Coastal Adaptation Study for Alexandrina Council

PORT ELLIOT

Horseshoe Bay is the sole focus of this report. Green Bay and Crockery Bay are reported within a separate document.

By Integrated Coasts: Western, Hesp, and Bourman (2019)

Report to be cited as: Western, M, Bourman, R., Hesp, P (2019) Coastal Adaptation Study for Alexandrina Council (Cell SF8 Horseshoe Bay) prepared by Integrated Coasts, South Australia.

TABLE OF CONTENTS

Note:

Cell SF8 includes Horseshoe Bay, Green Bay and Crockery Bay. Due to the significance of Horseshoe Bay as a premier beach site, Horseshoe Bay has been allocated its own report. The assessment for Green Bay and Crockery Bay are reported within a separate document.

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Introduction

This document is a partial output for the Coastal Adaptation Study for Alexandrina Council (Cell: Port Elliot). This document also represents an output from the coastal adaptation assessment tool designed by Integrated Coast.

This document should be read in conjunction with the main report, *Coastal Adaptation Strategy for Alexandrina,* that explains more fully the underpinning methodology. Definition of terms within this work are adopted from www.coastadapt.com.au (Glossary).

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

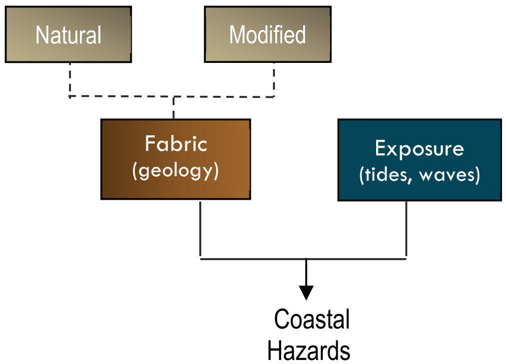
Finally, in a coastal adaptation study, we are also interested to know how this relationship between ***fabric*** and ***exposure*** may change over time, and what this may mean in the context of our coastal settlements.

Our sea levels have been quite stable for several thousand years. However, in recent times, the rate of sea level rise has escalated. Last century, sea levels rose at ~2-3mm per year. In this century, seas are rising in our region on average at ~4-5mm per year.

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 1: Conceptual assessment 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. We conduct this evaluation within the regional setting of secondary coastal cell **Fleurieu southeast coast** (CoastAdapt) and within tertiary cell **Southern Fleurieu 8** (Nature Maps). These cells are depicted on the following pages. (Crockery Bay and Green Bay are assessed within a separate document).

Introduction

Regional Setting

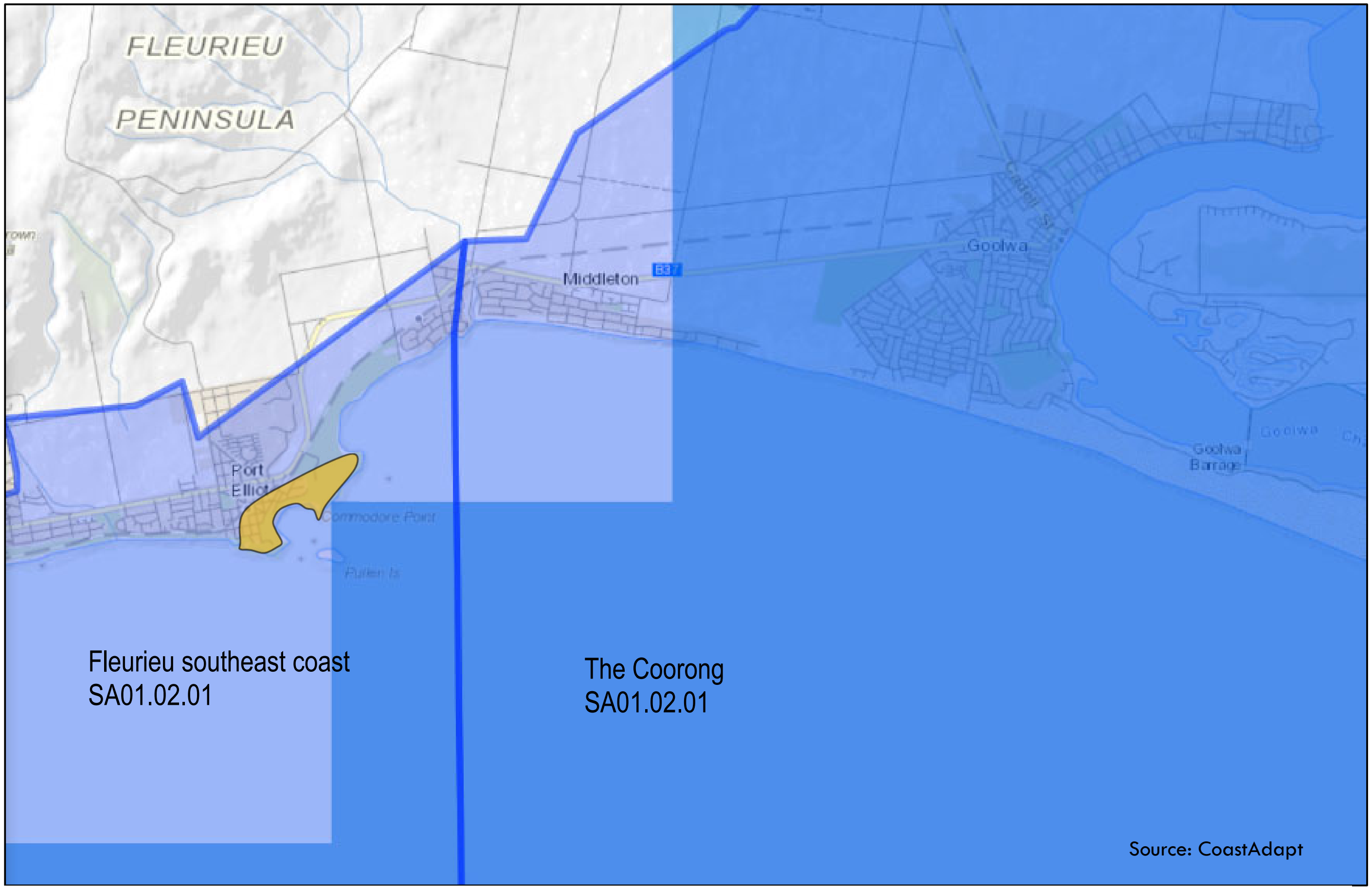
Map: SF8

Secondary Cell: Fleurieu

Tertiary Cell: Port Elliot

Minor cell: Horseshoe Bay

Secondary Cell



CoastAdapt:

Australian regional setting
Cell: Fleurieu - southeast coast.

Geomorphology of the cell:
Exposed, south facing, bedrock dominated, moderate-high energy coast with some embayed wave dominated beaches.

Outcrops of Encounter Bay Granite dominate the Port Elliot cell forming headlands, islands, and rocky reefs. The resistant granite has a strong influence on the orientation of approaching waves, which have moulded sandy bays such as Horseshoe Bay and Crockery Bay.

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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Introduction

Regional Setting

Map: SF8

Secondary Cell: Fleurieu

Tertiary Cell: Port Elliot

Minor cell: Horseshoe Bay

Tertiary Cell

Nature Maps (SA)
The yellow line on the map represents the following coastal characteristics:

Shoreline class:
Reflective beach bordered by 30m high granite headlands.

Sand rating:
Coarse

Relative Exposure:
Sheltered - low energy wave (0.5m to 1m)

Form:
Low to moderate 3-10 deg

Backshore 1:
Urban (on western end)
Escarpment/lawn (middle of bay)
Dunes (eastern end).

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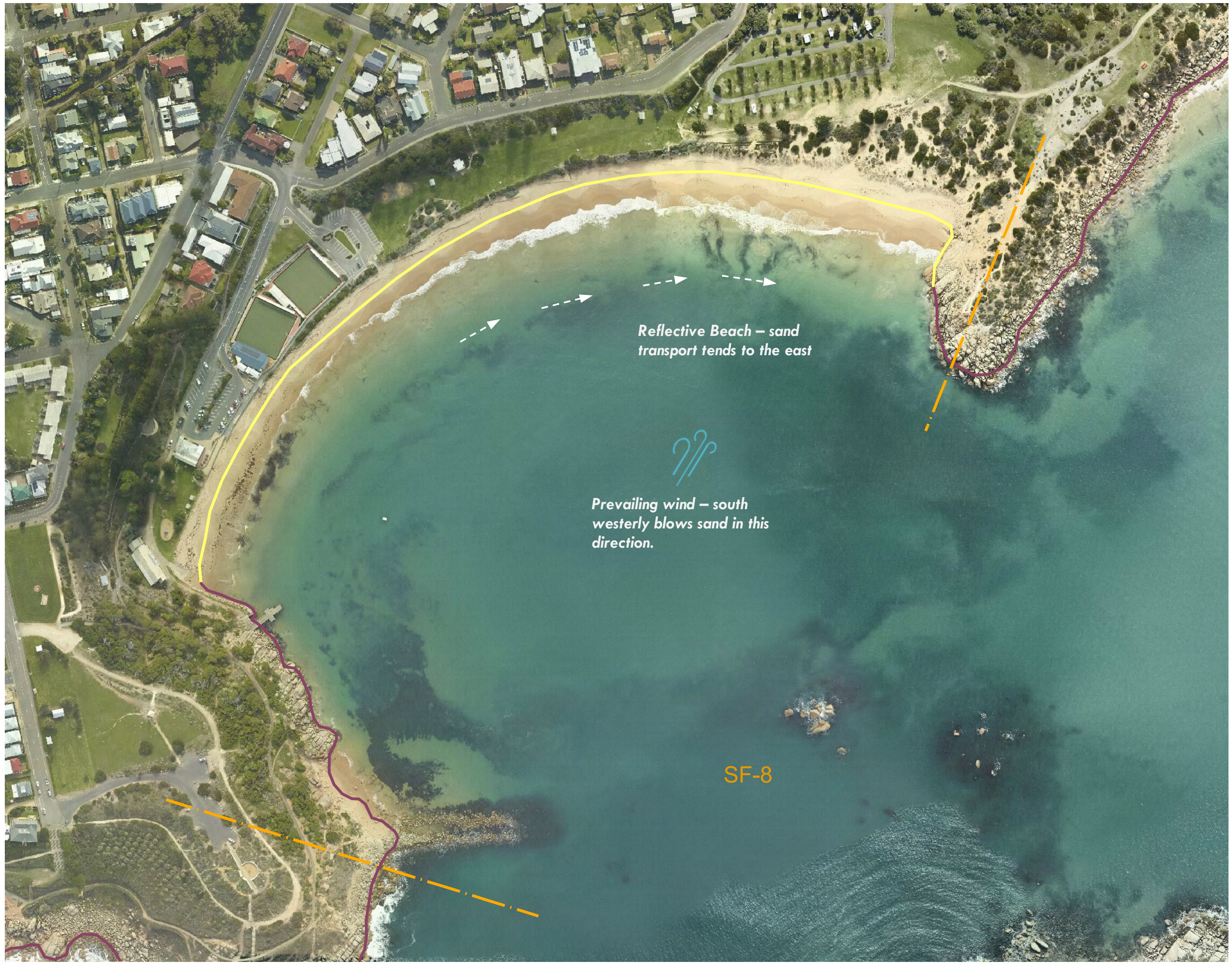

1. SETTLEMENT HISTORY

1. Settlement history

The purpose of this section is four-fold:

- To identify the circumstances of settlement and expansion of in the coastal context[1],
- To conduct an archival search at Coastal Management Branch to identify any past coastal issues,
- To review historical photographs that promote understanding of changes along the coastline,
- To identify any storm events that have impacted the coastline.

BRIEF HISTORY

Prior to European settlement the Port Elliot region was inhabited by the Ngarrindjeri people[2].

Early European explorers and settlers saw the potential for expansion along the fertile lower reaches of the River Murray. However, the mouth of the Murray River was completely unsuitable for navigation[3]. The impetus for the founding of Port Elliot was the need for an ocean port near the River Murray through which to export goods and produce.

1851-1900

Port Elliot was proclaimed in 1851 and the jetty, obelisk, mooring points and harbour-master's cottage were completed soon after. The railway line upon which horse drawn carriages operated was completed by 1854.

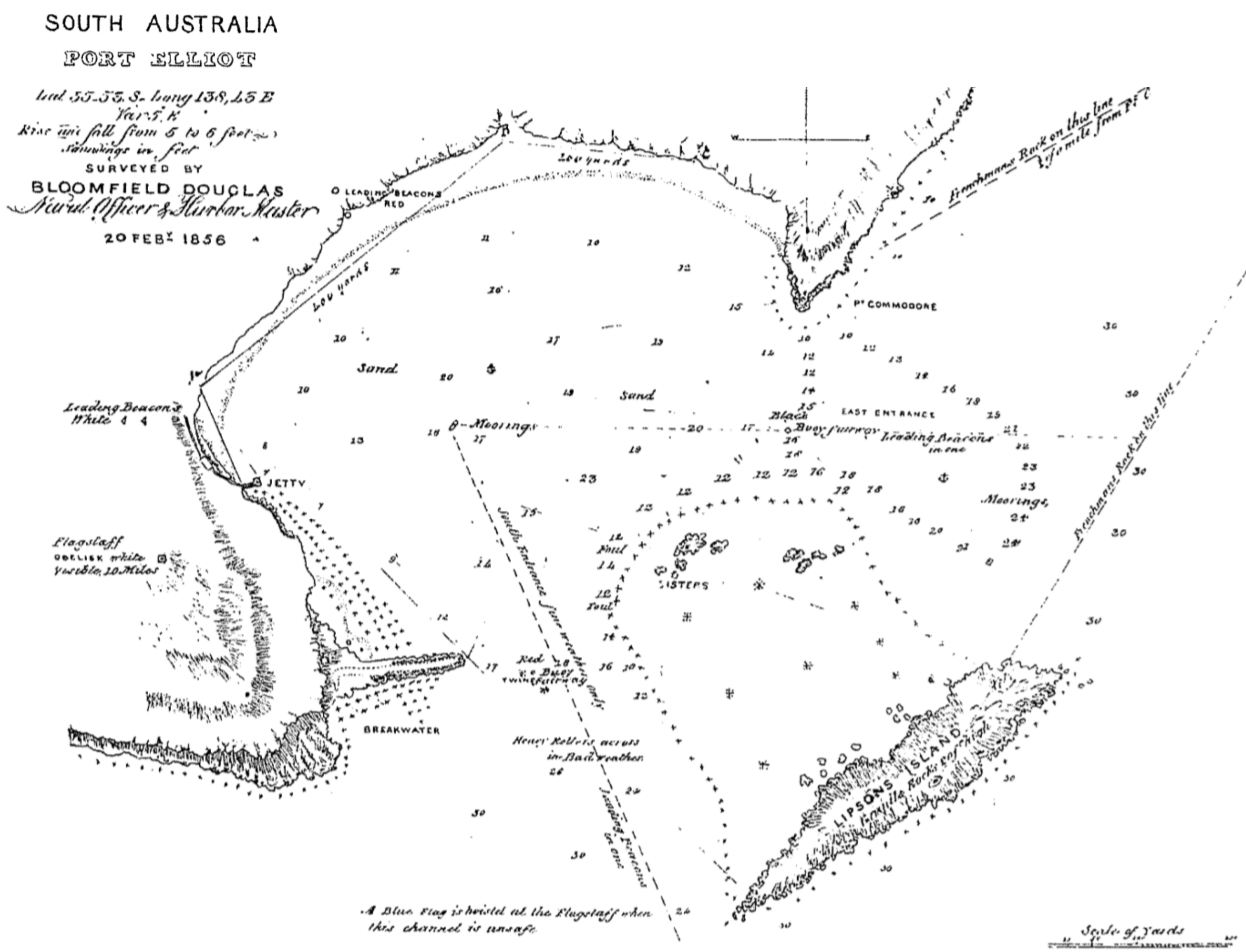

Figure 1: Survey of harbour in 1856 by Bloomfield Douglas is the first bathymetric survey of Horseshoe Bay. Rise and fall is given as 6 to 7 feet and depth of water at the jetty at 7 feet (although it is not clear from the map at what tide). The length of the breakwater scales at approximately 120 yards.

[1] Port Elliot and Goolwa Heritage Study, 1981
[2] See the Ngarrindjeri Ratalang Cultural Heritage Management Plan.
[3] History and Heritage of Coastal Engineering p.7

1. Settlement history

BRIEF HISTORY (CONTINUED)

Ships began calling regularly from 1852 reaching a peak of 85 ships visiting in 1885.

Work on the breakwater began in 1853 using granite blasted from the side of Freeman Nob at the rear of the breakwater. The work was completed in 1855 but soon after, heavy seas dislodged some of the rocks.

In 1856 four (or five) ships were wrecked in the bay and the railway line was extended to Victor Harbor as an alternative port. Mistakes made in the construction of the Port Elliot breakwater were rectified in the construction of the breakwater at the new port at Victor Harbor.

By 1865 only one ship visited Port Elliot and the port was closed in the following year. The township had undergone rapid expansion in these few years. Expansion continued, but at a slower pace over the following decades.

By the turn of the century, Port Elliot had become a 'resort' town. Guest houses were constructed, and expansion occurred on the southern side of the railway line. Increased mobility due to the rise of motor vehicles resulted in increasing recreational use in Horseshoe Bay.

Coastal notes:

Perhaps rocks were dislodged from the end of the breakwater (Fig 1).

Note the abandoned cliffs and likely location of backshore when sea level was higher (Fig 2,3).

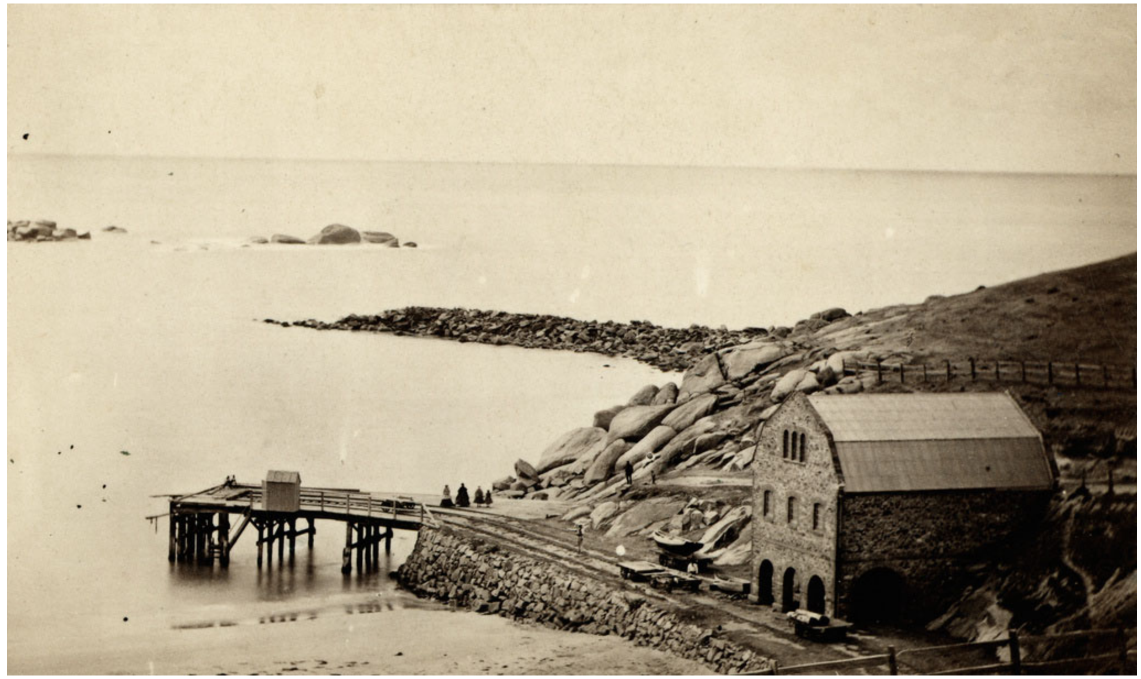

Figure 2: Earliest photograph of Horseshoe Bay in 1860

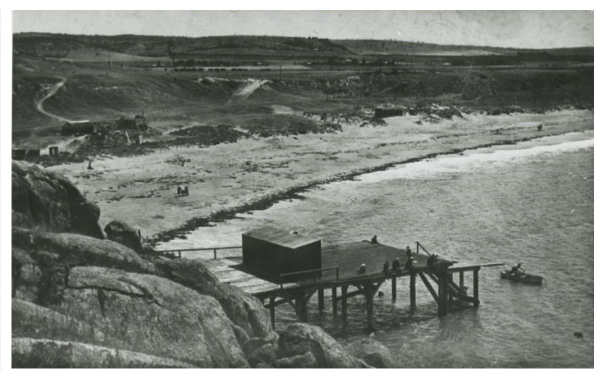

Figure 4: Jetty in original form c.1900

1. Settlement history

BRIEF HISTORY (CONTINUTED)

1900 to circa 1930

The Port Elliot region continued to grow as a recreational town with Horseshoe Bay as its prime attraction. In1914, plans show changes from the foreshore usage as 'reserve for railway' to 'reserve for recreation'[4].

