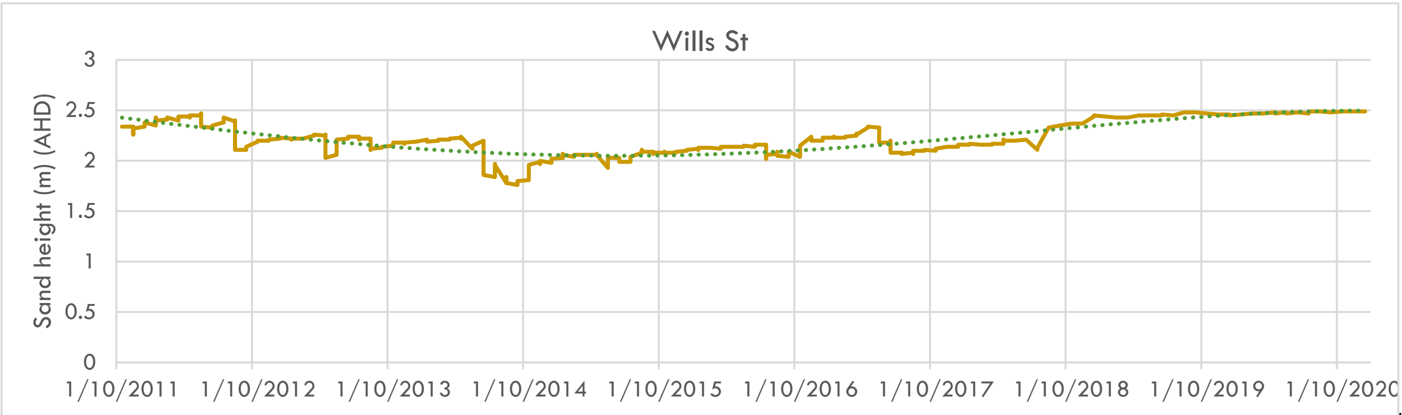
King Street

This pole is positioned within the dune slope (see photo previous page). This section of beach underwent significant erosion 2004 to 2011 and it is likely when the pole was installed that it was on the beach (not dune). Sand levels have recovered since and the dune rebuilt. These findings are congruent with DEM comparison and shoreline analysis.



Wills Street

This pole is positioned on the beach several metres seaward of the vegetation line (see photograph on previous page). This area was less impact by erosion in 2004 to 2011. The winter sand cycles are observed in most years. These findings are congruent with the DEM comparison (which shows no increase in sand levels and shoreline analysis, which shows little movement).

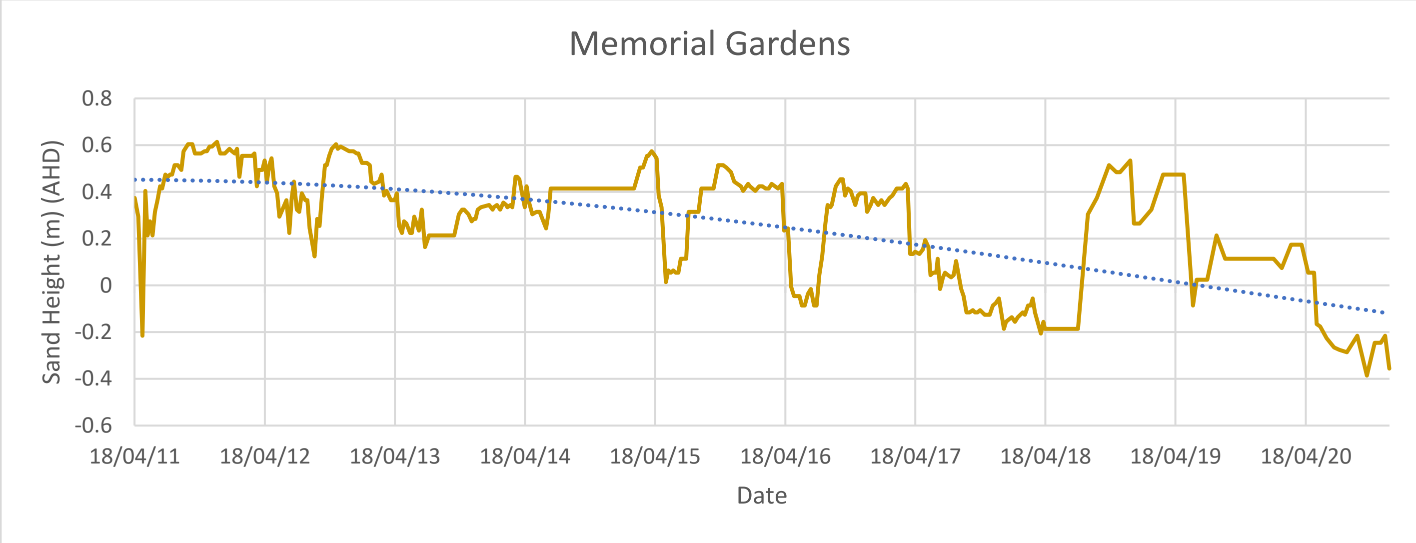


4-3 Coastal fabric – beach profile changes (Victor Harbor Coastcare)

Flinders Parade – Bridge Terrace

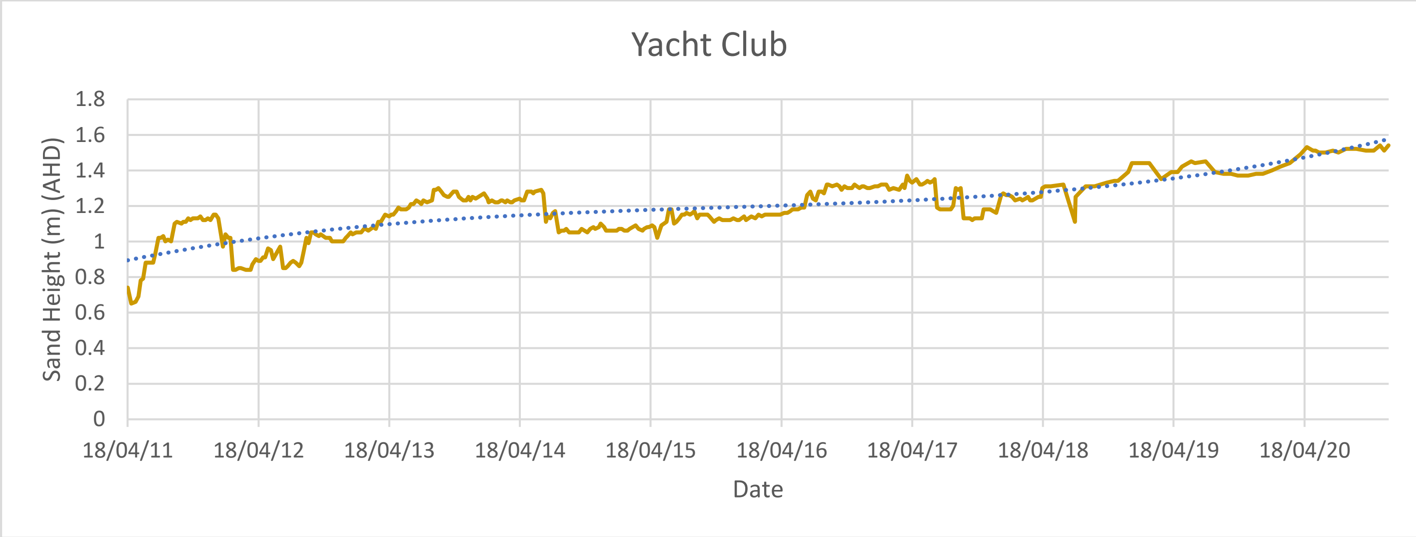
<u>Soldiers' Memorial Gardens</u>

This pole is positioned on the beach several metres approximately 2m seaward of the base of the rock protection which was installed in 1989. Therefore, in the context of all the beach poles this pole is positioned at the lowest point on the beach profile in the intertidal zone. The lower sand levels are evident in relation to winter cycles. Overall, the sand levels on the beach have been declining in this location from 2011 to 2020. This trend is more difficult to identify in the profile analysis (note – the 2018 profile line concluded at the low tide mark).



<u>Yacht Club</u>

This pole is positioned a few metres above the current wave runup area. However, in 2011 it may have been in this location of the beach profile. The long-term trend since 2011 is for increasing sand levels in the location of this beach pole.



4-4 Coastal fabric – human intervention (Cell 11.1)

MODIFIED COASTS

Background: 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 The Esplanade Beach are noted below.

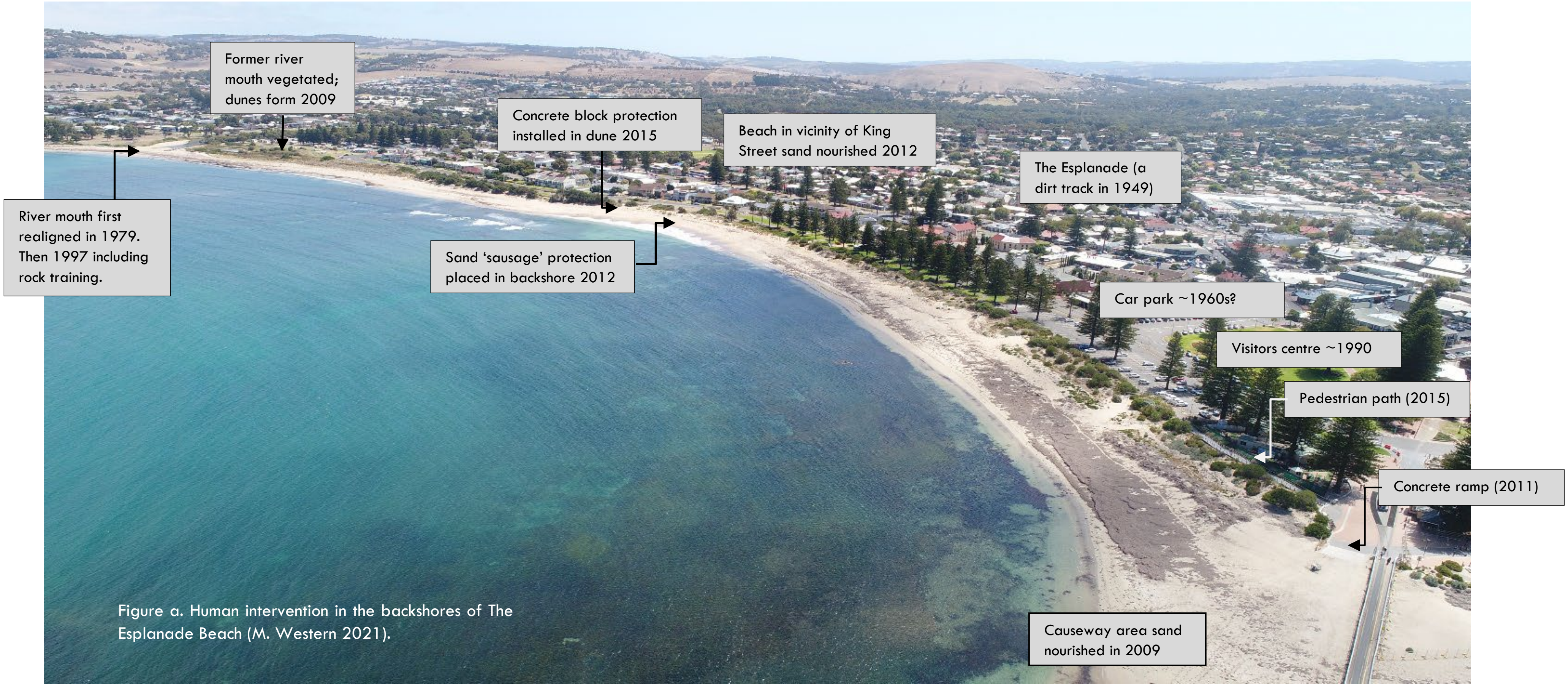


Figure a. Human intervention in the backshores of The Esplanade Beach (M. Western 2021).

4-4 Coastal fabric – human intervention (Cell 11.1)

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:

Coastal Open Space

Coastal Conservation zoning controls all development in the foreshore area. Referrals are required to SA Coast Protection Board.

Caravan Park

A zone for short term tourist accommodation. In areas prone to flooding… buildings and structures should be designed and constructed so that they can be removed in the event of a hazard.

Residential Zoning (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. Setbacks from roads are not specifically assigned (apart from diagram p. 201).

Regional Centre Zone (Visitor Facilities Policy 11)

Tourist related activities – hospitality, accommodation, tourist retail, visitor facilities. Setback required from The Esplanade is 3m to 4.5m depending on structure.

Referrals:

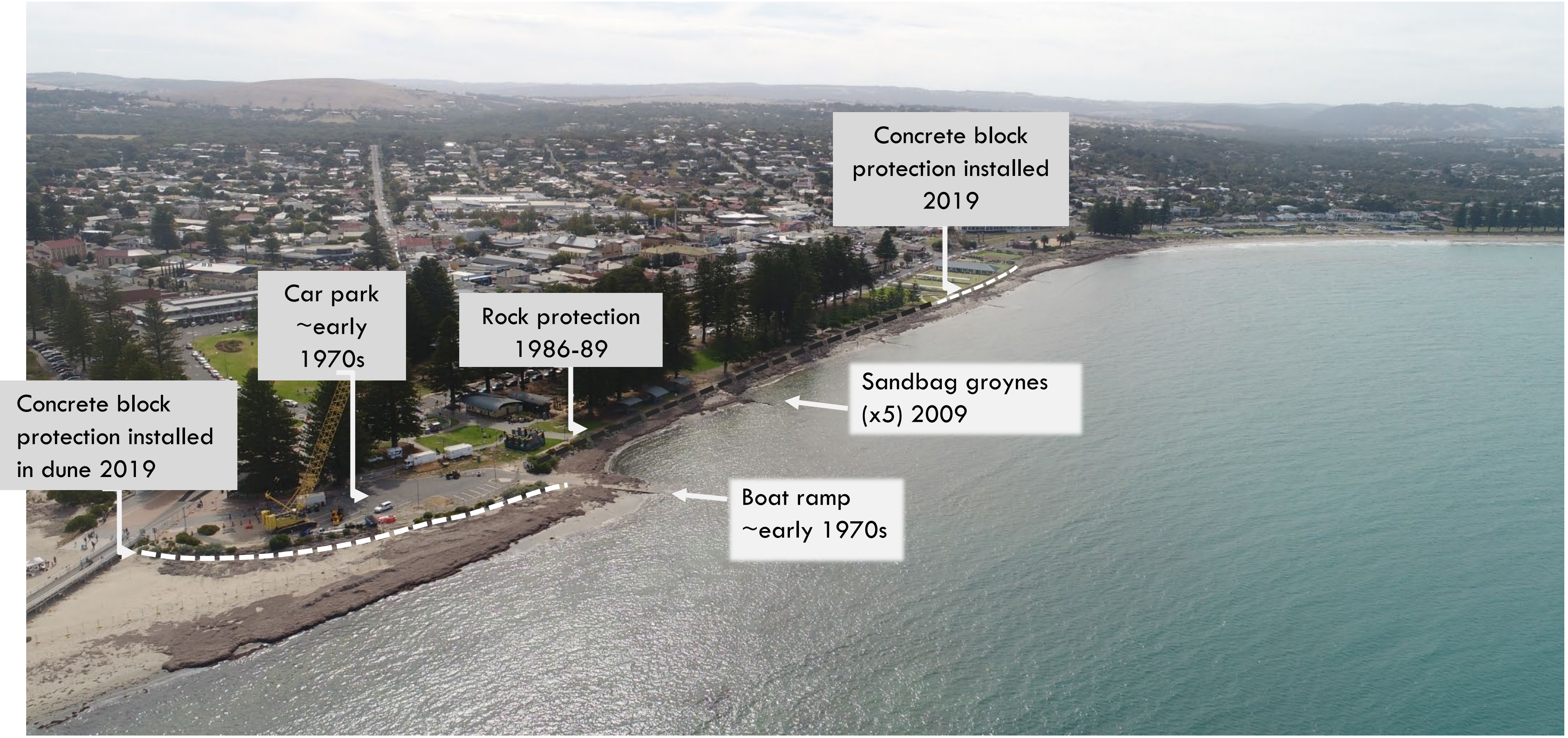
There is no requirement to refer any development proposal to the SA Coast Protection Board that is situated behind the Coastal Open Space Zone.

Waterfront Policy 24 (Residential) applies to the first row of houses (and sometimes the second row of houses) landward of The Esplanade.

4-4 Coastal fabric – human intervention (Cell 11.2)

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.



4-4 Coastal fabric – human intervention (Cell 11.2)

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:

Coastal Open Space

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

Residential Zoning (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. Setbacks from roads are not specifically assigned (apart from diagram p. 201).

Regional Centre Zone (Town Centre Character Policy 9)

Community and recreation facilities, historical transportation facilities – hospitality, accommodation, tourist retail, visitor facilities. Setback required from The Esplanade is 1.5m to 3.0m depending on the type of structure.

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.

Waterfront Policy 24 (Residential) applies to the first row of houses (and sometimes the second row of houses) landward of Bridge Terrace.

4-4 Coastal fabric – human intervention

WORKS AND STRATEGIES

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

- Protection works have been installed at various locations.
- Sandbag groynes and sand 'sausage' installed along The Esplanade and Flinders Parade beaches.
- Sand nourishment programs have been carried out on most beaches (Sand dunes in front of the caravan park, beach at King Street, the causeway, Soldiers Memorial Gardens.
- Formal access ways have been established and the numbers rationalised since 2013 (report by AWE).
- Vegetation programs and weed controls have continued to maintain improving vegetation of dunes.
- Storm water piping was installed to dune system in vicinity of King Street (after report by AWE in 2013).
- Excess seaweed wrack is combined with sand and deposited in the backshore of The Esplanade beach.
- Beach poles have been installed at five locations along the beaches and volunteers have been collecting sand level data since 2011.

Project notes

Increased erosion that occurred post 2000 was the impetus for many of the works. 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.

Figure a. Police Point (the causeway) M. Western, 2021

4. Coastal fabric – summary table

Victor Harbor Central (Cell 11)

Victor Harbor Central		Coastal context - natural				Modified	Coastal changes			
Cell	Location	Bathymetry	Benthic	Beach	Backshore	Human	70 years	10 years	**Erodibility**	**General notes**
11.1	Inman River to Police Point (the causeway)	Slope 1:300 (-5m at 1500m offshore). Slope of seabed increases seaward of Granite Is.	Nearshore and surf-zone dominated by sand, covered by continuous and patchy seagrass beds. Offshore is a low profile continuous or patchy reef.	Fine to medium sand beach	Narrow low height vegetated dunes 3.5m -4.5m AHD, behind which reserve/car park positioned and esplanade road at 3.5m to 4.5m AHD. The Esplanade set back ~60m	Extensive dune field removed in 1800s. Storm water outlets at low elevations prevent dune from forming in these locations.	Sand dunes reinstated to Esplanade Beach. Overall shoreline receded in King Street location but accreted near causeway.	The shoreline receded 2007 to 2011 especially in King Street region, in last seven years sand levels have recovered.	High	Increases storminess in period of 2007 to 2011 caused significant erosion. Sand levels have returned over the last few years and shoreline position accreted a little.
11.2	Police Point (causeway) to Hindmarsh River.	Slope 1:100 (-10m at 1000m offshore).	Nearshore and surf-zone dominated by sand, covered by dense seagrass beds. Offshore is dominate by sand with patchy seagrass cover.	Fine to medium sand beach	Rock or concrete seawall from causeway to bowling club, then very narrow, low height dune (7m to 8m wide) backed by walking path and playing fields.	Sand dunes removed or flattened for gardens and clubs. Hard protection to gardens and bowling club.	Seawall installed in 1920, replaced with rock 1989. Shoreline north of the playing fields has accreted.	Sand levels declining adjacent rock revetment. Shoreline north of playing fields very stable since 1999.	Moderate-high (partially protected)	The Soldiers Garden and bowling club were vulnerable to inundation prior to installation of the wall and promenade in 1920. Storms have repeatedly overtopped this area.

Erodibility Rating: Moderate-high (2-3) (due to partial protection)

Victor Harbor Central: key points

The backshores have been extensively modified with the removal or flattening of a significant dune field. These have been replaced by parks, playing fields and roads. Esplanade roads are set back ~60m which means the main issue in the context of sea level rise will be for Council will be to manage its own assets. Most of Victor Harbor has been built on softer sediments of sand and glacial deposits. The shallow water dissipates the wave energy by the time waves reach the shore. The installation of the breakwater may have changed the angle of refraction of waves around Granite Island and increased erosion in vicinity of the gardens/bowling club. From 1920s onward this region has been protected but remains subject to overtopping. A stormy period between 2007 and 2011 caused significant erosion to Esplanade Beach.

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 from the Southern Ocean by Rosetta Head and Granite Island, Nature Maps (SA) has assigned the exposure rating for Encounter Bay as 'sheltered' and the wave height as 'low'.

Storm surges

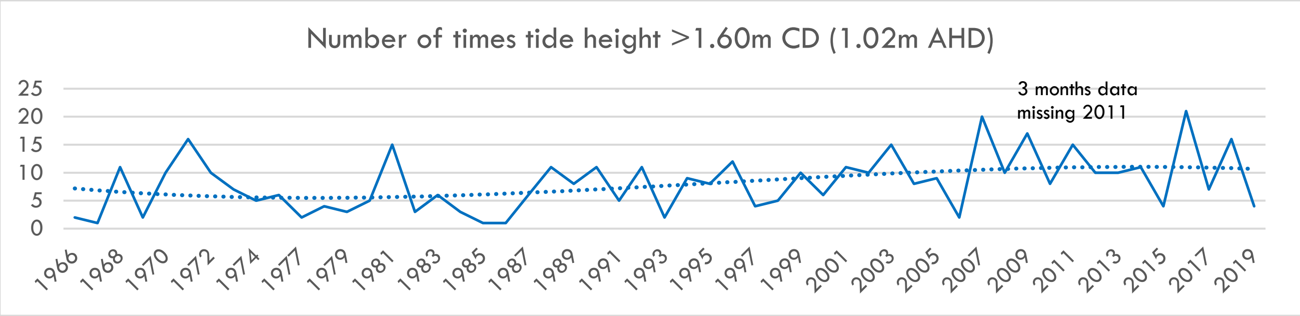
Despite this protection, when a number of meteorological conditions combine, storm surges can produce water levels up to 1.0m higher than the predicted astronomical tide. To manage the risk of these events upon human infrastructure, SA Coast Protection Board has set storm surge policy risk levels for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

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

Routine high water

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

Figure a: 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[2] at on average rate of 1.7mm per year. The average level of the ocean is known as *global mean sea level* (GMSL). Changes in global sea level occur due to melting ice and the thermal expansion of the ocean water mass. While the average rate of rise was 1.7mm over the last century, this rate of rise was not constant. Rates of sea level rise were higher in the period 1920s to1940s[5] (in the context of higher global temperatures and melting of the Greenland ice sheets[6]). Over the following decades the rate of sea level slowed but in the 1990s sea levels again rose at a faster rate, comparable to that of the 1930s era. 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.

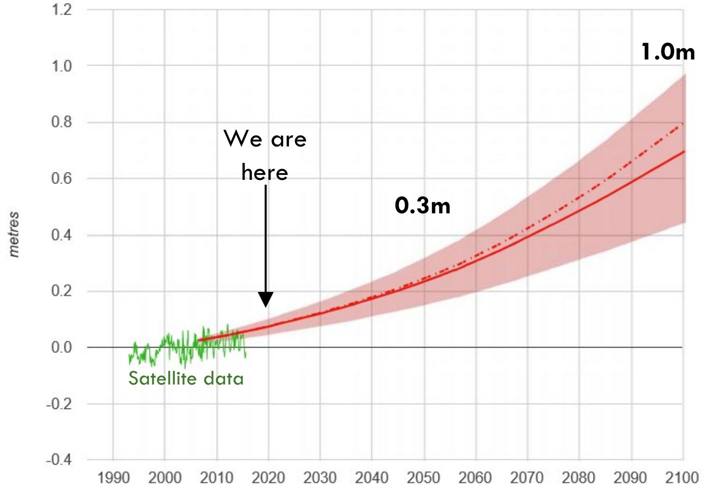


Figure a: Sea level rise high emissions scenario (RCP 8.5) and including SA Coast Protection Board sea level rise policy projections (Adapted from CoastAdapt, 2017)

[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 11

Victor Harbor Central

Coastal Exposure

Overview

SA Classification (Nature Maps)

Cell: Fleurieu 11

11.1 Victor Harbor Central South

Relative Exposure:
Sheltered
Wave energy:
Low
Shoreline class
Reflective

11.2 Victor Harbor Central North

Relative Exposure:
Moderate
Wave energy:
Low
Shoreline class
Low Tide Terrace

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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 (archives)

The settlement history section (ps. 7,9,12-15) has described previous storm events in detail. Generally, the historical storm record shows that storm activity was more prevalent in the 1920s to 1940s, quieter in the 1950s to early 1970s, and escalated again thereafter. The impacts of numerous historical storms are recorded for Soldiers Memorial Gardens and the playing fields. Only one incident is recorded which impacted the Esplanade Beach in a significant way (2 Oct 1928) but at the time there were no sand dunes in the backshore. In particular, we observe increased impacts from storms after 1990 (especially within the Encounter Bay region, the installation of the cycleway/carparks accompanied by increases in width and height of the embankment in the backshore may also be a factor).

