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R1918 Rev 2

May 2025

City of Stirling

# Mettams Pool
# Coastal Adaptation Options Assessment

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# Executive Summary

Mettams Pool, located north of Trigg Point within the City of Stirling, has been identified as a coastal hotspot within Western Australia (Seashore 2019). In 2022, the City completed a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP; Cardno) for their extents. This process identified Mettams Pool, along with Watermans Bay, as a high priority site for coastal adaptation and recommended that further detailed investigations and adaptation options assessments be undertaken.

This project has been completed for the Management Unit (MU) of Mettams Pool (MU3) identified in the CHRMAP, which extends from Hamersley St in the north to Bailey St to the south and includes Mettams Pool.

The City, on behalf of a broader Project Working Team (PWT) including the Department of Planning, Lands & Heritage (DPLH) and Department of Transport (DoT) engaged M P Rogers & Associates (MRA) to provide coastal engineering and community and stakeholder engagement services for the development of coastal adaptation options at Mettams Pool. These works were completed along with similar works at Watermans Bay, also identified as a high priority site requiring further investigation.

To consider the input of stakeholders and representatives of the broader community a Mettams and Watermans Reference Group (Reference Group) was established. The Reference Group included 2 Councillors and 6 community representatives to represent the wider community, along with members of the PWT. A series of four workshops was held with the Reference Group, along with a broader series of consultation and feedback as part of the City's ongoing consultation. This enabled stakeholders to provide input and direction into the development of the potential adaptation options for Mettams Pool.

The CHRMAP identified 4 potential coastal adaptation options which were recommended for further detailed investigation and development. These included the following:

- Sand nourishment.
- Seawalls.
- Groynes / Headland enhancements.
- Nearshore breakwaters / reef enhancements.

Each of these adaptation options were considered for managing the coastal erosion risk at Mettams Pool. Option 4; nearshore breakwaters or reefs; was split into two separate options, emergent and submerged structures. The adaptation options were developed and presented to the Reference Group, outlining key advantages, disadvantages and considerations for each.

Options were assessed against the relevant key success criteria from the CHRMAP. This identified that the only adaptation option which met the criteria on its own was sand nourishment. This was primarily due to the need to retain a sandy beach forming a key success criteria. As a result, the options were modified to all include an element of sand nourishment.

A Multi Criteria Analysis (MCA) was developed to evaluate the potential adaptation options, based on a range of relevant technical, social, environmental and economic criteria. This process is useful for assessing multiple, often conflicting, decision making criteria and identifying a preferred option with the highest score. The criteria were related to the key success criteria for the project.

Based on the MCA completed for the concept adaptation options, the highest ranking option was sand nourishment. It was recommended that this option is further evaluated for progression to future design phases.

To progress the sand nourishment option, a number of further considerations are required. Firstly, further investigation is required to assess sand sources. The City is currently assessing potential offshore sand sources which may offer benefit in providing large quantities of sand at a reduced cost. These investigations should be continued. Depending on the source of sand, approvals processes of up to 1-2 years may be required for new sites. As a result, the City's current short term nourishment activities are appropriate to continue.

The outcomes of this project and the recommendations made are based on the currently available information, including the stakeholder values, understanding of coastal processes and particularly the adopted success criteria from the CHRMAP. Should these change in the future, the MCA can be revisited to determine the highest ranking and preferred adaptation approach.

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# 1. Introduction

Following a series of severe weather events in 2009 that put at risk critical landward infrastructure, the City of Stirling (City) commenced investigations and studies on their coastal processes to provide them with relevant information for long term solutions.

In 2019, Watermans Bay and Mettams Pool were identified as coastal erosion hotspots in the Assessment of Coastal Erosion Hotspots in Western Australia prepared for the Department of Planning, Lands and Heritage (DPLH) and the Department of Transport (DoT) by Seashore Engineering (Seashore, 2019).

To clarify the risks to the coastal assets, the City engaged Cardno (WA) Pty Ltd (Cardno) to complete a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) consistent with the requirements of the State Planning Policy 2.6, the State Coastal Planning Policy (SPP2.6; WAPC,2013).

Cardno (2022a to 2022e), found that Watermans Bay (MU1) and Mettams Pool (MU3) required further investigation in the immediate term and, depending on the outcomes, active management in the short term.

Given the similarities between the two locations, the City has now engaged M P Rogers & Associates Pty Ltd (MRA) to complete a coastal adaptation options assessment for both locations. The desire is to build on the existing works completed and develop unique and individual concept adaptation options for each location.

The scope of the works includes the following.

- Review the existing site conditions, sediment transport, wave climate and locations of existing infrastructure.
- Develop conceptual models to describe the relationship between coastal processes, existing structures, sediment transport and their effects on beach morphology and coastal movement at Watermans Bay and Mettams Pool.
- Using the knowledge obtained from the above, review and refine the adaptation options shortlisted in the City's CHRMAP. This includes 'soft' and 'hard' engineering options or a combination of both.
- Present refined adaptation options for both Watermans Bay and Mettams Pool to the community and stakeholders and undertake a Multi-Criteria Analysis (MCA) to select a single concept for each site for development in the detailed design phase.

This report presents a summary of the outcomes and recommendations of the adaptation options assessment prepared for **Mettams Pool**.


**Figure 1.1 Location of the Site**

# 2. Site Setting & Knowledge Summary

## 2.1 General

The City is responsible for 6.5 km of coastline, extending from Watermans Bay in the north to Peasholm Beach in the south. This report specifically relates to Mettams Pool, located in the northern parts of the City's municipal boundary. The following sections will review both locations in the context of:

- Site settings.
- Met-ocean (meteorological and oceanographic) conditions.
- Previous studies.

## 2.2 Site Settings

Mettams Pool is located in the Marmion Marine Park, which extends from Burn Rocks in the north, Trigg Point to the south and seaward from highwater mark. This may affect the approval process for any in-water works at the sites.

### 2.2.1 Mettams Pool

As defined in the City's CHRMAP, Mettams Pool extends from Hamersley St in the north to Bailey St in the south.

Short (2006) states that the beach is approximately 600 m in length. The "pool" is located at the southern end where it is protected by calcarenite reefs. The beach is backed by a vegetation bluff fronted by a 50-100 m wide reef platform that generates the irregularities in the shoreline (Figure 2.1).

The following is noted at Mettams Pool:

- The beach area to the north is open to ocean influences.
- Parts of the beach are defined as a perched beach (the areas to the south).
- It is embayed by limestone headlands.

Mettams Pool has a relatively large catchment area (Eliot et al., 2005). The beach attracts a large number of visitors from the northern corridor suburbs, but also from eastern and southern suburbs.

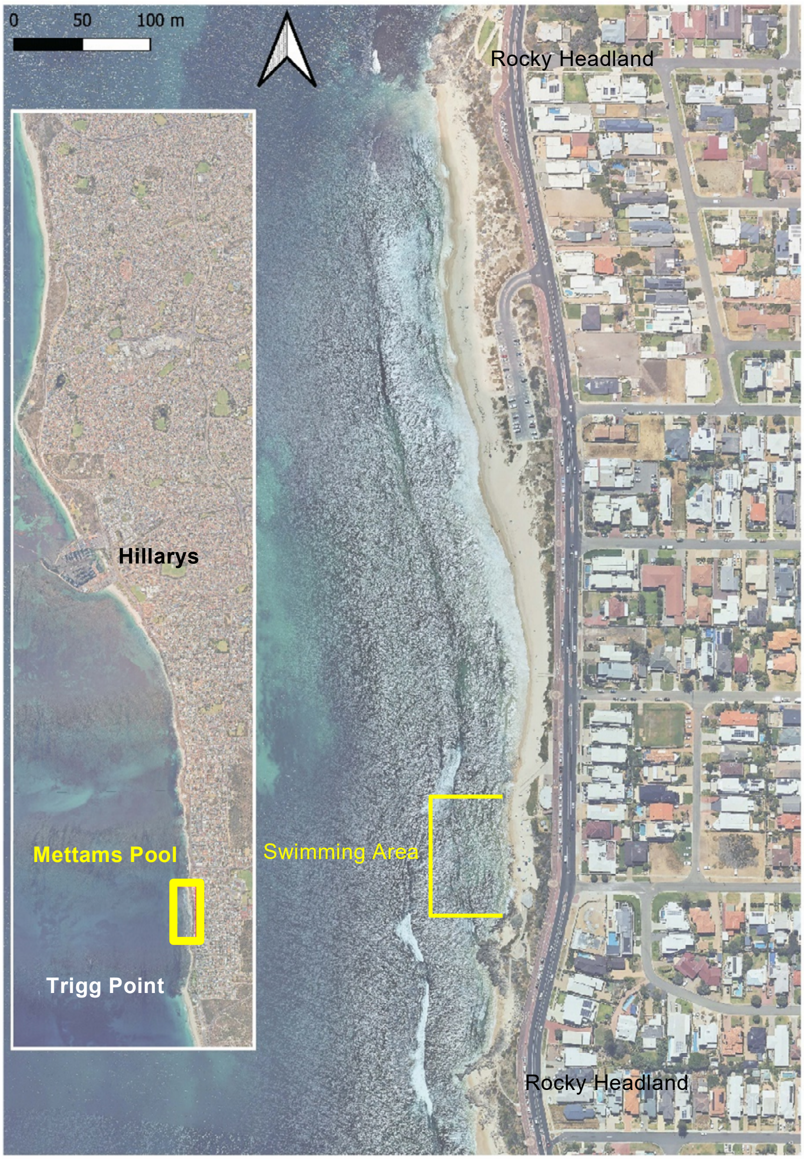



**Figure 2.1 Mettams Pool**

Mettams Pool includes several built and natural assets. Some of the key built infrastructure includes:

- West Coast Drive (WCD).
- Recreational Shared Pathway (RSP).
- Gazebo and Water Access Ramp.
- Beach Access Ramp and Geosynthetic Sand Container (GSC) seawall.
- Toilet block and viewing platform.

An oblique aerial of the site, taken in February 2022 is presented in Figure 2.2. The figure shows a significant amount of rock platform exposed at the southern end of the beach which is evident of post summer conditions. The photograph below was taken during the early hours of the morning therefore does not depict the number of users the beach attracts.  Community groups using the beach includes swimmers, sunbakers, walkers, surfers and windsurfers.

**Figure 2.2 Mettams Pool – Oblique Aerial Photograph (February 2022)**

Photographs showing the typical summer beach conditions at Mettams Pool are presented in Figures 2.3 and 2.4.  These show the wider beach prevalent in summer, the occasional appearance of the calcarenite reef at the waterline, GSC seawall protecting the access ramp and sections of vegetated dune.

**Figure 2.3 Northern Section of Mettams Pool Beach (January 2024)**

**Figure 2.4 Southern Section of Mettams Pool Beach (January 2024)**

Photographs showing the typical winter beach conditions at Mettams Pool are presented in Figures 2.5 and 2.6. These show the narrower and steeper beach prevalent in winter, more pronounced calcarenite reef at and above the waterline, and a scarp at the base of the foredune.

**Figure 2.5 Northern Section of Mettams Pool Beach (March 2023)**

**Figure 2.6 Southern Section of Mettams Pool Beach (March 2023)**

## 2.3 Met-Ocean Climate

Met-ocean refers to the combined meteorological and oceanographic conditions such as wind, wave and water levels found at a particular location. Met-ocean conditions vary spatially and temporally depending on factors such as weather patterns, bathymetry and directional exposure.

### 2.3.1 Regional Wind Climate

The regional wind climate is intrinsically linked to regional and local wave conditions relevant to the site. The wind regime influences coastal processes through the generation of waves and currents as well as feeding dune systems with wind-blown beach sand. Hence, an understanding of the Perth wind climate is required to understand wave and sediment dynamics that can be expected seasonally and during different meteorological events.

During the summer months, the local meteorological conditions are determined by the interaction of the diurnal sea / land-breeze cycle with the larger regional scale weather patterns. The most important of these is the Subtropical High-Pressure Belt – a series of discrete high-pressure cells (anticyclones) which encircles the Earth at mid-latitudes (20 to 40 degrees), continuously moving from west to east. A notional line joining the centres of these cells is known as the High-Pressure Ridge. During summer, the High-Pressure Ridge lies between 35 and 40°S, and hence strongly influences the weather of the coastal waters along the City's shoreline. Each high-pressure cell generates anti-cyclonic winds that rotate anti-clockwise in the Southern Hemisphere. These winds blow from the south-east as a high-pressure cell approaches from the west, and then rotate through east and north-east to north as the high-pressure cell passes through to the Great Australian Bight. This is illustrated in the figure below.

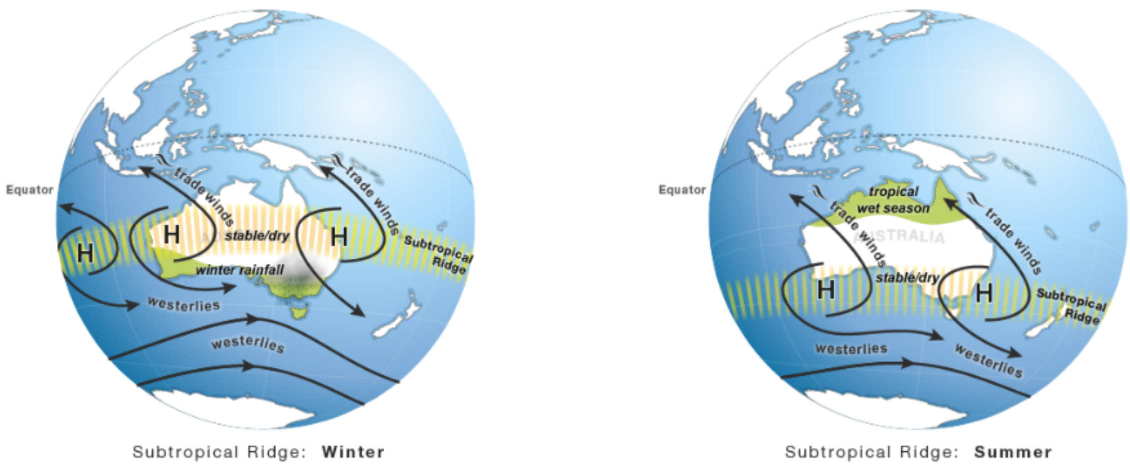
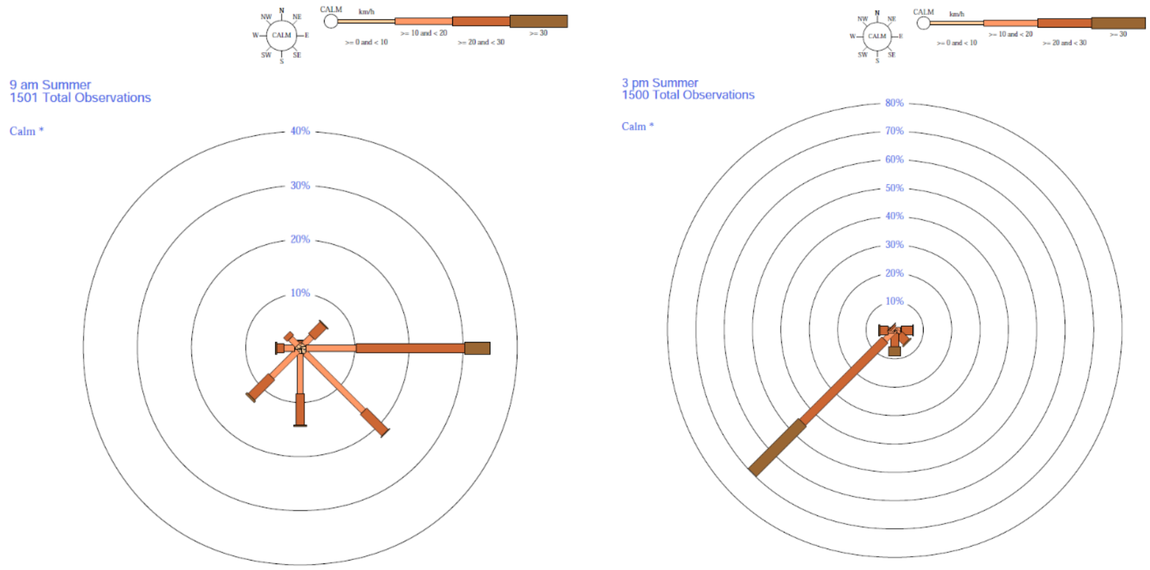



**Figure 2.7 Seasonal Changes of Subtropical Ridge (Bureau of Meteorology, BoM, 2017)**

Superimposed on the regional scale weather patterns is the land and sea-breeze mechanism. During a typical summer day, the land heats up at a significantly faster rate than the adjacent ocean. This causes the air above the land to become warmer and less dense relative to that over the water. A pressure gradient in the atmosphere between the ocean and the land results, causing an onshore wind to develop. The onset of the sea-breeze is usually just around noon, although this can vary. Over the course of the afternoon, the wind typically becomes stronger, as the land continues to heat up, and swings to a more southerly direction. The maximum wind strength is usually reached in the hour or so just prior to sunset, after which the winds steadily drop.

During the night, when the land becomes cooler than the ocean surface, a land-breeze may occur, particularly if the sky is clear. The mechanism of wind generation is analogous to that of the day-time sea-breeze, except that the atmospheric pressure gradient is in the opposite direction, and hence the winds are offshore. Land-breezes are typically much weaker than sea-breezes. A swing in direction of the wind from the south through south-east to east throughout the course of the night following a sea-breeze is frequently observed. This is largely due to the weakening of the sea-breeze and the resurging dominance of the regional scale high pressure systems described previously.

Near Fremantle, the sea breeze regularly reaches 20 to 25 knots during the summer months and typically blows from the south to south west. This is shown in the following 9am and 3pm wind roses taken from Swanbourne for the month of January. The winds at Mettams Pool are considered comparable to those at Swanbourne.




## Figure 2.8 Summer Wind Climate at Swanbourne (BoM)

Occasionally in summer, dissipating tropical cyclones may pass through the region. These have a pronounced, short term effect on the regional weather patterns.

### 2.3.2 Regional Wave Climate

An understanding of the regional wave climate is required to assess local wave and sediment dynamics. The Rottnest wave buoy is one of the longest directional and non-directional wave records in WA. Assessment of this dataset provides an insight into the wave trends and characteristics of the Perth coastal region.

The south-west coast of Australia has one of the most energetic wave climates of the continent. The Perth Metropolitan coast is located at the south-western margin of the Australian Continental Shelf. High energy and long period swell waves from the Indian and Southern Oceans arrive at the edge of the continental shelf (west of Rottnest Island) without any obstructions resulting in energetic wave conditions along the Perth coast (Hemer et al. 2007).

MRA (2018a) completed a regional assessment of wave climatology at a number of locations throughout south-west WA, including the Perth coastal region utilising wave data from the Rottnest wave buoy. The results showed that the locally generated waves (sea waves) that develop in response to the summer wind pattern are almost entirely from the south-west quadrant, as winds from easterly directions lack the fetch from the mainland to generate waves of significant magnitude. This is evidenced by the results showing average total significant wave heights in summer months of around 1.7 – 1.8 m whilst locally generated waves have an average peak direction of around 220-225$^{o}$.

Predictably, in winter, the average significant wave height is greater than other parts of the year. Average total significant wave heights during winter months vary at around 2.5 – 2.8 m. Directions of locally generated waves are more westerly than in summer (~255$^{o}$) with greater standard deviation observed. This reflects the more westerly wind conditions experienced in winter as well as the large swing in wave and wind conditions from north-east through to south-west that often occur during winter storms.

### 2.3.3 Local Wave Climate

As the offshore waves travel toward the shore, they are greatly affected by the nearshore bathymetry and the reefs. Waves travelling to the shoreline of Mettams Pool are modified by the following physical processes.

- Reflection off the reef faces.
- Depth limited breaking on the reef tops, banks and other shallow areas.
- Diffraction through the gaps in the reefs.
- Attenuation due to hydraulic turbulence and bottom friction as the waves travel over the reefs and other areas of shallow water.
- Refraction and shoaling.

These processes act to varying degrees and significantly modify and attenuate the waves as they approach the coast. The reefs and nearshore bathymetry provide significant protection from the offshore waves. The resultant waves that break on the beach are critical mechanism in the transport of sand in the littoral zone at the sites.

### 2.3.4 Water Levels

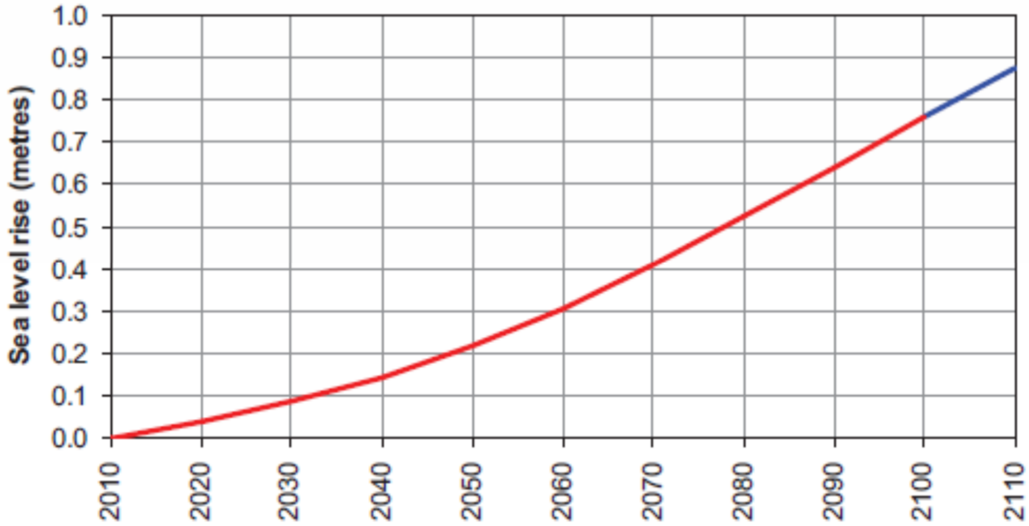
Water levels fluctuate on varying timescales as a result of astronomical, meteorological and hydrological effects.

The astronomical tides along the Perth Metropolitan coastline are predominantly diurnal (one tidal cycle each day) and relatively small in amplitude. The daily range is typically about 1.0 metre during spring tides and less than 0.3 metre during neap tides.

Seasonal shifts in the sea level occur due to meteorological and oceanographic effects. Typically, the mean sea level in the southwest of Australia rises 0.1 metre during winter and falls 0.1 metre during summer.

During storm events (both winter storms and cyclones) barometric and wind effects can cause significant storm surges. In rare storms, the surge can exceed 1 metre above the astronomical tide level. In winter storms, the storm surge often reaches 0.4 metres.

Sea level rise results in an increase in mean sea level which must be allowed for in coastal planning and design. It is considered by superposition of an allowance on all design water levels over the relevant planning horizon.  The magnitude of this allowance has been determined in accordance with information published by the DoT relating to the appropriate allowance for sea level rise in Western Australia (DoT, 2010).  A plot showing the recommended allowance is provided in the following figure.




## Figure 2.9 Recommended Sea Level Rise Allowance (DoT, 2010)

Changes in water levels can affect coastal processes in several ways.  Higher water levels can allow more wave energy to pass over the nearshore reef systems and reach the shoreline.  Water levels can also change the level at which waves can impact the beach.

### 2.3.5 Available Data & Measurements

On the Western Australian coastline, the DoT and BoM has historically collected the majority of publicly available metocean data.  Available metocean data collected along the Perth Metropolitan coastline includes waves, water levels and winds.

Key current measurement stations and locations are indicated in Figure 2.10 and include the following:

- Waves south west of Rottnest Island and at Cottesloe.
- Water levels at Fremantle and Barrack St, Perth.
- Winds at Ocean Reef, Swanbourne and Rottnest Island.

There are other stations and datasets which have historically been used, including wave measurements at Ocean Reef and Fremantle and tides at Hillarys Boat Harbour (HBH).  However, these are generally shorter term or temporary records.

The DoT also installed a measurement device offshore from Mettams Pool.  The device measured wind, wave and current data between the period of 10 May to 7 December 2022 (Figure 2.10).  This is only a short term / temporary record, however, can be used to review and validate data closer to the coast.

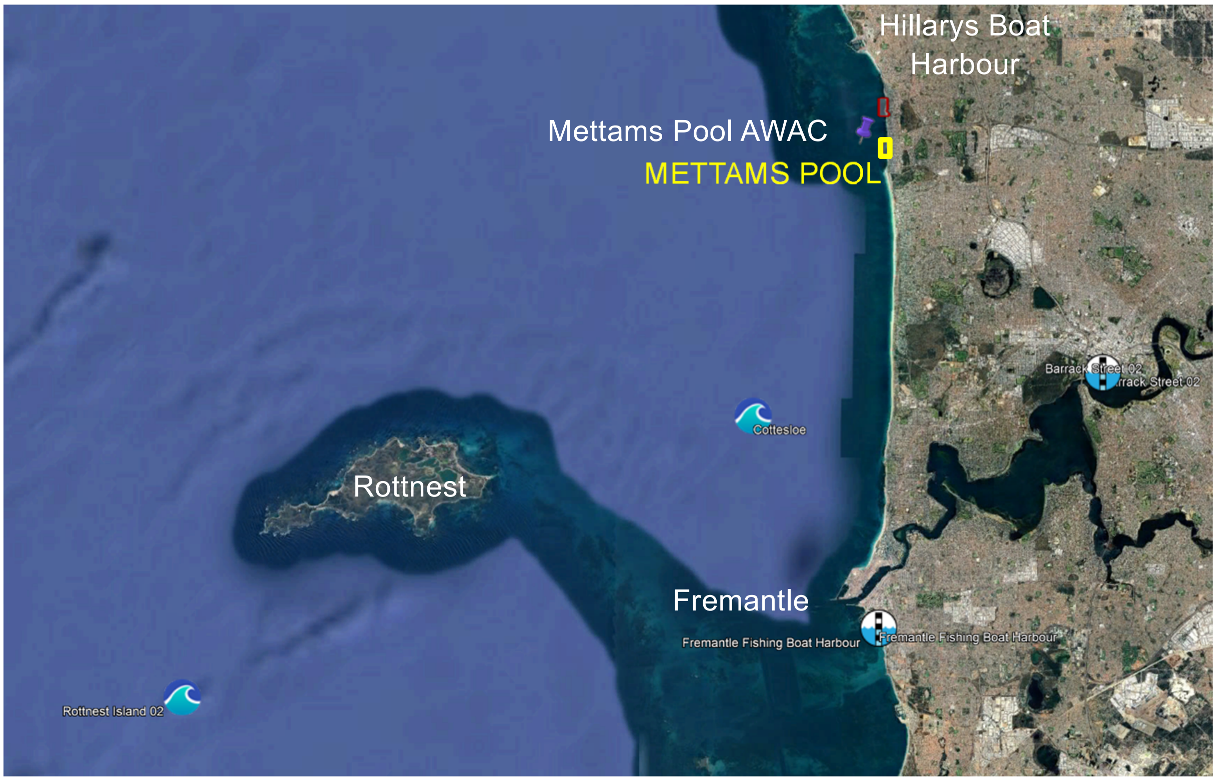



**Figure 2.10 Key Metocean Measurement Stations**

### 2.3.6 Frequency of Events

As wave conditions are the key driver of sediment transport, the number of key wave events experienced has a large impact on shoreline change. MRA has previously assessed and described the key wave events critical for sediment transport on the Perth Metropolitan coastline (MRA 1997). The relative occurrence of these key events in a year can influence sediment transport and beach widths or observed erosion / accretion. For instance, a large number of sea breeze events, which transport sand from south to north, can result in narrower beaches on the north side of structures or headland features. Conversely, a large number of winter storm events, which typically transport sand to the south, can place erosive pressure on sites reliant on northerly feed.

A description of the key wave events and the criteria used to determine the occurrence of each are provided in Table 2.1.

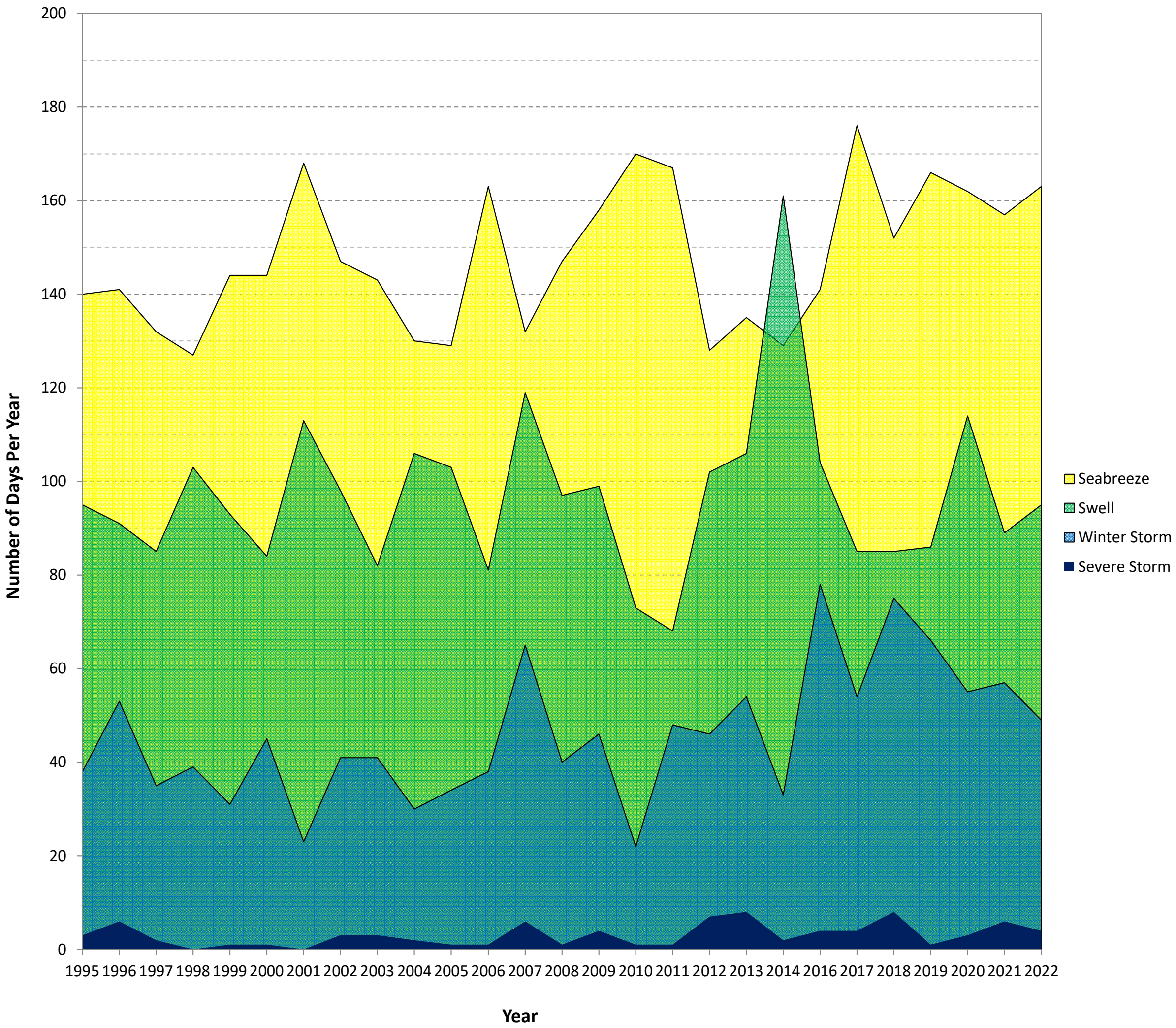
MRA has analysed wave conditions from the Rottnest wave buoy to determine the relative frequency of key events each year. Figure 2.11 provides a summary of the frequency of events for sea breezes, swells, winter and severe storms between 1995 and 2022.

### Table 2.1 Overview of Wave Event Type & Occurrence Characteristics

| Event | Characteristics |
|---|---|
| Severe Storm<br><br>Severe storms events are generated by passing cold fronts or dissipating tropical cyclones that occasionally pass through the region in late summer. These events are similar in nature although more severe than typical winter storms. | Significant Wave Height ($H_s$) > 6 m, with a strong "sea" component<br><br>Wind Speed ~ 60 knots<br><br>Wind Direction - originating from the north to northwest and swinging to the southwest |
| Moderate Storm<br><br>Moderate storms are generated locally by the passage of cold fronts, typically in winter, and vary significantly in wave height and period from storm to storm. Wave heights often exceed 4 metres, with periods ranging from 6 to 10 seconds. The direction of approach for these storm waves typically ranges from northwest to southwest over the course of the storm's passage. | $H_s$ > 3 m with a strong "sea" component<br><br>Wind Speed ~ 40 knots<br><br>Wind Direction - originating from the north to northwest and swinging to the southwest |
| Swell<br><br>Swell waves are generated by distant storms in the Southern Indian Ocean and continually reaches the offshore area throughout the year. During summer, swell typically ranges from 1 to 2 metres, with periods ranging from 8 to 16 seconds, generally approaching from the west to southwest. In winter, swell typically ranges from 1 to 3 metres, with periods ranging from 10 to 20 seconds, generally approaching from almost due west. | $H_s$ > 2 m, with a strong "swell" component<br><br>Peak Wave Period ($T_p$) > 8 seconds |
| Sea Breeze<br><br>Sea breezes are generated by the land and sea breeze system and are most prevalent during summer. The formation of these waves is limited by the duration and offshore extent of the sea breeze system. Typically, wave heights range from 0.5 to 1.5 metres, with periods ranging from 3 to 6 seconds. These waves generally approach from the east in the morning and from the south to west in the afternoon. | $H_s$ < 2 m<br><br>$T_p$ < 8 to 10 seconds<br><br>Wind Direction - generally from the east in the morning, swinging south to west in the afternoon |

Note:

1. Wave occurrences are determined in individual days, not events.




### Figure 2.11 Frequency of Key Wave Events from 1995 to 2022

The figure shows that there can be significant interannual variability key wave events and therefore sediment transport. This needs to be considered in assessments of “typical” years or overall sediment transport.

## 2.4 Geology & Geomorphology

The geology and geomorphology of the City’s coastline and the greater Perth Metropolitan coastline is described in detail by Searle & Semeniuk (1985). The current shoreline lies on the Swan Coastal Plain, and generally comprises of Holocene beach and dune sediment deposits overlying late Pleistocene, calcarenite limestone. These formations are the dominant landforms along the coast (Searle & Semeniuk, 1985).

Searle & Semeniuk (1985) broadly classified the coast into a number of sectors. The section of the City’s shoreline from Wembley Downs to Trigg Point lies at the northern end of the Cape Bouvard to Trigg Island sector, which the authors describe as extensive but discrete cells of Holocene sediment accretion. The coast in this sector is generally characterised by long predominantly straight sandy beaches.

The section of shoreline north of Trigg Point lies at the southern end of the Whitfords to Lancelin sector, which the authors describe as a dominantly straight rocky shore with isolated accretionary cusps. The coast in this sector is generally characterised by rocky coasts and pocket beaches interspersed with straight sandy beaches (Searle & Semeniuk, 1985).

This general characterisation of the sector is represented across the study area, with sandy beach and dune systems to the south and limestone cliffs, headlands and nearshore reef platforms north of Trigg.

The indicative geology of the Perth Metropolitan area is presented in Jones et al (2005). An extract of this geology around the study area is presented in Figure 2.12.