The foreshore was sometimes used in the early 1900s as a 'fisherman's camp' (Fig 5).

The first bowling green was established in 1913 (Fig 7).

Initial recreational activities were concentrated on the south-western end of the bay where swimming was safer and the jetty in close proximity (Fig 6).

Port Elliot was used as a place of respite for the soldiers in World War 1 and the Memorial Gardens were established in this period (not pictured).

Coastal Notes:

Fig 6: Note height and nature of the dunes in the mid-section of the bay. These dunes are also seen in Fig 4.

Note the distance between green and foreshore (Fig 6). Either the green has been repositioned or the coast has receded significantly (likely the former).

Permissions pending from State Library.

Figure 5: Fisherman's camp c.1908

Figure 6: Horseshoe Bay c.1900

Figure 7: First bowling green installed by 1913 (photograph 1914).

[4] Port Elliot and Goolwa Heritage Study, 1981, p.6c

1. Settlement history

BRIEF HISTORY (CONTINUED)

1930s to 1970s

The modern shape of the western side of the bay was formed in this era.

The sea-wall was installed to the western side circa 1930, most probably as a means to contain the reserve for public use rather than to act as any form of protection from actions of the sea (Figure 8,9).

A second bowling green was constructed circa 1940 (Figure 10).

A caravan park was established to the north-east of the second bowling green (Figure 10). It is likely that the caravan park expanded slowly to the east transforming the former dune into a green space for camping.

A kiosk was first installed at the current location of the SLSC and then in the position of the current café (Flying Fish). The carpark was formalised between the bowling club and the kiosk.

A Surf Life Saving Club was formed in the same era and now occupies the southern part of the bay.

Coastal Notes:

Fig 8: There appears to be a small dune system forward of the current line of dunes adjacent the bowling club (also a beach shelter or changing room).

Note the substantial dune system on the eastern end (now the location of the caravan park)

Figure 8: Low sea-wall constructed to foreshore and associated reserve furniture (circa 1930)

Figure 9: Photograph taken after Figure 7 (circa 1930)

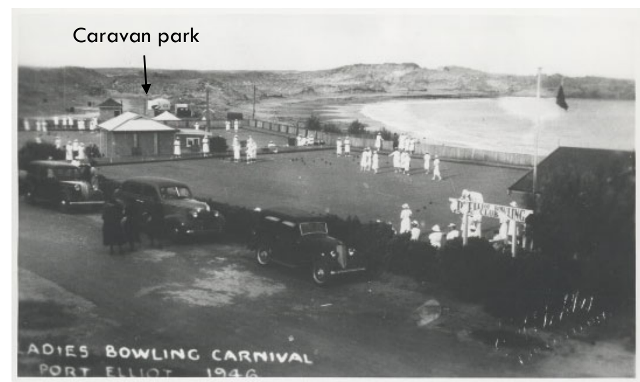

Figure 10: Second bowling green and caravan park

1. Settlement history

BRIEF HISTORY (CONTINUED)

1980s to current

In 1983, Doug Wallace and Associates completed the Coast Management Study for Port Elliot to Middleton that laid the foundation for Port Elliot in its final form.

By this stage, the decision had already been made to relocate the caravan park into the dune area in the north east of the bay and to allocate the former caravan park area into green space.

Dune fencing and formalised accessways were introduced to the dunes in the centre of the bay (fronting the new green space). The dunes were vegetated, as were the narrow dunes in front of the bowling greens.

Additional carparking was installed between the bowling green and the new green space (former caravan park). (Not a recommendation of the study)

Damage created by two separate storms (1980s) to the wall in front of the carpark resulted in an upgrade to the seawall and the installation of a wider board walk area (1990s).

The kiosk was extended/ renovated to create the Flying Fish Café in between the southern green space and the middle carpark (1990s).

Circa 2007 a boardwalk was installed seaward of the bowling club and amendments made to the area in front of the Flying Fish Café.

Figure 11: Horseshoe Bay in its modern form (2018). (Compare tidal lines and seaweed lines to Figure 8)

1. Settlement history

ARCHIVAL REVIEW

Archival research for this project has been confined to that which is held by Coastal Management Branch (DEW). This archive is likely to contain the key coastal reports and issues since the 1970s. It is likely that Alexandrina Council has further archive (not reviewed)

1970s

The first mention in the archive is a request for ‘controlling sand drift at Port Elliot’ but the details that prompted the request are unknown (19740823).

In 1975, a project to restore the cliff face in the vicinity of the War Memorial was undertaken at cost of $6000. This may be the time when the retaining wall was installed to the base of this cliff (19750128).

In 1975, a request was made to construct a boat ramp for launching the SLSC jet ski (19750711).

In 1978, Coast Protection Board allocated $16,000 for the planning of the relocation of the Port Elliot Caravan Park into its current location (197806613)

1980s

Council made application for funding for the sea wall abutting the carpark noting, “the stone wall has been built for many years and without a foundation...and as a result of low sand levels and high tides 12m is in a dangerous state” (19800430).

Engineers drew up plans (in the archive) and cost of repairs was put at $5200 (19810505).

In 1981, Council expressed concerns about the condition of the breakwater stating, ‘the breakwater is disintegrating at a fast rate and Council seeks urgent cooperation’. CPB requested that the Council collect and forward any historical information about the breakwater (19810505, 19811014).

The Port Elliot to Middleton Coast Management Study was completed in 1983 (19830900) (see next page).

In 1985, Coastal Management Branch produced a plan for Stage 1 for proposed works at old caravan park site. This proposal also noted that the ‘bowling greens to be relocated in the future’ (19850702).

In 1987, the Council requested assistance from CPB because ‘the rate of erosion seems to be accelerating’ at the bank of the ‘old caravan park site’, and ‘recent storms have resulted in collapse of small sections of the bank’ (19870909). Officers from Coastal Management Branch inspected the site in the following year noting (19880227):

- Erosion is occurring in the centre of the bay
- Sand is collecting within the new caravan park
- Rock protection not recommended because increased loss of sand was likely

The recommendations as to a possible management strategy included collecting sand annually from the eastern end and deposit in the vicinity of the SLSC (19880277) or in the middle of the bay (19880303). Coastal Management Branch added, ‘it is difficult to evaluate the protection that sand will provide due to lack of knowledge about sand movement rates in the bay’ (19880303).

In 1989, a second section of wall in front of the carpark was damaged by storms. The cost to repair approximately 25m of wall was estimated at $15600. CPB considered this excessive and only agrees to pay half (19890926). Council seems to have drawn up a master plan in 1981 repair and the existing plans are implemented (plans in file).

The replacement wall incorporated a revised entry point to the beach (steps heading west), and it is likely that the overall width of the promenade in front of the carpark was widened seaward.

Source: M. Western, 2018

1. Settlement history

ARCHIVAL REVIEW (CONTINUED)

The foundational document for the development of Horseshoe Bay in the late 1980s and 1990s was the **Port Elliot to Middleton Coast Management Study** completed in 1983 by Doug Wallace and Associates (19830900). Key recommendations of the report were:

- To provide more carparking with recommendation that this be supplied in the old railway cutting (The Cutting).
- The dune adjacent the lawn area had deteriorated, recommendation to fence the dune and provide formalised access points.
- New toilet and change room facilities were required (on western end)
- To reassess the long-term future of the bowling club. The report noted that such relocation would make available additional land for public recreation purposes in a prime foreshore position.
- That a pedestrian walkway be constructed to link the western section to the eastern section of the bay.

Many of these recommendations were implemented apart from:

- Additional carparking was provided east of the bowling greens (not in The Cutting)
- Retention of an internal service road.
- It is unknown as to what deliberations were made about the bowling club.

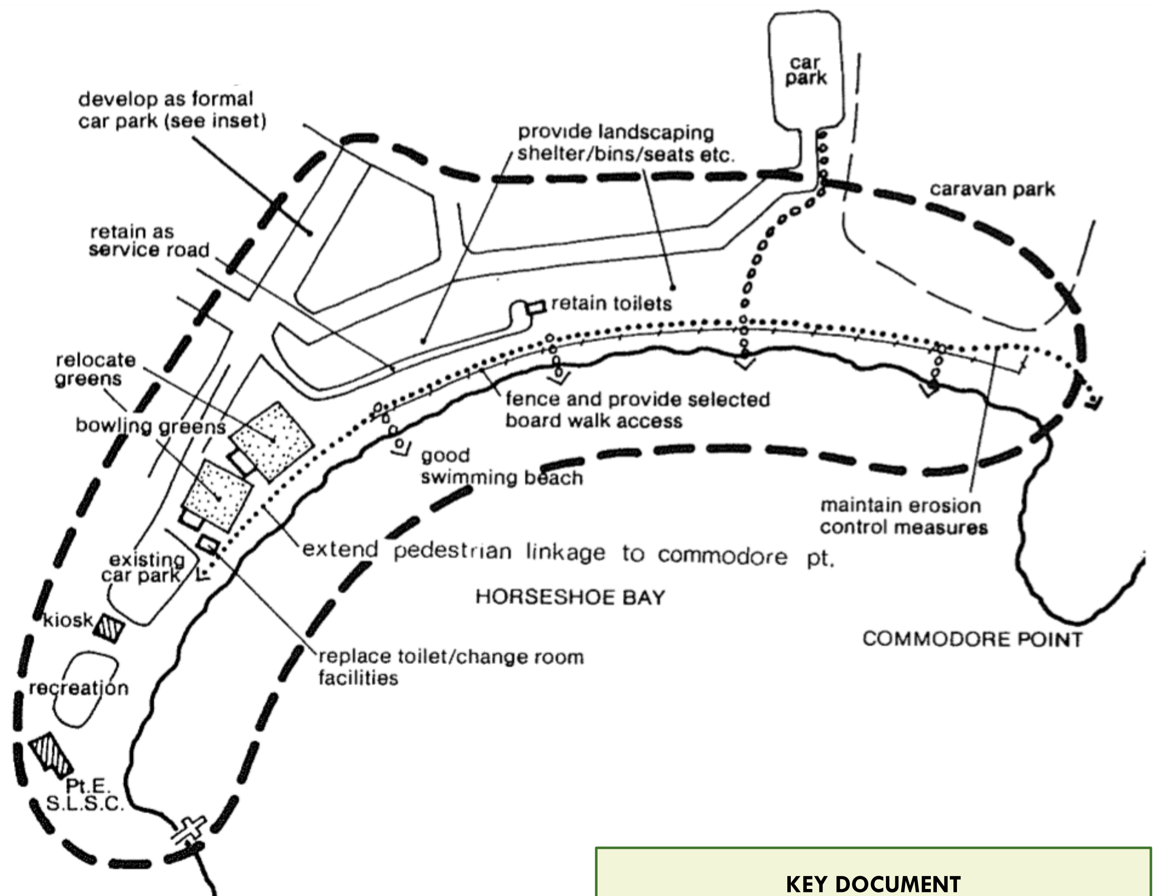

Figure 12: Coastal Management plan for Horseshoe Bay.

KEY DOCUMENT

Port Elliot to Middleton Coast Management Study by Doug Wallace and Associates, 1983 formed the basis of the current form of Horseshoe Bay (building on work by CPB in recommending relocation of caravan park).

1. Settlement history

ARCHIVAL REVIEW (CONTINUED)

1990s to 2000s

In 2007, Council requested feedback about the potential risk of erosion and sea level rise in the context of consideration for a lease renewal for the Port Elliot Bowling Club (20070727).

Coastal Management Branch noted that comment had been given in the context of plans for redevelopment of the Horseshoe Bay promenade and landings (2006, not reviewed). The following conclusion was offered:

'The location of the bowling club is such that it will become increasingly vulnerable to erosion as the effects of sea level rise become more apparent. However…when this might require relocation or major protection works is unclear…it is likely that relocation might be the preferable long-term option compared with expensive protection works that would affect the character of the foreshore'.

The key points were that: the bowling club is situated with very little buffer between the beach and the boundary wall, and that hard protection works is likely to promote loss of sand on the beach over time.

STUDIES AND PLANS

Note: Only one study was located for Horseshoe Bay, the Port Elliot to Middleton Coast Management Plan. There may be other studies or plans relating to the upgrade of the foreshore in 2007. No studies seem to exist about coastal processes – sand movement etc.

Figure 13: Small buffer between green and beach. (Photograph, M. Western, 2018)

Figure 14: Boardwalk constructed adjacent bowling club circa 2007 (Photograph, M. Western, 2018)

What do we learn from the archives?

The 1980s was the era when erosion seemed to come to the fore within Horseshoe Bay. Storm erosion undermined the seawall adjacent the carpark in two places. Then the middle of the bay experienced increased erosion.

The 1980s was the time in which the caravan park was moved, carparking installed, toilets upgraded, and pedestrian controls introduced to reduce impact on the dunes.

The relocation of the bowling club was a repeated theme, first mentioned in 1983, 1985, and 2007.

Coast Protection Branch was consulted on the condition of the breakwater (1981), erosion issues (1987) and advice concerning sea level rise (2007).

Caveat: It is possible that other digital communication exists between Coastal Management Branch and Council that has not been reviewed, especially after year 2000.

1. Settlement history

The purpose of this section is to identify visually how humans have intervened in the bay. The methodology employed is to take modern photographs from the same viewpoint as historical photographs.

HISTORICAL COMPARISONS

Figure 15: **First intervention** was installation of breakwater, jetty, and stone walling. The breakwater changed the way in which wave action interacted with the bay. Photograph taken in 1889 from what is now the Blue Dolphin Holiday Apartments.

Figure 16: **Second intervention** was installation of western bowling green. Note the original frontal dune line and the slope of the backshore in 1889

Figure 17: To counteract the natural slope of the backshore, the site was benched, using existing soil on site, and imported fill (later). Photograph of bowling green and esplanade walk from southern side.

1. Settlement history

HISTORICAL COMPARIONS (CONTINUED)

The purpose of this section is to identify visually how humans have intervened in the bay. The methodology employed is to take modern photographs from the same viewpoint as historical photographs.

C.1930

2018

Figure 18: The next major intervention was the construction of a **sea wall** from the western end of the bay to the bowling club. The probable purpose was to provide separation of the reserve and the beach, and not to provide protection from actions of the sea. Source: State Library of SA.

Figure 19: The western end of the wall is the original construction. The section to the right of the pine tree has been replaced, and beach access point modified. It is also likely that this section is higher than the original walling.

Assessment notes:
Sand levels adjacent the wall were surveyed at 2.20m to 2.40m AHD. These levels appear comparable with the walling on the western end, but lower in 2018 on the eastern end of the wall. However, the promenade section is further forward and likely constructed higher than the 1930s version.

1. Settlement history

HISTORICAL COMPARISONS(CONTINUED)

The purpose of this section is to identify visually how humans have intervened in the bay. The methodology employed is to take modern photographs from the same viewpoint as historical photographs.

C.1946

Figure 20: By 1946, the bowling greens had been constructed in their current locations. The caravan park began in this era also on the eastern side of the bowling green. (State Library of SA)

2018

Figure 21: The caravan park slowly expanded eastwards until the late 1980s when it was relocated into the dune section on the eastern end of the bay.

Assessment notes:
Note the size of the dunes between the pictured caravan and the beach, as well as the substantial dunes at the eastern end of the 1946 caravan park. Over a time period of 40 years the caravan park slowly encroached into the foredunes, and along the shore to the east.

1. Settlement history

HISTORICAL COMPARISONS (CONTINUED)

The purpose of this section is to identify visually how humans have intervened in the bay. The methodology employed is to take modern photographs from the same viewpoint as historical photographs.

C.1910 (1913?)

Figure 22: The **final major intervention** in the bay was the relocation of the caravan park from the mid-section of the bay into the dune field at the eastern end. The State Library states that this photograph was taken C1910. However, it appears as if the **bowling green fence is in view**, and thus this may be 2013 or later. Source: State Library of SA.

Assessment notes:
Note the former frontal dunes around the bay.

Note the tidal swales in 1910. These appear about 20m away from the base of the dunes. Currently tidal swales reach the base of the current embankment. (Caution: direct comparison may not be valid, depending on the tidal regime at which the 1910 photograph was taken).

2018

Figure 23: Photograph taken from behind the SLSC. (Source M. Western, 2018)

HUMAN INTERVENTION
Development has proceeded for 150 years from the western end to the east. This development has placed a rigidity in the foreshore from the jetty to the west side of the caravan park. While planting in the mid-section of the bay does provide some cohesion, there is also a rigidity in this section of the bay so that it no longer operates like a natural dune with inherent flexibility to adjust to changing conditions.

COASTAL FABRIC

The current coastal fabric is a combination of natural geology and human intervention.

In this section we evaluate:

- Ancient coastal formation
- Overview of current coastal fabric
- Changes to shoreline from 1860 to 2018
- Changes to seafloor since 1977
- Human intervention

2. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

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

COASTAL FORMATION

Today we live in an interglacial period, the most equitable time for human beings. The previous time in Earth history was about 125,000 years ago during what is called the Last Interglacial when locally it was warmer and wetter than at present with sea level being 2m higher than now. Remnants of this shoreline remain along the Alexandrina coast and it is possible to map out the approximate location of the last interglacial shoreline which provides a useful indication of where sea level may rise to in the future due to naturally occurring changes plus the influence of human impacts.

Modern coastline

The modern coastline developed after sea level rose between 17,000 and 7000 years ago at a rate of ~10mm /year at the end of the Last Glacial Maximum. With sea level rise, large reserves of sand, including the last glacial maximum desert dunes on the exposed continental shelf, were carried landward, providing source material for the modern beaches and dunes.

Tectonic Movement

Relicts of the geological history of the area are preserved in places along the Alexandrina Coastline. Ancient metamorphic and granitic rocks at Middleton and Port Elliot bring stability to the shoreline at those locations. Permian glacial sediments and alluvium of the last interglacial age form the back shore of easily eroded coastlines, while offsets of limestones of various ages record the tectonic behaviour of the area. In particular, offsets of the last interglacial shoreline (125,000 years old), which originally stood at ~2m above present sea level confirm the ongoing tectonic uplift of the Mount Lofty Range and the South East Coastal Plain, with subsidence occurring in the Murray Estuary. Consequently, most of the study area is undergoing subsidence at an approximate rate of 0.02mm/yr.