There are two main ways in which the coastline can be impacted by storm activity. The first relates to storms that coincide with high astronomical tides and which are accompanied by winds from the south-west to south-east. These winds cause 'mounding up' of water along the coastline (known as a storm surge). The five highest storm surges on record since 1965 at the Victor Harbor tide gauge occurred[7]:

- 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

However, the storm damage archives are <u>not</u> correlated with any of these events. The event of 14 May 1987 (third highest on record) is the only event in which we have photographic evidence (Figures a, b, c). Significant swell action is not observed in any of these photographs. In fact, the water adjacent Soldiers Memorial Gardens is best described as 'still' due to its position in the lee of the south-west wind.

Figure b. Soldiers Memorial Gardens. Third highest recorded storm on 14 May 1987. (Photograph - Coast Protection Board, 19870514).

Figure c. Inman River. Third highest recorded storm on 14 May 1987. (Photograph - Coast Protection Board, 19870514).

Figure a. Esplanade Beach. Third highest recorded storm on 14 May 1987. (Photograph - Coast Protection Board, 19870514).

[7] Measured in Chart Datum (i.e. from tide charts).

5. Coastal exposure – previous storm impact

COASTAL STORMS

The second major factor that causes damage to the Victor Harbor coastline is the swell size from the Southern Ocean. Swell waves generated in the Southern Ocean to the south-west of Australia have been recorded as the largest of any in the world's oceans[8]. When larger swells combine with higher astronomical tides the damage to the coast can escalate considerably.

The impact along The Esplanade Beach and Kent Reserve is experienced from waves driven directly by the wind through the gaps between Granite Island and Wright Island. The overtopping that occurs along Soldiers Memorial Gardens and the playing fields is generated by large swells that refract around the breakwater and impact the beach (Figures a, b, c).

Professor Bourman (geomorphology section) holds the view that the formation of the sand spit (Police Point) is explained by these contrasting wave patterns. He also suggests that the construction of the breakwater has changed the angle of wave refraction and this may account for the increased erosion and overtopping at Soldiers Memorial Gardens and the playing fields.

Figure a (top). Wave refraction pattern around the breakwater (M. Keates in The Times, 25 June 2017).

Figure b (middle). Large swells overtopping the breakwater, smaller swells reaching the shore along Flinders Parade (Dani Brown in The Times, 25 June 2017).

Figure c (bottom). Surfing along Flinders Parade on the swell reduced in size (Dani Brown in The Times, 25 June 2017).

[8] Pattiaratchi C. and R. Jones (2005).

[9] Australian Water Environments (2013), Victor Harbor Coastcare submission (2021), and the opinion of this project.

Stormy period (2007 to 2011)

Erosion was particularly prevalent along Esplanade beach from 2007 to 2012. The dominant theory of the time was that sand supply was prevented from moving eastwards past the rock training wall that was installed when the Inman River mouth was realigned in 1997. In an effort to retain sand supply on the beach, sandbag groynes were installed in 2009 and sand nourishment applied to the groynes. It is generally agreed that the groynes were ineffective in retaining sand on the beach and preventing erosion of the backshore[9].

The conclusion of this project is that the larger contributing factor of the erosion was increased 'storminess' from the Southern Ocean in this time period. Integrated Coasts evaluated the tide gauge record and found that there was an increased periodicity of higher storm events in the period 2007 to 2011. It is likely that the repeated higher storm and tidal action caused sand loss from which the beach was unable to recover (See graph next page).

Dr Phil Watson has evaluated tide gauge data around Australia to identify longer-term sea-level rise trends with a focus on gauges that have capture periods longer than 70 years so as to reduce the 'noise' of natural variability in the data[10]. Therefore, the Victor Harbor tide gauge does not qualify for this type of analysis but as a contribution to this project Dr. Watson

[10] Watson, P.J., (2011, 2020)

5. Coastal exposure – previous storm impact

COASTAL STORMS

applied a 20-year analysis time frame to the data to identify mean sea level rise trends (Figure b). A more rapid increase in sea level is observed post 2005, but it is important to remember that this analysis also includes normal variability rather than being indicative of a longer underlying trend of a rate of sea level rise.

Without dismissing the issue of sand littoral supply entirely, it is likely that the erosion of the beach was primarily caused by increased exposure at a periodicity from which the beach was unable to recover. It is unlikely that sandbag groynes would be an effective control measure in this context.

The screen shot below from a video of a moderate storm of 4 June 2012 at only 1.35m CD (0.77m AHD) shows wave action impacting the backshore (Figure c).

Figure c (above). Storm action on 4 June 2012 was not a significantly high tide (1.35 CD), but after 4-5 years of storm action, low sand levels on the beach means increased impact on the backshore

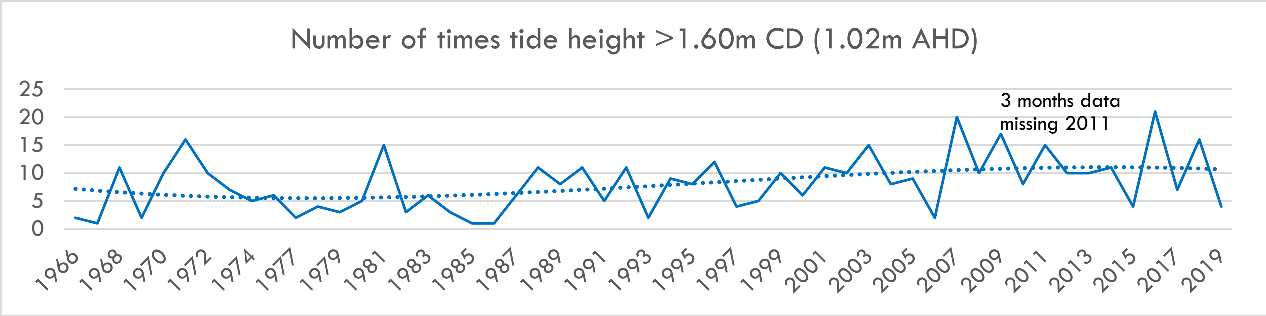

Figure a (above). Number of times Victor Harbor exceeded 1.60m CD (1.02m AHD) from 1965 to 2019.

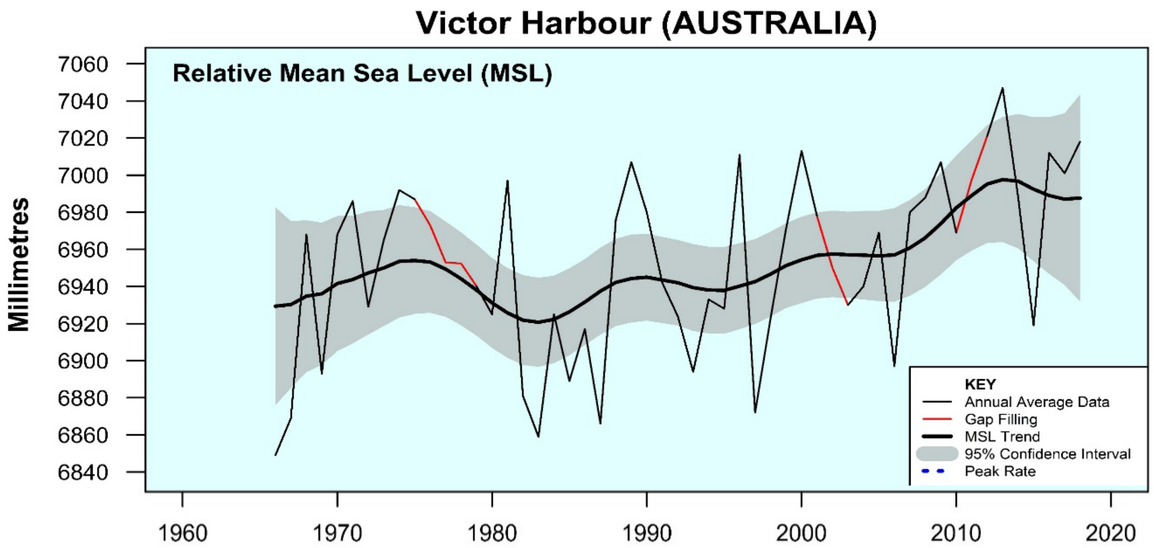

Figure b (right). Relative mean sea level rise using 20-year time frame analysis. Dr P. Watson advises that a 50-year time frame analysis is required to determine the rate of sea level rise that is less impacted by natural variability. The application to this study is the observed increase in rate post 2005 which correlates to the increased erosion of Esplanade Beach. Source: Dr. P. Watson (email correspondence).

5. Coastal exposure – location map (Cell 11.1a)

Location

Fleurieu 11.1a

Victor Harbor Central

Location Map

Inman River Area

The scenarios modelled are:

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

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
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 11.1a

Victor Harbor Central

2020 scenario

Event: Routine high water

Inman River Area

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 model is rendering this event with too much depth. This is probably because wave set up and wave runup would not penetrate into this region for this event.

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5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 11.1a

Victor Harbor Central

2050 scenario

Event: Routine high water

Inman River Area

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	0.30m
Total risk	1.60m AHD

Wave run-up of 0.30m is included.

Assessment: The model is rendering this event with too much depth but correctly at the shoreline. This is probably because wave set up and wave runup would not penetrate into this region for this event.

The caravan park is not flooded in this scenario.

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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 – routine high water (2100)

Routine high water

Fleurieu 11.1a

Victor Harbor Central

2100 scenario

Event: Routine high water

Inman River Area

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.

Assessment: The model is rendering flood too deep within the estuary, but correctly at the shoreline. Making allowances for this:

- Kent Reserve – depth 0.20m
- Caravan Park where shown – depth 0.60m

The impact of routine high-water events of this depth would erode the frontal dunes away.

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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 11.1a

Victor Harbor Central

2020 scenario

Event: 1 in 100 sea-flood risk

Inman River Area

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 model is rendering flood too deep within the estuary, but correctly at the shoreline. Making allowances for this:

- Minor flooding into Kent Reserve
- Caravan park probably not flooded.

Impact on the dunes would be significant but likely to recover as this scenario is a rare event.

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 11.1a

Victor Harbor Central

2050 scenario

Event: 1 in 100 sea-flood risk

The Inman River Area

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 model is rendering flood too deep within the estuary, but correctly at the shoreline. Making allowances for this:

- Kent Reserve – 0.20m deep.
- Caravan park flooded at depths ~0.60m where shown.

Impact on the dunes would be significant and unlikely to recover if seas rise as projected.

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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 11.1a

Victor Harbor Central

2100 scenario

Event: 1 in 100-year event

The Inman River Area

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: The model is rendering flood too deep within the estuary, but correctly at the shoreline. Making allowances for this:

- Kent Reserve – ~1.0m deep.
- Caravan park flooded at depths ~1.30m where shown.

If seas rise as projected, the frontal dunes will be eroded away in Kent Reserve and on Victor Harbor side.

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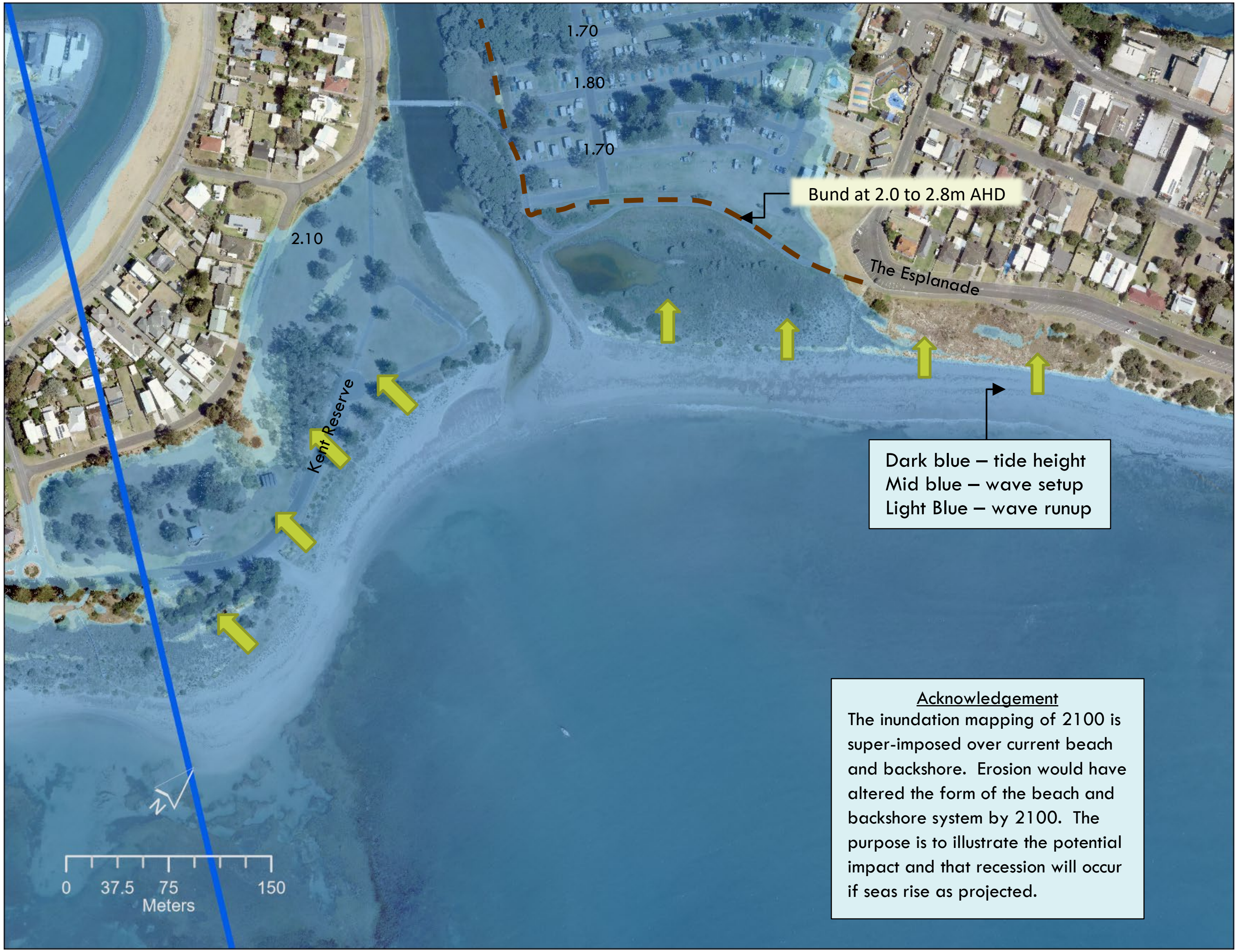

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – summary (Cell 11.1a)

Summary

Fleurieu 11.1a

Victor Harbor Central

Summary

The Inman River Area

2020-2050

The current 1 in 100-year storm surge event would have impact on dunes but these are likely to recover. Sea levels 0.30m higher than present are likely to cause some recession of the dunes. The earthen bund around the caravan park is likely to protect the caravan park to 2050.

2050-2100

Seas levels at 1.0m higher than present would cause significant flooding of Kent Reserve and the caravan park. The frontal dunes in Kent Reserve and the dunes to the front of the caravan park and The Esplanade would be eroded away.

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5. Coastal exposure – location map (Cell 11.1b)

Location

Fleurieu 11.1b

Victor Harbor Central

Location Map

The Esplanade Beach

The scenarios modelled are:

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

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Sheltered

Wave energy:
Low

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5. Coastal exposure – routine high water (2020)

Routine high water

Fleurieu 11.1b

Victor Harbor Central

2020 scenario

Event: Routine high water

The Esplanade Beach

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

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

The event modelled:

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

Wave run-up of 0.30m is included.

Assessment: The modelling is congruent with observations and the current impact on beach on the western side but may be too low on eastern side.

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5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 11.1b

Victor Harbor Central

2050 scenario

Event: Routine high water

The Esplanade Beach

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	1.30m AHD
Sea level rise	0.30m
Wave set-up	0.30m
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 the dunes/ vegetation line to recede. (Note, the modelling may be rendered too low for this event).

Note the lower sand levels in locations of storm water outlets.

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5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 11.1b

Victor Harbor Central

2100 risk:

Event: Routine high water

The Esplanade Beach

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

Wave run-up of 0.30m is included.

Routine highwater events at 1.0m higher than present would cause significant recession of the dunes. Either they would retreat (and only if there were no hold points in the backshore) or be eroded away. The latter is more likely.

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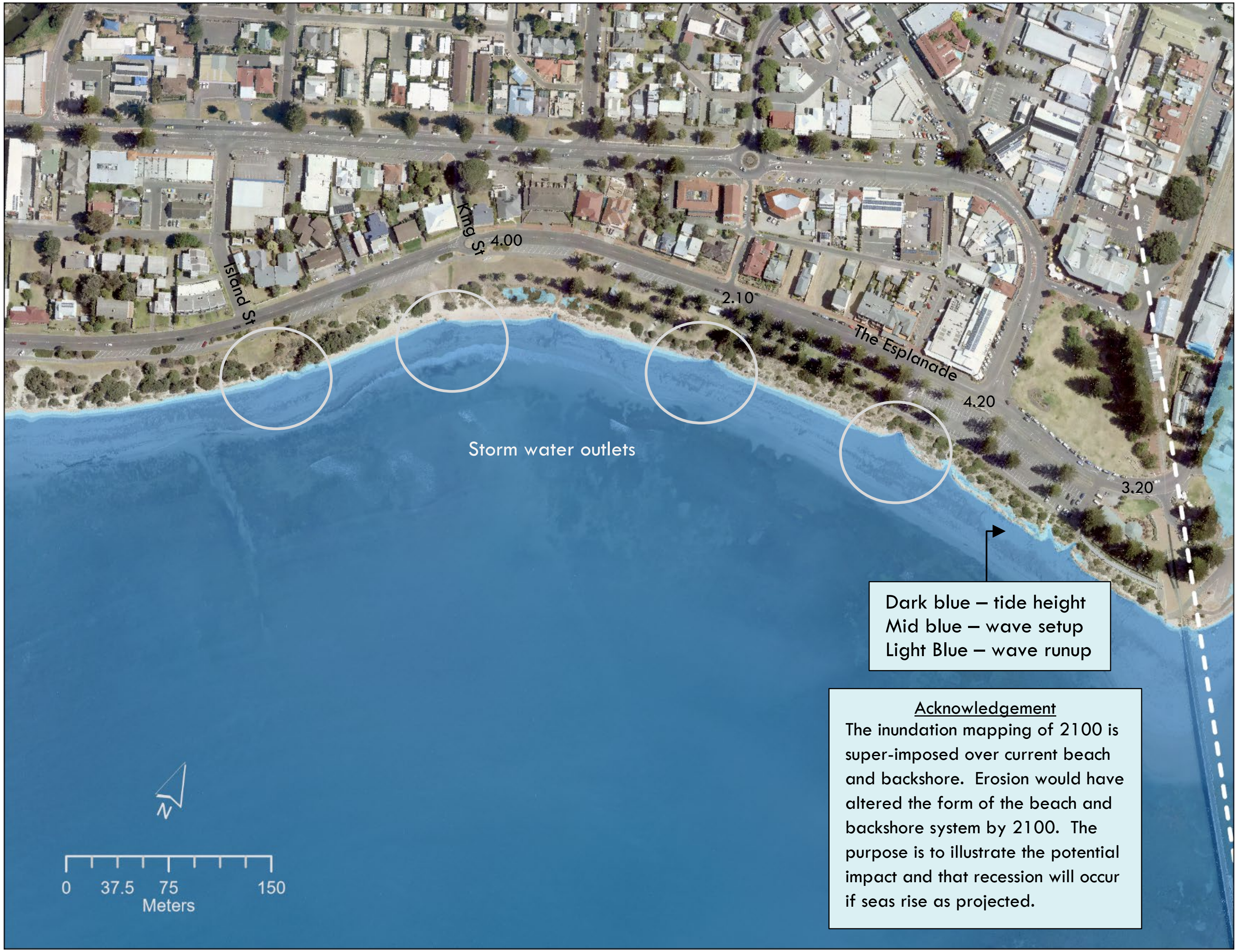

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – storm surge (2020)

Storm surge

Fleurieu 11.1b

Victor Harbor Central

2020 scenario

Event: 1 in 100 sea-flood risk

The Esplanade Beach

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 similar impact as storm event 9th May 2016, but no known impacts have been recorded.

This event would have significant impact on the dunes but as this is a rare event the dunes and beach would most likely recover in this current era.

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 11.1b

Victor Harbor Central

2050 scenario

Event: 1 in 100 sea-flood risk

The Esplanade Beach

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 event would have significant impact on the dunes and the scenario modelling suggests that overtopping of the dunes is likely (the modelling underestimates wave action on more vertical surfaces and slopes).

Combined with higher routine high water events in this era, recession of the dunes is likely (3-5m).

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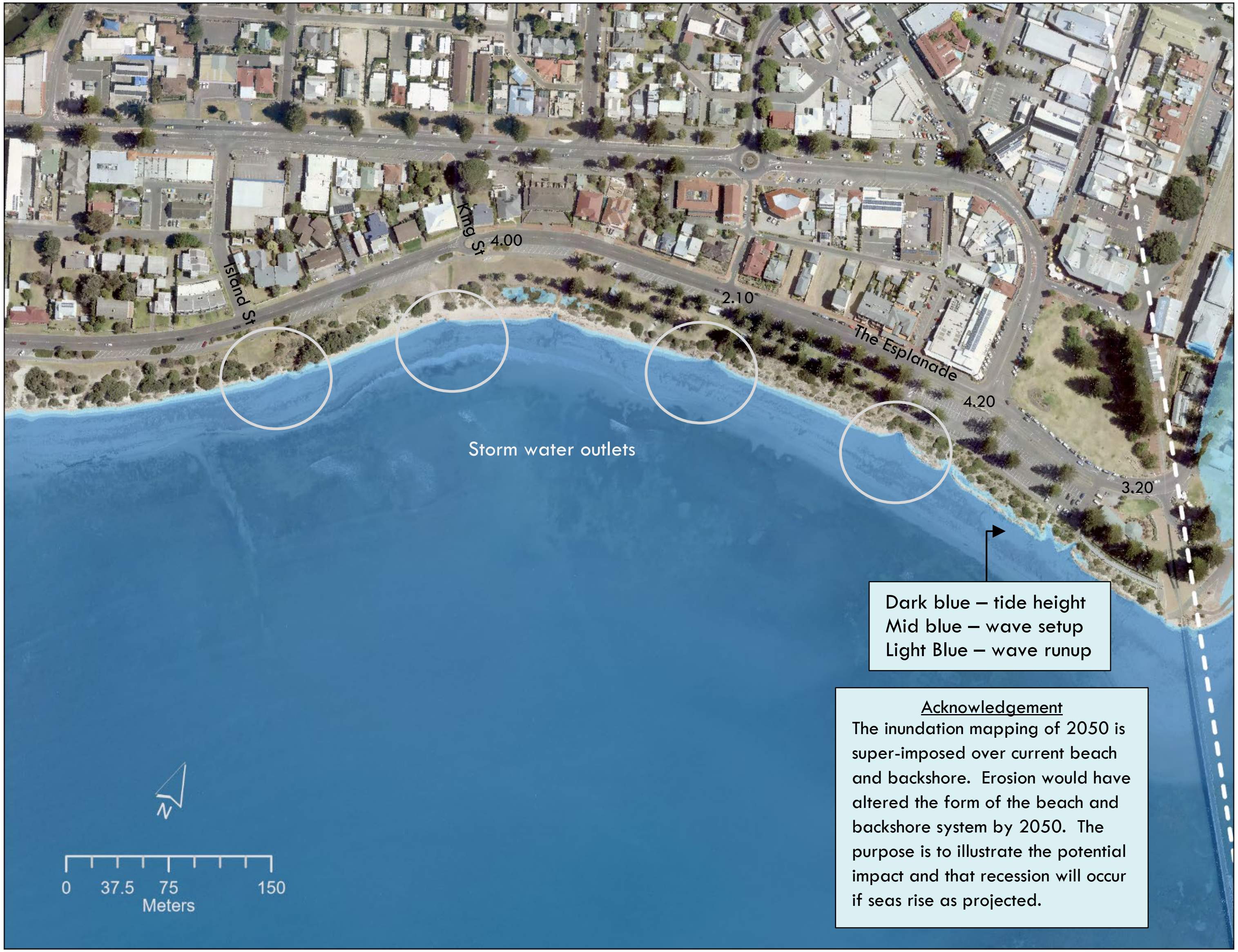

5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 11.1b

Victor Harbor Central

2100 scenario

Event: 1 in 100-year event

The Esplanade Beach

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:

The modelling suggests that this event would overtop the dunes and flow through the reserve and car park behind. However, as this scenario modelling for 2100, it is likely that the dune system would have been eroded away and recession of the coastline well underway.