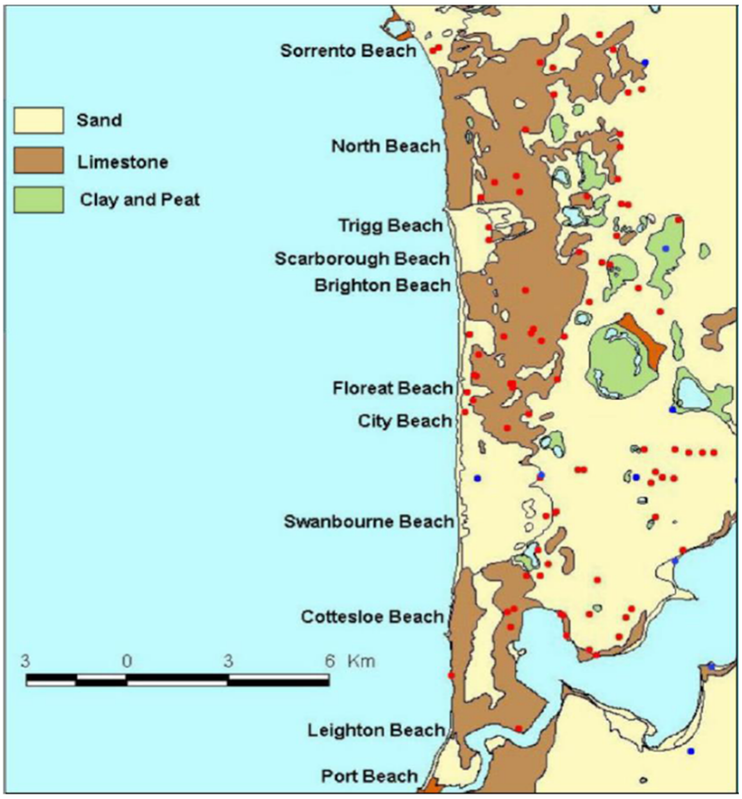



**Figure 2.12 Geology of the Sites (from Jones et al, 2005)**

The figure also suggests that:

- There may be some underlying limestone rock through sections of Brighton and Scarborough.
- Scarborough and Trigg are predominantly sandy.
- North of Trigg the coastline predominantly consists of exposed or underlying limestone rock.

Oblique aerial photographs of the City's shoreline are presented in Figures 2.13 and 2.14. It is noted that these photographs are from 2010 and there have been changes to the shoreline, and development in the area, since this time. However, they provide a useful distinction between the sections of predominantly sandy and rocky shorelines within the City.

**Figure 2.13 General Sandy Shoreline from Scarborough to Trigg**

**Figure 2.14 General Rocky Shoreline North of Trigg**

As part of a previous shoreline classification for the Perth Metropolitan area, the DPLH and DoT classified the shorelines as sandy or rocky. The rock is Tamala limestone, which can offer significant protection from coastal erosion. This is the same material present on the rocky shorelines of Cottesloe and Halls Head, Mandurah. In Mandurah, surveys of the rocky cliffs from early last century indicate there has been less than 5 m movement of the cliffs in over 100 years. This shows that competent limestone, at appropriate levels, can provide protection and withstand the erosive effects of the ocean.

## 2.5 Local Bathymetry & Coastal Topography

The bathymetry of the study area is generally characterised by a gentle slope from the beach out to around -10 mCD followed by a flatter area with relatively gradual changes in depth. Beginning at Trigg Island, a system of offshore reefs emerges, becoming progressively shallower and more prominent as they extend northward. These reefs appear to delineate the western boundary of the flatter offshore areas in the northern half of the study area.

For context, CD refers to Chart Datum, which is the reference plane to which charted depths and drying heights are often related (Australia Government, 2024). It represents a level so low that the tide rarely falls below it and as a result is often used in nautical charts. Chart Datum is typically defined by a low-water level, such as Lowest Astronomical Tide (LAT) or Indian Spring Low Water (ISLW), and is usually referenced to a specific port or harbour, such as the Fremantle Fishing Boat Harbour (FFBH). At FFBH, Chart Datum is 0.77 metres below Australian Height Datum (AHD). AHD is the official national vertical datum for Australia.

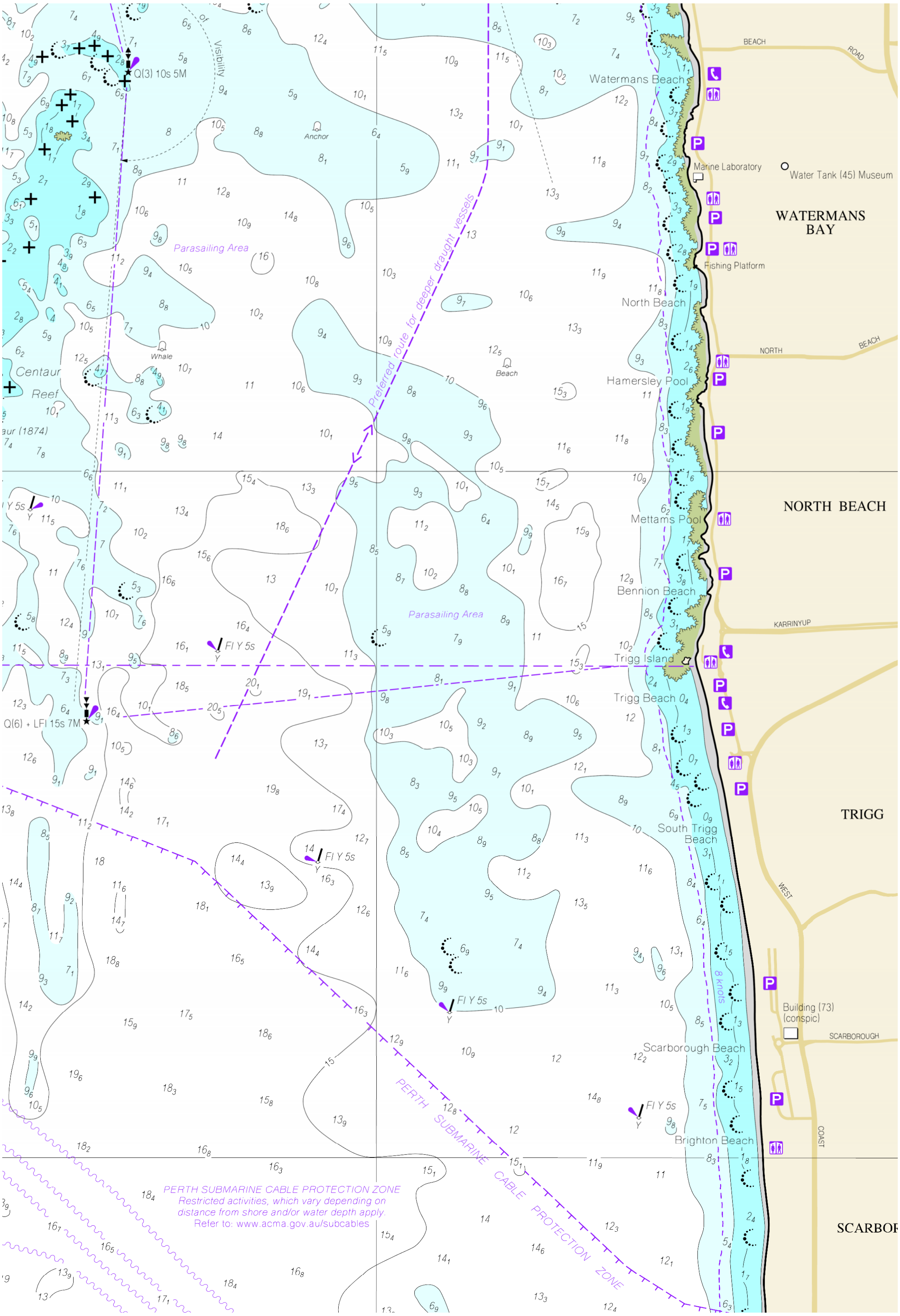



**Figure 2.15 Bathymetry (excerpt from Nautical Chart WA 957)**

## 2.6 Previous Studies

Numerous studies and investigations have previously been completed for the shoreline encompassing Mettams Pool. Several of these, relevant to this project, are summarised below to provide context to later sections of this report.

### 2.6.1 Coastal Processes

#### Watermans Bay & Mettams Pool Coastal Investigations (MRA, 2010)

In 2010, the City engaged MRA to complete a coastal assessment of the dynamics at Watermans Bay and Mettams Pool. The coastal assessment included:

- A review of the fundamental driving forces in the area, including waves, water levels, currents and coastal processes.
- A review of the coastal structures and recent coastal works in the area.
- A review of historical shoreline movement at the two beaches.
- Identifying possible causes of the recent shoreline erosion at the two beaches.
- Investigation of options to minimise and/or manage the erosion experienced at the two beaches.

Based on this investigation, the following issues and management measures for Mettams Pool were identified.

- There was a reasonable buffer to the toilet block, RSP and WCD at that time. However, it was recommended the long term risks are assessed, including investigation of underlying rock levels at the site.
- It was recommended the City monitor the beach and endeavour to determine the underlying rock levels to make a responsible assessment of the likely impacts of future climate change.

#### Strategic Coastal Processes Study (BMT JFA, 2016)

In 2013, the City engaged BMT JFA to undertake a Strategic Coastal Processes Study. The purpose of this was to develop an understanding of the coastal processes impacting 6.5 km of the City's shoreline. To achieve this, BMT JFA collated and reviewed the following information:

- Available Literature.
- Survey, LIDAR & LADS bathymetric and topographic information.
- Aerial photography to 2013.

Based on a review of the available literature, it was noted that the beaches within the city adhered to the following characteristics.

- The beaches from Fremantle to Trigg form an almost self-contained sediment compartment with net northward transport, displaying seasonally oscillatory alongshore transport within internal cells (Masselink and Pattiaratchi, 2001).
- Given the persistent weather systems and sea breeze activity there is a net northward longshore sediment transport in summer driven by persistent sea breeze and net southward

longshore sediment transport in winter from the northwest and west-northwesterly swells. The net movement north during summer is considered greater than that observed in winter, resulting in a northward bias (Masselink and Pattiaratchi, 2001).

- In the vicinity of coastal structures or natural headlands, the seasonal variation in littoral drift direction induces a seasonal cycle of beach change that is different from the classic transition from summer to winter profile. During summer, a beach located south of an obstacle becomes progressively wider due to the accumulation of sediment against the obstacle. At the same time, the beach located north of the obstacle becomes narrower; and the opposite will occur during winter.

BMT JFA's assessment of aerial photography involved the preparation of a shoreline movement plan from 1953 to 2013. Trends in key areas of interest, including Mettams Pool, were summarised in the study. The following trends were noted:

- Little change in net movement, equating to approximately 5 m, was experienced between 1965 and 2013.

- There appeared to be a small erosional trend across the site. However, it was noted that the net movements were considered to be within the margin of error of shoreline mapping.

Following a review of available information, a first pass assessment of the potential hazard zone was undertaken. It is important to note that this was not a detailed assessment. The assessment, undertaken over a large scale, was the first step in identifying areas which may be vulnerable to coastal hazards over various planning horizons.

Preliminary estimates of the factors that contribute to coastal hazards were provided to allow a first pass assessment of the 6.5 km of shoreline. These factors provided a preliminary estimate of the coastal erosion hazard zone of 170 m over a 100-year planning horizon. This allowed for the identification of a number of sites that may be vulnerable to coastal erosion over this horizon.

Through this process, Watermans Bay and Mettams Pool were identified as potential 'hot spots' which may be vulnerable to coastal hazards. As shown in the figure below, the 170 m coastal erosion hazard zone indicates that important infrastructure such as the RSP and WCD may be vulnerable to coastal hazards over a 100-year planning horizon.

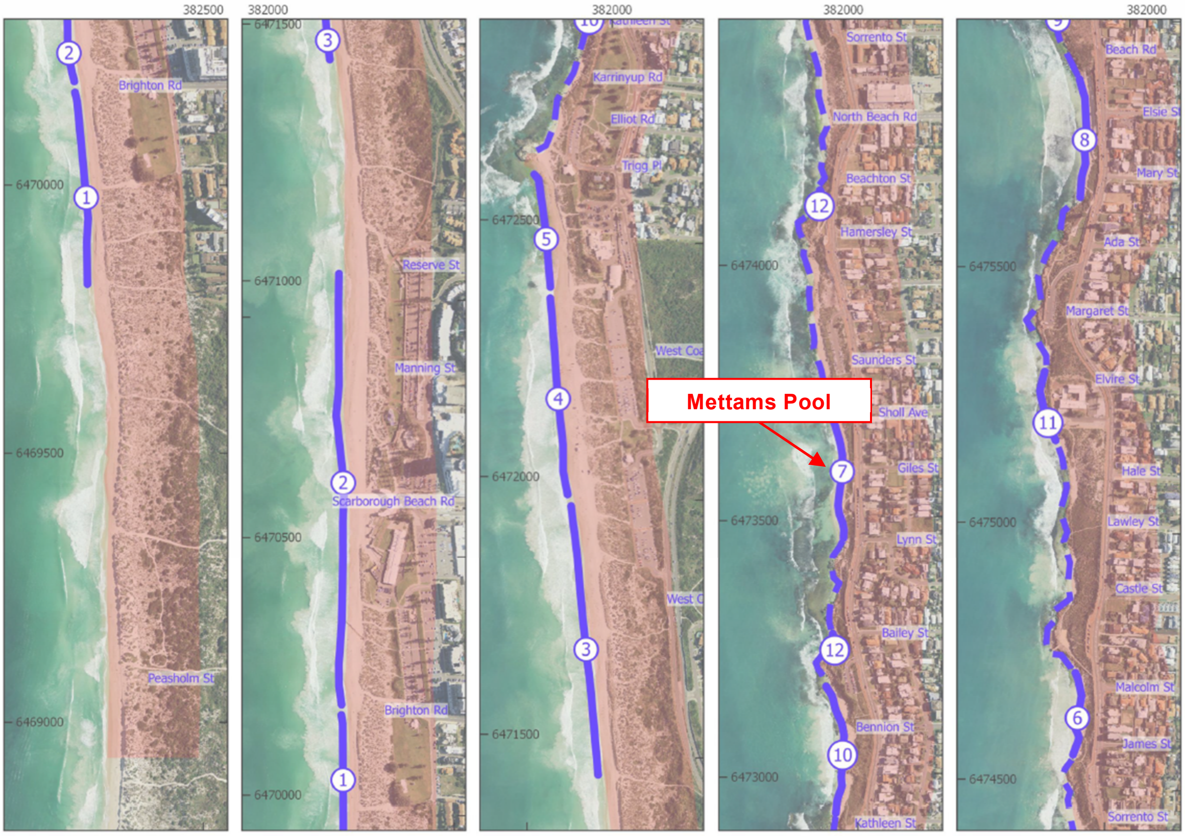



**Figure 2.16 Coastal Erosion Vulnerability based on 170 m Coastal Erosion Hazard Zone (BMT JFA 2016)**

The coastal erosion hazard zone above was prepared based on high level estimates useful for initial identification of 'hot spots' or high-risk areas. However, limited site-specific information was utilised and therefore further site-specific analysis and modelling is required to define these risks and allow preparation of adaptation strategies.

### Mettams Pool Defensive Works – Concept Design Report (MRA, 2020)

In 2020, MRA were engaged by the City to provide the following:

- Three conceptual designs to protect the City's assets at Mettams Pool that were presented at a community forum to allow selection of a preferred option.
- Development of the City's preferred option to 15% concept design to allow preparation of construction cost estimates and development of a preliminary construction method for the works.
- Upon finalisation of the 15% concept design advise the City on potential funding for:
  - Short term sand nourishment and associated adaptation works at key access locations to prolong the useful life of the existing assets; and
  - Continued completion of the City wide CHRMAP, including Mettams Pool, which will provide further justification for any adaptation works in this location.

To determine those assets at risk, a coastal erosion hazard assessment was completed for Mettams Pool in accordance with State Planning Policy 2.6: State Coastal Planning Policy (SPP2.6; WAPC 2013).

Figure 2.17 illustrates the coastal erosion hazard lines, with consideration of the HSD and the locations of competent rock. The figure shows that at Mettams Pool:

- At some locations, WCD is at risk of undercutting due to erosion during the 100 year ARI event.
- Across the majority of the site, WCD is within the coastal erosion hazard zone for the 25-year (and greater) planning horizons.
- Where there is a lack of competent rock, residential lots at the rear of WCD are within the coastal erosion hazard zone for the 25-year (and greater) planning horizons.

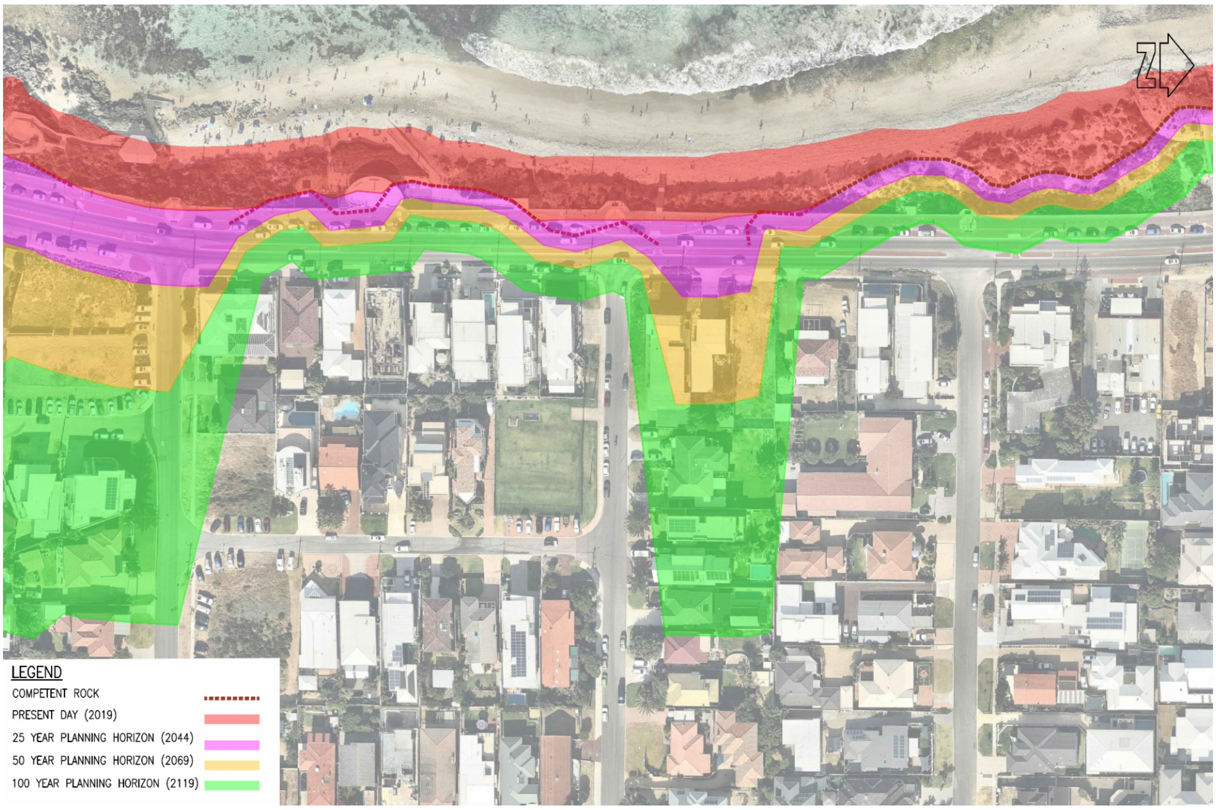
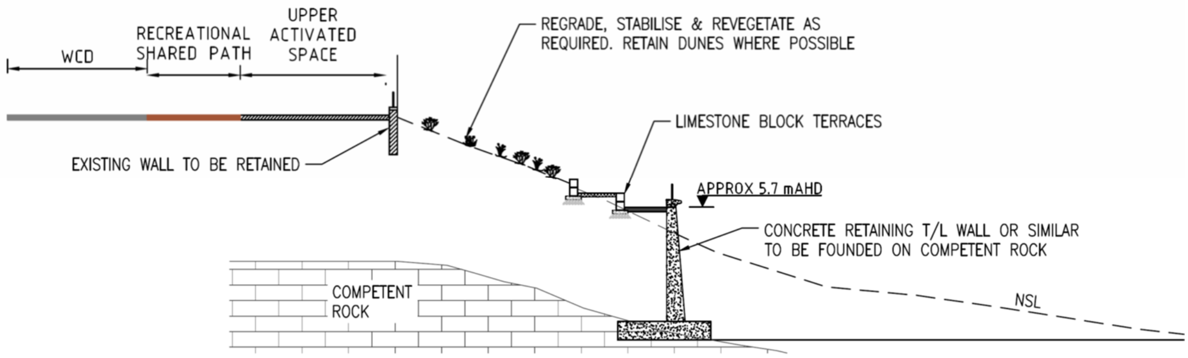



**Figure 2.17 Mettams Pool Coastal Erosion Hazard Zones**

Using this information, three conceptual designs were developed. The preferred adaptation option was determined to be “Option 2 – Over Activated Space”, shown in Figure 2.18. The design established a larger lower level recreational space that could be used in the future even once the existing sand / dune system is lost. The lower level recreational space and relocated facilities would be founded on competent rock ‘future proofing’ them against ongoing shoreline change.

Inclusive of contingency allowances (50% and 90% confidence probability of not being exceeded), the cost of the preferred option was estimated to be approximately $5.4 million.




## Figure 2.18 Option 2 – Typical Cross Section

The community was presented with all adaptation options, and they strongly opposed a rock revetment to protect Mettams Pool infrastructure from coastal erosion. Instead, they preferred a vertical seawall that minimised impact on foreshore amenity. While Option 2 was favoured at the time, the assessment did not comprehensively evaluate all potential coastal adaptation options.

### Trigg to Sorrento Sand Sharing (MRA, 2021a)

In 2021, the City and City of Joondalup engaged MRA to assess the potential viability of sand sharing between Joondalup and Stirling. In particular, the assessment considers the key locations of Sorrento Beach, Whitfords Nodes, Watermans Bay and Mettams Pool, and included:

- Updating the shoreline movement assessment information from Cottesloe to HBH to build a conceptual model of sediment movement.
- Assessing the viability of sand sharing based on potential back passing and bypassing operations. This also considered the natural movements for normal, mild, and stormy years, as well as how much of a sand source currently exists at Sorrento.
- Consideration of constructability, access and other management requirements needed for the potential sand sharing works.

  **Note:** These works did not involve the back passing / bypassing of sand; instead, they investigated the viability of the proposal with respect to logistics, cost, and quantities.

MRA's assessment of shoreline movement used the position of the coastal vegetation line using aerial photography, as it is considered to be a good indicator of shoreline position, generally represents the limit of coastal processes and is less susceptible to short term fluctuations than other markers such as the waterline.

Both the longer term (ie 1942 to 2016) and shorter term (ie 1990 to 2016, since the construction of HBH) shoreline movement trends were assessed. The following items were noted at Mettams Pool:

- For the period between 1990 to 2016, the shoreline experienced recession at a rate of 200 $m^3$/year.
- MRA estimated that in the period between 2016 to 2018, Mettams Pool has lost approximately 4,600 $m^3$/year (MRA, 2020).

- The relative movement of the vegetation lines at Mettams also indicates some episodic erosion, consistent with this rapid change.


**Figure 2.19 Sediment Budget for Watermans Bay & Mettams Pool (MRA, 2021a)**

Following the review of the shoreline movement rates, a short term management strategy was developed which involved extracting sand from Sorrento and back passing / bypassing the sand to Whitfords Nodes, Watermans Bay and Mettams Pool. It was calculated that approximately 53,000 $m^3$ of sand could be sustainably extracted at Sorrento between HBH and the northern most groyne. However, when considering the current volumes required to offset the long term trends at each location, the source of sand at Sorrento may be depleted in 7 years.

### Stirling Coastal Monitoring (MRA 2023 & MRA, 2023a)

A coastal monitoring program has been established for the City's shoreline. The program was established under a Coastal Adaptation and Protection (CAP) Grant from the DoT in 2021 and includes the following elements.

- Beach and hydrographic surveys completed every 6 months, from behind the main dune to several hundred metres offshore. 18 profiles are completed over approximately 7 km.
- Inspections and photographic monitoring of the beaches within the study area every six months.
- Mapping of the shoreline from aerial photographs taken every year.
- Analysis of the monitoring surveys by experienced professional coastal engineers, identifying areas of accretion or erosion.
- A report on the monitoring results and analysis each year, highlighting notable variations in shoreline movements and metocean conditions.

The table below illustrates the frequency of the coastal monitoring activities undertaken for the City's coastline. As outlined in the table, the monitoring activities commenced in March 2022, therefore only limited comparisons can be made.

### Table 2.2 Frequency of Coastal Monitoring Activities

| Activity | Frequency | 2022 | | 2023 | |
|---|---|---|---|---|---|
| | | March | October | March | |
| Beach Profile Surveys | 6 monthly | ✓ | ✓ | ✓ | |
| Shoreline Mapping | Annual | | ✓ | | |
| Photographic Monitoring | 6 Monthly | ✓ | ✓ | ✓ | |

It should be noted that the surveys are notionally completed in October and March every year following winter and summer respectively, the beach profiles have been developed to retain those previously collected and the shoreline mapping is completed by mapping the position of coastal vegetation line using ortho-rectified aerial photography.

Figure 2.20 below illustrates the position of the “0 mAHD Contour or Mean Sea Level (MSL)” and “Vegetation Line” relative to the 2022 baseline. The 0 mAHD contour displays seasonal trends whereas the vegetation line is a longer-term indicator of shoreline change. The following is noted for Mettams Pool:

- The Mettams Pool foreshore has experienced erosion at the 0 mAHD and Vegetation Line over the past year; however, it has not yet reached the 5 m trigger.
- The data collected reflects only one year of changes from the 2022 baseline and may represent seasonal shoreline fluctuations. A longer monitoring period is required to determine whether these trends indicate a long-term shift or are simply seasonal variations.

The Australian Government’s (2024) definition of MSL is “*a tidal datum; the arithmetic mean of hourly heights of the sea at the tidal station observed over a period of time (preferably 19 years)*”.

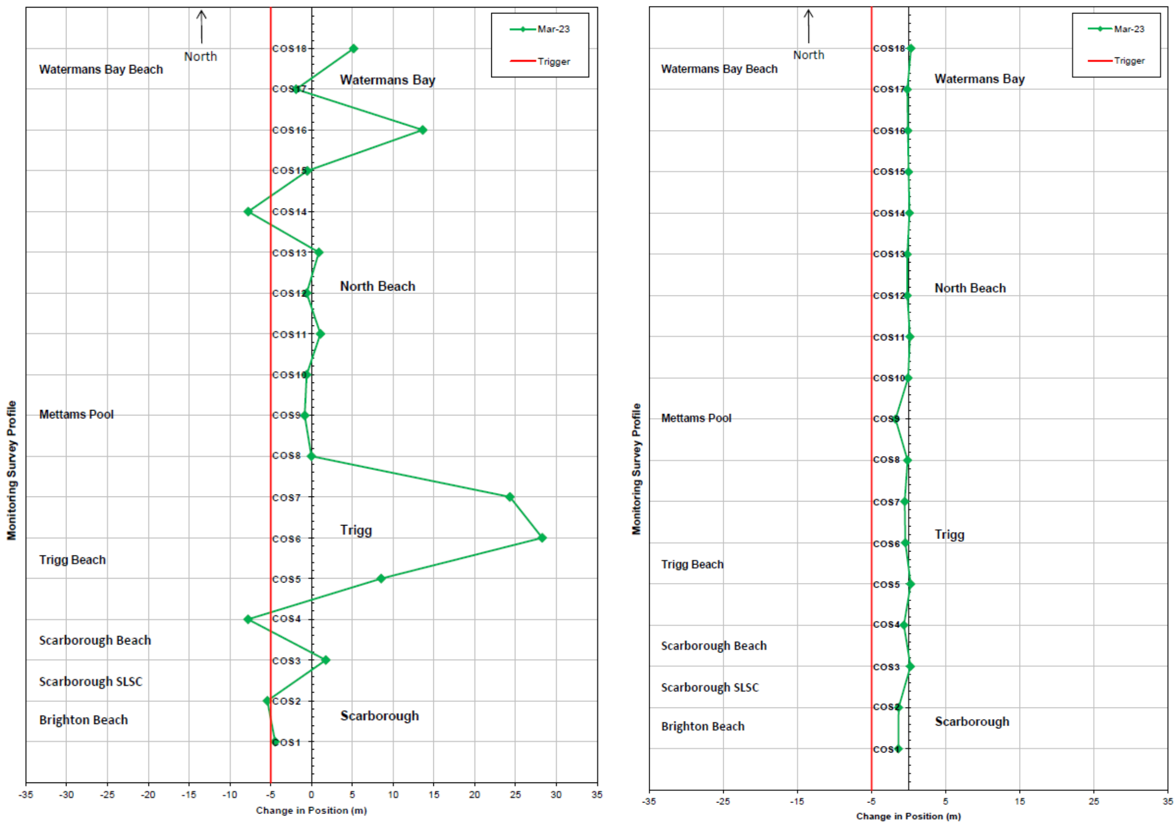



**Figure 2.20 Position of MSL (L) & Vegetation Line (R) Relative to 2022**

Recommendations from the report included that monitoring of the shoreline should be continued to carefully review the areas eroding to determine whether the movement observed during the current reporting period are trends and need to be managed. It was also strongly recommended that the sand nourishment at Mettams Pool be continued until a longer term adaptation solution is implemented, as it is slowing the beach's erosional trend, but also provides a secondary benefit of nourishing the beaches to the north.

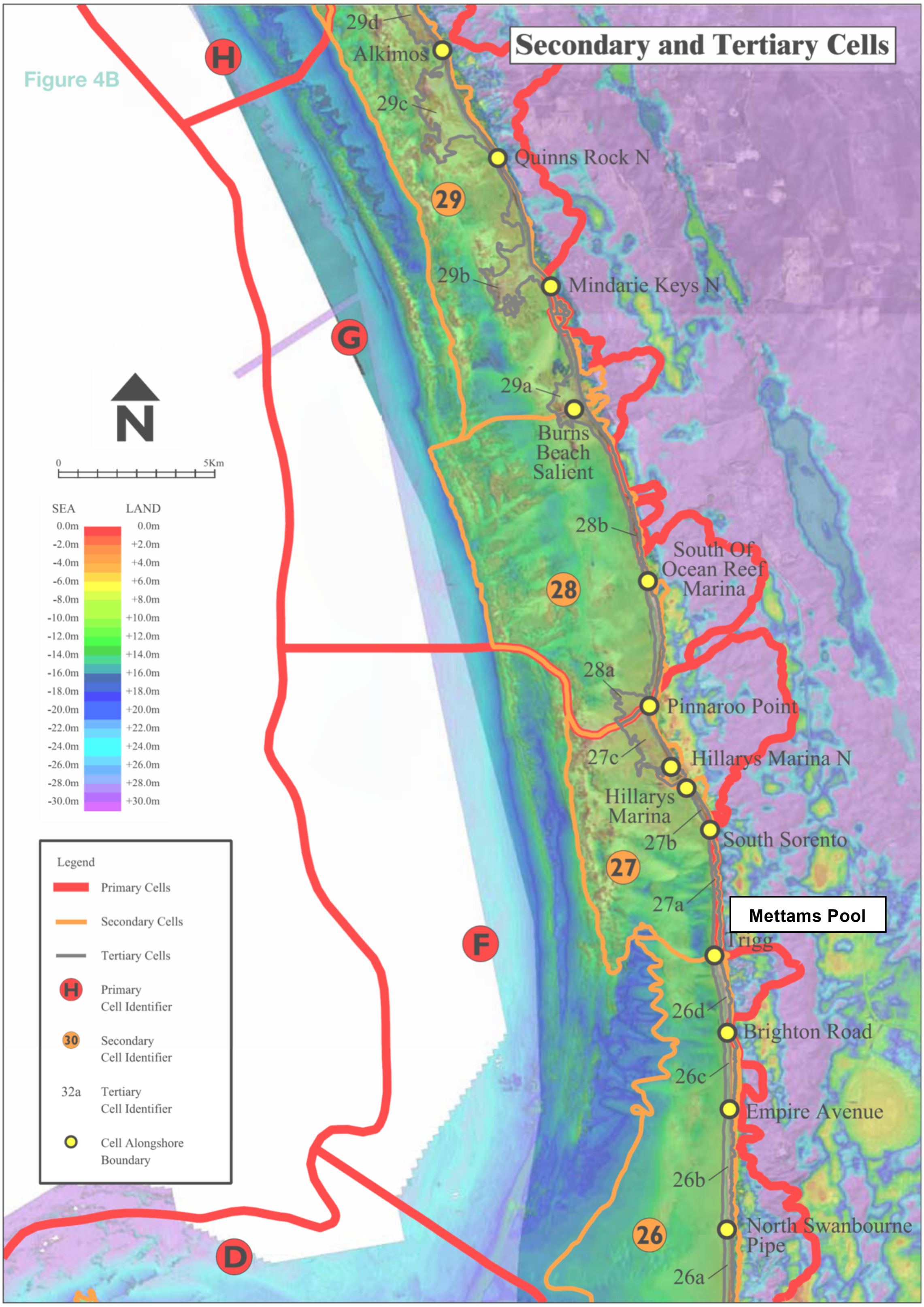
### 2.6.2 Geomorphology & Geology

#### Sediment Cells

Sediment cells are considered a 'natural' management unit for the conservation of sediment. Stul et al (2007) suggests that coastal engineering studies and management plans should considered the entire sediment cell given that it links the marine and terrestrial environments. Sediment cells are considered to provide a platform that supports interpretation of historic trends, understanding of contemporary processes and the projection of future coastal change. Sediment cells are sections of the coast within which sediment transport processes are strongly related. They include areas of sediment supply (sources), sediment loss (sinks) and the sediment transport processes linking them (pathways).

Investigations by Searle & Semeniuk (1985) and Eliot et al (2005) classified the Mandurah to Two Rocks coastline in terms of primary and secondary sediment cells. More recently Damara WA (2012) and Seashore (2015) classified the coastline between Cape Naturaliste and Moore River in terms of primary, secondary and tertiary level sediment cells.

The differences in cell hierarchy reflect the varying timescales for assessment of each sediment cell level. Primary cells relate to geological processes and trends that may alter over geological timescales, but are considered to be relatively constant in the shorter developmental planning timeframes.  Secondary cells describe the contemporary sediment movement and inter-decadal trends and landform response (Damara WA, 2012).  Tertiary cells generally cover the reworking and movement of sediment in the nearshore area with shoreline responses of the seasonal to inter-annual timescales.  Figure 2.21 shows an extract from Seashore (2015) presenting the boundaries of the sediment cells containing Mettams Pool.




## Figure 2.21 Sediment Cell Boundaries

Mettams Pool is seen to be located within Secondary Sediment Cell 27, extending from Trigg to HBH.

### Geophysical Investigation (GBGMAPS, 2018)

In September 2016 and May / June 2018, GBGMAPS Pty Ltd (GBGMAPS) carried out geophysical subsurface investigations along approximately 3.8 km section of the City's coastal dune system from Trigg Island to Watermans Bay.

The geophysical investigation was carried out following the identification of a number of areas within the City's shoreline, such as Watermans Bay and Mettams Pool, which may be vulnerable to coastal hazards. Several of these areas are located between rocky headlands or at locations where rock lenses are observed but rock levels underneath the dune system are unknown. Hence, an investigation of rock levels was undertaken to provide some clarity of the level of protection afforded by underlying rock.

For Mettams Pool the investigation suggested:

- Sholl St rock elevations are approximately 6 to 7 mAHD at the rear of the dune.
- The portions of the site in front of Giles and Lynn St appear to be afforded minimal protection by underlying rock. The model suggests rock elevations at these locations may be less than 4 mAHD.

### DCP Investigation (DTE, 2019)

MRA engaged DTE Geotechnical to complete probing with Dynamic Cone Penetrometers (DCP's) at Mettams Pool to confirm rock levels from the geophysical investigations.