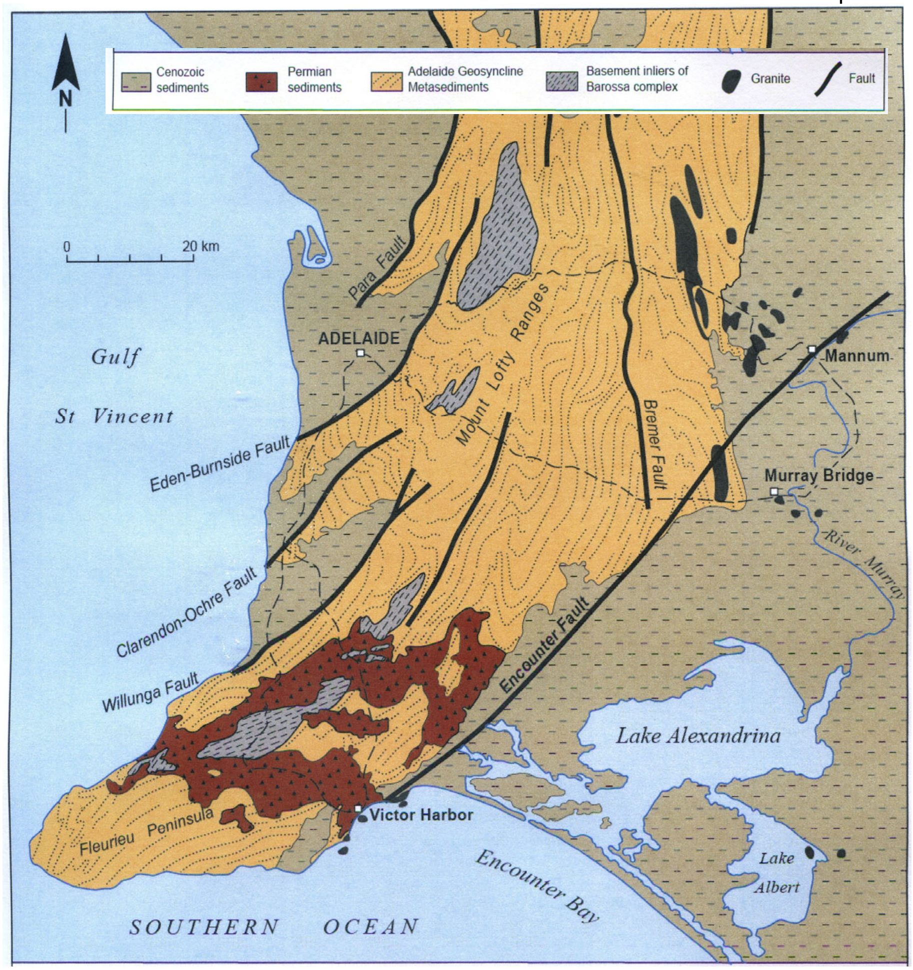

Figure 24: The location of the Encounter Fault, which runs out to sea near Watson Gap. This fault separates the uplifting Mount Lofty Ranges, on which sits the Chiton to Watson Gap coastal sector, from the subsiding Murray Basin, the setting for the remainder of the Alexandrina Coast.

TAKE AWAY POINTS

- Land areas to the east of Watson Gap (including Cell 8) are subsiding, but at a very low rate of 0.02mm/ yr.
- Sea levels at the end of the Last Interglacial (when ice levels were at their lowest), were approximately 2m higher than they are at present.

2. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

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

COASTAL FORMATION

Outcrops of Encounter Bay Granites dominate the Port Elliot coastline between Knight Beach (Cell SF9) and Fisherman Bay (Cell SF7), forming headlands, islands and rocky reefs. Granite outcrops have had a profound impact on the character of the shoreline at Port Elliot. Horseshoe Bay is flanked by the granite headlands of Freeman Knob (30m) and Commodore Point (20m).

Beach compartment

These headlands enclose a semi-circular bay 500m across at its widest. Waves approaching the bay are refracted (bent) and diffracted (spreading out after passing through openings) by the islands, headlands, rocky reefs and remnants of an artificial breakwater on the western side of the bay (Figure 25).

Less resistant rocks and sediments in between the rocky headlands have been eroded by the dominant south-westerly waves, which sweep into the bay, fashioning and mimicking the smooth curve of Horseshoe Bay.

Horseshoe Bay is a classic reflective beach where most wave energy is reflected back to sea off the beach face. The beach face in Horseshoe Bay is characteristically steep and prominent beach cusps are common along its length (ie a repeated curves pattern in the sand along the beach). Sand is basically trapped within Horseshoe Bay but tends to move alongshore to the east due to the reflective nature of the waves.

Lady Bay, the original ladies' bathing beach, is situated on the western extremity of Horseshoe Bay and is still protected by the breakwater immediately to the south.

Horseshoe Bay has been formed by the various wave patterns that have interacted with softer sediments between the headlands. The overall slope of the beach is steep, and waves tend to run a long way up the shore.

Figure 25: Wave and sand patterns in Horseshoe Bay

2. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

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

COASTAL FORMATION

Prevailing southerly to south-westerly winds have blown sand from Horseshoe Bay to form a small dune field inland from the Commodore Point headland. This wind regime also explains the greater build-up of sand on the eastern side of Horseshoe Bay.

An abandoned cliff line backs the bay and a flat area in front of the cliff may be a shore platform related to the higher sea level of the Last Interglacial, but this is difficult to establish.

A caravan park, the establishment of which involved topographical modification, formerly occupied the area between the shore and the old cliff line (see also p. 21).

While it is not possible to ascertain exactly where the last shoreline was positioned at the end of the Last Interglacial when sea levels were 2m higher, it is likely that the shoreline was further inland at this time.

TAKE AWAY POINTS

Horseshoe Bay has been formed by the various wave patterns that have interacted with softer sediments.

The beach is a classic reflective beach.

Sand is essentially trapped within the bay, but sand tends to move east alongshore due the reflective nature of the waves.

The strong south-westerly wind has created the sand dune behind Commodore Point.

In the Last Interglacial when sea levels were ~2m higher than present, the shoreline would have been further inland.

Figure 26: 1949 aerial photograph showing the bays, headlands and islands of the Port Elliot coast from Boomer to Fisherman Bay (R. Bourman)

2. Coastal Fabric - natural

Form

Map: SF8-1

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot (West)

Minor cell: Horseshoe Bay

Form

Beach

Coarse sandy beach

Backshores

Backshore 1
North-west: seawalls
North: earthen embankment
North-east: sand dunes

Backshore 2:
Steeply sloping soft/hard rock shore rising above 30m AHD at 300m inland.

Bathymetry

Overall slope of ocean floor:
-5m ~0.5 km from beach (overall slope ratio 1:100) or <5 deg.

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2. Coastal Fabric - natural

Geology

Map: SF8-1
Secondary Cell: Fleurieu SE Coast
Tertiary Cell: Port Elliot
Minor cell: Horseshoe Bay
Geology

Geology

Beach and backshore 1:

Semaphore sand – unconsolidated white bioclastic quartz- carbonate sand of modern beaches and transgressive dune fields.

Age: Holocene

Backshore 2 (sloping upwards of above 30m at 300m inland)

Undifferentiated quaternary rocks

Age: Pleistocene – Holocene

Granite outcrops at either end of the bay are Encounter Bay Granite.

Map source: www.sarig.sa.gov.au

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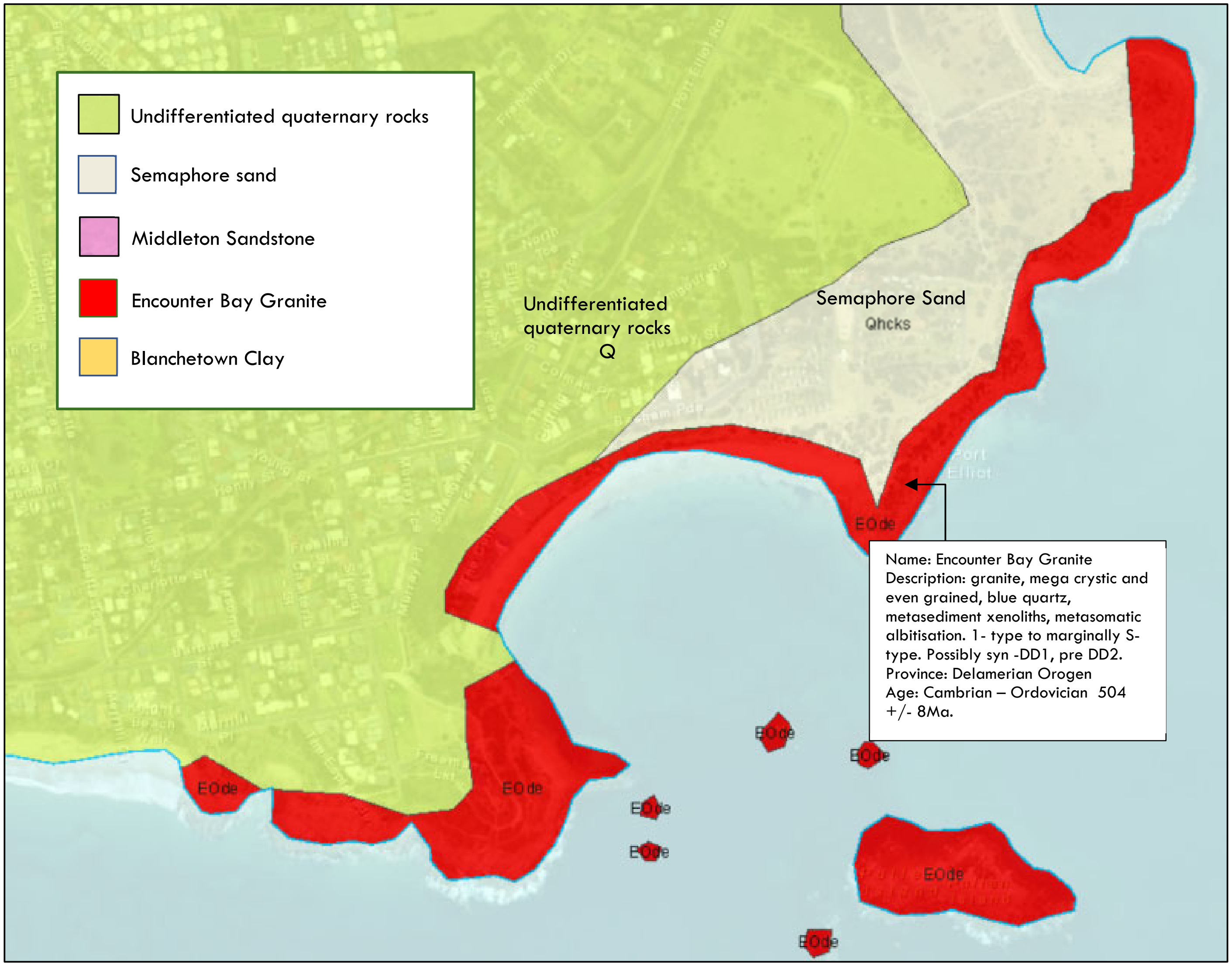

2. Coastal Fabric - natural

Benthic

Map: SF8-1

Secondary Cell: Fleurieu SE Coast

Tertiary Cell: Port Elliot

Minor cell: Horseshoe Bay

Benthic

Benthic

Surfzone and immediate nearshore is sand dominated.

Subtidal reef is variously present along with seagrass. Rock outcrops in places.

(Map Source: Nature Maps, Department of Environment and Water)

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2. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

Medium term changes

Map: SF8-1

Horseshoe Bay

Changes 1860 to 2018

1949

Assessment

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

Note the location of the bowling greens in same position today.

Contour lines are not necessarily relevant but are included to provide a visual marker.

Inset photograph provides oblique view from the same era.

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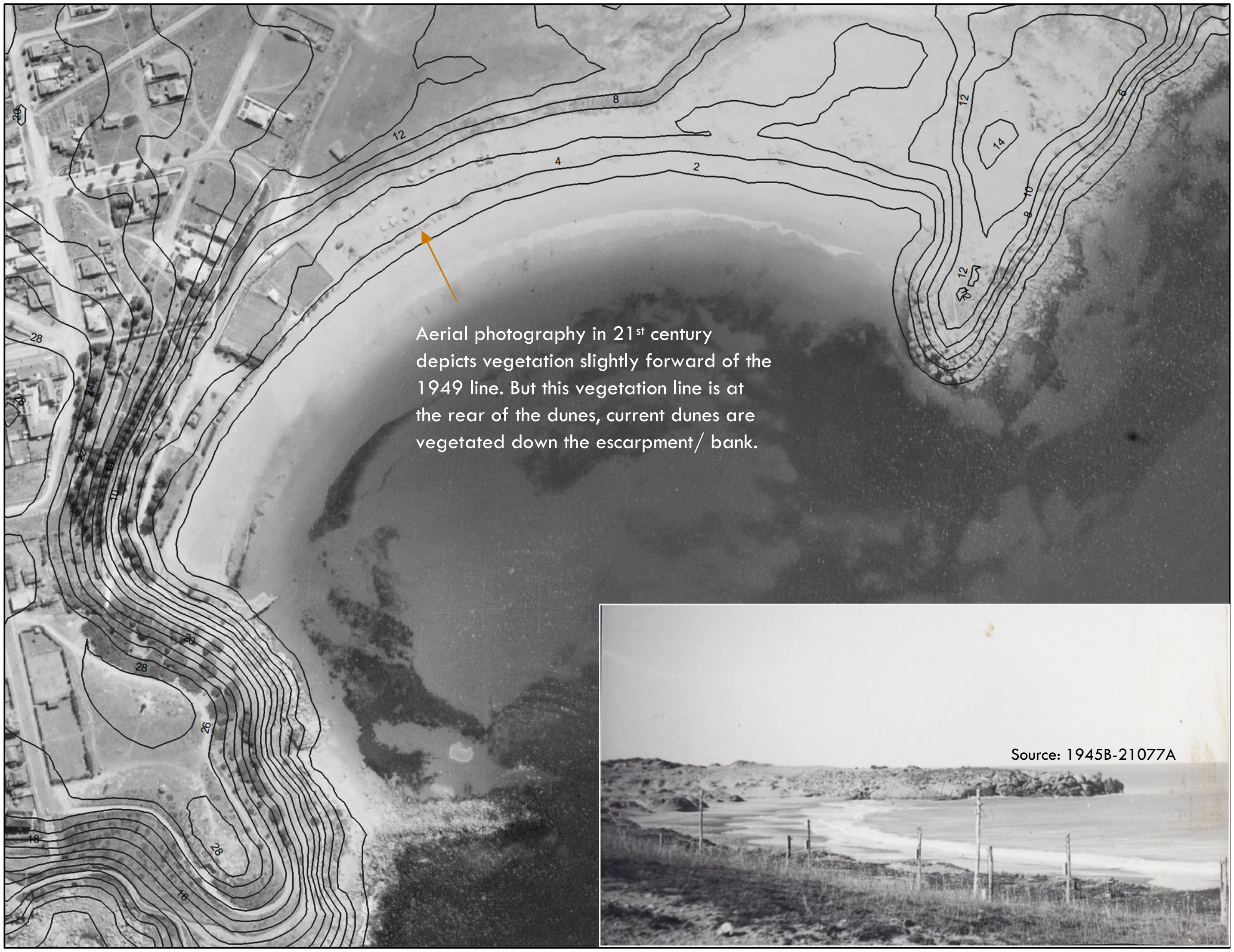

2. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

Medium term changes

Map: SF8-1

Horseshoe Bay

Changes 1860 to 2018

2018

Assessment

Aerial Photograph from 1949 provides the basis for comparison of coastal change over the last seventy years.

Note the location of the bowling greens in same position today.

Contour lines are not necessarily relevant but are included to provide a visual marker.

Dune vegetation appears in a similar position, but the nature of the dunes and beach profile is very different (see next page).

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2. Coastal Fabric - natural

Medium term changes

Map: SF8-1

Horseshoe Bay

Changes 1860 to 2018

1944 -2018

Assessment

Although the vegetation line appears similar adjacent the bowling club and 'green space', the nature of the beach and dune system are markedly different:

- The dune system is far higher in 1944, elevated above the former caravan park area (see Fig. 27)
- The volume of sand at the back of the beach is far greater in 1944 (and therefore the overall slope is greater)
- Tidal cusps appear much closer to the back of the beach in 2018.

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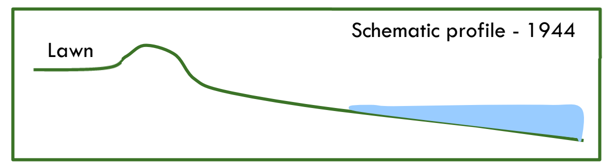
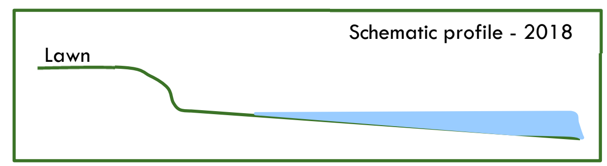
Figure 27: Photograph taken in 1944 (three years prior to the aerial photograph on previous page). Source: State Library of SA.

Figure 28: Photographs taken on 14 November 2018 (M. Western)

Caution: care needs to be exercised in making direct comparisons between the photographs as the way the depth of field is portrayed is different.





DISCUSSION:

The schematic profiles demonstrate that loss of sand from the dune system and beach has potential for greater impact from coastal processes to the base of the dune. (even without sea level rise).

In late 1980s, Coastal Management Branch noted loss of sand from the centre of the bay.

2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Changes 1860 to 2018

Two further comparative photograph techniques add to the picture of medium-term changes (1860 to 2018).

1. Comparison of sand changes using two photographs taken from the same viewpoint (note the two sets of coloured rocks provide contrast points)

C.1908

B 17466/4

Figure 29: Fisherman Camp, circa 1908 (State Library of SA.

2018

Figure 30: Horseshoe Bay, M. Western, 14 November 2018 (taken from similar location as the seated fisherman)

<u>Comparison:</u>

- Note the presence of vegetation and a small dune which would have been out of tidal range in 1908.
- Note the line of seaweed in 2018 from a previous event (unknown). We know that tides do get to the wall (almost).
- Note the position of the yellow line. A comparison between the two sets of rocks reveals that this line replicates exactly the curve of the beach in 1908.
- Sand levels are not excessively low in 2018 picture. Sand is currently covering the base of the ramp, whereas in winter it can be 200mm lower. The point in the context of this study is that the sand is not excessively low in November 2018.

<u>Preliminary conclusion:</u>

The evidence supports the notion that the beach has receded on the western end, and tidal action is higher.

2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Changes 1860 to 2018

1. Comparison of sand changes using two photographs taken from the same viewpoint

1915

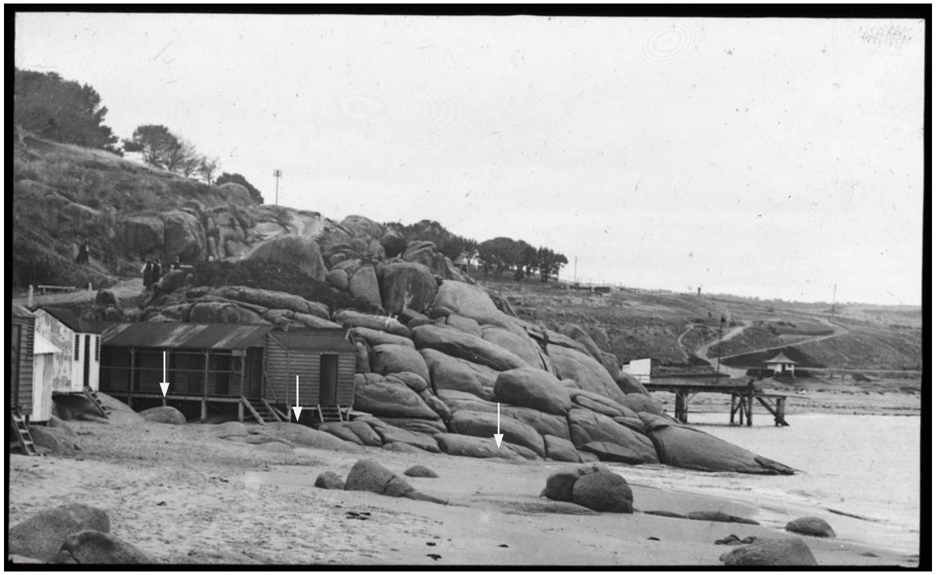


Figure 31: Photograph by Tenterfield in 1915 (State Library).

2018

Figure 32: Lady Bay (M.Western, 2018)

<u>Comparison:</u>

- Note the location of the three rocks in each photograph
- The tide is at approximately the same level
- The volume of sand is very similar in both photographs
- The nature of Lady Bay beach in 1915 is essentially the same as 2018.

Explanatory note: perspectives from the different types of camera create a different portrayal. Depth of field appears different.

<u>Preliminary conclusion:</u>

The nature of Lady Bay beach has not changed over a 100-year period.

2. Coastal Fabric - natural

MEDIUM TERM CHANGES

Changes 1860 to 2018

2. Use a known reference point and compare the tidal regime (using seaweed and swale lines) to evaluate differences over time

C.1890

Figure 33: Photograph of Port Elliott foreshore, 1890, (State Library).

2018

Figure 34: Photograph by M. Western (2018).

This study compares the height of all the tides by analysing seaweed lines and high tide marks in the context of one (or two) rocks that remain in same position as 1860. Click on link below to access the full comparison.