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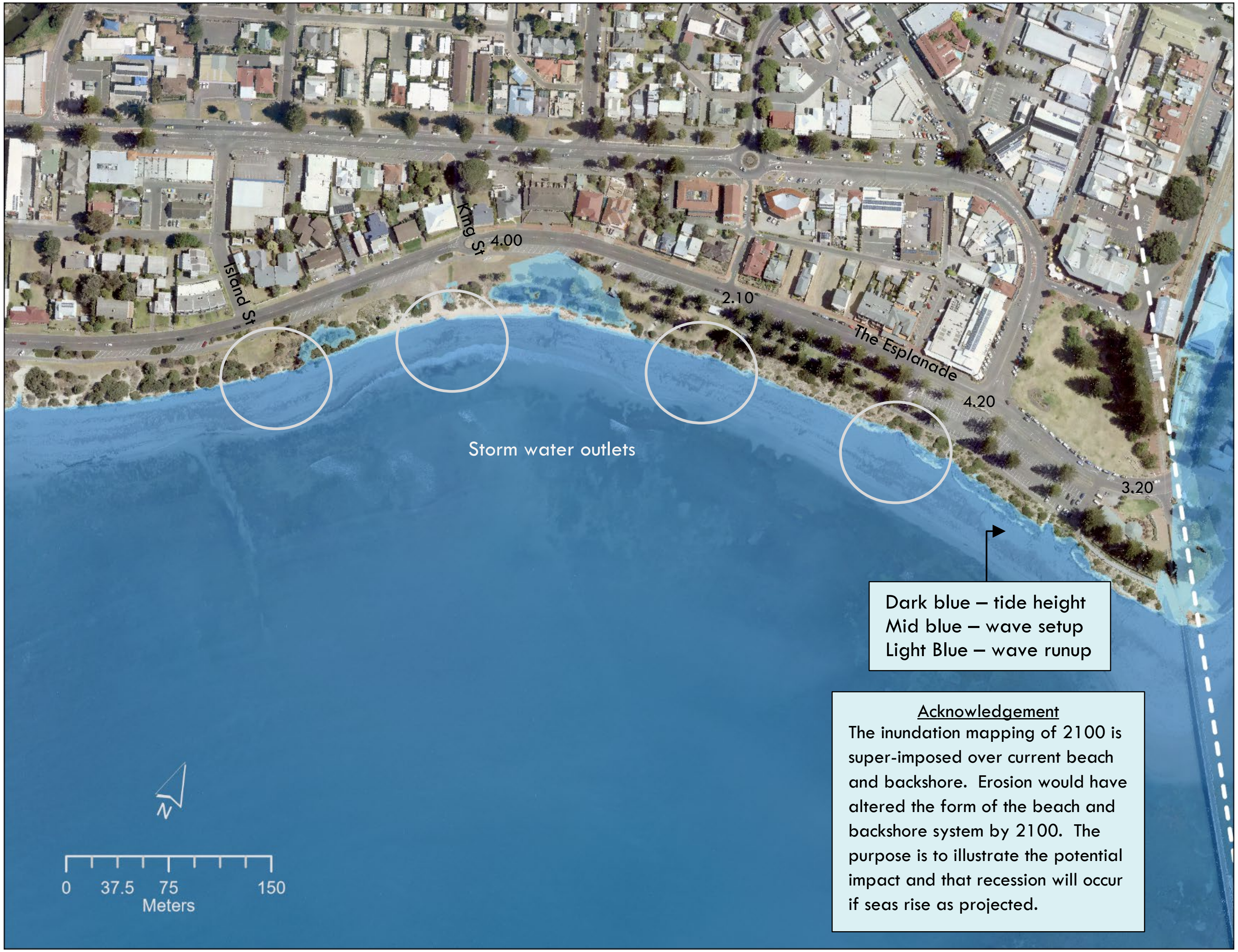

Acknowledgement
The inundation mapping of 2100 is super-imposed over current beach and backshore. Erosion would have altered the form of the beach and backshore system by 2100. The purpose is to illustrate the potential impact and that recession will occur if seas rise as projected.

5. Coastal exposure – summary (Cell 11.1b)

Summary

Fleurieu 11.1b

Victor Harbor Central

Summary

The Esplanade Beach

2020-2050

Recent history has shown that increased storminess can occur over a period of years which causes recession of the dunes and lower sand levels (2007 to 2011).Sea levels 0.3m higher than present are likely to cause recession of the dunes, perhaps removing them in places.

2050-2100

If seas rise as projected, scenario modelling suggests that these dunes would either retreat or erode away. As the dune field is narrow and infrastructure is positioned behind, it is most likely that the dunes would be eroded away.

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5. Coastal exposure – location map (Cell 11.2a)

Location

Fleurieu 11.2a

Victor Harbor Central

Location Map

Flinders Parade

The scenarios modelled are:

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

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Moderate

Wave energy:
Low

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5. Current exposure – routine high water (2020)

Routine high water

Fleurieu 11.2a

Victor Harbor Central

2020 scenario

Event: Routine high water

Flinders Parade

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

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

The event modelled:

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

Wave run-up of 0.30m is included.

Assessment: The modelling appears congruent with observations in this location. Heights AHD have been added to key locations.

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5. Coastal exposure – routine high water (2050)

Routine high water

Fleurieu 11.2a

Victor Harbor Central

2050 scenario

Event: Routine high water

Flinders Parade

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	0.30m
Total risk	1.60m

Wave run-up of 0.30m is included.

Routine highwater events at 0.30m higher than present in the context of rock and concrete block protection are likely to cause further loss of sand on the beach (which currently is in decline). In areas, some recession of the beach is likely. Frequent overtopping is likely to occur adjacent the Soldiers Memorial Gardens.

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5. Coastal exposure – routine high water (2100)

Routine high water

Fleurieu 11.2a

Victor Harbor Central

2100 scenario

Event: Routine high water

Flinders Parade

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

<u>The event modelled:</u>

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

Wave run-up of 0.30m is included.

Routine high water at 1.0m higher than present would completely inundate the reserve back to Flinders Parade. This is congruent with the geomorphological finding that this area was likely formed at the Holocene high stand (~4-5000 years ago) when seas were 1m higher than present.

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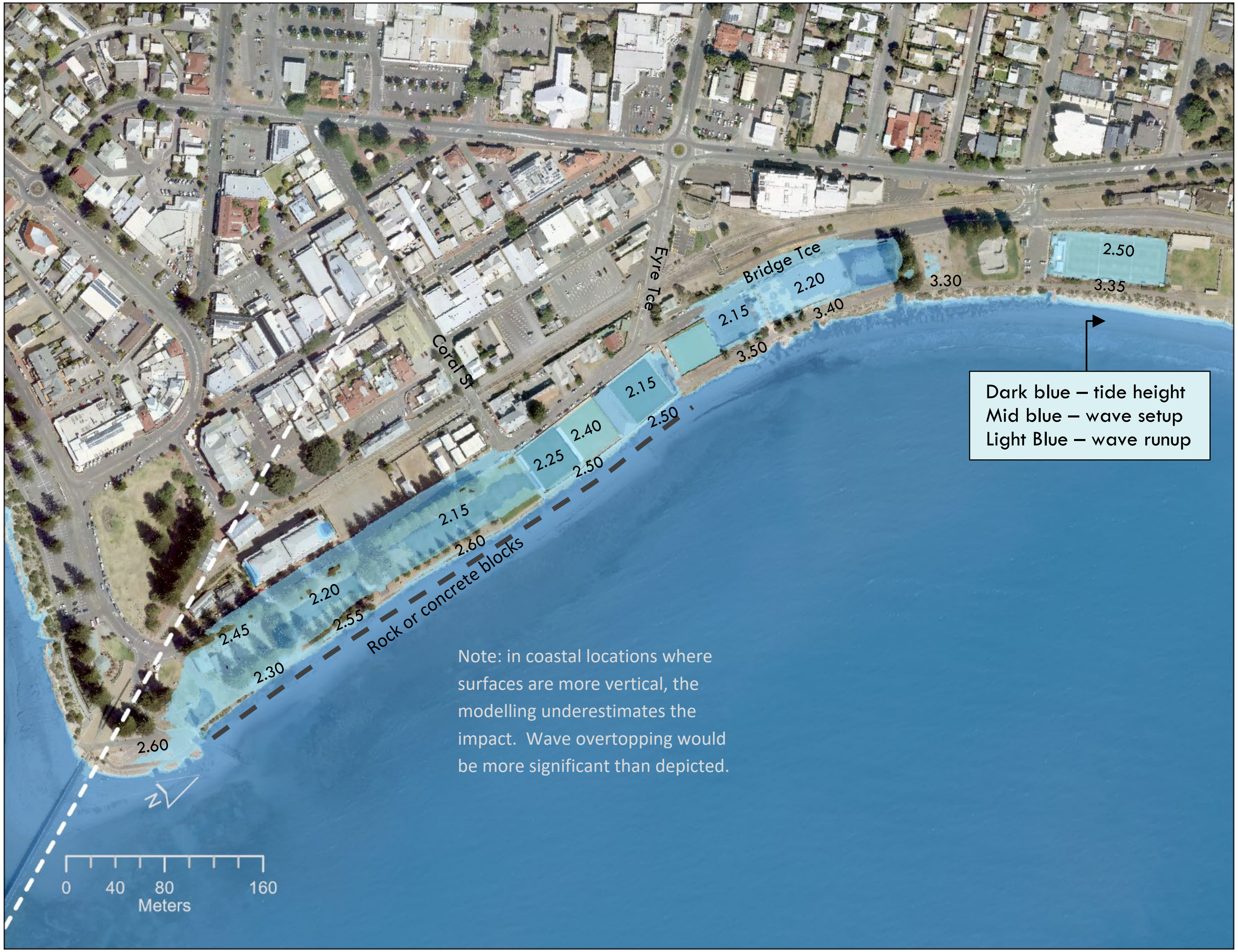

5. Coastal exposure – storm surge (2020)

Storm surge

Fleurieu 11.2a

Victor Harbor Central

2020 scenario

Event: 1 in 100 sea-flood risk

Flinders Parade

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.

The tide height (storm surge height) is of similar magnitude to 9 May 2016 (which was 1.64m AHD). No reports are currently available to confirm the impact of this event.

Note, impact of waves on vertical surfaces is significantly higher than modelled. The modelling shows that this event would overtop the protection works and promenade and flood most of the reserve and playing fields.

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 11.2a

Victor Harbor Central

2050 scenario

Event: 1 in 100 sea-flood risk

Flinders Parade

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.

The scenario modelling indicates that most of reserve would be significantly over topped with water depths in Soldiers Memorial Gardens up to 0.50m and up to 0.40m in the bowling club, tennis courts etc. Note, impact of waves on vertical surfaces is significantly higher than modelled.

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5. Coastal exposure – storm surge (2100)

Storm surge

Fleurieu 11.2a

Victor Harbor Central

2100 scenario

Event: 1 in 100 sea-flood risk

Flinders Parade

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.

The scenario modelling indicates that the reserve would be significantly overtopped, and water is likely to flow over Flinders Parade at depths up to 0.50m. Water depths in Soldiers Memorial Gardens would be up to 1.20m and up to 1.10m in the bowling club, tennis courts, volleyball court. Note, impact of waves on vertical surfaces is significantly higher than modelled.

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5. Coastal exposure – summary (Cell 11.2a)

Summary

Fleurieu 11.2a

Victor Harbor Central

Summary

Flinders Parade

2020-2050

Increasingly, water would overtop the rock revetment and promenade (which it does in current times). The current storm surge event would flood the Soldiers Memorial Gardens and bowling club at low depths, and at depths up to 0.50m in 2050.

2050-2100

If seas rise as projected by the end of the century, the reserve area and playing fields seawater overtop the promenade and protection at least a few times a month flooding up to depths of 0.50m. The 1 in 100-year event would flood the Soldiers Memorial Gardens and playing fields up to depths of 1.20m and flow across Franklin Parade.

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5. Coastal exposure – location map (Cell 11.2b)

Location

Fleurieu 11.2b

Victor Harbor Central

Location Map

Bridge Terrace

The scenarios modelled are:

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

The timing of the scenarios:

- Current
- 2050
- 2100

Nature Maps (SA) assigns:

Relative exposure:
Moderate

Wave energy:
Low

Integrated Coasts
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5. Coastal exposure – routine high water (2020)

Routine high water

Fleurieu 11.2b

Victor Harbor Central

2020 scenario

Event: Routine high water

Bridge Terrace

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

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

The event modelled:

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

Wave run-up of 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 11.2b

Victor Harbor Central

2050 scenario

Event: Routine high water

Bridge Terrace

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.

Modelling indicates the impact would be relatively low.

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

<u>Acknowledgement</u>
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 – routine high water (2100)

Routine high water

Fleurieu 11.2b

Victor Harbor Central

2100 scenario

Event: Routine high water

Bridge Terrace

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 at 1m higher than present would cause recession of these dunes and overtopping of water is likely. Note, impact of waves on vertical surfaces is expected to be higher than modelled.

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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 11.2b

Victor harbor Central

2020 scenario

Event: 1 in 100 sea-flood risk

Bridge Terrace

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.

The current 1 in 100-year event would have significant impact on the dunes and some overtopping is likely. However, in the context of a rare event, the beaches and dunes could be expected to rebuild in this location.

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5. Coastal exposure – storm surge (2050)

Storm surge

Fleurieu 11.2b

Victor Harbor Central

2050 scenario

Event: 1 in 100 sea-flood risk

Bridge terrace

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.

The 1 in 100-year event in 2050 would have significant impact on the dunes and some overtopping is likely. In the context of increasing routine high-water events, some erosion and recession of these dunes 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 11.2b

Victor Harbor Central

2100 scenario

Event: 1 in 100 sea-flood risk

Bridge Terrace

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.

The 1 in 100-year event projected for 2100 would significantly overtop the dunes and walking path. Playing fields would be inundated up to depths of 0.50m. The car park in front of the yacht club would be inundated up to 0.40m with waves likely interacting with the building. In the context of the routine tides projected for 2100, it is likely that the dune system would erode away and the shoreline retreat.

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5. Coastal exposure – summary (Cell 11.2b)

Summary

Fleurieu 11.2b

Victor Harbor Central

Summary

Bridge Terrace

2020-2050

Actions of the sea at 0.3m higher is likely to bring recession to the shoreline measured in metres. Minor over topping of the dunes is likely by 2050 for 1 in 100-year storm events.

2050-2100

If sea levels rise as projected, then routine high-water events combined with storm events will cause significant recession to the dunes. Both routine high-water events and extreme events will overtop the dunes and walking path more frequently, with inundation depths over the playing fields up to 0.50m deep and 0.30m deep in front of the yacht club.

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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.

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.

The 'closure depth' is the depth where most sediment transport due to waves and wave induced currents terminates (Hesp and Hilton, 1996). This closure depth cannot easily be determined at Bashams Beach due to the fact that the nearshore region is dominated by complex three-dimensional geomorphology and includes sand, possible bedrock outcrop, and reef. Onshore/offshore sediment transport processes are

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

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 Police Point sand spit upon which much of the original Victor Harbor settlement was constructed, was formed in the Mid-Holocene period about 4-5000 years ago when seas were ~1m higher than present. The key issue in the context of this project is the current assessment of the likely impact of a future rise of 1m in sea level. Therefore, former tides at 1m higher than present would have interacted with a shoreline that would have been more in line with the position of current-day Flinders Parade and Bridge Terrace. The dune field observed in the photograph below which once extended to current day Warland Reserve, would have been formed as sea levels became lower over the last 4-5000 years. The understanding of the geomorphology of the region assists in providing a picture of the future under higher tidal action.

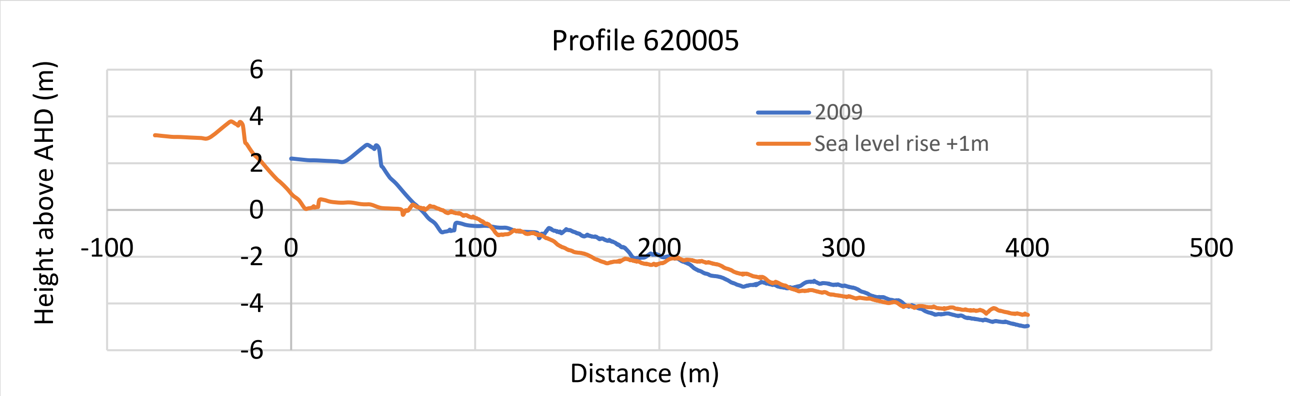
Flinders Parade – Bridge Terrace (eastern coastline)

The depth of closure at SA Coast Protection Board profile line 620005 is estimated at -4.5m 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 invalid.

5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

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 negligible, the Bruun Rule would estimate recession at this location of **46.7m** with a sea level rise of 1m by 2100.If the shoreline were able to translate upwards and landwards essentially maintaining its current morphology or profile shape, then the recession associated with a sea level rise of 1m would be in the order of **74m** assuming the depth of closure is actually -4.5m. Figure 3 indicates this recession. This is merely an approximation as it assumes the entire reef could move landwards as part of the overall shoreline translation, something that is highly unlikely to occur. One might regard the 74m shoreline recession amount as a worst-case scenario for 2100. However, a rise in sea level of 1m would likely mean that significantly higher wave energy will reach the shoreline as the present reef systems will not dissipate wave energy to anywhere near the same degree as present.



The actual coastline recession could be considerably more than estimated because if the reef remains largely intact, sea level is higher, wave energy is higher at the shoreline and therefore storm surge is also greater, and the amount of sand available in the dune-beach-immediate surfzone out to approximately -1.0m water depth is all that is available to translate upwards and landwards with sea level rise, the amount of recession could be considerably greater!

In the context of recent geomorphology

The context of recent geomorphology (Section 3) also provides a way in which to consider the impacts of 1m of projected sea level rise. Dr Bob Bourman notes that the Police Point sand spit upon which much of the original Victor Harbor settlement was constructed, was formed in the mid-Holocene period about 4-5000 years ago when seas were ~1m higher than present. Therefore, former tides and storms at 1m higher than present would have interacted with a shoreline that is more in line with the position of current-day Flinders Parade and Bridge Terrace. This finding is somewhat congruent with the sea-flood modelling that indicates impact in a similar shoreline position (Figure c).

Figure a. Police Point was likely formed 4-5000 when seas were 1m higher than present and coastal areas upon which the gardens and playing fields are now situated were sand dunes.

Figure b. Sea flood mapping for projected sea level rise of 1m by 2100 suggests a future coastline under natural conditions that aligns with Flinders Parade and Bridge Terrace.

5. Exposure – erosion (2100)

Summary

Cell 11.1

Victor Harbor Central

2100 risk:
Erosion outlook

Flinders Parade – Bridge Terrace

Based on the erosion modelling of the previous pages, and assuming that no human intervention was present, the likely range of shoreline recession would be between 47m and 74m.

The general distance between Flinders Parade and Bridge Terrace is 50-60 metres, that suggests under natural conditions the shoreline would retreat to this location which is congruent with the findings of the geomorphology for recent times when seas were ~1m higher 4-5000 years ago. The flood mapping at 1m higher provides an additional viewpoint that appears congruent with this assessment. The impact on the shoreline is likely to be less towards Hindmarsh River which is in a more sheltered location.

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5. Exposure – erosion (2100)

Shoreline recession due to sea level rise

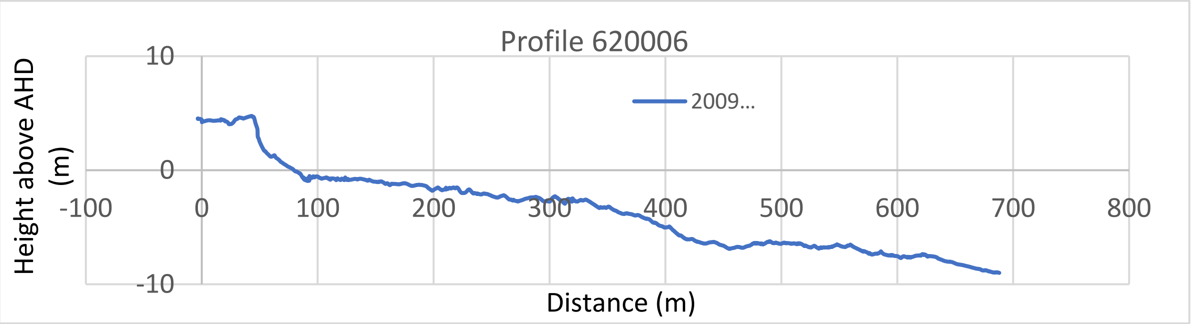
The Esplanade Beach (southern section of coast)

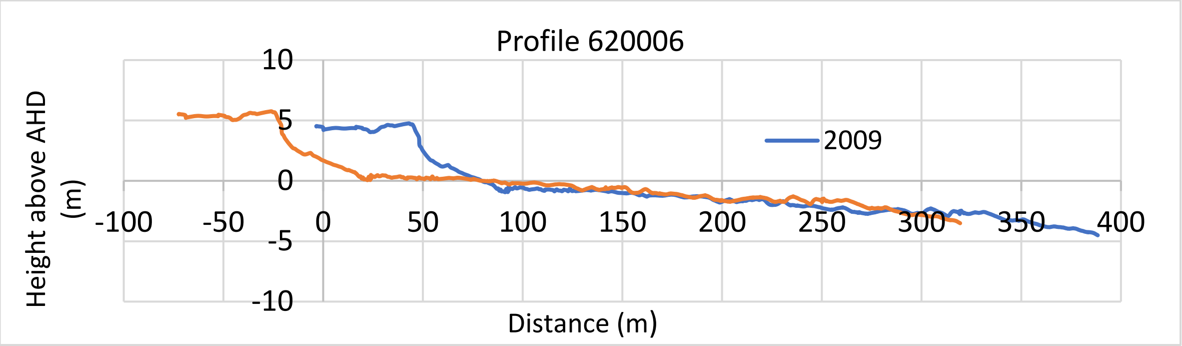
Profile 620006 is characterised by a seagrass and reef dominated nearshore. Massive amounts of seagrass wrack are delivered to the shore at times forming significant natural 'wrack-walls' and disparate piles of wrack at times (Figure a).

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 invalid as noted above. 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 negligible, the Bruun Rule would estimate recession at this location of **35m** with a sea level rise of 1m by 2100.

If the shoreline were able to translate upwards and landwards essentially maintaining its current morphology or profile shape, then the recession associated with a sea level rise of 1m would be in the order of **69m** assuming the depth of closure is actually -4.5m. Figure 5 indicates this recession.

