Coastal Adaptation Study

for Alexandrina Council

MIDDLETON BEACH

Cell SF5

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 SF5 Middleton Beach) prepared by Integrated Coasts, South Australia.

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Front Cover: Photograph, SA Coast Protection Board, 2008

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

Introduction

This document is a partial output for the Coastal Adaptation Study for Alexandrina Council (Cell: Middleton Beach). 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 Study 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 (eg 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

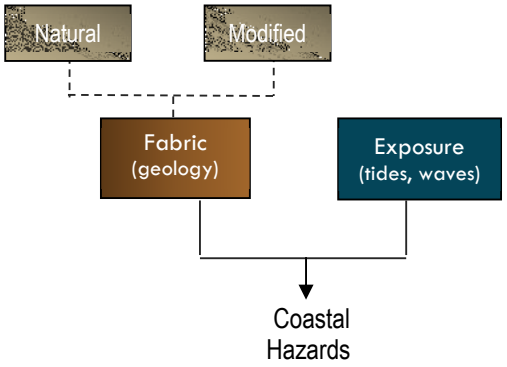
Finally, in a coastal adaptation study, we are also interested to know how this relationship between ***fabric*** and ***exposure*** may change over time, and what this may mean in the context of our coastal settlements.

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 on average at ~4-5mm per year in our region.

The general consensus of the scientific community is that the rate of sea level rise will continue to escalate towards the end of this century (~10-15mm per year). These projections are based on sound physics, but the exact rate is uncertain.

What is certain is that if seas rise as projected then the relationship between fabric and exposure will change significantly in some coastal locations.

Figure 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 **Coorong** (CoastAdapt) and within tertiary cell **Southern Fleurieu 5** (Nature Maps).

These cells are depicted on the following pages.

Introduction

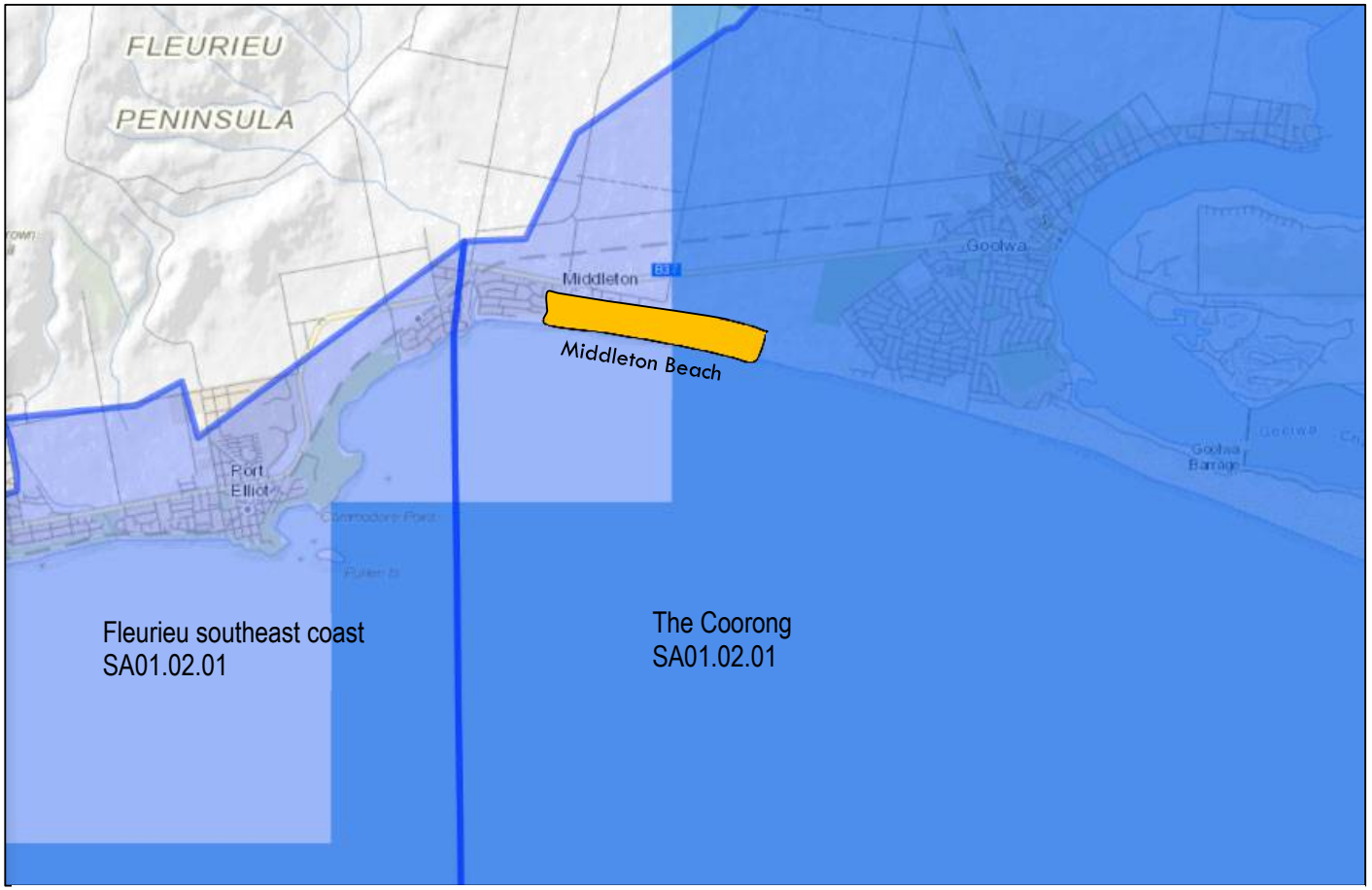
Regional setting

Map: SF5
Secondary Cell: Coorong
Tertiary Cell: Southern Fleurieu 5
Middleton Beach
Secondary Cell

Australian regional setting
Cell: Coorong

Geomorphology of the Coorong cell:

Sheltered to exposed, W-SW facing curving barrier, with beach-foredune ridges (Lacapede Bay) to massive dune transgression - onshore transport (mix of quartz & carbonate beach sand).



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The dominant regional processes influencing coastal geomorphology in this region are the Mediterranean to humid cool-temperate climate, micro-tides, high energy south-westerly swells, westerly seas, carbonate sediments with interrupted swell-driven longshore transport, and the Southern Annular Mode (driving dominant south-westerly swells and storms). Regional hazards or processes driving large scale rapid coastal changes include: mid-latitude cyclones (depressions), storm surges and shelf waves.
Source: https://coastadapt.com.au/sites/default/files/docs/sediment_compartments/SA01.03.01.pdf

Introduction

Regional setting

Map: SF5

Secondary Cell: Coorong

Tertiary Cell: Southern Fleurieu 5

Middleton Beach

Tertiary Cell

SA Regional setting
Yellow line depicted from Nature Maps (Department of Environment and Water) represents the following:

Shoreline class
Dissipative Beach

Sand rating
Fine medium sandy beach

Exposure:
Very high

Form:
-10m at 900m off-shore (< 5 degrees)

Backshore 1:
Vegetated dunes of varying heights, one section of cliff (5m high).

Backshore 2:
Varies

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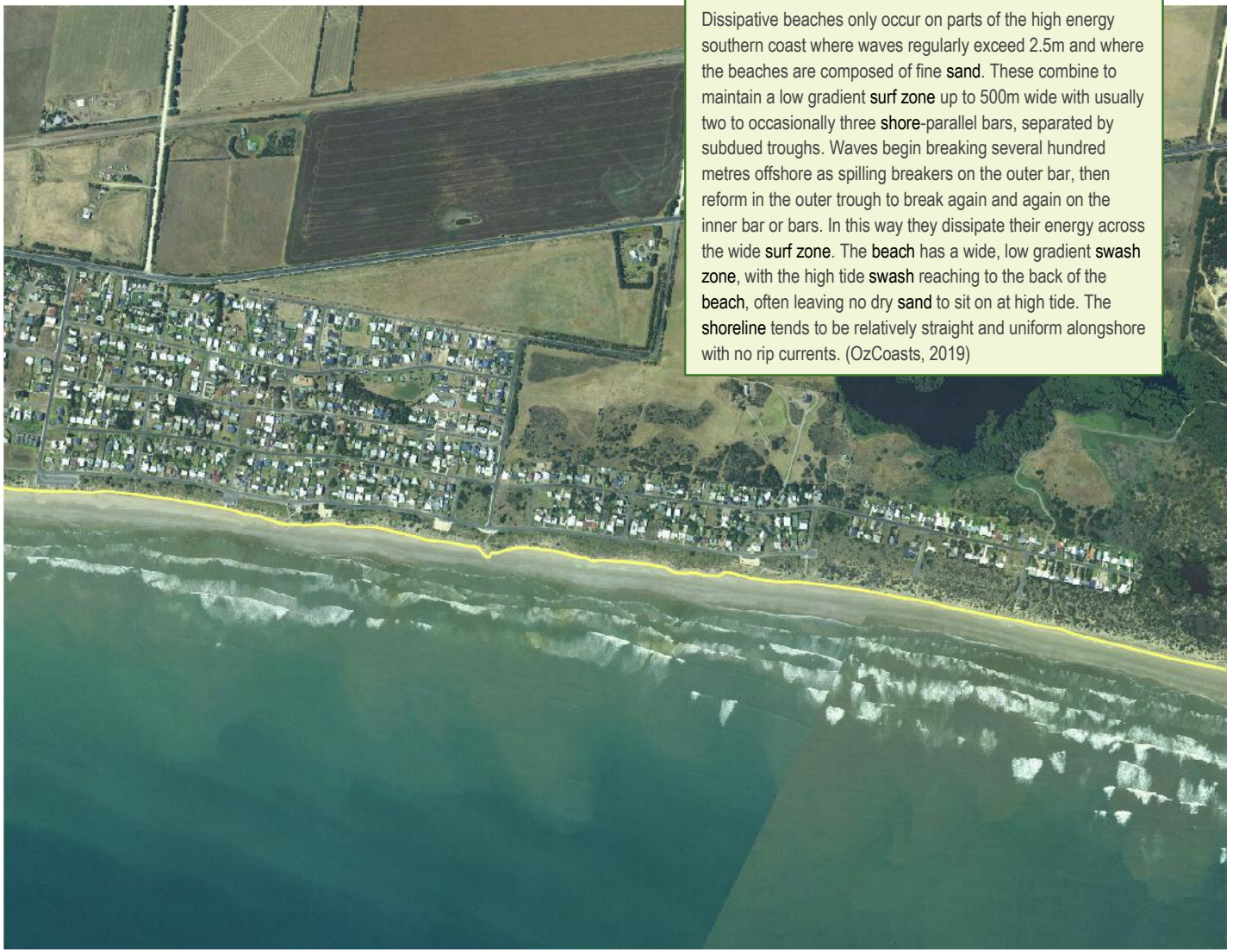

Dissipative Beaches

Dissipative beaches only occur on parts of the high energy southern coast where waves regularly exceed 2.5m and where the beaches are composed of fine sand. These combine to maintain a low gradient surf zone up to 500m wide with usually two to occasionally three shore-parallel bars, separated by subdued troughs. Waves begin breaking several hundred metres offshore as spilling breakers on the outer bar, then reform in the outer trough to break again and again on the inner bar or bars. In this way they dissipate their energy across the wide surf zone. The beach has a wide, low gradient swash zone, with the high tide swash reaching to the back of the beach, often leaving no dry sand to sit on at high tide. The shoreline tends to be relatively straight and uniform alongshore with no rip currents. (OzCoasts, 2019)

1. SETTLEMENT HISTORY

A historical review ensures that the circumstances in which the settlement was founded are understood and key documents and events are identified and reviewed. In this section we:

- Give a brief history of the settlement
- Review archives at Coastal Management Branch
- Identify key studies and plans
- Identify any key storm events (if known).

1. Settlement history

The first purpose of this section is to identify the key factors of settlement history in the context of the coastal environment. It is not to provide a comprehensive historical account. In particular, we are interested in identifying any key ocean impacts, and past protection and management strategies.

A second purpose is to identify key studies so that we build appropriately upon previous work.

BRIEF HISTORY

Prior to European settlement the Middleton Beach region was inhabited by the Ngarrindjeri people.

Middleton's history as township was directly related to changes in railways. The first siding was established in 1854, and for a time Middleton's population was equal to Goolwa's population. Middleton's significance as a railway centre ended soon after 1885 when the railway was diverted, and the original town has remained largely the same since.

Goolwa, Port Elliot and Middleton became, with Victor Harbor, major resort centres, amongst the earliest outside Adelaide.

Middleton west (of Middleton Creek) was established first in the 1950s and 1960s.

Middleton East (surfers subdivision) was implemented in mid 1970s (19771200).

KEY STUDIES AND PLANS

There are no studies or plans relating to Middleton Beach. The Middleton Foreshore Plan (19771200) is reviewed in SF6, this plan only extending to Chapman Road and not related to this Cell.

ARCHIVAL REVIEW

Records exist in hardcopy within the archives of Coastal Management Branch from 1974 to 1983. Scans are referenced within text according to date.

Dune restoration

The first mention of work in SF5 is the reinstatement of sand dunes at the eastern end of Surfers Subdivision at cost of ~$4400, of which Coast Protection Board contributed 70%. The exact nature of the location and work is unknown (19770517, 19780613).

One person lodged a complaint in 1990 noting that increased vehicle and pedestrian traffic had damaged the dunes further (19900122).

Note: For historical references to Middleton Point/ Creek area refer to settlement history in SF6.

SETTLEMENT HISTORY
Key points

Middleton Beach was first developed on the west side of Middleton Creek in the 1950s and 1960s.

The east side of Middleton Creek was developed first in mid 1970s.

First mention in the archival review was the restoration of sand dunes at the eastern end of Surfers Subdivision. This may be dunes in front of Tukuremoar Reserve.

COASTAL FABRIC

In this section we evaluate coastal fabric in more detail :

- Ancient coastal formation
- Overview of current fabric
- Changes to shoreline over seventy years
- Changes to seafloor since 1977
- Human intervention

Note: Due to the changing nature of the backshores for this cell, an overview of the coastal fabric is provided in this section of work and then a more fine-grained assessment is conducted for five locations within this cell with a special focus on areas that contain infrastructure within the backshores.

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 2-5m higher than present.

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.

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. The coastline east of Middleton Creek is very dynamic, changing with variations in sea level, wind, storm waves and tidal conditions. A prominent feature of this section of coastline has been recent coastal erosion, which has been particularly marked in the softer rocks of the Middleton to Goolwa Section of the coastline.

KEY POINTS

- Land areas to the east of Watson Gap (including Cell 7) are subsiding, but at a very low rate of 0.02mm/ yr.
- The coastline from Middleton to Goolwa is very dynamic and has undergone significant erosion in times before the 1950s.

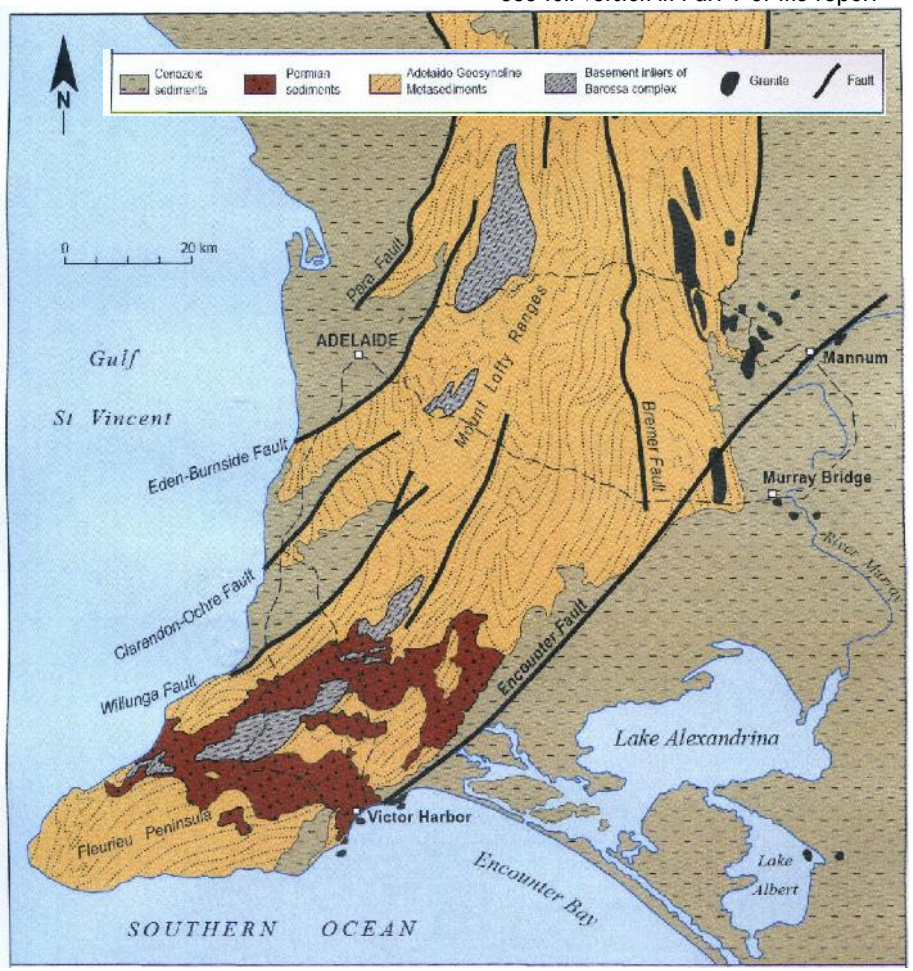

Figure 2: The location of the Encounter Fault, which runs out to sea near Watson Gap. This fault separates the uplifting Mount Lofty Ranges, on which sits the Chiton to Watson Gap coastal sector, from the subsiding Murray Basin, the setting for the remainder of the Alexandrina Coast.

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

Surfers Beach

Eastwards of the alluvial cliffs of Middleton Beach calcrete begins to replace the alluvium of the Pooraka Formation. Calcrete is a duricrust, a resistant surface capping, in which the cementing agent is calcium carbonate that can be derived from the underlying rock. At Surfers, the material underlying the calcrete is aeolianite, a former coastal sand dune that has been turned into rock (lithified). The original sand dune contained shelly fragments, which have been partly dissolved by soil and ground waters and reprecipitated to cement the former unconsolidated sand into a rock-like mass. The original bedding or layering of deposition in the former sand dune is well preserved at Surfers Beach where it has been exposed by erosion. The disposition of the bedding changes, dipping at various angles. This is known as cross bedding and indicates that the sand was being blown from the west during the formation of the dune.

At the surface there is a greater concentration calcium carbonate, the original bedding of the sand dune has been destroyed, and there is the development of a very resistant and massive layer of hard, white calcrete. In some places possible worm trails have been preserved in the calcrete, which was originally part of a soil profile, where plant and animal activity probably aided calcrete formation. Reddish soil occurs sporadically on the aeolianite and also fills solution hollows, which extend through the calcrete into the underlying aeolianite.

Former plant roots, which have been turned into rock by precipitation of calcium carbonate around the old roots, are also visible in the eroding cliff. Large blocks of aeolianite with its calcrete capping and overlying sandy soil have broken from the cliff top and tumbled onto the beach, indicating that active coastal erosion is still occurring.

There is no build-up of a sand dune at the base of the cliffs as at Middleton. Boulders and pebbles derived from higher calcretes have been cemented onto massive calcrete on the western end of the Surfers aeolianite dune, although superficially they appear to be resting loosely on the surface. Purple coloured sands on the beach at the western side of the aeolianite dune at Surfers probably contain rutile, a titanium mineral.

The sand dune that now forms the aeolianite cliffs at Surfers formed when the sea level was lower than at present (-12 m), so that no beach shells related to the dune are found on the land. The former beach lies well below present sea level. However, the age of the dune has been determined by thermoluminescence techniques, which have returned an age of 103,000 ± 6,000 years Before Present (BP).

Changes 1860s to 1949

In the adjacent cells either side of SF5, significant evidence exists for substantial erosion occurring between the 1860s and 1949. It is safe to assume that erosion also occurred within this cell within the same period, but no specific details are known.

Figure 3: The aeolianite cliffs at Surfers Beach have a long history of active erosion. This photo was taken in the 1950s (Dr R Bourman)

2. Coastal Fabric - natural

Overview

Map: SF5

Secondary Cell: Coorong
Tertiary Cell: Middleton Beach

Form

Beach

Fine-medium sand beach

Backshores

Backshore 1: Varies (see map)

Backshore 2: Varies (see map)

Bathymetry

Overall slope of ocean floor: -10m ~1km from beach (overall slope ratio 1:100).

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2. Coastal Fabric - natural

Overview

Map: SF5

Secondary Cell: Coorong

Tertiary Cell: Middleton Beach

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 (varies)

Semaphore sand

Age: Pleistocene – Holocene

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

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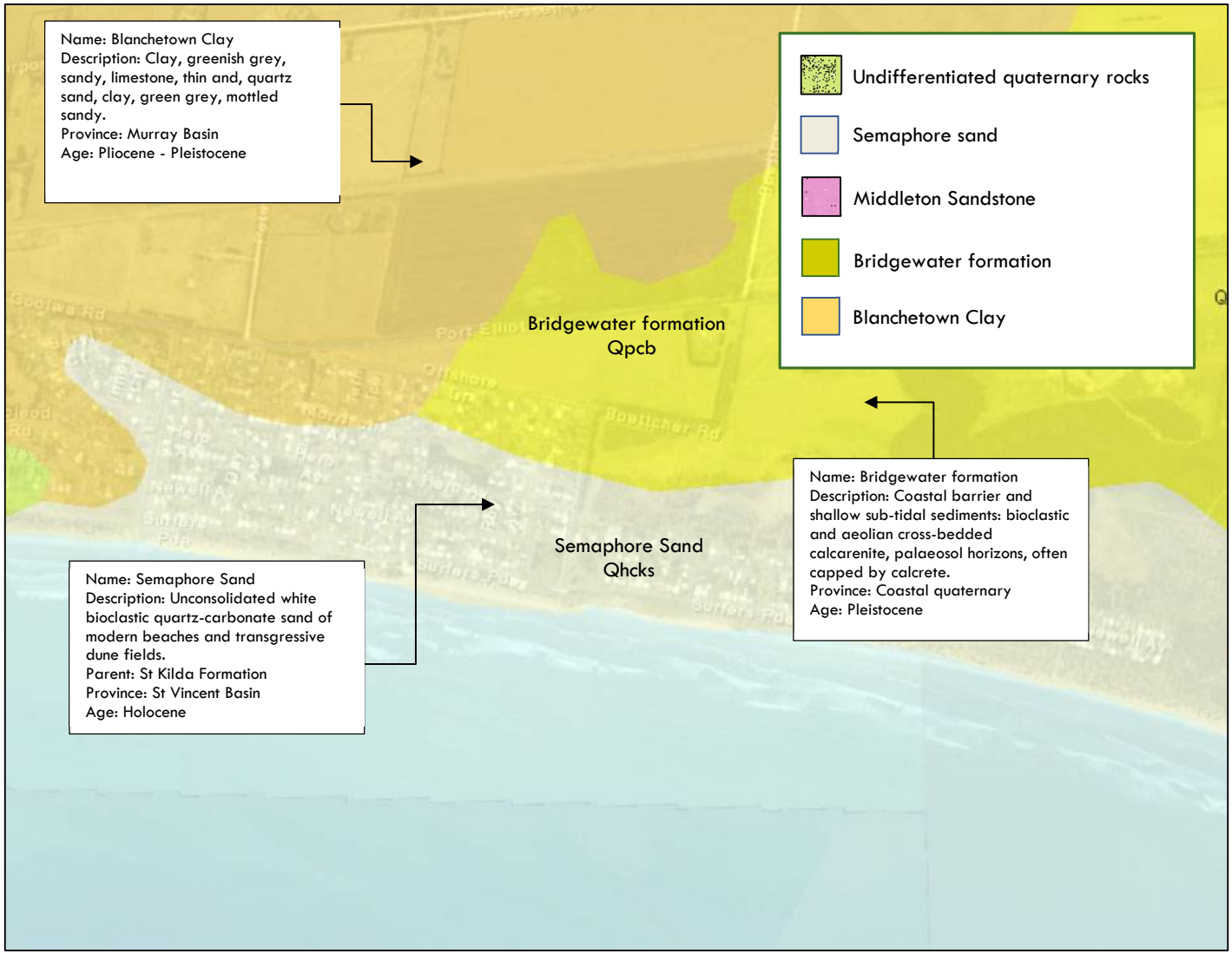

2. Coastal Fabric - natural

Overview

Map: SF5

Secondary Cell: Coorong
Tertiary Cell: Middleton Beach

Benthic

Benthic

Wide, low gradient, fine sand, dissipative surfzone often with two or more shore parallel bars and troughs. Wave energy can be significant and the surfzone may be several hundred metres wide during storms.