The results of this investigation indicate that rock levels at Mettams Pool are at lower elevations than suggested by the geophysical investigation. Interrogation of the DCP investigation indicates the actual rock level may be around 0.5 to 1.5 m lower than the results of the geophysical investigation suggest.

The presence of rock in the tidal range will likely alter and potentially slow down erosion of the shoreline. WAPC (2013) suggests competent rock should extend 1 m above the active limit of the shoreline to provide coastal protection.

The locations and extents of competent rock likely to resist erosion have been estimated based on the geophysical and DCP investigations and is shown in the figure below for Mettams Pool.

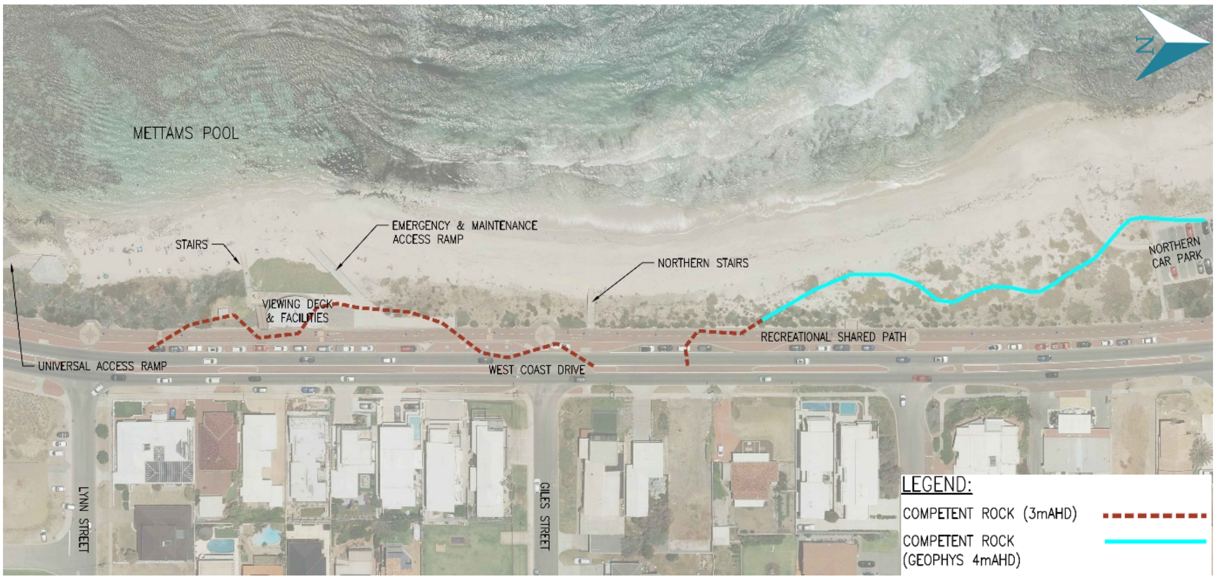



**Figure 2.22 Mettams Pool – Estimated Extents of Competent Rock**

## 2.8 Environmental & Heritage Conditions

### 2.8.1 Contamination & Acid Sulphate Soils (ASS)

The Department of Water and Environmental Regulations (DWER) Contamination and ASS risk maps were used to identify the risk of ASS at Mettams Pool. These maps are available at dataWA portal (https://catalogue.data.wa.gov.au/dataset/acid-sulphate-soil-risk-map-swan-coastal-plain-dwer-055).

The map shows no known contamination at or near the site.

### 2.8.2 Marine Park

The Department of Biodiversity, Conservation and Attractions' (DBCA) Legislated Land and Water map was used to identify the marine park at Mettams Pool. These maps are available at the dataWA portal (DBCA – Legislated Lands and Waters (DBCA-011) – Datasets – data.wa.gov.au), with the relevant area shown in Figure 2.23.

Mettams Pool is located within the Marmion Marine Park. This may affect the approval process for any in-water works at the sites.

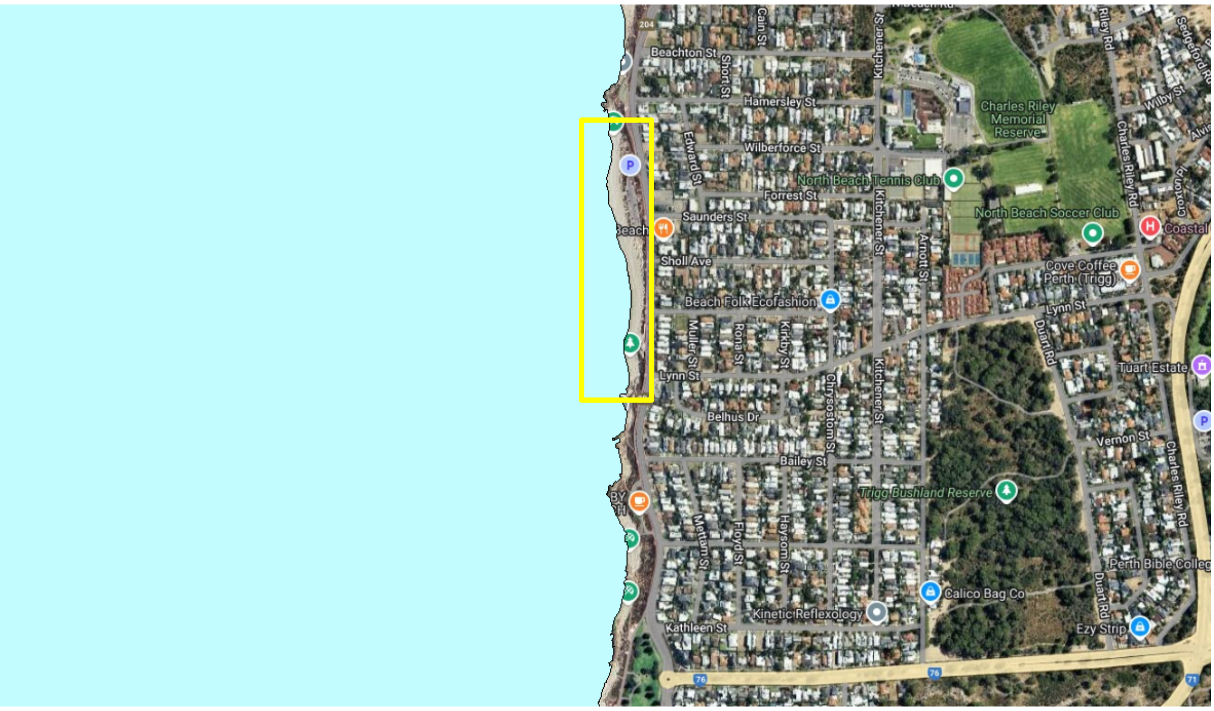



**Figure 2.23 Mettams Pool & Marine Parks**

### 2.8.3 Aboriginal Heritage

The DPLH are responsible for assessing the impact of development on Aboriginal Heritage sites. MRA completed an online search of Registered Aboriginal sites using the Aboriginal Cultural Heritage Inquiry System (Aboriginal Cultural Heritage Inquiry System (dplh.wa.gov.au)) and found that no registered Aboriginal Sites were located at Mettams Pool.

This does not mean that Mettams Pool has no cultural importance. Therefore, it may be worth consulting with appropriate authorities regarding the works, such as traditional owners, Aboriginal corporations, and state heritage councils or agencies.

### 2.8.4 Surveys & Coastal Monitoring

#### LiDAR/LADS Surveys

Bathymetry surveys have been obtained for the section of foreshore that includes Watermans Bay and Mettams Pool. This includes the following years:

- 2009 Laser Airborne Depth Sounder (LADS) survey.
- 2015 Light Detection and Ranging (LiDAR) survey.

Figure 2.24 shows a difference plot between the two surveys.

Given the large differences (ie large erosional and accretional trends greater than 2 m) which can be observed in certain areas nearshore and in locations of hard structures (such as car parks and roads), it was determined that a more in-depth review was needed for both surveys before it can be relied upon.

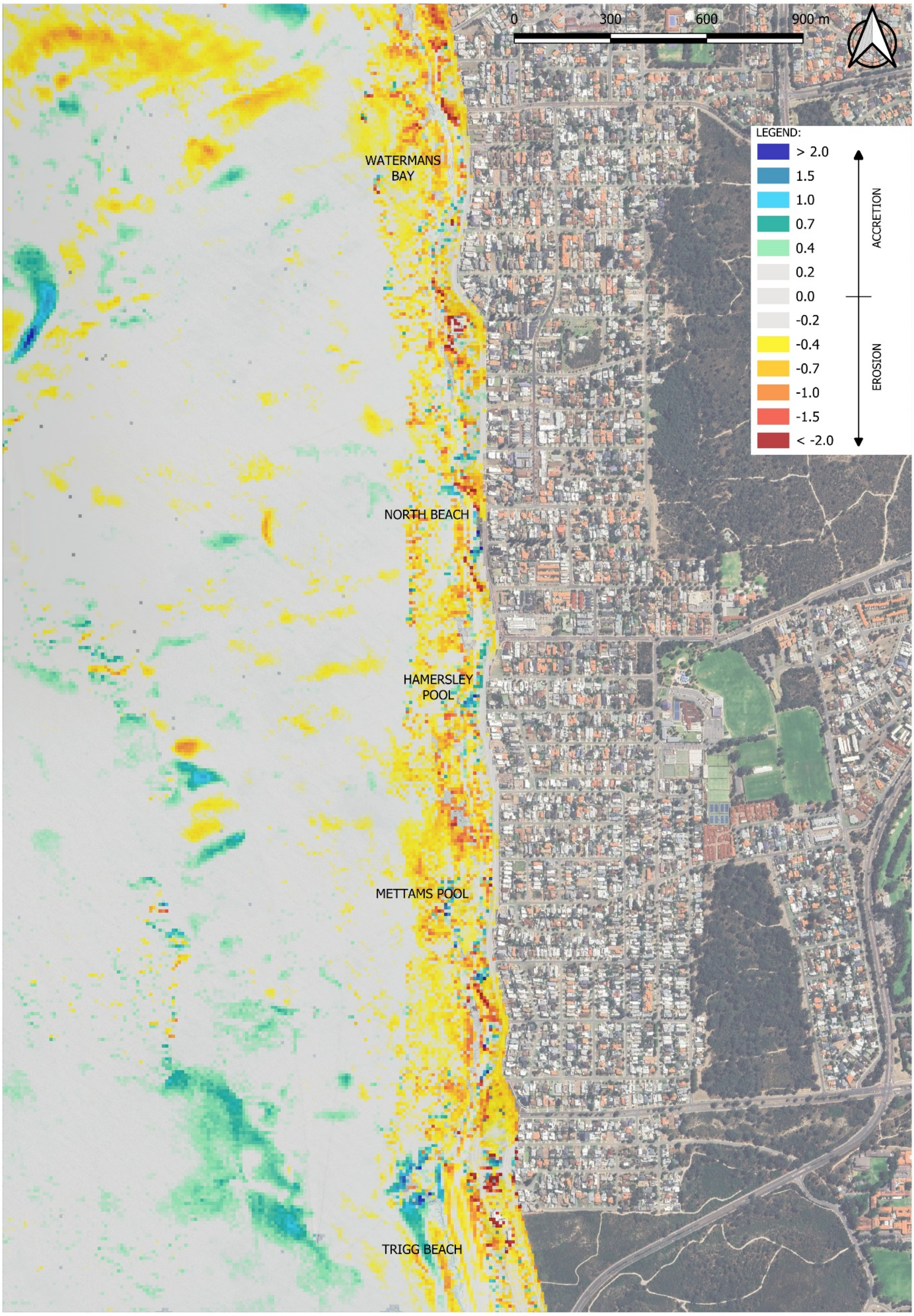



**Figure 2.24 Bathymetric Difference 2009 to 2016 (Trigg to Marmion)**

The review focused on eight transects like those displayed in Figure 2.25. Most profiles were assessed in locations where hard structures were present prior to the 2009 survey. The 2009 data was plotted against historical shoreline profiles collected on the same transects. A disparity can be seen between the 2009 LiDAR survey and the historical shoreline profiles in both the onshore and nearshore regions.

In July 2024, the DoT Coastal Information team re-examined the LiDAR data collected in 2009 and 2016 and provided the following advice:

- Seabed bathymetric data (below mean sea level): both the 2009 and 2016 datasets are of acceptable quality and are recommended for use.
- Beach and sand dune topography (above mean sea level): the 2016 dataset is recommended, as it provides a 5 m resolution and uses a combination of LADS and Riegl sensors, offering a detailed representation of the land / sea interface.
- 2009 LiDAR Data - this dataset is not suitable for landward analysis.

Given this, the 2009 LiDAR survey was not relied upon for this works.

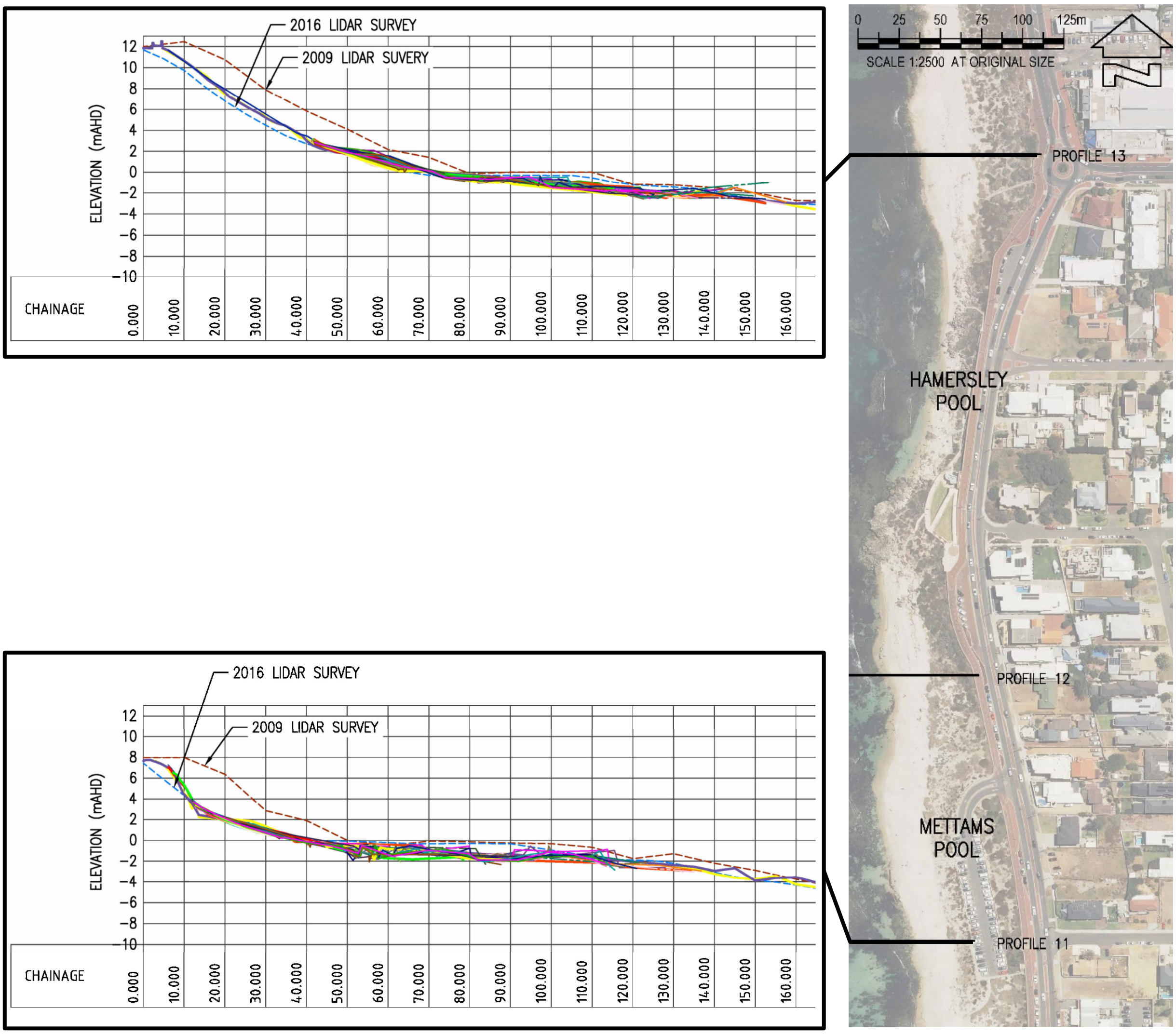



**Figure 2.25 Validation of Bathymetric Survey**

### Feature Surveys

More detailed surveys have been completed for the City's coastline however only capture discrete sections of the coastline. The following surveys have been collected along the City's coastline:

- A full feature survey of Mettams Pool to support the Mettams Pool Defensive Works project (MRA, 2020).

- Volumetric survey of both Mettams Pool and Trigg Point to determine the cut and fill volumes for the beach nourishment works completed in March 2022.

More recently, as part of MRA's engagement, JBA were engaged to undertake a feature survey of Mettams Pool, shown in the figure below. This survey shows the lines and levels of key features along the coastline. Due to OH&S concerns, the nearshore fringe reefs could not be surveyed in detail. This area is considered critical to the development of the coastal adaptation option. Therefore, where feature survey data could not be captured, DoT's 2016 LiDAR survey was used to fill the gaps. As detailed above, DoT's 2016 LiDAR survey was validated and determined to be appropriate.

Figure 2.26 shows the most recent feature survey at Mettams Pool.


**Figure 2.26 Mettams Pool Feature Survey**

### Coastal Monitoring

Coastal monitoring has been completed in various forms within the City since 1955. This has included beach width measurements through Scarborough and more wide scale monitoring. The following measurements / monitoring has been captured along the City's coastline.

- Historical beach widths at Scarborough (1955 - 1985) – Measurements were taken at 6 stations on Scarborough Beach, extending from the now southern side of the amphitheatre to the northern extent of the car park (MRA 2006).

- Revised coastal monitoring program (2009 - 2015) – A revised program was commenced in 2009 and involved collecting 10 beach profiles to the water line at Scarborough as well as 19 coastal profiles. The beach profiles provide an indication of the beach variation on a 1 to 3-month timeframe.

- Current coastal monitoring program (2022 – Current) - As detailed in Section 2.6.1 of this report, the City has recently re-established its coastal monitoring program. A range of information is collected as part of this works, and includes:

    - Beach Profile Surveys – Surveyed beach profiles that are notionally completed in October and March every year following winter and summer months.

    - Shoreline Mapping – Mapping of the position of the coastal vegetation line using ortho-rectified aerial photography.

    - Photographic Monitoring – Photographs at 28 fixed locations that are notionally completed in October and March every year following winter and summer months

Refer to Figure 2.27 for the beach profiles and photograph monitoring locations.

The *Northern Beaches Alliance* (Cities of Nedlands, Cambridge, Stirling, Joondalup, Wanneroo and the Shire of Gingin) is also undertaking coastal monitoring and extends from Two Rocks in the north to Cottesloe in the south. The information gathered as part of the monitoring activities includes:

- Ground Surveys – Completed every 6 months and extended into the water as far as possible.

- Airborne Surveys – Completed every 6 months for the acquisition of LiDAR and aerial imagery.

October 2023 was the first period where the aforementioned data was acquired for the City's coastline, with a plan to complete at 6 monthly intervals.

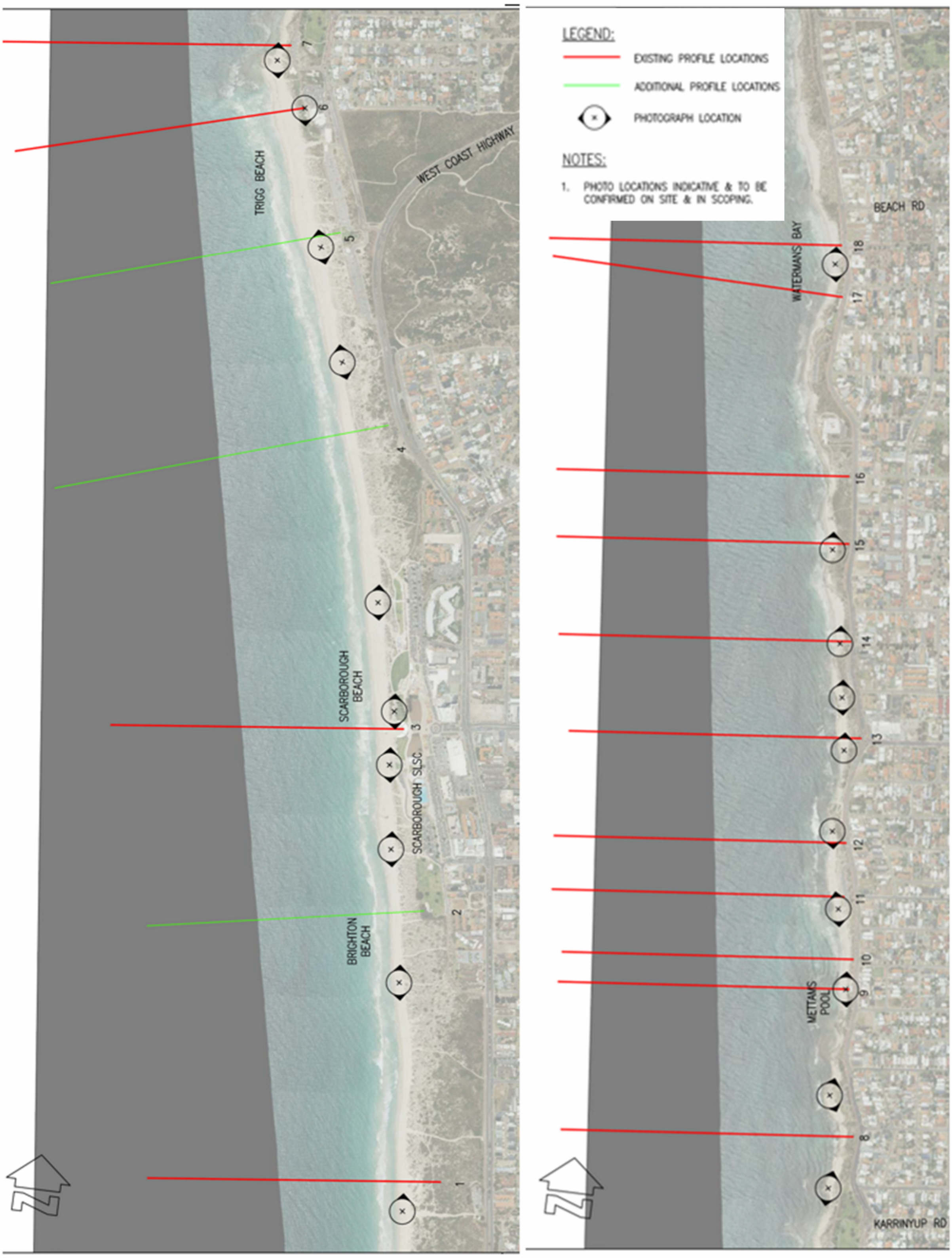



**Figure 2.27 Beach Profiles & Photograph Monitoring Locations**

# 3. Coastal Hazard Risk Management & Adaptation Planning

In 2021, Cardno commenced the preparation of the City's CHRMAP. This assessment was completed in accordance with the requirements of State Planning Policy No. 2.6: State Coastal Planning Policy (SPP2.6, WAPC 2013). The CHRMAP was developed for the entire length of the City's shoreline stretching approximately 7 km from Peasholm St, Scarborough to Beach Rd, Watermans Bay.

The scope of the study was to:

- Identify and characterising risk and vulnerability for all the assets and areas that may be impacted within the next 100 years.
- Develop adaptation and management measures to address intolerable risks in the short term (< 10 years).
- Develop and implement strategic measures to avoid intolerable risks beyond this timeframe.

One of the key requirements of the CHRMAP is to involve the community and stakeholders throughout the planning journey to ensure the coastal values and adaptation pathways are acceptable to the community and people who interact with the coast and key assets along the coastline.

In total, more than 270 people attended pop-up information stalls, 230 people responded to a coastal values survey and 29 people attended an online asset mapping tool. Based on the results of the community engagement process, the table below details the success criteria developed to guide the CHRMAP process.

As detailed in Table 3.1, one of the key success indicators for a coastal adaptation project at Mettams Pool is preserving the function and opportunity for recreation activities along the coastline (such as walking/running, swimming and surfing).

**Table 3.1 Success Criteria for the City's CHRMAP (Cardno, 2022a)**

| | |
|---|---|
| 1 | Preserve the function and opportunity for recreation activities along the coastline (such as walking/running, swimming and surfing). |
| 2 | Preserve the existing hospitality venues along the coastline and access to them. |
| 3 | Ensure the natural environment is protected and sustained in its current condition or an improved condition (concerning the dunes and flora and fauna). |
| 4 | Develop solutions to coastal processes that are sustainable (financially, socially and built form) and locally responsive. |
| 5 | Revisit regularly with community and key stakeholders their values in relation to development adjacent the coastline. |
| 6 | Maintain services that maximise community benefit for all. |
| 7 | Ensure the coastline is safe and accessible to all. |
| 8 | Achieve a balance between access needs and environmental sensitivities. |

Six MUs were established based on shared sediment compartments, similar coastal features and a focused concentration of coastal assets and associated risks (Figure 3.1).

The following sections discuss the outcomes for the relevant MU for Mettams Pool.

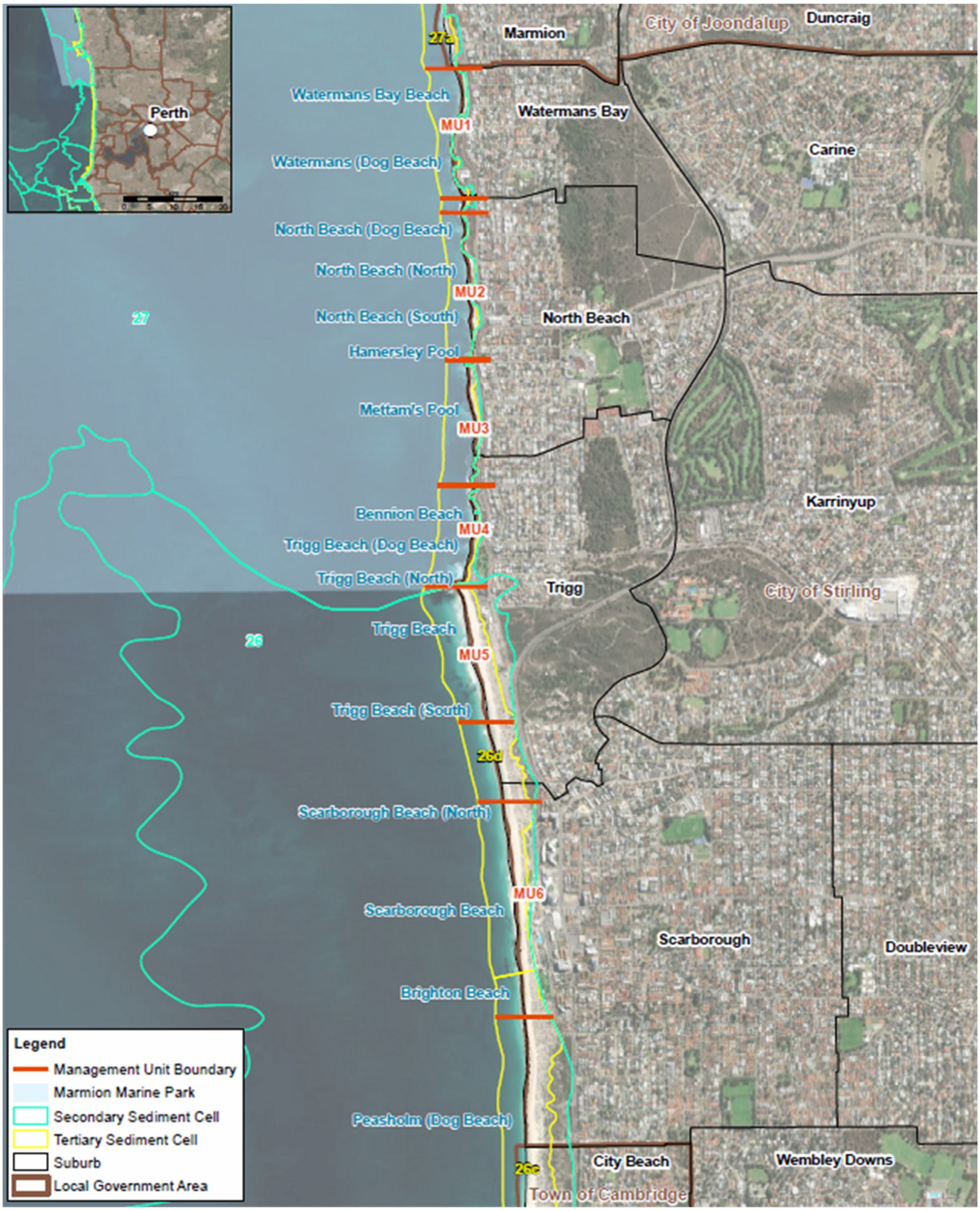
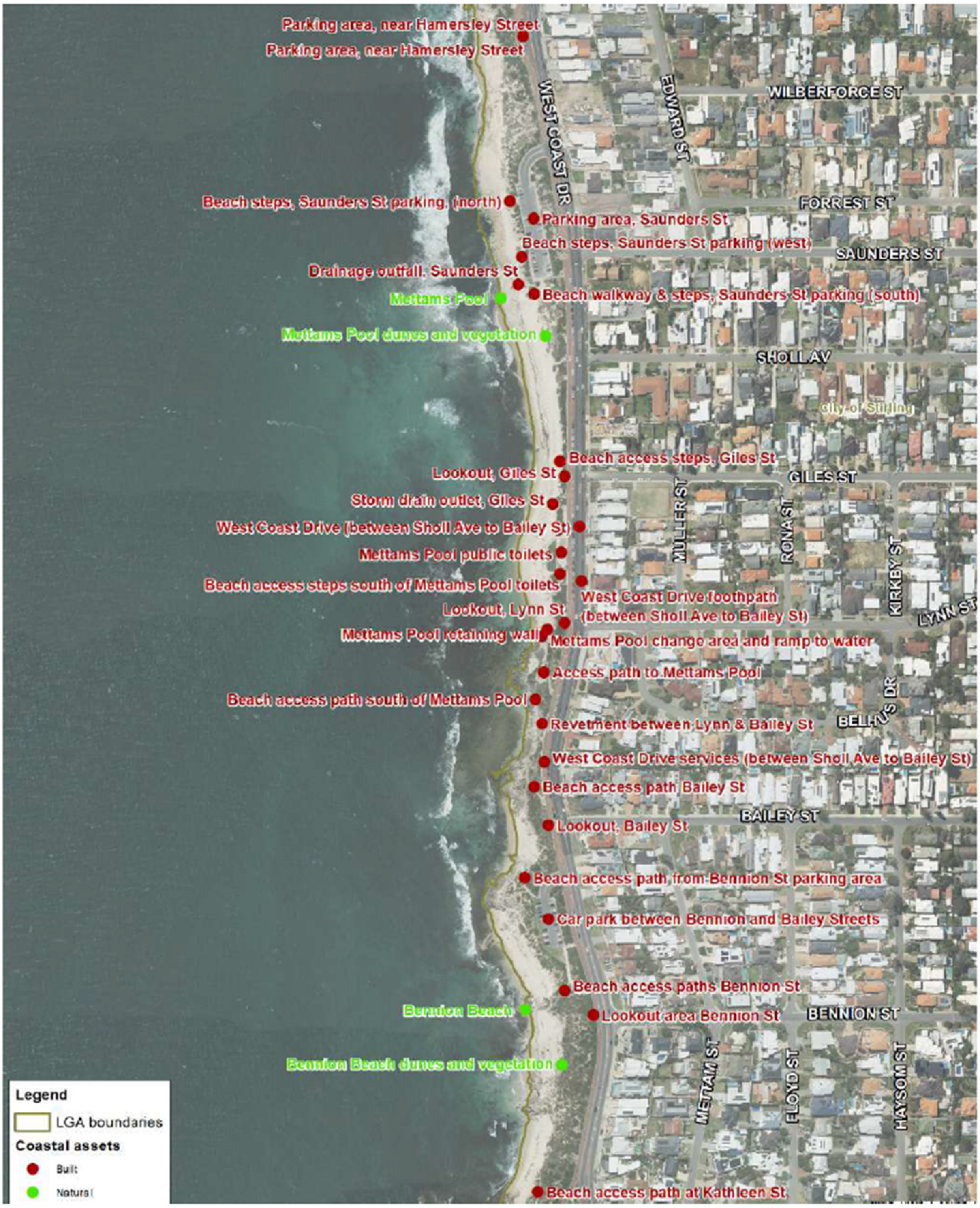



**Figure 3.1 CHRMAP Coastal Management Units (Cardno, 2022c)**

## 3.1 MU3 – Mettams Pool

MU3 extends from Hamersley St in the north to Bailey St to the south, and only includes Mettams Pool. Figure 3.2 identifies both the natural and built assets located within MU3. This includes key items such as beach access points, WDC, RSP, lookout, carparks and amenities, retaining wall, revetment and the beach.




## Figure 3.2 MU3 – Asset Locality Plan

Following the identification of the natural and built assets within each MU, a coastal hazard assessment was undertaken to assess the impact of sea level rise, associated with climate change. Figure 3.3 presents both the coastal erosion and inundation hazards for MU3.

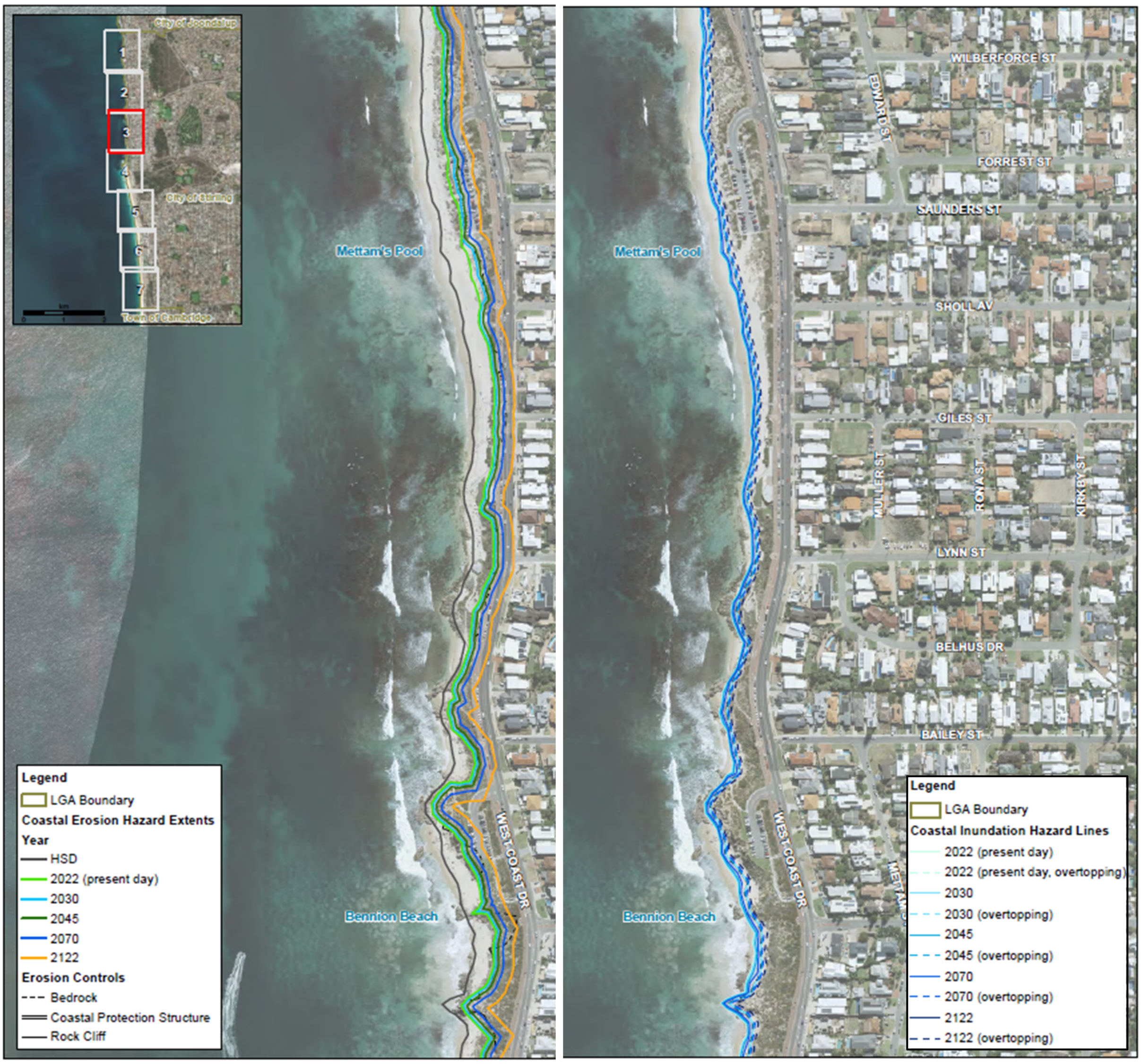



**Figure 3.3 MU3 – Coastal Erosion & Inundation Hazards**

Cardno (2022d) identified that MU3 was a priority site which required further investigation in the immediate term and, depending on the outcomes, active management in the short term.