There are multiple issues with estimating the magnitude of shoreline recession based on both the Bruun Rule and the translation method indicated above (Figure 5) and all data should be regarded as indicative only.





In the context of recent geomorphology

The context of recent geomorphology (Section 3) also provides a way in which to consider the impacts of 1m of projected sea level rise. Dr Bob Bourman notes that the Police Point sand spit upon which much of the original Victor Harbor settlement was constructed, was formed in the mid-Holocene period about 4-5000 years ago when seas were ~1m higher than present. The dune fields depicted in Figure (a) on page X were likely formed in this era as sea levels decreased.

Figure a (top). SA Coast Protection Board profile 620006

Figure b (bottom). Shoreface-beach and dune translation modelling suggests 69m of recession.

5. Exposure – erosion (2100)

Summary

Cell 11.2

Victor Harbor Central

2100 risk:

Erosion outlook

The Esplanade Beach

Based on the erosion modelling of the previous pages, and assuming that no human intervention was present, the likely range of shoreline recession would be between 35m and 69m.

The general distance between the current shoreline and The Esplanade is X metres, that suggests under natural conditions the shoreline would retreat to this location which is congruent with the findings of the geomorphology for recent times when seas were ~1m higher 4-5000 years ago.

The flood mapping at 1m higher provides an additional viewpoint that appears congruent with this assessment.

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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?'

5. INMAN RIVER

The focus of this part of the study relates to primarily to coastal adaptation in the context of projected sea level rise and not matters that relate to the health or ecology of the river in a general senses. The report, *Inman River Estuary Action Plan*, 2010, prepared by Sinclair Knight Merz for Adelaide and Lofty Ranges Natural Resources Management Board, provides a context from which to evaluate the general health of the river.

In particular we assess the impact within the estuary of routine high-water events and 1 in 100-year storm surge events at increased depths of 0.30m by 2050 and 1.0m by 2100 in relation to:

- Public assets
- Private assets
- Social disruption (public safety and community concern)
- Ecosystems.

The modelling does not consider any possible impact of flows from rainfall events.

In relation to ecosystems, we are particularly looking for impacts related to increased flows of salt water into areas that are currently freshwater environments.

5. Coastal exposure – Routine high water (2020)

Routine high water

Fleurieu 11

Victor Harbor Central

2020 scenario

Event: Routine high water

Inman River

Sea level rise will increase the level of sea water flowing up the Inman River potentially causing inundation to locations along the river bank.

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 runup has not been included in the modelling.

The caravan park is protected by an earthen bund at heights 2.00m to 2.50m AHD. (Note this bund has not been surveyed but height estimated within the digital elevation model). Routine high-water is not having any impact in the caravan park or surrounding areas.

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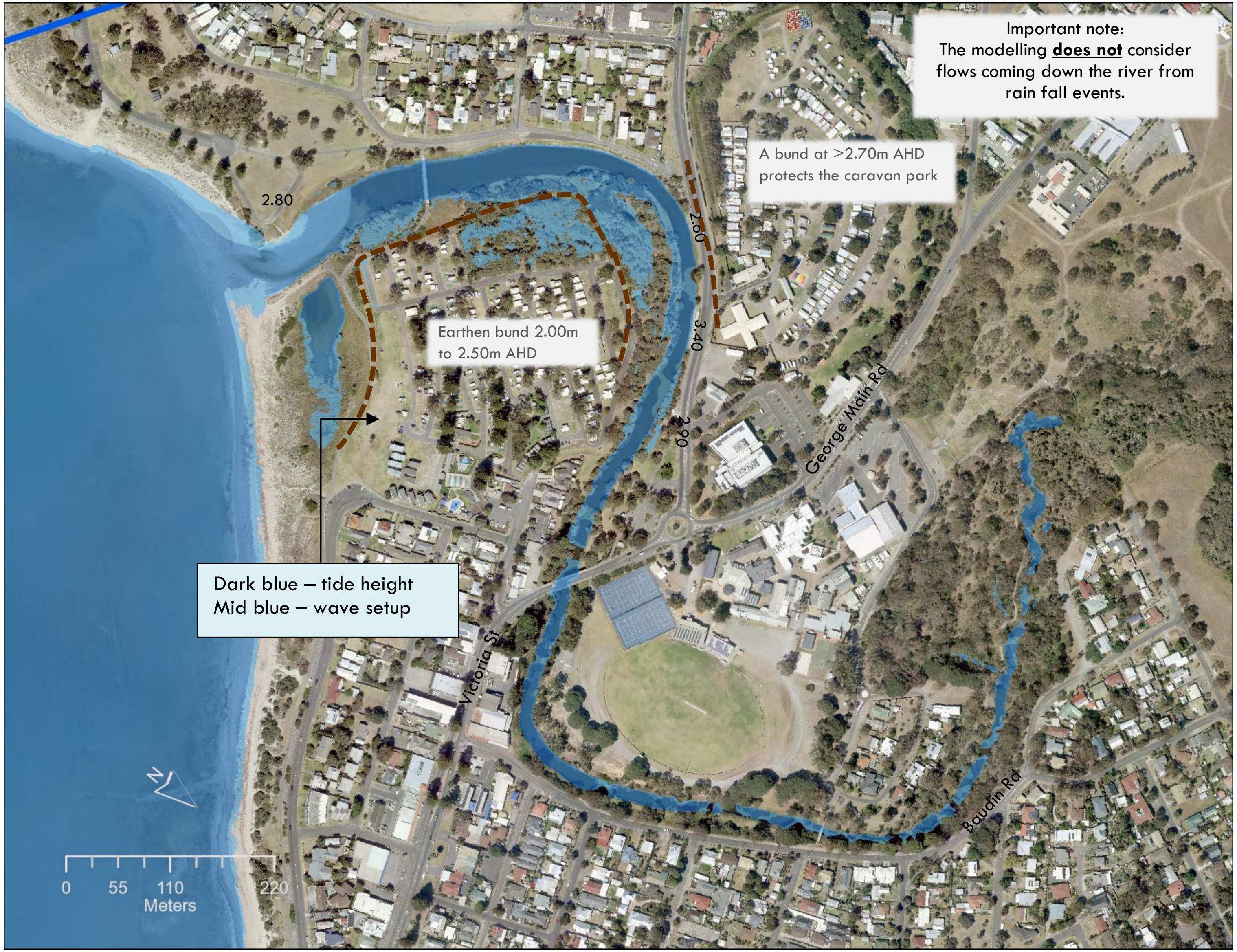

5. Coastal exposure – Routine high water (2050)

Routine high water

Fleurieu 11

Victor Harbor Central

2050 scenario

Event: Routine high water

Inman River

Sea level rise will increase the level of sea water flowing up the Inman River potentially causing inundation to locations along the river bank.

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 runup has not been included in the modelling.

The caravan park is protected by an earthen bund at heights 2.00m to 2.50m AHD. (Note this bund has not been surveyed but height estimated within the digital elevation model). Routine high-water at 2050 is unlikely to have any impact in the caravan park or surrounding areas.

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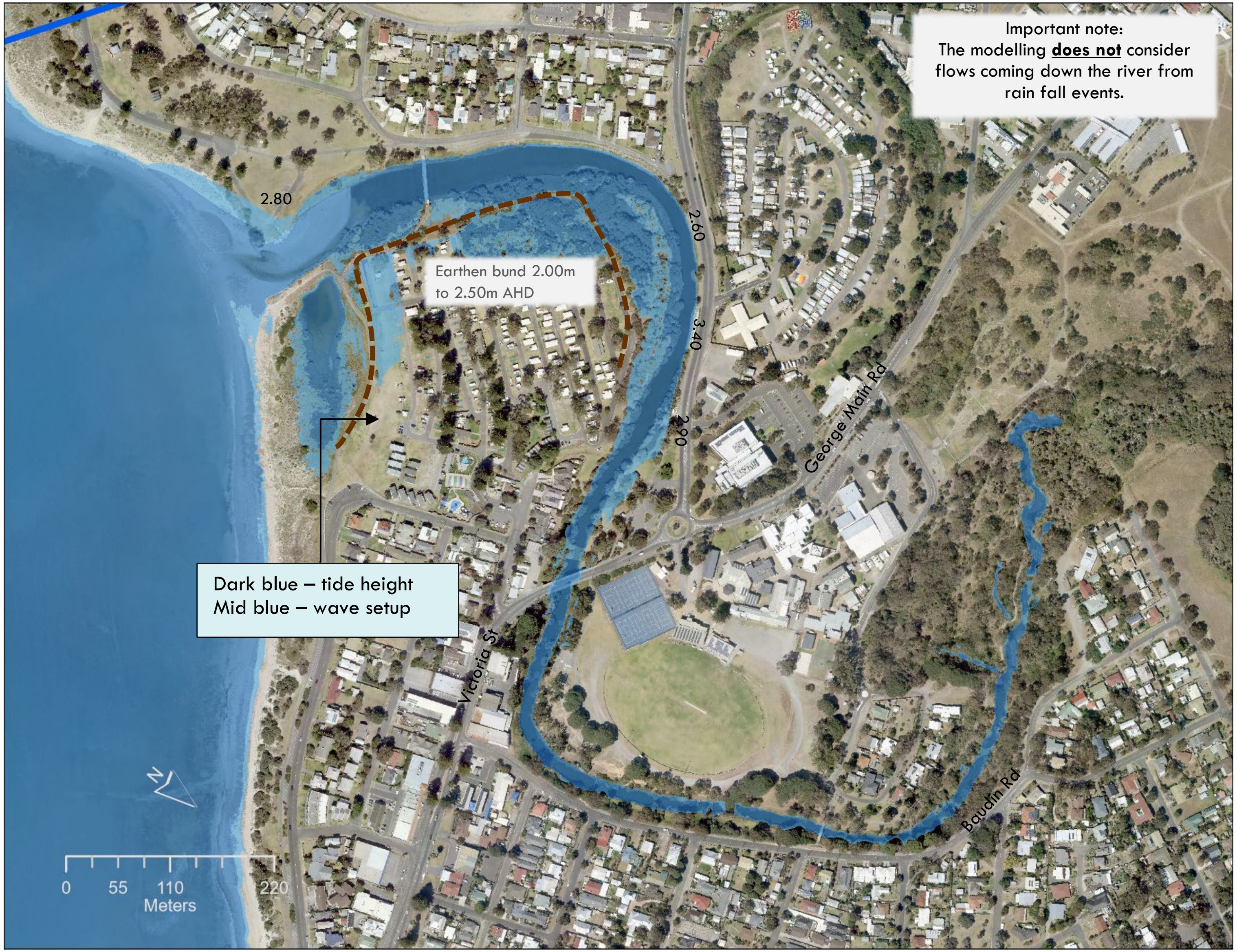

5. Coastal exposure – Routine high water (2100)

Routine high water

Fleurieu 11

Victor Harbor Central

2100 scenario

Event: Routine high water

Inman River

Sea level rise will increase the level of sea water flowing up the Inman River potentially causing inundation to locations along the river bank.

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 runup has not been included in the modelling.

The caravan park is protected by an earthen bund at heights 2.00m to 2.50m AHD. Seawater flows projected for 2100 would significantly overtop the bund and flood the caravan park.

Some flooding over the embankments may disrupt the ecology.

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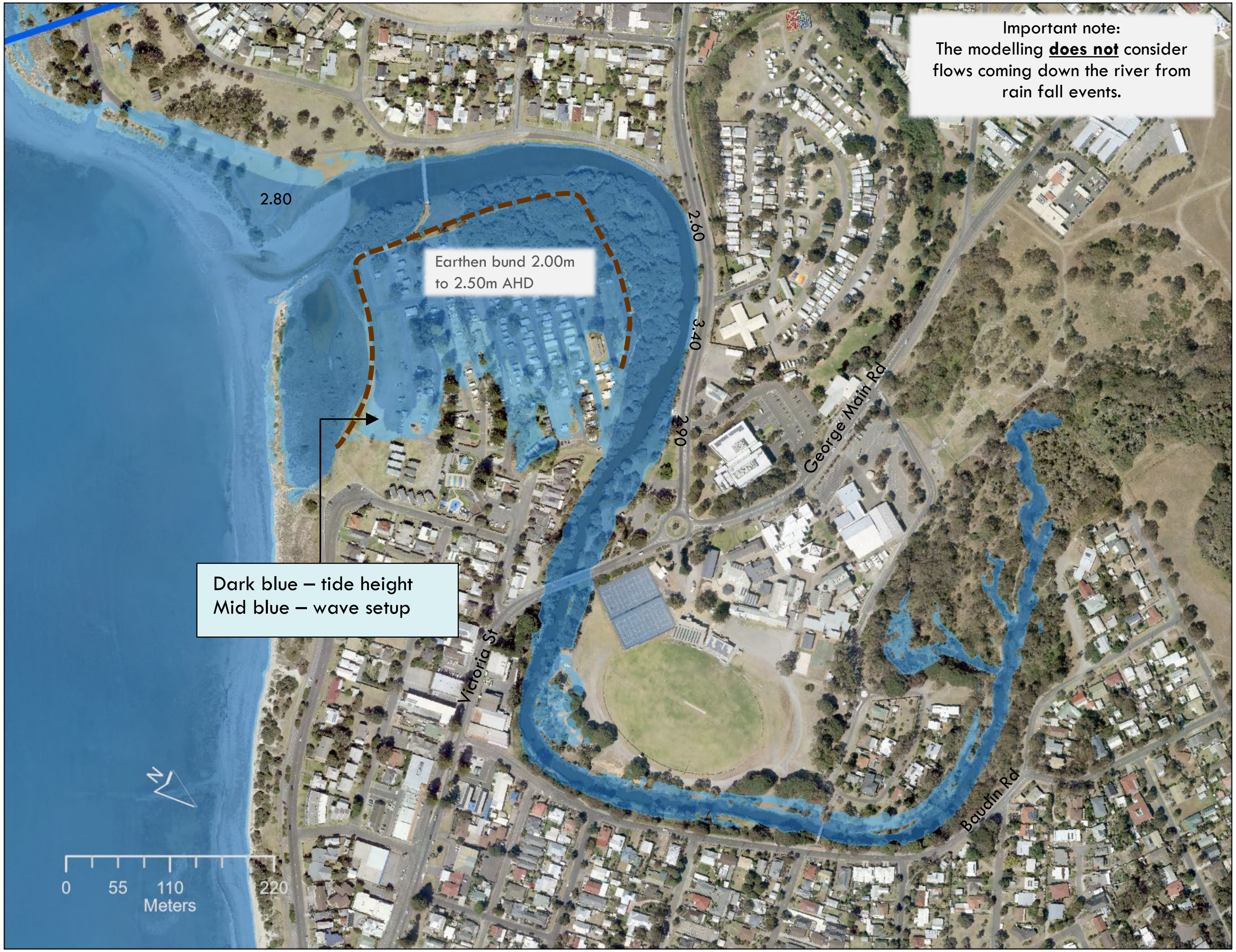

5. Coastal exposure – Storm surge (2020)

Storm surge

Fleurieu 11

Victor Harbor Central

2020 scenario

1 in 100-year sea-flood risk

Inman River

SA Coast Protection Board allowance for 1 in 100-year event for Victor Harbor Central is:

Storm surge	1.75m AHD
Wave setup	0.30m
	2.05m AHD

The darker blue represents storm surge height (ie the height of water that would be measured at a tide gauge) and the lighter blue is the wave setup. The energy from wave runup would be dissipated close to the shoreline and therefore has not been included in modelling for Inman River.

The modelling within the estuary is likely to be depicted higher than actual due to the presence of wave setup. The bund around the caravan park is likely to be adequate.

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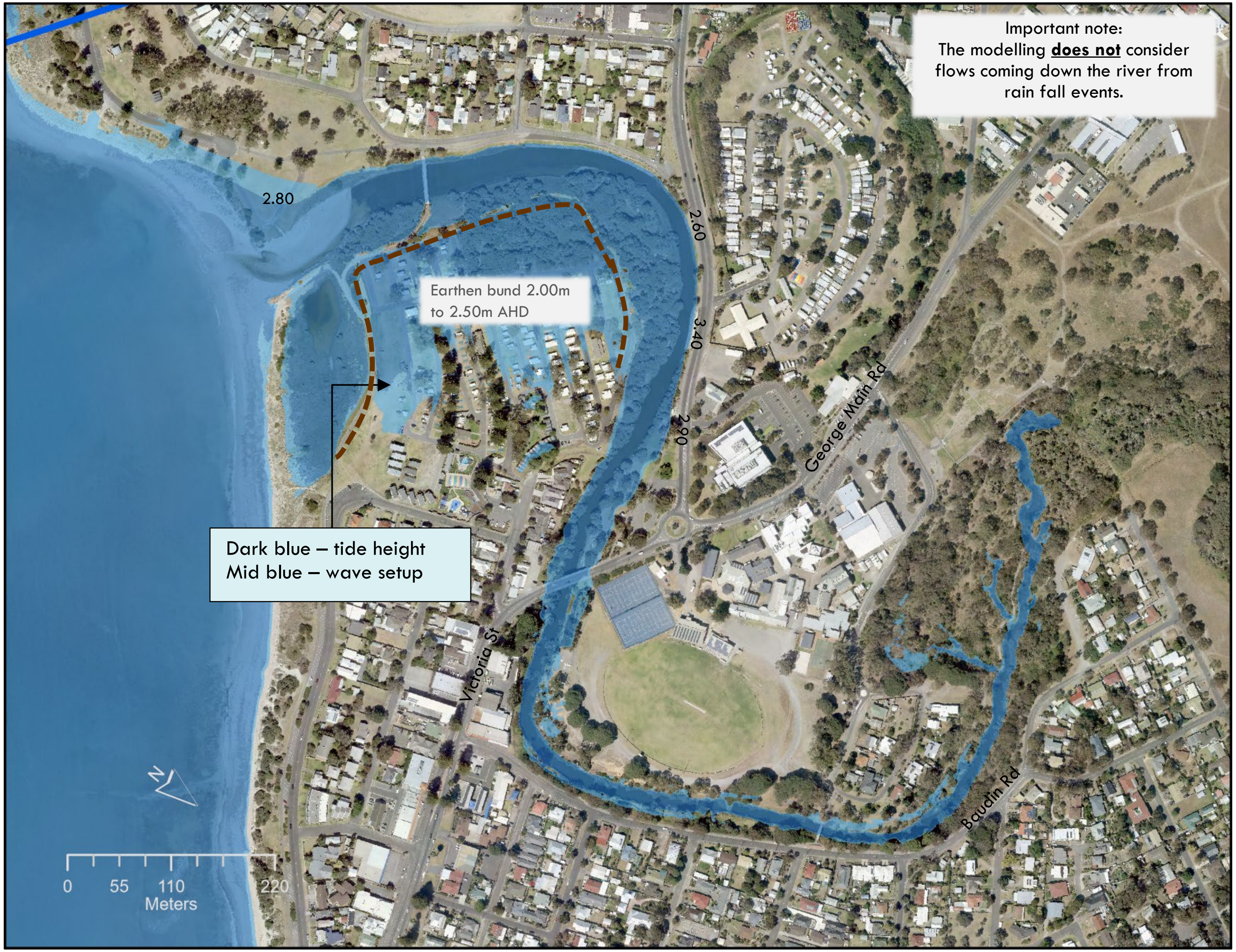

5. Coastal exposure – Storm surge (2050)

Storm surge

Fleurieu 11

Victor Harbor Central

2050 scenario

Event: 1 in 100-year sea-flood risk

Inman River

SA Coast Protection Board allowance for 1 in 100-year event for Victor Harbor Central with allowance for 0.30m sea level rise for 2050 is:

Storm surge	1.75m AHD
Sea level rise	0.30m
Wave setup	0.30m
	2.35m AHD

The caravan park is protected by an earthen bund at heights 2.00m to 2.50m AHD. Seawater flows projected for 2050 is likely to overtop the bund in places would and flood the caravan park.

Some sea water flooding over the embankments may disrupt the ecology.

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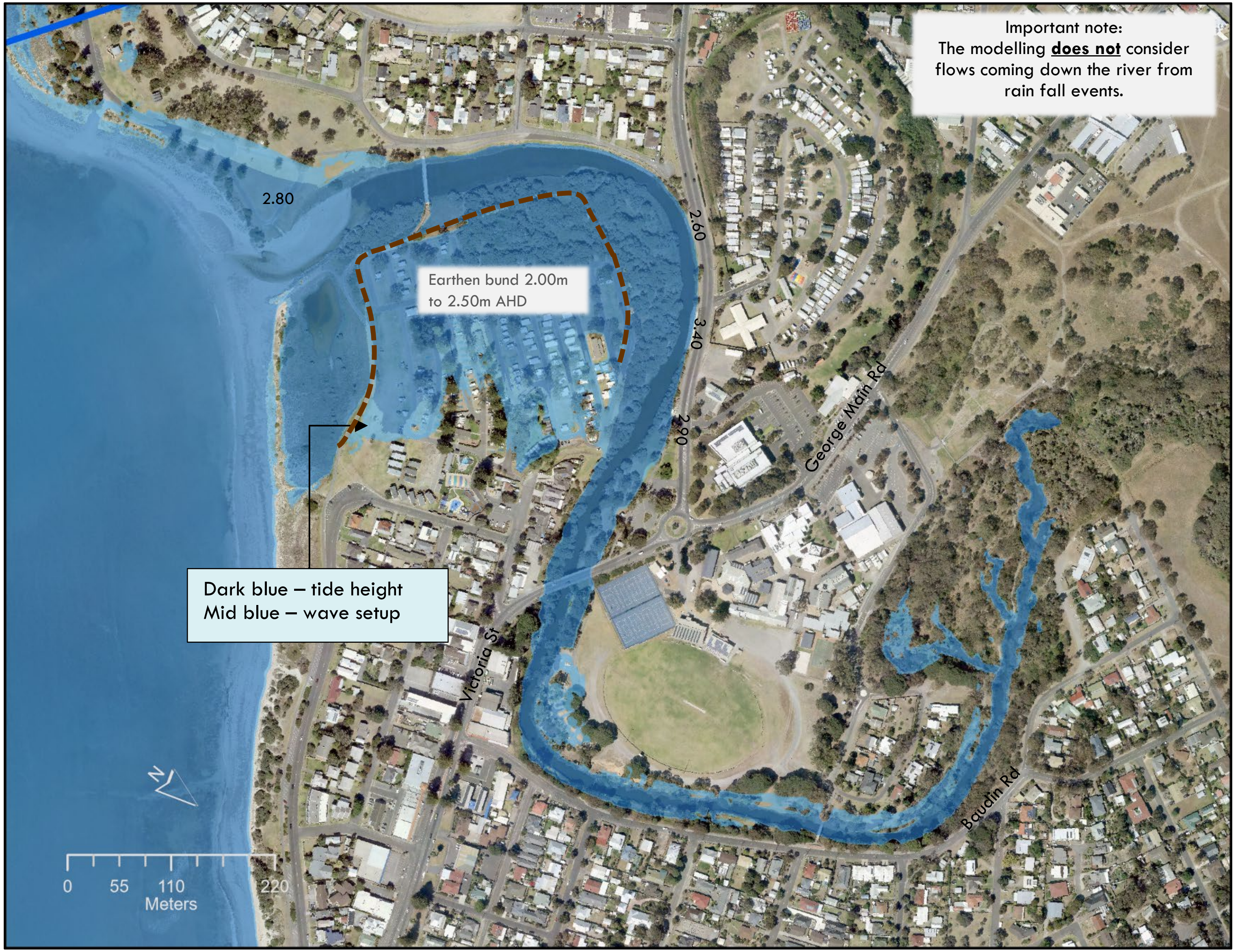

5. Coastal exposure – Storm surge (2100)

Storm surge

Fleurieu 11

Victor Harbor Central

2100 scenario

Event: 1 in 100-year sea-flood risk

Inman River

SA Coast Protection Board allowance for 1 in 100-year event for Victor Harbor Central with allowance for 1.00m sea level rise for 2100 is:

Storm surge	1.75m AHD
Sea level rise	1.00m
Wave setup	0.30m
	3.05m AHD

The caravan park is protected by an earthen bund at heights 2.00m to 2.50m AHD. Seawater flows projected for a 1 in 100-year event for 2100 would significantly over top the bund and flood the caravan park.

Sea water flooding would be significant over the banks of the river, including into the oval area. Generally, flows at 2100 will disrupt freshwater ecologies along the river.