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2. Coastal fabric - natural

Medium term changes

Map: SF5

Secondary Cell: Coorong
Tertiary Cell: Middleton Beach

Sediment change

Assessment

Coastal Management Branch from Department of Water and Environment (DEW) has conducted two profile surveys (number 615006, 615007) of the ocean floor from 1977 to 2009.

A small dune developed on the crest of the scarp/cliff over time post-2000. The beach has accreted from 1993 to 2014 as shown in the profile and supported by aerial photos (see previous) .

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3. Coastal fabric - modified

Overview

Map: SF5

Secondary Cell: COORONG

Tertiary Cell: Middleton Beach

Minor cell: NA

Land use

Land use: Council Reserve

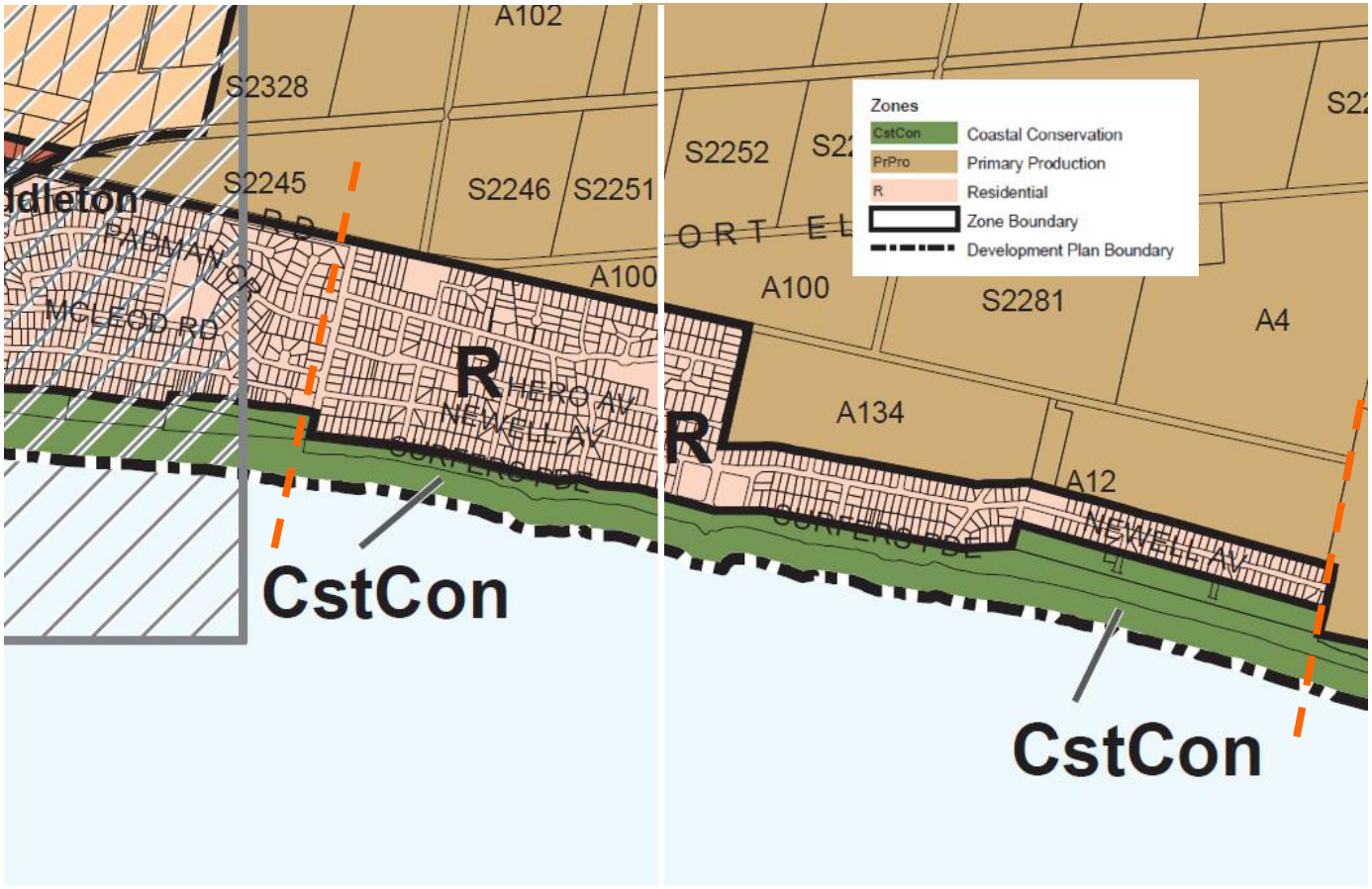
Zoning: Coastal Conservation (incorporates Council Reserve and foreshore). Zoning to the north of the reserves is predominantly Residential, with Primary Production in the western portion of the cell.

Policy Area: Southern Policy Area 11 is overlain the Residential section.

Precinct: Surfers Beach 22 also applies to the residential area.

The Coastal Conservation zoning ensures that development is limited and any proposal must be referred to Coast Protection Board.

In Precinct 22, detached dwellings are only permitted dwelling type. Allotments connected to sewer scheme can be 450m^2



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The 'Coastal Areas' section of the Development Plan (pp 23-27) has maintained standard South Australian planning policy library text apart from the insertion of PDC 11 (p. 24) that deals with the aim to limit the impact of private and public access to coastal areas.

The 'flooding' section of 'Hazards' in the Development Plan (p. 38,39) has maintained standard South Australian planning policy library text apart from the insertion of PDC 7 that deals with development within the River Murray region (not relevant here).

4. Inherent hazard risk assessment

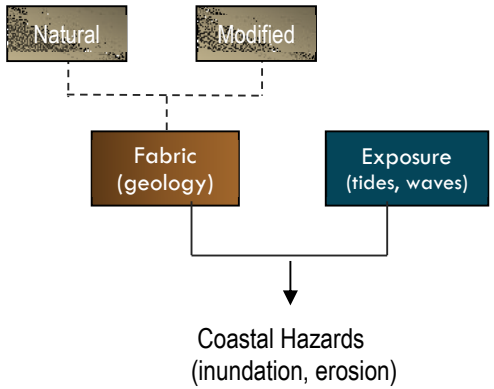
CoastAdapt identifies two main coastal hazards:

- 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

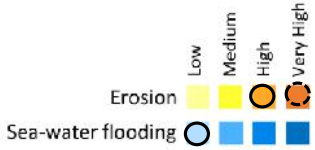
Due to the slope and elevation of backshore 1, there is no inundation hazard risk for Middleton Beach.

Note this inherent hazard risk assessment does not apply to area east of Miami Street.

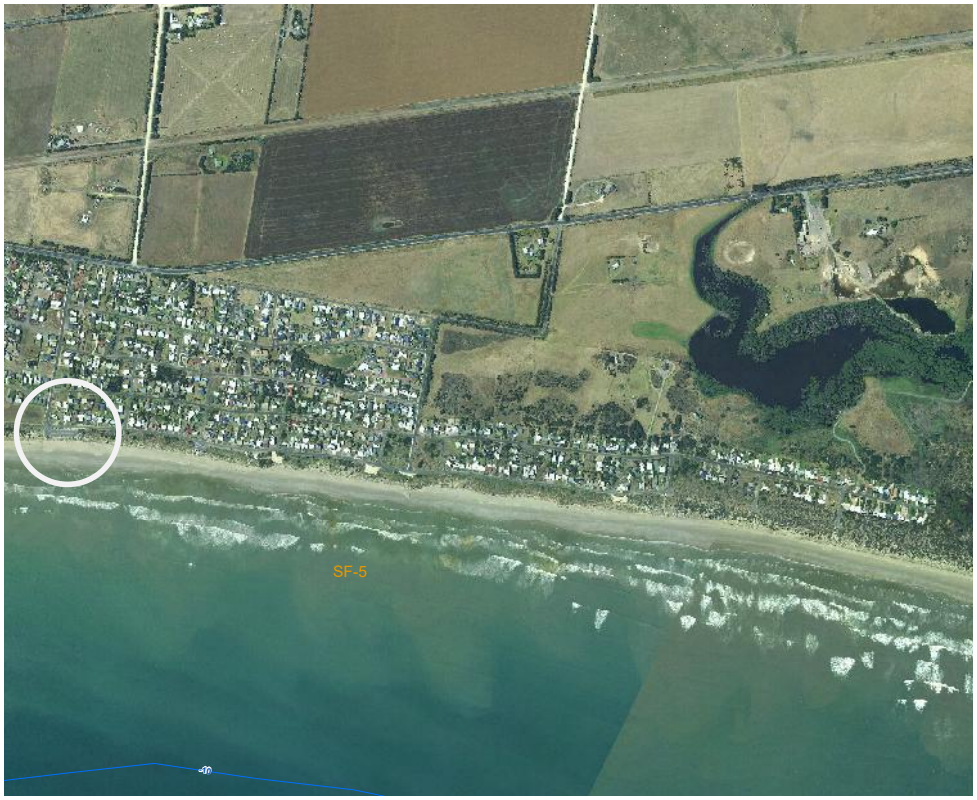
Erosion hazard risk

Evaluation steps	Assessment factors	Inherent hazard risk
Allocate initial erosion hazard rating from geological layout table.	Sandy beach, backshore 1: dune backshore/soft cliff backshore , backshore 2: semaphore sand rising to 14m AHD at 300m inland	High
Should this rating be amended due to human intervention such as a protection item? If so, how?	No, human intervention is limited to dune fencing.	High
Apply an exposure rating (Nature Maps)	Nature Maps assigns an exposure rating of 'Very exposed'.	Very high
Assess any impact on backshore 1	Due to the nature of this beach which is dissipative in nature, the location of the dune escarpment relates to the routine actions of wave run-up (monthly high water).	Very high
Assess any influence from Benthic	Offshore is unconsolidated sand	Very high
Assess the sediment balance	Middleton Beach has been largely stable for 70 years. Currently undergoing a period of accretion over last 10 years.	High (+)
Assess any other factors that may warrant a change of inherent hazard risk.	Nil	High (+)

Inherent Hazard Risk – Middleton Beach



1. Chapman Road



Coastal Fabric - natural

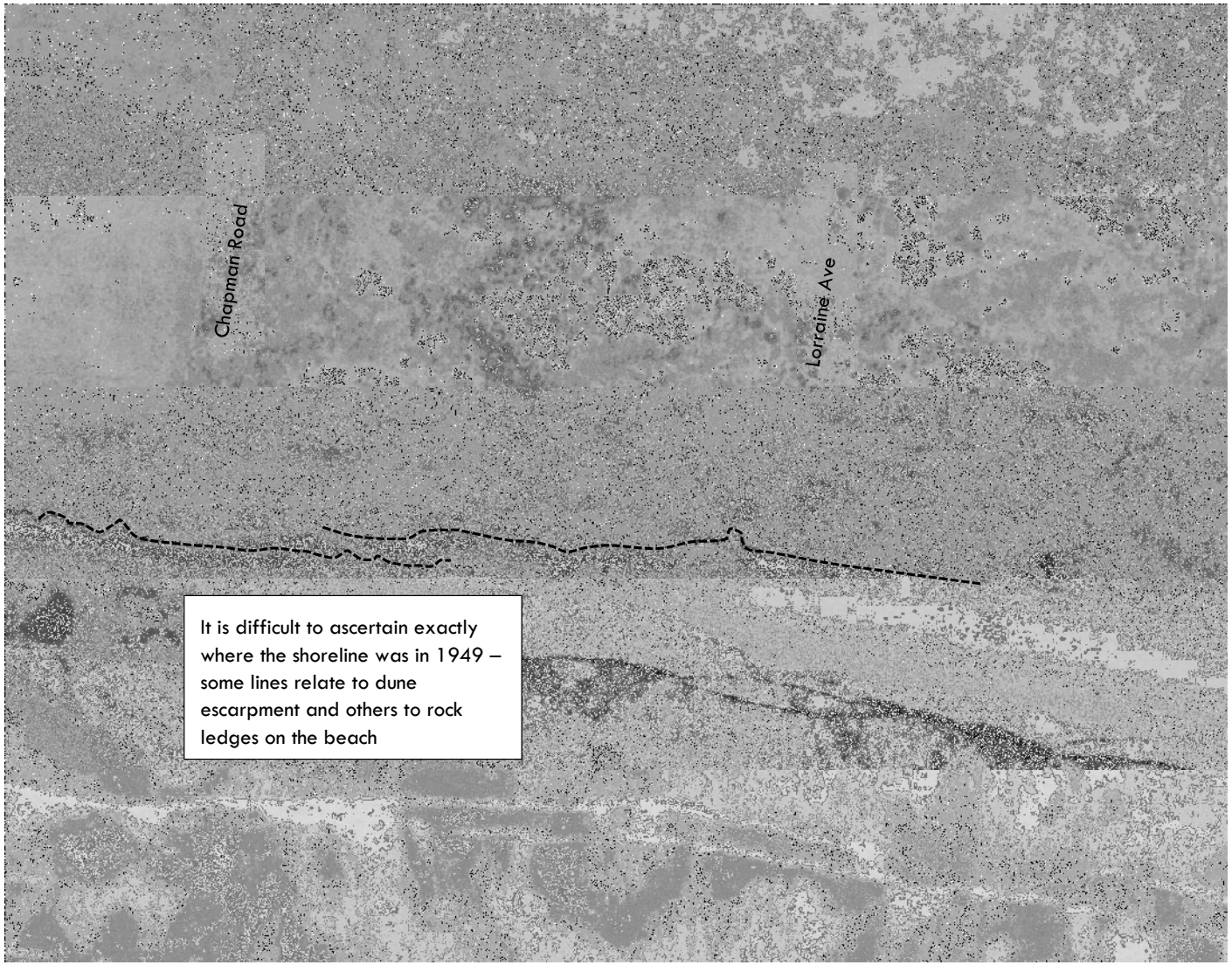
Medium term changes

Map: SF5-1
Middleton Beach
Changes 1949 to 2018
Chapman Road Carpark
1949

Assessment

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

The photograph on this page is SF5 east of current-day Chapman Road.



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Coastal Fabric - natural

Medium term changes

Map: SF5-1
Middleton Beach
Changes 1949 to 2018
Chapman Road Carpark
2006

Assessment

A The photograph on this page is SF5-1, east of current-day Chapman Road.

Comparison to 1949, demonstrates 8-10m recession in vicinity of Chapman.

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Coastal Fabric - natural

Medium term changes

Map: SF5-1

Middleton Beach

Changes 1949 to 2018

Chapman Road Carpark

2018

Assessment

Comparison between 2006 and 2018, demonstrates additional erosion of ~2m in vicinity of Chapman Road carpark.

Note also that the location of the frontal dune is the same as 1949 to the east of the carpark.

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Coastal fabric - modified

HUMAN INTERVENTION

Protection strategies:

Currently no hard protection strategies are utilised in this cell apart from rock placed to the front of the Chapman Road carpark (below right).

Archives explain that management strategies were employed in the 1970s and 1980s. These include fencing around carparks and access ways, and the installation of stairs and boardwalks.

Infrastructure:

Storm water infrastructure is located on the west end of the carpark (below left). See below for description of impacts from storm water flows.

A 2000m^2 carpark is situated 7-8m behind the dune escarpment. Rock has been previously placed to the front of the carpark which may indicate that when the coastline was eroding (rather than accreting) that protection was required to protect the carpark.

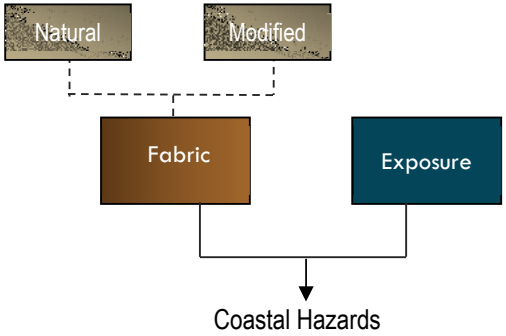
Surfers Parade is situated approximately 40m from the dune escarpment.

COASTAL FABRIC

Summary and conclusions

Progress report

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the fabric of the cell. In the next section we will deal with the 'exposure' of the cell.



Summary:

Middleton Beach – Chapman Street (Cell 5-1) is situated within the Coorong secondary cell that stretches from Middleton Point to Café Jaffa.

Beach

A dissipative beach of fine-medium sand.

Backshore 1

Low height vegetated dune only 8m wide in front of the Chapman Road carpark, and ~40m wide everywhere else in this region.

Erodibility rating: High erodibility (3)

Backshore 2:

Landward of the esplanade road (Surfers Parade) the backshore of semaphore sand (former dune) rises to above 14m AHD at 300m inland. Urban settlements are situated behind the esplanade road.

Erodibility rating: high erodibility (3)

Benthic

The intertidal and subtidal zones are dominated by sand (dissipative beach).

Human intervention

A 2000m^2 carpark is situated at the end of Chapman Road, positioned ~8m behind the dune escarpment. The esplanade road (Surfers Parade) runs parallel to the shoreline and is set back ~40m from the dune escarpment. Urban settlement is situated behind the esplanade road.

Analysis

A comparative analysis of photographs from 1949 to 2006 demonstrates that the shoreline may have eroded 8-10m. Since ~2006 this section of beach has been actively accreting.

A comparative analysis of the profile line captured by Department of Environment and Water from 1977 to 2018 (615006) also shows the coast in this location has been accreting (p. 14).

In summary, while some evidence exists for erosion at Chapman Road carpark, overall this section of beach presents as 'stable' but is likely to go through cycles of erosion and accretion within decadal timeframes.

EXPOSURE

Current and Future

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

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

Current exposure- storm event

Storm event

Map SF5-1

Middleton Beach

Event: 21-22 November 18

Chapman Road Carpark

Assessment

A storm event on 21-22 Nov 2018 provides the basis for establishing wave effect parameters.

The event was recorded at Victor Harbor gauge at 11.45pm at a height of 1.99 (CD) or 1.41m (AHD).

Analysis within SF5 of seaweed strands and other markers after the event demonstrated wave effects were ~1.70m above tidal gauge height. Wave set-up 0.5m and 1.2m wave runup.

Wave effects were very large but this event occurred at a lower tide and had minor impact on beach and backshore.

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Current exposure – storm surge

Storm surge

Map SF5-1
Surfers - Middleton

Current: 1 in 100 Year risk:

Chapman Road Carpark

Assessment

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

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

Wave run-up is 1.2m and depicted in light blue.

In this event wave run-up would flow up the beach and impact the base of the dunes causing some erosion/ scarping.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband.

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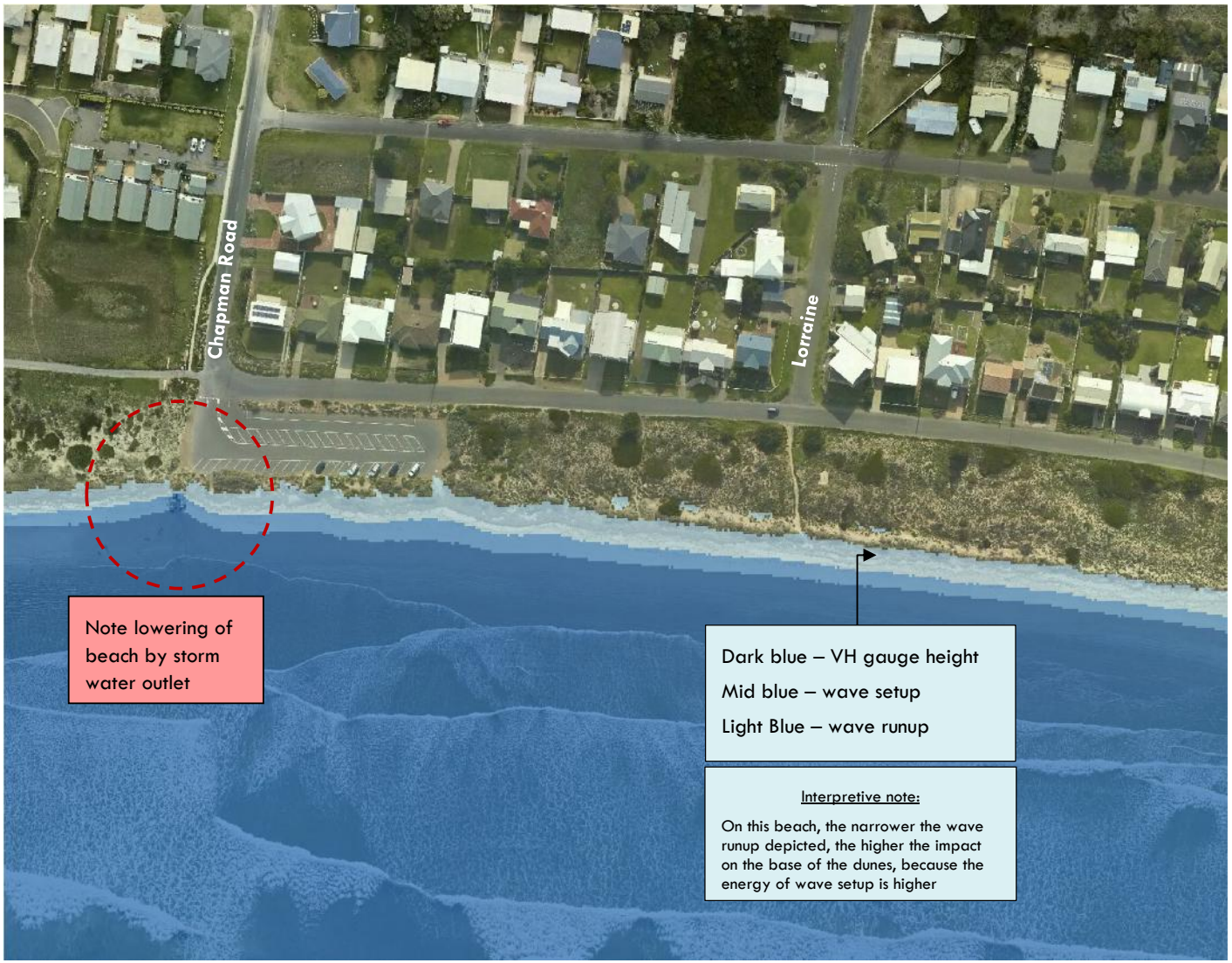

Current exposure – monthly high water

Monthly high water

Map SF5-1

Middleton Beach

Current: monthly high water

Chapman Road Carpark

Assessment

Extreme events are very rare and can have a significant impact. 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. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.30m
Total risk	1.80m

Wave run-up of 0.80m is included.

The current impact on beach and backshore is low.

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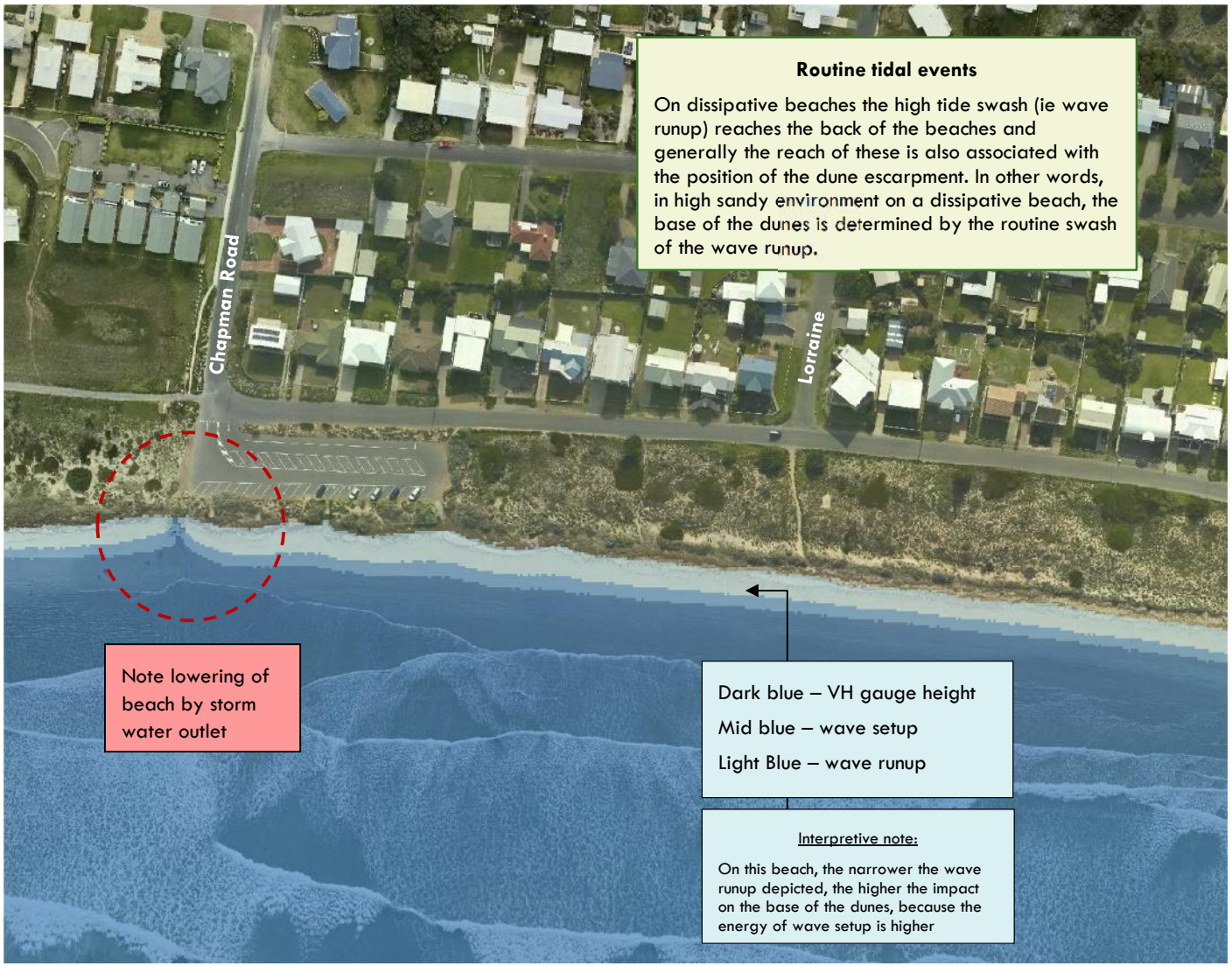

Current exposure – storm water

Storm water

Map SF5-1

Middleton Beach

Current: Storm water

Chapman Road Carpark

Assessment

This map predominantly depicts Cell SF6-2. However, the storm water from large portion of this cell drains to the beach at Chapman Road carpark.