The report detailed that the general approaches recommended to adapt to the risk of coastal erosion to be:

- Avoiding further permanent development on land which has been identified as prone to erosion over the next 100 years;
- Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure, until such time that risk levels require transition to a managed retreat pathway;
- Protecting infrastructure at Mettams Pool in the short term, through beach nourishment in the short term and through the construction of coastal engineering protection in the short to medium term (likely nearshore reef enhancement but subject to more detailed assessment); and

- Planning for the eventual managed retreat of existing assets in the foreshore reserve as risk becomes intolerable.

Table 3.2 below depicts the results of the Multi-Criteria Analysis (MCA) for the coastal adaptation options assessed. Four options were considered “likely to deliver a positive outcome” or “require further assessment” when considering protecting the infrastructure at Mettams Pool in the short to medium term. These included:

- Beach Nourishment.
- Groynes / Headland Enhancement.
- Nearshore Reefs / Breakwaters.
- Revetments / Seawalls.

Subsequently, further refinement of these coastal adaptation options, or a combination of these options, will be undertaken in this report.

## Table 3.2 MU3 – Coastal Adaptation Options (Cardno, 2022d)

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Planned / Managed Retreat | PMR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | PMR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | PMR3 | Planning controls for managed retreat | Residential and commercial property. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) / Headland enhancement | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR5 | Revetment(s) / Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Further assessment |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

# 4. Shoreline Movement Analysis

## 4.1 Sediment Transport Pathways

From a coastal engineering perspective, the most important coastal process is generally the interaction of waves, currents and beaches to generate sediment transport. There are three fundamental mechanisms that can transport sand towards or away from a point on the beach:

- Longshore sediment transport.
- Cross-shore sediment transport.
- Wind blown losses.

The following sections discuss the fundamental mechanisms for sandy coastlines, such as Trigg and Scarborough Beaches, as well as the perched and rocky coastlines such as Watermans Bay and Mettams Pool.

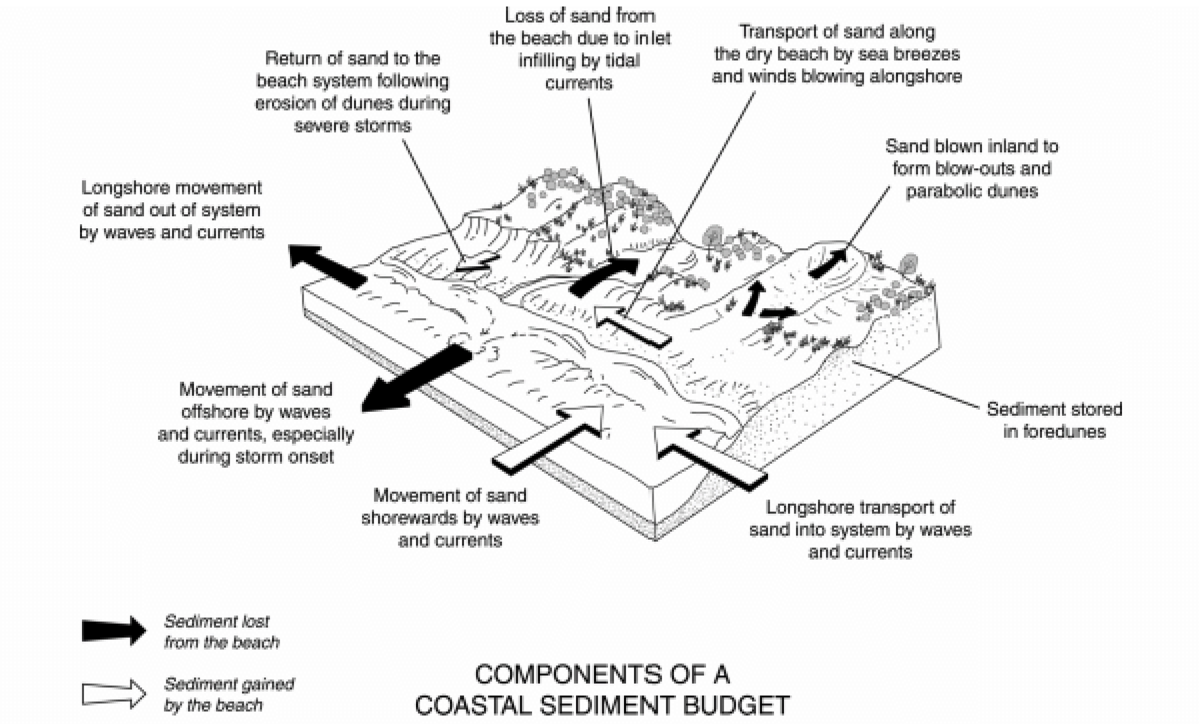



**Figure 4.1 Sediment Transport Pathways (WAPC 2003)**

## 4.2 Longshore Sediment Transport & Processes

A simplistic description of longshore sediment transport is that in the surf zone of sandy beaches, the breaking waves agitate the sand and place it into suspension. If the waves are approaching the beach at an angle, then a longshore current can form and this can transport the suspended sand along the beach. The suspended load transport is accompanied by a bed load transport where sand is rolled over the bottom by the shear of the water motion.

There can also be considerable variation in magnitude and direction of the longshore transport from season to season and year to year. In Perth, longshore sediment transport is typically north in summer and south in winter. The strong sea breezes blow from the south-west in summer, creating wind waves at an angle to the shoreline. This transports sediment to the north

(Masselink and Pattiaratchi 2001). In winter, severe storms generate waves from the north, swinging to the south over their duration. This typically transports sediment to the south in winter storms (Masselink and Pattiaratchi 2001).

However, longshore sediment transport along the rocky sections north of Trigg is more complex than the sandy beaches at Trigg and Scarborough. Figure 4.2 depicts typical longshore transport mechanisms along rocky coastlines.

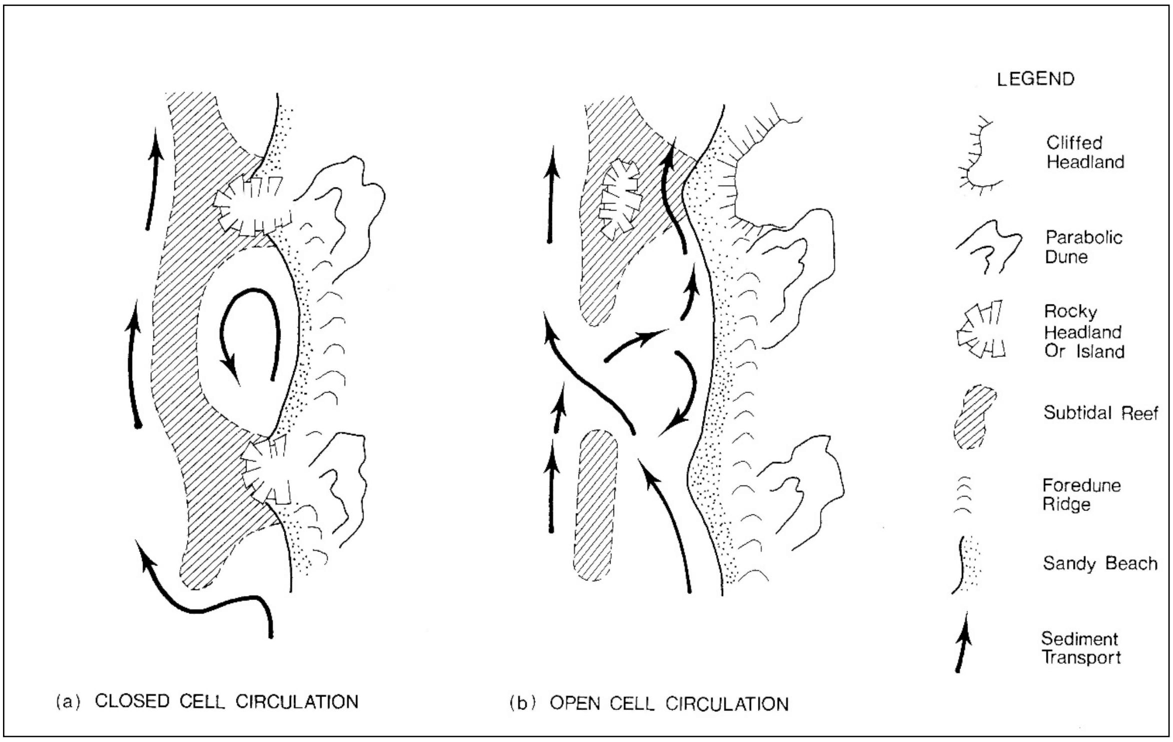



**Figure 4.2 Longshore Transport Along Rocky Coastlines (Sanderson & Eliot 1999)**

Sections of coast such as at Mettams Pool are most likely a combination of (a) and (b) in Figure 4.2. Channels exist through to the open ocean, allowing sediment to be transported offshore between the reefs. However, Mettams Pool is partially bounded by rocky headlands, particularly to the south. Subsequently, some of the sediment will be transported adjacent to the coast and some will be transported on the outer edge of the reef.

### 4.2.1 Sediment Cells

Sediment cells were introduced in Section 2.6 of this report. The sediment cells for this study area are presented in Table 4.1 below.

Generally, consideration of the Secondary and Tertiary Sediment Cells are most relevant for typical short to medium term sediment movements.

**Table 4.1 Sediment Cells within the Study Area (Damara WA, 2012)**

| Primary Cell | Secondary Cell | Tertiary Cell |
|---|---|---|
| F. South Mole to Pinnaroo Point | 27. Trigg to Pinnaroo Point | b. South Sorrento to HBH |
| | | a. Trigg to South Sorrento |
| | 26. Mudurup Rocks to Trigg | d. Brighton Road to Trigg |
| | | c. Empire Avenue to Brighton Road |

### 4.2.2 Previous Coastal Works

#### Shoreline Control Structures

Shoreline control structures such as groynes can influence coastal movement and need to be considered as part of any assessment of coastal change.

Within this sediment cell between Cottesloe Groyne and HBH, several structures have been constructed to manage coastal erosion, including Cottesloe Groyne, City Beach Groynes and Sorrento Groynes. HBH is a significant barrier to most longshore transport and forms the northern most barrier to the assessment area. Given that these structures are located within the sediment cells of the study area, they can cause significant disruption to the coastal dynamics. A brief discussion of the structures is provided below.

- Cottesloe Groyne – In the 1950's there was a decline in popularity due to the underlying rock being exposed during winter as a result of the prevailing north westerly winds. Cottesloe Groyne was constructed in the 1960's in efforts to capture the sediment at the southern end of the beach.

- City Beach Groynes – Includes the Floreat Groyne to the north and City Beach Groyne to the south and were originally constructed in 1957 and 1935 respectively. The older groyne (City Beach Groyne) was constructed to control the sand drift and 'square' the surf, while the newer structure (Floreat Groyne) was needed to control the down drift erosional effects caused by the City Beach Goyne. Both groynes have been subject to maintenance works since their construction.

- Sorrento Groynes – Includes the Northern, Central and Southern groyne and were constructed in the early 1980s to mitigate beach erosions at Sorrento Beach. All groynes have been subject to maintenance works since their construction.

- HBH – Was completed in the second half of 1986. HBH comprises of two external breakwaters, with the southern breakwater tying in to the northern most extent of Sorrento Beach, extending approximately 650 m offshore.

The structures listed above can influence sediment movement and therefore need to be considered as part of the shoreline movement analysis. Consequently, given HBH was the last structure to be built within the sediment cells of the study area, the assessment must consider the trends in sediment movement since the second half of 1986. Furthermore, as the breakwater extends to a water depth of approximately -6.0 mAHD, sediment transport past the structure is considered very small or non-existent. Thus, HBH is considered the northern most extent of the sediment cell for the purposes of this study.

Other larger scale coastal developments and protection works include the recent redevelopment at Scarborough Beach. These works are generally limited to the area behind the coastal dunes and therefore are currently having limited impact on sediment movement. As the beach and dunes erode, these works may play a bigger role in altering coastal dynamics.

From time to time the City also completes other coastal management works which can influence the coastline. This includes, among other items:

- Beach raking and grading.
- Management of beach access ways.
- Management of wind-blown sand.
- Beach fencing, which can control movement and dune / vegetation growth.
- Revegetation works.
- Protection works.
- Beach nourishment works.

Although most of these activities are only considered to have small local impacts, some have the ability to affect the results obtained from the shoreline movement analysis techniques.

Mapping of the coastal vegetation line over a long period of time can provide indicative movements of sediment along the coast. In areas where there are fixed structures like beach fencing and seawalls or the beach may be 'perched', have varying nearshore reef or a modified dune profile, this methodology of estimating sediment change is noted to have some drawbacks and therefore should be considered when determining shoreline movement rates.

Beach nourishment will be discussed in further detail in the section below.

### 4.2.3 Beach Nourishment Activities

Beach nourishment activities can affect the assessment of coastal change and therefore need to be accounted for in order to obtain a comprehensive understanding of the present-day conditions.

Beach nourishment activities need to be considered for Secondary and Tertiary Sediment Cells, taking into account all activities along the coastline from HBH in the north to Cottesloe Groyne in the south. Therefore, nourishment works conducted within the following Local Government Areas (LGA) was reviewed.

- City of Joondalup (CoJ).
- City (City of Stirling).
- Town of Cambridge (ToCa).
- City of Nedlands (CoN).

- Town of Cottesloe (CoCo).

Information was gathered from Coastal Managers and through MRA's extensive knowledge of coastal adaptation projects within the Perth Metropolitan region. Of the five LGAs listed above, only the City and CoJ have conducted beach nourishment activities following the construction of HBH. A brief discussion of these activities is provided below.

### City of Stirling

In the short term, beach nourishment is being completed as a temporary management solution to restore beach amenity and provide a buffer for coastal erosion. This is consistent with the recommendation of the CHRMAP.

Table 4.2 below details the beach nourishment activities as well as the approximate volumes and harvest and deposit locations completed by the City.

**Table 4.2 Beach Nourishment Activities Completed by the City of Stirling**

| Date | Approx. Volume ($m^3$) | Harvest / Deposit Locations |
|---|---|---|
| 2009 | 1,400 | Scarborough Beach / Watermans Bay |
| Circa 2010[1] | 2,500 | Ocean Reef Marina / Watermans Bay |
| 2012[2] | 500 | Terrestrial Source / Watermans Bay |
| Apr 2021 | 2,200 | Sorrento Beach / Mettams Pool |
| Nov / Dec 2021 | 5,000 | Trigg Beach / Mettams Pool |
| Nov / Dec 2022 | 5,000 | Trigg Beach / Mettams Pool |

Notes:
1. Sand was used to fill the GSCs of the revetment therefore not used for the purposes of beach nourishment.
2. Information provided by the City suggested a small quantity of sand was placed at Watermans Bay however the specific quantity is not known. Therefore, an indicative estimate is provided.

Most of the beach nourishment activities have occurred at Mettams Pool where the sand has been placed above the water line, on the beach and base of the dunes. Figure 4.3 shows aerial photographs of Mettams Pool before and after one of the nourishment episodes, in March 2021. The increased beach width in the post nourishment photograph is evident.

Figure 4.3 Mettams Pool (L) February 2021 (pre nourishment) (R) April 2021 (post nourishment)

### City of Joondalup (CoJ)

The CoJ has established a coastal monitoring program for the shoreline within its boundaries since 2015. The work involves a range of monitoring activities with the frequency of these events either continuously (fixed camera monitoring), biannually (photo monitoring), annually (shoreline mapping) or biennial (beach profiles).

Monitoring suggests the shoreline in front of the Hillarys Beach Park and at Pinnaroo Point, directly north of HBH, has been receding at various rates. MRA (2018) recommended that sand bypassing be completed around HBH to assist with the following:

- Reducing the continued erosion trend observed north of HBH, including at Hillarys Beach Park and Pinnaroo Point.
- Assist with sand accumulation issues at the accreting Sorrento Beach.

This recommendation has been made in subsequent reports, with the volume of sand nourishment suggested to be increased from 10,000 to 15,000 $m^3$ by MRA (2021b) to address the continued recession.

Table 4.3 below details the beach nourishment activities as well as the approximate volumes and harvest and deposit locations.

The sand used for beach nourishment works north of HBH is harvested from Sorrento Beach (ie removed from the system) and needs to be considered as part of the shoreline movement analysis.

### Table 4.3 Beach Nourishment Activities Completed by the City of Joondalup

| Date | Approx. Volume ($m^3$) | Harvest / Deposit Locations |
|---|---|---|
| Dec 2018 | 8,400 | Sorrento Beach / North of HBH |
| Mar / Apr 2020 | 8,700 | Sorrento Beach / North of HBH |
| Mar 2021 | 8,000 | Sorrento Beach / North of HBH (5,800 $m^3$) & Mettams Pool (2,200 $m^3$) |
| Oct / Nov 2021 | 8,000 | Sorrento Beach / North of HBH |
| Oct / Nov 2022 | 8,000 | Sorrento Beach / North of HBH |
| Oct / Nov 2023 | 10,000 | Sorrento Beach / North of HBH |

### 3.5 Coastal Monitoring

As detailed in Section 2.8.4 of this report, coastal monitoring has been completed in various forms within the City since 1955. This has included beach width measurements through Scarborough and more wide scale monitoring.

Monitoring datasets play a crucial role in validating both information used for shoreline movement analysis and the assessment itself. Reliable validation information ensures the accuracy of analyses, enabling more precise predictions of present-day conditions and effective coastal management strategies.

The City has invested time and financial resources into data collection, both through its own initiatives and part of the NBA. These efforts reflect a strong commitment to improving the understanding and management of shoreline dynamics. However, it is important to note that their monitoring programs have only recently been re-established therefore there are gaps in the data. As a result, most of the data currently available is not useful for this current shoreline movement study, however, it will be invaluable in the years to come.

Despite this limitation, consistent shoreline profiles have been collected at several locations along the City's foreshore since December 2011. This historical dataset is useful as it provides a solid foundation for validating changes over time.

## 4.3 Cross-Shore Sediment Transport

The second mechanism is the onshore / offshore movement of beach sand, commonly referred to as cross-shore sediment transport. During significant storm events, the strong winds generate high steep waves and an increase in water level known as storm surge. These factors, acting in concert, allow the waves to attack the higher portion of the beach that is not normally vulnerable.

For sandy beaches, the initial width of the surf zone is often insufficient to dissipate the increased wave energy of the storm waves. The residual energy is often spent in eroding the beach face, beach berm and sometimes the dunes. The eroded sand is carried offshore with return water flow where it is deposited and forms an offshore bar. Such bars can eventually grow large enough to break the incoming waves further offshore, causing the wave energy to be spent in a wider surf zone. This is shown diagrammatically in Figure 4.4.

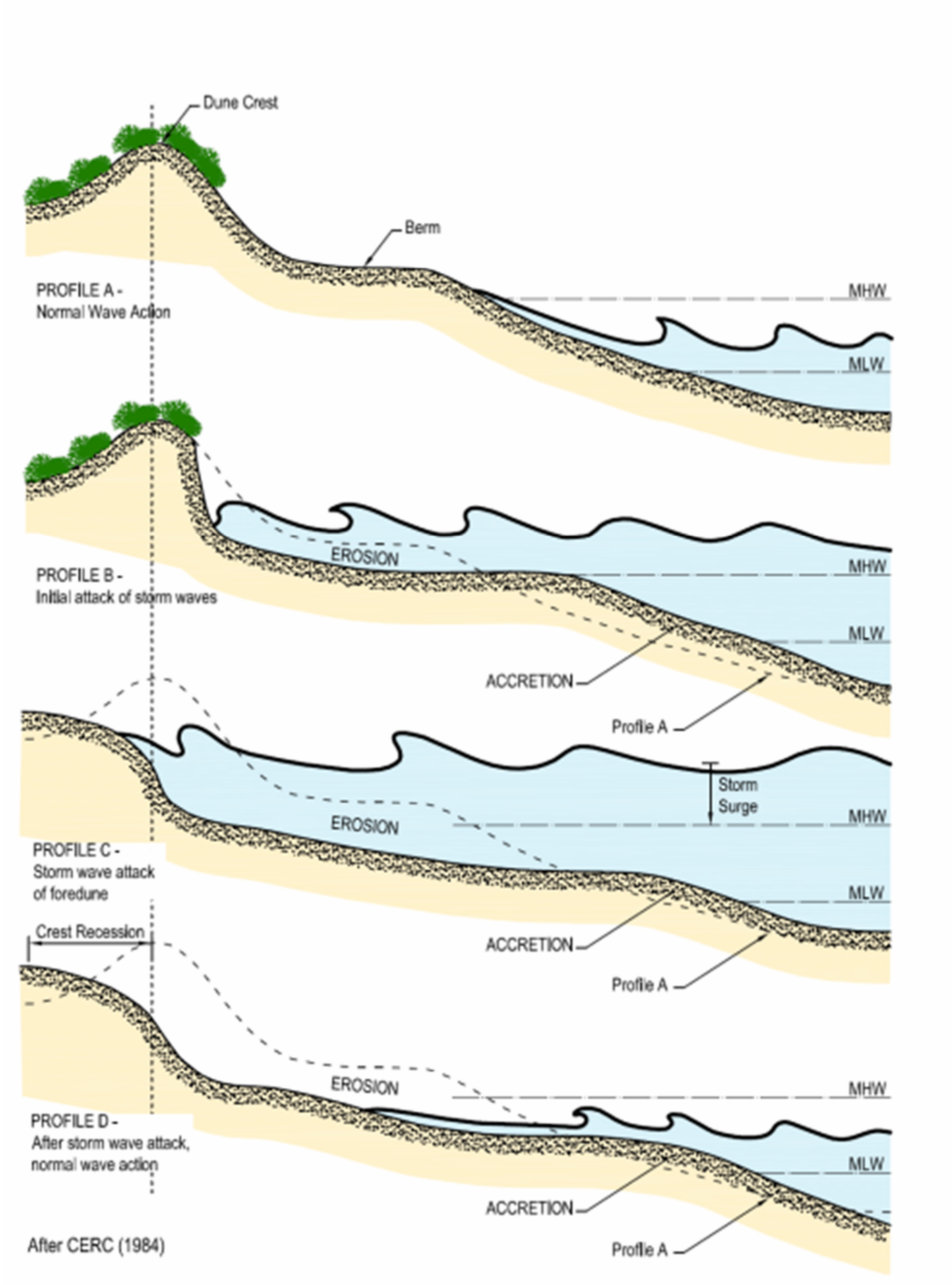



**Figure 4.4 Severe Storm Erosion Mechanism**

Erosion of sandy beaches during storms can be quite rapid and significant changes can occur in a matter of hours. Subsequent to the storm, the swell activity may move sand from offshore to the shore. This onshore process is generally at a much, much slower rate than the storm erosion.

### 4.3.1 Perched Beaches

The processes for cross-shore transport on the rocky sections of coast north of Trigg are much more complex. In many cases the underlying rock platforms and reefs mean the beaches act as perched beaches. Perched beaches are believed to undergo rapid changes in beach width during storm events. This is due to the following mechanisms:

- The low volumes of sediment available for erosion. If a storm event has a capacity to move a fixed volume of sediment it will cut further landward on a perched beach than on a nearby sandy beach.

- The influence of bed-rock on the groundwater conditions in the beach. Outgoing water contains a larger amount of sediment than sandy beaches as the water can't percolate through the bed-rock.

Figures 4.5 & 4.6 indicate the general processes for accretion and erosion on a perched beach.

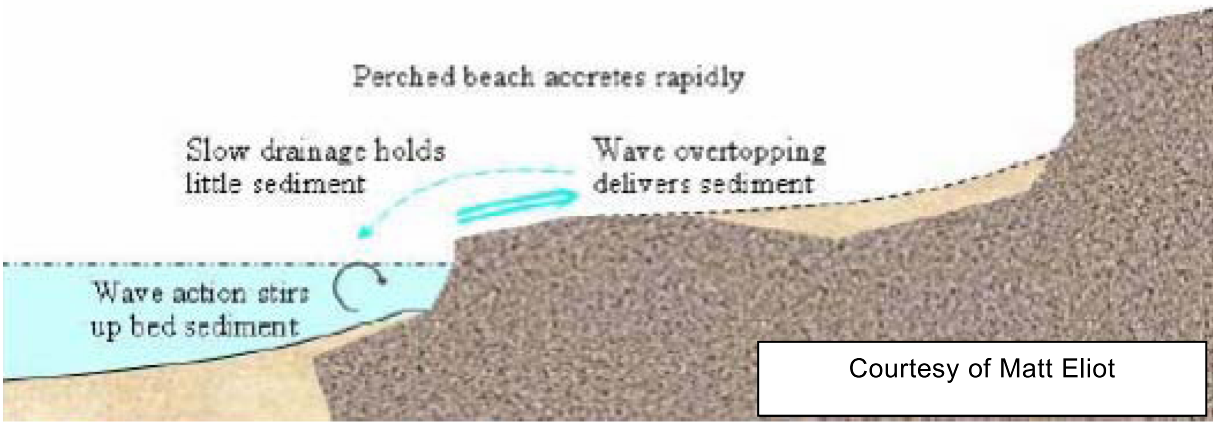



**Figure 4.5 Process of Perched Beach Accretion**

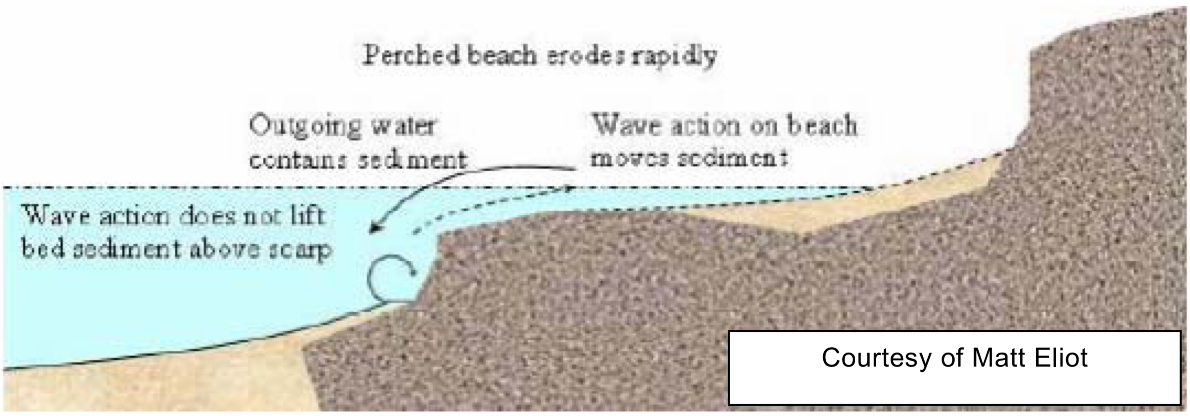



**Figure 4.6 Process of Perched Beach Erosion**

### 4.3.2 Coastal Features

The nearshore reefs and features further complicate transport. MRA (2010) and BMT JFA (2016) has previously examined these movements.

Onshore feed of sediment occurs due to the action of swell waves along the coast. The coastline between Trigg Island and HBH is bordered by offshore reefs, which produce a significant amount of Calcium Carbonate (CaCO3) sediment (Sanderson & Eliot 1999). Stul & Eliot (2006) previously measured the CaCO3 content of most Perth metropolitan beaches, including the Stirling beaches. Figure 4.7 shows the CaCO3 for the Stirling coastline.

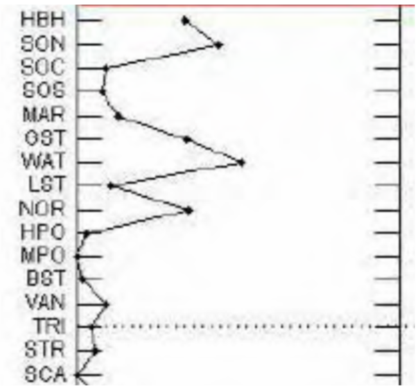



**Figure 4.7 CaCO3 Content of Stirling Beaches (Stul & Eliot 2006)**

The figure shows that the CaCO3 content increases from 15% at Trigg (TRI) to 60% at Watermans (WAT). This suggests that onshore feed from the offshore reef system occurs in the region.

## 4.4 Wind Blown Sand

The final mechanism for the movement of sediment is wind-blown sediment transport. This can move sand from the beach into nearby dunes. This is the mechanism by which coastal dunes are formed and grow. There needs to be careful management of the public use and access through coastal dunes to prevent dune blowouts occurring due to lack of vegetation. The coastal dunes form a natural buffer to accommodate the erosion during severe storms.

## 4.5 Mapping of Coastal Vegetation Lines

One method used to analyse the movement of the shoreline is through mapping the position of the coastal vegetation from aerial imagery.

The coastal vegetation is considered to represent the boundary between the back beach and the dune toe where the vegetation first appears and therefore is a good representation of shoreline position. The vegetation line is also considered to represent the limit of coastal processes and is less susceptible to short term fluctuation than other markers such as the waterline. It is also a very good visual indicator of the buffer to infrastructure. By mapping the historical position of the vegetation line, changes to the shoreline can therefore be estimated.

Shoreline position data between Cottesloe Groyne to HBH was obtained and extracted from several sources. These sources include:

- DoT vegetation lines extracted from aero-triangulated aerial photographs between 1940 to 2016;

- Vegetation lines extracted by MRA using orthorectified aerial imagery for the shoreline movement plans developed for the City (MRA 2010, 2020).

- Vegetation lines extracted by MRA using orthorectified aerial imagery for the shoreline movement plans developed for the CoJ (MRA 2016, 2017, 2018, 2019, 2021b, 2022, 2023c).

A review was conducted of the available vegetation lines. It was concluded that the baseline vegetation line needed to extend the required length of the Secondary Sediment Cell (ie HBH in the north to Cottesloe Groyne in the south) and be after the construction of the HBH. The 1990 vegetation line met these requirements and therefore was defined as the baseline position of the vegetation line. The vegetation lines listed below were also deemed appropriate for the analysis.

- 2004.

- 2016.

- 2019.

- 2022.

The chainage intervals for the mapping of the vegetation line are shown in Appendix A. The position of the vegetation lines relative to the 1990 location was determined at each interval from the shoreline movement plan, with results presented in Figure 4.8.

A series of shoreline movement time history plots have also been prepared for discrete chainage locations at Mettams Pool in Figure 4.9.

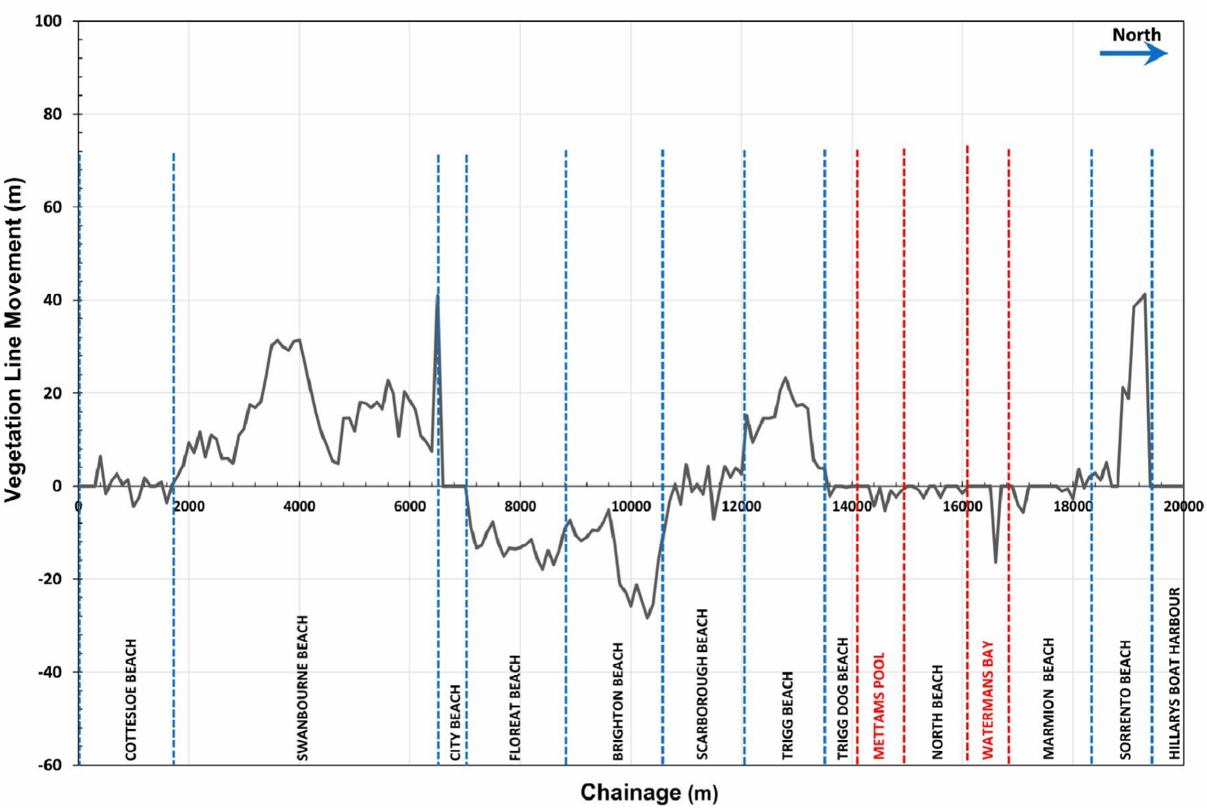
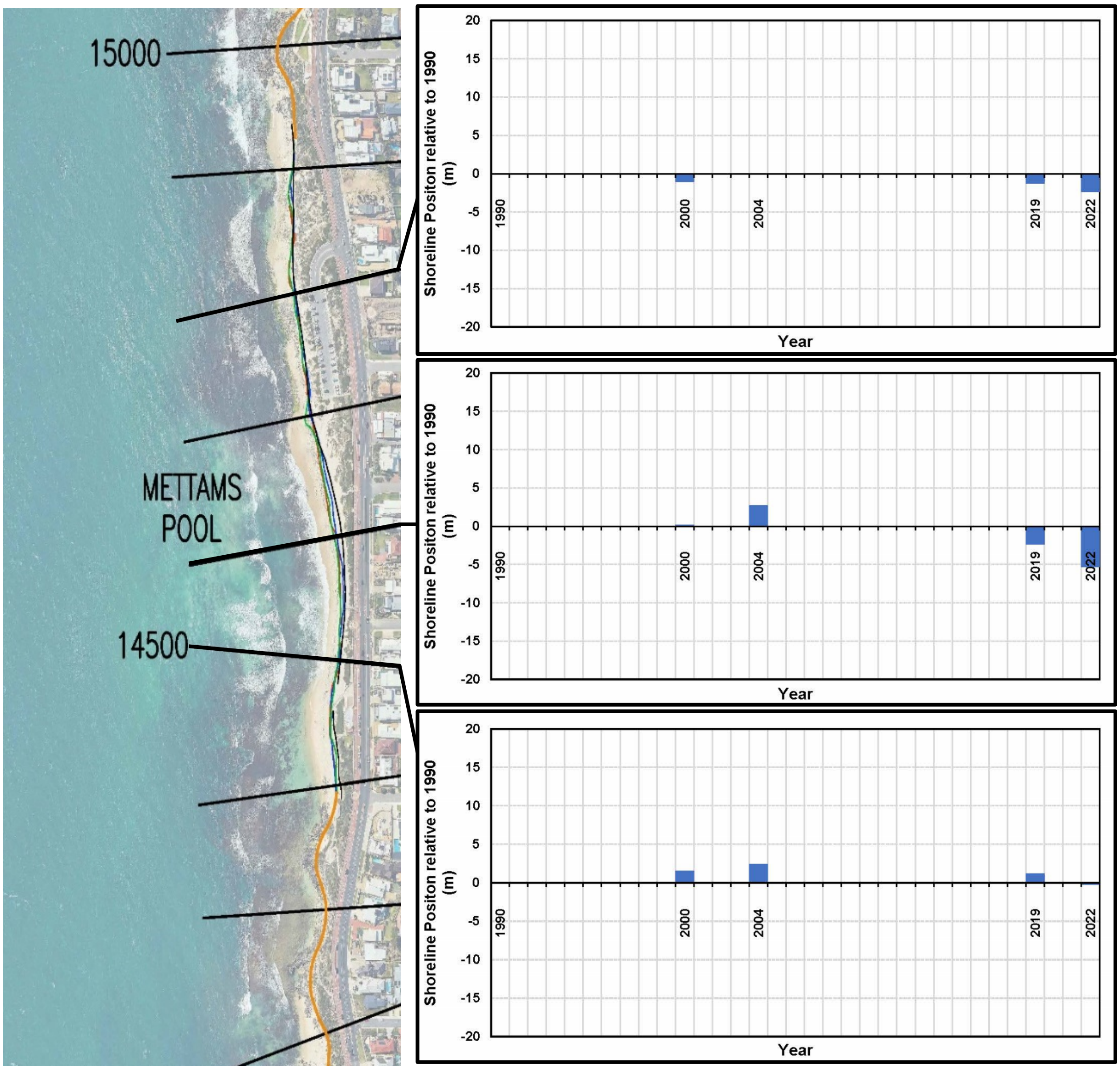



**Figure 4.8 Vegetation Line Movement 1990 to 2022**




## Figure 4.9 Time History of Shoreline Movement

The vegetation line movement plot indicates the following.