Summary conclusions from tidal study:

The evidence supports the notion that the beach has receded in this location. This distance can be further quantified by onsite measure, but it is likely ~12m.

Comparisons between photographs over time show seaweed strands at approximately 20m from the sea wall. In current photographs seaweed strands (and tidal marks) are found very near the sea wall.

2. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

Medium term changes

Map: SF8-1

Horseshoe Bay

Changes 1970s to 2018

1970s -2018

Assessment

Coastal Management Branch has conducted beach profile surveys around the State from the 1970s onward. Beach Profile 615002 has been conducted in location in Figure 37.

A comparison of the lines indicates that the nearshore is slightly lower in 2009 than 1977, but the beach and immediate nearshore has built upwards slightly compared to 1977. The position of the top of the scarp/cliff is virtually identical. This is likely due to a 'hold the line' coastal strategy where planting and fencing measures have prevented recession.

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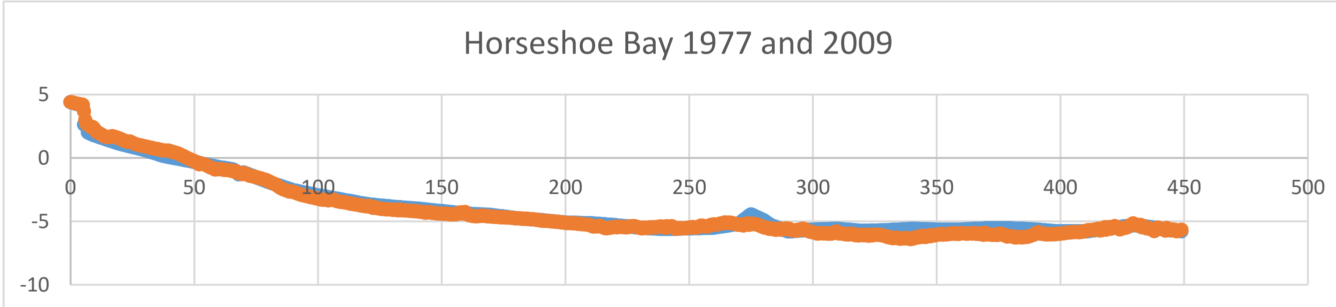


Figure 35: Topographic profiles surveyed by Department of Environment and Water on survey line 615002 out the middle of Horseshoe Bay. The reef appears to have been eroded and the nearshore is slightly lower in 2009 (orange line) compared to 1977 (blue line).

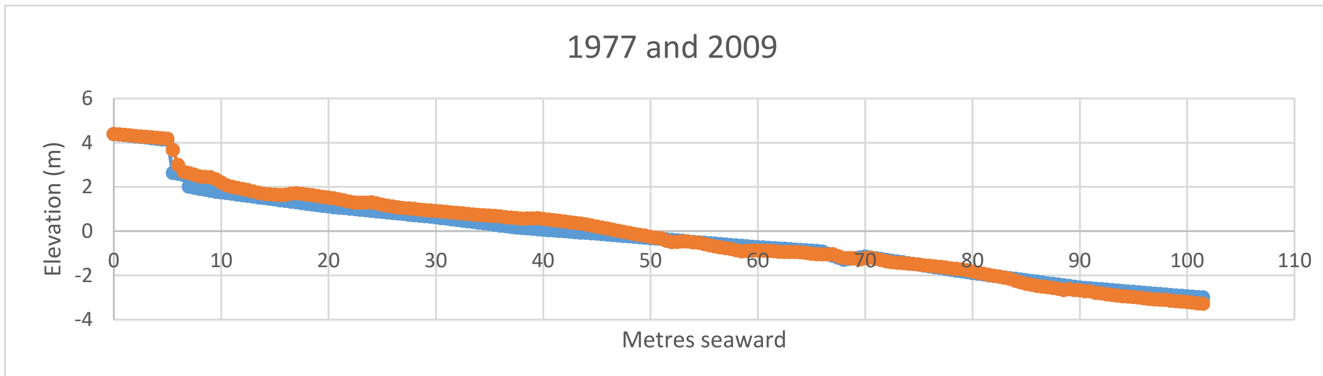


Figure 36: Detailed comparison of the 1977 and 2009 beach and surfzone-immediate nearshore topographic profiles for Horseshoe Bay. Surprisingly, the 2009 profile indicates that the beach has built upwards slightly compared to 1977, although the position of the top of the scarp/cliff is virtually identical.

Figure 37: Location of profile line (SA Nature Maps, 2018)

2. Coastal Fabric - natural

SUMMARY - MEDIUM TERM CHANGES

Changes 1860 to 2018

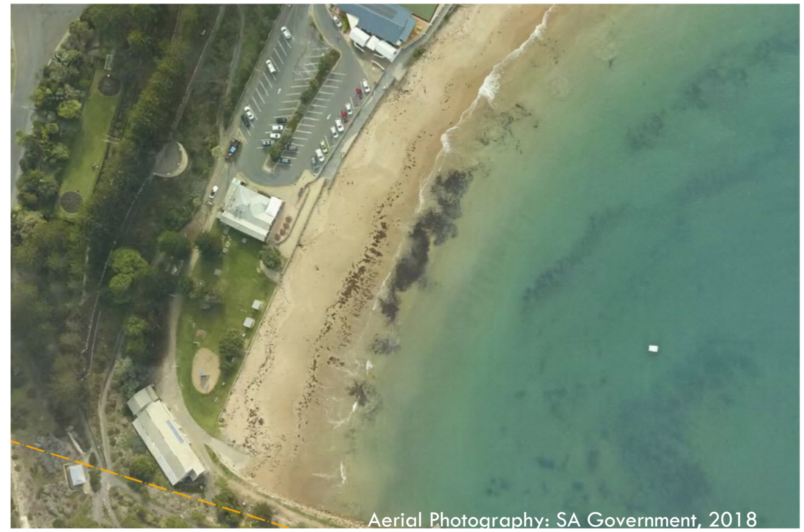
Taking into account that sea level has risen approximately 200-300mm since 1860:

Western end – seawall section (SLSC to Green 1)

- The profile of the beach appears to have receded ~12m.
- The low dune and vegetation observed in 1908 demonstrates that the tide was not encroaching into this region at the time (Figure 29).
- High tide now appears ~20m closer to the wall. Higher tide events reach the wall.
- Sand levels immediately adjacent the wall appear at similar height to 1930s.

Mid-section – embankment section (Green 1 to caravan park)

- Vegetation line tends to be further forward of 1949 due to the 'hold the line' approach to coastal management.
- The installation of the bowling greens in 1913 created a rigid and elevated edge on the coastal side.
- Early photographs show a relatively large dune system between the bowling club/ caravan park and the beach. It is likely that the caravan park slowly encroached into the dunes and converted these areas into grass.
- Overall, a substantial loss of dune has changed the back profile of the beach.
- Early opinions in the 1980s suggested that loss of sand from the mid-section was increasing the erosion of the base of the bank. Vegetation and fencing helped to stabilise the bank, but also increased the rigidity of the line.
- Early photographs show cusps further away from the base of the bank. Modern tidal events (not extreme) are more routinely approaching the base of the bank (perhaps ~20m closer).



Summary – medium term changes

SUMMARY - MEDIUM TERM CHANGES

Changes 1860 to 2018

Eastern end - Dune section (Caravan Park to Commodore Point)

- Early photographs demonstrate that this area was a sandy dune field.
- It was converted to caravan park in the 1980s (with support and oversight of Coastal Management Branch).
- Vegetation has increased throughout the dune field the frontal dune
- Sand has always accumulated in this section due to long-shore drift of sand eastward, and south-westerly winds blow sand up on to the dune.

2. Coastal Fabric - natural

How the geology (fabric) of the coast has changed over time.

Short term changes

Map: SF8-1

Horseshoe Bay

Changes 2003 to 2018

2003 -2018

Assessment

This photograph taken by Coastal Management Branch in 2003 is the first picture available of the coastline in the current period.

The coastline in its 2003 form is a result of the 'hold the line' strategy employed in 1980s and 1990s.

Dunes are well-vegetated and fenced, and formalised access ways provided in three places within the centre green space.

Note: comparison with aerial photograph in 1997 reveals similar condition of dunes and vegetation.

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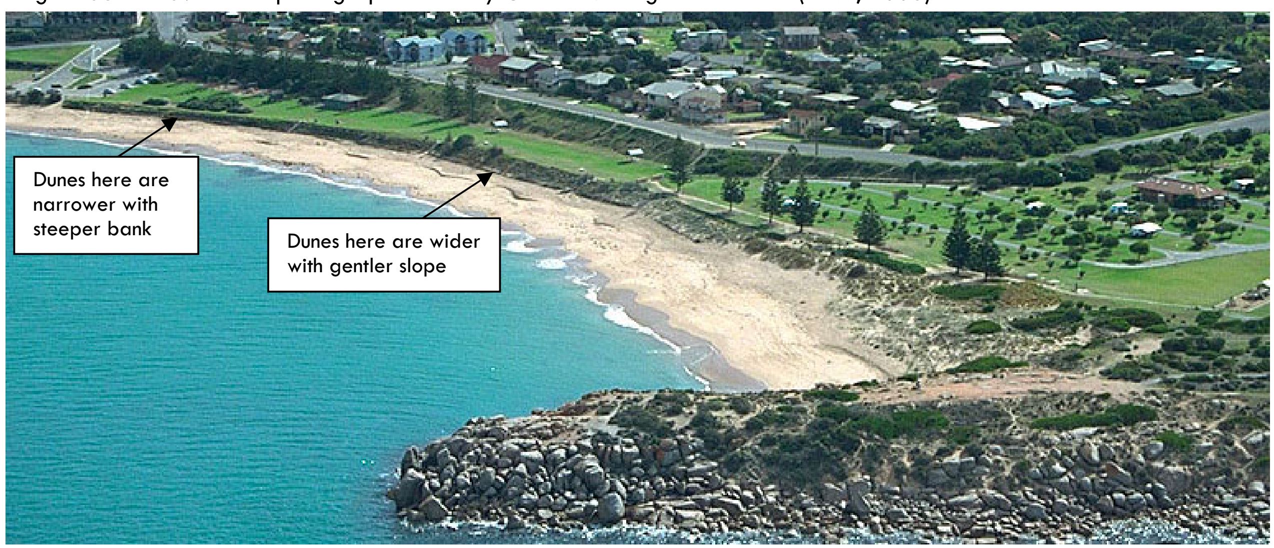
Figure 38 and 39: Aerial photographs taken by Coastal Management Branch (DEW, 2003)



2. Coastal Fabric - natural

Evaluating how the geology of the coast has changed over time.

Short term changes

Map: SF8-1

Horseshoe Bay

Changes 2003 to 2018

2006

Assessment

Vegetation appears in similar location but in much drier condition (drought).

Minor erosion appears around pedestrian access point in centre of green space.

Contour lines provide markers from which to assess changes.

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2. Coastal Fabric -natural

Evaluating how the geology of the coast has changed over time.

Short term changes

Map: SF8-1

Horseshoe Bay

Changes 2003 to 2018

2009

Assessment

Minor recession (2m) has occurred in the centre of the bay between 2006 and 2009. Vegetation generally in a dry state (drought era).

Vegetation was moved from adjacent the bowling green to install a pedestrian promenade.

Contour line are included to provide a visual comparison marker.

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2. Coastal Fabric - natural

Evaluating how the geology of the coast has changed over time.

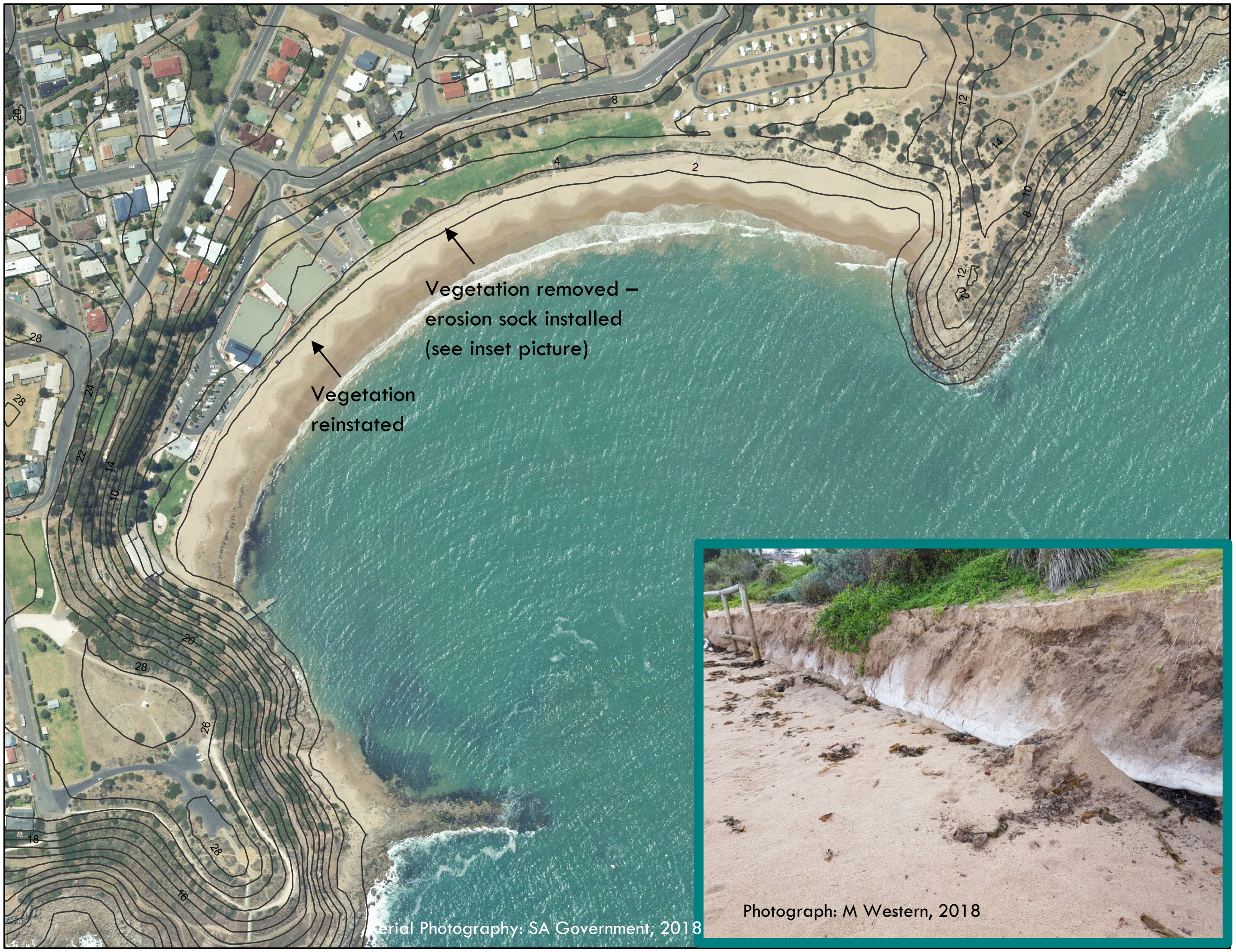
Short term changes

Map: SF8-1

Horseshoe Bay

Changes 2003 to 2018

2013



Assessment

Ongoing erosion problems resulted in vegetation removed from the dunes on the eastern side of the 'green space' and an erosion sock installed (see inset picture).

This sock was buried and planting installed on the dune. The storm event of July 2018 uncovered it.

Contour lines are not necessarily relevant but are included to provide a visual marker.

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2. Coastal Fabric - natural

Evaluating how the geology of the coast has changed over time.

Short term changes

Map: SF8-1

Horseshoe Bay

Changes 2003 to 2018

2016

Assessment

Vegetation is establishing itself over the sock and dune.

Minor recession has occurred on the western side of the 'green space'.

Contour lines are not necessarily relevant but are included to provide a visual marker.

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2. Coastal Fabric - natural

Evaluating how the geology of the coast has changed over time.

Short term changes

Map: SF8-1

Horseshoe Bay

Changes 2003 to 2018

2018

Assessment

Comparison between 2003 and 2018.

IN a 15-year period the rear dune has changed significantly. While the bushes are far more developed in 2018, the base of the dune has been eroded significantly (see also next page).

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Figure 40: Aerial photographs taken by Coastal Management Branch (DEW, 2003)

2. Coastal Fabric - natural

SHORT TERM CHANGES

Changes 2003-2018

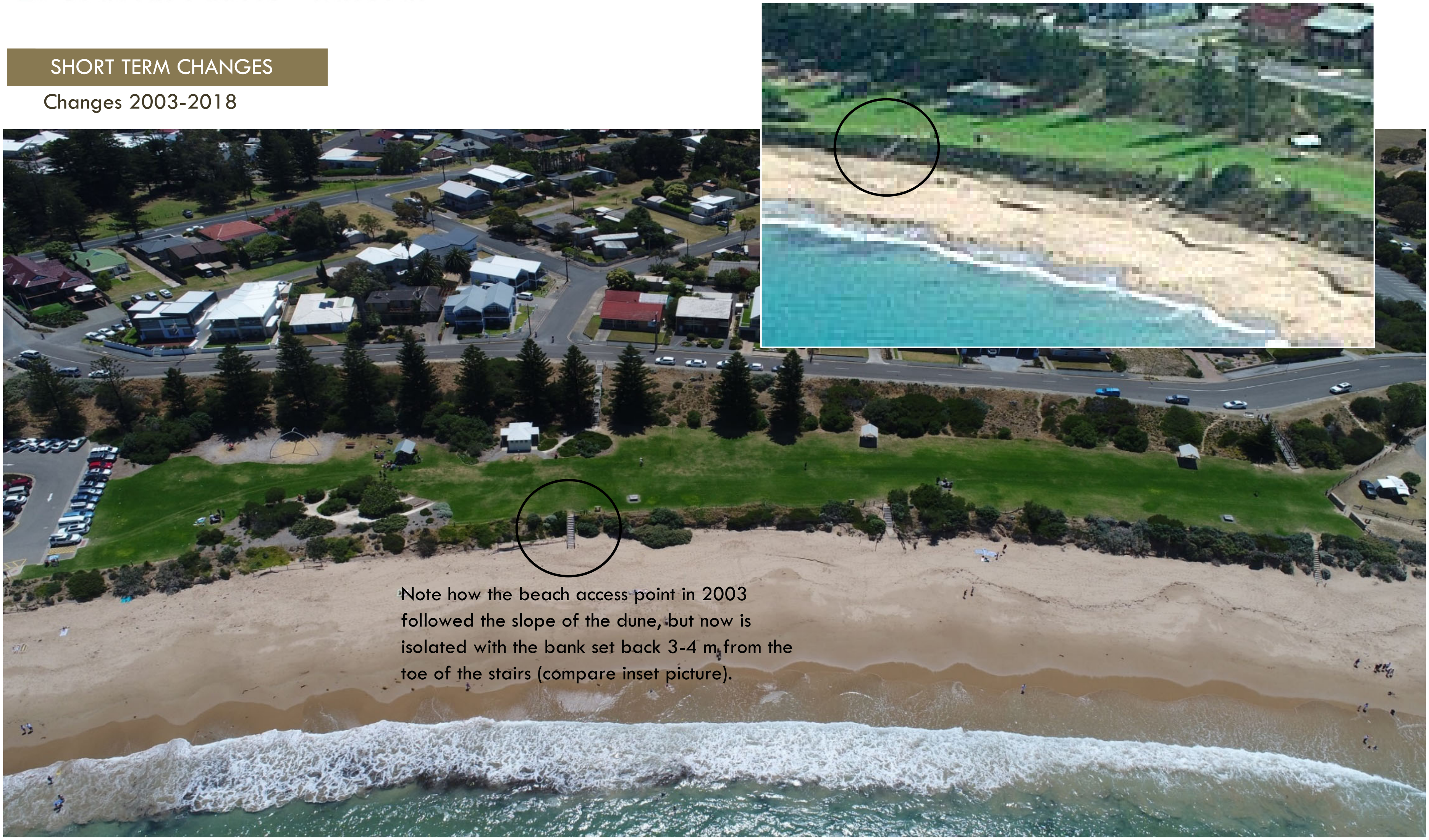


Figure 41 and 42: Comparison between backshore profiles of 2003 and 2018, DEW, 2003.