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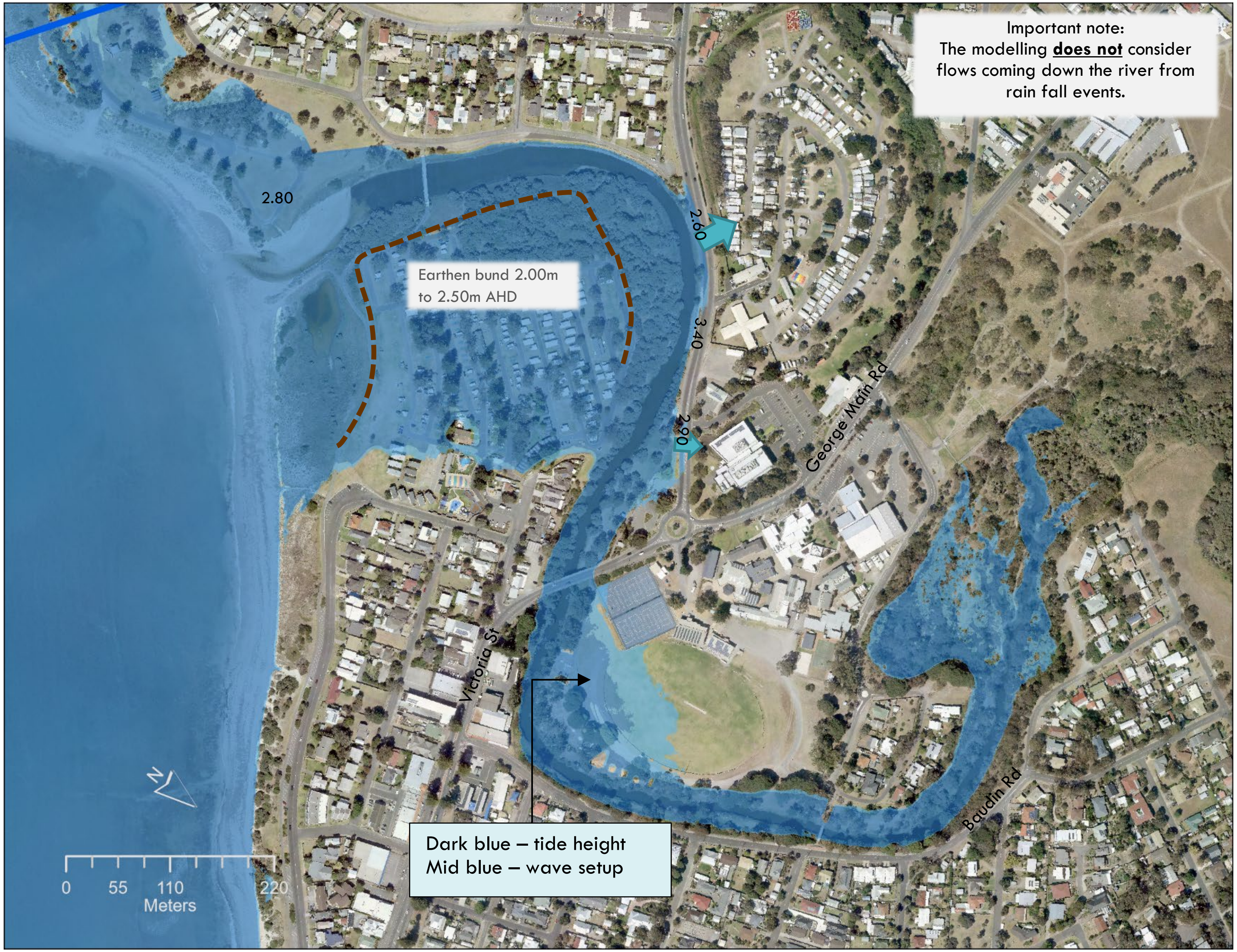

5. HINDMARSH RIVER

The focus of this part of the study relates to primarily to coastal adaptation in the context of projected sea level rise and not matters that relate to the health or ecology of the river in a general senses. The report, *Hindmarsh River Estuary Action Plan*, 2012, prepared by Sinclair Knight Merz for Adelaide and Lofty Ranges Natural Resources Management Board, provides a context from which to evaluate the general health of the river.

In particular we assess the impact within the estuary of routine high-water events and 1 in 100-year storm surge events at increased depths of 0.30m by 2050 and 1.0m by 2100 in relation to:

- Public assets
- Private assets
- Social disruption (public safety and community concern)
- Ecosystems.

The modelling does not consider any possible impact of flows from rainfall events.

In relation to ecosystems, we are particularly looking for impacts related to increased flows of salt water into areas that are currently freshwater environments.

5. Coastal exposure – Routine high water (2020)

Routine high water

Fleurieu 11

Victor Harbor Central

2020 scenario

Event: Routine High Water

Hindmarsh River

Sea level rise will increase the level of sea water flowing up the Hindmarsh River potentially causing inundation to locations along the riverbank.

The event modelled:

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

Wave runup has not been included in the modelling.

This scenario is the current scenario and impacts are current. Council informs that the mouth of the river is opened mechanically when river levels become too high in the lower estuary. Residents inform that the walkway under the bridge becomes flooded on occasions (and this is also related to mouth opening).

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5. Coastal exposure – Routine high water (2050)

Routine high water

Fleurieu 11

Victor Harbor Central

2050 scenario

Event: Routine High Water

Hindmarsh River

Sea level rise will increase the level of sea water flowing up the Inman River potentially causing inundation to locations along the river bank.

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 runup has not been included in the modelling.

The scenario for 2050 indicates increased incursion of seawater into the floodplain area south of the high school. Anecdotes from residents suggest that this area is sometimes currently flooded (but this may relate to rain fall events). The residential area between Hindmarsh Road and Persons Rd is protected by an earthen levee and concrete retaining wall.

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5. Coastal exposure – Routine high water (2100)

Routine high water

Fleurieu 11

Victor Harbor Central

2100 scenario

Event: Routine High Water

Hindmarsh River

Sea level rise will increase the level of sea water flowing up the Inman River potentially causing inundation to locations along the river bank.

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 runup has not been included in the modelling.

The scenario for 2100 indicates significant and regular incursion of seawater into the floodplain area south of the high school. The residential area between Hindmarsh Road and Persons Rd is protected by an earthen levee and concrete retaining wall. The earthen levee is at an appropriate height, but the height of the retaining wall is unknown.

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5. Coastal exposure – Storm surge (2020)

Storm surge

Fleurieu 11

Victor Harbor Central

2020 scenario

1 in 100-year sea-flood risk

Hindmarsh River

SA Coast Protection Board allowance for 1 in 100-year event for Victor Harbor Central is:

Storm surge	1.75m AHD
Wave setup	0.30m
	2.05m AHD

The scenario for 2020 suggests that if the 1 in 100-year event occurred, the flood plain south of the high school would be inundated. This would depend on the nature of the mouth at the time and possible flow rates and volume of water. The residential area between Hindmarsh Road and Persons Rd is protected by an earthen levee and concrete retaining wall. The earthen levee is at an appropriate height, but the height of the retaining wall is unknown (further research).

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5. Coastal exposure – Storm surge (2050)

Storm surge

Fleurieu 11

Victor Harbor Central

2050 scenario

Event: 1 in 100-year sea-flood risk

Hindmarsh River

SA Coast Protection Board allowance for 1 in 100-year event for Victor Harbor Central with allowance for 0.30m sea level rise for 2050 is:

Storm surge	1.75m AHD
Sea level rise	0.30m
Wave setup	0.30m
	2.35m AHD

The scenario for 2050 suggests that if the 1 in 100-year event occurred, the flood plain south of the high school would be inundated. This would depend on the nature of the mouth at the time and possible flow rates and volume of water. The residential area between Hindmarsh Road and Persons Rd is protected by an earthen levee and concrete retaining wall. The earthen levee is at an appropriate height, but the height of the retaining wall is unknown (further research).

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5. Coastal exposure – Storm surge (2100)

Storm surge

Fleurieu 11

Victor Harbor Central

2100 scenario

Event: 1 in 100-year sea-flood risk

Hindmarsh River

SA Coast Protection Board allowance for 1 in 100-year event for Victor Harbor Central with allowance for 1.00m sea level rise for 2100 is:

Storm surge	1.75m AHD
Sea level rise	1.00m
Wave setup	0.30m
	3.05m AHD

The scenario for 2100 indicates that if the 1 in 100-year event occurred, the flood plain south of the high school would be inundated but the high school would remain largely unaffected.
The residential area between Hindmarsh Road and Persons Rd is protected by an earthen levee and concrete retaining wall. The earthen levee is at an appropriate height, but the height of the retaining wall is unknown. Further research required.

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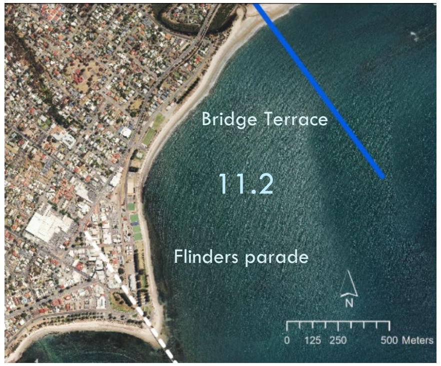
COASTAL EXPOSURE – Summary table

Victor Harbor Central (Cell 11)

Victor Harbor		Coastal context - natural				Modified	Exposure*	Scenario Modelling	
Cell	**Location**	**Bathymetry**	**Benthic**	**Beach**	**Backshore**	**Human**	**Waves**	**2020 - 2050**	**2050-2100**
11.1a	Inman River	Slope 1:300 (-5m at 1500m offshore).	Nearshore – sand and seagrass. Low profile reefs offshore.	Fine-medium sand beach	Estuary, Dunes, and caravan park.	River mouth realigned, sand dunes introduced, bund to protect caravan park	Sheltered exposure Low energy waves	Actions of the sea at 0.3m higher will cause some recession of the frontal dunes, but the caravan park is likely to remained protected.	Actions of the sea at 1.0m higher are likely to remove the sand dunes and sea-water would overtop the levee system around the caravan park.
11.1b	Esplanade Beach	Slope 1:300 (-5m at 1500m offshore).	Nearshore is sand. Low profile reefs and seagrass offshore.	Fine-medium sand beach	Low height dunes, grassed reserve, road infrastructure.	Concrete blocks, sand sausages (x2) buried for protection. Sand dunes removed.	Sheltered exposure Low energy waves	Actions of the sea at 0.3m higher will cause permanent recession of the dunes (likely in order of 10-15m.	Actions of the sea at 1.0m higher are likely to cause recession of the dunes (35 to 63m).
11.2a	Flinders Parade	Slope 1:100 (-10m at 1km offshore).	Sand and dense seagrass beds	Fine-medium sand beach	Rock or concrete block protection, reserve and bowling club.	Rock and concrete block protection. Sand dunes removed.	Moderate exposure Low energy waves	This area is protected by rock and concrete blocks. Sea levels at 0.3m are likely to lower sand levels on the beach.	Significant and regular overtopping of the protection works. Severe undermining of the protection works due to loss of sand from beach.
11.2b	Bridge Terrace	Slope 1:100 (-10m at 1km offshore).	Sand and dense seagrass beds	Fine-medium sand beach	Low height dune (partial), playing fields/ clubs and road.	Playing fields in former sand dune area.	Moderate exposure Low energy waves	Actions of the sea at 0.3m higher will cause some recession of the shoreline (measured in metres)	Actions of the sea at 1.0m higher will cause significant shoreline recession (measured in decametres), and also increase the backshore slope.



Victor Harbor Central – Key Points

11.1 Episodes of erosion are likely caused by periods of increased storminess. Actions of the sea at 0.3m higher cause some recession of the sand dunes but the caravan park will remain protected by the levee. Post 2050 overtopping will occur over the levee around the caravan park and Kent Reserve will be increasingly flooded. The dunes to Esplanade Beach will experience significant retreat, the dunes in front of the caravan park likely lost.

12.2 The southern section is protected by rock/concrete, the northern section more sheltered toward Hindmarsh River. Actions of the sea at 0.3m will decrease sand levels on the beach, or cause recession where not protected. Sea levels at 1m higher will cause significant impact on protected and unprotected surfaces. Overtopping of the protection items will be frequent and significant. Sand levels will be lost on the beach.

6. Storm water runoff from urban settlement

6. Storm water runoff from urban settlement

Purpose

The purpose of this study is to evaluate the impact of storm water that flows from urban areas to the coast. Large volumes of rainwater can quickly accumulate and flow from the impervious surfaces of urban settlements. Storm water flowing over softer embankments can cause gullying and instability. Storm water rushing out to the beach can cause gullying of the dunes and scouring of the beach. Over time cliffs, embankments and dunes break down and sand levels are likely to drop on the beach. In the context of sea level rise, the locations where storm water is impacting beach and backshores are likely to be the first points along the coast that become vulnerable.

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 could 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

<u>Overview of the study</u>

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.

<u>In the context of coastal adaptation</u>

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

Cell 11.1a

Victor Harbor Central

Storm water:

Current design

Storm water outlet assessment Inman River

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

It is likely in this scenario that the water depth modelled is higher than actual due to the inclusion of wave runup (more relevant for storm surge events)

Location 41 is prime storm water infrastructure draining water from the northern side of Bay Road (see inset photograph). Regarding 42, storm water can flow down the bank. Other locations are likely to maintain function.

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ID	OUTLET	HEADWALL	ENDCONTROL	IMPACT	ELEVATION	2020	2050	2100
19	Pipe (RCP)	No	No	Erosion channel	3.04	1.74	1.44	0.74
40	Pipe (RCP)	No	No	Erosion channel	3.02	1.72	1.42	0.72
41	Pipes (RCP)	No	Tidal flap	multiple pipes	0.29	-1.01	-1.31	-2.01
42	Pipe (RCP)	No	No	poor condition	0.86	-0.44	-0.74	-1.44
43	Pipe (RCP)	Yes	Tidal flap	None	1.11	-0.19	-0.49	-1.19

6. Storm water runoff from urban settlement

Storm Water

Cell 11.1b

Victor Harbor Central

Storm water:

Current design

Storm water outlet assessment The Esplanade Beach

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

Inspection of the outlet reveals that wave runup is sometimes interacting with the storm water outlet in this current era. However, it is unlikely that actions of the sea would close the tidal flap for routine tidal events up until 2050 (with the exception of location 13). Storm water does significantly lower sand levels on the beach. This will tend to increase the erosion and gullying of the backshore. See also inset comment.

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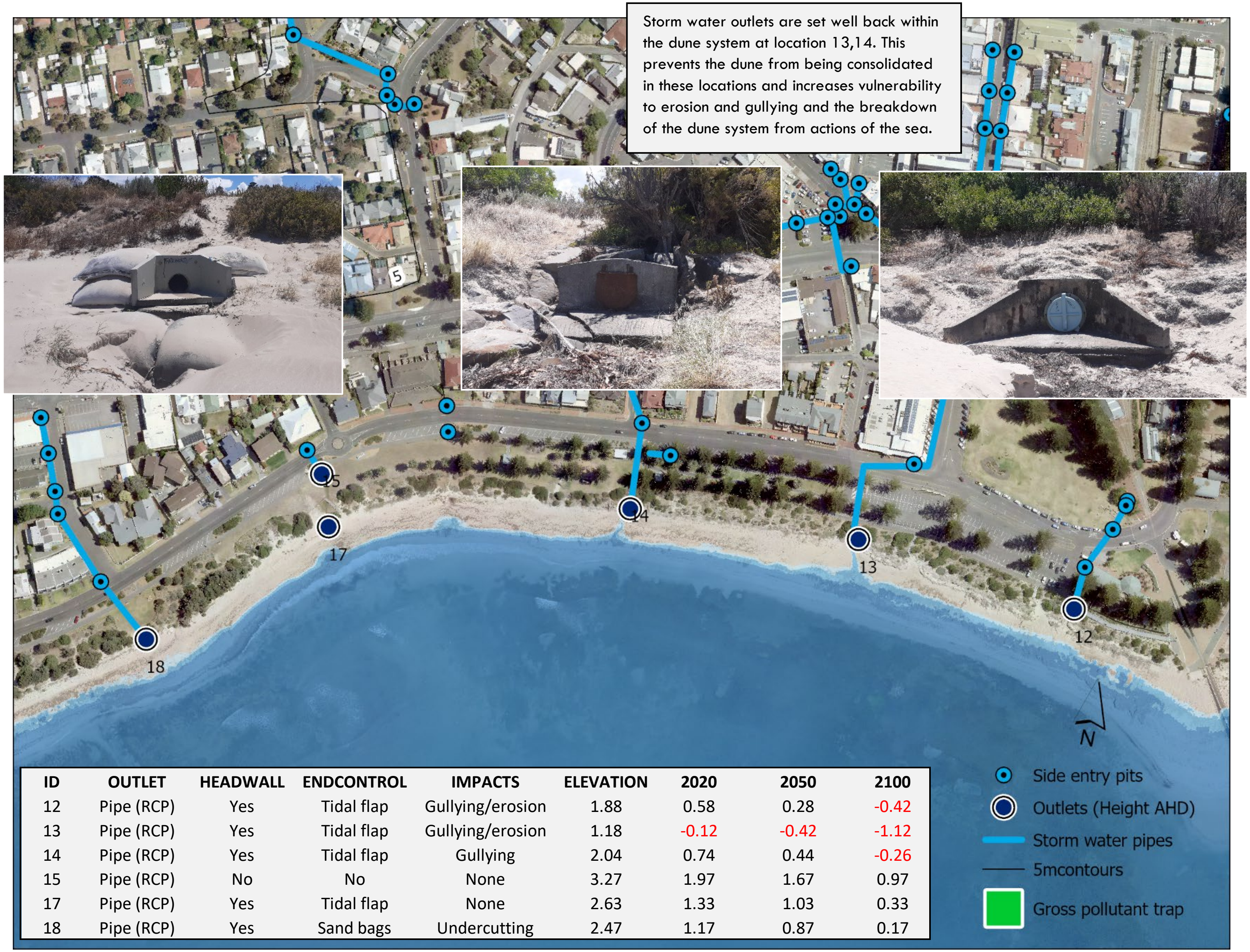
Storm water outlets are set well back within the dune system at location 13,14. This prevents the dune from being consolidated in these locations and increases vulnerability to erosion and gullying and the breakdown of the dune system from actions of the sea.



ID	OUTLET	HEADWALL	ENDCONTROL	IMPACTS	ELEVATION	2020	2050	2100
12	Pipe (RCP)	Yes	Tidal flap	Gullying/erosion	1.88	0.58	0.28	-0.42
13	Pipe (RCP)	Yes	Tidal flap	Gullying/erosion	1.18	-0.12	-0.42	-1.12
14	Pipe (RCP)	Yes	Tidal flap	Gullying	2.04	0.74	0.44	-0.26
15	Pipe (RCP)	No	No	None	3.27	1.97	1.67	0.97
17	Pipe (RCP)	Yes	Tidal flap	None	2.63	1.33	1.03	0.33
18	Pipe (RCP)	Yes	Sand bags	Undercutting	2.47	1.17	0.87	0.17

6. Storm water runoff from urban settlement

Storm Water

Cell 11.2a

Victor Harbor Central

Storm water:

Current design

Storm water outlet assessment Flinders Parade

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

Storm water outlets in this location are set at very low elevations and therefore it can be expected that these are closed on a regular basis. Catchments that flow to outlets 8 and 9 are relatively large (compared to 10,11).

It is difficult to conceive that the current design will manage projected sea level rises of 0.30 by 2050 and 1.00 by 2100.

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ID	OUTLET	HEADWALL	ENDCONTROL	IMPACTS	ELEVATION	2020	2050	2100
8	Pipe (RCP)	Yes	Tidal flap	Gullying/scarping	0.80	-0.50	-0.80	-1.50
9	Pipe (RCP)	Yes	Tidal flap	Gullying/undercutting	0.87	-0.43	-0.73	-1.43
10	Pipe (RCP)	Yes	Tidal flap	Obstructed by wrack.	1.45	0.15	-0.15	-0.85
11	Pipe (RCP)	No	No	Gullying. Partially Blocked	1.09	-0.21	-0.51	-1.21

6. Storm water runoff from urban settlement

Storm Water

Cell 11.2b

Victor Harbor Central

Storm water:

Current design

Storm water outlet assessment
Bridge Terrace

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 storm water outlets in this location are set above impact from projected sea level rises.

Wave runup interacts within the vicinity of this tidal flap (wave runup is not included in the analysis table) but this flap is likely to remain functional until ~2050.

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ID	OUTLET	HEADWALL	END CONTROL	IMPACTS	ELEVATION	2020	2050	2100
1	Pipe (RCP)	Yes	No	None	5.05	3.75	3.45	2.75
2	Pipe (PVC)	No	No	None	4.68	3.38	3.08	2.38
3	Pipe (PVC)	No	No	None	4.34	3.04	2.74	2.04
4	Pipe (RCP)	No	Concrete gutter	None	4.96	3.66	3.36	2.66
5	Pipe (PVC)	No	No	None	5.39	4.09	3.79	3.09
6	Pipe (RCP)	No	No	Gullying/erosion	1.64	0.34	0.04	-0.66
7	Pipe (RCP)	Yes	Tidal flap	Gullying/erosion	1.29	-0.01	-0.31	-1.01

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.

In the location of **Inman River**, a confluence of events is most likely. With increasing sea levels, the tidal flaps for function of the multiple pipes under Bay Road may be impeded (storm water engineer input required).

The tidal outlets at The **Esplanade Beach** are set higher than observation suggests (exception is location 12). The wave runup from higher storm events is interacting with the base of these units. Flow from these outlets cause deep gullying across the beach in rain events. Equally significant is that the need to keep the flow paths clear, prevents Council from building and consolidating the dunes to act as a buffer against sea level rise. Increasing sea levels will more frequently penetrate into these gaps in the dunes and cause a much more rapid breakdown of the dunes and backshore (Figure a).

The tidal outlets on **Flinders Parade** are set at very low elevation and wave runup consistently interacts with these outlets (Figure b). In particular locations 8 and 9 are connected to relatively large catchment areas and are set at the same height as routine high-water (without wave setup). In the context of sea level rise and storm event, it is likely that these tidal flaps will increasingly be closed and in the context of a significant rain event may exacerbate flooding within the township.

The tidal outlets on **Bridge Terrace** are set at higher elevations (exception is location 7 but this is likely to remain functional.

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

Only two gross pollutant traps are installed within Victor Central (location 43 which drains into the wetlands associated with the Inman River, and location 7 situated on Bridge Terrace). It was outside the scope of this assessment to identify any negative impacts from the lack of gross pollutant traps at other locations. However, some of these outlets are connected to relatively large catchments.

The assessment was undertaken in February at a time of low rainfall. However, significant gullying was observed on The Esplanade Beach (Figure c). Along

Figure a. Dunes cannot be built and consolidated in the gaps where storm water flows which will be the points in which increasing sea levels will flow and cause the rapid breakdown of the dunes.

Figure b. Outlets along Flinders Parade are set at very low elevations. Increasing sea levels will increase the times at which these tidal flaps are closed and increase the risk that flooding will be exacerbated within the township.

Figure c. Gullying on The Esplanade Beach. In the context of sea level rise, increasing actions of the sea will impact these areas first and break down the dunes in the backshore.

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.

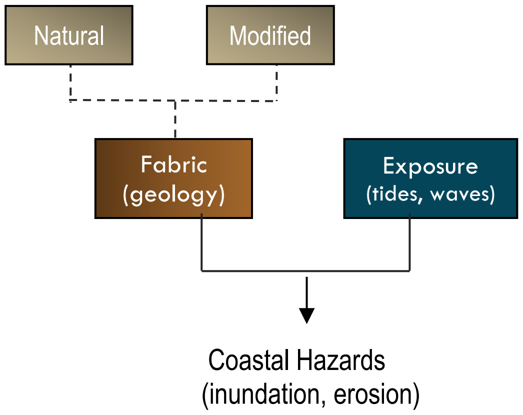
7. Hazard impacts and risks

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.

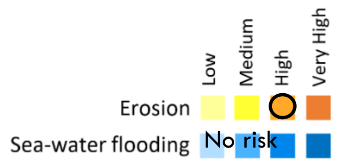
The risk assignments range from 'low' to 'very high' and may include a 'no risk' category. For example, coastal land that is elevated above any inundation risk will be assigned 'no risk'. A dotted circle to the right of the main assignment indicates that the risk assignment requires intensifying due 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:

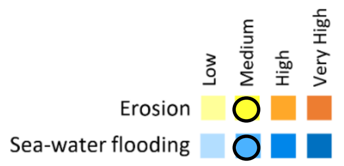
The Esplanade Beach (Cell 11.1)

Fine to medium sandy beach backed by narrow low height vegetated dunes. Nearshore and surf-zone is dominated by sand, covered by continuous and patchy seagrass beds. Offshore is a low profile continuous or patchy reef. Exposure is rated as 'sheltered' and wave energy, 'low'. Overall slope of ocean floor is 1:300. Historical shoreline analysis demonstrates that the shore periodically undergoes erosion and accretion cycles.