- There is a significant accretion trend at Swanbourne, Trigg and Sorrento beaches. In several locations, the beaches have experienced a total net accretion of greater than 20 m over the 32-year timeframe.
- There is an erosional trend from the northern end of City Beach to the northern end of Brighton Beach. In one location, the beach had receded up to approximately 30 m over a 32 year timeframe.
- From Trigg Point to the southern end of Marmion Beach, the vegetation line has been sable or experienced minor erosion.

The results of the rocky section of coast north of Trigg should be interpreted with caution, as shoreline movement results determined using the position of the vegetation line are considered less reliable for these types of coastlines. This will be discussed in further detail below.

To better illustrate the trends in shoreline movement over time in a spatial context, the shoreline movement time history plots should be referred to. Figure 4.9 suggests the following at Mettams Pool.

- The time history plots suggest that the shoreline position had either not changed or accreted in 2004, 14 years after the baseline position was recorded. Since this time, the shoreline has eroded at varying rates.

- The plot shows that the beaches which are more open to the ocean influences are subjected to larger erosional trends than those shorelines protected by headlands or fringe reefs / rock platforms.

Although the vegetation line provides insight into the response of the shoreline over the 32-year period, the vegetation lines alone does not provide the full picture. This is evident in areas such as at Scarborough, where the vegetation line is controlled by fencing, influenced by recreational use and foot and vehicle traffic. In places, the vegetation line is non-existent. This can be seen in the aerial photograph in Figure 4.10

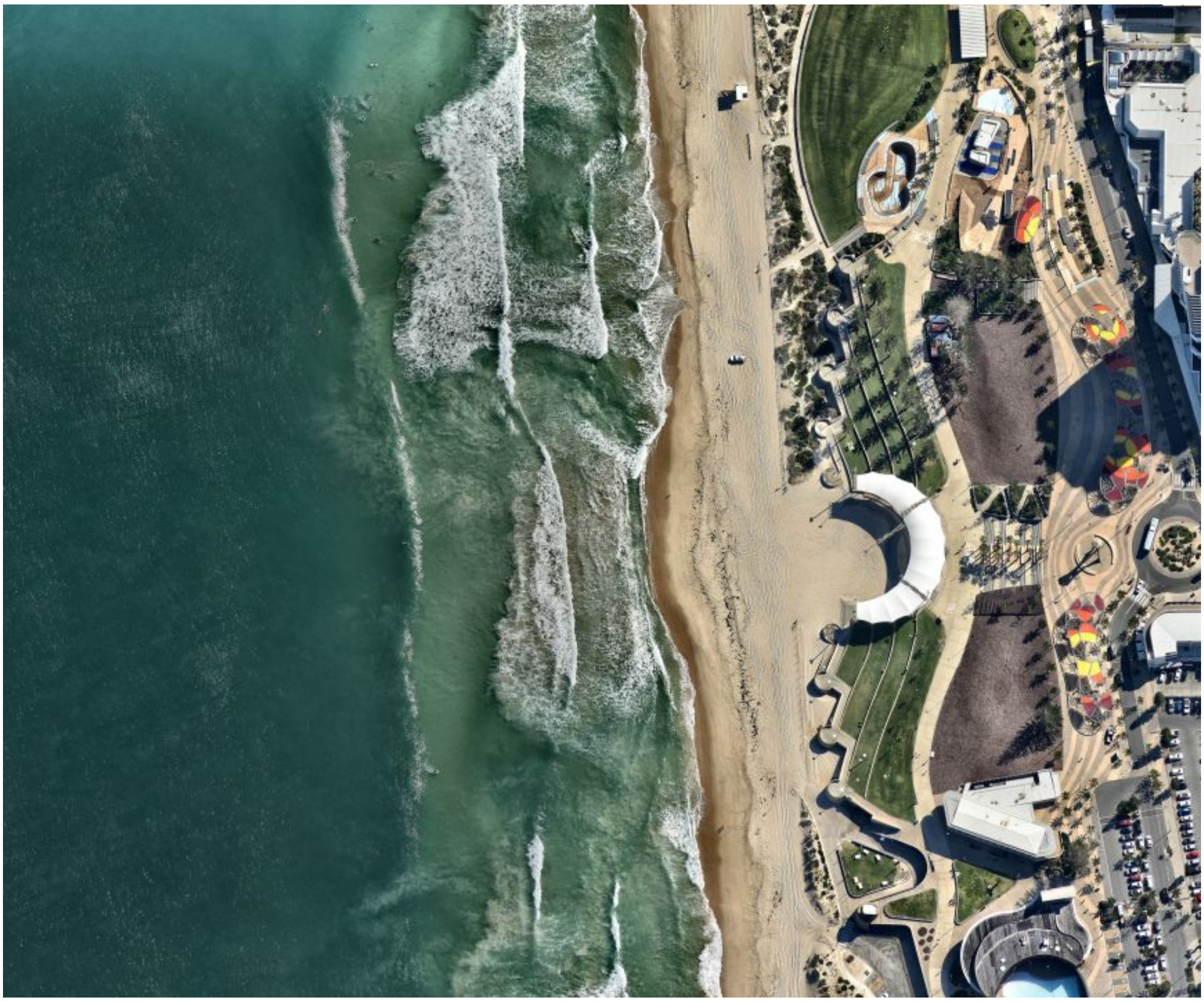


**Figure 4.10 Limitations of Vegetation Line Mapping through Scarborough Beach**

This is consistent with other areas within the study area. Therefore, to better understand the sediment dynamics of the City's coastline, mapping of the Mean Sea Level (MSL) has also been considered.

## 4.6 Mapping of Mean Sea Level

Digital Earth Australia (DEA) is an initiative by the Australian Government, managed by Geoscience Australia, to provide reliable and accessible information derived from satellite imagery. It utilises decades of Earth observation data to help monitor and manage Australia's unique environment.

One of the features that DEA provide is the DEA Coastline which utilises work by Bishop-Taylor et al. (2021) to analyse satellite data from Geoscience Australia's Digital Earth Australia program. The software combines satellite data with tidal modelling to map the typical location of the MSL throughout Australia for every year since 1988.

For this assessment shoreline movement data was extracted from the DEA website for the period between 1988 to 2022. Shoreline movement data is provided at 30 m intervals along the coastline.

A review was conducted of the DEA Coastline data.  It was concluded that where shoreline movement rates were prescribed to ‘rocky coastlines’ (as defined by DoT), the rates were discounted as part of the assessment.  Figure 4.11 below provides a comparison between mapping of the vegetation line and MSL.

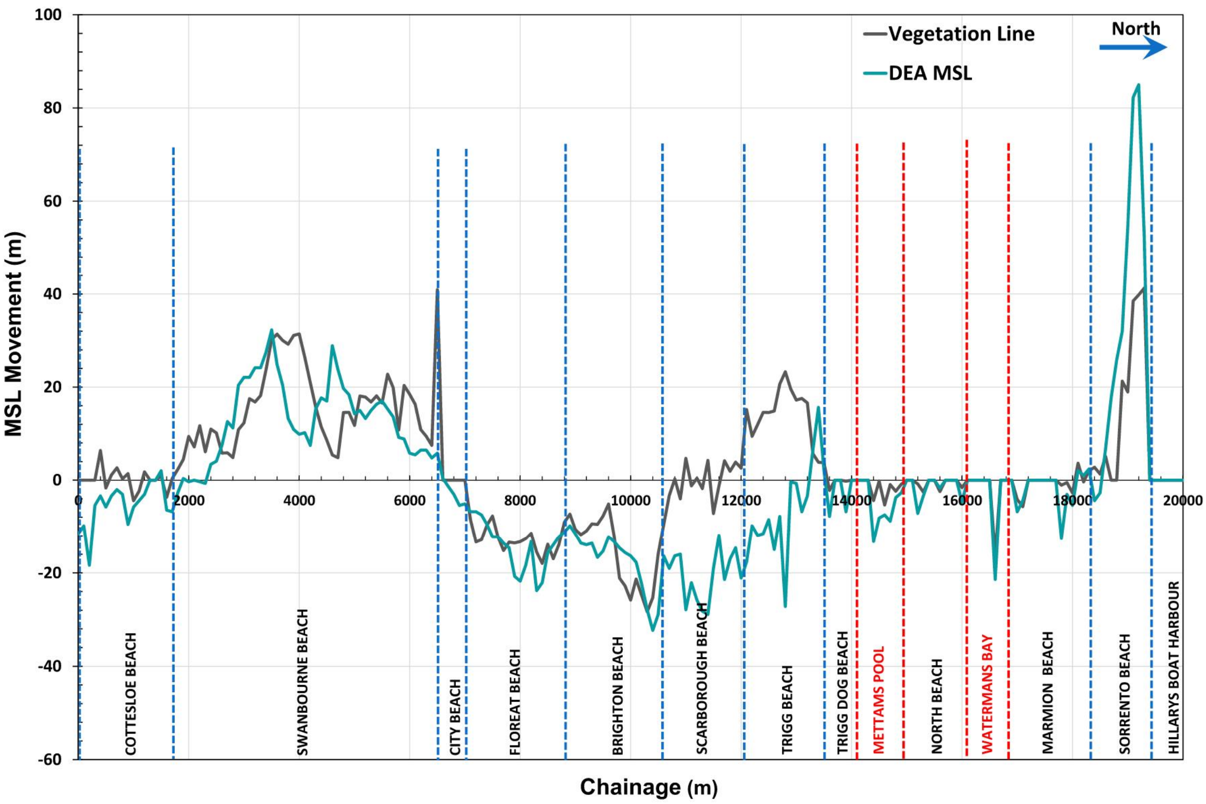



**Figure 4.11 Shoreline Movement 1990 to 2022 Comparison**

Figure 4.11 indicates the following.

- For ‘sandy coastlines’ (ie Swanbourne Beach to Brighton Beach), both methods are relatively consistent in predicting the changes to the shoreline.
- Areas where the vegetation line has been stabilised by fencing or other structures (City, Scarborough and Sorrento beaches), there is a disparity between results.
- Excluding the northern most extent of Trigg Beach, most of the foreshore at Trigg Beach is shown to be eroding, this is a contrasting result from the mapping of the vegetation line.

DEA Coastline is a valuable tool for analysing sediment dynamics, but similar to the vegetation line mapping it does have limitations that need consideration.  One limitation is that the MSL position can be influenced by short-term changes, potentially skewing the long-term analysis.  It also relies on machine learning to differentiate pixels and interpret the location of the MSL, which can be impacted by things such as seagrass, waves, rock or reef.  Subsequently, both analysis techniques should be considered for a holistic approach to assessing the sediment dynamics on the City’s coastline.

## 4.7 Shoreline Movement

The final shoreline movement model was developed by reviewing the shoreline at discrete locations and assessing the conditions. The change was then assessed at intervals, using a combination of the vegetation line and MSL analysis. The result of the analysis is shown in the figure below.

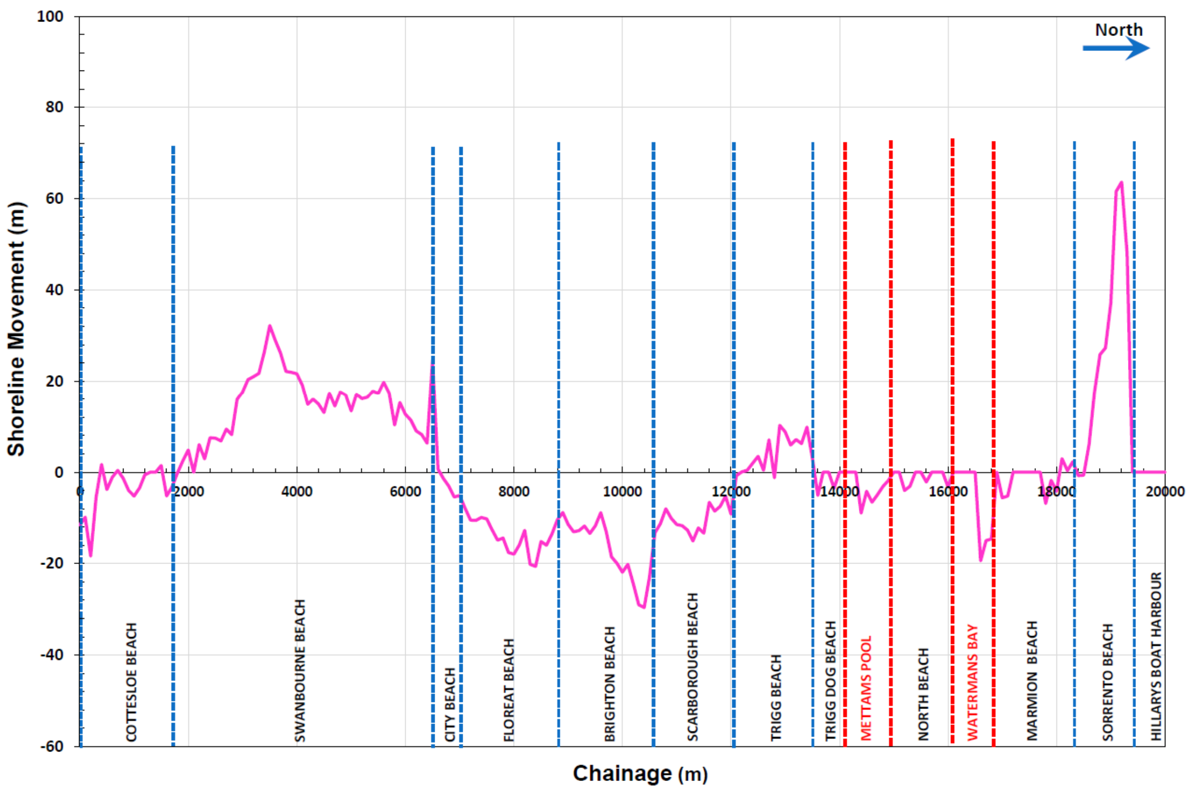



**Figure 4.12 Shoreline Movement 1990 to 2022**

## 4.8 Conceptual Sediment Movement Models

The extent of shoreline movement captured by the above assessment can be used to estimate the volumes of erosion and accretion within the study area. These volumes were estimated by multiplying the observed shoreline movement, by the active profile height estimated for each area. Figure 4.13 provides an overview of the sediment budget for the entire length of the foreshore from HBH in the north to Cottesloe in the south. While Figure 4.14 shows discrete changes at Mettams Pool.

The values in the figure are in $m^3$/year, and are indicative only. The negative values, in red, indicate recession of the shoreline, whilst the positive values, in green, indicate accretion.

It is noted that these quantities do not show all potential sources and sinks of sediment, including onshore feeds and offshore losses, which may alter fluxes between the areas of interest. However, they represent the significant changes onshore, which are critical for infrastructure protection.

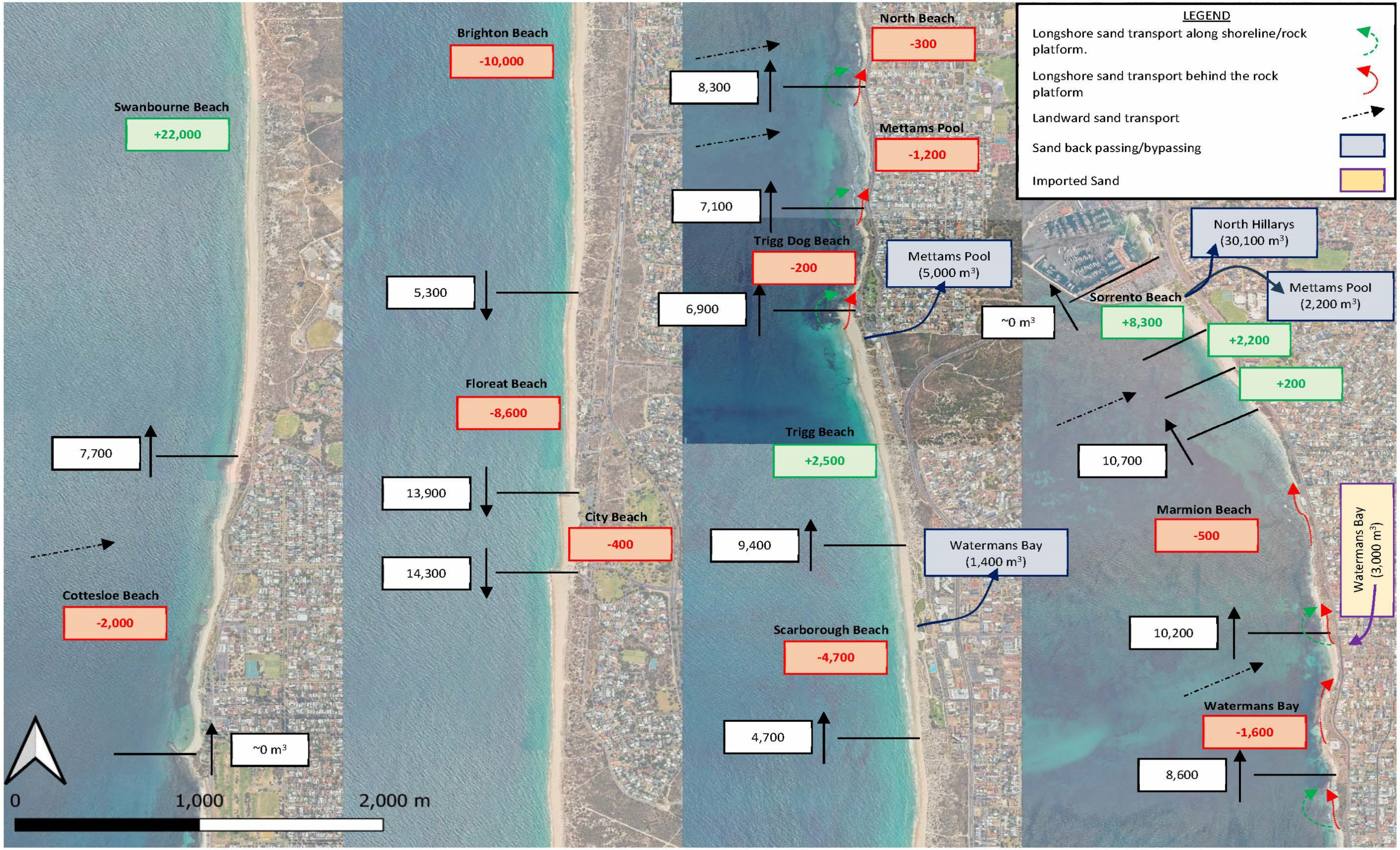



**Figure 4.13 Sediment Budget Overview (Hillarys Boat Harbour to Cottesloe Groyne)**

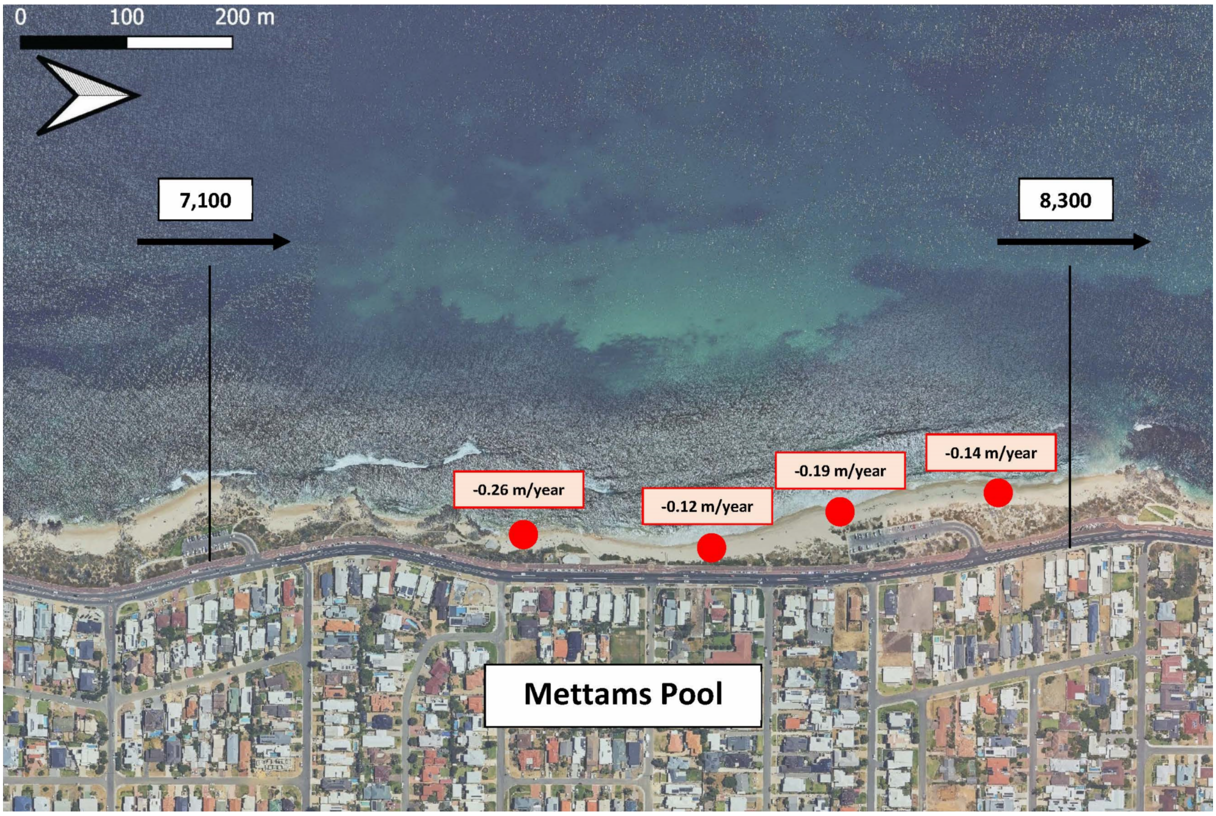



**Figure 4.14 Sediment Budget**

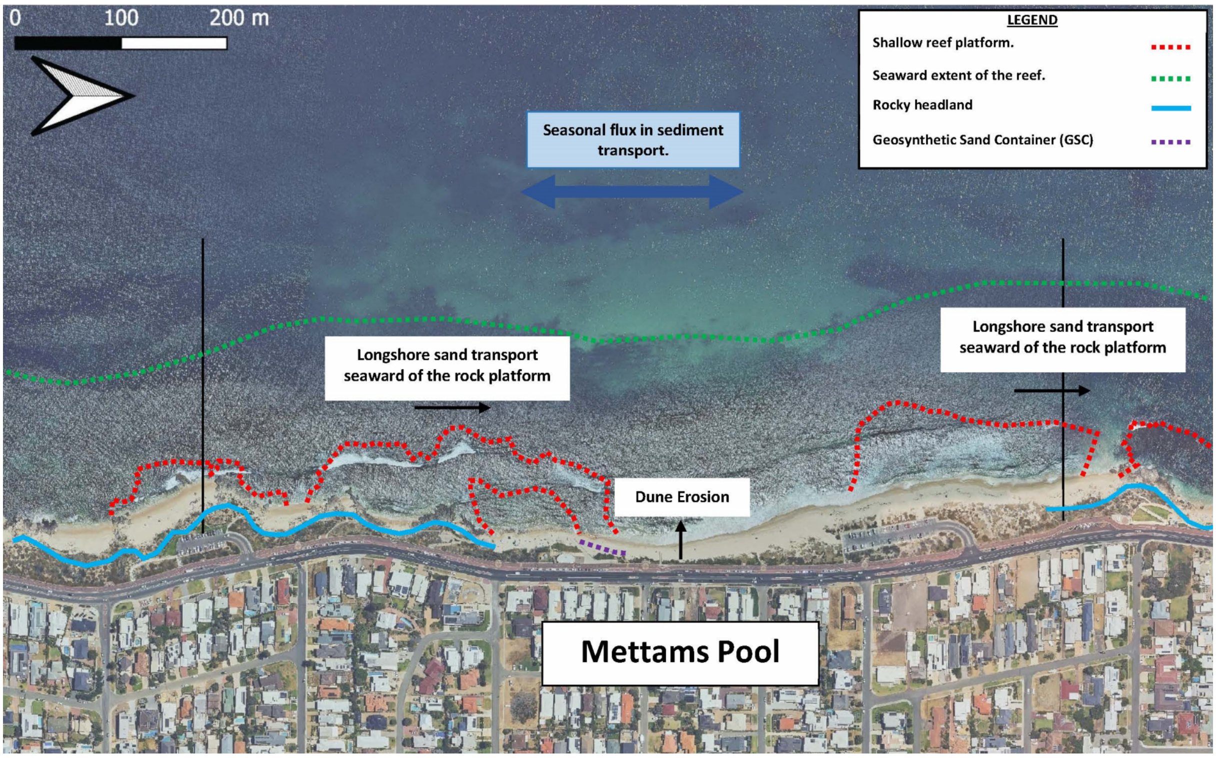
In general, the figures above show that the net sediment transport is to the north in the order of approximately 10,000 m³/year. This is highlighted by accretion on the southern sides of Trigg Point and HBH. At Mettams Pool, the following is noted:

- An average of 1,200 $m^3$ of sediment is lost from the beach and dunes per year.
- The largest rate of change is -0.3 $m^3$/year at the southern end of the shoreline.

The coastal dynamics at Mettams Pool are significantly more complex than what occurs on a typical sandy coastline. Figure 4.15 highlights the complex nature of the coastline, where the movement of sediment is multifaceted and controlled by met-ocean conditions.

For the foreshore north of Trigg Point, longshore transport is considered to occur via the transport of sediment between the headlands and shallow tidal reefs, directly seaward of the shallow tidal reefs or further offshore. Whereas, with cross-shore transport sediment is moved offshore /onshore via beach slopes, gaps and channels in the rock platform, over and across the shallow tidal reefs or sand ramps connecting beaches with offshore sand banks (BMT JFA, 2016). This suggests that the sediment pathway along this section of the foreshore is closely linked to the coastal topography.

Moreover, given that Mettams Pools is a perched beach, they are also suggested to undergo more rapid changes than sandy coastlines. BMT JFA (2016) investigation concluded that perched beaches may recover more slowly from daily summer sea breezes erosion. Where rock platforms are present, the energy from storm waves and water levels can be attenuated which can result in less coastal erosion than what is generally expected for sandy coastline that is exposed to the same conditions.




## Figure 4.15 Coastal Dynamics

# 5. Wave Model Set-up & Calibration

## 5.1 General

Wave modelling was completed to transfer the offshore design conditions to Mettams Pool.

## 5.2 SWAN Wave Model

The Delft3D suite of models provides an integrated model approach that can be used to simulate wind fields, wave climates and water levels associated with severe storm events. These models have been extensively used around the world and are recognised as high-quality models. An integrated modelling approach has been adopted for this study to best represent the physical processes that generate extreme wave heights. SWAN is a third-generation wave model which sits within the Delft3D suite. The model computes random, short-crested wind-generated waves in coastal regions and inland waters (Deltares, 2011).

The physical processes that lead to the generation of extreme wave heights operate on a significant spatial scale. Due to computational limitations, it is not efficient to model large areas at high resolutions. Nested modelling techniques have been utilised within the Delft3D model for this study.

## 5.3 Grids

Grid nesting allows sections of the overall grid to be modelled at significantly greater resolution to capture the key features and bathymetry surrounding the area of interest. Utilising curvilinear, variable grids allows key features such as reefs, channels, shoals and banks to be well resolved, even if they are not located close to the area of interest but would still have significant impact on wave conditions at the sites. The grid sizes and resolutions for different regions in the model domain are presented in Table 5.1.

**Table 5.1 Model Grid Size**

| Grid | Area | Grid Size | Varying Resolution |
|---|---|---|---|
| Grid A | Two Rocks to Fremantle | 89 km x 35 km | 2,000 - 600 m |
| Grid B | Pinnaroo Point to City Beach | 15 km x 10 km | 150 - 100 m |
| Grid C | Sorrento Beach to Trigg Beach | 5 km x 4.5 km | 20 - 10 m |

Figure 5.1 shows the model domain and extents of the grids. Figures 5.2, 5.3 and 5.4 present the domain and bathymetry for each of the grids prepared for the model. Bathymetry and topography data were sourced from the following sources:

- Most recent LiDAR survey data, including:
  - 2015 Perth Survey.
  - 2015 Ocean Reef Survey.
- 2024 JBA Feature Survey.