2. Coastal Fabric - natural

SHORT TERM CHANGES

Changes 2000-2018

Since 2003, parts of the frontal dune have been eroded back by ~4m and the dune escarpment has become increasingly vertical (see inset diagram).

2. Coastal Fabric - natural

SUMMARY - SHORT TERM CHANGES

SLSC to Bowling Green 1

No notable changes have occurred in this section over fifteen years.

Green 2 to entrance to Caravan Park

The main issue in this area is increased erosion in the centre of the bay. This is similar to the complaints of the 1980s.

The dune escarpment has been eroded back ~4m at its base and become vertical in many places.

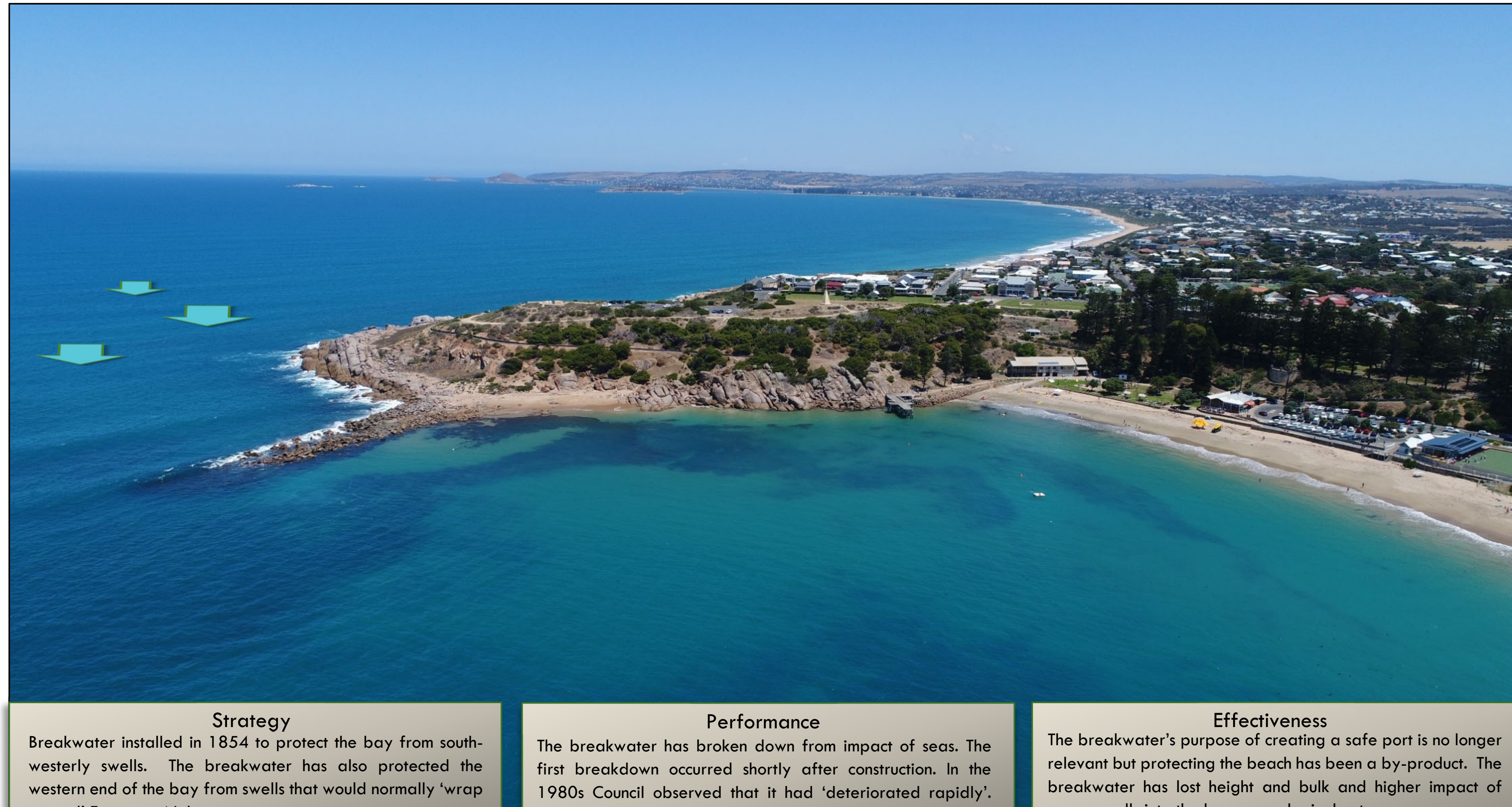
Caravan Park

No notable issues – sand continues to collect in this corner and blows into the caravan park.

3. Coastal Fabric – modified

THE BREAK-WATER

Evaluating how human intervention has modified the fabric of the coast



Strategy

Breakwater installed in 1854 to protect the bay from south-westerly swells. The breakwater has also protected the western end of the bay from swells that would normally 'wrap around' Freemans Nob.

Performance

The breakwater has broken down from impact of seas. The first breakdown occurred shortly after construction. In the 1980s Council observed that it had 'deteriorated rapidly'. See photographic comparison next page.

Effectiveness

The breakwater's purpose of creating a safe port is no longer relevant but protecting the beach has been a by-product. The breakwater has lost height and bulk and higher impact of ocean swells into the bay seems logical outcome.

3. Coastal Fabric – modified

THE BREAKWATER

Evaluating how human intervention has modified the fabric of the coast

C.1942

2018

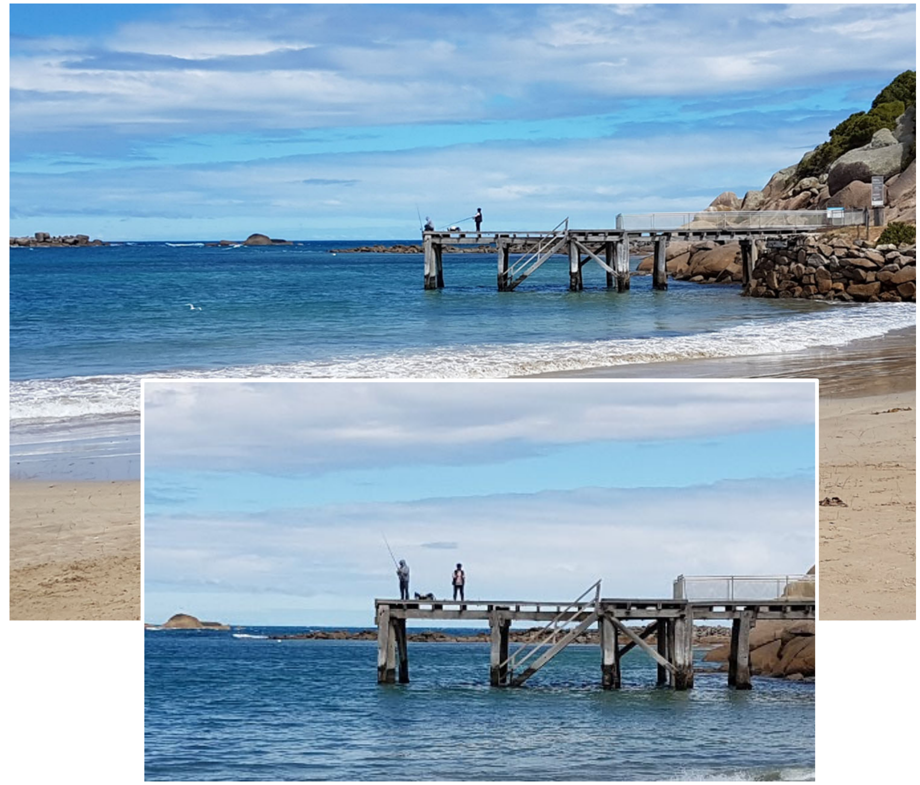


Figure 43. The point of this comparison is to quantify changes to the breakwater. Note the lower section at the end of the breakwater. The archives say that blocks were dislodged in the first storms, and perhaps this was the location. Note that the breakwater in 1942 is almost 'level top' aligned with the former jetty. Source: State Library, permissions pending.

Figure 44: In the first photograph on the right, an attempt was made to align the top of the jetty in a similar way. However, the second photograph makes it very plain how much height the breakwater has lost since 1942. The lower section is still seen in current day. The archives above noted that in the 1980s, there was a 'rapid disintegration' of the breakwater. This was also the time of high erosion and storm activity in the bay.

Research questions: What does a lower top to the breakwater mean in the context of sea level rise? Could the lower top, and a higher sea actually increase the height of the waves into the bay?

3. Coastal Fabric – modified

JETTY RETAINING WALL

Evaluating how human intervention has modified the fabric of the coast

Source: M Western

Source: M Western

Strategy

The rock wall was originally installed to provide retaining to the access way for rail deliveries to the jetty. A portion was added to the end at the time the boat ramp was installed, and minor additions have been made to the top of the wall.

Performance

Due to its location in the most protected part of the bay, the wall has had very little direct impact from the sea.

Effectiveness

Although most of the wall was constructed in 1850s, the wall appears to remain in appropriate condition to serve the purpose of retaining the accessway to the jetty.

3. Coastal Fabric – modified

STONE WALL SECTION

Evaluating how human intervention has modified the fabric of the coast

Strategy

Low stone wall installed circa 1930 to separate the reserve from the beach and to provide elevation to the carpark, and not primarily to protect from actions of the sea. See earlier tidal analysis that shows that it is unlikely that seawater encroached to the wall very frequently.

Performance

Damage reports in the 1980s stated that the wall was built without foundation. Walling in front of the carpark failed in two places and was reconstructed. The wall was constructed forward of the old line, and new entrance provided. A section of wall requires repairs (see next page).

Effectiveness

The wall has been effective in dividing reserve and carparking infrastructure from the beach. The new section is likely to withstand actions of the sea, but sand may be undermined from the base of the wall. Older sections of the wall are likely to perform poorly if they came under constant impact.

3. Coastal fabric – modified

STONE WALL SECTION

Stone wall on eastern end appears straight and sound. Mortar appears to be wearing away. The wall does not suffer routine impact from the sea. Routine impact is likely to cause the wall to deteriorate (Fig 45).

Stone wall in front of café is cracking and moving forward. Repairs are likely required (Fig 46).

Walling in front of the carpark was replaced in the 1980s and is in sound condition (Fig 47).

A board walk has been constructed over the top of the western end of the wall. While this tends to hide the wall from view, the wall still must be capable of protecting the base of the bank. Seaweed strands show location of a recent high tide. The wall appears to be less stable in this location (Fig 48).

Photograhs: Fig 45-48 M Western, 2018

3. Coastal fabric - modified

EMBANKMENT SECTION

Evaluating how human intervention has modified the fabric of the coast

Strategy

Erosion in the 1980s necessitated action to slow erosion. Pedestrian access ways were limited, dunes fenced, and dunes/embankment vegetated. This strategy appeared effective until circa 2008 (P.37).

Performance

Over the last ten years, erosion has increased. It is likely that sand level in the centre of the bay have dropped, combined with increases of sea level, has seen increasing recession of the dunes, and the escarpment of the bank becoming vertical. An erosion sock was installed in 2013 to a section of the bay.

Effectiveness

The embankment imposes a rigid line that wasn't operating when the foreshore had a substantial dune system (see p. x). Vegetation encourages cohesion of the bank but also increases the rigidity of the line. Increasing sea levels, loss of sand, is likely to make this embankment increasingly ineffective.

3. Coastal fabric – modified

NATURAL DUNE SECTION

Evaluating how human intervention has modified the fabric of the coast

Strategy

Erosion in the 1980s necessitated action to slow erosion. Pedestrian access ways were limited, dunes fenced, and dunes/embankment vegetated. This strategy appeared effective until circa 2008 (P.37).

Performance

The reflective nature of the bay tends to move sand to the east and this nourishes the dunes. Excess sand accumulates behind the dunes in the caravan park and is removed periodically.

Effectiveness

The dune system remains nourished.

The pedestrian way could be narrowed to limit the impact of foot traffic when entering the beach.

3. Coastal fabric – modified

SUMMARY

Where formerly the bay was a sloping shoreline in the western end and backed by dunes in the mid-section of the bay, human intervention has placed a rigidity in the system.

First, to provide separation and elevation on the front edge to create 'benches' for structures such as reserve and carpark (minor elevation of the shore edge).

Second, to provide an elevated flat 'bench' for bowling greens (more major elevation of the front edge to the shore)

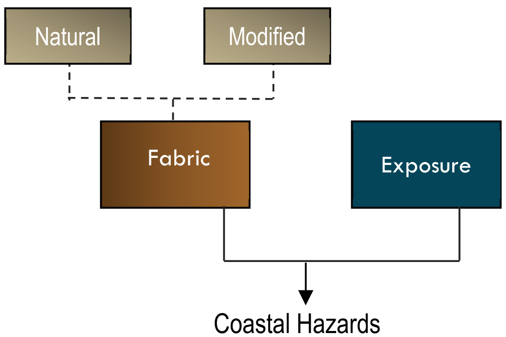
Third, in the mid-section the flexibility inherent in a dune system has been lost and replaced with an inflexible grassed/ vegetation edge. This combined with a loss of the former sloping sand profile on the beach has resulted in the base of the embankment coming under increasing wave attack.

Evaluating how human intervention has modified the fabric of the coast

COASTAL FABRIC

Progress report:

So far, we have completed a review of settlement history and completed an assessment of the 'fabric' of the cell, how the cell was formed and changes that have occurred over time. In the next section we will deal with the 'exposure' of the cell.



Summary:

Horseshoe Bay (Cell 8:1) is situated between granite outcrops at either end of the bay.

Beach

The beach compartment is classified as a 'sandy beach'. The bay was formed over time by the way in which waves have interacted with the more erodible sediments between the granite outcrops.

Backshore 1:

The western part of the bay was originally a sandy beach with gently rising shore of softer sediments. This section of the bay is now dominated with man-made features: seawalls, carpark, and bowling club.

The middle section of the bay may have been a 'shore platform'. The original dune system has eroded away leaving an almost vertical embankment consisting of various soft sediments (may contain some imported fill).

The eastern section of the bay has retained the natural dune system near the beach. A caravan park now occupies the former dune field behind.

Backshore 2:

The western and middle sections of the bay are backed by 'abandoned cliffs', the land behind slopes upward to above 30m AHD at 300m inland.

Benthic

Surfzone and immediate nearshore is sand dominated.

Subtidal reef is variously present along with seagrass. Rock outcrops in places.

Human intervention

Human intervention has placed a rigidity in the beach system for most parts of the bay (western and middle). Seawalls dominate the western part of the bay, and a grassed reserve and near vertical embankment dominates the middle section. All of these provide for an inflexible beach/ dune system.

Analysis

A comparative analysis of photographs from 1949 to 2018 demonstrate that the shoreline (dune line) has been largely stable. However, this is largely due to the adoption of a 'hold the line' strategy.

Since 2003, erosion has largely removed the dunes in the middle of the bay, replacing them with a vertical escarpment.

Increasing sea levels will exacerbate existing erosion in the bay, and sand volume is likely to be lost in the vicinity of seawalls and vertical embankment.

However, the extent of the erosion will be limited by the geological layout of the bay (ie most of the bay is backed by abandoned cliffs and rising landform underpinned by quaternary rocks. This same feature suggests that inundation/ flooding will not be a significant hazard over the coming century.

Erodibility rating:

Backshore 1: In areas where no human intervention has taken place: High erodibility (3)

Backshore 2: Low erodibility (1)

CURRENT EXPOSURE

Evaluating how actions of sea and other weather events currently impact the coastal fabric by:

- Analysing a current storm event
- Applying current 1 in 100 sea-flood risk scenario
- Analysing routine high tide impact.
- Analysing storm water runoff

4. Current exposure – storm event

Storm event

Map SF8-1

Horseshoe Bay

Event: 21-22 Nov 2018

Assessment

A significant storm event impacted the Alexandrina coast on evening of 21-22 November 2018.

The event was recorded at Victor Harbor gauge at 11.45pm at height of 2.02 (CD) or 1.43m (AHD). Wind speeds between ~11.00pm and 2.00am with gusts up to 107kmph and 104kmph were recorded at Hindmarsh Island. High tide was scheduled for 1am but highest tide was recorded at 11.45pm. This suggests that high wind speeds coincided with rising tide.

Seaweed strands in the centre of the bay indicated a storm height (with wave effects at 2.90m AHD).

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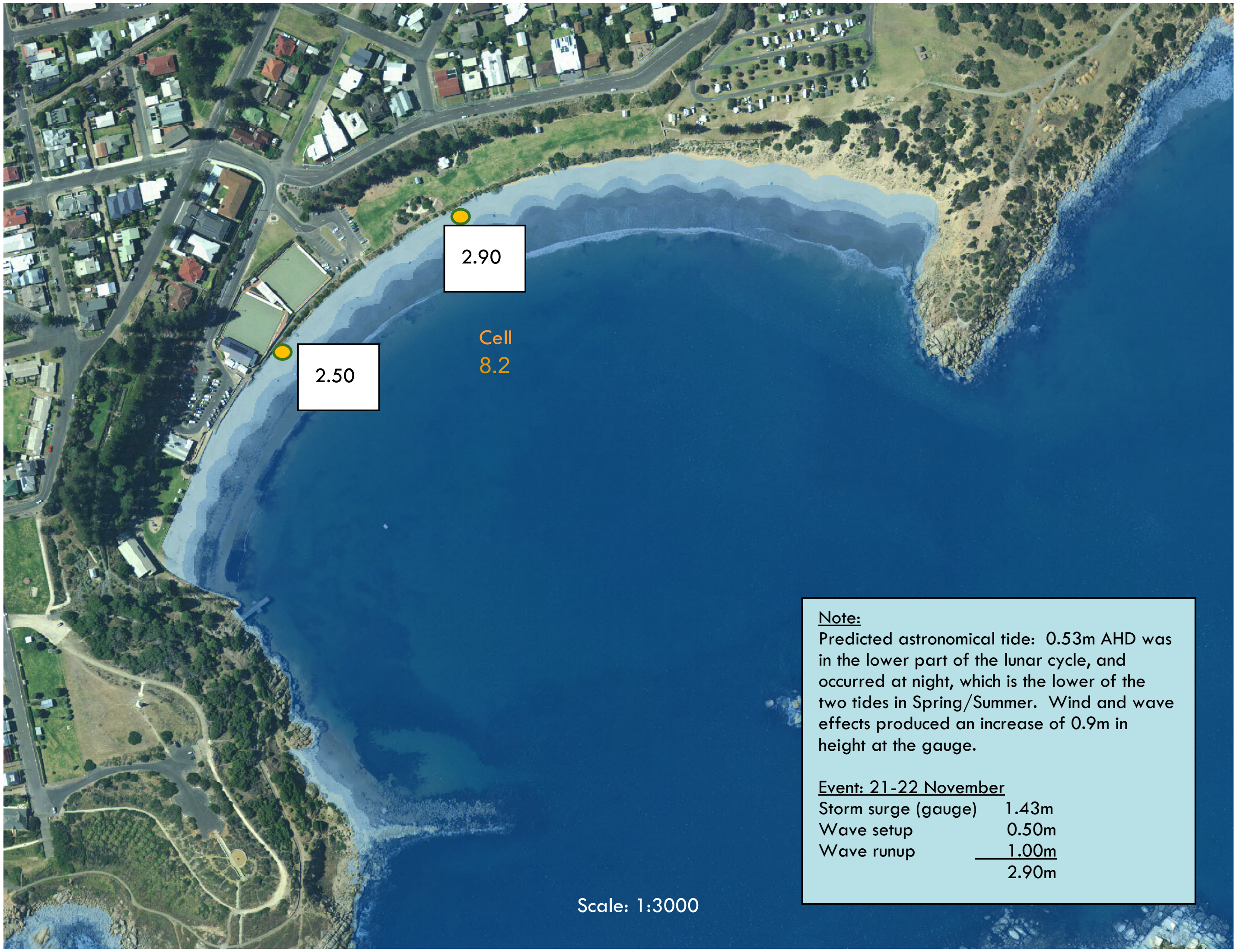

4. Current exposure – storm surge

Storm surge

Map SF8-1

Horseshoe Bay

Current Risk:

1 in 100-year event risk

Assessment

The current 1 in 100-year ARI risk set by Coastal Protection Board is:

Storm surge	1.75m AHD.
Wave set-up	0.50m
Risk	2.25m AHD

Wave run-up has not been included in the modelling. No areas are vulnerable to inundation. In this scenario, wave run up would impact the base of the banks and walls all around the bay.