The maps pictured on the previous pages depict how storm water flow is lowering the beach in this location.

See also next page.

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Current exposure – storm water

Storm water

Map SF5-1

Middleton Beach

Current: Storm water

Chapman Road Carpark

Assessment

Storm water is collected in a side entry pit on Chapman Road and then is piped to the foreshore (presumably with water collected from higher up within the settlement as well).

Note sand levels around the outlet on the beach.

Storm water collected in Side Entry Pit and piped to foreshore (outlet blocked).

Left: Note the scouring from storm water outflow (DEM 2018). Impacts from storm effects will be greater in locations where the beach has been lowered. Sea level rise will exacerbate the problem.

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Current exposure - erosion

Erosion

Map SF5-1

Middleton Beach

Current Erosion outlook

Chapman Road Carpark

Assessment

Historical comparison of aerial photographs from 1949, 2006, and 2016 demonstrate the rate of erosion in SF5.

It is difficult to ascertain the rate of erosion between 1949 and 2006. Some evidence exists that recession has taken place in front of the carpark but the dune to the east appears in the same location.

It appears that the shoreline as accreted in this location from 2006 to 2018. The rocks installed to protect the carpark (probably circa 2006) are now covered over by the dune and vegetation.

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Future exposure – storm surge (2050)

Storm surge

Map SF5-1

Middleton Beach

2050: 1 in 100-year risk

Chapman Road Carpark

Assessment

The risk set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.50
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the dunes. The impact of this event on the current dunes would be very high.

Water would likely enter carpark at Chapman.

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Future exposure – storm surge (2100)

Storm surge

Map SF5-1

Middleton Beach

2100: 1 in 100-year risk

Chapman Road Carpark

Assessment

The risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

The modelling shows that if an event of this magnitude occurred that wave setup would directly impact the base of the dunes, and overtopping would be severe. Erosion extreme.

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Future exposure – monthly high water (2100)

Monthly high water

Map SF5-1
Middleton Beach

2100: Monthly high water

Chapman Road Carpark

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event. 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
Plus sea level rise	1.00
	2.50m
Wave set up	0.30m
Total risk	2.80m

Wave run-up of 0.8m has been included.

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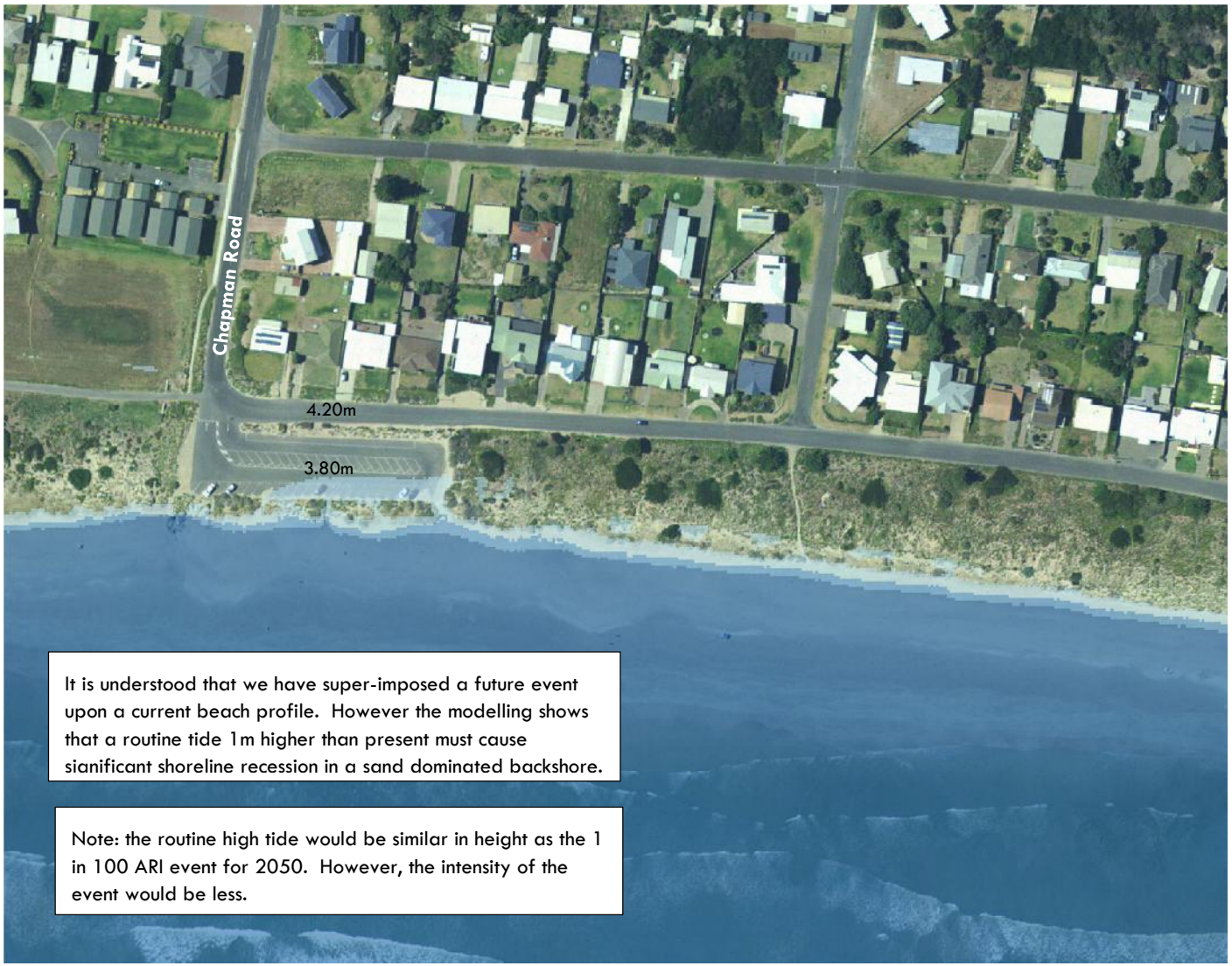

It is understood that we have super-imposed a future event upon a current beach profile. However the modelling shows that a routine tide 1m higher than present must cause sianificant shoreline recession in a sand dominated backshore.

Note: the routine high tide would be similar in height as the 1 in 100 ARI event for 2050. However, the intensity of the event would be less.

Future exposure – erosion (2100)

Erosion

Map SF5-1
Middleton - Surfers
2100 Erosion outlook
Chapman Road Carpark

Assessment

Because of the varying types of foreshores and backshores and urban layouts in Cell SF5, the approach in this assessment is to identify the likely trends over the coming century.

On a dissipative beach with sandy backshores, the shoreline will be dictated by the swash zone of wave run-up. The 2100 routine tidal map demonstrates that should seas rise as projected, then the shoreline will retreat.

How soon it would erode back to the road is not known.

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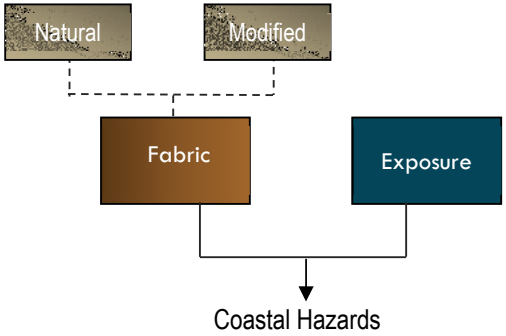
The approach in this assessment is to identify erosion zones back to the esplanade road. Erosion in other cells indicates that a sea level rise of 1m would cause shoreline recession at greater distances than this road.

SUMMARY

Progress report:

So far, we have completed a review of settlement history, an assessment of the 'geology' or 'fabric' in the vicinity of Chapman Road and the current and future exposure.



Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Middleton and Goolwa Beaches. 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 (current: 1 in 100-year risk)

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

If this event was to occur it would impact the base of the dunes and cliffs in a significant manner. However, the nature of the beach is such that the sand volume and dune escarpments would likely be rebuilt.

Monthly high water (current)

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 break down the dune system over time. Routine high tides are unlikely to be causing any significant erosion in this current era.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event would significantly impact the dune escarpment.

Monthly high water (every 1 or 2 months)

The nature of the beach is such that the location of the dune escarpment is normally also related to the influence/impact of the swash zone. However, it has already been noted that the Alexandrina coastline goes through cycles of accretion and erosion. An increase of sea level by 0.3m may result in the cycle moving landwards.

Future exposure (indicatively by 2100)

Storm surge and monthly high water

The 1 in 100 ARI storm event would significantly impact the beach and dune, especially in the southern areas. High tides 1m greater than today would also routinely impact the dunes and the areas behind the dunes.

Routine tidal action 1m higher than present will cause the dune escarpment to recede (it is the nature of a dissipative beach).

The extent of the recession is unknown but modelling in other areas indicates that the esplanade road would come under attack in the time period 2050 -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 of the likely extent of recession, and where impacts will be 'felt' the most.

Hazard Impacts

Chapman Road

Map SF5-1

Middleton Beach

Items at risk

Chapman Road Carpark

Public assets
Beach access points (x3)
Fencing
Carpark
Storm water infrastructure
Esplanade road.

Private assets
Private assets are situated behind the esplanade road and therefore are afforded protection as long as the road remains unaffected.

Safety of people
No anticipated increase to safety of people (above normal safety issues at a beach)

Ecosystem disruption
The geological layout with rising backshore indicates that impacts into broader ecosystems will not occur.

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markwestern@integratedcoasts.com
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Hazard Impacts

Chapman Road

Map SF5-1

Middleton Beach

Assets at risk

Public

Council has a responsibility to maintain the beach access points along the coastline.

In this section we identify each beach access point and provide brief risk outlook.

Sand has accumulated around the stairs 0.6m to 0.8m.

On upgrade, consider removing one set of stairs and consolidate into one larger set in the middle. Also consider alternative slope to ramp (identify a way to prevent storm surges coming through the gap).

Chapman Road

Sand has accumulated at about 0.6m since installation of the stairs. Currently not at risk.

Note location of seaweed strands at entrance points. These indicate that the access points are routinely being impacted by actions of the sea.

Chapman Road

Sand has accumulated at about 0.8m since installation of the stairs. Currently not at risk.

Chapman Road

Provision for vehicular access. Not at risk, but does provide access point for the flow of water in extreme events (see modelling)

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8. RISK ASSESSMENT

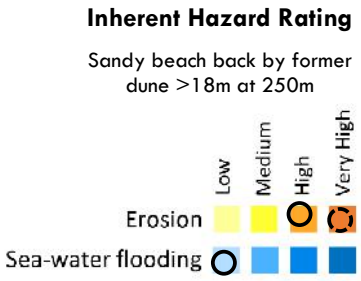
Inherent hazard rating

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.



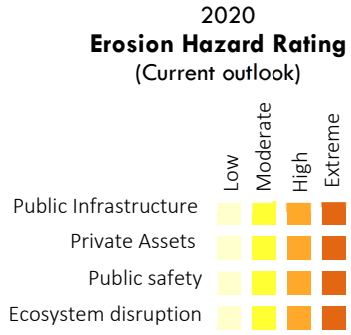
Specific Risk Assessment

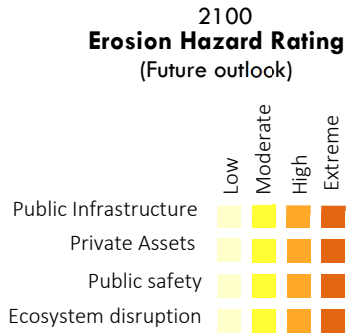
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- 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 specific 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 risk assessment utilises the risk assessment framework of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding or erosion (See next page).





Yet to be assigned

Erosion assessment

Middleton (Chapman Road)

Risk identification: Erosion may cause the dunes to recede impacting public infrastructure

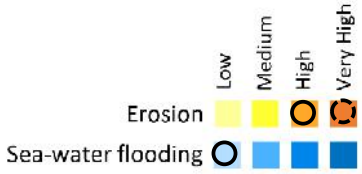
Coastal processes	Middleton Beach marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. The beach at Chapman Road is backed by a small dune system. The inherent hazard risk rating is categorised as 'high' to 'very high'. Historical comparisons showed that between 1949 and 2006 the shoreline retreated 10-12m, but since 2006 the shoreline has showed signs of accretion.

Are any strategies employed to mitigate the risk? Nil.

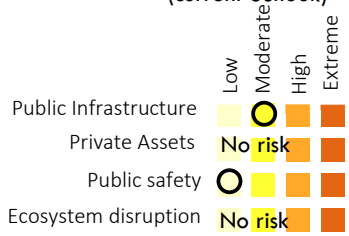
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carparks x1, access stairs x2, access ramp x1, storm water infrastructure, esplanade road.	current	*Possible*	*Moderate*	Moderate
		2100	*Likely*	*Significant*	High
Private assets	Private assets are not impacted as long as the road remains unaffected. A moderate rating is given for 2100 as erosion may have reached the road.	current	*No risk*	*No risk*	No risk
		2100	*Possible*	*Moderate*	Moderate
Safety of people	This assessment does not relate to general beach safety of pedestrians or swimmers. It relates only to how the safety of people may be exacerbated due to increased sea level (and associated impacts)	current	*Rare*	*Minor*	low
		2100	*Rare*	*Minor*	low
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. The geology of the area contains the risk and therefore there is no perceived risk.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk

Inherent Hazard Rating

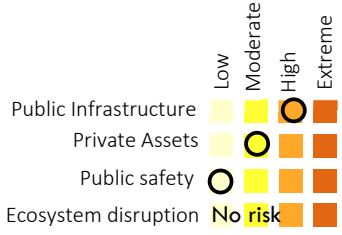
Sandy beach back by former dune >18m at 250m



Erosion Hazard Rating
2020
(current outlook)



Erosion Hazard Rating
2100
(future outlook)



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	Currently the dunes at Chapman Road have been in an accretion cycle. However, in a high exposure and low resistance environment, if sea levels rise as projected, then shoreline recession is almost certain.

ADAPTATION PROPOSALS

Adaptation options

ADAPTATION OPTIONS

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

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

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These 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 have limited development.

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 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.

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.

MIDDLETON BEACH – CHAPMAN ROAD

An **incremental approach** to adaptation is recommended.

In the context of a high energy sand dominated beach it is unlikely that protecting the dunes will be viable in the second half of this century. Therefore, a managed **retreat strategy** should be employed. This does not mean 'surrender' but rather monitor and adapt to the recession when it begins to occur. The strategy may also mean some low-cost protection options to provide longevity to an existing asset. But over time, assets within the erosion zone should be reconfigured so that a greater buffer is created between the asset and the shoreline. This strategy will also allow for the coastline to go through its normal recession and accretion cycles without unnecessarily impacting assets.

Because there is unlikely to be any immediate threat, the approach should be to **monitor** this beach over time, with special attention to changes/impacts to the back shore. Monitoring over time will enable decision makers to determine when the beach is operating within its normal parameters, and when it has moved out of its range due to sea level rise.

Review **planning** controls and consider limiting any further densification of sites on Surfers Parade.

Implement **storm water** controls (see p. 42)

[1] CoastAdapt also includes 'community education'.

Adaptation proposals

Retreat

Map SF5

Middleton (Surfers)

Adaptation proposal

Chapman Road Carpark

Monitor

The base of the escarpment should be regularly monitored, especially after storm events. (See conclusion of this report for more details on monitoring)

Respond – managed retreat

If seas rise as projected and dunes begin to recede, then a retreat strategy should be employed. When the carpark is due for an upgrade, it could be reconfigured and constructed further away from the shoreline. At times interim protection works could be employed to prolong the life of the carpark.

Planning

Review planning controls and consider limiting further densification of sites adjacent Surfers Parade.

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markwestern@integratedcoasts.com
www.intearatedcoasts.com

Adaptation proposals

Retreat

Map SF5

Middleton (Surfers)

Adaptation proposal

Chapman Road Carpark

Approach: incremental

Storm water

The modelling demonstrates that storm water lowers the level of the beach. With increasing sea levels, the outlet will come under increased attack.

It is recommended that the storm water be detained or retained within the existing swale. A wetland could be created (retained), or a detention system where water is detained within the swale and then let out to the shore at a slower rate.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Adaptation proposals

Storm water issue - site inspection by engineer: 26 June 2019.

'The existing stormwater outlet to the beach is blocked with sand. Existing stormwater erosion protection appears to be effective at the outlet. However, the overall beach level has dropped as a result of stormwater outflow across the beach'. (Will Souter)

CHAPMAN ROAD CARPARK – MIDDLETON

Chapman Street stormwater outlet

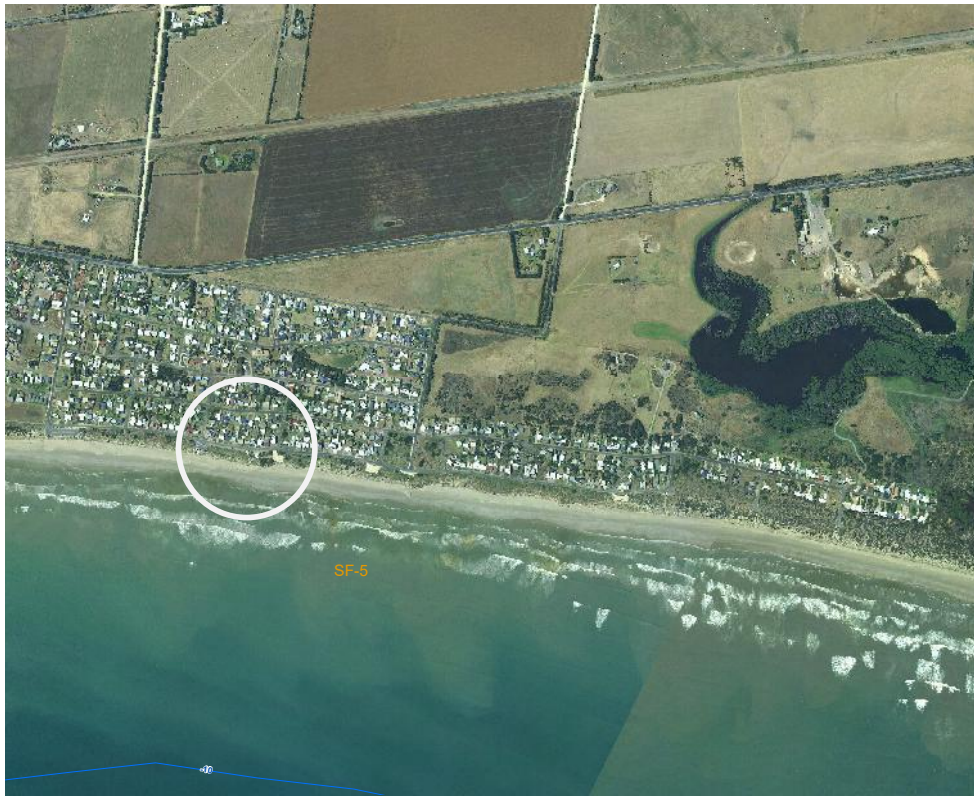
To minimise further erosion of the beach at the stormwater outlet, it is proposed to re-direct the stormwater to a detention basin. This may be achieved by establishing a wetlands area in the council reserve north of the carpark. A controlled outflow rate shall be utilised, to minimise the flow out to the beach. The required detention storage volume in the basin shall be determined during the design stage.

Protection shall be provided at the pipe outlet to prevent it from becoming blocked and/or causing beach erosion.

Replenish the beach sand to the area adjacent the current stormwater outlet. Sand shall be locally sourced via beach scraping.

Refer drawing 18084-19 for details on the above.

2. Lorraine and Skye Ave carparks



Coastal Fabric - natural

Medium term changes

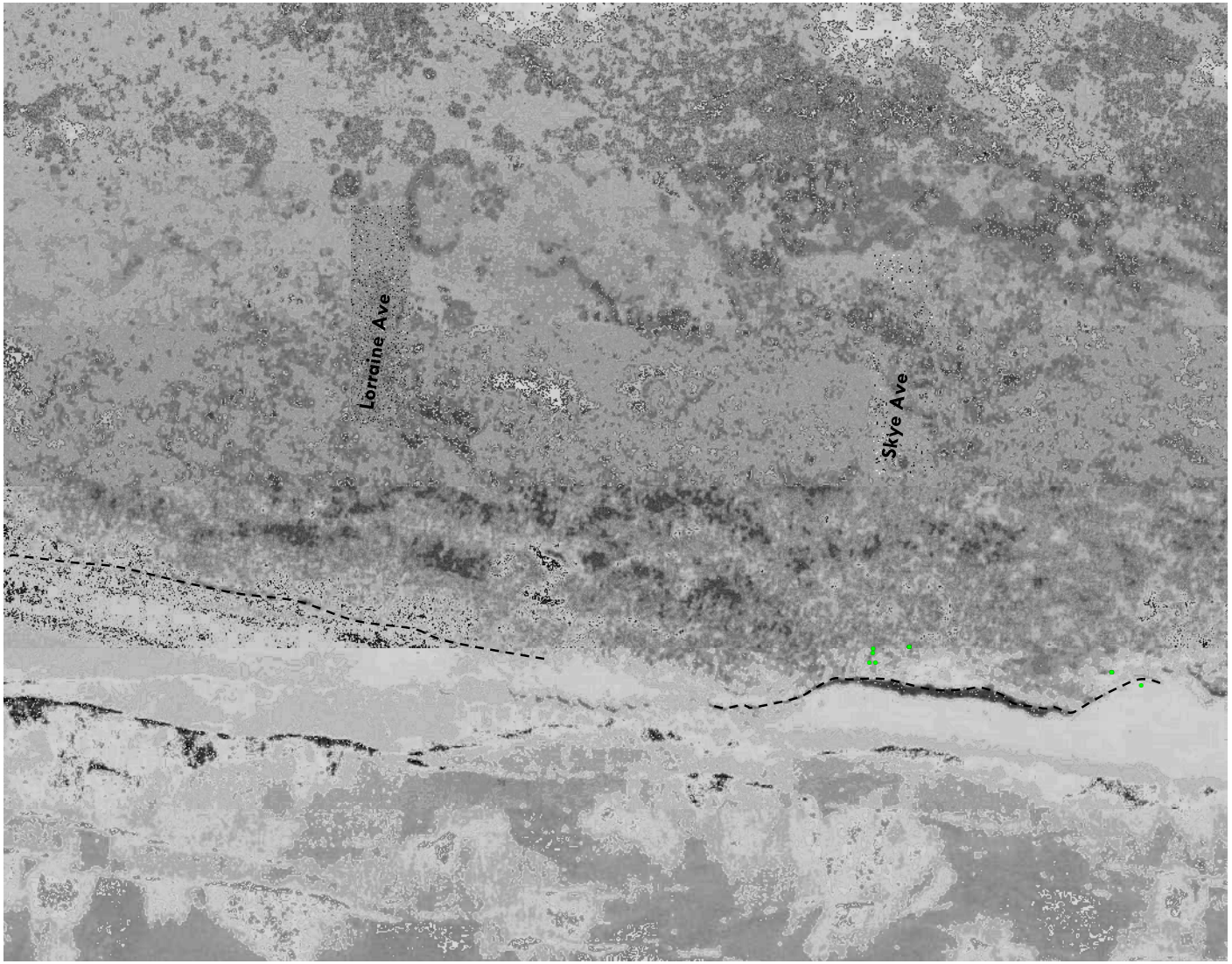
Map: SF5-2
Middleton Beach
Changes 1949 to 2018

Lorraine/ Skye Ave
1949

Assessment

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

The photograph on this page is SF5-2 in the vicinity of current day Lorraine and Skye Aves



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markwestern@integratedcoasts.com
www.integratedcoasts.com
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Coastal Fabric - natural

Medium term changes

Map: SF5-2
Middleton Beach
Changes 1949 to 2018
Lorraine/ Skye Ave
2006

Assessment

A The photograph on this page is SF5-2, in the vicinity of Lorraine and Skye Aves

The coastline in the vicinity of Skye and Lorraine Avenue carparks has eroded ~12-17m since 1949.