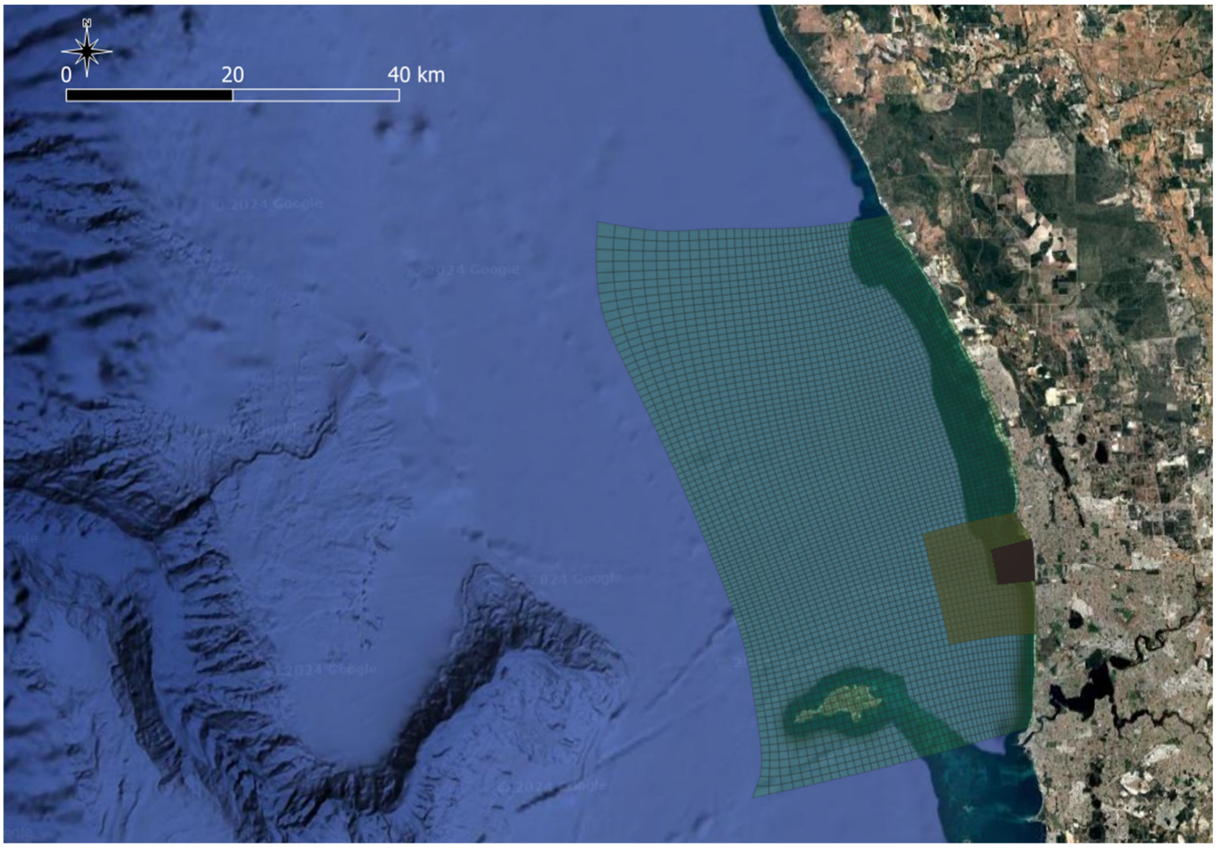



**Figure 5.1 Wave Model Domains**

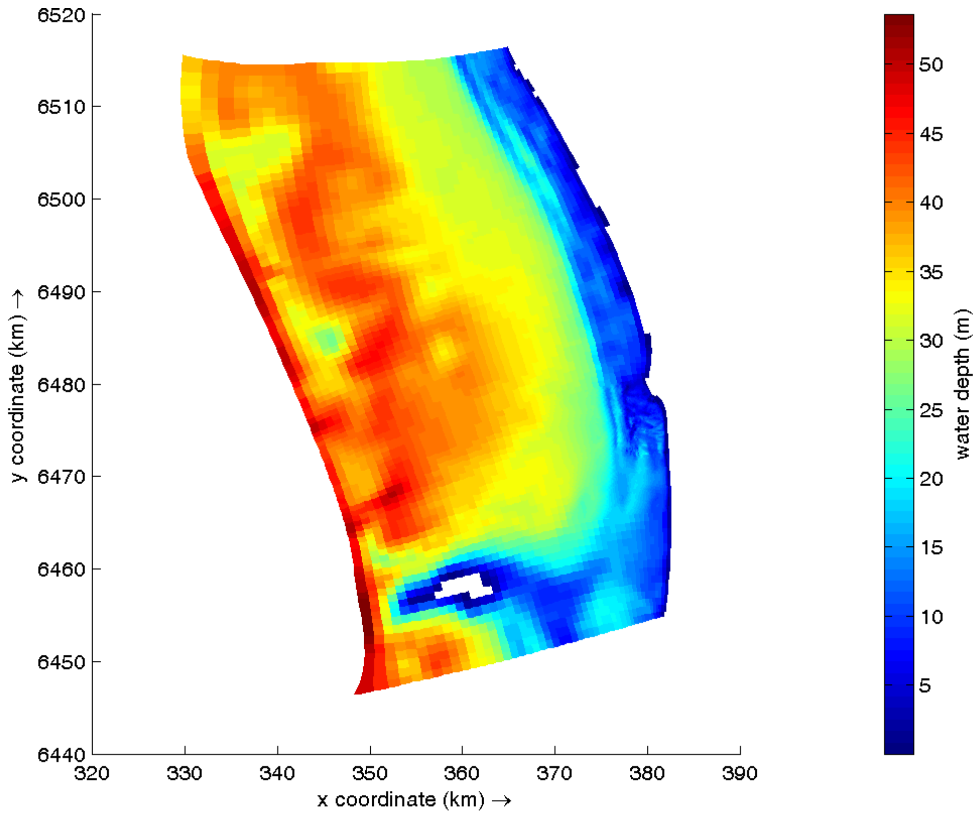
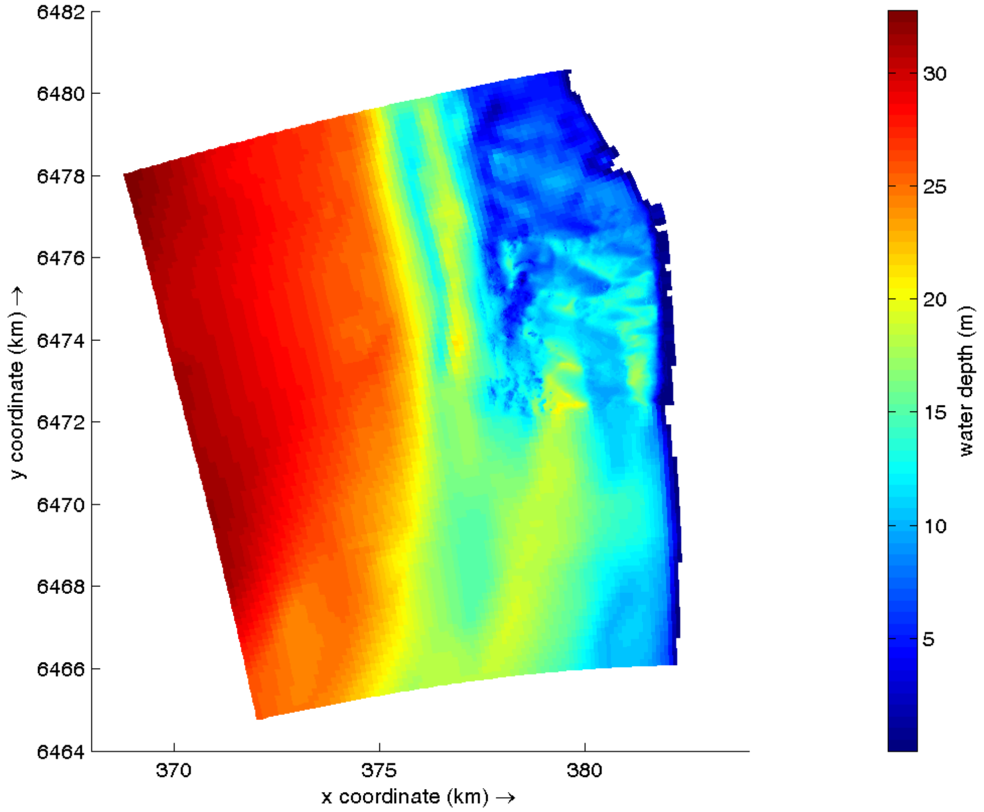
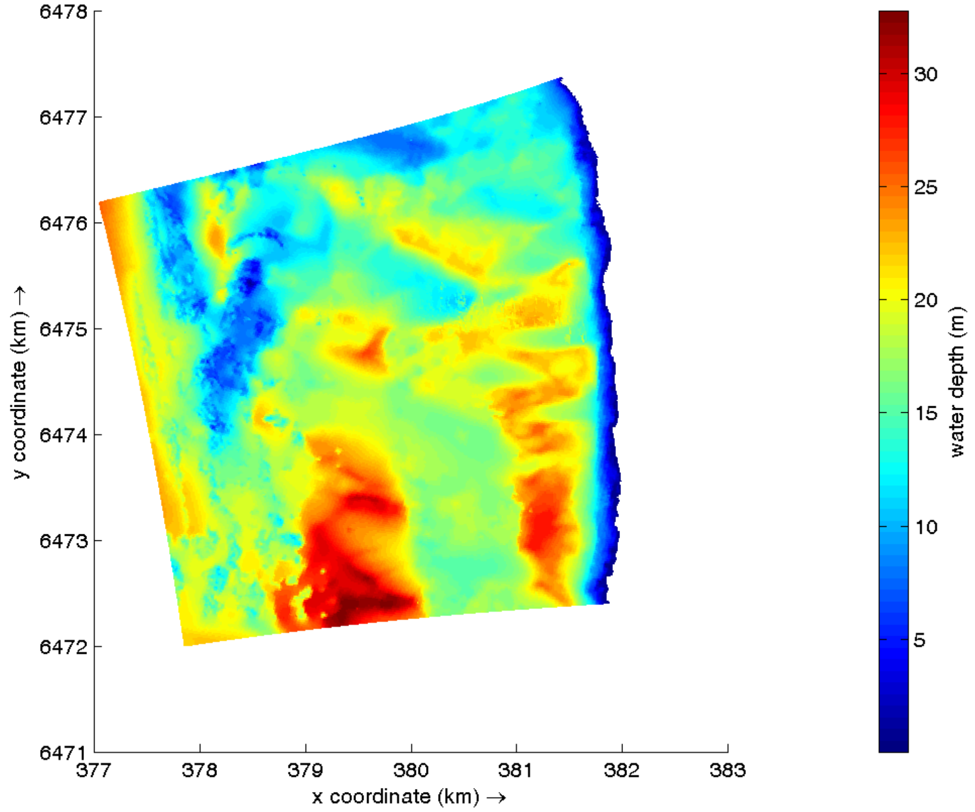



**Figure 5.2 Grid A Bathymetry**




## Figure 5.3 Grid B Bathymetry




## Figure 5.4 Grid C Bathymetry

## 5.4 Model Calibration

Following establishment of the grids, calibration and validation of the model was undertaken to ensure model predictions adequately reflected reality. MRA has validated the Delft 3D model at numerous locations across the Perth Metropolitan coastline including Ocean Reef (MRA 2016a & 2019a) and Joondalup (MRA 2016b).

To further validate the model's ability to accurately represent conditions at the site, wave data for an 18-day period between 10 to 28 June 2022 were simulated within the model domain to determine if the model predictions matched measurements.

### 5.4.1 Model Inputs

The data record for water levels, waves and wind velocities were obtained from the FFBH tide gauge, the Rottnest wave buoy and the Ocean Reef wind station respectively. The details of the recording devices are provided in the table below and locations shown in Figure 5.5.

**Table 5.2 Model Input Data**

| Inputs | Location (Lat, Long) | Depth/Elevation |
|---|---|---|
| Rottnest Wave Buoy | -32.0942, 115.4078 | ~48 m water depth |
| Fremantle Fishing Boat Harbour Tide Gauge | -32.0558, 115.7394 | ~5 m water depth |
| Ocean Reef Wind Station | --31.7594, 115.7278 | ~10 m above sea level |

### 5.4.2 Calibration Data

Calibration for the model was undertaken via comparison of model outputs with observations at locations where data was available. A comparison of model outputs against the Mettams Pool wave data provided by DoT was undertaken. Details of the wave data is provided in Table 5.3 whilst its location is shown in Figure 5.5.

**Table 5.3 Calibration Data**

| Inputs | Location (Lat, Long) | Depth/Elevation |
|---|---|---|
| Mettams Pool Wave Data | -31.9652, 115.7384 | ~10 mAHD |


**Figure 5.5 Model & Calibration Data Locations**

## 5.5 Calibration Period

The purpose of the modelling is to establish wave conditions at the site for development of concept options at Mettams Pool. Therefore, calibration and validation of the model was focussed on ensuring conditions simulated by the model accurately reflected those experienced during an 18-day period. The calibration period did not include any severe wave events. The largest wave event captured during the 18-day period was 6.7 m which is below the 7.05 m extreme wave expected for a 1-year ARI event, outlined in the table below.

**Table 5.4 Calibration Period**

| Start Date | End Date | Peak Hs (m) at South-west Rottnest Wave Buoy | 1-year ARI Event at Peak Hs (m) at South-west Rottnest Wave Buoy |
|---|---|---|---|
| 10/06/2022 | 28/06/2022 | 6.7 | 7.05[1] |

Notes:
1. Based on analysis completed by MRA (2018a).

Figure 5.6 shows the input data for the calibration period along with the 1-year ARI peak significant wave height at the input data location.

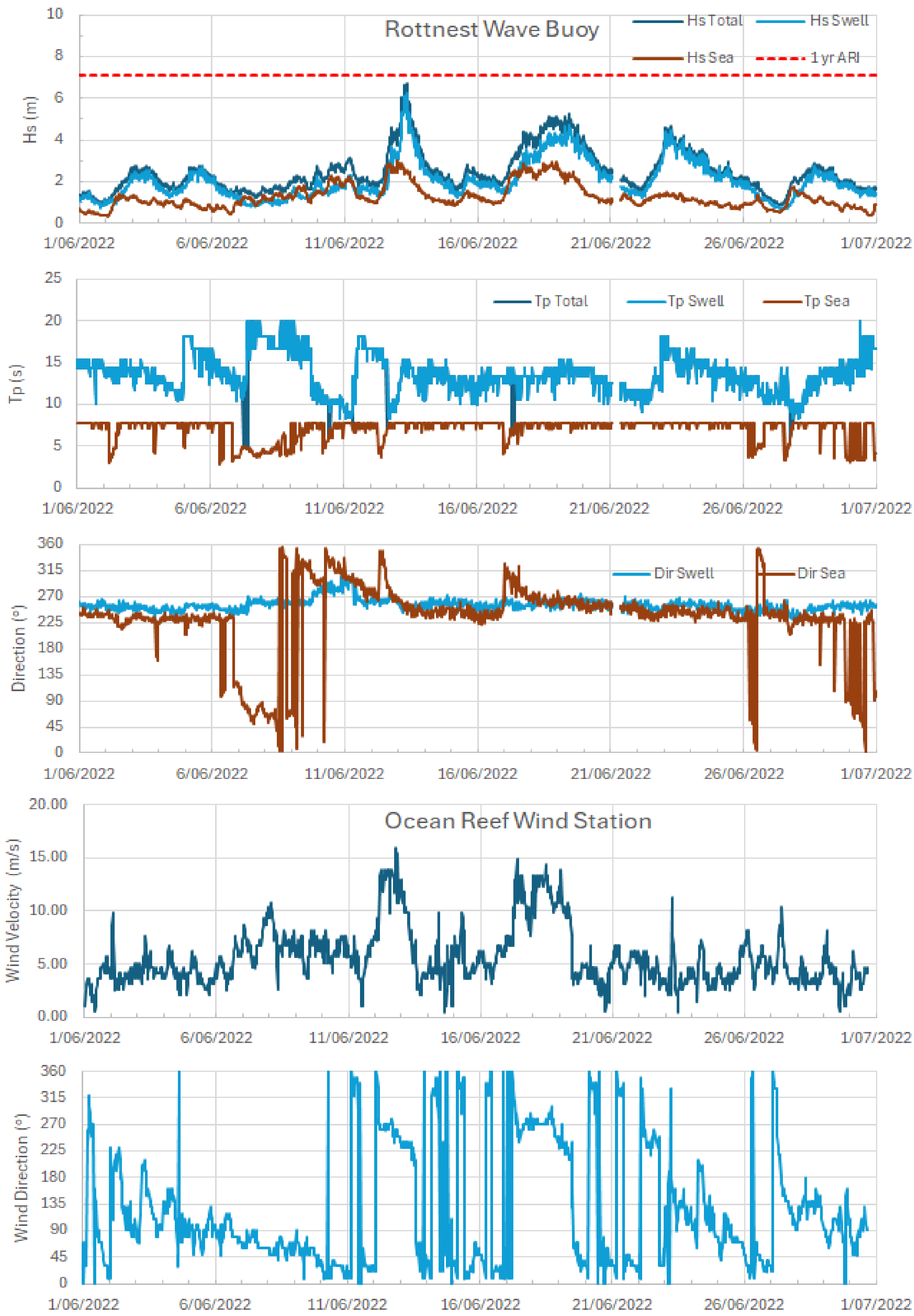



**Figure 5.6 Calibration Period Input Data**

## 5.6 Calibration Results

Due to the extensive range of locations along Western Australia's coastline for which the model has been calibrated and validated, no adjustments for wave energy reduction through breaking, bed friction, refraction, or shoaling were necessary to accurately reproduce the incident wave heights at the site where DoT Wave Measurement Data was collected for Mettams Pool.

Time history plots showing the results of the wave modelling for the calibration period against Mettams Pool wave data are presented in Figure 5.7. As is evident, the model slightly over predicts the wave height however is generally consistent when predicting the wave period. There also appears to be a slight phase shift between the measured and modelled data. Nonetheless, for the use of establishing design conditions at Mettams Pool, the results are conservative but appropriate.

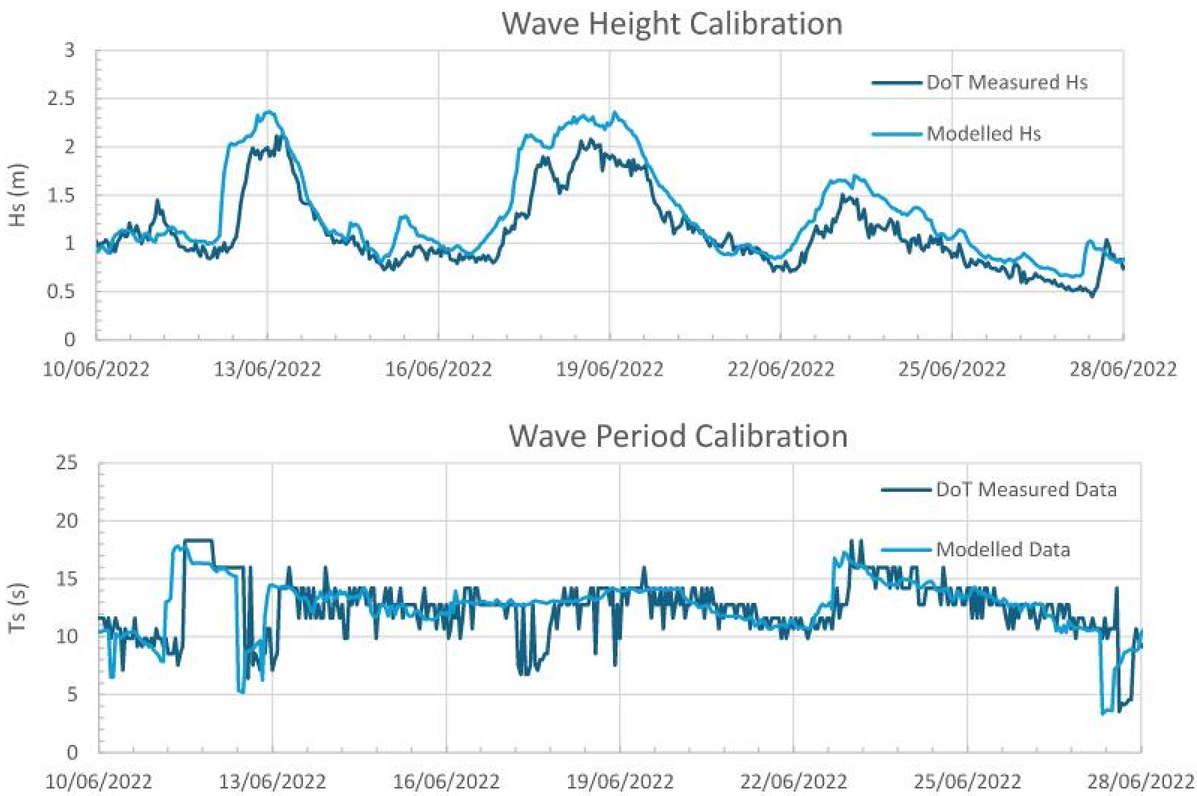



**Figure 5.7 Comparison of Measured vs Modelled Data**

## 5.7 Modelled Scenarios

MRA (2020) conducted a detailed met-ocean study to support the design of the Ocean Reef Breakwaters. The study involved analysing relevant historical met-ocean data to determine design wave conditions, ensuring that the breakwaters meet functional design criteria, including armour stability, overtopping, harbour tranquillity, and navigability.

The analysis involved reviewing all significant wave events ever recorded by the Rottnest wave buoy and synthesising these events to represent wave events of various ARIs. This process involved:

- Scaling of input spectral wave data over the event by a factor to achieve the required ARI significant wave height at Rottnest wave buoy at the peak.
- Selection of a steady input water level consistent with the required ARI peak water level event at FFBH tide gauge with 50 years of sea level rise linearly imposed.
- Scaling of input winds over the event by a factor to achieve the required ARI 2- and 4-hour moving averaged wind speeds.

The synthesised events are a combination of the corresponding ARI wind, water level and offshore wave events. It is noted that this approach is a reasonably conservative method of estimating the ARI event as typically the peak wave, water level and wind conditions during winter fronts in WA do not occur in the same instant.

From MRA's review of the study, the following scenarios were modelled to evaluate the wave conditions at Watermans Bay and Mettams Pool for the 50-year and 100-year ARI events. A directional sensitivity analysis was also undertaken for the 100-year ARI event, whereby the incident wave and wind directions were rotated by 25° north and 25° south. Hence, four scenarios in total were modelled for the sites, refer to Table 5.5.

Scenario modelling involved simulating the entire storm event with waves and winds reflective of the real historical event scaled to achieve the target peak magnitudes. Water levels were applied as a consistent level across the simulation.

### Table 5.5 Modelled Design Scenarios

| Scenario Reference | Water Level (mAHD) | Offshore Wave Height (m) | Offshore Wave Direction (°) | Offshore Wave Event | 2-hr Wind (m/s) | 4-hr Wind (m/s) | Modelled Wave Height at Mettams Pool (m) |
|---|---|---|---|---|---|---|---|
| **50-year ARI Events** | | | | | | | |
| July18 | 1.58 | 6.87 | 315.00 | 02/07/2018 11:50 | 22.7 | 21.6 | 2.10 |
| **100-year ARI Events** | | | | | | | |
| July18 | 1.62 | 9.16 | 257.5 | 22/07/2018 23:20 | 22.2 | 21.4 | 2.32 |
| July18_RotS | 1.62 | 9.16 | 232.5 | 22/07/2018 23:20 | 22.2 | 21.4 | 2.31 |
| July18_RotN | 1.62 | 9.16 | 282.5 | 22/07/2018 23:20 | 22.2 | 21.4 | 2.39 |

## 5.8 Model Results

The results for the 50-year and 100-year ARI events at Watermans Bay are summarised in Table 5.6 and Figures 5.8 and 5.9.

**Table 5.6 Model Results**

| Average Recurrence Interval (years) | Significant Wave Height (m) | Tp (s) | Water Level (m) |
|---|---|---|---|
| 50 | 2.10 | 5.41 | 1.2 |
| 100 | 2.39 | 8.21 | 1.2 |

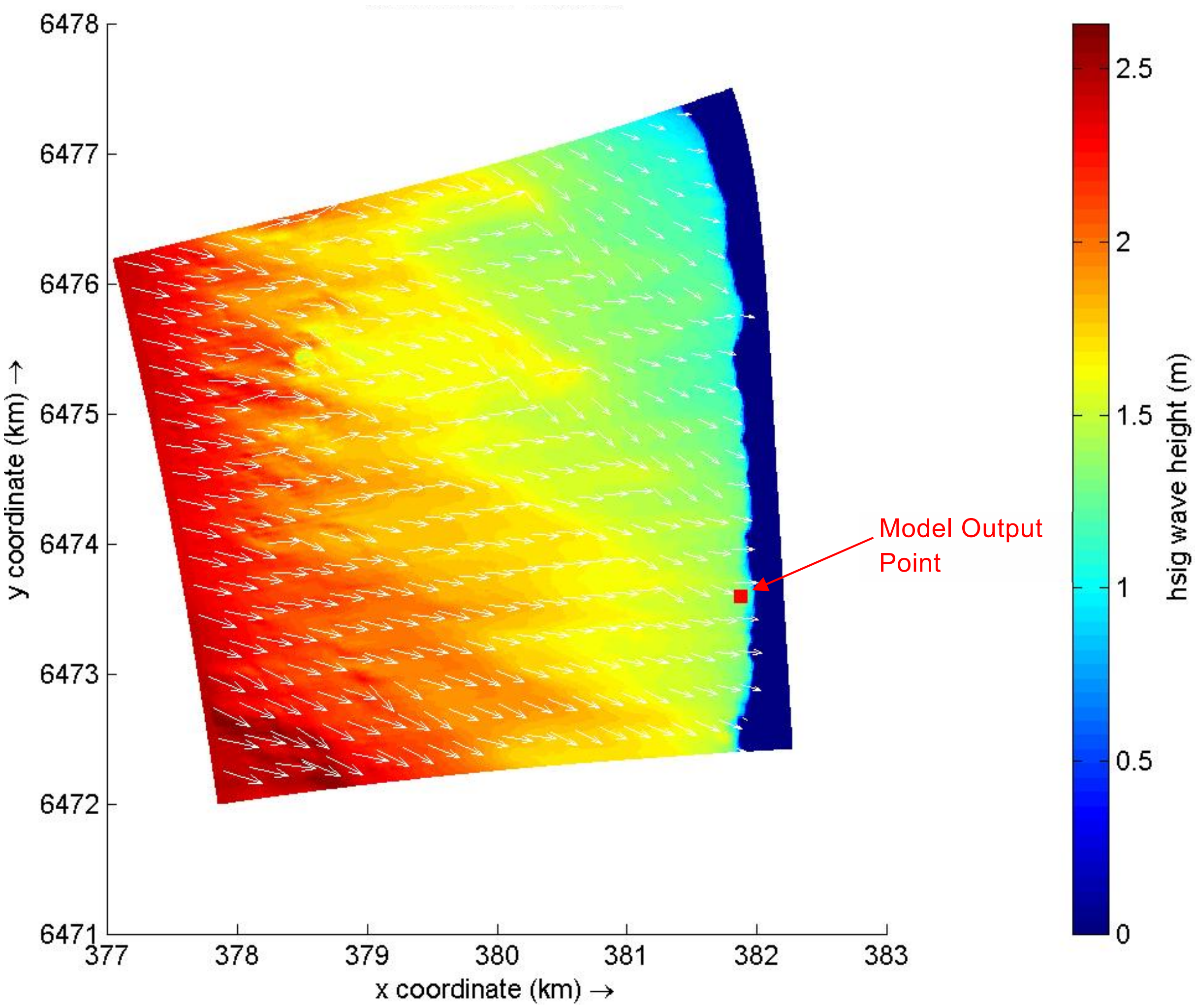



**Figure 5.8 50-Year ARI Model Results**

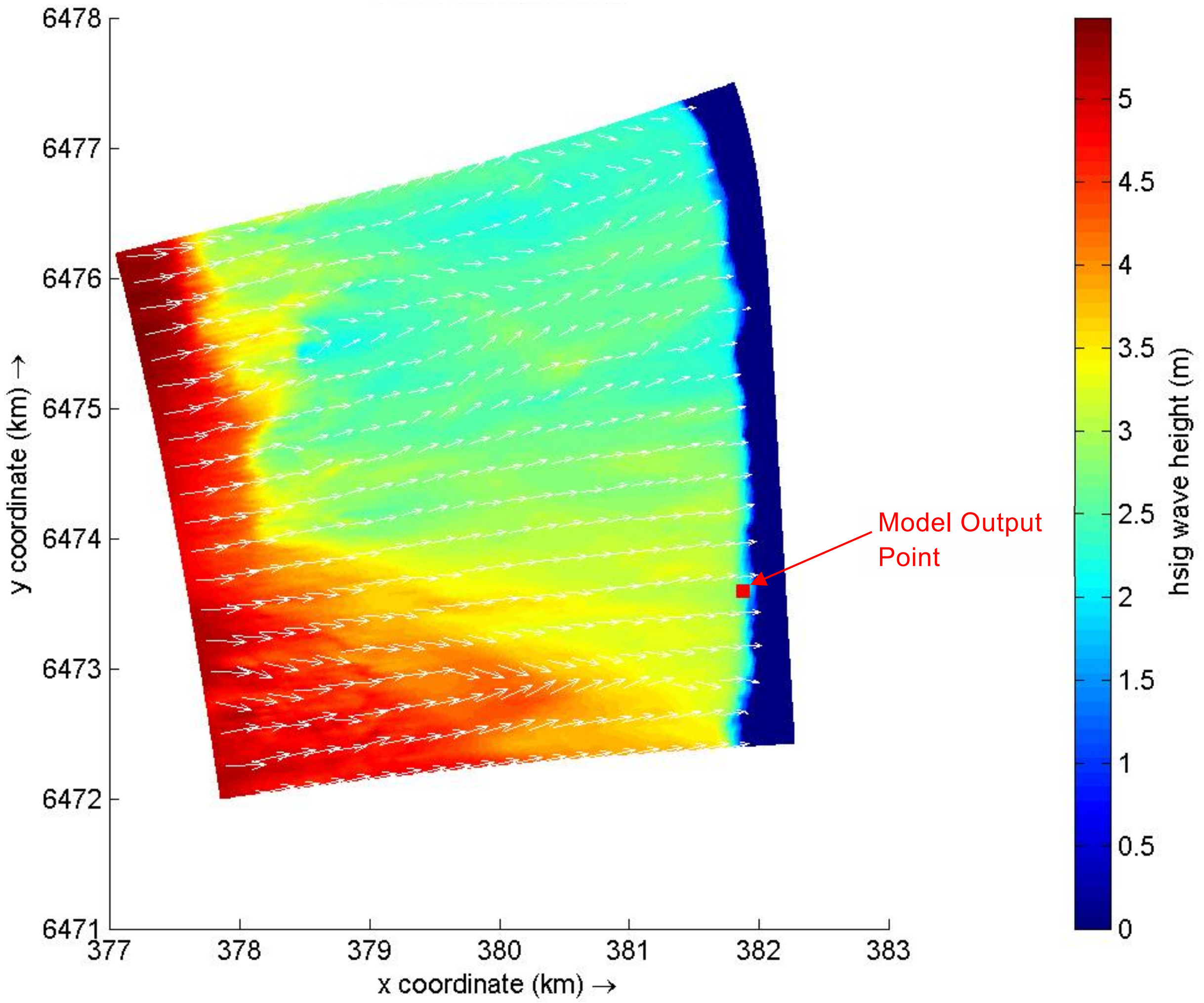



**Figure 5.9 100-Year ARI Model Results**

# 6. Stakeholder Engagement & Communication

## 6.1 General

To support the development of coastal adaptation options for Mettams Pool, along with Watermans Bay, MRA engaged 361 Degrees to assist the City in implementing a Community and Stakeholder Engagement Plan (the Plan). The Plan, aligned with the City's Community and Stakeholder Engagement Policy and assisted to guide the adaptation concept development from December 2023 to March 2025.

The Plan aimed to:

- Build on previous consultation while minimising stakeholder fatigue.
- Foster shared understanding of coastal hazards, community values, and key infrastructure risks.
- Ensure transparency and stakeholder confidence in final recommendations.

A hybrid engagement approach combined digital communication and face-to-face engagement through the Mettams & Watermans Reference Group (Reference Group). Stakeholder input was used to inform the options and the Multi-Criteria Analysis (MCA) completed to compare options.

## 6.2 Mettams & Watermans Reference Group

The Reference Group was established to bring together key stakeholders, government agencies, and technical experts. This group played a crucial role in aligning project partners, reviewing data, and refining adaptation options. The participating organisations present in the Reference Group included:

- City of Stirling Officers.
- Ward Councillors.
- Department of Planning, Lands and Heritage.
- Department of Transport.
- Department of Biodiversity, Conservation and Attractions.
- MRA.
- 361 Degrees.
- Ricardo (Benefits Distribution Analysis Consultant).

Additionally, for Workshops 3 and 4, representatives from the following key community groups were invited:

- Surfing WA.
- Stirling Natural Environment Coast Care.
- Coast Whispers Facebook Group.

- Mettams Pool Swimming Group.
- Watermans Bay Swimming Group.

The Reference Group served as a collaborative platform to foster meaningful dialogue, build consensus, and enhance transparency in shaping adaptation recommendations. While it had no formal decision-making authority, its input was instrumental in:

- Reviewing CHRMAP data and validating community values from previous consultations.
- Contributing to evaluation criteria and weightings for the Multi-Criteria Analysis (MCA).
- Providing feedback on conceptual adaptation options for Mettams Pool and Watermans Bay.
- Minimising consultation fatigue by leveraging existing knowledge and fostering trust through clear and transparent communication.

The Reference Group was presented with the information summarised in this report and assisted in development and assessment of the various adaptation options. Full details of the Plan and the outcomes can be found in 361 Degrees (2025).

# 7. Concept Options

This work builds on previous efforts undertaken by the City, with the objective of developing site-specific coastal adaptation concepts for Mettams Pool. A key reference document guiding the basis of design is the CHRMAP, completed by Cardno in 2022. The CHRMAP was developed in accordance with the requirements of SPP2.6.

The CHRMAP (Cardno, 2022d) identified that, to protect infrastructure at Mettam Pool in the short to medium term, a combination of beach nourishment and coastal engineering measures would be required. Specifically, it was suggested that nearshore reefs might offer suitable protection, though further detailed assessments are necessary. Additionally, three other alternative options were highlighted as “likely to deliver a positive outcome” or as “requiring further assessment” for infrastructure protection at these sites. All options requiring further assessment include:

- Beach Nourishment.
- Revetments / Seawalls.
- Groynes / Headland Enhancement.
- Nearshore Reefs / Breakwaters.

Each of these options will be reviewed and assessed against the key success indicators for coastal adaptation at Mettams Pool, as reproduced in the table below.

### Table 7.1 Success Criteria for the City’s CHRMAP (Cardno, 2022a)

| | |
|---|---|
| 1 | Preserve the function and opportunity for recreation activities along the coastline (such as walking/running, swimming and surfing). |
| 2 | Preserve the existing hospitality venues along the coastline and access to them. |
| 3 | Ensure the natural environment is protected and sustained in its current condition or an improved condition (concerning the dunes and flora and fauna). |
| 4 | Develop solutions to coastal processes that are sustainable (financially, socially and built form) and locally responsive. |
| 5 | Revisit regularly with community and key stakeholders their values in relation to development adjacent the coastline. |
| 6 | Maintain services that maximise community benefit for all. |
| 7 | Ensure the coastline is safe and accessible to all. |
| 8 | Achieve a balance between access needs and environmental sensitivities. |

It is noted that items 2, 5, 6 and 8 from the key success criteria table are not considered relevant for evaluating the preferred adaptation approach for Mettams Pool. This is due to:

- There are no hospitality venues in the direct study area seaward of WCD.

- The consultation is an ongoing process being completed by the City as part of and external to this project.
- If the coastal adaptation options are appropriately designed and implemented, the current level of services offered to the community will be maintained.
- If key success indicators 3 and 7 are satisfied in totality, then it can be assumed that the concept option achieves an appropriate balance between access needs and environmental sensitivities.

The key success criteria reproduced in the table above are general and require further discretisation to assess the performance of the coastal adaptation options. To undertake a subjective assessment of each of the adaptation options, the intent of each success criteria in relation to coastal adaptation has therefore been assessed and expanded to develop a comparable set of requirements each concept option must achieve.

Table 7.2 below details MRA's interpretation of the intent of the key success criteria.

### Table 7.2 Intent of the Relevant Key Success Criteria

| | |
|---|---|
| **1** | Preserve the function and opportunity for recreation activities along the coastline (such as walking/running, swimming and surfing). |
| **Interpretation** | The coastal adaptation options must satisfy the following requirements to meet the objective of this success criteria:<br>■ Maintain or improve beach width, profile and continuity<br>■ Maintain or improve local nearshore seastate<br>■ Ensure there are no down / up drift effects to the coastline<br>■ Ensure both natural and man-made assets / infrastructure are protected<br>■ Ensure that coastal amenity is maintained |
| **3** | Ensure the natural environment is protected and sustained in its current condition or an improved condition (concerning the dunes and flora and fauna). |
| **Interpretation** | The coastal adaptation options must satisfy the following requirements to meet the objective of this success criteria:<br>■ Maintain or improve the beach and dune environment<br>■ Maintain or improve the marine park |
| **4** | Develop solutions to coastal processes that are sustainable (financially, socially and built form) and locally responsive. |
| **Interpretation** | The coastal adaptation options must satisfy the following requirements to meet the objective of this success criteria:<br>■ Ensure options are constructable / maintainable<br>■ Ensure materials are durable, sustainable and able to be sourced<br>■ Ensure options are adaptable<br>■ Ensure options are cost effective<br>■ Ensure options consider local met-ocean conditions |
| **7** | Ensure the coastline is safe and accessible to all. |
| **Interpretation** | The coastal adaptation options must satisfy the following requirements to meet the objective of this success criteria:<br>■ Maintain or improve accessibility |

## 7.1 Beach Nourishment

Beach nourishment is a coastal management strategy aimed at protecting upland structures, infrastructure, and dunes from erosion caused by cross-shore and longshore sediment transport. By adding sand to the upper beach profile, nourishment enhances the sand buffer, reducing the vulnerability of at-risk areas to storm events and wave action.

Beach nourishment is considered a "soft" engineered solution as it complements the natural environment, maintaining or improving beach amenity. This often garners strong community support, particularly when the nourishment enhances recreational and aesthetic values.

A photograph showing beach nourishment being completed is presented in Figure 7.1.

**Figure 7.1 Beach Nourishment (Mettams)**

Beach nourishment can be undertaken as follows:

- Standalone Beach Nourishment – Sand can be placed on the beach without additional control structures. While cost-effective initially, this approach often requires more frequent maintenance, as sand is naturally redistributed by coastal processes. Met-ocean conditions, such as storms or prevailing winds, can cause the nourished material to erode or migrate, necessitating periodic renourishment.

- Combined with “Hard” Engineered Structures – When paired with groynes, nearshore breakwaters, or headlands, beach nourishment benefits from reduced sand movement away from the target area. These structures slow erosion, extend the lifespan of the nourishment, and lower long-term maintenance costs.

It is often a perception from the community that beach nourishment is ineffective or wasteful as nourishment is affected by the natural cycle of erosion and deposition, often losing sand during storm events or due to long-term coastal processes.

It is also worth noting that the cost of sand sourcing, transport, and placement can become prohibitive, especially for large or frequent nourishment projects. Additionally, poorly chosen borrowed sediment, material with mismatched aesthetic or physical properties, can affect public satisfaction and beach usability.

Regular monitoring of nourished beaches is essential to ensure that an adequate sand buffer is maintained to protect critical assets.

## 7.2 Revetment / Seawall (Vertical)

Revetments (sloping seawalls) and vertical seawalls are two commonly used coastal protection structures designed to safeguard landward assets from coastal erosion and wave attack. The protective effects of both types of seawalls are localised to their extents, providing targeted protection where needed.