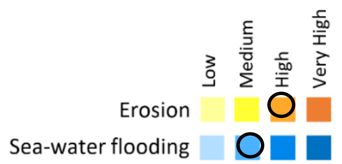
Flinders Parade – Bridge Street (Cell 11.2)

Fine to medium sandy beach backed by rock or concrete seawall from causeway to bowling club, then very narrow, low height dune backed by walking path and playing fields. Nearshore and surf-zone dominated by sand, covered by dense seagrass beds. Offshore is dominate by sand with patchy seagrass cover. Exposure is rated as 'moderate' and wave energy, 'low'. Overall slope of ocean floor is 1:100. Historically, storms have often overtopped the bowling club/ tennis court area which has been increasingly protected over time (beginning with the 1920 seawall).



Inman River (caravan park, Kent Reserve)

Inman River is estuary between the Caravan Park and Kent Reserve. The mouth has been trained west from its former position. Sand dunes have been installed to the bank on the east. An earthen bund protects the caravan park.



7-2 Description of hazard impacts

Public assets at risk

Seawall and foreshore infrastructure

Modelling demonstrates that in the latter part of the century the current foreshore layout along Flinders Parade and Bridge Terrace is unlikely to be viable. The current sea wall would be constantly undermined by routine tidal action and larger storm events. Storm surge modelling demonstrates that waves would overtop the existing infrastructure into gardens and playing fields.

Carparks and reserves

If seas rise as projected, then the dunes along The Esplanade are likely to recede and eventually threaten the reserve, carparks (boat ramp and visitors centre) and other infrastructure behind. Kent Reserve would become increasingly flooded by seawater.

Caravan park

The caravan park on Inman River is currently protected by a levee. Post 2050 this levee will become increasingly ineffective against rising sea levels. The frontal dunes

Storm water

Storm water outlets are positioned at low elevations on The Esplanade Beach and Flinders Parade. The function of these is likely to become increasingly impeded by rising sea levels and therefore increasing the potential for rain water flooding in the township.

Figure a. The Esplanade Beach – erosion in the second half of this century is likely to impact carpark, reserve, visitor centre.

Figure b. The Esplanade Beach – erosion in the second half of this century is likely to impact carpark, reserve, visitor centre.

Description of hazard impacts (cont)

Private assets at risk

Private assets are set behind esplanade roads and therefore are not generally at risk from projected sea levels in this century. (It is understood that the playing fields are leased to clubs from the Council. The exception may be the Yacht Club).

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 are low, it is unlikely that there will be increase risk to public safety due to sea level rise. The exception may be along the promenade adjacent the Soldiers Memorial Gardens and bowling club which is likely to subject to increased overtopping which may impact pedestrians.

As observed when The Esplanade beach was within an erosion cycle between 2007 and 2011, community concern can grow. In times such as these, various community views grow, and sometimes the tendency to assign blame escalates. (Note: this factor is one reason that this project has focussed on establishing a baseline understanding as to how the coast has been formed and changes over time. The more we can know about how a coastline operates the less room there will be for community misunderstanding).

It is understood that the Soldiers Memorial Gardens and playing fields are locations where many community interests intersect. If inundation increases into these areas, or protection works fail, community concern can grow. Additionally, when the community as a whole attempts to find long term solutions that might preserve the coastal environment in a more natural form, various interest groups may become concerned. These various strands relating to coast and community can cause social disruption.

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 altered nature of most of the backshore, the potential for ecosystem disruption is minimal. The exceptions will be the impact of saltwater at Soldiers Memorial Garden, Kent Reserve, and locations noted on the flood mapping for Inman River and Hindmarsh River.

Additionally, coastal areas which are habitats for shore nesting birds are likely to be disturbed or lost by retreating shorelines. The impact is likely to be the greatest in locations where shorelines are unable to retreat naturally due to human intervention.

Summary: Hazard Impacts

The main threat that sea level rise will bring increasing impact to backshores so that the dune system will recede on The Esplanade beach to an extent that carparks, reserves, visitors centre, and caravan park are under threat from erosion or inundation. The main threat to the Flinders Parade will be increasing overtopping of the protection works so that the reserve and playing fields are increasingly flooded. As the protected backshore is unable to recede, sand levels will continue to lower on the beach which may in time be lost for community use. Community concern may cause social disruption and ecosystem disruption is likely to occur in some freshwater ecologies in reserves/parks and within the two estuaries. Habitats of shore nesting birds are likely to be disturbed or lost.

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

Victor Harbor Central (Cell 11.1)

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

Coastal setting	Coarse sand beach backed by narrow low height vegetated dunes 3.5m -4.5m AHD. A reserve or carpark is positioned behind the dunes and the esplanade road at 3.5m to 4.5m AHD. In the mid-1800s a significant dune system covered the foreshore area back to Warland Reserve. Nearshore and surf-zone is dominated by sand, covered by continuous and patchy seagrass beds. Offshore is a low profile continuous or patchy reef. Exposure is rated as 'sheltered' and wave energy, 'low'. Overall slope of ocean floor is 1:300. Significant seaweed rack often accumulates on the beach. Historical shoreline analysis demonstrates that the shore periodically undergoes erosion and accretion cycles.

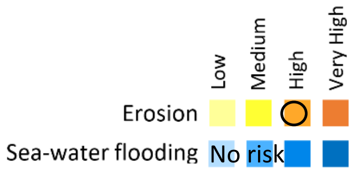
Are any strategies employed to mitigate the risk? Concrete blocks installed on beach King Street, sand nourishment program utilising seaweed wrack.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	The Esplanade Road, Encounter Bikeway, carparking are generally set well back behind the dunes. Beach access points and storm water outlets are set in the immediate backshore. Increasing sea level will continue to threaten these.	current	*Unlikely*	*Moderate*	medium
		2100	*Very Likely*	*Catastrophic*	Extreme
Private assets**	Private assets are situated landward of The Esplanade at a distance greater than 60m.	current	*No risk*	*No risk*	No risk
		2100	*Unlikely*	*Minor*	Low
Social disruption (including public safety)	Public safety and enjoyment may be increasingly at risk. This was evidenced with recent erosion (2007 to 2011). Introduced groynes marred the beach for some and community concern was high. Increased sea levels may cause further beach losses.	current	*Rare*	*Insignificant*	medium
		2100	*Possible*	*Minor*	Extreme
Ecosystem disruption	Due to the slope of the backshore in this location and the nature of infrastructure already in the backshore, large scale eco-system disruption is unlikely. *However, bird habitats may be disturbed or lost*.	current	*Unlikely*	*Minor*	low
		2100	*Possible*	*Moderate*	Medium*

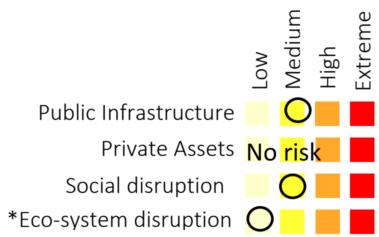
**Council not necessarily liable for private assets

Inherent Hazard Rating

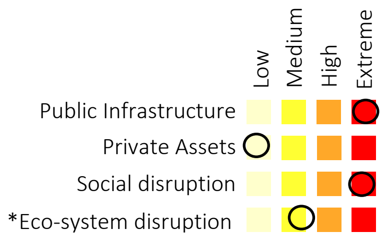
Coarse sand bench backed by low height vegetated dunes



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.

Victor Harbor Central (Cell 11.2)

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

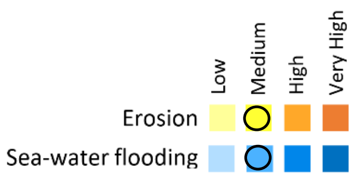
Coastal setting	Fine to medium sandy beach backed by rock or concrete seawall from causeway to bowling club, then very narrow, low height dune (7m to 8m wide) backed by walking path and playing fields. In the mid-1800s the foreshore contained a small dune system that extended back to Flinders Parade. Nearshore and surf-zone dominated by sand, covered by dense seagrass beds. Offshore is dominate by sand with patchy seagrass cover. Exposure is rated as 'moderate' and wave energy, 'low'. Overall slope of ocean floor is 1:100. Historically, storms have often overtopped the bowling club/ tennis court area which has been increasingly protected over time (beginning with the 1920 seawall).

Are any strategies employed to mitigate the risk? Rock revetment or concrete blocks from the causeway to the bowling club.

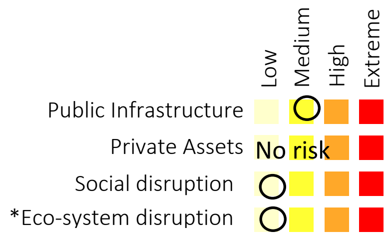
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Car park, boat ramp, playground, Soldiers Memorial Gardens, bowling club and other playing fields (southern sections heavily protected) Heavy seas already overtop the protection works, projected sea level rise will substantially increase risk.	current	*Unlikely*	*Moderate*	medium
		2100	*Certain*	*Catastrophic*	Extreme
Private assets**	Private assets are situated landward of Flinders Parade at a distance greater than 70m. Bowling clubs and other clubs are leased from Council. (Who owns the Yacht Club?)	current	*No risk*	*No risk*	No risk
		2100	*Unlikely*	*Minor*	Low
Social disruption (including public safety)	If the adaptation strategy is to continue protection, then this area will be increasingly dominated by protection works, and loss of aspect and access to the beach which will continue to decline in sand level until lost.	current	*Rare*	*Insignificant*	Low
		2100	*Possible*	*Minor*	Very 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	*No risk*	*No risk*	Medium*

Inherent Hazard Rating

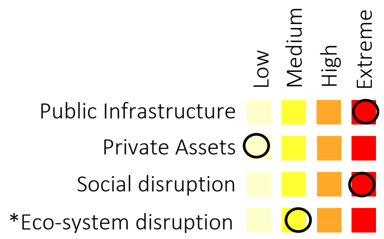
Narrow coarse sand bench backed by protection or low height dunes in the north.



Erosion Hazard Rating
(current outlook 2020)



Erosion Hazard Rating
(future outlook 2100)



**Council not necessarily liable for private assets

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: Victor Harbor Central (Cell 11.1)

The Esplanade Beach

(11.1)

Coastal description:

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

Fabric - Coastal history

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

Exposure - Scenario modelling

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

Storm water runoff

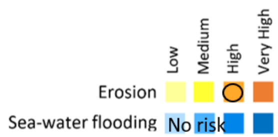
Storm water from urban settlement is being appropriately managed so that none flows to the coast in an uncontrolled manner. However, storm water outlets set in the backshore of the Esplanade Beach (x3) prevent the sand dunes from being consolidated. Increasing actions of the sea will first impact these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

Overview of Impacts

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

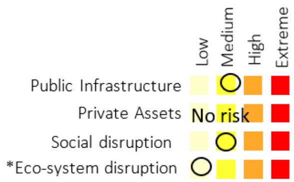
Inherent Hazard Rating

Coarse sand bench backed by low height vegetated dunes



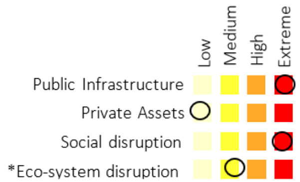
Erosion Hazard Rating

(current outlook 2020)



Erosion Hazard Rating

(future outlook 2100)



8. Summary: Victor Harbor Central (Cell 11.2)

Flinders Parade – Bridge Terrace (11.2)

Coastal description:

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

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

Fabric - coastal history

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

Exposure – scenario modelling

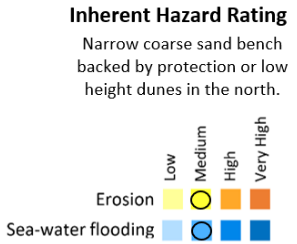
Minor overtopping occurs regularly in vicinity of gardens and bowling club. Scenario modelling for 2050 indicates increased overtopping, recession of the beach in unprotected locations, loss of sand in protected locations. Post 2050, both routine high-water events and 1 in 100-year storm surge events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

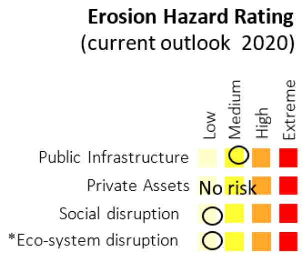
Storm water runoff

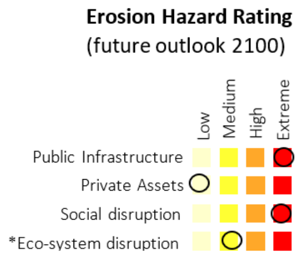
Storm water outlets in the vicinity of the gardens and bowling club are set at very low elevations. Increasing sea levels will close the tidal flaps more frequently and increase the likelihood of increased flooding from rain events.

Overview of Impacts

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







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:

- **Avoidance** – Avoid the impacts of coastal hazards by ensuring that assets are not placed in areas that could be impacted in the future.
- **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.
- **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).
- **Managed retreat** – Progressively move assets or services away from areas that could be impacted by coastal hazards now or in the future.
- **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.

Planning

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

Engineering

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

Environmental management

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

Adaptation timing

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

Incremental approach

A series of relatively small actions and adjustments aimed at continuing to meet the existing goals and expectations of the community in the face of the impacts of climate change.

Transformative approach

In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant that they can only be addressed through more dramatic action. Transformational adaptation involves a paradigm shift: a system-wide change with a focus on the longer term. A transformative approach may be triggered by an extreme event or a political window when it is recognised the significant change could occur.

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

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

Adaptation Strategy

The Esplanade Beach

Cell 11: 1

Adaptation strategy

2. COASTAL SETTING - SUMMARY

Coastal processes

Early photographs show that a substantial dune system existed along The Esplanade Beach which penetrated inland to what is now known as Warland Reserve. By the 1930s this dune system was completely removed but has been slowly reinstated from the 1970s onward.

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 of 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.

Coastal outlook

The erosion and accretion cycles are expected to continue as they relate to the various climate systems. However, the modelling indicates that if seas rise as projected that the longer-term trend will be for recession of the dune system by ~50m by 2100, and ~10 to 15m by 2050.

It is also generally accepted[3] that increased depths of water over the reefs will reduce their sheltering effect and swells of greater size will be generated. In addition to this factor, recent studies have demonstrated that the height of the swell in the Southern Ocean has been increasing in the over the last thirty years. While the increases in height are only measured in centimetres, if this trend continues, then swells of greater size will impact the Esplanade Beach from the Southern Ocean[4].

Legacy issues (human intervention)

On the positive side, the early planners positioned The Esplanade Road 40-50 metres landward of the highwater mark. Additionally, unlike Encounter Bay and Flinders Parade, the beach profile is in its natural state.

There are two main legacy issues. The first is the installation of carparking, buildings and to a lesser extent the Norfolk Pines and infrastructure within Memorial Gardens. These act as hold points to prevent the dune system from receding as it would do naturally in the context of rising sea levels. The carpark is positioned ~20m from the highwater mark and the pathway adjacent the visitors centre is 12-13m. The second legacy issue is the installation of four storm water outlets in the 1940s that are positioned at the rear of the existing dune system. It is impossible to build a stable dune system when storm water flows scour and channel the beach, and into these gaps tides routinely flow.

Figure a: A substantial dune system formerly existed on Esplanade Beach. Victor Harbor1866

Figure b: Legacy issues- the carpark constructed ~20m from the highwater mark and storm water outlets that prevent a stable dune system from being established on the beach.

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[3] Hesp, AWE, 2013, Magryn

[4] 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 The Esplanade Beach as there is sufficient distance between the highwater mark and infrastructure to implement a management plan. Additionally, 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 for Esplanade Beach and did find reference to storms that overtopped the frontal dune system resulting in seawater flowing up the street toward the Crown Hotel. However, these anecdotes relate to a time in the 1930s and 1940s when the sand dunes had been completely removed from the foreshore.

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[5].

In summary, considering the storm record, the current rate of sea level rise, and the general layout of this coastal region, an incremental approach is recommended for The Esplanade beach.

[5] 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).

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 social significance such as within Victor Central, additional 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'[6]. 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 (30-40 years) is that every new proposal can be assessed within that strategy and cost savings are likely to be achieved over the longer term.

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

Adaptation response – 'hold the line'

The current coastal adaptation strategy has been to **'hold the line'**, which saw management options such as groynes and sand 'sausages' installed at Esplanade Beach in the time period 2005 to 2011.

A protection strategy should be deemed viable for 30 to 40 years and to cater for sea-flood risk levels set by Coast Protection Board at:

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

Coastal Management Study, 2013 - strategy

The Coastal Management Study (2013) generally recommended a 'hold the line' strategy noting in the first instance that soft environmental responses are preferred such as sand nourishment and dune vegetation.

- Soft management strategies

The study recommended sand replenishment to build up the height of the dune in high-risk areas (Option 4). In particular, the study recommended a trial of disposal of seaweed wrack by mixing with sand higher than 50% of the mix.

Adaptation strategy

Adaptation response (cont.)

Sand was to be obtained 'from scraping the beach face seaward of the erosion scarp or by using imported sand, either from further along the beach or an external source. The placement of the sand was to maintain a shore parallel alignment of the escarpment'.

However, one of the problems associated with this technique is that the storm water outlets prevent the seaweed wrack, or any other imported sand, from being disbursed evenly along the beach which could create a consolidated dune (Figure a). This management technique, while managing the seaweed wrack, has limited long term usefulness for building and stabilising a dune system when storm water and seawater flows through the dunes. Furthermore, if seas rise as projected then the storm water outlet locations will be the most vulnerable to incursions from the sea.

Figure a: Flows from storm water outlets placed at the back of the beach prevent a consolidated and well vegetated dune from being built which could act as a natural defence in the context of rising sea levels.

- Engineering strategies

The Coastal Management Strategy 2013 proposed four engineering options:

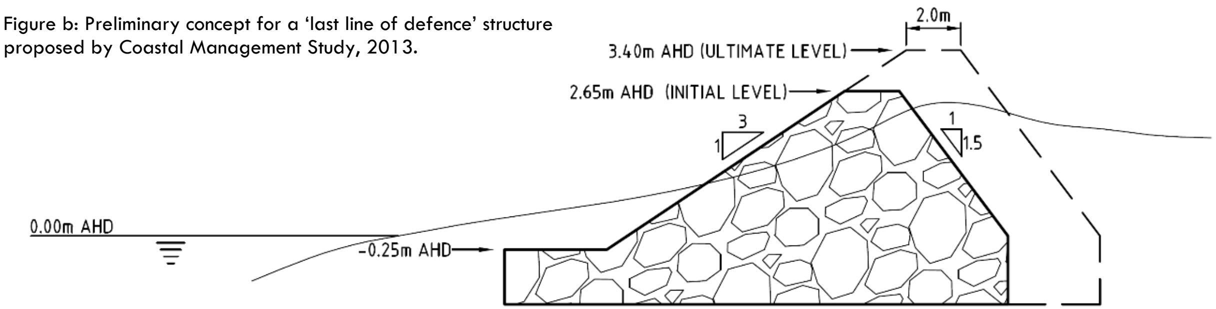
Option 1 - Rock revetment sea wall located adjacent to fore dune as far landward as possible at 2.65m AHD with ability to increase height to 3.4m AHD as sea level rises further (Figure b).

Option 2 - Vertical concrete sea wall located behind fore dune within reserve to 3.4m AHD with rock protection on coastal side.

Option 3 - Rock revetment sea wall located adjacent to fore dune as far landward as possible to 2.65m AHD with parapet wall on top of wall to 3.4m AHD to reduce wave overtopping.

Option 4 - Rock armoured earthen levee located adjacent to fore dune as far landward as possible to 2.65m AHD with ability to increase height to 3.4m AHD as sea level rises further.

Figure b: Preliminary concept for a 'last line of defence' structure proposed by Coastal Management Study, 2013.



- Summary

In summary, the broad strategy of the Coastal Management Study was to implement soft management techniques, and then use 'last line of defence' options if the soft management options ceased to be effective in the context of sea level rise. This project team concurs with this broad strategy, and we describe ways in which a soft management strategy could be implemented below.

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

- Sand nourishment was implemented 3x from 2009 to 2012 at various locations along the beach,
- Sandbag groynes installed 2009,
- Sand sausage at back of beach 2004,
- Concrete block seawall installed in the vicinity of King Street in 2015 and covered with sand (see photograph next page).

Adaptation strategy

Adaptation response (cont.)

Concrete block seawall - review

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 a: Concrete block seawall installed within the dune and covered over with sand (Coast and Marine Branch, email, 2021).

Adaptation response parameters

In summary, there are three 'hold the line strategies' that may be employed along The Esplanade Beach.

1. Environmental strategies that consolidate natural dune systems with sand nourishment and/or vegetation.
2. Concrete block seawalls which may be effective placed within dune systems to act as an interim 'line of defence'. However, these are yet to be proven within an erosion cycle and therefore performance should be monitored.
3. Rock revetment, which has a proven track record with dissipating wave energy, as has been installed in the vicinity of Soldiers Memorial Gardens.

Cell 11.1 – Inman River to the causeway

This section of coast is characterised by:

- A dune system with heights predominantly at 3.50m AHD to 4.50m AHD (with a lower section adjacent the river mouth (2.60m to 3.00m AHD).
- Human intervention has not altered the natural profile of the beach and waves runup to the base of the dune unhindered.
- There are some gaps all the way through the dune system. One gap has been formalised between Inman Street and Island Street to provide access for vehicles and machinery and there are three main gaps in the dunes for storm water flow.
- There are some gaps on the landward side of the dunes where lawned areas or parks have been created.

The unifying strategy for Cell 11.1 is to build and consolidate a well-vegetated dune system that is more likely to erode and accrete with the various climate systems, but overall is capable of receding by 5-10m by 2050 (but this may be earlier or later depending on the actual rate of sea level rise).

The seaweed wrack combined with sand is deemed appropriate by this project team and it appears that there might be ample supply to assist in building the dune system.

If the dune system recedes, and the concrete block seawall strategy has proven itself, then this strategy could be employed at the back of the beach, and the dune system rebuilt in front of it again.

As a last line of defence, the hard protection options provided by the Coastal Management Study could be employed, but these are more likely to be required post-2050.

Fundamental to the success of this strategy is to close all the gaps which consist of:

- Storm water outlets
- Beach pedestrian access points
- Gaps at natural ground (but it will be necessary to provide one gap for vehicle access).

An adaptation strategy is also considered for the caravan park adjacent the Inman River.

Adaptation strategy – Inman River to Inman Street

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

Inman River to Inman Street

Coastal setting

Estuary with frontal dune, and wetland swale behind within former riverbed.

The height of the dune is predominantly 2.60m to 3.00m AHD, increasing in height to Inman Street.

The dune in the vicinity of the training wall tends to erode and accrete on a frequent basis (Compare main photo, Feb, 2021, Inset top, March, 2020, inset bottom, 2018).

The 1 in 100-year storm risk level is set at 1.75m AHD with 0.30m wave setup and 0.30m wave runup*.

Existing protection:
The bikeway forms frontal protection to the caravan park at 2.00m AHD . A levee is situated around the caravan park at 1.90m or above (see next page).

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*It is recommended that wave and tidal studies be carried out within Victor Harbor Central to enable more site-specific allowances for wave setup, wave runup and wave overtopping (if relevant) to be allocated. For example, it is likely that wave impacts are larger on Esplanade Beach than in the area nearer the Bluff Boat Ramp.

Adaptation strategy – Inman River to Inman Street

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

Inman River to Inman Street

Existing layout

The map depicts the current terrain and layout of the caravan park and frontal dune system. Current risk is 1.75m AHD (plus wave setup 0.30m). This levee is likely to protect to current risk but no higher.

Exposure (future)

The sea-flood risk projected for 2050 is 2.05m AHD plus wave setup at 0.30m which may penetrate up the river enough to overtop the levee.

The sea flood risk for 2100 is 2.75m AHD with wave setup of 0.30m, giving a total risk height of ~3.00m AHD.

As most of the site is less than 2.00m AHD the caravan park may not be viable by the end of the century without significant protection.

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Adaptation strategy – Inman River to Inman Street

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

Inman River to Inman Street

Adaptation Strategy

Survey and assess the levee around the caravan park and raise and widen to cope with projected event for 2050.

Assess native vegetation implications and weigh these against preserving the caravan park.