The area in front of the Skye Avenue carpark has suffered the most erosion.

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Coastal Fabric - natural

Medium term changes

Map: SF5-2
Middleton Beach
Changes 1949 to 2018
Lorraine/ Skye Ave
2018

Assessment

The coastline in the vicinity of Skye Avenue carparks eroded ~12-17m from 1949 to 2006 but has accreted slightly in this region by ~2m.

The area in front of the Skye Street carpark has suffered the most erosion.

Works associated with installation of stairs at Skye Avenue appear to have moved the coastline seaward by ~1-2m.

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Coastal fabric - modified

HUMAN INTERVENTION

Protection strategies:

Currently no hard protection strategies are utilised in this portion of the coastline.

Archives explain that management strategies were employed in the 1970s and 1980s. These include fencing around carparks and access ways, and the installation of stairs and boardwalks.

Infrastructure:

A 900m^2 carpark is situated ~11m behind the dune escarpment at the end of Lorraine Ave.

A 620m^2 carpark is situated ~6m from the beach at the end of Skye Ave.

Surfers Parade is situated approximately 36-38m from the dune escarpment.

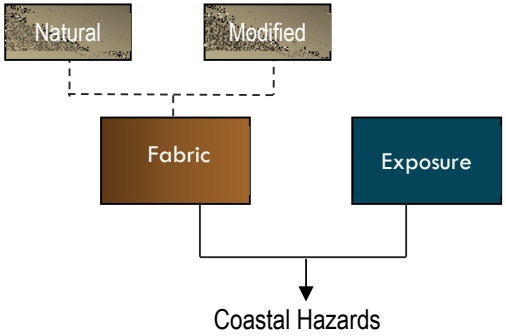
Behind the esplanade road is situated urban settlement.

COASTAL FABRIC

Summary and conclusions

Progress report

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the fabric of the cell. In the next section we will deal with the 'exposure' of the cell.



Summary:

Middleton Beach – Lorraine and Skye Aves (Cell 5-2) is situated within the Coorong secondary cell that stretches from Middleton Point to Café Jaffa.

Beach

A dissipative beach of fine-medium sand.

Backshore 1

Low height vegetated dune only 11m wide in front of the Lorraine Ave carpark, and rocky backshore at Skye Ave carpark, 6m from beach. Generally, elsewhere the dunes are 36-38m wide back to Surfers Pde.

Erodibility rating: high (3)

Backshore 2:

Landward of the esplanade road (Surfers Parade) the backshore of semaphore sand (former dune) rises to above 14m AHD at 300m inland. Urban settlements are situated behind the esplanade road.

Erodibility rating: high (3)

Benthic

The intertidal and subtidal zones are dominated by sand (dissipative beach).

Human intervention

A 2000m^2 carpark is situated at the end of Chapman Road, positioned ~8m behind the dune escarpment. The esplanade road (Surfers Parade) runs parallel to the shoreline and is set back ~40m from the dune escarpment. Urban settlement is situated behind the esplanade road.

Analysis

A comparative analysis of photographs from 1949 to 2006 demonstrates that the shoreline may have eroded 8-10m. Since ~2006 this section of beach has been actively accreting.

A comparative analysis of the profile line captured by Department of Environment and Water from 1977 to 2018 (615006) also shows the coast in this location has been accreting (p. 14).

In summary, while some evidence exists for erosion at Chapman Road carpark, overall this section of beach presents as 'stable' but is likely to go through cycles of erosion and accretion within decadal timeframes.

EXPOSURE

Current and Future

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

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

Current exposure- storm event

Storm surge

Map SF5-2
Middleton Beach

Event: 21-22 November 18

Skye/Lorraine carparks

Assessment

A storm event on 21-22 Nov 2018 provides the basis for establishing wave effect parameters.

The event was recorded at Victor Harbor gauge at 11.45pm at a height of 1.99 (CD) or 1.41m (AHD).

Analysis within SF5 of seaweed strands and other markers after the event demonstrated wave effects were ~1.70m above tidal gauge height. Wave set-up 0.5m and 1.2m wave runup.

Wave effects were significant but this event occurred at a lower tide and had minor impact on beach and backshore.

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markwestern@integratedcoasts.com
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Current exposure – storm surge

Storm surge

Map SF5-2

Middleton Beach

Current: 1 in 100-year risk

Skye/Lorraine carparks

Assessment

The current risk set by Coast Protection Board is:

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

Wave run-up is 1.2m and depicted in light blue.

In this event wave run-up would flow up the beach and impact the base of the dunes causing some erosion/ scarping.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband.

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Current exposure – monthly high water

Monthly high water

Map SF5-2

Middleton Beach

Current: monthly high water

Skye/Lorraine carparks

Assessment

Extreme events are very rare and can have a significant impact. 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. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.30m
Total risk	1.80m

Wave run-up of 0.80m is included.

The current impact on beach and backshore is low.

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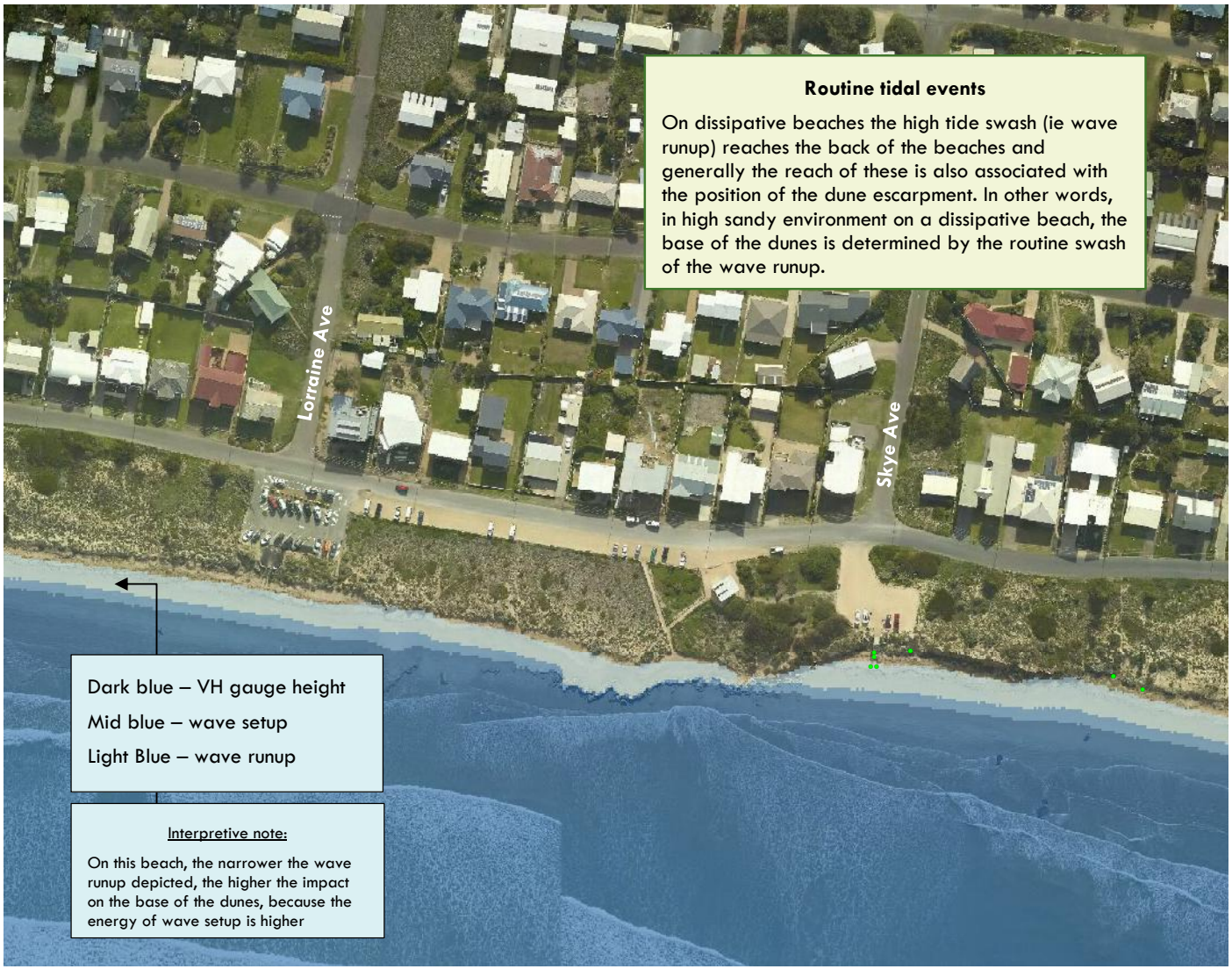

Current exposure – storm water

Storm water

Map SF5-2

Middleton Beach

Storm water

Skye/Lorraine carparks

Assessment

Storm water:

It appears if the northern side of Middleton (Surfers) drains to Tukemuror Reserve. It is not clear how storm water is managed on the southern side of this map apart to note that there appears nil impact upon the shoreline. There do not appear to be any outlets to the sea in this location.

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Current exposure - erosion

Erosion

Map SF5-2

Middleton Beach

Current Erosion outlook

Skye/Lorraine carparks

Assessment

Historical comparison of aerial photographs from 1949, 2006, and 2016 demonstrate the change in the position of the shoreline.

The shoreline of 2006 has eroded 12-17m when compared with 1949.

For the same location between 2006 and 2018 there has been an accretion of ~2m. It appears that the shoreline has accreted in this location from 2006 to 2018 by ~2m.

The exact timing of the ongoing erosion and accretion cycles is unknown.

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Future exposure – storm surge (2050)

Storm surge

Map SF5-2

Middleton Beach

2050: 1 in 100-year risk

Skye/Lorraine carparks

Assessment

The risk set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.50
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the dunes. The impact of this event on the current dunes would be very high.

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Future exposure – storm surge (2100)

Storm surge

Map SF5-2

Middleton Beach

2100: 1 in 100-year risk

Skye/Lorraine carparks

Assessment

The risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

The modelling shows that if an event of this magnitude occurred that wave setup would directly impact the base of the dunes, and overtopping would be severe. Erosion extreme.

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Future exposure – monthly high water (2100)

Monthly high water

Map SF5-2

Middleton Beach

2100: monthly high water

Skye/Lorraine carparks

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event. 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
Plus sea level rise	1.00
	2.50m
Wave set up	0.30m
Total risk	2.80m

Wave run-up of 0.8m has been included.

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It is understood that we have super-imposed a future event upon a current beach profile. However the modelling shows that a routine tide 1m higher than present must cause sianificant shoreline recession in a sand dominated backshore.

Note: the routine high tide would be similar in height as the 1 in 100 ARI event for 2050. However, the intensity of the event would be less.

Future exposure – erosion (2100)

Erosion

Map SF5
Middleton Beach
2100 Erosion outlook
Skye/Lorraine carparks

Assessment

Because of the varying types of foreshores and backshores and urban layouts in Cell SF5, the approach in this assessment is to identify the likely trends over the coming century.

On a dissipative beach with sandy backshores, the shoreline will be dictated by the swash zone of wave run-up. The 2100 routine tidal map demonstrates that should seas rise as projected, then the shoreline will retreat.

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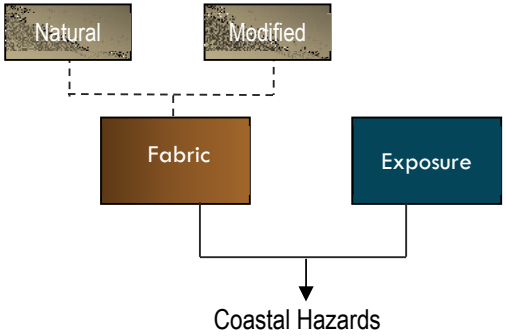
SUMMARY

Progress report:

So far, we have completed a review of settlement history and completed an assessment of the 'geology' or 'fabric' in the vicinity of Skye and Lorraine Aves and the current and future exposure.



Coastal Fabric

Lorraine and Skye Ave carparks are situated on a dissipative sandy beach, within the sand dune backshore.

Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Middleton and Goolwa Beaches. 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 (ie at the tide Victor Harbor tide gauge).

If this event was to occur it would impact the base of the dunes and cliffs in a significant manner. However, the nature of the beach is such that the sand volume and dune escarpments would likely be rebuilt.

High tides (every 1 or 2 months)

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 break down the dune system over time. Routine high tides are unlikely to be causing any significant erosion in this current era.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event would significantly impact the dune escarpment.

High tides (every 1 or 2 months)

The nature of the beach is such that the location of the dune escarpment is normally also related to the influence/impact of the swash zone. However, it has already been noted that the Alexandrina coastline goes through cycles of accretion and erosion. An increase of sea level by 0.3m is likely to result in the cycle moving landwards.

Future exposure (indicatively by 2100)

Storm surge and high tides

The 1 in 100 ARI storm event would significantly impact the beach and dune, especially in the southern areas. High tides 1m greater than today would also routinely impact the dunes and the areas behind the dunes.

Routine tides 1m higher than present will cause the dune escarpment to recede (it is the nature of a dissipative beach).

The extent of the recession is unknown but modelling in other areas indicates that the esplanade road would come under attack in the time period 2050 -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 of the likely extent of recession, and where impacts will be 'felt' the most.

Hazard Impacts

Lorraine and Skye

Map SF5-2

Middleton Beach

Items at risk

Lorraine/ Skye Ave

Public assets
Beach access stairs (x2)
Fencing
Carparks x3
Toilet amenities
Esplanade road.

Private assets
Private assets are situated behind the esplanade road. As long as the esplanade road was not impacted, private assets would be unaffected.

Safety of people
The rock ledge is being undermined by actions of the sea adjacent the Skye Ave entrance. People often sit under this ledge.

Ecosystem disruption
The geological layout with rising backshore indicates that impacts into broader ecosystems will not occur.

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markwestern@integratedcoasts.com
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Hazard Impacts

Lorraine

Map SF5
Middleton- Surfers
Assets at risk
Public

Council has a responsibility to maintain the beach access points along the coastline.

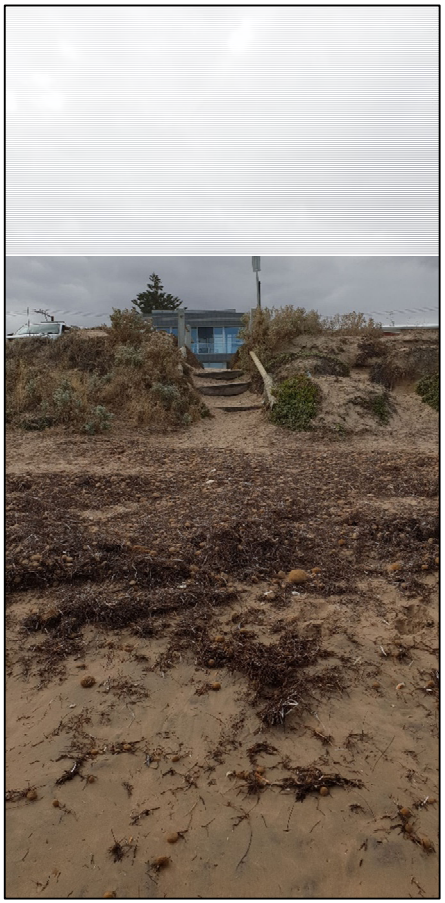
In this section we identify each beach access point and provide brief risk outlook.

Sand has accumulated around the stairs ~0.8m.

On upgrade, consider removing one set of stairs and consolidate into one to reduce access points to the beach. The larger set pictured could be located further back from the front of the dune.

Lorraine Ave

Sand has accumulated at about 0.8m since installation of the stairs. Currently not at risk.



Lorraine Ave

Small set of stairs on eastern end of the carpark (could be removed)

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Hazard Impacts

Lorraine / Skye

Map SF5
Middleton- Surfers
Assets at risk
Public

Council has a responsibility to maintain the beach access points along the coastline.

In this section we identify each beach access point and provide brief risk outlook.

Sand has accumulated around the stairs 0.8m-1m.

On upgrade, consider removing one set of stairs and consolidate into one larger set in the middle. Also consider alternative slope to ramp (identify a way to prevent storm surges coming through the gap).

Skye Ave

Beach access point on western side of the amenities block.

Skye Ave

Access stairs from Skye Ave carpark. Note seaweed strands in proximity of rock ledges. This area has been eroding.

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8. RISK ASSESSMENT

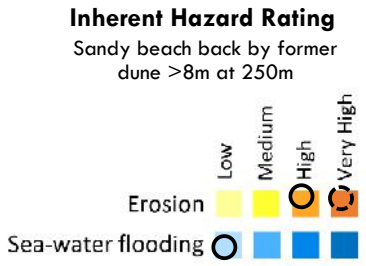
Inherent hazard rating

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:

- Erosion
- Sea-water flooding

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.



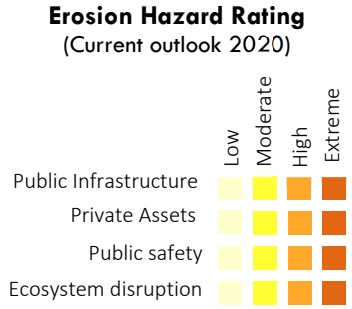
Specific Risk Assessment

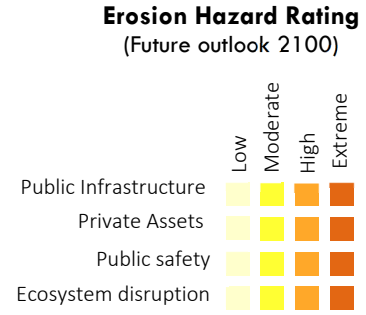
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

- Public infrastructure
- Private assets
- Public safety
- Eco-system 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.

The 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 framework of Alexandrina Council and is reported within standardised templates for the relevant hazard: erosion or inundation (see next page).





Not assigned as yet

Erosion assessment

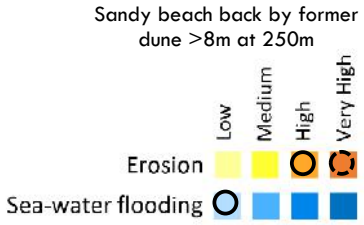
Lorraine and Skye Carparks (SF5)

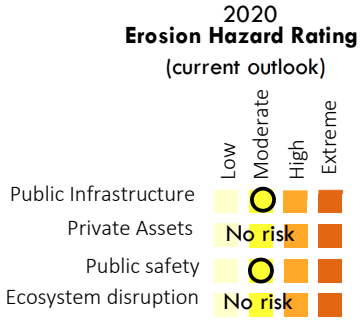
Risk identification: Erosion may cause the dunes to recede and thereby threaten Council owned infrastructure.

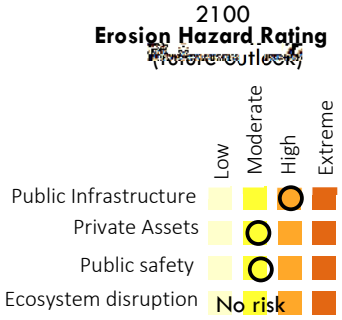
Coastal processes	Middleton Beach marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. The beach at Lorraine and Skye Aves is backed by a small dune system. Exposure is categorised as 'high', and wave energy high at ~2m. Historical comparisons showed that between 1949 and 2006 the shoreline retreated 12-17m, but since 2006 the shoreline has showed signs of accretion. Erosion has been greater at Skye Ave carpark.

Are any strategies employed to mitigate the risk? Nil.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carparks x2, access stairs x2, fencing, toilet block.	current	*Possible*	*Minor*	Moderate
		2100	*Likely*	*Significant*	High
Private assets*	Private assets are afforded default protection by virtue of the Council road. A moderate rating is given for 2100 as erosion may have reached the road.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	Moderate
Safety of people	This assessment does not relate to general beach safety of pedestrians or swimmers. However, the rock ledge adjacent Skye Ave access stairs is being undermined and people often sit immediately adjacent.	current	*Rare*	*Significant*	Moderate
		2100	*Rare*	*Significant*	Moderate
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. The geology/slope of the area contains the risk and therefore there is no perceived risk.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk







*Council not necessarily liable for private assets

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

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

Summary	Currently the dunes at Lorraine Ave have been in an accretion cycle. The access point from the Skye Ave carpark appears to be eroding (the whole area has undergone the most erosion in this section of coastline). However, in a high exposure and low resistance environment, if sea levels rise as projected, then shoreline recession is almost certain.

ADAPTATION PROPOSALS

Adaptation options

ADAPTATION OPTIONS

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

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

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These 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 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.

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.

MIDDLETON – LORRAINE/ SKYE

An **incremental approach** to adaptation is recommended.

In the context of a high energy sand dominated beach it is unlikely that protecting the dunes will be viable in the second half of this century. Therefore, a managed **retreat strategy** should be employed. This does not mean 'surrender' but rather monitor and adapt to the recession when it begins to occur. The strategy may also mean some low-cost protection options to provide longevity to an existing asset. But over time, assets within the erosion zone should be reconfigured so that a greater buffer is created between the asset and the shoreline. This strategy will also allow for the coastline to go through its normal recession and accretion cycles without unnecessarily impacting assets.

Because there is unlikely to be any immediate threat, the approach should be to **monitor** this beach over time, with special attention to changes/impacts to the back shore. Monitoring over time will enable decision makers to determine when the beach is operating within its normal parameters, and when it has moved out of its range due to sea level rise.

Review **planning** controls and consider limiting further densification of sites on Surfers Parade.

[1] CoastAdapt also includes 'community education'.

Adaptation proposals

Retreat

Map SF5

Middleton (Surfers)

Adaptation proposal

Lorraine/Skye Carparks

Monitor

The base of the escarpment should be regularly monitored, especially after storm events.

Respond – managed retreat

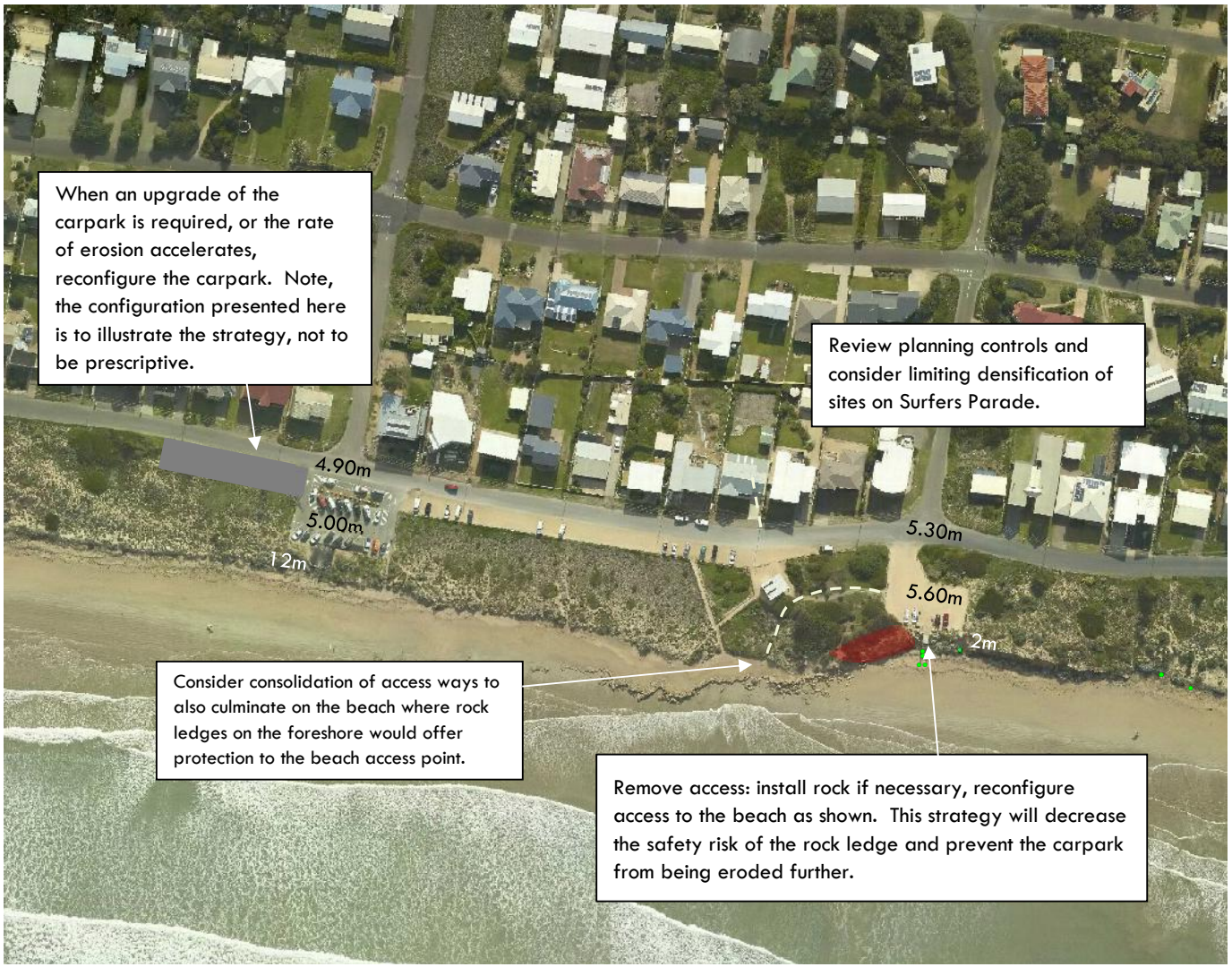
If seas rise as projected and dunes begin to recede, then a retreat strategy should be employed. When the carpark is due for an upgrade, it could be reconfigured and constructed further away from the shoreline.