Revetments in Western Australia are typically constructed from rock. Rock (pr rubble mound) revetments are typically flexible structures capable of adapting to changes caused by ongoing wave action. The allowable level of damage is typically considered during the design process, which influences the selection of rock size and the structure's slope. These seawalls dissipate wave energy through their voids, reducing wave reflection and minimising scour.

They can be constructed from various materials, including natural stone like granite and limestone or prefabricated concrete units. Revetments can be either exposed or integrated into the landscape through burying or planting, offering a "softer" appearance. Where space exists, they can be buried under dunes to provide a last resort protection. They are also highly adaptable to future modifications, such as increasing crest height if design conditions change.

Revetments require a significant structural footprint due to their sloping nature but generally have lower capital and maintenance costs compared to other coastal protection structures. An example revetment is presented in Figure 7.2

**Figure 7.2 Rock Revetment (Rottnest Island)**

In contrast, vertical seawalls are rigid structures made from materials such as concrete, limestone blocks, sheet piling or secant piling. Their design is highly customisable, allowing for tiered levels, integrated beach access points, or other features. However, they are less adaptable to future modifications; for example, increasing the wall height may impose additional structural loads that the original design might not support.

While vertical seawalls provide effective localised protection, they offer limited recreational or amenity value and do not prevent long-term beach width reduction in front of the structure. In many cases, they accelerate scouring and increase erosion rates.

Vertical seawalls have higher upfront capital and maintenance costs. When constructed along coastlines, they must be founded on competent rock or at depths where the risk of undermining is minimal. Although they occupy a smaller structural footprint than rubble mound seawalls, significant excavation and shoring may be required to ensure a stable foundation. An example vertical wall is presented in Figure 7.3.

**Figure 7.3 Vertical Seawall (Terraced – Rockingham)**

Previous community consultation completed by the City for the work in MRA (2020) considered revetments and vertical seawalls. The community provided clear feedback in that project that revetments were not appropriate, due to their larger footprint reducing available beach width. As a result, only a vertical seawall option is being investigated for this project.

## 7.3 Groynes / Headland Enhancement

Groynes are attached, shore perpendicular structures, that interrupt the longshore sediment transport reducing the amount of sediment that can be transported away from an at-risk area. These structures are often combined with sand nourishment to provide an increased beach width. The structures also help to retain the placed nourishment over a longer timeframe reducing renourishment requirements. A photograph of a typical groyne is presented in Figure 7.4

**Figure 7.4 Groyne (City Beach)**

For this project, headland enhancements are considered to function similarly to groynes by enhancing the natural rock formations and features to control sediment transport.

Groynes / headlands are typically designed to minimise the amount of sediment that can be transported over, and around structures. This is achieved by increasing the height and length of the structure. The amount of sediment transport allowed around the groyne is dependent on the local conditions and balance of capital and maintenance cost.

Groynes / headlands can be constructed from a range of products. Rubble mound (rock) structures are robust with long design lives (~50 years) with limited maintenance requirements. GSC structures provide a softer structure which can be safer for the public to interact with but have far reduced design life (~15 years). Hence, these are typically used for temporary solutions.

## 7.4 Nearshore Breakwaters

Nearshore or offshore breakwaters can be attached or detached, shore-parallel structures that reduce the amount of wave energy reaching the shoreline in their shadow. They function similarly to natural bars, reefs or nearshore islands that dissipate wave energy reaching the shoreline. These structures are often combined with sand nourishment as they help to retain the placed sand over a longer timeframe reducing renourishment requirements.

In the context of this assessment, the nearshore breakwaters are assumed to be fully emergent (extend above water) structures. An example of a nearshore breakwater is presented in Figure 7.5.

**Figure 7.5 Nearshore Breakwater (Kwinana)**

Nearshore breakwaters function similarly to groynes by slowing longshore sediment transport. However, unlike groynes, sediment can continue to move behind the breakwaters, resulting in a different shoreline shape compared to the foreshore prior to the construction of the structure.

Behind the nearshore breakwaters, wave diffraction patterns reduce the longshore movement of sediment, causing material to accumulate near the structure's centreline. This results in sediment buildup directly behind the nearshore structures and a scalloped shoreline between them. In the areas between these nearshore structures, wave energy is less affected by diffraction, allowing sediment transport to continue.

Nearshore breakwaters are likely to be more expensive than groynes or headland enhancement in both the capital and operational phases. Nearshore breakwaters are constructed in deeper water meaning that often greater material quantities are required, and construction is more difficult being in water. Furthermore, as nearshore structures allow longshore sediment transport to continue behind the structures, renourishment requirements are typically greater compared to groynes.

The benefit of the in water structures is that a single, continuous beach compartment is provided. This can provide improved recreation and connectivity through the foreshore area. Comparatively, a groyne field separates the beach into smaller compartments which can interrupt connectivity along the foreshore.

There can be environmental benefits of the structures as the submerged rocks provide habitat for marine flora and fauna. However, this benefit can be offset by the smothering of any existing marine flora and fauna within the footprint of the proposed structures.

### 7.4.1 Submerged Breakwaters (Reefs)

Submerged breakwaters control sediment similarly to emergent structures by dissipating incident wave energy, thereby slowing littoral drift behind them. The key difference is that, as the structures are submerged, they still allow some wave energy to pass over them. This can increase during high water level events. The lower the elevation of the submerged breakwater, the more wave energy can pass over it, contributing to longshore sediment transport and reducing the structure’s effectiveness.

Submerged breakwaters are typically positioned at or below the Mean Low Water Level (MLWL) at depths ranging from 2 to 10 m. A more recent concept is the idea of Multi-Purpose Reefs (MPRs), which are submerged breakwaters designed not only to dissipate wave energy and slow littoral drift but to provide additional functions such as enhancing surfing or snorkelling amenities, provide fish habitat, promote biodiversity or other functions.

The performance of Submerged Constructed Reefs (SCRs), including MPRs, to provide effective coastal adaptation is not well-documented. Some studies, such as Mariani et al. (2012) and Blacka et al. (2013), provide detailed reviews of Australian and international surf reef projects. These studies found that, among SCRs designed for coastal protection, just over half delivered some level of protection, although often not to the degree initially predicted. Blacka et al. (2013) reported that only one of the five MPRs reviewed might provide reasonable coastal protection.

The effectiveness of MPRs for both surfing and coastal protection depends heavily on tidal range, swell directionality, and safety concerns for reef users. These safety considerations often result in a design that is suboptimal for both coastal protection and surfing.

More recently, a coastal adaptation project at Palm Beach, Queensland, incorporated a MPR as part of a large scale sand nourishment project. This was installed in 2019, and 5 years post construction had been seen to be effective in retaining the nourished sand around the reef (City of Gold Coast, 2024). Locally, trials into MPRs for coastal adaptation have been commenced at C Y O'Connor Beach in recent years, although shoreline monitoring following the first stage of implementation have not shown significant change in the protection offered (MRA 2024). Significant amounts of research are currently being completed around submerged structures for the purpose of coastal adaptation.

As the primary objective of this report is coastal adaptation, it is recommended that the submerged breakwaters be only slightly submerged and potentially emergent during low water conditions. This design would provide better control of any sand nourishment placed behind the structure.

A significant benefit of submerged breakwaters is their reduced visual impact compared to emergent structures. Structures positioned just below the water level have minimal visual intrusion, preserving the natural amenity and aesthetic of the site.

## 7.5 Analysis of Concept Options Against the Relevant Key Success Criteria

As an initial filter, each of the adaptation options was assessed against the relevant key success criteria. The outcome of this assessment is presented in the following sections:

### 7.5.1 Beach Nourishment

#### Preserve opportunity for recreation activities

Sand nourishment can be placed to achieve a wide beach and provide opportunities for recreational activities.

#### Ensure natural environment is protected in current condition or improved

Through beach nourishment, incorporating creation of dunes where possible, the natural environment can be protected in its current condition or improved. The sand placed can also act as a sediment feed to downdrift beaches, reducing impacts on those areas.

**Develop solutions that are sustainable (financially, socially and built form)**
Beach nourishment can be completed in an environmentally sustainable manner. However, the large ongoing costs mean that it may not be considered financially sustainable. This requires further assessment.

**Ensure the coastlines is safe and accessible to all**
Sand nourishment can ensure the coastline is safe and accessible.

### 7.5.2 Seawall

**Preserve opportunity for recreation activities**
A seawall can be constructed to provide opportunities for recreational activities on its landward side.

**Ensure natural environment is protected in current condition or improved**
Construction of a seawall may protect the natural environment on its landward side, but would not protect the beach in front. In addition, there may be significant impacts on the dunes during construction.

A seawall alone would not provide a sediment feed to downdrift beaches, impacting on those areas and not preserving the current shoreline condition.

**Develop solutions that are sustainable (financially, socially and built form)**
A seawall could be constructed in a durable manner and may be seen as more financially sustainable than ongoing works such as sand nourishment, but requires further consideration. It would not be considered sustainable in the context of retention of a beach.

**Ensure the coastlines is safe and accessible to all**
A seawall could be designed to incorporate access to the beach, although there may not be a beach retained following construction.

### 7.5.3 Groynes / Headland Enhancements

**Preserve opportunity for recreation activities**
Groynes or headlands would be able to preserve and provide opportunities for recreational activities. However, they would also impact recreational opportunities in the area of the structures.

**Ensure natural environment is protected in current condition or improved**
Construction of groynes may assist in protection of the natural environment on the protected shoreline. However there would be environmental impacts in their footprints and there may be impacts on the dunes during construction.

Groynes alone would not provide a sediment feed to downdrift beaches, also impacting on those areas and not preserving the current shoreline condition.

**Develop solutions that are sustainable (financially, socially and built form)**
Groynes could be constructed in a durable manner and may be seen as more financially sustainable than ongoing works such as sand nourishment, but require further consideration. They are unlikely to be viewed by the community as sustainable solutions.

**Ensure the coastlines is safe and accessible to all**
Groynes can be designed to incorporate access to the beach. However, the groyne construction would compartmentalise the beach, reducing continuous access.

### 7.5.4 Nearshore Breakwaters (Emergent)

Preserve opportunity for recreation activities
Nearshore breakwaters would likely directly in water recreational activities, including surfing, swimming and wind-surfing.

**Ensure natural environment is protected in current condition or improved**

Construction of nearshore breakwaters may protect the natural environment in their lee, but would impact the marine environment in their footprint, within a Marine Park. They would also not provide a sediment feed to downdrift beaches, impacting on those areas and not preserving the current shoreline condition.

**Develop solutions that are sustainable (financially, socially and built form)**

Nearshore breakwaters could be constructed in a durable manner and may be seen as more financially sustainable than ongoing works such as sand nourishment, but require further consideration. They are unlikely to be viewed by the community as sustainable solutions.

**Ensure the coastlines is safe and accessible to all**

Nearshore breakwaters can provide continuous beach access on the shoreline in their lee, but this depends on retention of the beach. They would not address the current access issues at the site.

### 7.5.5 Submerged Breakwaters (Reefs)

**Preserve opportunity for recreation activities**

Submerged breakwaters would be designed to complement in-water recreational activities.

**Ensure natural environment is protected in current condition or improved**

Construction of submerged breakwaters may protect the natural environment in their lee and be seen as low impact, but would directly impact the marine environment in their footprint, within a Marine Park. They would also not provide a sediment feed to downdrift beaches, impacting on those areas and not preserving the current shoreline condition.

**Develop solutions that are sustainable (financially, socially and built form)**

Submerged breakwaters could be constructed in a durable manner and may be seen as more financially sustainable than ongoing works such as sand nourishment, but require further consideration. They are likely to be viewed by the community as more sustainable solutions.

**Ensure the coastlines is safe and accessible to all**

Submerged breakwaters can provide continuous beach access on the shoreline in their lee, but this depends on retention of the beach. They would not address the current access issues at the site.

### 7.5.6 Summary

Table 7.3 presents a summary of the concept options against the relevant key success criteria. The assessment indicates that only beach nourishment satisfies all key success criteria when implemented in isolation. However, beach nourishment is often considered financially unsustainable when large or ongoing volumes are required due to costs associated with sand sourcing, transport and placement.

To mitigate these costs, strategies include selecting borrow sediment with compatible characteristics, conducting a detailed assessment of the required sand nourishment volumes and thoroughly evaluating potential sediment sources. These sources may include terrestrial sites such as quarries, beach sand traps, and development spoil, as well as marine sources like dredged channels, offshore shoals, and similar deposits.

### Table 7.3 Analysis of Concept Options Against the Relevant Key Success Criteria

| Options \ Success Criteria | Preserve opportunity for recreation activities | Ensure natural environment is protected in current condition or improved | Develop solutions that are sustainable (financially, socially and built form) | Ensure the coastlines is safe and accessible to all |
|---|---|---|---|---|
| **Beach Nourishment** | ✓ | ✓ | ? | ✓ |
| **Seawall** | ✓ | X | ? | ? |
| **Groynes / Headland Enhancement** | ? | X | ? | ? |
| **Nearshore Breakwaters (Emergent)** | X | X | ? | ? |
| **Submerged Breakwaters (Reefs)** | ✓ | X | ? | ? |

For all other coastal adaptation options that were determined not to satisfy the relevant success criteria in isolation, MRA evaluated these in combination with other options, such as beach nourishment. Table 7.4 presents the results of MRA's evaluation. The following key points emerged from the analysis:

- Certain options, such as nearshore breakwaters combined with seawalls and beach nourishment, may meet the key success criteria. However, implementing all three options in combination was considered cost-prohibitive and thus reviewed but not pursued further.
- Nearshore breakwaters and Groynes or Headland Enhancement combined with beach nourishment does not fully satisfy the key success criteria due to their significant impact on beach amenity and recreation. Nonetheless, these options have been further developed, as they were identified through the CHRMAP process as either "likely to deliver a positive outcome" or "requiring further assessment" for infrastructure protection at the site.

## Table 7.4 Assessment of Combined Options

| Combination of options to meet the success criteria | Beach Nourishment | Seawall | Groynes / Headland Enhancement | Nearshore Breakwaters (Emergent) | Submerged Breakwaters (Reefs) |
|---|---|---|---|---|---|
| **Beach Nourishment** | ✓ | ✓ | X[1] | X[1] | ✓ |
| **Seawall** | – | – | X | X | X |
| **Groynes / Headland Enhancement** | – | X | – | X | X |
| **Nearshore Breakwaters (Emergent)** | – | X | X | – | X |
| **Submerged Breakwaters (Reefs)** | – | X | X | X | – |

Notes:

1. This option is not deemed to satisfy the relevant key success criteria however the concept option will be developed, and the option will be assessed via the MCA process.

Based on this assessment, the following coastal adaptation options have been developed for Mettam Pool:

- Option 1 (Beach Nourishment).
- Option 2 (Seawall & Beach Nourishment).
- Option 3 (Groynes / Headland Enhancement & Beach Nourishment).
- Option 4a (Nearshore Breakwaters (Emergent) & Beach Nourishment).
- Option 4b (Submerged Breakwaters (Reefs) & Beach Nourishment).

For each of the concept options outlined above, the following items form the basis of design. This basis of design outlines the high-level approach taken during the development of all concept options.

- Design Life – The structures are considered to remain fit for purpose, with appropriate maintenance for a period of 50 years.

- Maintain Present-Day Beach Location – The design focuses on preserving the current beach location without attempting to restore beach width to pre-1990 levels. Sand volumes have been estimated solely for maintaining the present shoreline position over the 50-year design life. No allowances have been made for reclaiming previously eroded foreshore areas.

- Downdrift Effects:

    - The design ensures that no adverse downdrift effects occur due to the implementation of the proposed concept options. This requires maintaining a sediment feed at the site (refer to Section 4) while accounting for shoreline recession associated with projected sea-level rise over the next 50 years.

    - MRA has been engaged to develop concept options for both Watermans Bay and Mettams Pool. Given both sites are in the same primary and secondary sediment cells, any works at Mettams Pool may impact conditions at Watermans Bay and vice versa. However, this assessment assumes a worst-case scenario where the favourable effects of the adjacent project has not been considered. This is appropriate while the timing and certainty of the works is unknown.

- Preservation of Beach Width, Slope, and Continuity:

    - Community engagement highlighted that preserving the beach's recreational function is a key success criterion. Consequently, each concept option must provide adequate beach width to support recreational activities.

    - Beach nourishment volumes were estimated considering that the borrowed sediment closely matched that of the native material (ie an overfill ratio of 1:1.1) which ensures a consistent beach slope.

- Constructability & Design:

    - All concept options have been developed assuming land-based construction, as similar projects at Watermans Bay and Mettams Pool have successfully been completed from land. Designs include provisions for land-based access to facilitate construction.

    - The primary objective of the proposed designs is coastal adaptation. Customisable features such as tiered levels for the vertical seawalls and MPRs should be evaluated for the preferred option within the context of a comprehensive foreshore masterplan and Benefit Distribution Analysis (BDA) that incorporates the local community's preferences and needs.

- Cost Considerations:

    - Preliminary costs for each option were estimated at 10% of the capital and maintenance costs. These typically cover site mobilisation and demobilisation, insurances, management plans, and similar expenses.

    - The maintenance costs for "hard" engineered structures are estimated at 1% per annum of the structure's cost, excluding preliminaries and contingencies.

The functional design requirements of each option are detailed in Sections 6.6 to 6.10 below.

## 7.6 Beach Nourishment (Option1)

The following functional design requirements have guided the development of the beach nourishment concept option.

### Beach Nourishment Quantities

The required sand volumes account for:

- Sand Buffer – Additional sand added to the upper beach profile to protect upland infrastructure from storm events and wave action. High-level sand nourishment volumes were estimated using SBEACH a software developed by the Coastal Engineering Research Centre to simulate beach profile evolution in response to storm events. The results from the modelling indicated that during the 100-year storm event approximately 20 $m^3/m$ of erosion could be expected.

- Beach Maintenance – A beach nourishment regime that considers both longshore transport and sea level rise. Longshore transport quantities were estimated via the shoreline movement analysis detailed in Section 4 of this report. Sand loss due to sea level rise was estimated using DoT's recommended sea level rise allowances (DoT, 2010).

- Frequency of Nourishment – Biennial sand nourishment was considered appropriate so seaward translation of the shoreline did not smother the nearshore reef, increase the current beach berm height and the beach profile did not extend beyond the operational reach of land-based heavy machinery. Seaward translation of the beach berm was estimated using the following equation:

$$W = \frac{\mathrm{V}}{(\mathrm{B} + h^*)}$$

Where: W = seaward translation of the berm.

B = design berm height.

$h^*$ = depth of closure.

V= volume of beach fill.

The following resources and standards were relied upon for the development of the beach nourishment concept option.

- DoT's recommended sea level rise allowance (DoT, 2010).
- Coastal Engineering Manual (CEM) (CEM,2006).
- Handbook of Coastal Engineering (Herbich, J. B., 2000).

The figures below illustrate the proposed beach nourishment to be undertaken as part of the capital works. The hashed line indicates the approximate location of the shoreline following the placement of the nourishment.

The sand buffer is designed with a slope of 1V:3H and is intended to be planted and stabilised to enhance durability and resistance to erosion. In contrast, the beach berm will feature a constructed slope of 1V:4H and an elevation of +2 mAHD, consistent with the current berm heights.

As the borrowed sediment closely matches the native material, the final beach berm profile is expected to closely resemble the existing one, with only a minor seaward shift.

### 7.6.1 Concept

The layout, section, and oblique image for Option 1 are illustrated in Figure 7.6 and included at a larger scale in Appendix B.

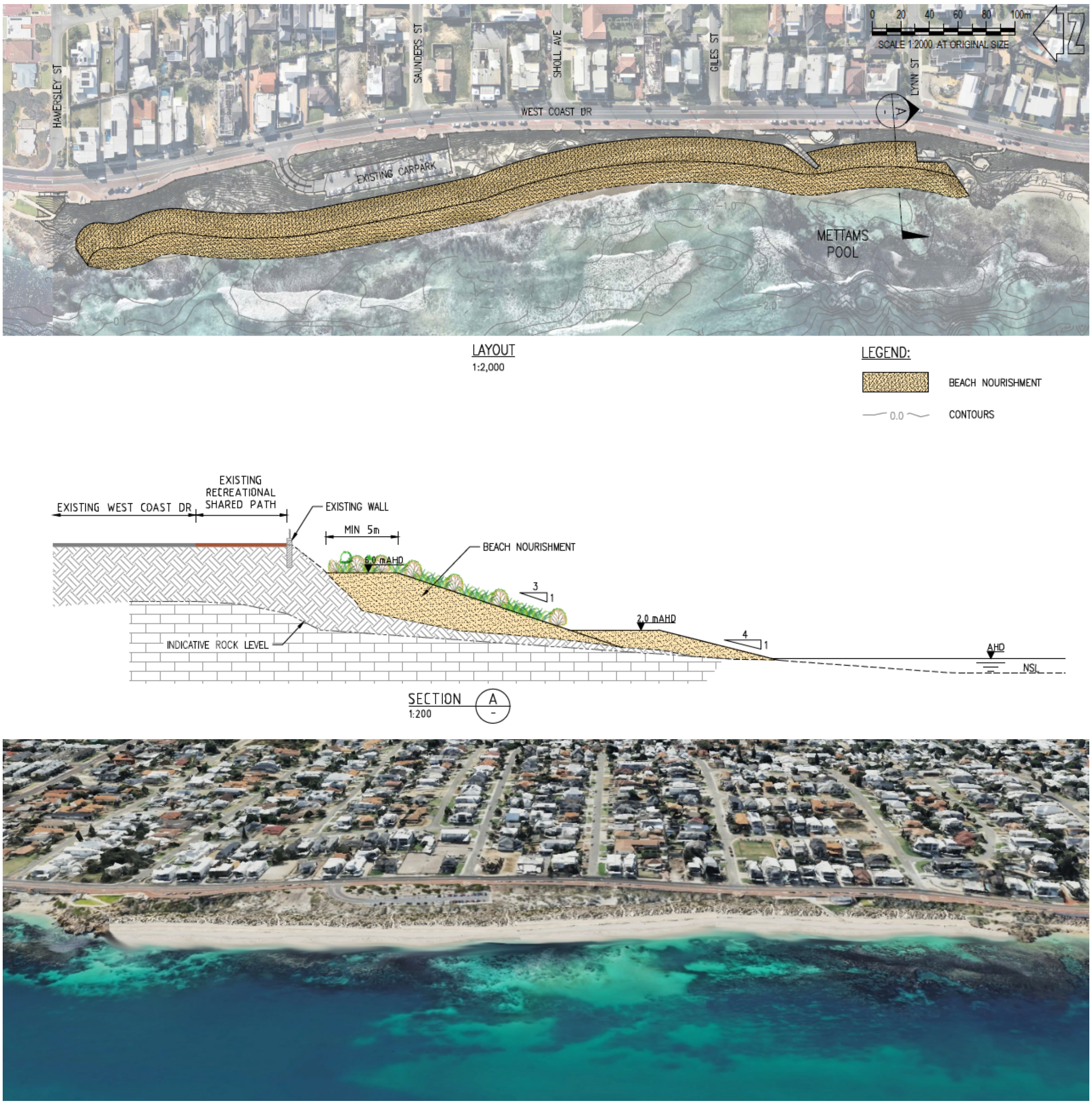



Figure 7.6 Option 1 – (Top) Layout (Middle) Section (Bottom) Oblique Image

Table 7.5 lists the advantages, disadvantages and considerations associated with Option 1.

**Table 7.5 Option 1 – Advantages, Disadvantages & Considerations**

| Advantages | Disadvantages | Considerations |
|---|---|---|
| ■ Protects infrastructure through nourishment of dune and providing storm buffer<br>■ Maintains continuity of the beach space<br>■ No encroachment into Marmion Marine Park<br>■ Minimal visual impact<br>■ Proven accessibility as sand has been placed at both sites before<br>■ Increases public safety by reducing exposure of the nearshore reef<br>■ Nourishment can be adjusted based on shoreline response<br>■ Dune stabilisation improves back beach ecology and vegetation | ■ Large volumes of borrowed sand required for nourishment<br>■ Beach nourishment causes beach disturbance<br>■ High capital and maintenance costs<br>■ Risk of nearshore reef smothering<br>■ Potential loss of buffer during severe or consecutive storm events, requiring additional nourishment – less guarantee<br>■ Logistical challenges with beach access during construction | ■ Requires an ongoing source of sand<br>■ Consideration of sediment movements |

### 7.6.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for Option 1. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 7.6 and 7.7 respectively.

**Table 7.6 Option 1 – Opinion of Probable Capital Cost**

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| 1 | Capital Nourishment | | | | | $ 1,850,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 1 | Item | $ 170,000 | $ 170,000 | |
| 1.2 | Source, transport and place beach nourishment from terrestrial sources | 24,000 | $m^3$ | $ 70 | $ 1,680,000 | |
| | Subtotal 1 | | | | $ 1,850,000 | $ 1,850,000 |
| | Contingencies | 20 | % | | $ 370,000 | $ 370,000 |
| | Subtotal 2 | | | | $ 2,220,000 | $ 2,220,000 |
| | Goods & Services Tax | | | | $ 222,000 | $ 222,000 |
| | Total Estimated Cost | | | | $ 2,442,000 | $ 2,442,000 |

### Table 7.7 Option 1 – Opinion of Probable Maintenance Cost Over 50 Years

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| | | | | | | |
| **1** | **Maintenance Over 50-year Horizon (Biennially)** | | | | | **$ 9,400,000** |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 25 | Item | $ 40,000 | $ 1,000,000 | |
| 1.2 | Beach nourishment to replace lost material | 120,000 | $m^3$ | $ 70 | $ 8,400,000 | |
| | **Subtotal 1** | | | | **$ 9,400,000** | **$ 9,400,000** |
| | **Contingencies** | **20** | **%** | | **$ 1,880,000** | **$ 1,880,000** |
| | **Subtotal 2** | | | | **$ 11,280,000** | **$ 11,280,000** |
| | **Goods & Services Tax** | | | | **$ 1,128,000** | **$ 1,128,000** |
| | **Total Estimated Cost** | | | | **$ 12,408,000** | **$ 12,408,000** |

## 7.7 Seawall & Beach Nourishment (Option 2)

The following functional design requirements have guided the development of the seawall and beach nourishment concept option.

### Wall Type

Given the community's response to the rubble mound (rock) seawall, only a vertical wall has been considered as part of the concept design. Like the Mettams Pool Defensive Work (MRA, 2020), a vertical L-wall is proposed for the project.

### Rock Levels

Rock levels are based on the investigations undertaken by GBGMAPS (2018) and DTE Geotechnical (2019) and have been used to estimate the following:

- Wall Height – It was determined that the geophysical investigations generally overestimate rock levels by approximately 1 m. Consequently, for rock levels estimated to be < +2 mAHD by the geophysical investigation, the footings were founded at +0.5 mAHD. For rock levels estimated to > +2 mAHD, the footings were founded at +2 mAHD.
- Wall Location / Extent – Where rock levels were estimated to be < +6 mAHD via the geophysical investigation, the assets / infrastructure required vertical wall protection.

### Beach Nourishment Quantities

The sand volumes are consistent with the requirements for "Beach Maintenance" as detailed in the beach nourishment option (Section 7.6).

The following resources and standards were relied upon for the development of the seawall and beach nourishment concept option.

- DoT's recommended sea level rise allowance (DoT, 2010).
- Mettams Pool Defensive Work (MRA, 2020).
- Rock level investigations undertaken by GBGMAPS (2018) and DTE Geotechnical (2019).
- Coastal Engineering Manual (CEM) (CEM,2006).

The figures below illustrate the proposed seawall and beach nourishment to be undertaken as part of the capital works. The hashed line indicates the approximate location of the shoreline following the placement of the nourishment.

The seawall toe is shown to be founded at the indicative rock level, as determined from existing geotechnical investigations. The top of the walls is located at an elevation of +6.0 mAHD, based on an interpretation of the site topography and existing infrastructure captured in the feature survey.

As with the beach nourishment option, the beach berm will feature a constructed slope of 1V:4H and an elevation of +2 mAHD, consistent with current berm heights.

The same material proposed for the beach nourishment option is also intended for the seawall. As a result, the final beach berm profile is expected to closely resemble the existing one, with only a minor seaward shift.

### 7.7.1 Concept

The layout, section, and oblique image for Option 2 are illustrated in Figure 7.7 and included at a larger scale in Appendix B.

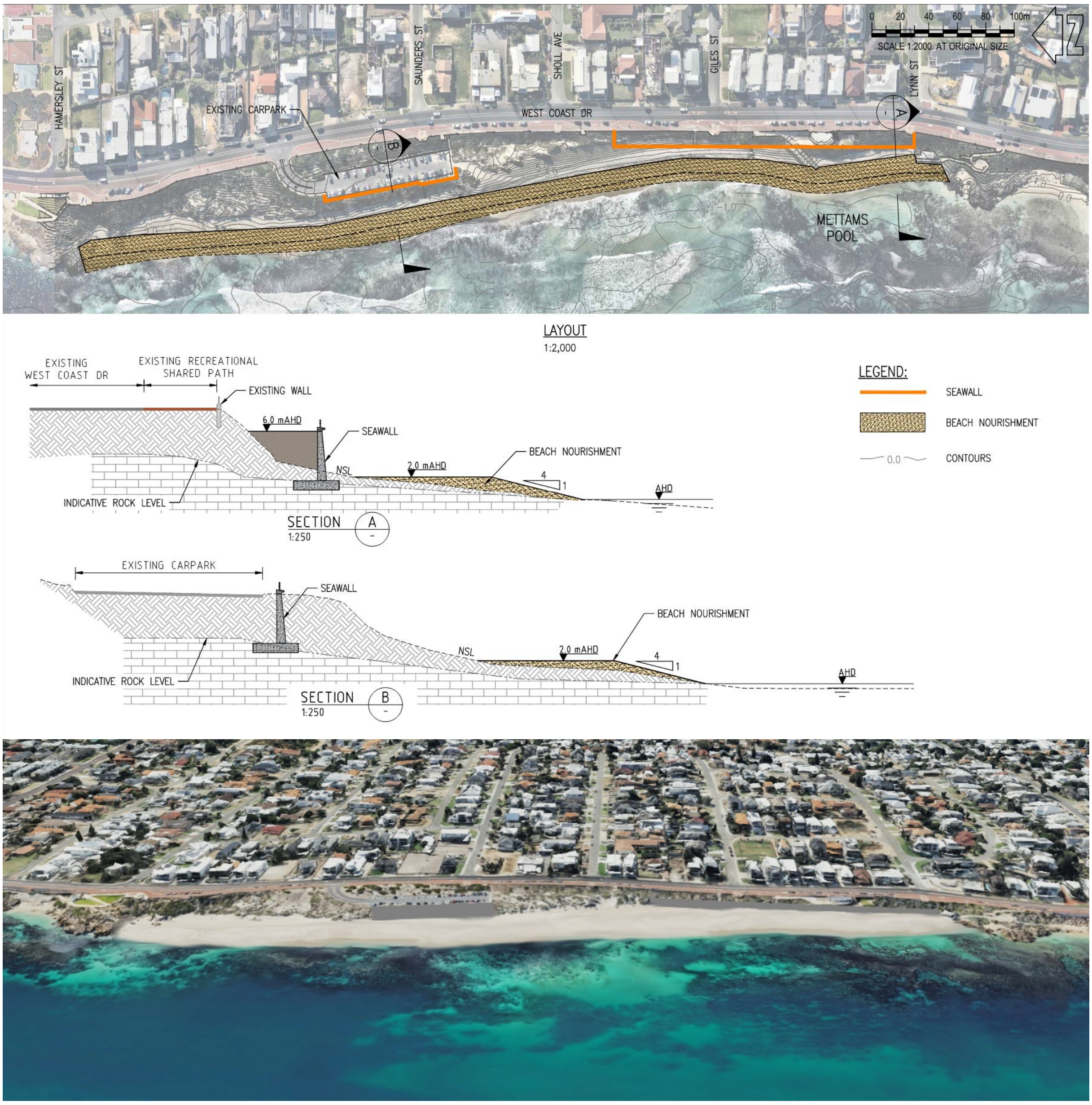



**Figure 7.7 Option 2 – (Top) Layout (Middle) Section (Bottom) Oblique Image**

Table 7.8 lists the advantages, disadvantages and considerations associated with Option 2.

### Table 7.8 Option 2 – Advantages, Disadvantages & Considerations

| Advantages | Disadvantages | Considerations |
|---|---|---|
| ■ Seawall protects infrastructure, sand provides beach<br>■ Maintains continuity of the beach space<br>■ No encroachment into Marmion Marine Park<br>■ Improves beach access<br>■ Increases public safety by reducing exposure of the nearshore reef<br>■ Nourishment can be adjusted based on shoreline response<br>■ Proven technique<br>■ Land-based construction | ■ Reduces usable beach width and profile<br>■ Significant visual impact of seawall<br>■ Significant volume of clearing to allow for construction<br>■ Large volumes of borrowed sand required for nourishment<br>■ Beach nourishment causes beach disturbance<br>■ High capital and maintenance costs<br>■ Risk of nearshore reef smothering as sand moves offshore<br>■ Logistical challenges with beach access during construction<br>■ Seawall is inflexible and may require replacement if damaged | ■ Clearing permit required<br>■ Requires an ongoing source of sand<br>■ Requires additional design of space to make functional<br>■ Consideration of sediment movements |

### 7.7.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for Option 2. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 7.9 and 7.10 respectively.

## Table 7.9 Option 2 – Opinion of Probable Capital Cost

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| 1 | **Capital - Seawall & Nourishment** | | | | | $ 6,008,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 1 | Item | $ 500,000 | $ 500,000 | |
| 1.2 | Source, transport and construct high-grade, reinforced concrete seawall | 180 | m | $ 8,600 | $ 1,548,000 | |
| 1.3 | Source, transport and construct deep founded seawall | 160 | m | $ 23,000 | $ 3,680,000 | |
| 1.4 | Source, transport and place beach nourishment from terrestrial sources | 4,000 | $m^3$ | $ 70 | $ 280,000 | |
| | **Subtotal 1** | | | | $ 6,008,000 | $ 6,008,000 |
| | **Contingencies** | 20 | % | | $ 1,201,600 | $ 1,201,600 |
| | **Subtotal 2** | | | | $ 7,209,600 | $ 7,209,600 |
| | **Goods & Services Tax** | | | | $ 720,960 | $ 720,960 |
| | **Total Estimated Cost** | | | | $ 7,930,560 | $ 7,930,560 |

## Table 7.10 Option 2 – Opinion of Probable Maintenance Cost Over 50 Years

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| 1 | **Maintenance Over 50-year Horizon (Biennially)** | | | | | $ 12,014,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 25 | Item | $ 40,000 | $ 1,000,000 | |
| 1.2 | Beach nourishment to replace lost material | 120,000 | $m^3$ | $ 70 | $ 8,400,000 | |
| 1.3 | Seawall maintenance | 50 | % | $5,228,000 | $ 2,614,000 | |
| | **Subtotal 1** | | | | $ 12,014,000 | $ 12,014,000 |
| | **Contingencies** | 20 | % | | $ 2,402,800 | $ 2,402,800 |
| | **Subtotal 2** | | | | $ 14,416,800 | $ 14,416,800 |
| | **Goods & Services Tax** | | | | $ 1,441,680 | $ 1,441,680 |
| | **Total Estimated Cost** | | | | $ 15,858,480 | $ 15,858,480 |

## 7.8 Groynes / Headland Enhancement & Beach Nourishment (Option 3)

The following functional design requirements have guided the development of the groynes / headland enhancement and beach nourishment concept option.

### Beach Alignment

Mettams Pool was assessed to exhibit a stable shape when evaluated using the parabolic bay shape methodology, considering the predominant wave direction. This stability was confirmed even with the inclusion of groynes / headland enhancement, suggesting that such structures are only needed in key locations to maintain the current beach width.