If this event did occur, then it is very likely that substantial damage would occur to the embankments in at the bowling club and green space (middle of bay). Older walls may also be impacted.

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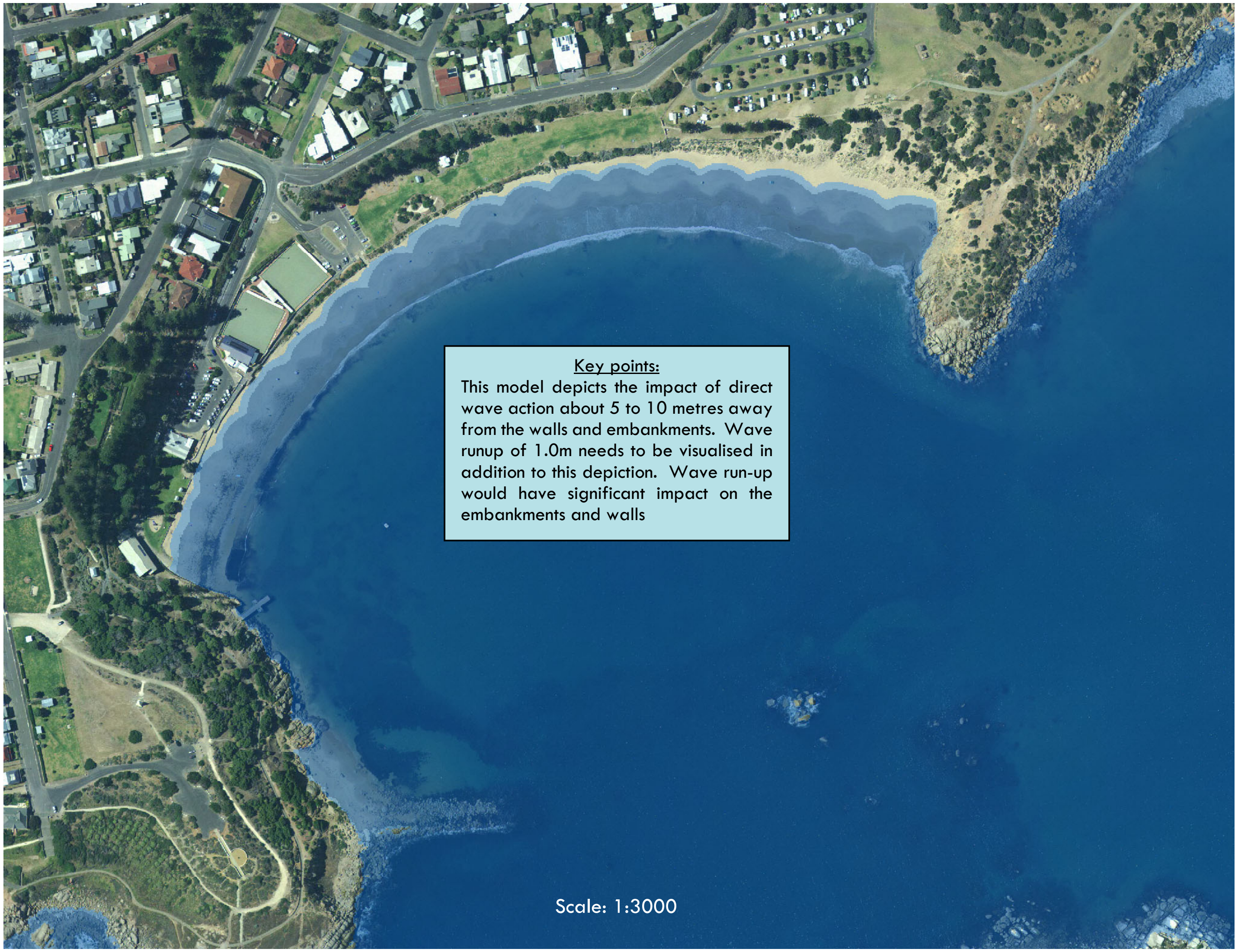

4. Current exposure – monthly high water

Monthly high water

Map SF8-1

Horseshoe Bay

Current risk:

Monthly high water

Assessment

Routine tidal action may also have an impact on the stability of a dune system over time.

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Horseshoe Bay. The event pictured here is expected to occur every one/ two months apart from within the summer months.

The event modelled:

Average high tide	1.50m
Wave set up	0.30m
Total risk	1.80m

Wave run-up has not been drawn. Current impact is likely to be very minor or nil.

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Clarification:
Monthly or bi-monthly high tide events are not necessarily major storm events, but it is assumed that some wave effects are present in the highest event each month.

4. Current exposure – storm water

Storm water pipe

Flow paths

Storm water

Map SF8-1

Horseshoe Bay

Current risk:

Storm water

Assessment

Storm water runoff on to a beach can scour and erode sand levels. The risk of the combined effect of a rain event and a storm tide event should be evaluated.

The key factor to be considered is the size of the catchment and the method of disposal.

The topography of the bay means that dealing with storm water is difficult. There are only three options:

- Drain to the beach
- Retain and pump away
- Retain and drain slowly to the beach

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4. Current exposure – erosion

Erosion

Map SF8-1

Horseshoe Bay

Current risk:

Erosion outlook

Assessment

Two recent events (22.11.18, 19.07.18) demonstrate that Horseshoe Bay is vulnerable to erosion in the mid-section of the bay.

The geomorphic analysis (p.37-39) showed that erosion was first noted in the 1980s (and an erosion reduction strategy employed). But the embankment has receded since 2003 and some remedial action is required.

Other sections of the bay are less vulnerable to erosion in the current era. Areas to the west are more protected, and areas to the east are fronted by a significant sand dune.

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4. Current exposure – sewer

Sewer

Map SF8-1

Horseshoe Bay

Current Risk

Impact upon sewer

Assessment

Sewer infrastructure that is ill-designed to cater for inundation can prove difficult to manage over time.

Should erosion continue to recede the beach/coast, then where sewer infrastructure is situated in proximity to the coast can be critical.

Summary:

Unlikely to be any issues with sewer infrastructure (assuming that it has been designed appropriately for its position, situation in the system).

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FUTURE EXPOSURE

Evaluating how future actions of sea and other weather events currently impact the coastal fabric by:

- Reviewing 1 in 100 scenarios for 2050 and 2100
- Reviewing monthly high tide scenarios for 2050 and 2100
- Analysing erosion risk to 2100

5. Future exposure – storm surge (2050)

Storm surge

Map SF8-1

Horseshoe Bay

2050 risk:

1 in 100-year event risk

Assessment

The current 1 in 100-year ARI risk set by Coastal Management Branch is:

Storm surge	1.75m AHD.
Wave set-up	0.50m
Risk	2.25m AHD
Plus 0.3m SLR	0.30m
Total risk	2.55m AHD

Most of the bay would receive direct impact from waves. Wave run-up of 1.0m had not been included because the modelling is made ineffective due to the steep slope of embankments and walls.

Some over-topping would occur into the western reserve section.If this event did occur, it is very likely that substantial damage would occur to the embankments in the middle of the bay.

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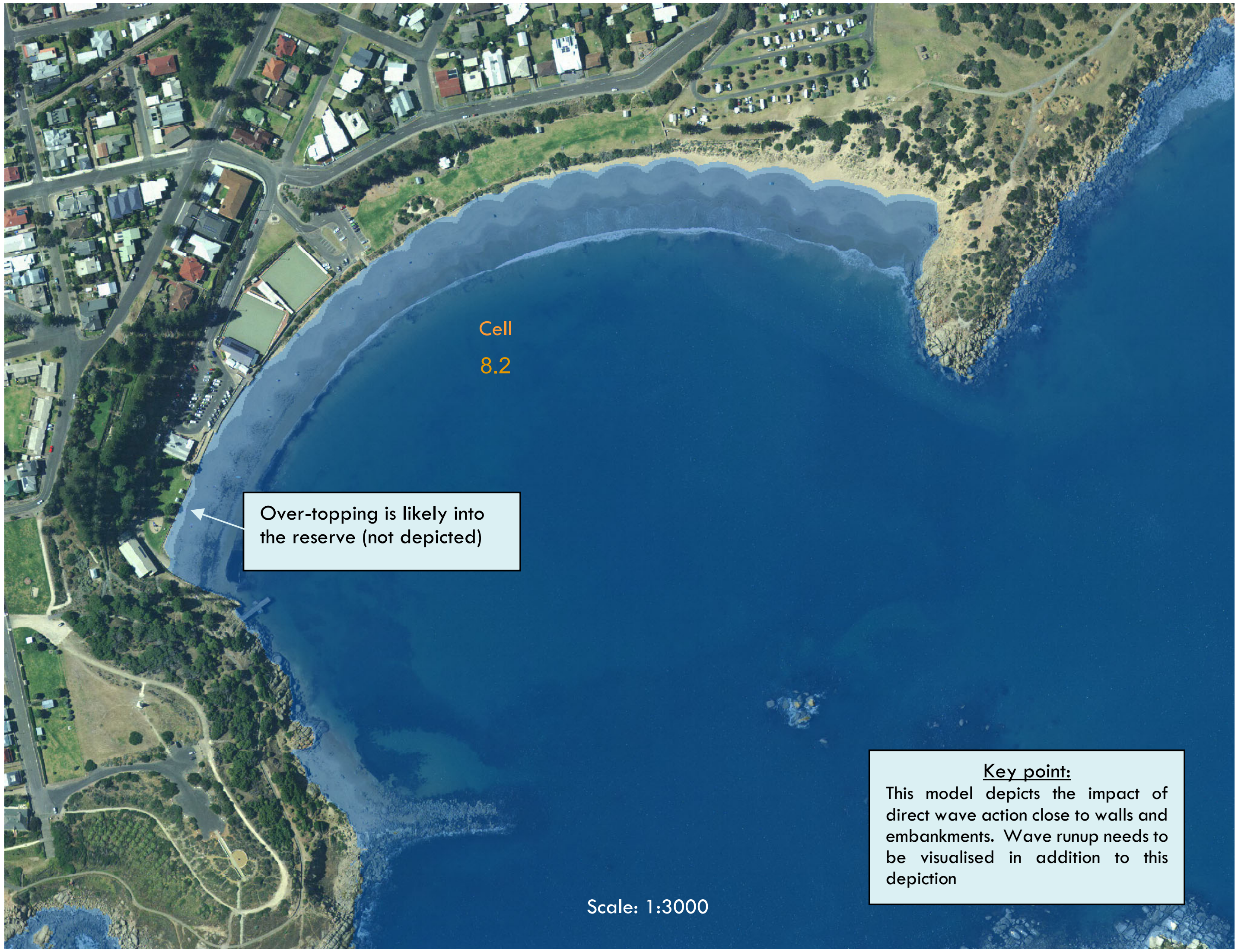

5. Future exposure – storm surge (2100)

Storm surge

Map SF8-1

Horseshoe Bay

2100 risk:

1 in 100-year risk
(without wave runup)

Assessment

The current 1 in 100-year ARI risk set by Coastal Management Branch:

Storm surge	1.75m AHD.
Wave set-up	0.50m
Risk	2.25m AHD
Plus 1.0m SLR	1.00m
Total risk	3.25m AHD

Most of the bay would receive direct impact from waves. Wave run-up of 1.0m has not been included because the modelling is made ineffective due to the steep slope of embankments and walls.

Some over-topping would occur into the western reserve section.

If this event did occur, it is very likely that substantial damage would occur to the embankments and dunes around the bay.

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Contextual note: the mapping of 2100 risk is super-imposed over current beach and dune system. Erosion would have altered the form of the beach and dune system by then. The purpose is to illustrate the potential impact of sea level rise and provide and indicator as to where the beach and dunes may recede over time.

Coastal exposure – storm surge (2100)

Storm surge

Map SF8-1

Horseshoe Bay

2100 risk:

1 in 100-year risk

(with wave runup)

Assessment

The current 1 in 100 ARI risk set by Coastal Management Branch is:

Storm surge	1.75m AHD.
Wave set-up	0.50m
Risk	2.25m AHD
Plus 1.0m SLR	1.00m
Total risk	3.25m AHD

Most of the bay would receive direct impact from waves. Wave run-up of 1.0m has been added to demonstrate the elevation of backshores. (Note: wave runup interacts differently with sea walls)

Some over-topping would occur into the western reserve section.

If this event did occur, it is very likely that substantial damage would occur to the embankments and dunes around the bay.

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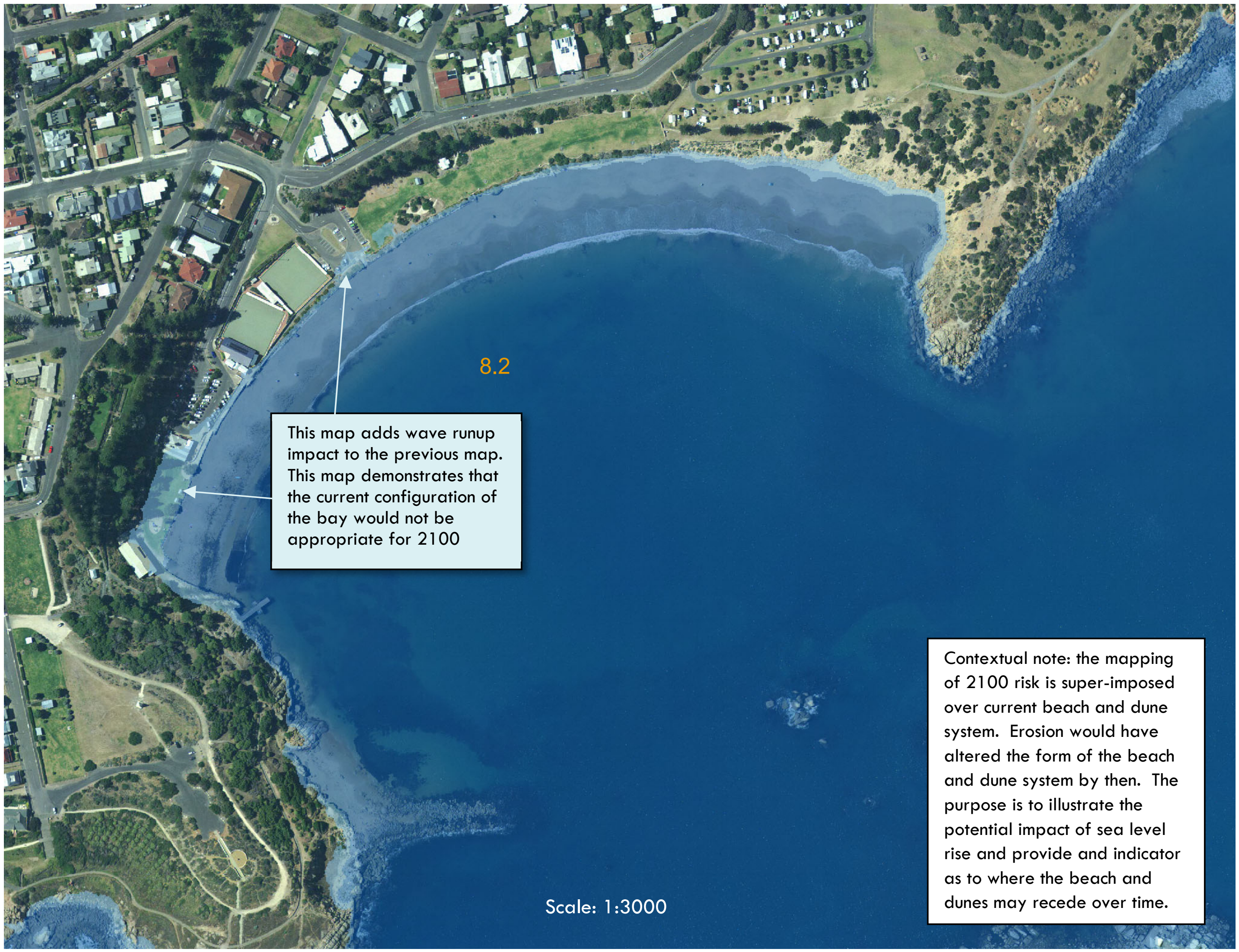

5. Future exposure – monthly high water (2050)

Monthly high water

Map SF8-1

Horseshoe Bay

2050 risk:

Monthly high water

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Horseshoe. This modelled event is expected to occur every one or two months.

Routine tidal action may have a larger impact on the stability of a dune system over time.

The event modelled:

Average high tide	1.50m
Wave set up	0.30m
Total risk	1.80m
Plus sea level rise	0.30m
	2.10M

Wave run-up has not been drawn.

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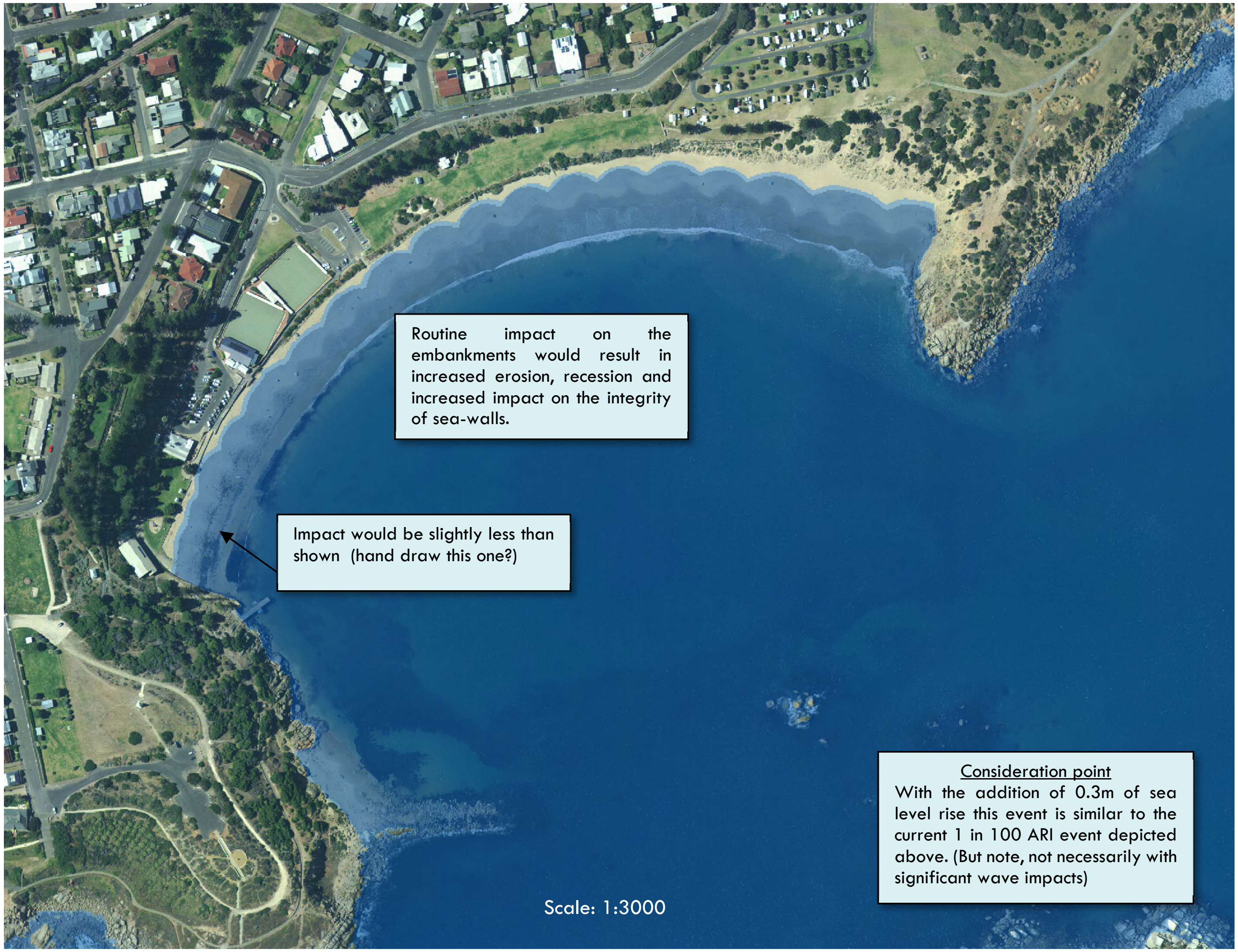

5. Future exposure – monthly high water (2100)

Monthly high water

Map SF8-1

Horseshoe Bay

2100 risk:

1 in 100-year risk

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event at Horseshoe. This modelled event is expected to occur every one or two months.