Recommended – reconfigure

Reconfigure access way from Skye Ave carpark (see also report next page).

Planning controls

Review planning controls and consider limiting densification of sites on Surfers Parade.



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markwestern@integratedcoasts.com

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Adaptation proposals

Engineer's Report

Magryn and Associates were contracted to review reports, conduct site inspections and make recommendations for adaptation options where engineering input was required. Will Souter (engineer) inspected the site on 26 June 2019.

Magryn make the following observations and recommendations (see also full report July 2019)

The cliffs adjacent the Sky Avenue carpark vary in height between approximately 1-1.5m west of the timber beach access stairs, to up to approximately 3.4m high to the east of the stairs.

The cliffs west of the access stairs were severely undercut, generally overhanging approximately 1.2-1.5m. At one location there was a void beneath the cliff extending inwards 2.4m from the outer edge of the cliff. There was seaweed built up along the base of the cliff. The cliffs are sandstone, which appear to have eroded at the base due to wave action during a storm event.

The cliffs east of the access stairs were severely undercut, particularly at the eastern end with approximately 1.6m overhang. Some large pieces of sandstone were on the beach at the base of the cliff, presumably fallen from the cliff. There is minimal erosion to the base of the cliff, hence the overall cliff appears stable.

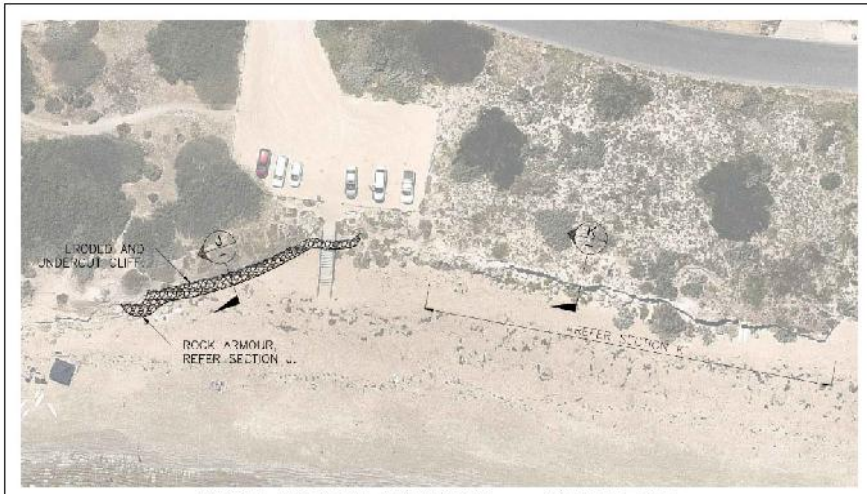
It was reported that people (in particular children) often sit under the overhanging sections of cliff, which poses a high safety risk if the cliff was to collapse. In our opinion the cliffs west of the access steps are higher priority, as erosion may continue to develop as a result of wave action at the base of the cliff.

Figure 11- Undercut cliff, west of access stairs.

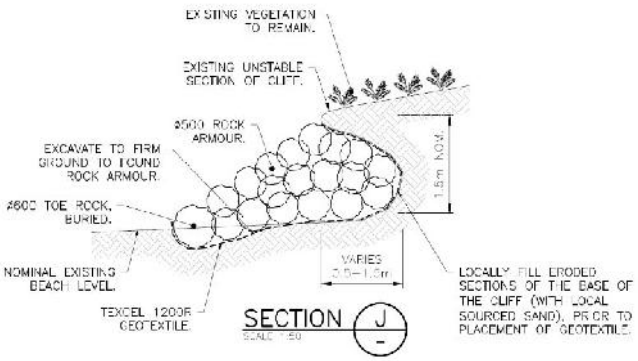
Figure 13- Cliffs east of access stairs.

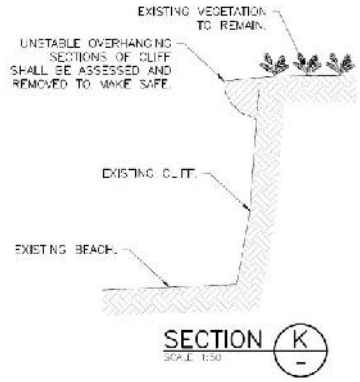
Adaptation proposals

Engineer's Report



SKYE AVENUE CARPARK – MIDDLETON





Skye Avenue cliffs:

The following adaptation strategies are recommended to be undertaken to the cliffs west of the access stairs:

- Install rock fill beneath the undercut sections of cliff, and match to the top of the existing cliff
- Establish a dune with sand (obtained locally by beach scraping) and match in to the top of the existing cliff. Provide protection with jute matting and planting

The following adaptation strategies are recommended to be undertaken to the cliffs east of the access stairs:

- Remove unstable overhanging sections of limestone to make safe. A detailed assessment (by an engineer) will need to be undertaken to ascertain the extent of unstable cliff.

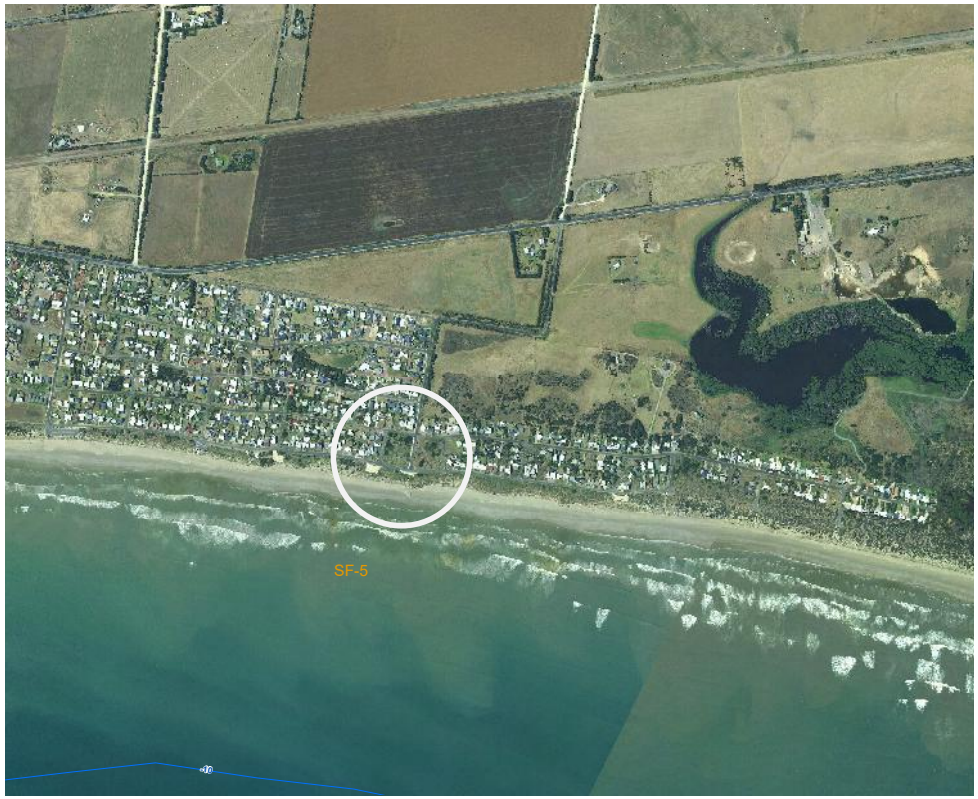
Refer drawing 18084-19 for details on the above. All existing vegetation shall remain. Relevant environmental approvals shall be obtained prior to undertaking work.

Integrated Coasts notes:

An alternative approach to extensive rock protection would be to close the beach access point, collapse the cliffs (or sign them as dangerous) and create a new access point to the west (adjacent the amenities block).

Minor rock protection is likely to be required where the stairs were formerly situated.

3. Bondi and Boettcher carparks



Coastal fabric - natural

Medium term changes

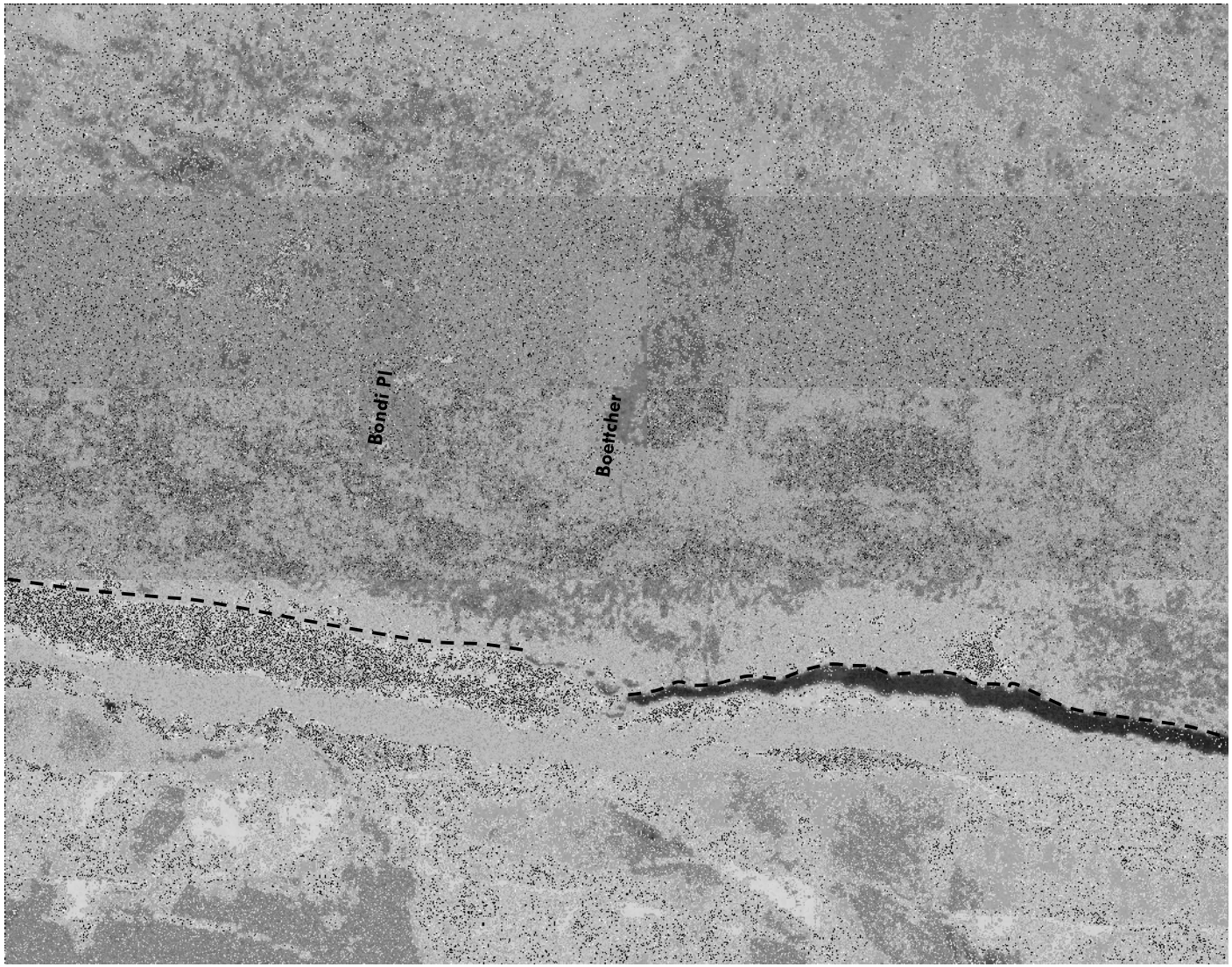
Map: SF5-3
Middleton Beach
Changes 1949 to 2018
Bondi/ Boettcher carparks
1949

Assessment

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

The photograph on this page is SF5-3 in the vicinity of Bondi Place and Boettcher Road.

The shoreline position in 1949 is marked with a dotted line.



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markwestern@integratedcoasts.com
www.integratedcoasts.com
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Coastal Fabric - natural

Medium term changes

Map: SF5-3

Middleton Beach

Changes 1949 to 2018

Bondi/ Boettcher carparks

2006

Assessment

The coastline in the vicinity of Bondi Place and Boettcher Road carparks has not shown any measurable recession since 1949.

However, the area immediately to the east of the Boettcher Road carpark has receded between 12 and 15m since 1949.

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Coastal Fabric - natural

Medium term changes

Map: SF5-3

Middleton Beach

Changes 1949 to 2018

Bondi/ Boettcher carparks 2018

Assessment

The coastline in the vicinity of Bondi Place and Boettcher Road carparks has not shown any measurable recession since 1949.

The coastline in the vicinity of Bondi Place and Boettcher Road shows an overall small accretion of around 1-2m from 2006.

However, the area immediately to the east of the Boettcher Road carpark has receded between 12 and 15m since 1949. A small dune has built at the base of the cliffs.

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markwestern@integratedcoasts.com
www.integratedcoasts.com
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Coastal fabric - modified

HUMAN INTERVENTION

Protection strategies:

Currently no hard protection strategies are utilised in this section of coast.

Archives explain that management strategies were employed in the 1970s and 1980s. These include fencing around carparks and access ways, and the installation of stairs and boardwalks.

Infrastructure:

A 750m^2 carpark is situated 21m behind the dune escarpment at the end of Bondi Place and a small carpark of 230m^2 is situated adjacent Surfers Parade, and set back 32m from the dune escarpment.

Surfers Parade is situated approximately 40m from the dune escarpment.

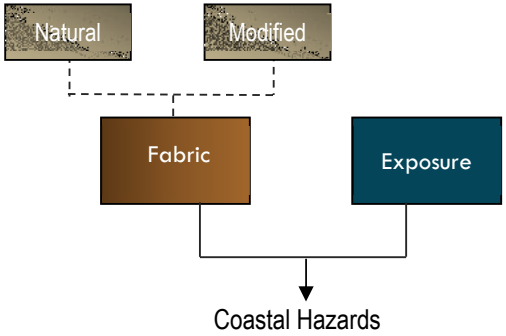
Behind the esplanade road is urban settlement.

COASTAL FABRIC

Summary and conclusions

Progress report

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the fabric of the cell. In the next section we will deal with the 'exposure' of the cell.



Summary:

Middleton Beach – Bondi Place (Cell 5-3) is situated within the Coorong secondary cell that stretches from Middleton Point to Café Jaffa.

Beach

A dissipative beach of fine-medium sand.

Backshore 1

Vegetated low-height dune

Erodibility rating: High erodibility (3)

Backshore 2:

Behind the low height dune is backshore of semaphore sand that slopes up to the esplanade road at >6m AHD and continues to slop upwards to 16m AHD at 250m landwards of the shoreline.

Erodibility rating: high erodibility (3)

Benthic

The intertidal and subtidal zones are dominated by sand (dissipative beach).

Human intervention

Two carparks are set well-back from the dune escarpment (20m and 32m). The esplanade road (Surfers Parade) runs parallel to the shoreline and is set back ~50m from the dune escarpment in the vicinity of the carparks. Urban settlement is situated behind the esplanade road.

The esplanade road is set back 25m from the cliff escarpment to the east of the carparks.

Analysis

A comparative analysis of photographs from 1949 to 2006 demonstrates that the shoreline has been very stable in the vicinity of the carparks.

The cliff escarpment has eroded ~15m since 1949, but a small incipient dune has been built at the base of the cliff at about the same distance as the erosion.

A comparative analysis of the profile line captured by Department of Environment and Water from 1977 to 2018 (615006) also shows the coast in this location has been accreting (p. 14).

In summary, overall the dune section of beach presents as 'stable' but is likely to go through cycles of erosion and accretion within decadal timeframes.

The cliff escarpment has receded (and naturally can't remake itself).

EXPOSURE

Current and Future

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

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

Current exposure- storm event

Storm event

Map SF5-3

Middleton Beach

Event: 21-22 November 18

Bondi/ Boettcher carparks

Assessment

A storm event on 21-22 Nov 2018 provides the basis for establishing wave effect parameters.

The event was recorded at Victor Harbor gauge at 11.45pm at a height of 1.99 (CD) or 1.41m (AHD).

Analysis within SF5 of seaweed strands and other markers after the event demonstrated wave effects were ~1.70m above tidal gauge height. Wave set-up 0.5m and 1.2m wave runup.

Wave effects were significant but this event occurred at a lower tide and had minor impact on beach and backshore.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

Current exposure – storm surge

Storm surge

Map SF5

Surfers - Middleton

Current: 1 in 100-year risk

Bondi/ Boettcher carparks

Assessment

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

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

Wave run-up is 1.2m and depicted in light blue.

In this event wave run-up would flow up the beach and impact the base of the dunes causing some erosion/ scarping.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Current exposure – monthly high water

Monthly high water

Map SF5-3

Middleton Beach

Current: monthly high water

Bondi/ Boettcher carparks

Assessment

Extreme events are very rare and can have a significant impact. 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. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.30m
Total risk	1.80m

Wave run-up of 0.80m is included.

The current impact on beach and backshore is low.

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markwestern@integratedcoasts.com

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Current exposure – storm water

Storm water

Map SF5-3

Middleton Beach

Storm water

Bondi/ Boettcher carparks

Assessment

Storm water:

No storm water infrastructure.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Current exposure - erosion

Erosion

Map SF5-3

Middleton Beach

Current Erosion outlook

Bondi/Boettcher carparks

Assessment

Historical comparison of aerial photographs from 1949, 2006, and 2016 demonstrate the rate of erosion in SF5-3.

The dune escarpment to the front of Bondi Pl carpark is in the same location as 1949 (this doesn't mean that it has been static as the coast does go through erosion and accretion cycles).

The cliff top to the east of Boettcher has receded up to 15m since 1949. A small dune has built at the base of the cliff.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Current exposure - erosion

Erosion

Map SF5-3

Middleton Beach

Current Erosion outlook

Bondi/Boettcher carparks

Assessment

A very small hole in the base of the cliff shows evidence of incursions of the sea which represents a potential undercutting threat.

See comments regarding carpark at Miami Blvd.

Recent block falls from cliffs demonstrate ongoing erosion potential (Photograph: M Hillman)

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Future exposure – storm surge (2050)

Storm surge

Map SF5-3

Middleton Beach

2050: 1in 100-year risk

Bondi/Boettcher carparks

Assessment

The 1 in 100-year risk set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.50
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the dunes. The impact of this event on the current dunes would be very high.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Future exposure – storm surge (2100)

Storm surge

Map SF5-3

Middleton Beach

2100: 1 in 100-year risk

Bondi/Boettcher carparks

Assessment

The 1 in 100-year risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

The modelling shows that if an event of this magnitude occurred that wave setup would directly impact the base of the dunes, and overtopping would be severe. Erosion extreme.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Future exposure – monthly high water (2100)

Monthly high water

Map SF5-3

Middleton Beach

2100 Routine high tide

Bondi/Boettcher carparks

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event. 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
Plus sea level rise	1.00
	2.50m
Wave set up	0.30m
Total risk	2.80m

Wave run-up of 0.8m has been included.

Note: the routine high tide would be similar in height as the 1 in 100 ARI event for 2050. However, the intensity of the event would be less.

It is understood that we have super-imposed a future event upon a current beach profile. However the modelling shows that a routine tide 1m higher than present must cause significant shoreline recession in a sand dominated backshore.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Future exposure – erosion (2100)

Future Exposure

Map SF5-3
Middleton Beach
2100 Erosion outlook
Bondi/Boettcher carparks

Assessment

Because of the varying types of foreshores and backshores and urban layouts in Cell SF5, the approach in this assessment is to identify the likely trends over the coming century.

On a dissipative beach with erodible backshores, the shoreline will be dictated by the swash zone of wave run-up. The 2100 routine tidal map demonstrates that should seas rise as projected, then the shoreline will retreat.

How soon it would erode back to the road is not known.

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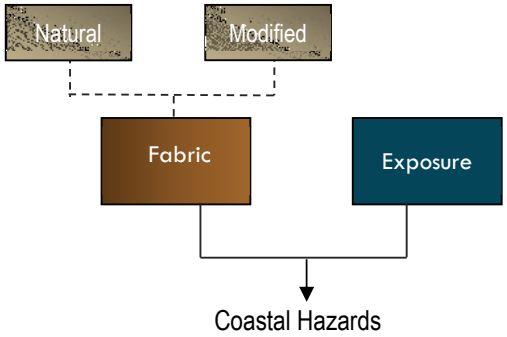
markwestern@integratedcoasts.com
www.integratedcoasts.com

SUMMARY

Progress report:

So far, we have completed a review of settlement history and completed an assessment of the 'geology' or 'fabric' in the vicinity of Bondi Pl and Boettcher Road and the current and future exposure.



Coastal Fabric

Bondi and Boettcher carparks are situated on a dissipative sandy beach, within the sand dune backshore and is assigned a resistance rating of (1) highly vulnerable

Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Middleton and Goolwa Beaches. 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 (ie at the tide Victor Harbor tide gauge).

If this event was to occur it would impact the base of the dunes and cliffs in a significant manner. However, the nature of the beach is such that the sand volume and dune escarpments would likely be rebuilt.

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 break down the dune system over time. Routine high tides are unlikely to be causing any significant erosion in this current era.

Erosion

The dune escarpment is in the same location as 1949. However, the cliff top to the east has receded by ~15m.

Future exposure (indicatively by 2050)

Storm surge

A 1 in 100 ARI storm surge event would significantly impact the dune escarpment.

Monthly high water

The nature of the beach is such that the location of the dune escarpment is normally also related to the influence/impact of the swash zone. However, it has already been noted that the Alexandrina coastline goes through cycles of accretion and erosion. An increase of sea level by 0.3m is likely to result in the cycle moving landwards.

Future exposure (indicatively by 2100)

Storm surge and monthly high water

The 1 in 100 ARI storm event would significantly impact the beach and dune, especially in the southern areas. High tides 1m greater than today would also routinely impact the dunes and the areas behind the dunes.

Routine tidal action 1m higher than present will cause the dune escarpment to recede (it is the nature of a dissipative beach).

The extent of the recession is unknown but modelling in other areas indicates that the esplanade road would come under attack in the time period 2050 -2100. However, the slope of the backshore in this location will tend to limit the extent of the erosion.

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 of the likely extent of recession, and where impacts will be 'felt' the most.

Hazard Impacts

Bondi and Boettcher

Map SF5-3

Middleton Beach

Items at risk

Bondi and Boettcher

Public assets
Beach access stairs (x1)
Fencing
Carparks x2
Esplanade road.

Cliff top has receded 15m since 1949, now 25m from the road.

Private assets
Private assets are situated behind the esplanade road and therefore are afforded protection as long as the Council chooses to protect the road.

Safety of people
None perceived above normal risks in a coastal zone.

Ecosystem disruption
The geological layout with rising backshore indicates that impacts into broader ecosystems will not occur.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Hazard Impacts

Bondi and Boettcher

Map SF5
Middleton- Surfers
Assets at risk
Public

Council has a responsibility to maintain the beach access points along the coastline.

Bondi Place access

Access trail covered by matting (plastic?). Seaweed indicates the current wave run-up zone.

Boettcher Road access

Wooden access stairs culminate in approximately in location of current wave run-up zone. On upgrade these could be positioned further landward.

Bondi Place

Access path unconsolidated but covered with walking trail matting (see next pic)

Bondi Place

Walking trail mat (recycled plastic)

Access stairs end point is situated in current swash zone. However, this section of beach has proved to be stable.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

8. RISK ASSESSMENT

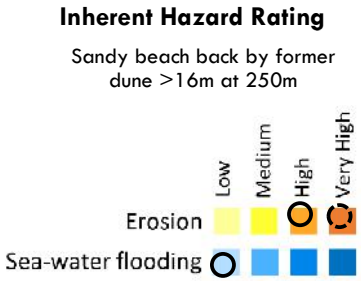
Inherent hazard rating

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.