Monitor the frontal dune to ensure that it maintains its vegetation. Use sand nourishment to raise low spots or increase width where necessary.

If seas rise as projected, facilitate the recession of the dune by allowing room for the dune to move landward, provide sand nourishment and vegetation.

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Adaptation strategy - Inman Street to King Street

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

Inman Street to King Street

Coastal setting:

Existing dune – generally well vegetated (3.50m to 5.00m AHD). There is room for dunes to retreat landward if seas rise.

The existing gap in the dunes between Inman Street and Island Street is for vehicular access.

The current 1 in 100-year storm event risk level is set at 1.75m AHD with allowance for 0.30m wave setup and 0.30m wave runup*

Existing protection:

Concrete block seawall installed in 2015 and covered with sand. Storm water outlet placed within the seawall.

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*It is recommended that wave and tidal studies be carried out within Victor Harbor Central to enable more site-specific allowances for wave setup, wave runup and wave overtopping (if relevant) to be allocated. For example, it is likely that wave impacts are larger on Esplanade Beach than in the area nearer the Bluff Boat Ramp.

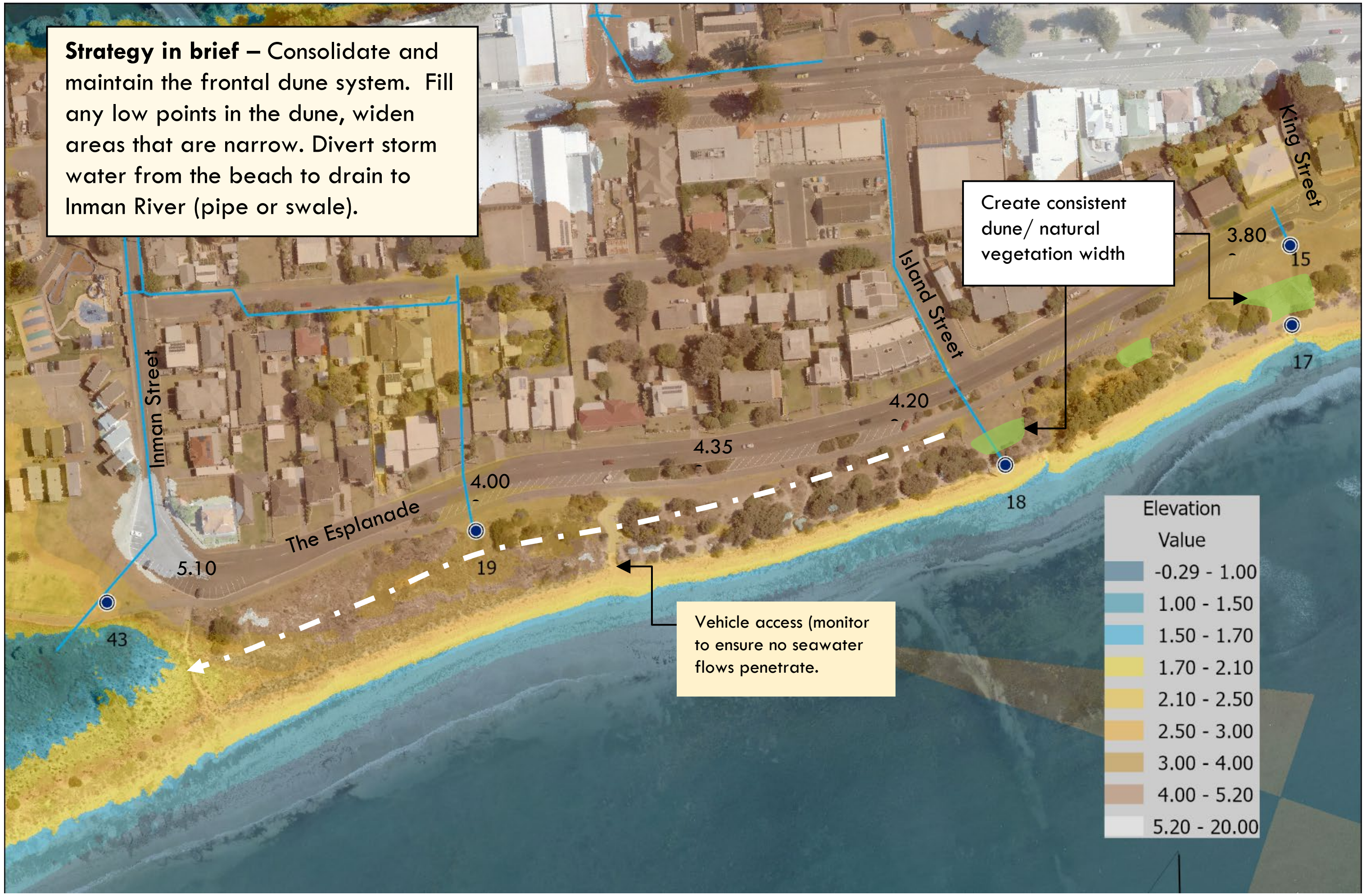
Adaptation strategy - Inman Street to King Street

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

Inman Street to King Street



Adaptation strategy

1. Create dune/ natural vegetation at consistent width to allow flexibility in case of retreat. Return half of the park at Island Street back to natural vegetation/dune.

2. Monitor dune health, height and width – sand nourish and vegetate as required.

3. Divert storm water from Island Street to Inman River (some may be open swale). Leave the King Street outlet in place.

Outlook 2050 to 2100

If seas rise as projected, the dune is likely to recede back to the road but the road here is well elevated and installation of hard protection items feasible (see also AWE above).

Magryn and Associates (Engineer) It is proposed to divert stormwater from the current outlet (which is onto the beach), and discharge to Inman River. The water then discharges to the ocean via the existing river outlet. Preliminary stormwater calculations were undertaken for a 1 in 100-year ARI rain event, which suggest that the proposal is feasible. The required pipe size would be in the order of 900mm diameter. The existing gaps in the dune system are proposed to be filled to create a continuous natural and vegetated dune.

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Adaptation strategy - King Street to the Causeway

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

King Street to Causeway

Coastal setting:
Existing dune – consolidated and vegetated (3.50m to 4.80m AHD).

Gaps in the dune system prevent a dune from being consolidated. Storm water scours the beach.
6 main gaps in the dune system:

- 3x storm water outlets (with height AHD)
- 3x access points

Existing protection/management:

Sand sausage buried at the back of the beach near King Street.

Seaweed wrack and sand combined and 'stockpiled' near the causeway.

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Note: The number of the storm water outlet corresponds to a photographic survey undertaken in February 2021 and the height of the invert is also recorded in AHD.

Adaptation strategy – King Street to the Causeway

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

King Street to the Causeway

Strategy 2021-2031
Build a substantial and consistent dune that is able to erode and accrete with changing climate systems, and act as a buffer in the context of sea level rise. To enable this to occur the gaps in the existing dune system will need to be filled:

- Divert storm water away from the beach.
- Remove storm water outlets, fill gaps, vegetate, position beach access points over the top of the dune. Calculation is for 870m³ to fill existing gaps.
- Monitor beach levels and use sand/ wrack to fill low spots.

Outlook 2050 to 2100:
The dune is likely to recede back to the carpark and Memorial Gardens. Employ hard protection option – concrete block wall or rock revetment (see above).

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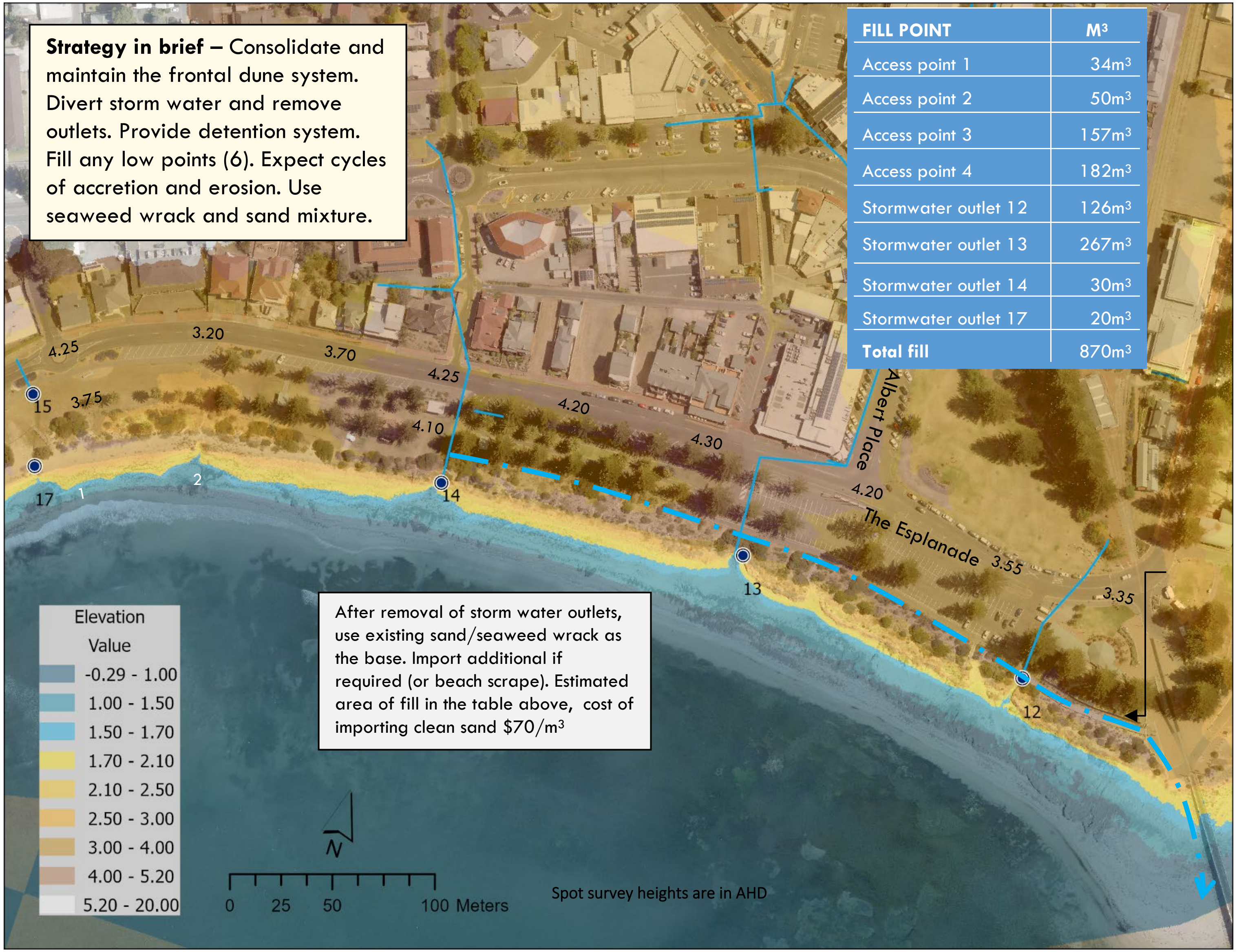
Strategy in brief – Consolidate and maintain the frontal dune system. Divert storm water and remove outlets. Provide detention system. Fill any low points (6). Expect cycles of accretion and erosion. Use seaweed wrack and sand mixture.

FILL POINT	M³
Access point 1	34m³
Access point 2	50m³
Access point 3	157m³
Access point 4	182m³
Stormwater outlet 12	126m³
Stormwater outlet 13	267m³
Stormwater outlet 14	30m³
Stormwater outlet 17	20m³
Total fill	870m³



After removal of storm water outlets, use existing sand/seaweed wrack as the base. Import additional if required (or beach scrape). Estimated area of fill in the table above, cost of importing clean sand $70/m³

Adaptation strategy - King Street to the Causeway

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

King Street to Causeway

Magryn and Associates

(Engineer review)

The proposal is to minimise the number of stormwater outlets along the beach between King Street and the causeway, allowing a more natural beach to form without regular erosion from beach wash out. The existing stormwater outlets would be removed, and all stormwater directed to the causeway, where it could be discharged below water level into the ocean. By discharging stormwater below water level, beach erosion issues are removed, however potential scouring below water should be addressed.

(Continued below, right)

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(Magryn, continued). A critical consideration for the above proposal is that adequate scour protection must be provided at the outlet, as all of the flow from a large catchment area will be discharged at one concentrated location (rather than dispersed to multiple outlets). The scour protection may include rock rip rap and a concrete headwall.

Adaptation strategy - King Street to the Causeway

Magryn and Associates

(Engineer review, continued)

A detention system would be beneficial to reduce the flow rate and velocity discharging at the outlet and therefore reduce the potential for scouring. However, the size that the detention system can be is limited by a number of factors, including:

- There must be sufficient head (height difference between the detention basin outlet and the main outlet) to enable the water to flow out. Hence, the outlet at the bottom of the detention basin must be above the main outlet and/or sea water level.
- Due to the limitations on the depth of the basin (discussed above), the plan area may need to be quite large to cater for a 1 in 100 year ARI rain event.

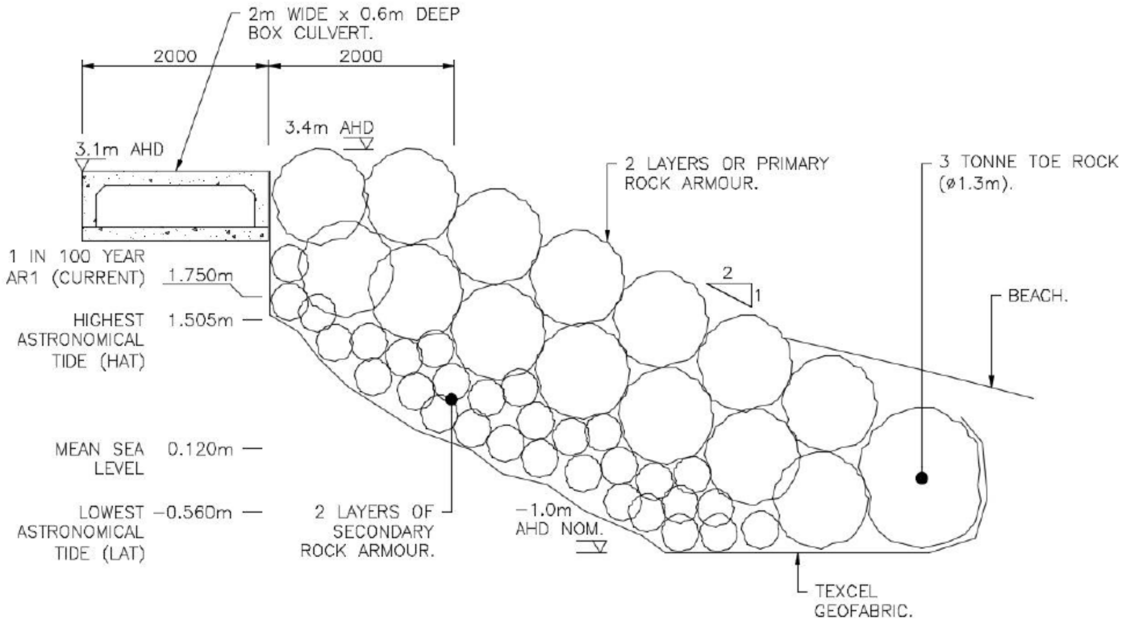
A box culvert may be a practical detention solution. Preliminary stormwater calculations were undertaken for a 1 in 100 year ARI rain event. The required pipe size would be in the order of 800mm diameter if no detention system is utilised. The flow rate at the outlet would be in the order of 1000 L/s with a velocity of 2 m/s.

If the flow rate at the outlet was restricted to 250 L/s, approximately 60,000L of detention storage would be required. A 2m wide by 0.6m deep box (by 50m long) culvert would provide sufficient storage capacity to achieve this. In order to restrict the flow at the outlet of the box culvert, approximately a 500mm diameter pipe would be required.

Installation of the box culvert to control stormwater could be completed in conjunction with an adaptation strategy for coastal protection. A raised pathway (to 3.4m AHD to accommodate 1 in 100 year ARI for 2100) could be constructed along the esplanade, with the box culvert beneath. Hard rock protection may be required along the outer face to protect against erosion and undermining.

Integrated Coasts (comment)

Protection items are currently not required. Consideration could be given to installing the box culvert now and the dune reinstated.



KING ST TO CAUSEWAY

SCALE 1:50

Adaptation strategy - King Street to the Causeway

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

King Street to Causeway

Outlook 2100

Discussion

The flood mapping provides insight into the long-term outlook to 2100. Note, if seas rise by 1m, then the dune system will erode away, and the new shoreline is likely to be at the carpark (assuming that defences are implemented).

The erosion modelling suggested that in its natural state this part of the coast would erode between 35 and 63m (we are using 50m).

The construction of the new causeway infers a long-term protection strategy of the land areas either side.

Therefore, in a strategic location such as this, the longer-term planning of the infrastructure (even in a preliminary sense) assists in decision making in this current time.

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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

In the context of this minor cell, monitoring will be crucial in the establishment of the dune system. Using drone technology to establish the various low points in the dune will mean that sand nourishment can be accurately targeted and vegetation growth monitored.

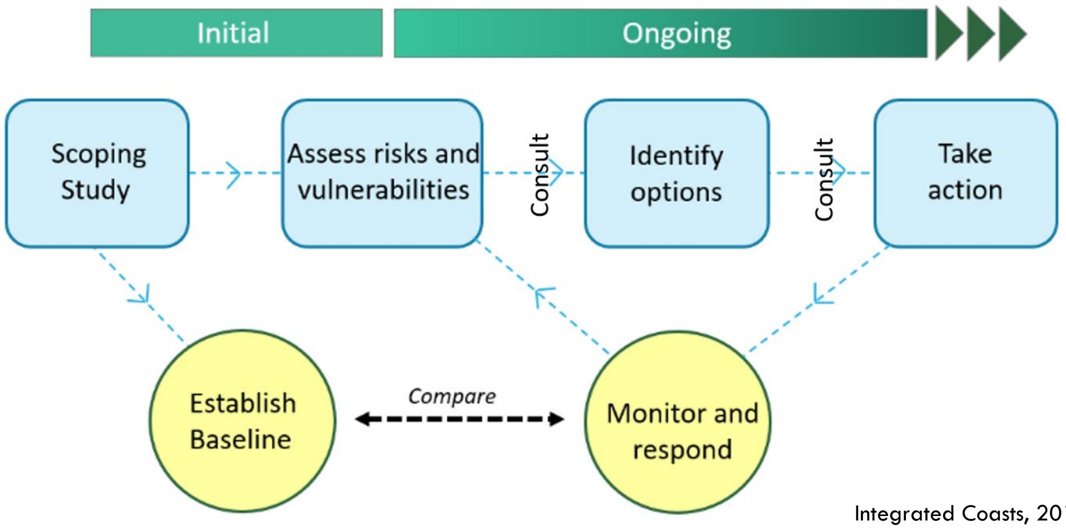
1. In the process of establishing the dune system, conduct terrain modelling using a drone at required intervals (suggested, 3 monthly for the first two years and then revaluate frequency of capture). Compare terrain levels within appropriate software from which to formulate targeted actions.

2. 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.

3. 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.

4. 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

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Adaptation Strategy

Flinders Parade

Cell 11: 2

Adaptation strategy

1. COASTAL PROCESSES - SUMMARY

Coastal setting

Early photographs show that the area in the vicinity Flinders Parade was a low coastal slope up to the main street, probably with a small incipient dune above the high-water mark (Figure a). The geomorphology study found that this area of coast was formed recently as the sea fell about 1m from the Holocene 'high stand' about 3000 years ago. The position of the shoreline of this section of coast was determined by the swells from the Southern Ocean which sweep around Granite Island. This impact has both created the curve in the bay and also helped create the sand spit (headland) upon which the causeway is now positioned. Figure (b) demonstrates how the two swell patterns have created the headland and how the swell has formed the curve of the bay along Flinders Parade.

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 with frequent overtopping into Soldiers Memorial Gardens, the bowling greens and former tennis courts. More recently, between 2007 and 2011 analysis of the tide gauge data demonstrated that elevated waters were experienced more regularly, and this coincided with increased impact along the backshores of Esplanade Beach and Flinders Parade.

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.

Legacy issues (human intervention)

The impetus for the first seawall in 1920 came in the context of planning for the Soldiers Memorial Gardens when it was recognised that regular higher tides were flowing into the region and making the gardens and recreational spaces unviable (Figure c). The seawall completely failed in the 1980s and was replaced with higher rock revetment. Progressively since this time, protection items have been constructed along the foreshore to the northern edge of the bowling clubs. Stormwater outlets were installed in the 1940s and are situated at low elevations along the beach. In summary, the main legacy issue relates to the creation of a 'hold line' that prevents the shoreline from adapting to various conditions, and in particular, sea level rise.

Coastal outlook

Over the last 100 years since the construction of the seawall, sea levels have risen ~200mm and this has likely contributed to the gradual loss of beach along Flinders Parade. The sea level rise trend appears on track for a further 300mm rise of sea level by 2050 but beyond this is more uncertain. It is also generally accepted that increased depths of water over the reefs will reduce their sheltering effect and swells of greater size will impact the shoreline[1].

Figure a: Victor Harbor, 1908 (SA State Library, B-17465-3)

Figure b: Victor Harbor, 1928 (SA State Library, B-4964)

Figure c: Victor Harbor, 1937 (SA State Library, 1937, B-23718)

[1] Hesp, AWE, 2013, Magryn

Adaptation strategy

Coastal outlook (cont.)

In addition to this factor, recent studies have demonstrated that the height of the swell in the Southern Ocean has been increasing over the last thirty years[2].

While the increases in height are only measured in centimetres, if this trend continues, then swells of greater size from the Southern Ocean will impact the beach along Flinders Parade and to a lesser extent Bridge Terrace (which has been accreting over the last fifty years). In other words, the same coastal conditions that formed the curve in the bay along Flinders Parade will be intensified in the context of sea level rise, and in natural conditions, an even greater curve would be formed. When we considered what the coast would 'want to do' in its natural condition, the modelling suggested that the coast would recede back to Flinders Parade by 2100 if seas rise as projected. Irrespective of how much the seas rise by 2100, the trend for erosion along Flinders Parade seems certain.

Council and the community should be encouraged to consider how to manage the future trend. The choice is either to fight the trend and build increasingly high defence systems that cut off access to the coast, and a sandy beach is lost, or go with the trend and establish coastal layouts that are designed to absorb and manage the trend. These are not necessarily moral decisions; the Netherlands have successfully built whole societies while managing water impacts, but these decisions are preferences about the type of future desired for the coastal zone.

2. ADAPTATION STRATEGY (2021-2031)

Adaptation approach - transformational

A transformational approach to dealing with Flinders Parade is to analyse how the coast would naturally respond to sea level rise, and then accommodate this as much as possible in a new master plan. An outcome of such an approach is likely to be a more natural form in the bay that can be enjoyed by people for decades to come, and with a long-term legacy of a sandy and natural beach. However, human intervention has placed a rigidity in the bay with hard structures. But more than that, to create spaces that are flat enough for playing surfaces and carparks, the front edge has been raised above the natural form of the bay.

The overarching adaptation principle

Currently the line of defence for this section of coast is the elevated embankment that has been formed just above the high-water mark. This embankment has formed a rigid and inflexible line in the bay that prevents the coast from eroding and accreting naturally. The overarching adaptation principle is to translate a raised line of defence adjacent to Flinders Parade and Bridge Terrace and design a more natural beach and a backshore that is able to accommodate various actions from the sea, as well as be able to manage the sea level rise trend to 2100. It is also relevant to consider that sea levels dropped from this line (i.e. Flinders Parade) over the last 3000 years when seas were ~1m higher.

<u>Planning and implementation time frames</u>

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'[3].

It is recognised that the proposals provided below are bold and have far-reaching consequences. Therefore, the adaptation strategy for 2021-2031 is to reconsider the development of a new master plan for Flinders Parade and Bridge Terrace. We see this project as a starting point in the discussion.