Routine tidal action may have a larger impact on the stability of a dune system over time.

The event modelled:

Average high tide	1.50m
Wave set up	0.30m
Total risk	1.80m
Plus sea level rise	1.00m
	2.80

Wave run-up has not been drawn.

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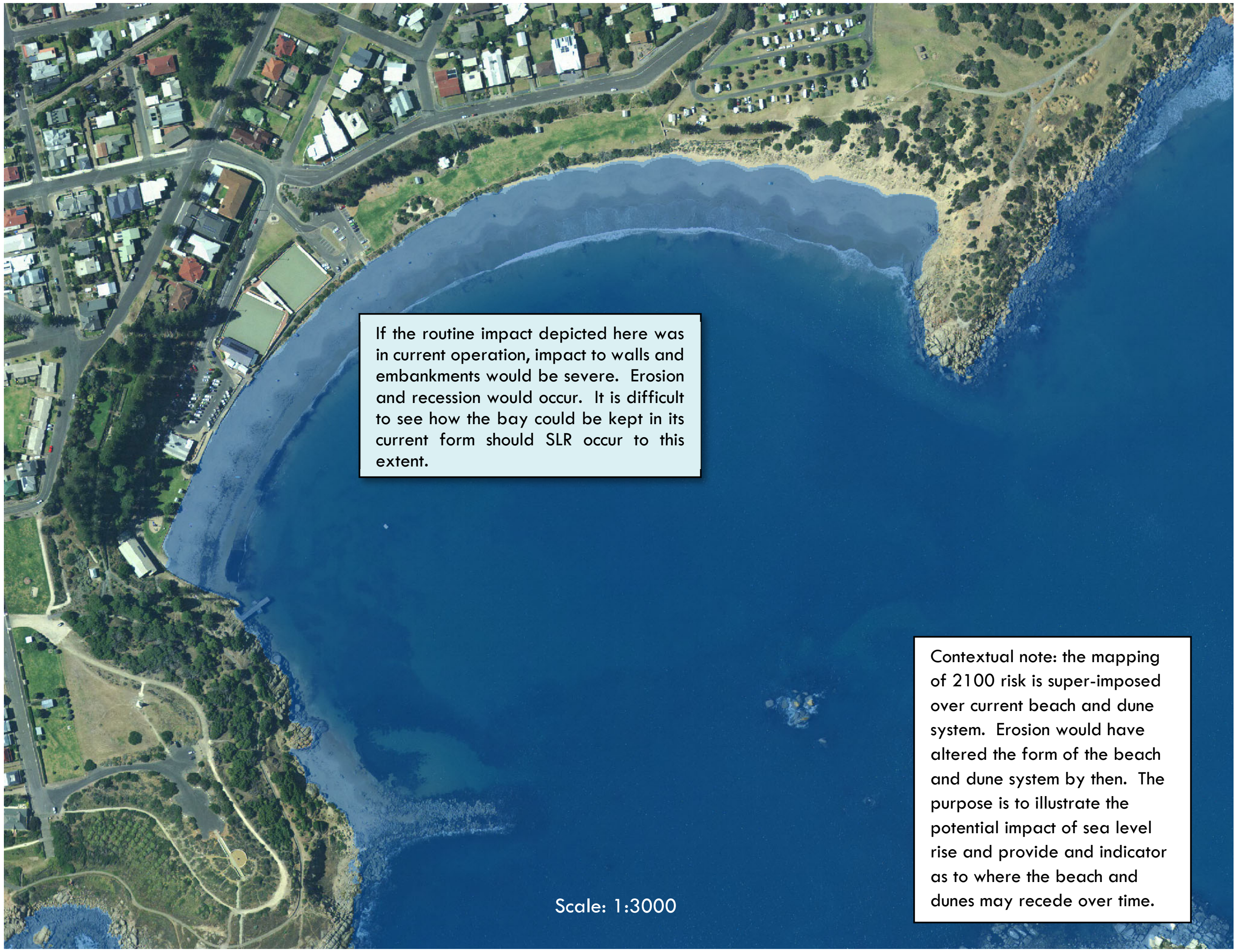

5. Future exposure - erosion

By Dr Patrick Hesp

See full version in Part 1 of the report

Shoreline recession due to sea level rise

In the following, we attempt to estimate shoreline retreat at Horseshoe Bay due to sea level rise. This is achieved by two 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.

Shoreline Change indicated by the Bruun Rule

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

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

Where

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

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

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

Equation (1) applies to the upper shoreface (Cowell et al., 2003a). It assumes that the upper shoreface keeps the same profile and translates seaward or landward depending on the sediment budget, and ignoring alongshore and across-shore changes in sediment supply (Le Cozannet et al. (2016).

Obviously this is a huge assumption in the case of many coastal tracts in South Australia.

In addition, the small, largely altered/destroyed foredune and relatively small dunefield system in the eastern portion of the bay present at Horseshoe Bay indicates it has never had more than a small sediment supply in the past.

Horseshoe Bay

There is extremely limited information available at Horseshoe Bay to determine alongshore and acrosshore 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.

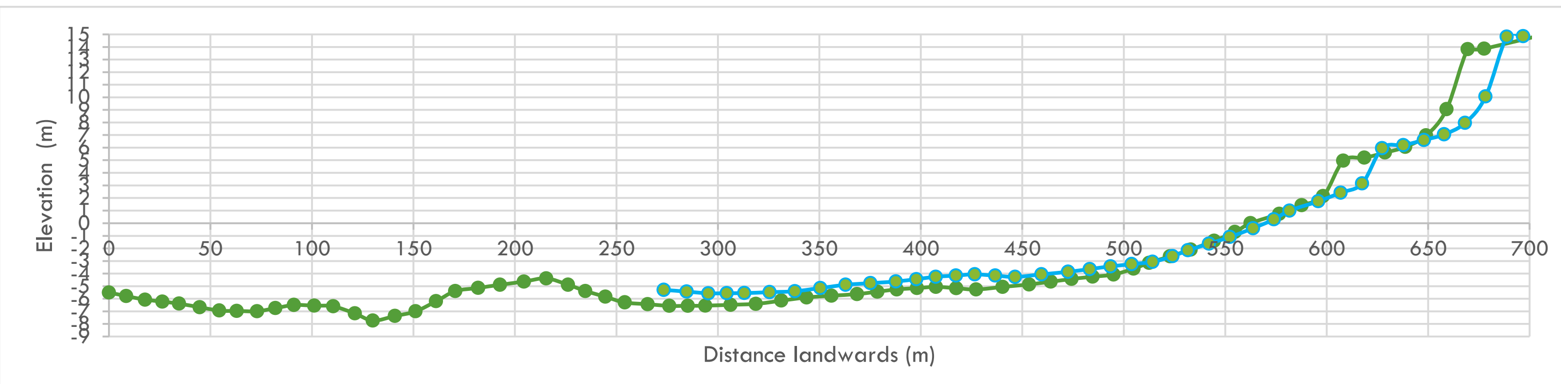

Figure 49: Topographic profile through the middle of Horseshoe Bay surveyed in November, 2018

5. Future exposure - erosion

By Dr Patrick Hesp

See full version in Part 1 of the report

Continued

Alternative approaches exist, but they are more complex and they require more data. Thus, for the purposes of obtaining some estimate of shoreline change driven by sea level rise, the Bruun Rule is first utilised.

An estimate of shoreline retreat due to a sea level rise of 1m by 2100 has been carried out for one topographic profile in the middle of Horseshoe Bay (the lower profile in Figure 50). The recession is based on a mean significant wave height ($\overline{Hs}$) of 0.5m, a closure depth *(dc)* of 4.45m and a beach profile width (backshore to depth of closure distance (*W*)) of 220m.

For a sea level rise of 1.0 metre, the Bruun Rule indicates a shoreline recession of 26.3m by 2100.

This number essentially indicates recession resulting in a cliffed dune/modified foreshore reserve and cliff. The vertical face or scarp of a dune is inherently unstable, and will collapse and slide to a stable angle of ~ 25° resulting in a zone of slope adjustment. This will produce further landward retreat of the dune crest in addition to that estimated by the Bruun Rule erosion.

Shoreface-Beach and Dune Translation Model

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 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.

Figure 2 indicates detail of the beach-dune system segment of the latest available topographic profile surveyed in November, 2018 and the estimated translated topographic profile for 2100.

It may be seen that the beach-foredune system will translate approximately 19.2 metres by 2100.

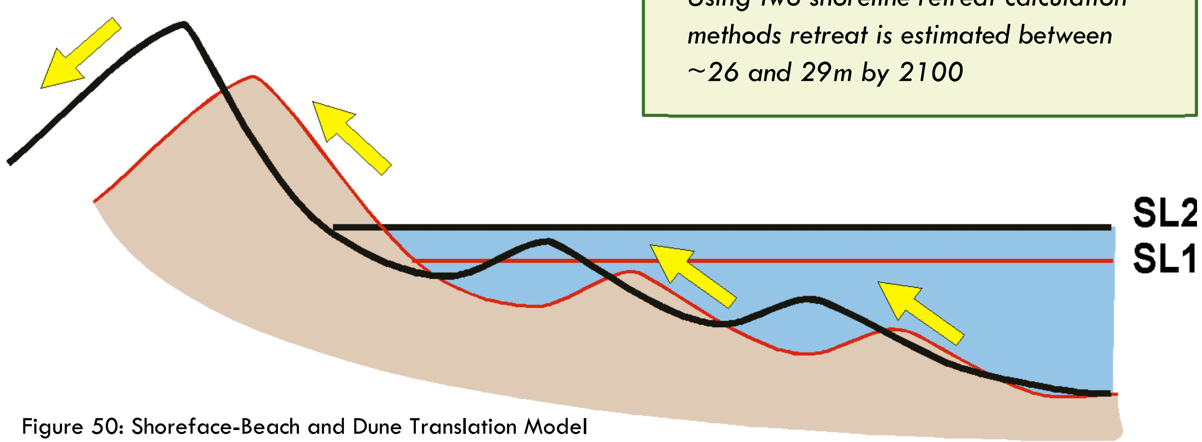

Figure 50: Shoreface-Beach and Dune Translation Model

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 highly modified and cliffed landscape present.

It also assumes that the foredune/cliff 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.

Adopting a factor of safety in the translation shoreline retreat model estimate by multiplying the number by 1.5 gives a translation retreat estimate of ~29m by 2100.

Using two shoreline retreat calculation methods retreat is estimated between ~26 and 29m by 2100

5. Future exposure - erosion

By Dr Patrick Hesp

See full version in Part 1 of the report

Future Exposure

Map SF8-1

Horseshoe Bay

2100 risk:

Erosion outlook

Assessment

A number of methodologies combine to produce the erosion outlook.

Storm flood scenarios and high tide scenarios indicate that existing dune/embankment will come under increasing pressure. If sea level rises by the projected 1m it is very unlikely that the bay could retain its existing formation (dune line and position of assets).

Using two erosion methodologies we arrived at ~26m to 29m erosion by 2100 (with projected rises of 1m), and ~8m by 2050 (with projected rises of 0.3m)

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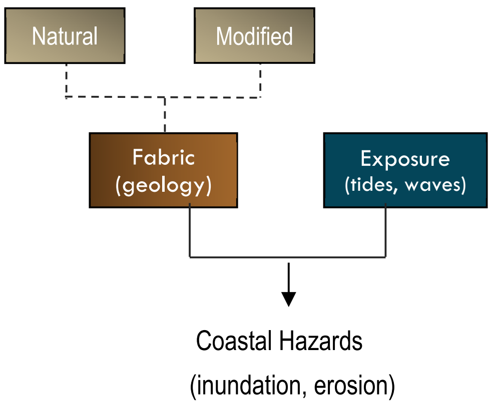
Figure 51: Estimated rates of erosion, P. Hesp, 2019

COASTAL EXPOSURE

Summary and conclusions

Progress report:

So far, we have completed a review of settlement history and completed an assessment of the 'geology' or 'fabric' of the cell (15-25). In the last section we also analysed current and future exposure (27-49).



Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Horseshoe Bay. However, while this storm produced significant wave effects the tide at the gauge was not exceptionally high (less ~0.20m than record of 9 May 2016).

Storm surge

Coast Protection Board has set 1 in 100 ARI event at 1.75m AHD (i.e. at the tide Victor Harbor tide gauge).

If this event was to occur, mapping shows that the impact of wave setup (i.e. waves that have just broken) would be almost at base of seawalls and embankments. This means that impact of wave run up (not mapped) would be significant.

Monthly high water

Extreme events such as a 1 in 100 ARI event can cause considerable damage but these are rare events. Routine tidal action is more likely to impact sea walls, embankments and dunes. Mapping indicates that routine tidal action is likely to be currently just interacting with the base of dunes and walls but not having any undue impact.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event would significantly impact the seawalls and embankments. The mapping indicates that wave set-up (i.e. waves that have just broken) would be directly impacting sea walls and dunes.

Monthly high water

Mapping shows that routine high tidal action would be regularly interacting with sea walls and embankments.

Loss of sand would result adjacent sea walls potentially undermining them, and recession would continue to occur on embankments and dunes.

Future exposure (indicatively by 2100)

Storm surge and routine high water

The 1 in 100 ARI storm event upon the current form of Horseshoe Bay would likely have a catastrophic impact upon infrastructure, embankments and dunes. Routine high tidal action would be constantly impacting the base of seawalls and embankments. Seawalls in their current locations are unlikely to be viable. Even if they were engineered to cope, loss of sand would result from the base of the seawalls.

Erosion to embankments and dunes is likely to be 8m by 2050 and ~26-29m by 2100.

Contextual note

Mapping of 2050 and 2100 scenarios is super-imposed over the current beach and dune system. It is understood that the layout of the beach and dune system will have changed, especially by 2100. However, this mapping does give an indication where impacts will be 'felt' the most.

Hypothetical point

Imagine we could bring forward actions of the sea in 2100 and superimpose them on the current fabric of the bay. It is unlikely that even one winter season would pass before most seawalls had been destroyed or undermined, and embankments and dunes severely eroded.

6. Inherent hazard risk assessment

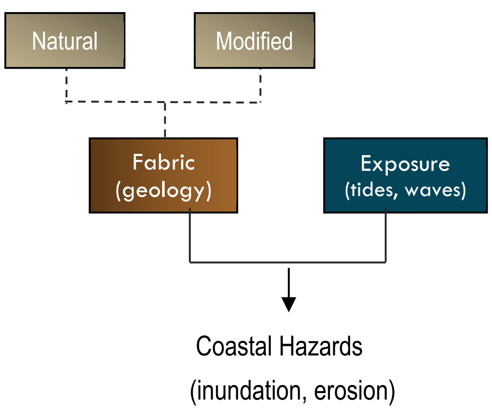
CoastAdapt identifies two main coastal hazards:

- Inundation
- Erosion

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 far 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.



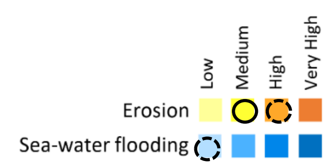
Inundation hazard risk

Due to the slope and elevation of backshore 1, there is limited inundation hazard risk for Horseshoe Bay (exception may for western end of the bay – low height seawall)

Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table (Main document)	Various backshores (including modified)	Medium
Should this rating be amended due to human intervention such as a protection item? If so, how?	Seawalls installed on the western side of the bay to provide level surfaces for carparking etc (not protection). These are likely to exacerbate erosion over time.	Medium
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of 'sheltered'. (suggest this is too low)	Medium
Assess any impact on backshore 1	High water events interact with the base of the escarpment in the lawn section of the bay (northern section)	Medium-high
Assess any influence from Benthic	Offshore reefs: with increasing depths of water, exposure may increase.	Medium-high
Assess the sediment balance	Shoreline position appears in a similar location, Coast Protection Board profile line shows slight accretion over last 10 years.	Medium-high
Assess any other factors that may warrant a change of inherent hazard risk.	Nil	Medium-high

Inherent Hazard Risk – Horseshoe Bay



HAZARD IMPACTS

In this section we identify and describe the potential hazard impacts within four main receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

7a. Assets at risk

Map SF8-1

Horseshoe Bay

Assets and Management

<u>Western section:</u>

The majority of assets are positioned in the S/W section.

Assets on the far south-western end will be easiest to manage. (Reminder: the event of 22 Nov 18, wave impact was 2.90m in middle of the bay and 2.50 in S/W end).

Assets such as the carparks and bowling greens with vertical edges will come under increased pressure.

If a 'hold the line' approach is taken, then the cost will be the installation and maintenance and repairs of defence systems.

If hard protection works are installed/maintained, loss of sand to the beach is often the result. Sea level rise will exacerbate this trend.

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7a. Assets at risk

Map SF8-1

Horseshoe Bay

Assets at risk

Middle section:

A 'hold the line' approach to this section of the bay is likely to mean the eventual need to use hard protection, and loss of sand from the beach as a result (assuming no nourishment program).

If a 'hold the line' approach is taken the cost is that of repairs and upgrades to the bank and protection works rather than a loss of assets.

If the question was, what does this part of the bay want to do naturally, then recede is the answer.

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7b. Safety of people

similar activities. The Surf Life Saving Club also operate in the bay.

Any increase in coastal hazards due to sea level rise are not expected to increase risks to people above existing risks. In other words, in the context of a coastal adaptation study, this hazard/risk assessment is not focussed on risks to people accessing the bay per se, but focussed on specifically on increased risks to safety because of sea level rise.

7c. Ecology at risk

Due to the elevated nature of the backshore, and the urban nature of most of the improvements, sea level rise is unlikely to have any major impact on the ecology of the bay (here we are referring to terrestrial ecology, not marine ecology).

RISK ASSESSMENT

In this section we conduct a formal risk assessment of hazard impacts upon the four receiving environments:

- Public assets
- Private assets
- Safety of people
- Eco-system

This risk assessment utilises the risk framework of Alexandrina Council.

8. RISK ASSESSMENT

Inherent hazard rating

Integrated Coasts has developed a risk classification system to operate over the State of South Australia that categorises the risk to a coastal cell in relation to two main hazards:

- Sea-water flooding
- Erosion

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 using a process that will also benchmark the locality in the context of all of South Australia.

The visual output from the inherent risk assessment process is purposefully designed so that it is immediately accessible and meaningful to a wide range of personnel involved in managing the coastal environs.

Specific Risk Assessment

Each of the cells are assessed more specifically for risk in the context of four receiving environments:

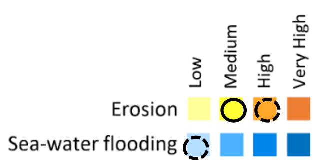
- Public infrastructure
- Private assets
- Public safety
- Ecosystem disruption

The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

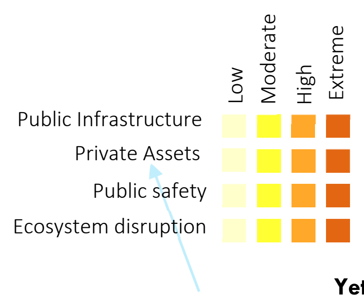
This risk assessment is provided for two eras: the current era, and the 'future outlook'. In this study, future outlook means the end of this current century. The assessment utilises the risk assessment of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding or erosion (see next page).

Inherent Hazard Rating

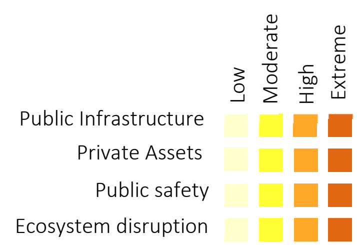
Sandy beach back by bedrock rising >30m at 300m inland



Erosion Hazard Rating
(Current outlook - 2020)



Erosion Hazard Rating
(Future outlook - 2100)



Yet to be assigned

8. Risk Assessment

Erosion assessment

Horseshoe Bay (SF8-1)

Risk identification: Erosion is currently, or may in the future, threaten the walls, embankments and dunes

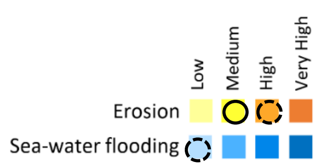
Coastal processes	Horseshoe Bay is categorised as a reflective coarse sand beach bordered by granite headlands. The shoreline is backed by sea-walls on western end, embankment in the centre, and dunes on eastern end. The bay is 'bedrock backed' with backshore rising above 10m at 100m inland from the shore. Exposure is categorised as 'sheltered', and wave energy low at 0.5m to 1m. Historical analysis reveals a significant change to the nature of the beach at which dunes were more significant (mid section to eastern end).