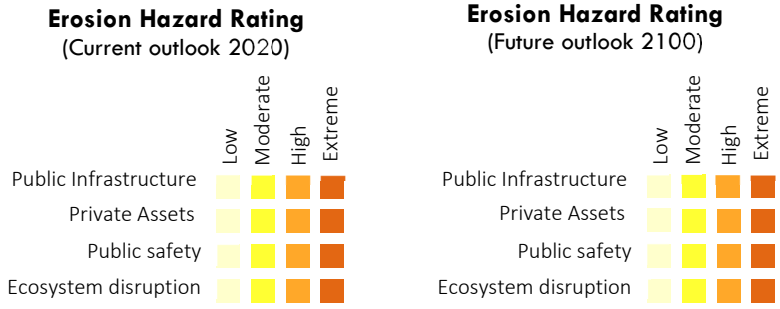
Specific Risk Assessment

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.

The 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 framework of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding or erosion (See next page).



Yet to be assigned

Erosion assessment

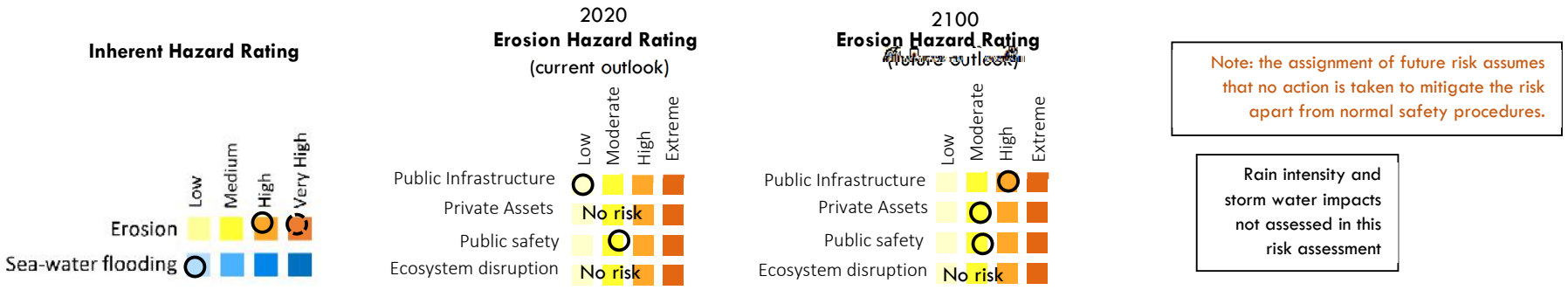
Bondi and Boettcher Carparks (SF5)

Risk identification: Erosion may cause the dunes to recede and thereby threaten Council owned infrastructure.

Coastal processes	Middleton Beach marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. The beach at Bondi Place and Boettcher Road is backed by a small dune system, that rises up to the road at 6.50m AHD to 9.90m AHD. Exposure is categorised as 'high', and wave energy high at ~2m. Historical comparisons showed that between 1949 and 2018 show that the dunes are in the same position. The top of the cliffs to the east have eroded back 15m from actions of the sea.

Are any strategies employed to mitigate the risk? Nil.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carparks x2, access stairs x1, fencing, esplanade road. The backshore is steeper here and erosion will be more limited by the slope.	current	*Rare*	*Minor*	Low
		2100	*Possible*	*Significant*	High
Private assets	Private assets are situated behind the esplanade road. As long as the road is not impacted, private assets will not be affected.	current	*No risk*	*No risk*	No risk
		2100	*Possible*	*Moderate*	Moderate
Safety of people	This assessment does not relate to general beach safety of pedestrians or swimmers. There are no perceived additional risks to people (apart from a cliff collapse and someone being at the base of the cliffs).	current	*Rare*	*Significant*	Moderate
		2100	*Rare*	*Significant*	Moderate
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. The geology of the area contains the risk and therefore there is no perceived risk.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk



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	Currently the dunes at Bondi and Boettcher have been in an accretion cycle. Cliffs to the east have eroded by 15m since 1949, but a low height dune has been currently been building over the last 10 years (approx.). If the coast was to go back into an erosion cycle, this dune is likely to be eroded away and direct wave action is likely to impact the base of the cliffs.

ADAPTATION PROPOSALS

Adaptation options

ADAPTATION OPTIONS

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

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

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These 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 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.

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 tat 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.

MIDDLETON – BONDI /BOETTCHER

An **incremental approach** to adaptation is recommended.

In the context of a high energy sand dominated beach it is unlikely that protecting the dunes will be viable in the second half of this century. Therefore, a managed **retreat strategy** should be employed. This does not mean 'surrender' but rather monitor and adapt to the recession when it begins to occur. The strategy may also mean some low-cost protection options to provide longevity to an existing asset. But over time, assets within the erosion zone should be reconfigured so that a greater buffer is created between the asset and the shoreline. This strategy will also allow for the coastline to go through its normal recession and accretion cycles without unnecessarily impacting assets.

Because there is unlikely to be any immediate threat, the approach should be to **monitor** this beach over time, with special attention to changes/impacts to the back shore. Monitoring over time will enable decision makers to determine when the beach is operating within its normal parameters, and when it has moved out of its range due to sea level rise.

Review **planning controls** and consider limiting densification of sites on Surfers Parade.

[1] CoastAdapt also includes 'community education'.

Adaptation proposals

Retreat

Map SF5

Middleton (Surfers)

Adaptation proposal

Bondi and Boettcher

Monitor

The base of the escarpment should be regularly monitored, especially after storm events. (See conclusion of this report for further explanation about monitoring strategies)

Respond – managed retreat

If seas rise as projected and dunes begin to recede, then a **retreat** strategy should be employed. When the carpark is due for an upgrade, it could be reconfigured and constructed further away from the shoreline.

Planning controls

Review planning controls and consider limiting further densification of sites on Surfers Parade.

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

4. Miami carpark (and cliffs)

Coastal Fabric - natural

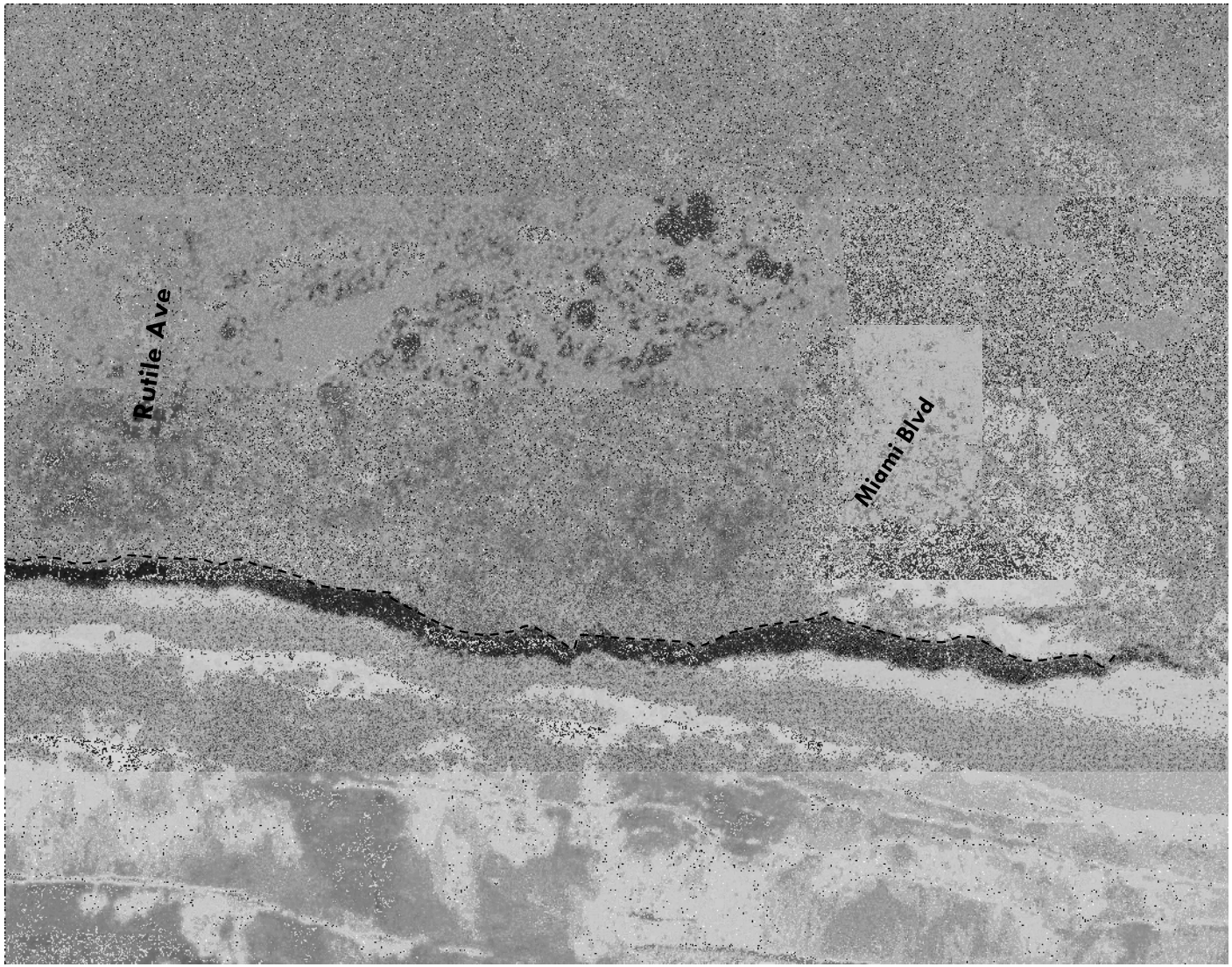
Medium term changes

Map: SF5-4
Middleton Beach
Changes 1949 to 2018
Rutilie Ave and Miami Blvd
1949

Assessment

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

The photograph on this page is SF5-4 which is now in the vicinity of Rutile Ave and Miami Blvd.



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

Coastal Fabric - natural

Medium term changes

Map: SF5-4

Middleton Beach

Changes 1949 to 2018

Rutilie Ave and Miami Blvd

2006

Assessment

It is difficult to ascertain the rate of erosion between 1949 and 2006 due to poor photograph in 2006.

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

Coastal Fabric - natural

Medium term changes

Map: SF5-2

Middleton Beach

Changes 1949 to 2018

Rutilie Ave and Miami Blvd

2018

Assessment

The cliff top in the vicinity of Miami Blvd carpark has receded 10-15m since 1949 caused by actions of the sea and aeolian impacts (wind, storm water run-off)

The cliff top in vicinity of Rutile Ave has receded at a slower rate.

An incipient dune has formed at the base of the cliffs, also about 10-15m in width.

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

Coastal fabric - modified

HUMAN INTERVENTION

Protection strategies:

Currently no hard protection strategies are utilised in this portion of the coastline.

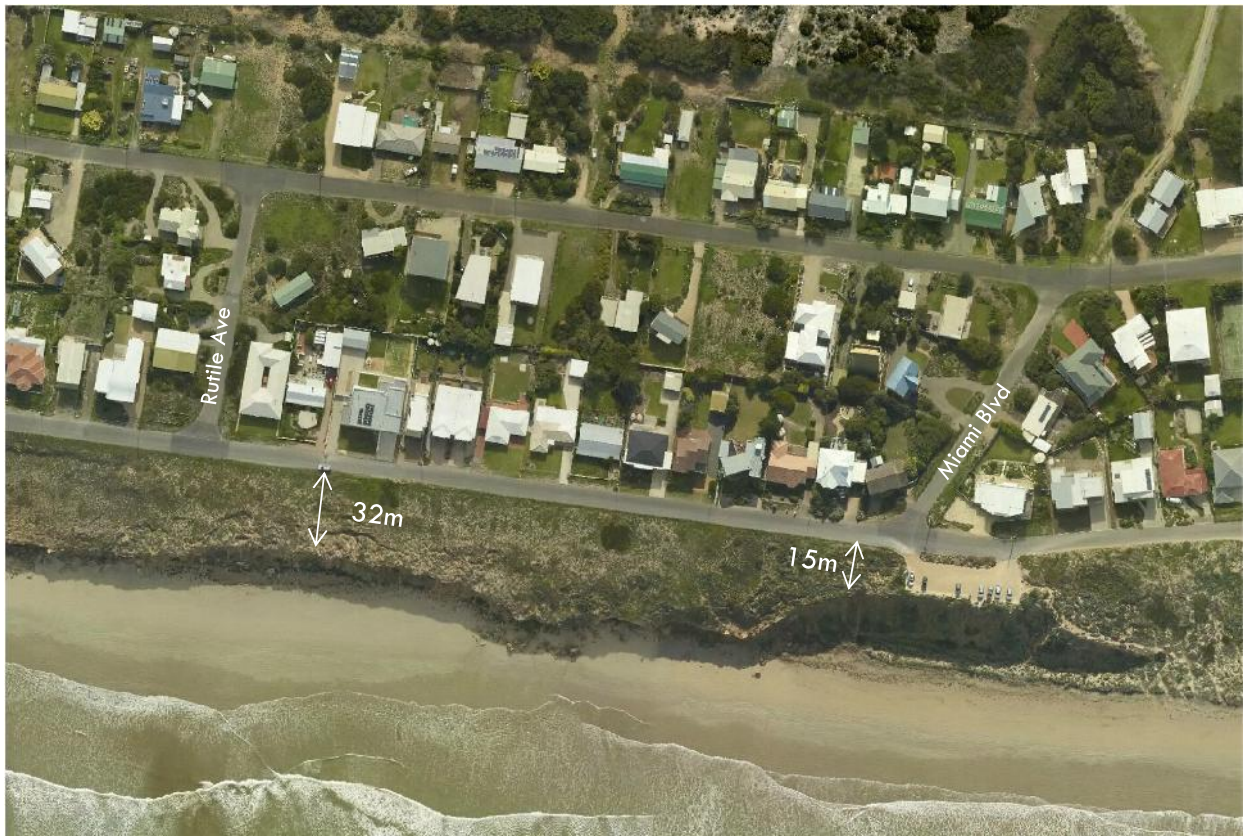
Archives explain that management strategies were employed in the 1970s and 1980s. These include fencing around carparks and access ways, and the installation of stairs and boardwalks.

Infrastructure:

A 540m^2 carpark is situated a few metres from the top of the cliff escarpment.

Surfers Parade is situated approximately 33-35m from the dune escarpment. At the Miami Street carpark the esplanade road is situated at 15m.

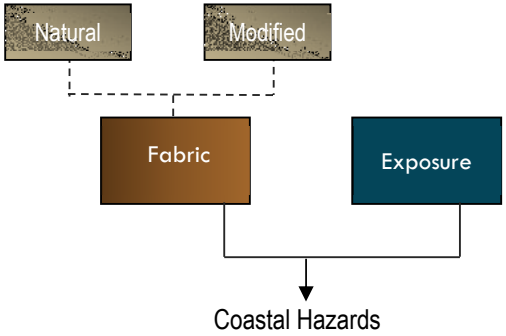
Behind the esplanade road is situated urban settlement.



COASTAL FABRIC

Progress report

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the fabric of the cell. In the next section we will deal with the 'exposure' of the cell.



Summary:

Middleton Beach – Miami Street vicinity (Cell 5-4) is situated within the Coorong secondary cell that stretches from Middleton Point to Café Jaffa.

Beach

A dissipative beach of fine-medium sand.

Backshore 1

Low height cliff approximately 6m high. Lithified semaphore sand.

Erodibility rating: high (3)

Backshore 2: Former dune (semaphore sand) rising to 16m AHD at 250 inland from cliff escarpment. Behind this former dune the contour drops to 3-4m AHD.

Erodibility rating: High (3)

Benthic

The intertidal and subtidal zones are dominated by sand (dissipative beach).

Human intervention

A carpark is situated at the end of Miami Road positioned a few metres back from the cliff escarpment. The esplanade road (Surfers Parade) runs parallel to the shoreline and is set back ~15-30m from the dune escarpment. Urban settlement is situated behind the esplanade road.

Analysis

A comparative analysis of photographs from 1949 to 2006 demonstrates that the shoreline may have eroded 10-15m. Since ~2006 this section of beach has been actively accreting.

A comparative analysis of the profile line captured by Department of Environment and Water from 1977 to 2018 (615006) also shows the coast in this location has been accreting (p. 14).

In summary, this section of coast has eroded in the past but currently presents as 'stable' but is likely to go through cycles of erosion and accretion within decadal timeframes.

EXPOSURE

Current and Future

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

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

Current exposure- storm event

Storm event

Map SF5-4

Middleton Beach

Event: 21-22 November 18

Rutile Ave and Miami Blvd

Assessment

A storm event on 21-22 Nov 2018 provides the basis for establishing wave effect parameters.

The event was recorded at Victor Harbor gauge at 11.45pm at a height of 1.99 (CD) or 1.41m (AHD).

Analysis within SF5 of seaweed strands and other markers after the event demonstrated wave effects were ~1.70m above tidal gauge height. Wave set-up 0.5m and 1.2m wave runup.

Wave effects were significant but this event occurred at a lower tide and had minor impact on beach and backshore.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Current exposure – storm surge

Storm surge

Map SF5-4

Middleton Beach

Current: 1 in 100-year risk

Rutile Ave and Miami Blvd

Assessment

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

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

Wave run-up is 1.2m and depicted in light blue.

In this event wave run-up would flow over the incipient dune and impact the base of the cliff.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband. Peninsula.

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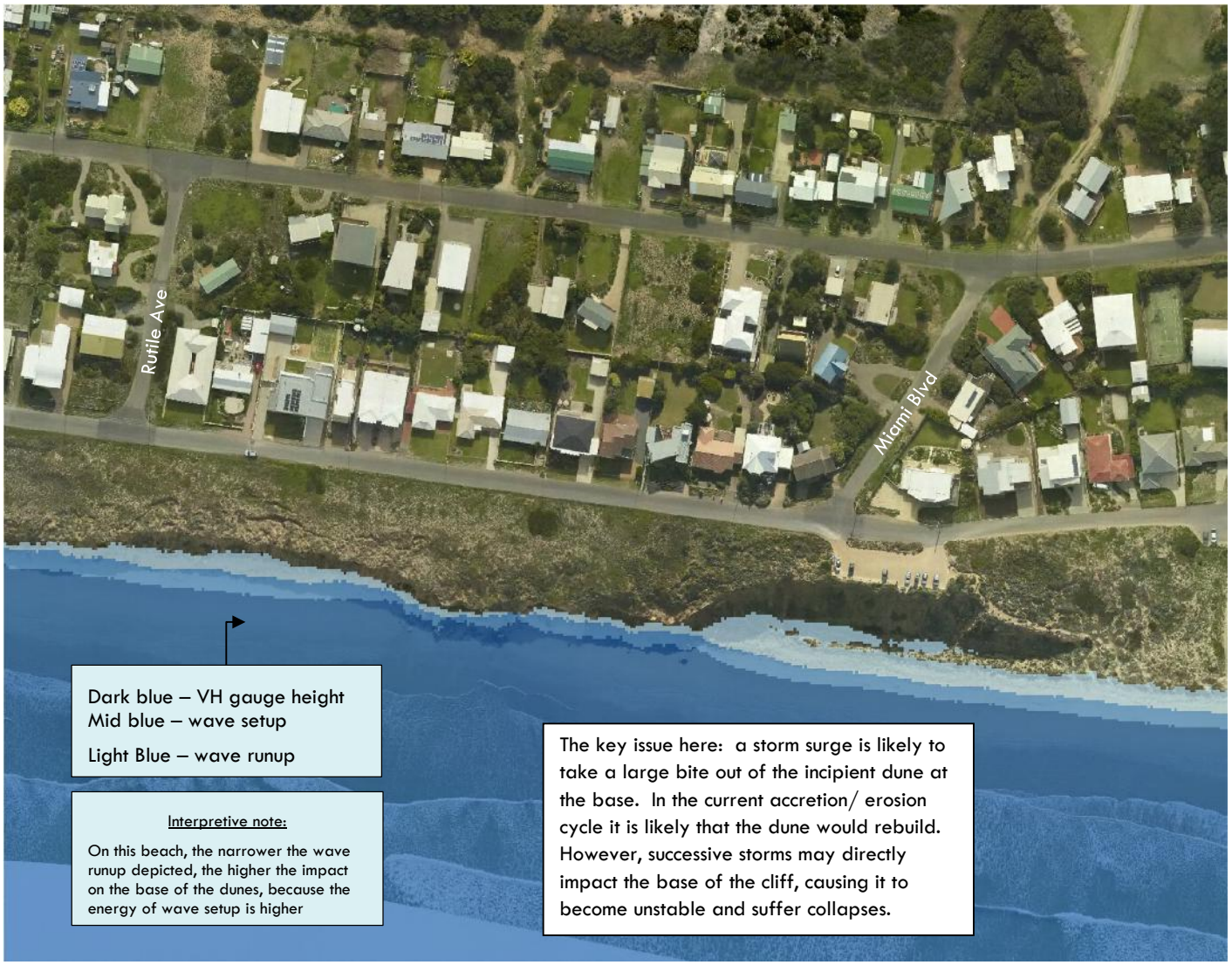

Current exposure – monthly high water

Monthly high water

Map SF5-4
Middleton Beach

Current: monthly high water

Rutile Ave and Miami Blvd

Assessment

Extreme events are very rare and can have a significant impact. 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. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.30m
Total risk	1.80m

Wave run-up of 0.80m is included.

The current impact on beach and backshore is low.

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markwestern@integratedcoasts.com
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Current exposure – storm water

Storm water

Map SF5-4

Middleton Beach

Storm water

Rutile Ave and Miami Blvd

Assessment

Storm water:

No storm water infrastructure.

No storm water infrastructure within plans or observed along coast.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Current exposure - erosion

Erosion

Map SF5-4

Middleton Beach

Current Erosion outlook

Rutile Ave and Miami Blvd

Assessment

Historical comparison of aerial photographs from 1949, 2006, and 2016 demonstrate the rate of erosion in SF5.

The cliff top in the vicinity of Rutile Ave has receded 9m since 1949. There is very little foredune at the base of the cliff and seaweed strands can be seen in close proximity to the base.

The cliff top in the vicinity of Miami Blvd has receded 10-15m, but a small dune has also built at the base about the same width.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Current exposure - erosion

Erosion

Map SF5-4

Middleton Beach

Current Erosion outlook

Rutile Ave and Miami Blvd

Assessment

A very small hole in the base of the cliff shows evidence of incursions of the sea which represents an undercutting threat to the cliffs.

See comments regarding carpark at Miami Blvd.

Recent block falls demonstrate ongoing erosion of cliffs. (Photograph: M. Hillman)

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Future exposure – storm surge (2050)

Storm surge

Map SF5-4
Middleton Beach

2050: 1 in 100-year risk

Rutile Ave and Miami Blvd

Assessment

The 1 in 100-year risk event set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.50
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the cliffs (to the east of the carpark). It is likely that the small dune in front of the carpark would be eroded away.