2 Hemer et al, 2008, p 651, Young and Ribal, 2019.

3 AWE, 2013, Victor Harbor Coastal Management Study, p. 50.

Adaptation strategy

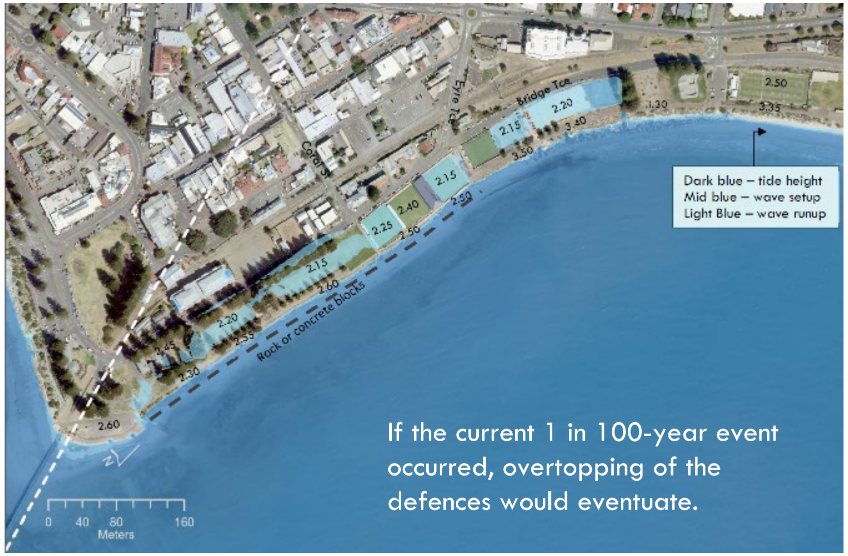
Long term considerations

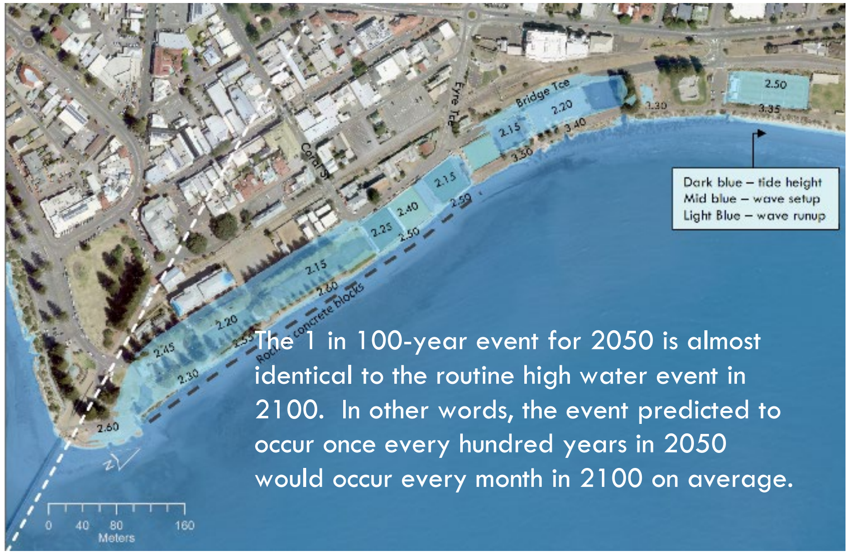
The modelling on this page demonstrates that protection items for sea level rise projections for 2100 are likely to be required at 1.50m higher than present (to manage overtopping on steeper walls). To raise defences this high will have the effect of 'cutting off' the community from the beach unless the land was also raised.

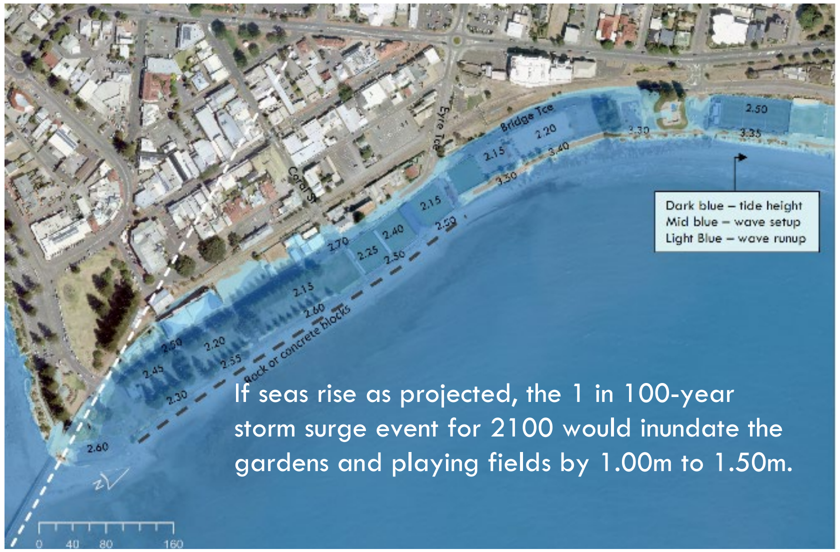
The modelling indicates that a sandy beach would be lost.

It is difficult to envisage how the storm water outlets in their current location would continue to function appropriately.

In view of the significant nature of the headland upon which the causeway is constructed and the nature of Soldiers Memorial Gardens it is presumed that these will need long term protection.







Figures: Integrated Coast, 2021. See exposure section in Part 1.

Adaptation strategy – Causeway to Coral Street

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Soldiers Memorial Gardens

Coastal setting

Formerly a sand spit upon which urban infrastructure now dominates.

The sand spit was originally formed by two different wave patterns. One from the south-west that has formed Esplanade Beach, and one that wrapped around Granite Island to form the coast along Flinders Parade.

The installation of the boat ramp in the 1970s changed the shape of the headland, increasing the width of the beach adjacent the current carpark. On the other hand, there is less sand adjacent Soldiers Memorial Gardens than in the 1940s to 1970s.

Coastal protection and management

Protected by either concrete block seawall or rock revetment seawall. Sandbag groynes were installed ~2005 in an attempt to retain more sand on the beach. These appear to have limited success.

Notes: The matter of sand supply and retention will be dealt with in the next section.

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Adaptation strategy – Causeway to Coral Street

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Soldiers Memorial Gardens

Existing layout

The map depicts the current terrain and layout of the backshore. Any area that is coloured green is at a lower level than the sea-flood risk for 2050.

The height of Flinders Parade is from 2.35 to 2.55m AHD.

Exposure (future)

The sea-flood risk projected for 2050 is 2.65m AHD (including wave effects).

The sea-flood mapping for 2100 indicates that this area will be difficult to protect without substantial increases in the height of the defence system.

This study accepts that the area of the headland and Soldiers Memorial Gardens (southern section) are likely to be required to be protected until at least the end of the century.

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Adaptation strategy – Causeway to Coral Street

Adaptation Strategy

Fleurieu 11.1

Victor Harbor Central

Inman River to Inman Street

Adaptation Strategy

The headland and the core section of Soldiers Memorial Gardens will require long term protection. Overtopping of the rock revetment and pathway occurs frequently along the Soldiers Memorial Gardens even though this section of coast is set above current risk levels. There are two options to consider in this current era: install an edge protection such as a seawall or accommodate overtopping into this region.

Outlook 2050 - 2100

If seas rise as projected, then this area of coast will require protection at greater heights. It may be most effective to consider raising the pathway and providing a raised edged to reduce the effects of overtopping. However, because this is a prime area for long term protection, it would be prudent to design works that would cater for 2070 + event.

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Adaptation strategy - Flinders Parade to Bridge Terrace

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Flinders Pde to Bridge Tce

Coastal setting:

Heavily modified backshore that was once a low slope back to what is now Flinders Parade. The current protection structures have been raised on what was the former incipient dune just above the highwater mark. Sand has been diminishing on this beach since the 1970s and moderate events overtop the protection structures.

Existing protection:

Rock revetment and concrete block seawall (to the northern end of the bowling club).

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Adaptation strategy - Flinders Parade – Bridge Terrace

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Flinders Pde to Bridge Tce

Legacy issues

Since 1920 the strategy has been to continue to protect and raise the front embankment.

The reserves are set in a swale between the front embankment and the road which are all at lower than 2.65m.

Bridge Terrace north of Eyre Ave is set at very low elevation 2.40m AHD compared to Flinders Parade (Between Coral and Eyre) which is set at 3.20m AHD.

Stormwater drains to the coast from the residential slopes to the west to storm water outlets (6-9) set at very low elevations on the beach.

When considering the long-term strategy there are two choices: remain with the current layout (which will require large defences above the high-water mark) or consider alternative layouts.

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Adaptation strategy - Flinders Parade – Bridge Terrace

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Flinders Pde to Bridge Tce

How to manage sea level rise to 2100

In a prime location such as Flinders Parade and Bridge Terrace consideration should be given to how sea level rise could be managed to 2100.

Sea flood risk is 3.35m AHD but overtopping would also need to be managed.

Currently the coastal ‘ridgeline’ is on the old foredune (existing pathway). To defend this will be difficult with the low-lying land behind without creating large defence works and losing the beach.

The core of the strategy is to create the ‘ridgeline’ at the road at 3.30m AHD and to create a new promenade ~8m wide adjacent the road at 3.50m AHD and to return the coast near the highwater mark to a more natural condition (see also next page).

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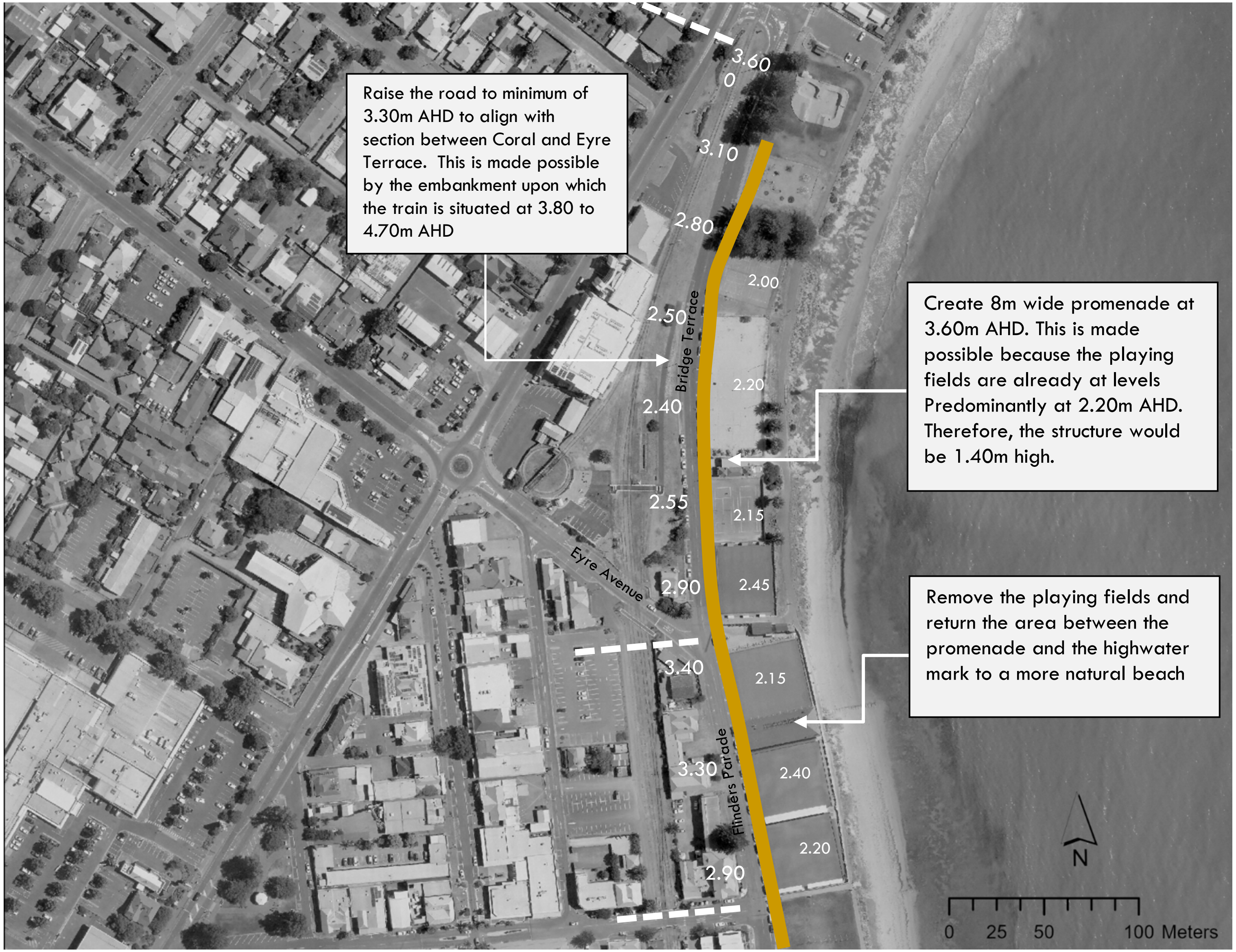


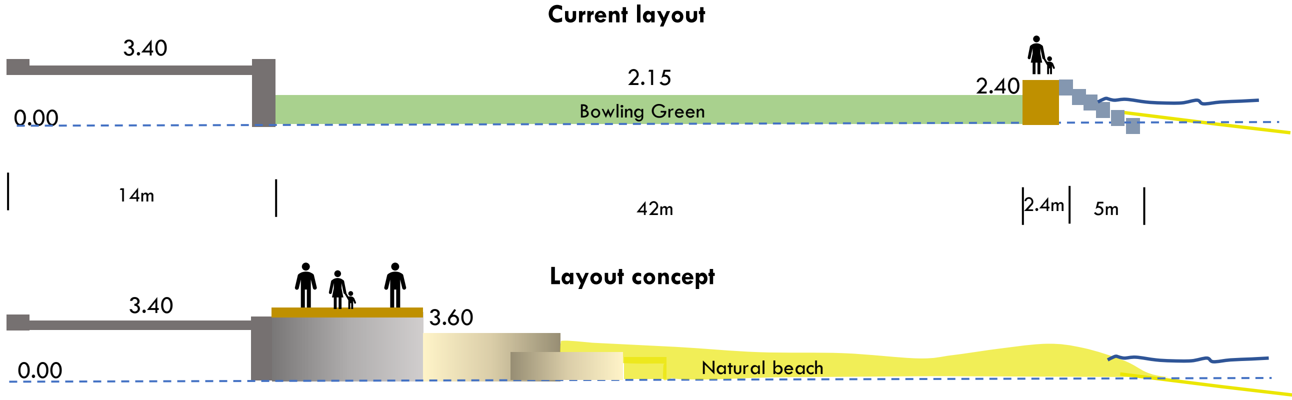
Adaptation strategy - Flinders Parade – Bridge Terrace

The concept of creating a 'ridge line' adjacent the road is demonstrated in two profile drawings. The drawings are to illustrate concepts and not to be proscriptive about how spaces are utilised.

Scale ~1:250
Sport heights in AHD

Profile 1 – Bowling green, Eyre Terrace

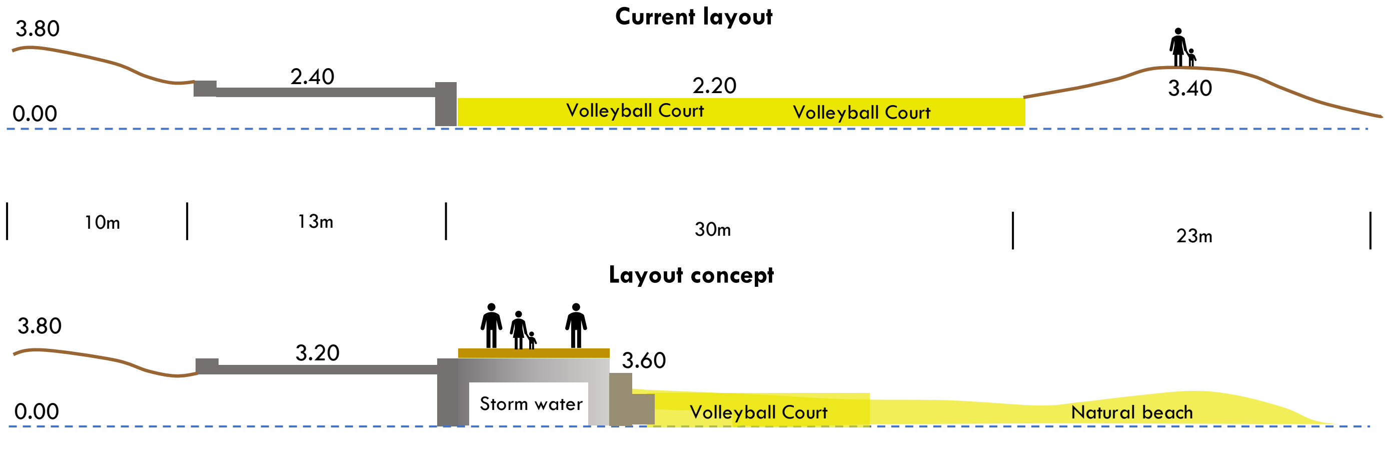
The sea edge of the current profile is under consistent attack from the sea and there is no flexibility in the protection system. If the current profile is retained, the walking trail will need to be continually increased in height and the protection works become more intense and intrusive into the fabric of the coast. It is likely that the beach will be completely lost in the long term. The second profile creates a higher edge near the road and creates spaces that will absorb the energy of the waves in higher storm episodes.



Profile 2 – Volleyball Court, Bridge Terrace.

In this location the front embankment is substantially higher than the remainder of the foreshore area and is in constant contact with actions of the sea. If the current layout remains, then the frontal embankment will need to be continually raised and eventually the beach will be lost. The other problem in this area is the disposal of stormwater at low elevations on the beach.

This concept raises the road against the trainline embankment (which will also assist with storm water issues) and creates a public space at the back of the beach. Beach areas can still be used as places for public activities such as volleyball.



Adaptation strategy - Flinders Parade to Bridge Terrace

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Flinders Pde to Bridge Tce

Public spaces

Kingscliff Beach in NSW provides an example of a beach that was continually eroded but an alternative approach created public spaces that also were able to absorb actions of the sea. The purpose of including this case study here is not to be proscriptive but illustrative.

The creation of public spaces in the Victor Harbor region could be provided in numbers of ways while still maintaining the adaptation principle for a more flexible and natural beach.

Project caveat: The project team view these proposals as preliminary concepts to provoke consideration of a master plan. They are caveated on the need for extensive investigation of coastal processes and sand supply.

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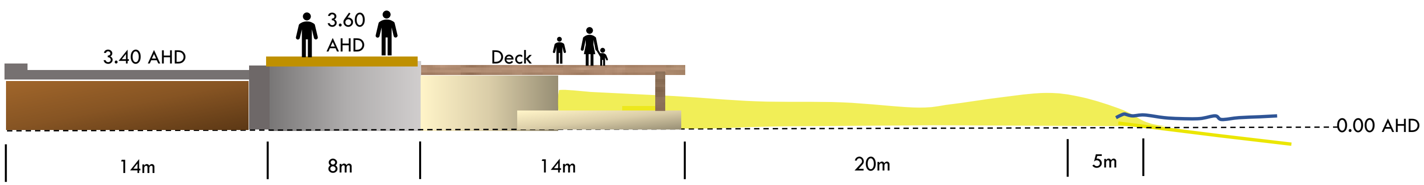
Layout concept



Adaptation strategy – Flinders Parade to Bridge Terrace

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Flinders Pde to Bridge Tce

Dealing with sand supply

Sand supply has been dropping steadily on this beach over decades. This may be partially due to installation of the boat ramp in the 1970s, the replacement of the seawall with rock revetment that effectively pushed the toe of the protection 8m seaward and ongoing sea level rise.

In consultation with the team, there was general agreement that a groyne positioned on the northern end of the Flinders Parade Beach would provide a means to manage sand along the coast in the context of creating a more natural beach.

However, this proposal is caveated with the need to do extensive analysis of coastal processes and sand supply before implementation.

Consider using the former boat ramp on the southern end of the beach in conjunction with a groyne structure to be implemented on the northern end of the beach. This structure could be utilised as a means to pipe storm water into deeper water and away from the beach.

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It is also noted that the beach further to the north along Bridge Terrace has been in a long-term accretion trend. The introduction of a groyne may cause this beach to go in to recession and this would need to be monitored. The best way to manage this issue is when the groyne is constructed/ designed, also design a way in which sand can be moved from one side to the other.

Adaptation strategy - Flinders Parade – Bridge Terrace

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Flinders Pde to Bridge Tce.

Dealing with storm water issues.

One of the problems on Bridge Terrace is how to manage storm water without draining to the beach. Three outlets are set at very low elevation (0.80 to 1.30m AHD) and in the context of sea level rise these will be difficult to manage. The proposal here is given in the context of raising the road to 3.20m AHD and creating a raised 'edge' to the backshore.

The proposal for a groyne could also be a part of a breakwater for a boat ramp facility which could also be designed to facilitate the flow of storm water away from the beach.

Note: The project team view these proposals as preliminary concepts to provoke consideration of a master plan. They are caveated on the need for extensive investigation of coastal processes and sand supply.

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Adaptation strategy - Flinders Parade to Bridge Tce.

Adaptation Strategy

Fleurieu 11.2

Victor Harbor Central

Flinders Parade to Bridge Tce

Adaptation Strategy

The proposal is to consider the development of a master plan that establishes a coastal layout that manages sea level rises projected for 2100, creates useable and pleasant public spaces and deals with storm water problems.

Note: The project team view these proposals as preliminary concepts to provoke consideration of a master plan. They are caveated on the need for extensive investigation of coastal processes and sand supply.

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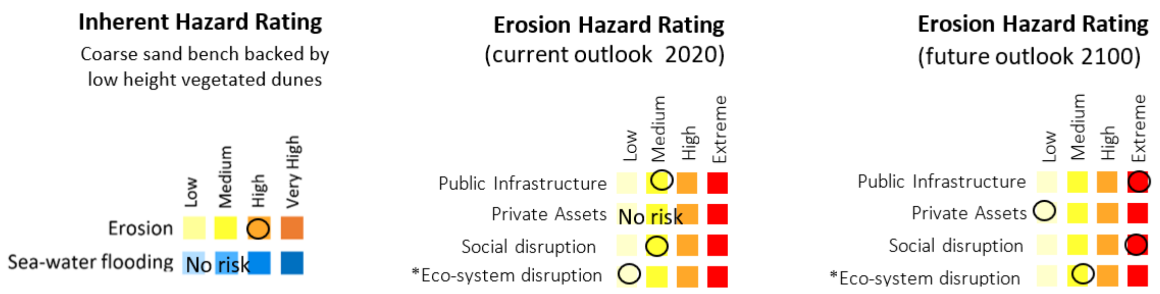
Adaptation Strategy: Victor Central – Esplanade Beach (Cell 11.1)

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

Risk outlook



Adaptation overview:

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

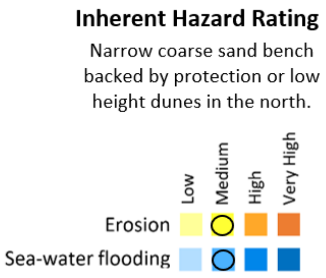
Summary table:

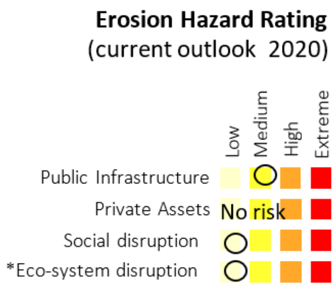
	Approach	Short-term strategy 2020	Mid-term strategy 2050	Long-term strategy 2100	Adaptation Type	Monitoring strategy
Victor Central Cell 11-1	Incremental [But formalise a strategy]	[Hold the line] Develop a consolidated dune from Inman River to Causeway	[Hold the line] Maintain the dune – manage any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

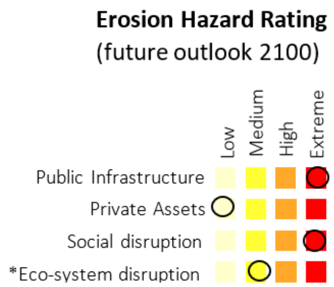
Adaptation Strategy: Victor Central – Flinders Parade (Cell 11.2)

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

Risk outlook







Adaptation overview:

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

Summary table:

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

Adaptation tasks: Victor Harbor Central (Cell 11)

	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 Victor Central.	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 in to the design of future protection items.	High	Now
3	In Cell 11.1, survey and inspect the levee surrounding the caravan park and report.	The digital elevation model indicates that this levee is at generally no lower than 1.90m AHD which is high enough to cater for current risk.	Low	5-10 years
4	Design and implement a program to consolidate and vegetate the dune system from the Inman River to the causeway. Remove gaps (storm water outlets and pedestrian points)	The distance between the esplanade road and the shoreline is sufficiently wide enough to implement a soft management approach.	High	Planning 1-2 Implementation within 5 years
5	Consider creating a master plan for the Flinders Parade – Bridge Terrace precinct.	It will be difficult to protect this area if seas rise as projected. The location is a significant area in the context of a historic town. It is recognised that this process will involve extensive engagement with stakeholders and therefore the first step is intentionally kept simple.	Moderate	1-2 years Master plan only