Are any strategies employed to mitigate the risk? Stone walls on the western end, vegetated embankment in the mid-section

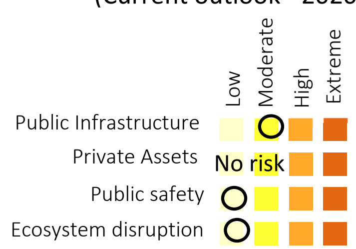
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carparks, sewer infrastructure, storm water infrastructure, walking paths, stone walls and wooden board walk, café, shelters, reserve furniture, toilet block.	current	*Possible*	*Moderate*	moderate
		2100	*Almost certain*	*Significant*	extreme
Private assets	Nil private assets – Surf Life Saving Club and Bowling Club leased from Council.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk
Safety of people	This assessment does not relate to general beach safety (this is SLSC). Current access ways in mid-section require upgrade. Unlikely that storms/ erosion will cause harm to people (any more than they do now).	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Ecosystem disruption	Vegetated embankments not assessed here as these relate more to a management strategy. There are no significant natural environments apart from the dune field on eastern end.	current	*Unlikely*	*Minor*	low
		2100	*Unlikely*	*Minor*	low

Inherent Hazard Rating

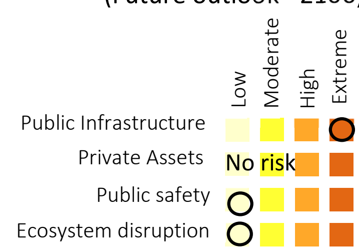
Sandy beach back by bedrock rising to 18m at 400m inland



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

Summary	Although the beach is only moderately exposed, evidence exists to show that the beach has declined in sand in the mid-section of the bay especially. The dunes have receded in elevation, and now have receded to almost vertical against the grassed area behind. Sea level rise is likely to place increased pressure on the centre area, and then toward the carpark and bowling greens. The rigid edges imposed to the bay are likely to be increasingly impacted under projected sea level rises, with loss of sand a by-product of the current strategy.

ADAPTATION PROPOSALS

Adaptation proposals normally fall into one of the following categories (or a combination of categories):

- Avoidance
- Hold the line (protect)
- Accommodate (or limited intervention)
- Managed retreat
- Loss acceptance
- Defer and monitor

Adaptation options

ADAPTATION OPTIONS

CoastAdapt notes that there are generally five categories of adaptation responses to climate change in the coastal zone:

- Avoidance
- Hold the line (protect)
- Accommodation (or limited intervention)
- Managed retreat
- Loss acceptance

Within each of the four response categories there is a range of potential adaptation options in the areas of:

- Planning
- Engineering
- Environmental management[1]

Planning

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

Engineering

In the context of climate change adaptation 'engineering' has come to describe adaptation options that make use of capital works strategies such as seawalls and levees. Such projects are 'engineered' to solve a particular challenge such as to protect coastal infrastructure from erosion and inundation damage. 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 continued growth of habitat such as seagrasses or reefs.

It may also include developing artificial reefs to reduce wave erosion of shorelines or engineered solutions to prevent encroachment of saltwater into freshwater systems.

In current times environmental management is the much preferred option to hard engineered options.

ADAPTATION APPROACHES

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.

Further reading and resources

This section of work adopts the framework and understanding of adaptation options from CoastAdapt. Further reading at:
https://coastadapt.com.au/understand-adaptation
https://coastadapt.com.au/adaptation options

[1] CoastAdapt also includes 'community education'.

Adaptation options

HORSESHOE BAY

In broad terms there are two main adaptation approaches to consider for Horseshoe Bay.

Incremental adaptation

To date, a 'hold the line' strategy has been employed for Horseshoe Bay. An incremental approach to adaptation would seek to mitigate specific problems as they emerged. For example, the mid-section of the bay has suffered erosion and recession. An incremental approach would identify a proposal to mitigate this particular problem, such as sand nourishment, revegetation, dune fencing, and perhaps the installation of more sand bags (erosion sock).

However, if seas rise as projected, strategies such as these will have limited viability and a final move to hard protection such as rock revetment is likely to be the only option. However, the installation of rock revetment in the context of rising seas is likely to result in reduction of sand on the beach. And then sand nourishment or other options may need to be considered. And so, the cycle of competition between humans and the sea would continue, with the sea winning in the end.

Similar examples could be given in relation to the current sea-walls and embankments in the vicinity of the carparks and bowling club in the western end of the bay. As sea levels rose, sand levels are likely to reduce adjacent sea-walls, in some case undermining them, and eventually they would require replacement. And so, the cycle would continue.

Transformational adaptation

As noted on the previous page, in some cases incremental adaptation is unlikely to appropriately manage changes brought about by climate change, in this case, rising sea levels.

Here is a way to consider this issue. Imagine we were able to bring forward in time the projected sea levels and associated wave and storm action from the year 2100. It is highly likely that within one winter, the existing structures of Horseshoe Bay would be severely damaged or destroyed. While recognising this is just a hypothetical way of looking at the issue, it does bring into focus the problem of dealing with adaptation incrementally.

One question to ask is – in the context of sea level rise, what does the bay want to do? To answer that question, it is helpful to review the form of the bay in 1900. The bay was formed by a receding sea level which left a gentle slope of softer sediments. As the seas rise, the bay will want to respond in reverse. The shoreline would recede.

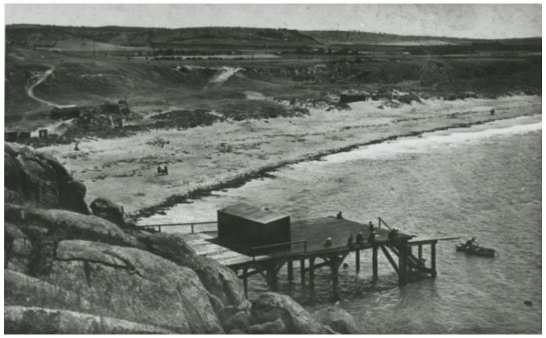


Figure 52: Geological layout of Horseshoe Bay 1900

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 bowling greens and carparks, the front edge has been raised above the natural form of the bay.

A transformational approach to dealing with Horseshoe Bay is to analyse how the bay would naturally respond to sea level rise, and then accommodate this as much as possible in design.

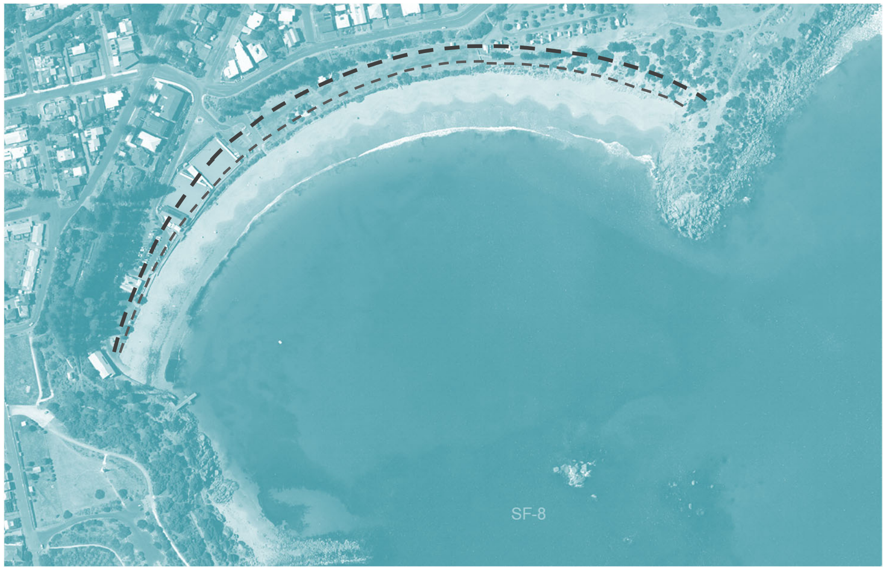
Figure 53: Bowling club has created an elevated front edge (M. Western 2018)

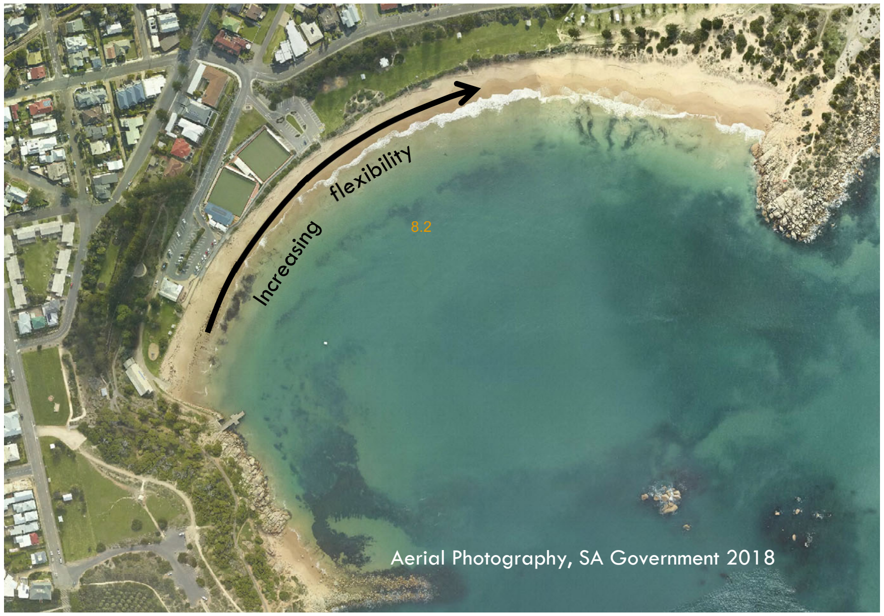
Adaptation options

A transformational approach to dealing with Horseshoe Bay is to analyse how the bay would naturally respond to sea level rise, and then accommodate this as much as possible in design. 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.

The overarching adaptation principle

As noted on p.54, human intervention has imposed a rigidity into Horseshoe Bay. It is recommended that the fundamental adaptation principle to be adopted for Horseshoe Bay is to replace this rigidity with **increasing flexibility** from the western portion of the bay to the eastern part of the bay. The reason for adopting this approach is that western end is the most sheltered and will be the area most able to accommodate the impacts of sea level rise. As we move around the bay to the east, the impacts from wave effects, which will be exacerbated by sea level rise over the course of the century, will need to be absorbed in some way by the back shore.





Aerial Photography, SA Government 2018

Adaptation proposals

This concept is further explained by dividing Horseshoe Bay into four main sectors:

1. The Reserve area (western end)
2. Bowling greens and carparks
3. Green space (middle section)
4. Natural dunes (eastern end)

The following general adaptation proposals are one way in which increasing flexibility can be implemented in the bay:

Section 1: The Reserve area

This area of Horseshoe Bay is the most protected from wind, and also protected from actions of the sea, both from the natural headland and the breakwater.

This area of Horseshoe Bay is the most suited to have a rigid sea-wall which will ensure that a defined public space can be maintained for picnics, play area, surf-life saving activities, and similar. The current sea wall is degenerating with age but for the most part coping adequately, but a properly designed replacement sea-wall is likely to be viable for decades to come.

<u>Adaptation OPTION:</u>

1. Monitor the integrity of the current sea wall and upgrade when necessary. But in particular review the section of wall through which storm water piping is positioned (See fig) and upgrade if required.

The overarching adaptation principle to cope with increase sea levels over the coming century is to:

Increase flexibility in the backshore of the bay from west to east.

Adaptation proposals

Section 4: The Dunes area (eastern end)

The eastern end of the bay is the most exposed. However, due to the reflective nature of the bay and the dominant wind direction, sand naturally accumulates in this corner of the bay. Therefore, while it is the most exposed, it is also naturally well-nourished with sand. An adaptation strategy should always seek to maintain this section of the bay as a natural dune system.

<u>Adaptation Proposals</u>

1. Maintain the existing natural dune in its current state.

2. Investigate the potential for sand harvesting from the eastern end for transport back to the western end as required.

The adaptation proposals for Section 2 and/or Section 3 should incorporate easy access to the beach for trucking sand from the eastern end.

This proposal comes with one caveat that a period of monitoring be undertaken to ascertain the nature of the existing sand movement in the bay (see section below). Key assumptions would need to be evaluated and backed up by sufficient data.

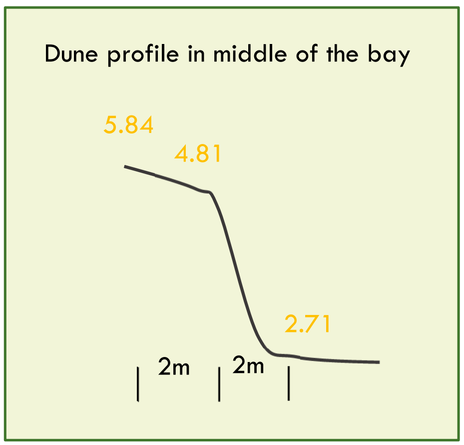
The overarching adaptation principle to cope with increase sea levels over the coming century is to:

Increase flexibility in the backshore of the bay from west to east.

Adaptation proposals

Section 3: The Green Space (mid-section)

In recent years this section of Horseshoe Bay has been subject to increasing erosion. Dune revegetation and dune fencing is no longer maintaining a natural dune. The dune has been replaced by a steep embankment of various soil types (see illustration below). In this location the difference between the top of the embankment and the beach is ~3m. Typically, the range between top and bottom of the embankment ranges between 2.7m and 3.1m.



Adaptation proposal

The adaptation proposal for this section of Horseshoe Bay is to reconstruct a natural dune. The preferred slope upon which to construct a dune on this beach is 15 to 20 degrees:

- Slope of 15 degrees requires 20m dune width
- Slope of 20 degrees requires 15m dune width

This strategy will increase flexibility in the beach and dune system in the rear of the bay so that natural exchange of sand can take place as the beach changes from season to season, and year to year. This strategy is the most likely to preserve Horseshoe Bay as a natural beach and more viable to cope with sea level rise, especially if sand nourishment options are are available later in the century.

A reminder of the profile of the beach in 1900 is provided below. The proposed sand dunes would be less in size, but the principle is the same.

Figure 56: Horseshoe Bay circa 1900 (SA State Library)

Adaptation proposals

Section 2: Bowling club and carparks

Section 2 should be viewed as a transitional space between the more rigid sea-wall of Section 1 and the natural dunes of Section 3 and 4. Section 2 should still be designed as a more formal recreational space but designed in such a way so that it follows the more natural slope of the bay. A foreshore designed in this manner will be much more capable of absorbing the impact of waves in storm events, and much more adaptable in the context of rising sea levels.

It has been noted previously that three recommendations have been made for the relocation of the bowling club in 1983, 1985 in the context of a management study, and then in 2007 in the context of managing sea level rise.

If relocation of the bowling club can be achieved, then there is the potential to both create improved public spaces and improve long term viability for Horseshoe Bay in the context of rising seas.

Adaptation proposal:

Create new master plan for Horseshoe Bay for Section 2.

It is recognised that much consultation would be required to obtain 'buy in' for the concept.

The proposal should be staged to allow implementation over the coming decade.

Case Study:

Kingscliff Beach, NSW

Using a stepped design has created usable public open spaces, but designed in such a way to absorb the energy of the waves, rather than a traditional vertical sea wall. The purpose of the case study is to provide an example of what could be done, not what should be done for Horseshoe Bay.

Figures 57: https://www.yoursaytweed.com.au/KingscliffForeshore/photos/44770

Adaptation proposals

Illustrative Concept

The plan on this page is a preliminary concept that demonstrates how all of the coastal adaptation and urban planning principles might be brought together in one plan. However, the purpose of this plan is not to be proscriptive but illustrative of how a plan might be brought together. It is recognised that significant amount of consultation is likely to be required to obtain long term 'buy in' for the concept.

Staged approach (preliminary):

1. Raise Council awareness

2. Consult with stakeholders

3. Input findings into proposed Master Plan

4. Baseline study – bathymetry, wave modelling, sand modelling (1-2 years)

5. Public and stakeholder consultation

6. Final design of foreshore area and dunes area. Incorporate design for easy access for beach nourishment program (if required in the future).

7. Staged implementation:

- Install dune system (this could be done earlier as a separate project and not contingent on the remainder of the plan)
- Consider relocation of café (not essential to the plan, lease expires in 2022)
- Consider relocation of bowling club (likely to be essential to the adaptation plan, lease expires in 2026)

It is acknowledged that the proposal is significant and represents a 'transformational' approach to coastal adaptation. However, the cost of implementation should be evaluated against the longer term cost of continual repairs, protection works, upgrade to sea walls and such like that will inevitably take place if seas rise as projected.

Adaptation proposals

<u>Concluding notes and observations:</u>

Further design work is not warranted until stakeholders have been consulted and acceptance has been established for a transformational approach.

It is imperative that any design to cater for the conditions of Horseshoe Bay over 50-80 years should be based upon sound data and monitoring (2 years). The following recommendations are based on preliminary discussions with Flinders University:

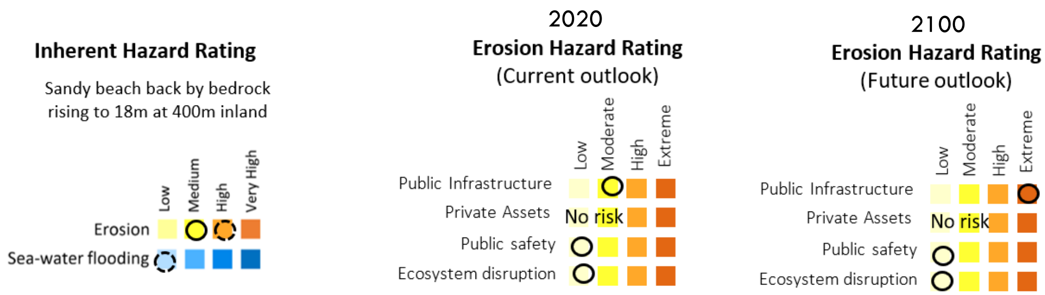
- Obtain bathymetry (can be done with jetski and equipment from Flinders University)
- Model waves within the bay (Flinders University has recently purchased software to undertake high level monitoring
- Monitor sand movements over two years (use a drone with mapping capability).

Preliminary budget for this work is suggested at 20k.

Adaptation Proposals: Horseshoe Bay (Cell SF8)

Coastal processes	Horseshoe Bay is categorised as a reflective coarse sand beach bordered by granite headlands. The shoreline is backed by seawalls on western end, embankment in the centre, and dunes on eastern end. The bay is 'bedrock backed' with backshore rising above 10m at 100m inland from the shore. Exposure is categorised as 'sheltered', and wave energy low at 0.5m to 1m. Historical analysis reveals a significant change to the nature of the beach where in times past (100 years) dunes were more significant (mid-section to eastern end).

Risk outlook:



Adaptation overview:

The long-term strategy for Horseshoe Bay is to 'hold the line' and the geological layout suggest this is feasible. However, to prevent the likely loss of the beach, in the short to mid-term, increased flexibility in the backshore is proposed for eastern sections of the bay by implementing natural dune system. Protection works are proposed for the western side of the bay that will be designed to absorb the impact of actions of the sea. These strategies are proposed to provide longevity to the beach, while allowing some recession of the shoreline as sea levels rise.

Adaptation proposals:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type	Monitoring strategy
Horseshoe Bay Cell SF8-1	Transformational (new Master Plan for the Bay)	Implement increased flexibility in the backshore (allowing some natural retreat if required)	Maintain sand nourished dune system.	Hold the line [The geological layout of the bay suggests this strategy is feasible]	Planning: New Master Plan Environmental (subject to plan): Implement dune system on eastern end. Engineering: Implement protection system to absorb impact from actions of the sea.	Initial monitoring required to quantify sand movement / volumes in the bay.