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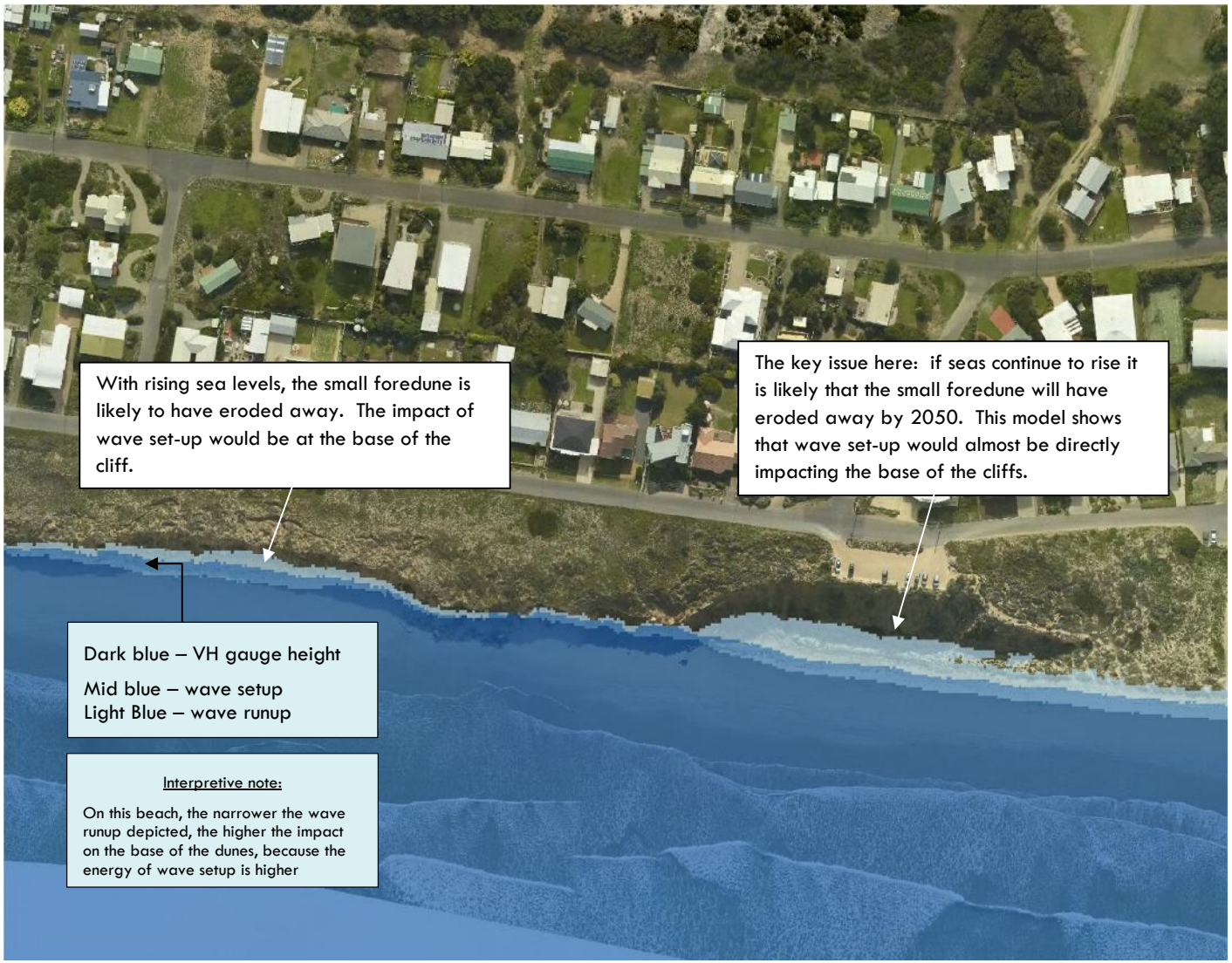

Future exposure – storm surge (2100)

Storm surge

Map SF5-4
Middleton Beach

2100: 1 in 100-year risk

Rutile Ave and Miami Blvd

Assessment

The 1 in 100-year event risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

The modelling shows that if an event of this magnitude occurred that wave setup would directly impact the base of the cliffs. Erosion extreme.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Future exposure – monthly high water (2100)

Monthly high water

Map SF5-4
Middleton Beach

2100: monthly high water

Rutile Ave and Miami Blvd

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event. 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
Plus sea level rise	1.00
	2.50m
Wave set up	0.30m
Total risk	2.80m

Wave run-up of 0.8m has been included.

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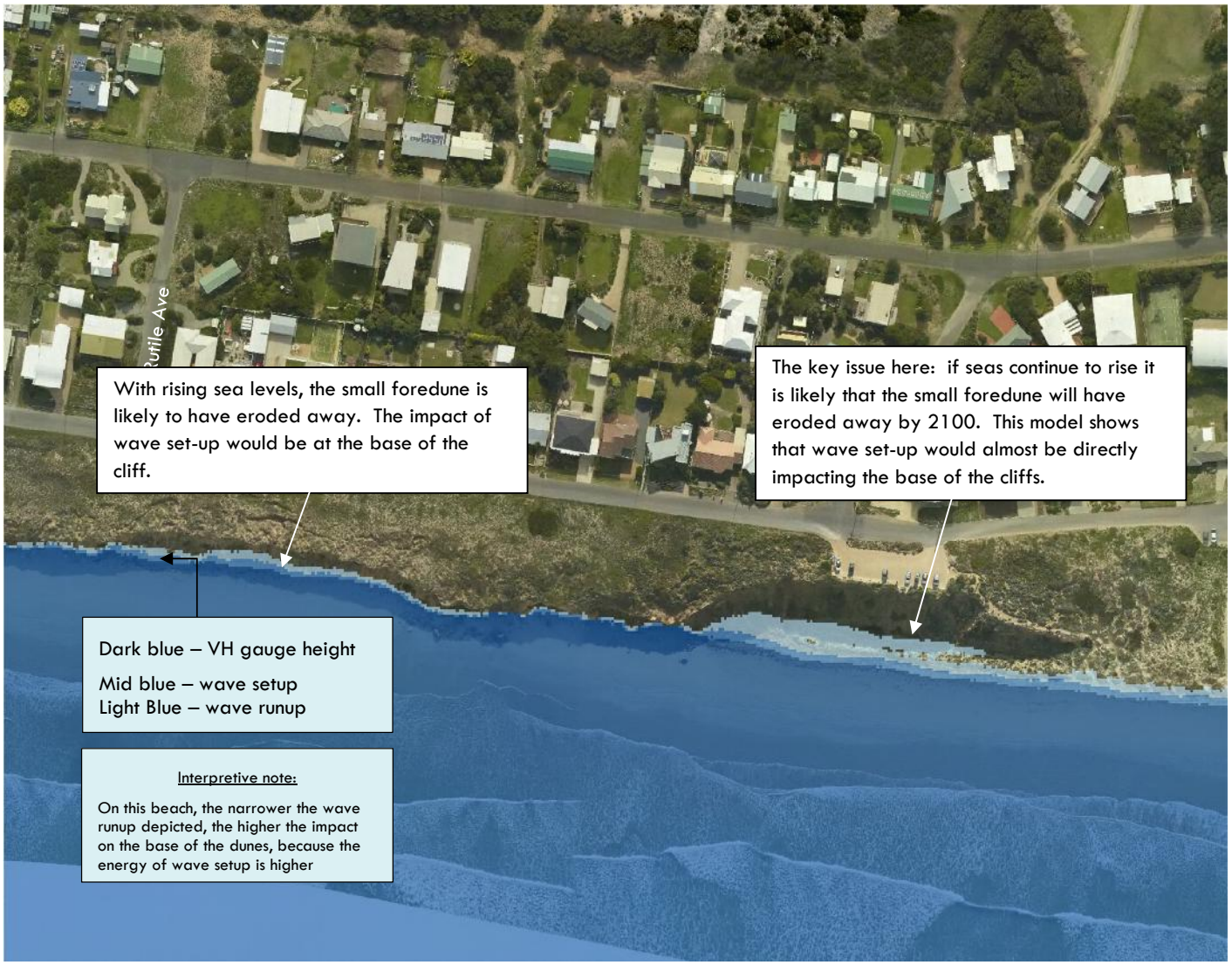

Future exposure – erosion (2100)

Future Exposure

Map SF5-4
Middleton Beach
2100 Erosion outlook
Rutile Ave and Miami Blvd

Assessment

Because of the varying types of foreshores and backshores and urban layouts in Cell SF5, the approach in this assessment is to identify the likely trends over the coming century.

On a dissipative beach with sandy backshores, the shoreline will be dictated by the swash zone of wave run-up. The 2100 routine tidal map demonstrates that should seas rise as projected, then the shoreline will retreat.

How soon it would erode back to the road is not known.

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markwestern@integratedcoasts.com
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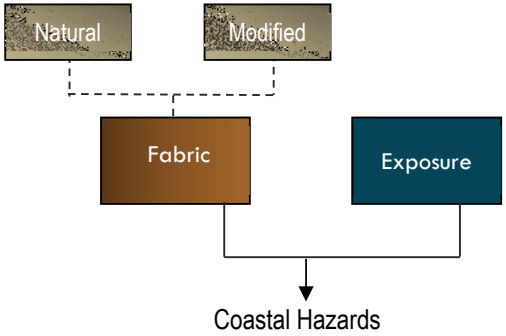
SUMMARY

Progress report:

So far, we have completed a review of settlement history and completed an assessment of the 'geology' or 'fabric' in the vicinity of Rutile Ave and Miami Blvd and the current and future exposure.



Coastal Fabric

The cliffs at Miami/ Rutile are situated on a dissipative sandy beach, within the sand dune backshore.

Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Middleton and Goolwa Beaches. 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 (ie at the tide Victor Harbor tide gauge).

If this event was to occur, it would impact the base of the dunes and cliffs in a significant manner. However, the nature of the beach is such that dune escarpments would likely be rebuilt, but the cliffs would not be.

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 break down the dune system over time. Routine high tides are unlikely to be causing any significant erosion in this current era.

Erosion

The cliff tops in this location have receded by 10-15m since 1949, but a small dune has built at the base of the cliffs since 2006.

Future exposure (indicatively by 2050)

Storm surge

If seas rise as projected, it is likely that the small foredunes will have eroded away and storm surge action will more directly impact the base of the cliffs.

Monthly high water

The nature of the beach is such that the location of the dune escarpment is normally also related to the influence/impact of the swash zone. However, it has already been noted that the Alexandrina coastline goes through cycles of accretion and erosion. An increase of sea level by 0.3m is likely to result in the cycle moving landwards, and erode the small dunes.

Future exposure (indicatively by 2100)

Storm surge and high tides

The 1 in 100 ARI storm event would significantly impact the base of the cliffs. High tidal action 1m greater than today would also routinely impact the base of the cliffs. Routine high tidal action 1m higher than present will cause the cliffs to recede towards the esplanade road.

The extent of the recession is unknown but modelling in other areas indicates that the esplanade road would come under attack in the time period 2050 -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 of the likely extent of recession, and where impacts will be 'felt' the most.

Hazard Impacts

Map SF5-4
Middleton Beach

Items at risk

Rutilie Ave and Miami Blvd

Public assets
Fencing
Carparks x1
Esplanade road.

Cliff top has receded 10-15m since 1949, now immediately adjacent the carpark, and 30m from esplanade.

Private assets
Private assets are situated behind the esplanade road. As long as the esplanade road is not impacted, private assets will remain unaffected.

Safety of people
Potential for cliff collapse although extremely unlikely could result in serious harm.

Ecosystem disruption
The geological layout with rising backshore indicates that impacts into broader ecosystems will not occur.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Hazard Impacts

Map SF5-4
Middleton Beach

Assets at risk

Rutilie Ave and Miami Blvd

Miami Blvd Carpark

The Miami Blvd carpark is positioned ~2m from the top of the cliff escarpment.

The visitors seat is position right on the edge of the escarpment.

The top of this escarpment has receded 15m since 1949. Currently a small dune has built at the base of the cliff that protects the cliff from impacts of the sea. Should this dune be eroded away, actions of the sea will directly impact the base of this cliff.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

8. RISK ASSESSMENT

Inherent hazard rating

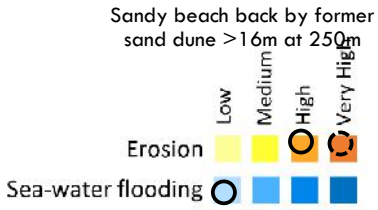
Integrated Coasts has developed a risk classification system to operate over the State of South Australia that categorises the risk to a coastal cell in relation to two main hazards:

- 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.

Inherent Hazard Rating



Specific Risk Assessment

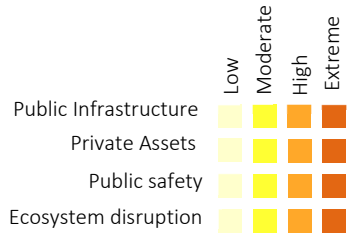
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

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

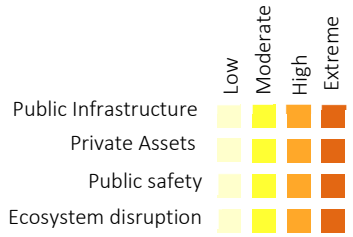
The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

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 framework of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding and erosion (see next page).

Erosion Hazard Rating
(Current outlook 2020)



Erosion Hazard Rating
(Future outlook 2100)



Yet to be assigned

Erosion assessment

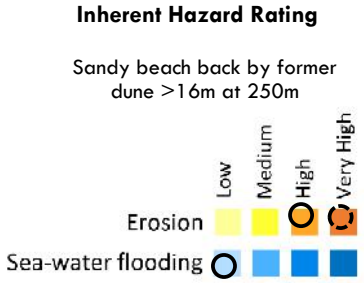
Miami Blvd Carpark (SF5)

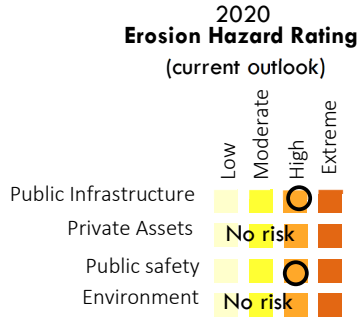
Risk identification: Erosion may cause the cliffs to recede and cause damage to Council infrastructure/ and jeopardise the safety of people.

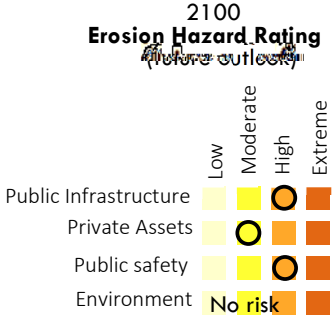
Coastal processes	Middleton Beach marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. The beach at Rutile and Miami is backed by aeolonite cliff with top at 16m AHD (at the esplanade road). Exposure is categorised as 'high', and wave energy high at ~2m. Historical comparisons showed that between 1949 and 2018 show that cliff top has receded ~10-15m (likely to be from actions of the sea, Dr Bourman).

Are any strategies employed to mitigate the risk? Nil.

Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Carparks x1, fencing, esplanade road. Magryn Engineering assessed the carpark and concluded that it was unlikely to be currently at risk. Higher sea levels are likely to erode the foredune and the cliff attacked.	current	*Rare*	*Significant*	High
		2100	*Possible*	*Catastrophic*	High
Private assets	Private assets are situated behind the esplanade road. As the long as the esplanade road is not impacted, private assets will remain unaffected.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	Moderate
Safety of people	This assessment does not relate to general beach safety. While a cliff collapse is very unlikely, the proximity of the carpark and the seat close to escarpment means that any cliff collapse could put people's safety at risk.	current	*Rare*	*Catastrophic*	High
		2100	*Rare*	*Significant*	High
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. The geology/ slope of the area contains the risk and therefore there is no perceived risk.	current	*No risk*	*No risk*	No risk
		2100	*No risk*	*No risk*	No risk







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	Modelling shows that actions of the sea would impact the base of the cliffs if the small foredune was eroded away, and more certainly in the context of sea level rise. This is likely to cause recession of the cliffs. The proximity of the carpark and seat at the very front of the carpark to the edge of the escarpment is of concern, in the context of rising sea levels, but also not knowing the structure and stability of this cliff. Note: Magryn Engineering inspected the carpark and concluded that it was not currently under threat (the only other option was 'no risk').

ADAPTATION PROPOSALS

Adaptation options

ADAPTATION OPTIONS

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

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

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These 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 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.

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 tat 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.

MIDDLETON – RUTILE/ MIAMI

An **incremental approach** to adaptation is recommended.

In the context of a high energy sand dominated beach it is unlikely that protecting the base of the cliffs will be viable in the second half of this century. Therefore, a managed **retreat strategy** should be employed. This does not mean 'surrender' but rather monitor and adapt to the recession when it begins to occur.

The proximity of the Miami Blvd carpark to the cliff top was evaluated by Magryn Engineering who concluded that the carpark was not currently at risk. While a cliff collapse is unlikely, if the dunes eroded away in a storm event, and this was followed by another storm event, direct impact could come on the base of the cliffs. Over the longer term, it is also expected that routine action will impact the base of the cliffs.

Ongoing **monitoring** should track the erosion of the cliff escarpment towards the road or the carpark.

Review **planning controls** and consider limiting further densification of sites on Surfers Parade.

[1] CoastAdapt also includes 'community education'.

Adaptation proposals

Retreat

Map SF5

Middleton (Surfers)

Adaptation proposal

Rutilie Ave and Miami Blvd

Monitor

The base and top of the escarpment should be regularly monitored, especially after storm events. (see further information about monitoring strategies at the conclusion of this report)

Respond – managed retreat

If seas rise as projected and dunes begin to recede, then a retreat strategy should be employed. The carpark could be removed to allow a larger buffer to the road.

Planning

Review planning controls and consider limiting further densification of sites on Surfers Parade.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Adaptation proposals

Engineer's Report

Magryn and Associates (engineers) were engaged to review the study by Integrated Coasts, conduct site inspections and make recommendations in regard to adaptation proposals.

Will Souter inspected the Miami Blvd carpark on 26th June 2019 and Magryn makes the following observations and recommendations (see full

Miami Blvd carpark

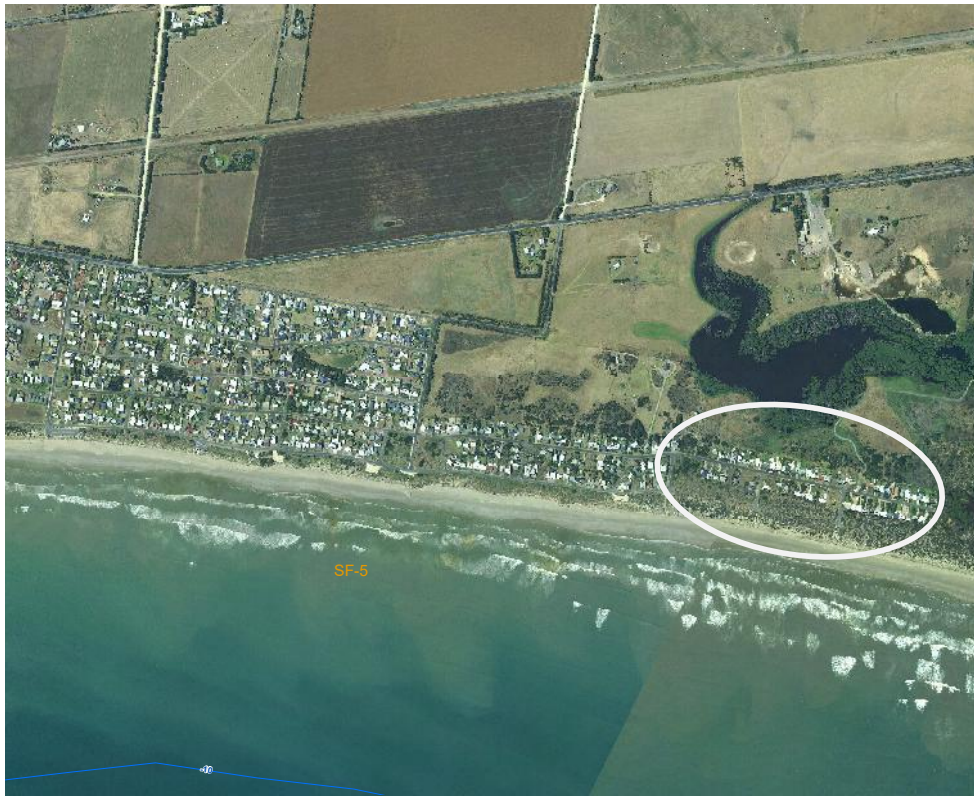
The cliff adjacent the carpark may continue to erode gradually over time, however in our opinion there is no immediate risk to the carpark. It is recommended to monitor the erosion and if it develops, consideration should be made to move the carpark extent/fencing to the north. This will prevent vehicles encroaching on the edge of the cliff, and greatly minimise associated risk.

The top of the cliff is a risk to public safety, hence council should continue to restrict access to the edge of the cliff.

Predicted future water levels may increase erosion and risk. This should be re-assessed in the future.

Figure 16- Existing cliff

5. Waikiki, Tahiti and Tongan



Coastal Fabric - natural

Medium term changes

Map: SF5-5
Middleton Beach
Changes 1949 to 2018

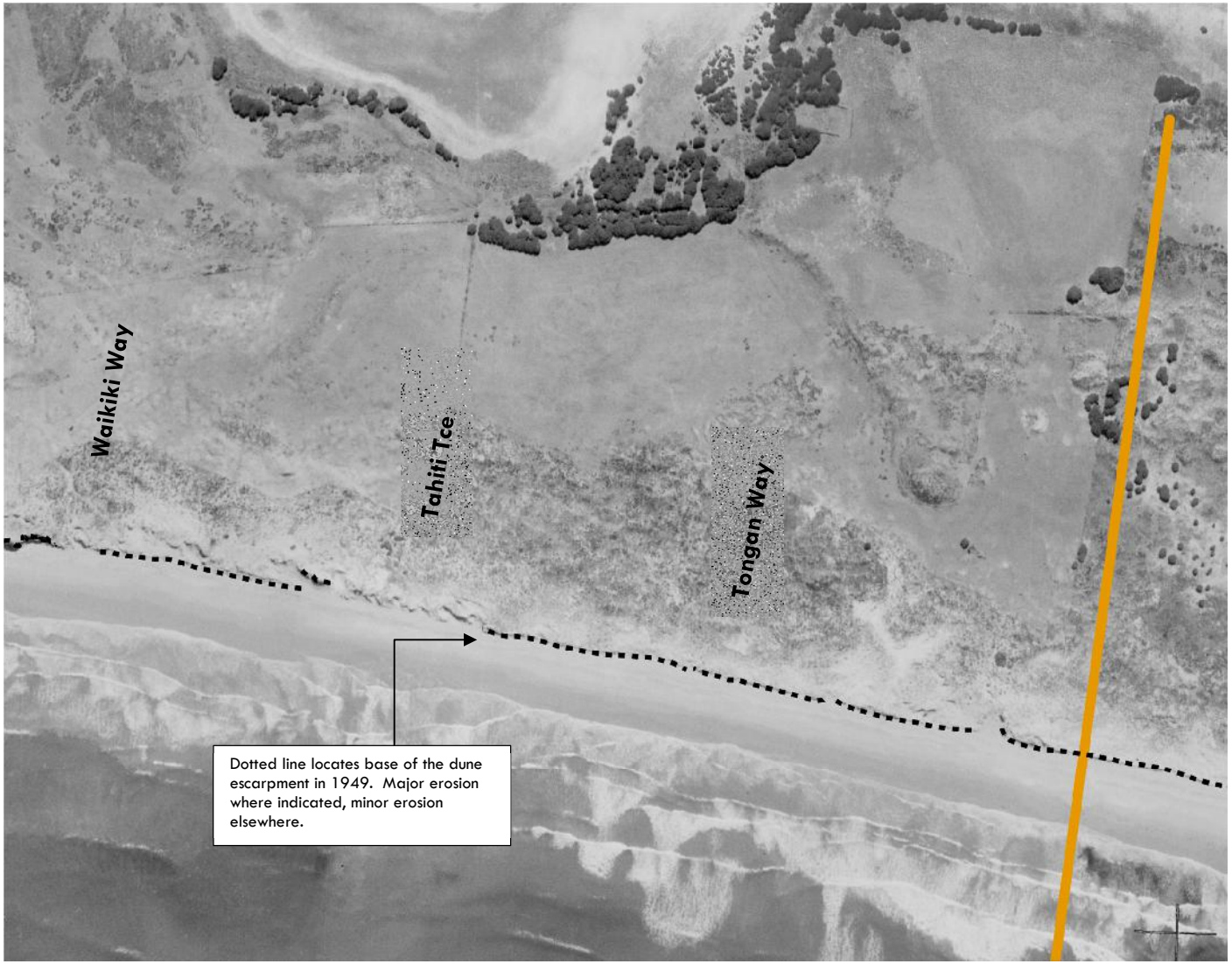
1949

Assessment

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

The photograph on this page is SF5 which is now in the vicinity of Waikiki, Tahiti and Tongan Way (on the eastern end of Middleton subdivision.

The shoreline position in 1949 is marked with a dotted line.



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

Coastal Fabric - natural

Medium term changes

Map: SF5-5

Middleton Beach

Changes 1949 to 2018

2006

Assessment

The coastline in the vicinity of Bondi Place and Boettcher Road carparks has not shown any measurable recession since 1949.

Comparison of 1949 to 2006, demonstrates 8-10m accretion at Waikiki Way, and 12-14 recession near the eastern cell border.

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

Coastal Fabric - natural

Medium term changes

Map: SF5-5

Middleton Beach

Changes 1949 to 2018

2016

Assessment

Comparison between 2006 and 1949, demonstrates that this section of coast has accreted since 2006.

The key point to understanding this coastline is to recognise that the coast cycles through periods of recession and accretion. These periods may be measured in decades rather than years.

Generally the Alexandrina coast has been in an accretion phase since 2006 (at least).

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

Coastal fabric

HUMAN INTERVENTION

Human intervention:

There are no obvious human interventions in this section of the coast apart from accessways and fencing.

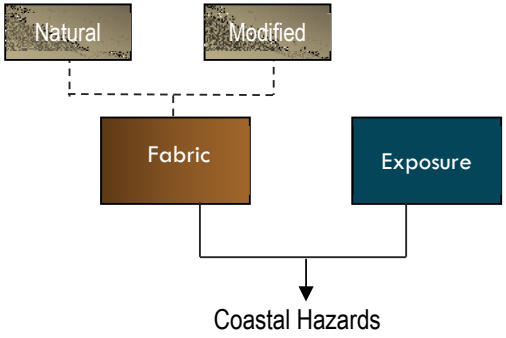
A row of houses is positioned behind the dunes but these are set back 100m from the dune escarpment.

However, the archives do mention the reinstatement of sand dunes at the eastern end of Surfers Subdivision at cost of ~$4400, of which Coast Protection Board contributed 70%. This may be the dunes to the east of Tongan Way (19770517, 19780613).

COASTAL FABRIC

Progress report

So far, we have completed a preliminary assessment, a review of settlement history and completed an assessment of the fabric of the cell. In the next section we will deal with the 'exposure' of the cell.



Summary:

Middleton Beach – Tahiti and Tongan (Cell 5-5) is situated within the Coorong secondary cell that stretches from Middleton Point to Café Jaffa.

Beach

A dissipative beach of fine-medium sand.

Backshore 1

Vegetated low-height dune

Erodibility rating: High erodibility (3)

Backshore 2:

Behind the dunes is a swamp at elevation 2m that stretches back 600m to the quarry and rising hinterland.

Erodibility rating: high erodibility (4)

Benthic

The intertidal and subtidal zones are dominated by sand (dissipative beach).

Human intervention

No infrastructure is set within the dunes apart from the cul-de-sacs of Tongan Way and Tahiti Way.

Analysis

A comparative analysis of photographs from 1949 to 2006 demonstrates that the shoreline has been very stable.

A comparative analysis of the profile line captured by Department of Environment and Water from 1977 to 2018 (615006) also shows the coast in this location has been accreting (p. 14).

In summary, overall the dune section of beach presents as 'stable' but is likely to go through cycles of erosion and accretion within decadal timeframes.

NOTE: This section of coast would be more effectively analysed as part of Cell 4 (Tokuremoar Reserve).

EXPOSURE

Current and Future

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

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

Current exposure- storm event

Storm event

Map SF5-5

Middleton Beach

Event: 21-22 November 18

Tahiti and Tongan

Assessment

A storm event on 21-22 Nov 2018 provides the basis for establishing wave effect parameters.

The event was recorded at Victor Harbor gauge at 11.45pm at a height of 1.99 (CD) or 1.41m (AHD).

Analysis within SF5 of seaweed strands and other markers after the event demonstrated wave effects were ~1.70m above tidal gauge height. Wave set-up 0.5m and 1.2m wave runup.

Wave effects were significant but this event occurred at a lower tide and had minor impact on beach and backshore.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Current exposure – storm surge

Storm surge

Map SF5-5

Middleton Beach

Current: 1 in 100-year risk

Tahiti and Tongan

Assessment

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

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

Wave run-up is 1.2m and depicted in light blue.

In this event wave run-up would flow over the incipient dune and impact the base of the cliff.

Contextual note:

Storms of this magnitude normally take a 'bite' out of the dunes. Examples exist of 14m recession in one night on Young Husband. Peninsula.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Current exposure – monthly high water

Monthly high water

Map SF5-5

Middleton Beach

Current: monthly high water

Tahiti and Tongan

Assessment

Extreme events are very rare and can have a significant impact. 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. The event pictured here is expected to occur every one or two months.

The event modelled:

Average high tide	1.50m
Wave effects	0.30m
Total risk	1.80m

Wave run-up of 0.80m is included.

The current impact on beach and backshore is low.

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markwestern@integratedcoasts.com

www.integratedcoasts.com

Current exposure – storm water

Storm water

Map SF5-5

Middleton Beach

Storm water

Tahiti and Tongan

Assessment

Storm water:

The only storm water infrastructure noted on this plan is on the eastern end of the subdivision.

Houses on the North side of Newell Ave must be draining into the reserve. It isn't clear where houses on the south side of Newell Ave drain storm water.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Current exposure - erosion

Erosion

Map SF5-5

Middleton Beach

Current Erosion outlook

Tahiti and Tongan

Historical comparison of aerial photographs from 1949, 2006, and 2016 demonstrate the rate of erosion in SF5.

The dunes in this section of coast has either accreted or is much the same position as 1949.

In he context of a dissipative coastline which is dominated by sand, the position of the dune escarpment is largely determined by the nature of the exposure (wave set-up and wave run-up).

It is likely that the coast cycles through periods of accretion and erosion over years/ decades.

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markwestern@integratedcoasts.com
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On the western end of this section of coast, the dune has accreted ~14m when compared to 1949. The dune elsewhere in this section of coast is in much the same position as 1949.

Current exposure - erosion

Erosion

Map SF5-5

Middleton Beach

Current Erosion outlook

Tahiti and Tongan

Assessment

The dune system in the Tahiti and Tongan region is 50-60m wide and at heights 5m to 6m.

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markwestern@integratedcoasts.com
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Future exposure – storm surge (2050)

Storm surge

Map SF5-5
Middleton Beach

2050: 1 in 100-year risk

Tahiti and Tongan

Assessment

The 1 in 100-year event risk set by Coast Protection Board for 2050 includes an allowance of 0.3m sea level rise:

Storm surge	1.75m AHD
Sea level rise	0.30
	2.05m AHD
Wave set-up	0.50
Risk	2.55m AHD

Wave run-up of 1.20m has been depicted.

Scenario modelling demonstrates that wave-set up would almost be at the base of the dune escarpment and therefore the impact on the dunes would be significant.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

Future exposure – storm surge (2100)

Storm surge

Map SF5-5
Middleton Beach

2100: 1 in 100-year risk

Tahiti and Tongan

Assessment

The1 in 100-year event risk set by Coast Protection Board for 2100 includes an allowance of 1.0m sea level rise:

Storm surge	1.75m AHD
Sea level rise	1.00
	2.75m AHD
Wave set-up	0.50
Risk	3.25m AHD

Wave run-up of 1.2m is indicated by the lighter blue shading.

An event of this magnitude would have significant impact on the dunes. (Dunes are only 5m to 6m high).

If water broke through Cell SF4 then flooding from the rear is possible.

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markwestern@integratedcoasts.com
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Future exposure – monthly high water (2100)

Monthly high water

Map SF5-5
Middleton Beach

2100: monthly high water

Tahiti and Tongan

Assessment

Monthly high tide data from 1965 to 2016 was averaged to provide a perspective of the more routine tidal event. 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
Plus sea level rise	1.00
	2.50m
Wave set up	0.30m
Total risk	2.80m

Wave run-up of 0.8m has been included.

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markwestern@integratedcoasts.com
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Future exposure – erosion (2100)

Future Exposure

Map SF5-5

Middleton Beach

2100 Erosion outlook

Tahiti and Tongan

Assessment

On a dissipative beach with sandy backshores, the shoreline will be dictated by the swash zone of wave run-up. The 2100 routine tidal map demonstrates that should seas rise as projected, then the shoreline will retreat.

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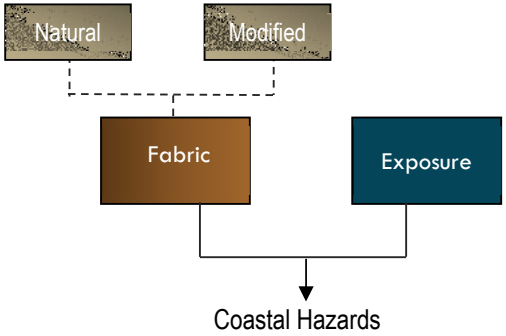
markwestern@integratedcoasts.com
www.integratedcoasts.com

SUMMARY

Progress report:

So far, we have completed a review of settlement history and completed an assessment of the 'geology' or 'fabric' in the vicinity of Tongan and Tahiti and the current and future exposure.



Coastal Fabric

The sand dunes in this region are situated on a dissipative sandy beach. Housing and road infrastructure is set within a more elevated portion of the swamp behind the dunes.

Current exposure

Baseline storm event

The event of 21-22 November 2018 provided a baseline event from which to quantify wave effects within Middleton and Goolwa Beaches. 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 (ie at the tide Victor Harbor tide gauge).

If this event was to occur it would impact the base of the dunes and cliffs in a significant manner. However, the nature of the beach is such that the sand volume and dune escarpments would likely be rebuilt.

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 break down the dune system over time. Routine high tides are unlikely to be causing any significant erosion in this current era.

Erosion

The beach is likely to go through normal erosion and accretion cycles. In this current time it appears to be accreting in this region with no net erosion since 1949.

Future exposure (indicatively by 2050)

Storm surge

If seas rise as projected, storm surge will have increased impact, but the beach may still recover.

Monthly high water

The nature of the beach is such that the location of the dune escarpment is normally also related to the influence/impact of the swash zone. An increase of sea level by 0.3m is likely to result in the cycle moving landwards, by up to 30m.

Future exposure (indicatively by 2100)

Storm surge and routine high water

The 1 in 100 ARI storm event would significantly impact the base of the cliffs. High tidal action, 1m greater than today would also routinely impact the base of the dunes. Routine tidal action, 1m higher than present will cause the dunes to erode back towards Newell Road.

Erosion modelling suggests that in the second half of this century these sand dunes may have eroded away and erosion is impacting urban settlement in this region.

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 of the likely extent of recession, and where impacts will be 'felt' the most.

Hazard Impacts

Map SF5-5

Middleton Beach

Items at risk

Tahiti and Tongan

Public assets
Fencing and informal access points. Road access and cul-de-sacs at Waikiki, Tahitit and Tongan

Private assets
Private houses and land are situated approximately 100m from the shoreline.

Safety of people
No perceived safety issues outside of normal beach safety issues.

Ecosystem disruption

If the sand dunes break down then sea water will flow through to the marsh land (this issue is reviewed in Cell SF4).

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markwestern@integratedcoasts.com
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Hazard Impacts

Map SF5-5

Middleton Beach

Assets at risk

Tahiti and Tongan

Beach access ways.

The beach access ways at Waikiki, Tahiti and Togan Way are constructed informally.

Waikiki Way
Natural path from Waikiki Way to the beach. No evidence of erosion of the entrance and seaweed strands further away from the entrance.

Tahiti Road
Wooden slat/ log walkway in poor condition at termination point. Seaweed strands appear in close proximity to the exit point.

Tongan Road
Tongan Road beach access is natural pathway. No evidence of erosion at the entry point, but seaweed strands are located in close proximity to exit point.

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markwestern@integratedcoasts.com
www.integratedcoasts.com

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:

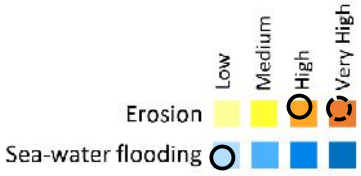
- Sea-water flooding
- Erosion

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.

Inherent Hazard Rating

Sandy beach back by low height dune and swamp at 2-3m AHD



Specific Risk Assessment

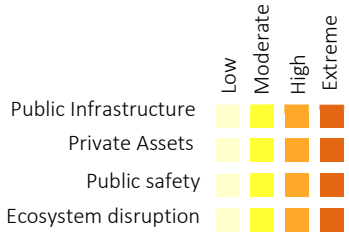
Each of the cells are assessed more specifically for risk in the context of four receiving environments:

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

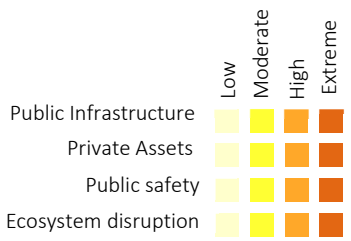
The term eco-system disruption is used to describe the situation where changes in a coastal region might bring about larger scale changes to the nature of the coastal environment that may threaten to disrupt the entire ecological system.

The 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. This assessment utilises the risk assessment framework of Alexandrina Council and is reported within standardised templates for the relevant hazard: seawater flooding and erosion (See next page).

Erosion Hazard Rating
(Current outlook)



Erosion Hazard Rating
(Future outlook)



Yet to be assigned

Erosion assessment

Tahiti and Tongan (SF5)

Risk identification: Erosion may cause the sand dunes to recede, thereby threatening private and public assets.

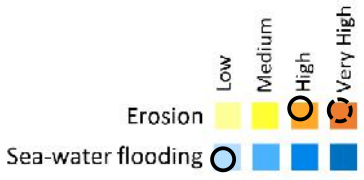
Coastal processes	Middleton Beach marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. The beach in the vicinity of Tahiti and Tongon is backed by low height sand dunes (5-6m high), and about 50-60m wide. Exposure is categorised as 'high', and wave energy high at ~2m. Historical comparisons showed that between 1949 and 2018 show that there has been nil net erosion or accretion in this region since 1949.

Are any strategies employed to mitigate the risk? Nil.

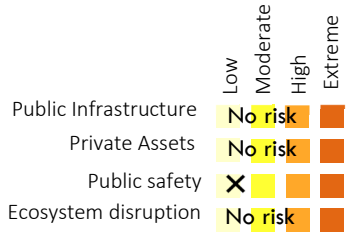
Receiving environment	Coastal Context	Time	Likelihood	Consequence	Risk
Public infrastructure	Roads and fencing.	current	*Rare*	*Significant*	No risk
		2100	*Possible*	*Significant*	High
Private assets*	Private property backs on to the dune system at about 100m from the shoreline.	current	*No risk*	*No risk*	No risk
		2100	*Unlikely*	*Moderate*	low
Safety of people	This assessment does not relate to general beach safety and there are no indicators that sea level rise will introduce new safety issues.	current	*Rare*	*Insignificant*	low
		2100	*Rare*	*Insignificant*	low
Ecosystem disruption	This assessment relates to large scale disruption to ecological systems. As noted in SF4, if sea water breaks through the dunes (especially east of SF5) then the ecology behind the dunes would likely be irreversibility altered.	current	*No risk*	*No risk*	No risk
		2100	*Possible*	*Significant*	High

Inherent Hazard Rating

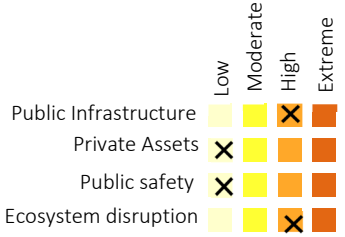
Sandy beach back by low height dune and swamp at 2-3m AHD



Erosion Hazard Rating
(current outlook)



Erosion Hazard Rating
(future outlook)



*Council not necessarily liable for private assets

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

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

Summary	Currently a 50-60m wide sand dune separates the shoreline from public assets (road infrastructure). Private dwellings are situated a further 40m inland. With rising sea levels this dune system could erode away, but this is more likely to occur in the latter part of this century (2050-2060).

ADAPTATION OPTIONS

Adaptation options

ADAPTATION OPTIONS

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

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

Within each of the four response categories there is a range of potential adaptation options in the areas of[1]:

- Planning
- Engineering
- Environmental management

Planning

These 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 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.

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 tat 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.

MIDDLETON – TAHITI AND TONGAN

An **incremental approach** to adaptation is recommended.

In the context of a high energy sand dominated beach it is unlikely that protecting the base of the cliffs will be viable in the second half of this century. Therefore, a managed **retreat strategy** should be employed. This does not mean 'surrender' but rather monitor and adapt to the recession when it begins to occur.

In this location there is a 50-60m buffer between the shoreline and public assets (road) and a 100m buffer between the shoreline and private assets. It is unlikely that this dune system will be eroded away until the latter part of the century should seas rise as projected.

Ongoing monitoring should track the location of the dune escarpment, first to ascertain its normal accretion/ erosion cycle, and then to identify when the beach has moved outside of its normal cycle due to sea level rise. is also expected that routine action will impact the base of the cliffs.

Review **planning** controls and consider limiting densification of sites on Newell Ave.

[1] CoastAdapt also includes 'community education'.

Adaptation options

Retreat

Map SF5

Middleton (Surfers)

Adaptation proposal

Tahiti and Tongan

Approach: incremental

Monitor

The base and top of the escarpment should be regularly monitored, to ascertain the beaches normal cycle of erosion and accretion, and then to identify when erosion is occurring outside the normal range due to sea level rise.

See further information about monitoring strategies at the conclusion of this report.

Planning controls

Review planning controls and consider limiting any further densification of sites on Newell Ave.

Integrated Coasts

markwestern@integratedcoasts.com

www.integratedcoasts.com

Monitor to identify then normal range of accretion and erosion, and then to identify when erosion is moving outside of that range due to sea level rise.

ADAPTATION PROPOSALS

Overview: Middleton Beach

Note: Adaptation strategies have been assigned to each of the carpark region. The strategy on the following pages summaries the adaptation approach

Adaptation options

ADAPTATION OPTIONS

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These 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 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.

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.

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In some locations, incremental changes will not be sufficient. The risks created by climate change may be so significant tat 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.

MIDDLETON BEACH

An **incremental approach** to adaptation is recommended.

In the context of a high energy sand dominated beach it is unlikely that protecting the dunes/foreshore will be viable in the second half of this century. Therefore, a **managed retreat strategy** should be employed. This does not mean 'surrender' but rather **monitor** and adapt to the recession when it begins to occur. The strategy may also mean some **low-cost protection** options to provide longevity to an existing asset. But over time, assets within the erosion zone should be reconfigured so that a greater buffer is created between the asset and the shoreline. This strategy will also allow for the coastline to go through its normal recession and accretion cycles without unnecessarily impacting assets.

Because there is unlikely to be any immediate threat, the approach should be to **monitor** this beach over time, with special attention to changes/impacts to the back shore. **Monitoring** over time will enable decision makers to determine when the beach is operating within its normal parameters, and when it has moved out of its range due to sea level rise.

Further research is required to determine how the existing dune system at border of cells SF4 and SF5 (Tokuremoar Reserve) may respond to increases in sea level in the latter part of this century.

[1] CoastAdapt also includes 'community education'.

Monitoring strategies

The purpose here is not to provide a design for a detailed monitoring program as this will be completed as a separate project. The purpose here is to provide a context for understanding why monitoring is necessary and broadly, what type of monitoring actions are likely to be adopted.

In most areas of Alexandrina coastline, this study has recommended an 'incremental approach' to adaptation (see page above). The main reason to adopt this approach is that most of the coastline is not currently at risk from erosion or inundation. In fact, large sections of the coastline have shown to be accreting over the last ten years.

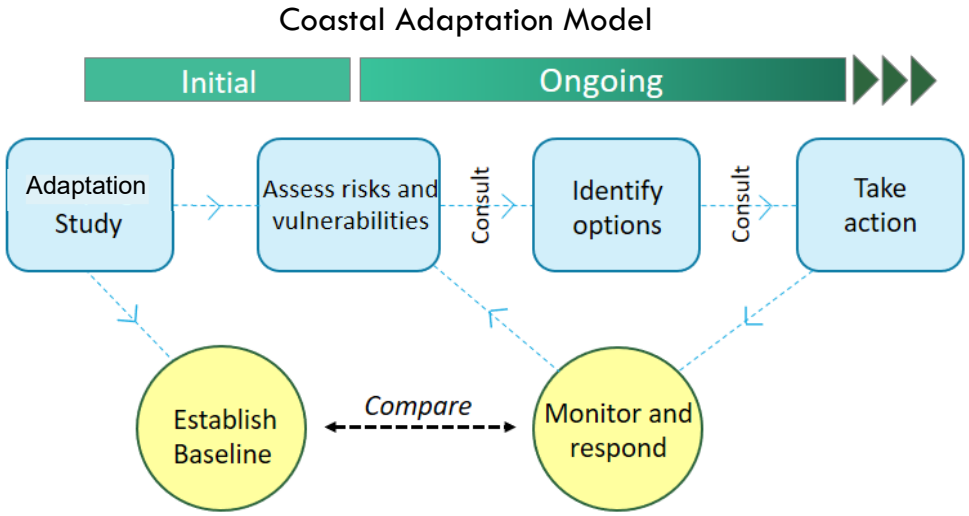
Prime response – 'monitor and respond'

Therefore, the prime adaptation response will be to 'monitor and respond'. Data will be collected on an ongoing basis and compared to the baseline we have established in this study.

We have established a baseline in two ways: First, the capturing of the digital elevation model in 2018 provides a point in time baseline of the current form of the coast. In 5- or 10-years' time (depending whether the coast is accreting or eroding), another digital elevation model could be captured, and comparisons made between the two digital models (Figure).

The second way in which this study has formed a baseline is by analysing coastal change over time. We have compared the position of the shoreline from 1949 to 2018 and identified areas of erosion and accretion. Overall, the coastline in most places appears to have been stable for 70 years. In some places it has eroded. This understanding of how a coast operates over time also forms part of the baseline understanding. In the future, we can use newly acquired aerial photographs to compare shoreline position in the future and use various techniques to monitor sand volumes (see also Main Report).

Figure: In a digital environment, software tools can be utilised to compare coastal change (Source: Aerometrex)

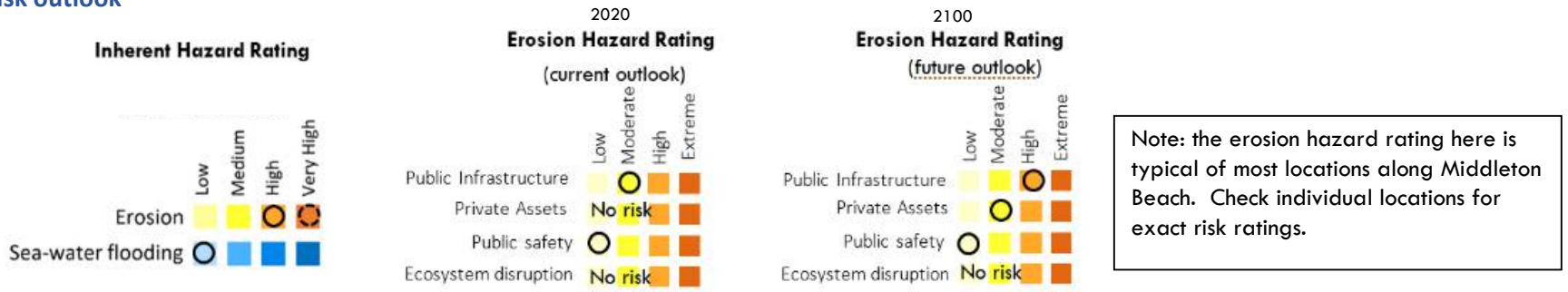


Integrated Coasts (2017)

Adaptation proposals: Middleton Beach (Cell SF5)

Coastal processes	Middleton Beach marks the beginning of the long dissipative beach that stretches eastward to Cape Jaffa. This is a high energy beach with backshores varying from low-height dunes, to soft rock cliffs. The inherent hazard risk rating is categorised as 'high' to 'very high'. Historical comparisons showed that between 1949 and 2006 the shoreline has retreated 10-12m in places, but since 2006 the shoreline has showed signs of accretion. Most of the shoreline is in a similar position as that of 1949. Further research is required to ascertain the likely impact on the dune system on the border of SF4 – SF5.

Risk outlook



Note: the erosion hazard rating here is typical of most locations along Middleton Beach. Check individual locations for exact risk ratings.

Adaptation overview:

The long-term strategy for Middleton Beach is 'managed retreat' if seas rise as projected. Erosion assessment in neighbouring cells suggest erosion of ~100m by 2100 but in this cell, this rate will depend on the nature of the backshore (which varies in this cell). Carparks and associated infrastructure are currently set at varying distances from the shoreline. The overarching aim is that these should be repositioned / reconfigured so that they are further away from the shoreline. On occasion, **short term protection** options may be required to protect carparks, but these should be cost-effective and only used as **an interim measure** while longer term relocation of infrastructure can be achieved. **Further research** is required to ascertain the likelihood that sea level rise in the latter part of this century may erode the lower and narrower dunes in SF4 (bordering SF5) and whether inland inundation may result that could impact infrastructure and the ecosystem.

Adaptation proposals:

	Approach	Short term strategy 2020	Mid-term strategy 2050	Long term strategy 2100	Adaptation Type	Monitoring strategy
Middleton Beach Cell SF5	Incremental [monitor and respond] Further research required at cell border SF4-SF5	Monitor [Also upgrade storm water infrastructure at Chapman Rd]	Monitor [relocate carparks as upgrades are required, interim protection may be required]	Managed retreat [carparks and associated infrastructure relocated/ reconfigured]	Engineering: Storm water, relocate or reconfigure carparks. Environmental: Interim protection works as required (ie sandbags)	Shoreline position, Storm impacts on backshore, sand volumes

Engineering works for Middleton Beach

Magryn Engineering provided preliminary design and costing for:

- Reconfiguration of storm water outflow to beach at Chapman Road (including detention pond)
- Collapse overhanging section of cliff and install protection to carpark at Skye Ave carpark (not pictured)

CHAPMAN ROAD CARPARK – MIDDLETON

CONCEPT ONLY
IT MUST NOT BE USED FOR CONSTRUCTION.

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C/– INTEGRATED COASTS
COASTAL ADAPTION STRATEGY
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PLAN
A3 18084–19 A