### Groynes / Headland Enhancement Location

The placement of the structures was determined based on site constraints. As the name suggests, headland enhancements focused on constructing shore-parallel structures at the northern and southern ends of the beach to reduce longshore sediment transport.

### Armour Rock Size

- Armour rock was estimated to be 8 tonnes for the concept design when using the van der Meer formula (CIRA, 2007) and the following conditions:
  Design Event – 100-year ARI design event conditions listed in Table 7.11.

- Rock Type – Based on limestone armour with a Saturated Surface Dry Density (SSDD) of 2.2 t/m$^3$.

### Table 7.11 100 Year ARI Design Event Conditions

| Significant Wave Height | Peak Wave Period | Water Level (including setup) |
|---|---|---|
| 2.39 m | 8.21 seconds | +1.2 mAHD |

### Beach Nourishment Quantities

The sand volumes are consistent with the requirements for “Beach Maintenance” as detailed in the beach nourishment option (Section 7.6).

The following resources and standards were relied upon for the development of the groynes / headland enhancement and beach nourishment concept option.

- DoT’s recommended sea level rise allowance (DoT, 2010).
- Coastal Engineering Manual (CEM) (CEM,2006).
- Handbook of Coastal Engineering (Herbich, J. B., 2000).
- The Rock Manual: The use of rock in hydraulic engineering (CIRIA, 2017).
- Coastal Stabilization: Innovative Concepts (Richards, S. & Hsu, J., 1993).

The figures below illustrate the proposed groynes / headland enhancement and sand nourishment to be undertaken as part of the capital works. The hashed line represents the indicative location of the shoreline following the placement of the nourishment.

A crest height of +3.0 mAHD has been adopted for the concept design, considering the existing elevation of the surrounding area while aiming to minimise impacts on amenity. No overtopping assessment was conducted to evaluate the risk to pedestrians.

The toe depth is shown to be founded at or below NSL, and the structures are designed with a slope of 1V:2H. Similarly to the beach nourishment, the beach berm will feature an as-constructed slope of 1V:4H and an elevation of +2 mAHD, consistent with current berm heights.

The same material proposed for the sand nourishment is also intended for the groynes / headland enhancement. As a result, the final beach berm profile is expected to closely resemble the existing one, with only a minor seaward shift.

### 7.8.1 Concept

The layout, section, and oblique image for Option 3 are illustrated in Figure 7.8 and included at a larger scale in Appendix B.

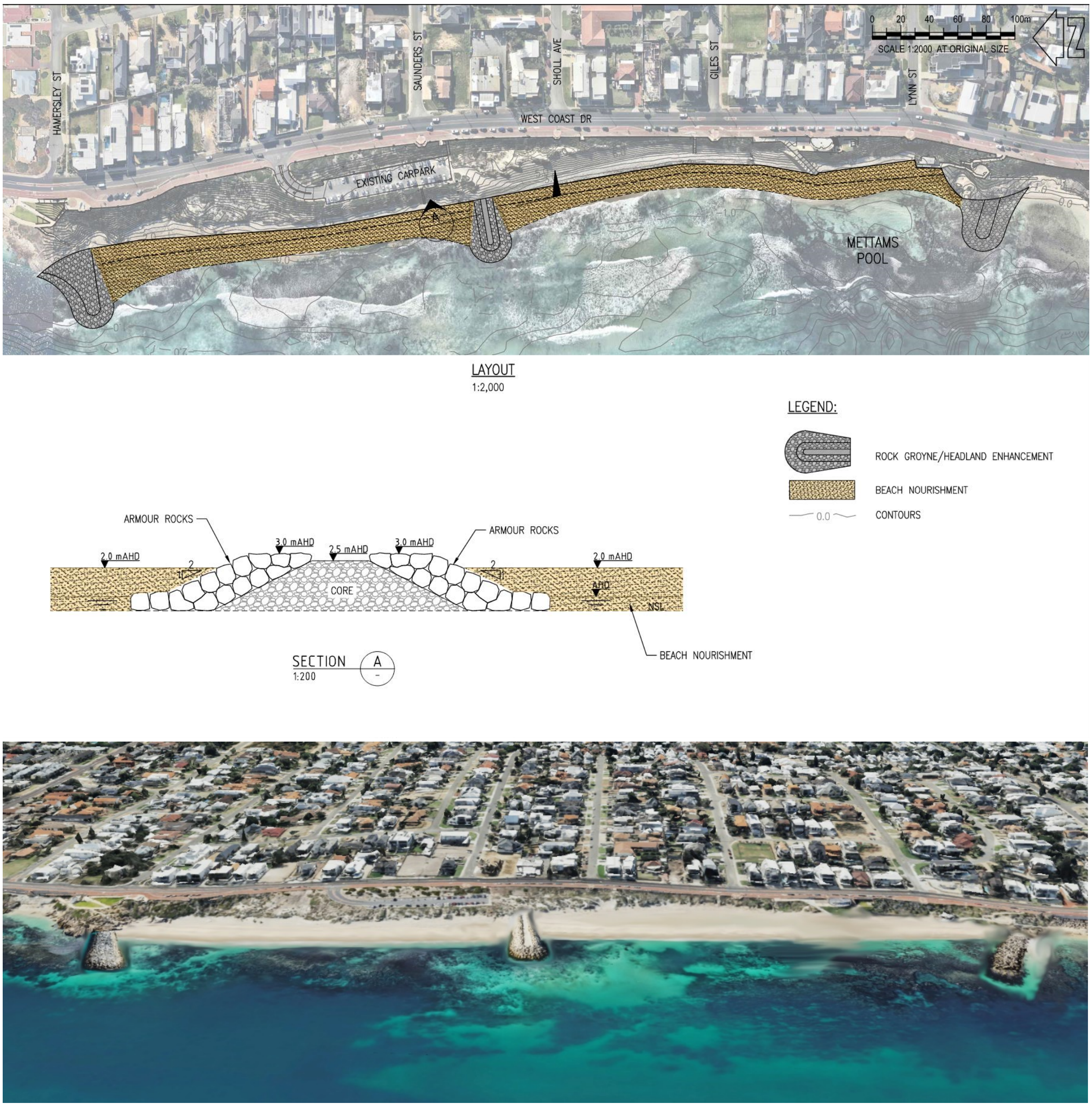



**Figure 7.8 Options 3 – (Top) Layout (Middle) Section (Bottom) Oblique Image**

Table 7.12 lists the advantages, disadvantages and considerations associated with Option 2.

### Table 7.12 Options 3 – Advantages, Disadvantages & Considerations

| Advantages | Disadvantages | Considerations |
|---|---|---|
| ■ Protects assets by increasing beach width, creating an erosional buffer<br>■ Maintains / increases current beach width and slope<br>■ Lower capital and maintenance costs<br>■ Dune stabilisation enhances back beach ecology, with minimal impact on flora and fauna<br>■ Improves public safety by reducing nearshore reef exposure<br>■ Nourishment can be adjusted as needed<br>■ Construction is largely land-based | ■ Reduces beach continuity due to shore-perpendicular structures<br>■ Groynes and headlands may be visually unappealing<br>■ Significant visual impact from the headland/groynes<br>■ Interrupts longshore sediment transport, potentially impacting the downdrift coastline<br>■ Encroaches into Marmion Marine Park, requiring additional environmental approvals<br>■ Structures may affect nearshore seastate and inhibit water-based such as surfing and wind surfing<br>■ Logistical challenges with beach access during construction<br>■ Increased relative maintenance and operational costs due to access restrictions | ■ Clearing permit required<br>■ Require an ongoing source of sand<br>■ Requires additional design of space to make functional<br>■ Consideration of sediment movements<br>■ Require Marine and Coastal Approval through DBCA |

### 7.8.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for Option 3. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 7.13 and 7.14 respectively.

## Table 7.13 Option 3 – Opinion of Probable Capital Cost

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| 1 | Capital - Groynes & Nourishment | | | | | $ 2,660,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc. | 1 | Item | $ 250,000 | $ 250,000 | |
| 1.2 | Source and transport sand from terrestrial sources | 4,000 | $m^3$ | $ 60 | $ 240,000 | |
| 1.3 | Placement of sand to undertake headland enhancemen as well as beach nourishment. | 4,000 | $m^3$ | $ 30 | $ 120,000 | |
| 1.4 | Source, transport and enhance limestone headlands. | 80 | m | $ 16,400 | $ 1,312,000 | |
| 1.5 | Source, transport and construct a limestone groyne. | 45 | m | $ 16,400 | $ 738,000 | |
| | Subtotal 1 | | | | $ 2,660,000 | $ 2,660,000 |
| | Contingencies | 20 | % | | $ 532,000 | $ 532,000 |
| | Subtotal 2 | | | | $ 3,192,000 | $ 3,192,000 |
| | Goods & Services Tax | | | | $ 319,200 | $ 319,200 |
| | Total Estimated Cost | | | | $ 3,511,200 | $ 3,511,200 |

## Table 7.14 Option 3 – Opinion of Probable Maintenance Cost Over 50 Years

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| 1 | Maintenance Over 50-year Horizon (Biennially) | | | | | $ 10,425,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 25 | Item | $ 40,000 | $ 1,000,000 | |
| 1.2 | Beach nourishment to replace lost material | 120,000 | $m^3$ | $ 70 | $ 8,400,000 | |
| 1.3 | Groyne maintenance | 50 | % | $2,050,000 | $ 1,025,000 | |
| | Subtotal 1 | | | | $ 10,425,000 | $ 10,425,000 |
| | Contingencies | 20 | % | | $ 2,085,000 | $ 2,085,000 |
| | Subtotal 2 | | | | $ 12,510,000 | $ 12,510,000 |
| | Goods & Services Tax | | | | $ 1,251,000 | $ 1,251,000 |
| | Total Estimated Cost | | | | $ 13,761,000 | $ 13,761,000 |

As outlined earlier, this option is NOT considered to appropriately meet the success criteria due to their significant visual and amenity impact in the marine environment, including on recreational activities.

## 7.9 Nearshore Breakwaters (Emergent) & Beach Nourishment (Option 4a)

The following functional design requirements have guided the development of the nearshore breakwaters and beach nourishment concept option.

### Beach Alignment

The design ensures that a well-developed salient / subdued salient will form following the construction of the nearshore breakwaters. This will ensure that longshore sediment transport is maintained. This was estimated in accordance with Chapter V-3 of the CEM (CEM, 2006) assuming the following:

- Location – The breakwaters are located approximately 50 m offshore at a depth of approximately -2 mAHD.
- Geometry – The breakwaters are approximately 40 m in length and are separated from one another by not less than 50 m.

### Armour Rock Size

The required rock size is consistent with the requirements detailed in the groyne / headland enhancement and beach nourishment concept option (Section 7.8)

### Beach Nourishment Quantities

The sand volumes are consistent with the requirements for "Beach Maintenance" as detailed in the beach nourishment option (Section 7.6).

The following resources and standards were relied upon for the development of the nearshore breakwaters and beach nourishment concept option.

- DoT's recommended sea level rise allowance (DoT, 2010).
- Coastal Engineering Manual (CEM) (CEM,2006).
- Handbook of Coastal Engineering (Herbich, J. B., 2000).
- The Rock Manual: The use of rock in hydraulic engineering (CIRIA, 2017).

The figures below illustrate the proposed nearshore breakwaters and beach nourishment to be undertaken as part of the capital works. The hashed line indicates the approximate location of the shoreline following the works. The change in the beach shape is attributed to the formation of a well-developed salient or subdued salient.

A crest height of +3.0 mAHD has been adopted for the concept design to minimise impacts on amenity while effectively dissipating nearshore wave energy.

The toe depth is shown to be founded at or below NSL, and the structures are designed with a slope of 1V:2H. Similar to the beach nourishment option, the beach berm will feature an as-constructed slope of 1V:4H and an elevation of +2 mAHD, consistent with current berm heights.

### 7.9.1 Concept

The layout, section, and oblique image for Option 4a are illustrated in Figure 7.9 and included at a larger scale in Appendix B.

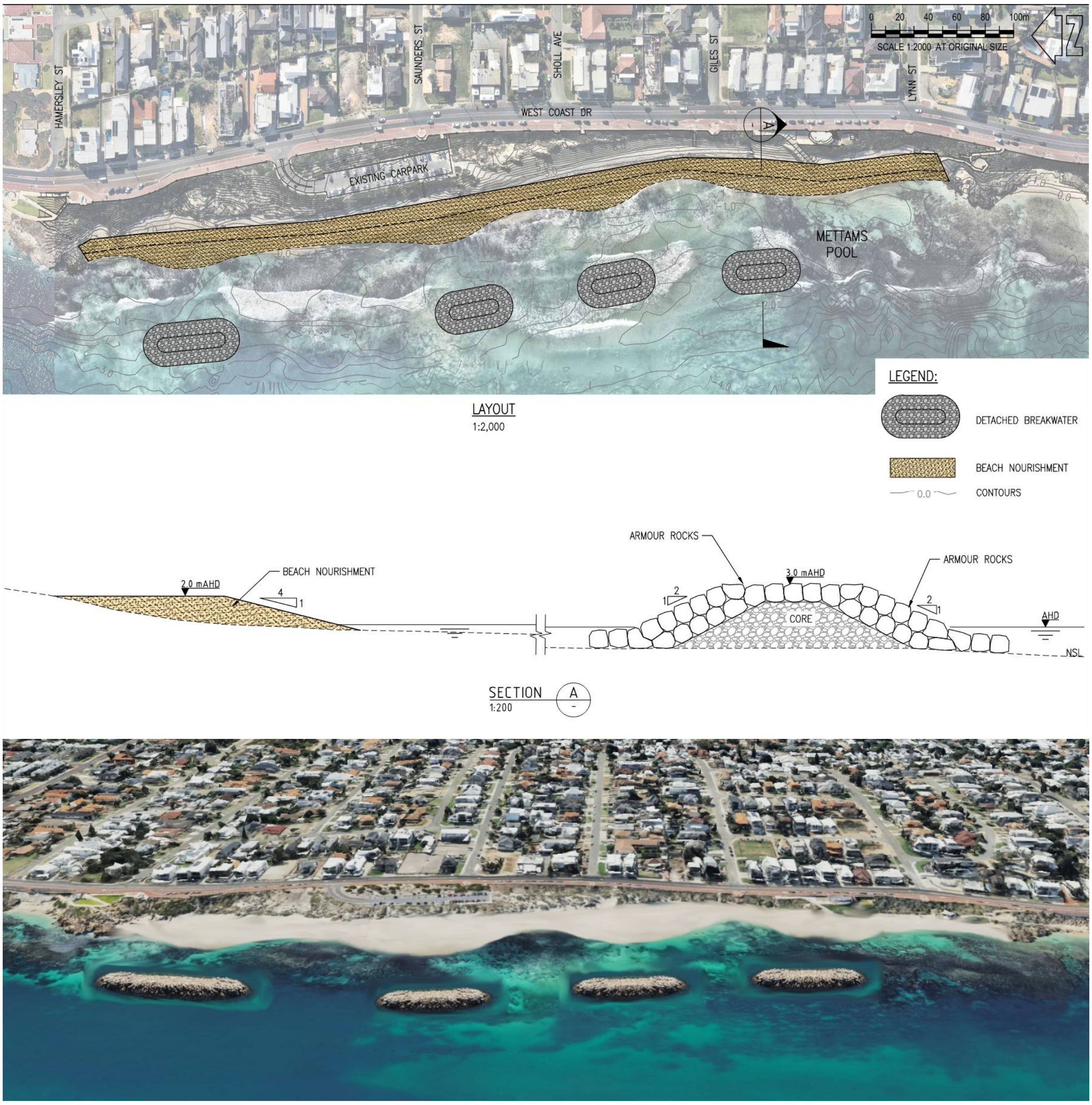



**Figure 7.9 Option 4a – (Top) Layout (Middle) Section (Bottom) Oblique Image**

Table 7.15 lists the advantages, disadvantages and considerations associated with Option 4a.

**Table 7.15 Option 4a – Advantages, Disadvantages & Considerations**

| Advantages | Disadvantages | Considerations |
|---|---|---|
| ■ Allows continuity of beach<br>■ Protects assets by increasing beach width, creating an erosional buffer or provide habitat<br>■ Maintains / increases current beach width and slope<br>■ Lower capital and maintenance costs<br>■ Dune stabilisation enhances back beach ecology, with minimal impact on flora and fauna<br>■ Improves public safety by reducing nearshore reef exposure<br>■ Nourishment can be adjusted as needed<br>■ May increase habitat around structures | ■ Headlands may be visually unappealing<br>■ Logistical challenges with in-water construction<br>■ Encroaches into Marmion Marine Park, requiring additional environmental approvals<br>■ Structures may impact water-based activities such as surfing and wind surfing<br>■ Interrupts longshore sediment transport, potentially impacting the downdrift coastline<br>■ Increased relative maintenance and operational costs due to access restrictions<br>■ Structures may damage nearshore reef | ■ Require Marine and Coastal Approval through DBCA<br>■ Require an ongoing source of sand<br>■ Consideration of sediment movements |

### 7.9.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for Option 4a. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 7.16 and 7.17 respectively.

### Table 7.16 Option 4a – Opinion of Probable Capital Cost

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| 1 | **Capital - Detached Headlands & Nourishment** | | | | | $ 5,088,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 1 | Item | $ 450,000 | $ 450,000 | |
| 1.2 | Source and transport sand from terrestrial sources | 4,000 | $m^3$ | $ 60 | $ 240,000 | |
| 1.3 | Placement of sand for breakwater construction as well as beach nourishment | 4,000 | $m^3$ | $ 30 | $ 120,000 | |
| 1.4 | Source, transport and construct limestone headlands | 230 | m | $ 18,600 | $ 4,278,000 | |
| | **Subtotal 1** | | | | $ 5,088,000 | $ 5,088,000 |
| | **Contingencies** | 20 | % | | $ 1,017,600 | $ 1,017,600 |
| | **Subtotal 2** | | | | $ 6,105,600 | $ 6,105,600 |
| | **Goods & Services Tax** | | | | $ 610,560 | $ 610,560 |
| | **Total Estimated Cost** | | | | $ 6,716,160 | $ 6,716,160 |

### Table 7.17 Option 4a – Opinion of Probable Maintenance Cost Over 50 Years

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| 1 | **Maintenance Over 50-year Horizon (Biennially)** | | | | | $ 11,539,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 25 | Item | $ 40,000 | $ 1,000,000 | |
| 1.2 | Beach nourishment to replace lost material | 120,000 | $m^3$ | $ 70 | $ 8,400,000 | |
| 1.3 | Breakwater maintenance | 50 | % | $4,278,000 | $ 2,139,000 | |
| | **Subtotal 1** | | | | $ 11,539,000 | $ 11,539,000 |
| | **Contingencies** | 20 | % | | $ 2,307,800 | $ 2,307,800 |
| | **Subtotal 2** | | | | $ 13,846,800 | $ 13,846,800 |
| | **Goods & Services Tax** | | | | $ 1,384,680 | $ 1,384,680 |
| | **Total Estimated Cost** | | | | $ 15,231,480 | $ 15,231,480 |

As outlined earlier, this option is NOT considered to appropriately meet the success criteria due to their significant visual and amenity impact in the marine environment, including on recreational activities.

## 7.10 Submerged Breakwaters (Reefs) & Beach Nourishment (Option 4b)

The following functional design requirements have guided the development of the submerged breakwaters and beach nourishment concept option.

### Locality

This concept option proposes enhancing the nearshore reef, generally following the -0.5 mAHD contour line as determined by the feature survey. The reefs are situated approximately 50 m from the foreshore at an average depth of -2.5 mAHD.

### Armour Rock Size

The required rock size is consistent with the requirements detailed in the groyne / headland enhancement and beach nourishment concept option (Section 7.8).

### Ongoing Reef Adaptation

The effectiveness of the reefs at controlling beach erosion is heavily dependent on the depth at which the structure is founded therefore reef adaptation works has been included as part of the ongoing maintenance works to ensure that the structure is founded at or directly below the water level. DoT's recommended allowance for sea level rise predicts 0.4 m increase in the water level between now and 2075 (50-year planning horizon).

### Beach Nourishment Quantities

The sand volumes are consistent with the requirements detailed in the beach nourishment option (Section 7.6), including volumes for:

- Sand Buffer.
- Beach Maintenance.

### Frequency of Nourishment

Biennial sand nourishment was considered appropriate as seaward translation of the foreshore did not smother the nearshore reef, increase the current beach berm height and the beach profile did not extend beyond the operational reach of land-based heavy machinery.

The following resources and standards were relied upon for the development of the submerged breakwaters and beach nourishment concept option.

- DoT's recommended sea level rise allowance (DoT, 2010).
- Coastal Engineering Manual (CEM) (CEM,2006).
- Handbook of Coastal Engineering (Herbich, J. B., 2000).
- The Rock Manual: The use of rock in hydraulic engineering (CIRIA, 2017).

The figures below illustrate the proposed submerged breakwaters and beach nourishment to be undertaken as part of the capital works.

A crest height of 0 mAHD has been adopted for the concept design, assuming that the primary role of the structure is coastal adaptation. As a result, the focus is solely on dissipating nearshore wave energy.

Given that the crest is below mean sea level, it is considered that there will be little to no impact on amenity.

The toe depth is shown to be founded at or below NSL, with the structures having a slope of 1V:4H.

Similar to the beach nourishment option, the sand buffer is designed with a slope of 1V:3H and is intended to be planted and stabilised to enhance durability and resistance to erosion. In contrast, the beach berm will feature a constructed slope of 1V:4H and an elevation of +2 mAHD, consistent with the current berm heights.

As the borrowed sediment closely matches the native material, the final beach berm profile is expected to closely resemble the existing one, with only a minor seaward shift.

### 7.10.1 Concept

The layout, section, and oblique image for Option 4b are illustrated in Figure 7.10 and included at a larger scale in Appendix B.

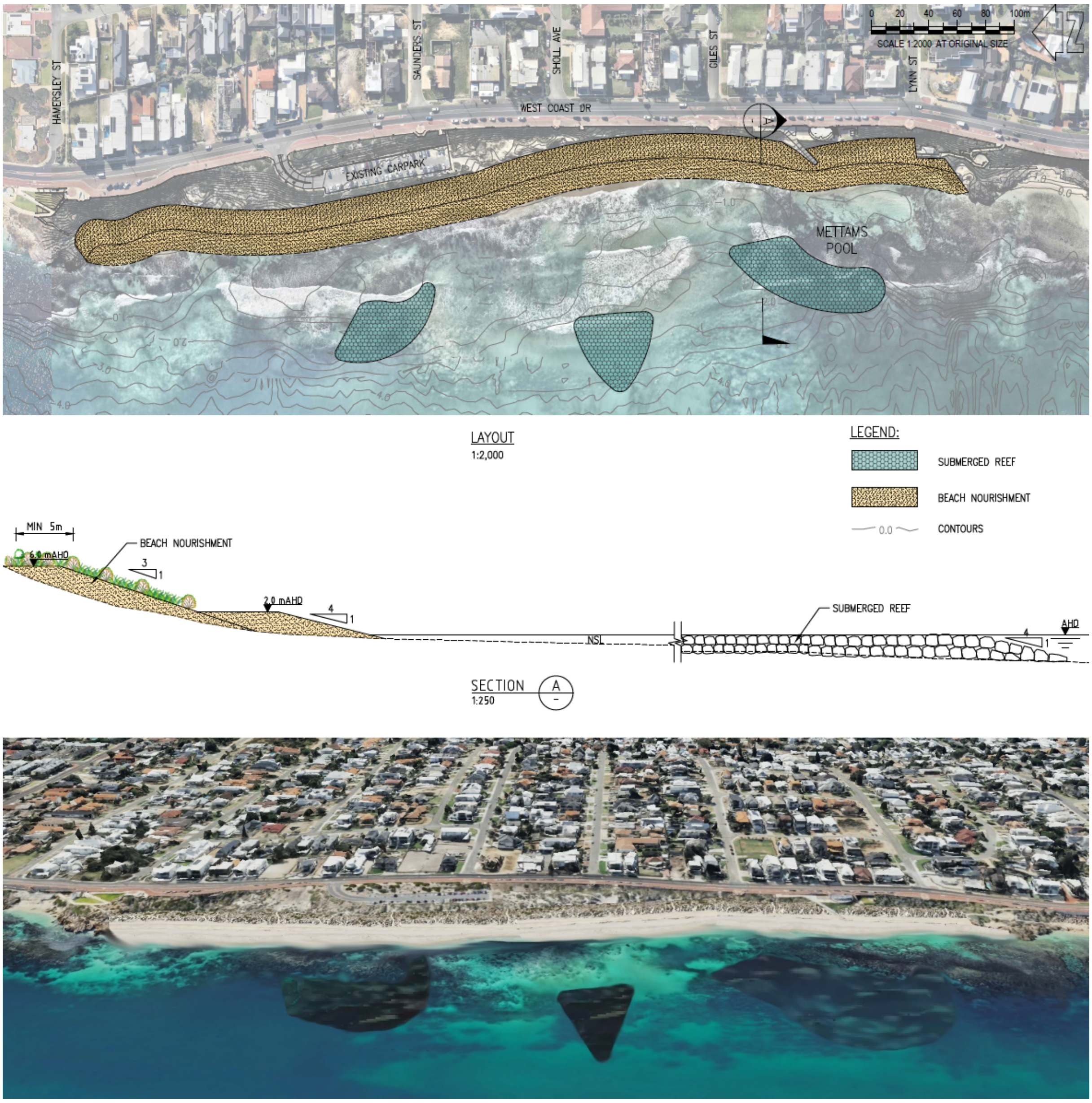



**Figure 7.10 Option 4b – (Top) Layout (Middle) Section (Bottom) Oblique Image**

Table 7.18 lists the advantages, disadvantages and considerations associated with Option 4b.

### Table 7.18 Option 4b – Advantages, Disadvantages & Considerations

| Advantages | Disadvantages | Considerations |
|---|---|---|
| ■ Protects infrastructure through nourishment of dune and providing storm buffer<br>■ Maintains continuity of the beach space<br>■ Structures can be designed to improve water based activities such as surfing and snorkelling<br>■ Structures can be designed to provide habitat opportunities<br>■ Minimal visual impact<br>■ Increases public safety by reducing exposure of the nearshore reef<br>■ Nourishment can be adjusted based on shoreline response | ■ Large volumes of borrowed sand required for nourishment<br>■ Beach nourishment causes beach disturbance<br>■ High capital and maintenance costs<br>■ Risk of nearshore reef smothering<br>■ Potential loss of buffer during severe or consecutive storm events, requiring additional nourishment – less guarantee<br>■ Logistical challenges with in-water construction<br>■ Encroaches into Marmion Marine Park, requiring additional environmental approvals<br>■ Interrupts longshore sediment transport as it reduces the wave energy reaching the coastline<br>■ Structures may damage nearshore reef | ■ Require an ongoing source of sand<br>■ Consideration of sediment movements<br>■ Require Marine and Coastal Approval through DBCA<br>■ Consider function of reef – solely protection, or surfing, MPR<br>■ Consider safety of reef if surfable |

### 7.10.2 Opinion of Probable Costs

The concept level capital and maintenance cost estimates have been calculated for Option 4b. These are based on Contractor and Supplier's rates for within the Perth Metropolitan region and are summarised in Tables 7.19 and 7.20 respectively.

## Table 7.19 Option 4b – Opinion of Probable Capital Cost

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| | | | | | | |
| 1 | **Capital - Submerged Reefs & Nourishment** | | | | | $ 6,281,000 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 1 | Item | $ 650,000 | $ 650,000 | |
| 1.2 | Source and transport sand from terrestrial sources | 24,000 | $m^3$ | $ 60 | $ 1,440,000 | |
| 1.3 | Placement of sand for reef construction as well as beacl nourishment | 8,100 | $m^3$ | $ 20 | $ 162,000 | |
| 1.4 | Beach nourishment | 15,900 | $m^3$ | $ 10 | $ 159,000 | |
| 1.5 | Source, transport and construct submergent limestone reefs | 25,800 | Tonne | $ 150 | $ 3,870,000 | |
| | **Subtotal 1** | | | | $ 6,281,000 | $ 6,281,000 |
| | **Contingencies** | 20 | % | | $ 1,256,200 | $ 1,256,200 |
| | **Subtotal 2** | | | | $ 7,537,200 | $ 7,537,200 |
| | **Goods & Services Tax** | | | | $ 753,720 | $ 753,720 |
| | **Total Estimated Cost** | | | | $ 8,290,920 | $ 8,290,920 |

## Table 7.20 Option 4b – Opinion of Probable Maintenance Cost Over 50 Years

| Item | Activity | Quantity | Units | Unit Rate | Subtotal | Total for Item |
|---|---|---|---|---|---|---|
| | | | | | | |
| 1 | **Maintenance Over 50-year Horizon (Biennially)** | | | | | $ 11,838,100 |
| 1.1 | Preliminaries including site establishment, mobilisation, insurances, management plans etc | 25 | Item | $ 40,000 | $ 1,000,000 | |
| 1.2 | Beach nourishment to replace lost material | 120,000 | $m^3$ | $ 70 | $ 8,400,000 | |
| 1.3 | Reef maintenance and adaptation | 63 | % | $3,870,000 | $ 2,438,100 | |
| | **Subtotal 1** | | | | $ 11,838,100 | $ 11,838,100 |
| | **Contingencies** | 20 | % | | $ 2,367,620 | $ 2,367,620 |
| | **Subtotal 2** | | | | $ 14,205,720 | $ 14,205,720 |
| | **Goods & Services Tax** | | | | $ 1,420,572 | $ 1,420,572 |
| | **Total Estimated Cost** | | | | $ 15,626,292 | $ 15,626,292 |

# 8. Multi-Criteria Analysis (MCA)

An MCA assessment was developed to evaluate the five concept options, based on a range of relevant criteria, and determine a preferred option. An MCA is a useful tool to evaluate multiple, often conflicting, decision-making criteria and select an option that achieves the best overall score. This was the most reasonable way to account for the diverse needs and requests of the long list of stakeholders for coastal adaptation at Mettams Pool.

The MCA process involves determining ratings and weightings for each of the criteria. Based on the ratings and weightings of the criteria, an overall score can then be calculated for each of the options being assessed.

Each of the criteria and respective weightings are shown in the MCA provided in Appendix C. As shown, there are four broad criteria (technical, social, environmental and economic) that each incorporate various sub criteria. Details of the criteria and weightings and how there were developed and rated are provided below.

## 8.1 Overall Broad Criteria

The overall broad criteria and weightings are listed below:

- Technical (25%).
- Social (25%).
- Environmental (25%).
- Economic (25%).

The weightings for the broad criteria were developed by the Mettams Pool and Watermans Bay Reference Group in Workshop 3.

The technical criteria relate to the implementation of an option from a technical perspective, basically interrogating how well each option may work and how much certainty there is with the concept design. Inclusion of a set of criteria that assesses the technical competence of an option at the concept design stage is considered to be extremely important, as there is no point in implementing an option to achieve the social and environmental criteria unless it is feasible to construct and operate from a technical perspective. The technical criteria were therefore assigned a 25% overall rating.

The social criteria relate to the key values identified through the community engagement process, which has been discussed in Sections 3 and 7 of this report. This is important, as the community are the primary users of the beach and subsequent amenity, which will be determined by the selected adaptation option. The social criteria were therefore assigned a 25% overall rating.

The environmental criteria relate to the preservation of the beach environment and marine park. The back beach at Mettams Pool is significantly vegetated and connects the coastline through a vegetation corridor. Mettams Pool is also located in the Marmion Marine Park, which extends from Burns Rocks in the north, Trigg Point to the south and seaward from the highwater mark. Given this, the environmental criteria equally as important in guiding the selection of an adaptation option. The environmental criteria were therefore assigned a 25% overall rating.

Finally, economic criteria relate to the implementation of an option from a financial perspective. This is extremely important, as there is no point in selecting an option for implementation to achieve the social and environmental criteria unless it is feasible from an economic perspective. The economic criteria were therefore assigned a 25% overall rating.

## 8.2 Technical

The technical sub criteria and weightings are listed below and shown in Table 8.1:

- Effectiveness (60%).
- Adaptability (30%).
- Legal / approval requirements (10%).

### Table 8.1 Technical Sub Criteria

| TECHNICAL | | | | |
|---|---|---|---|---|
| Description | | Effectiveness | Adaptability | Legal / approval requirements |
| | | Weighting 60% | Weighting 30% | Weighting 10% |
| Rating Description | | Expected effectiveness of the scheme at achieving the key objectives without ongoing modifications or risks of failure/poor outcomes. | Ease with which option can be modified to account for changes in conditions, etc in the future | Extent of effort and time required to receive approval for option |
| Rating Scale | 1 | Not expected to be effective | Modification not possible | Extreme effort required - >12 month timeframe for approvals |
| | 2 | Slightly effective | Only slight modifications possible with large effort | Significant effort required to achieve approvals 6 to 12 month period |
| | 3 | Effective | Reasonable potential for modification with some effort | Some issues with approvals, but addressed over 3 to 6 month period |
| | 4 | Very effective | Modifications readily possible with moderate level of effort | Minor issues with approvals, but easily addressed |
| | 5 | Completely effective | Complete modification of option easily achieved | No issues with approvals |

These sub criteria and weightings were developed by MRA, based on experience and knowledge of similar projects recently completed in the Perth Metropolitan region. These technical sub criteria were rated by MRA for each of the five adaptation options.

The Mettams Pool and Watermans Bay Reference Group were consulted on each of the technical sub criteria and provided input to the scales and weightings adopted.

## 8.3 Social

The social sub criteria and weightings are summarised below and shown in Table 8.2:

- Provide beach and active recreation opportunities (30%).
- Provide coastal amenity (30%).
- Ensure coastline is accessible for all (20%).

- Provide recreational facilities including ablutions and changerooms, shade and shelter (20%).

### Table 8.2 Social Sub Criteria

| SOCIAL | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| Description | | Provide beach and active recreation opportunities | Provide coastal amenity | Ensure the coastline is accessible for all | Provide recreational facilities including ablutions and changerooms, shade and shelter |
| | | Weighting 30% | Weighting 30% | Weighting 20% | Weighting 20% |
| Rating Description | | Extent that the option provides useable beach area and active recreation opportunities | Extent that the option provides opportunities for passive recreation and amenity, such as provision of dual use path and areas to sit and view the water. | Ranking based on provision and likely functionality of access to the beach. | Ranking based on provision and likely functionality of the ablutions, changerooms, shade and shelter. |
| Rating Scale | 1 | Significant loss in beach area and active recreation opportunities | Significant loss of amenity and passive recreation opportunities | Access not provided | Ablutions, changerooms, shade and shelter not provided |
| | 2 | Slight decrease in beach area and active recreation opportunities | Slight decrease in amenity and passive recreation opportunities | Access provided but with potential loss of functionality due to change in beach or areas of beach usage | Ablutions, changerooms, shade and shelter provided but with potential loss of functionality due to change in beach or areas of beach usage |
| | 3 | No net change in beach area and active recreation opportunities | No net change to amenity and passive recreation opportunities | Access provided within scheme with minimal potential for loss of functionality | Ablutions, changerooms, shade and shelter provided within scheme with minimal potential for loss of functionality |
| | 4 | Slight increase in beach area and active recreation opportunities | Slight increase in amenity and passive recreation opportunities | Access provided with for all most of the time | Ablutions, changerooms, shade and shelter provided with improved functionality |
| | 5 | Significant increase in beach area and active recreation opportunities | Significant increase in amenity and passive recreation opportunities | Access provided for all at all times | Ablutions, changerooms, shade and shelter ideally situated |

These sub criteria and weightings were developed based on the results of the community engagement process.

## 8.4 Environment

The environmental sub criteria and weightings are summarised below and shown in Table 8.3:

- Preservation of beach environment (beach and vegetated dunes) (50%).
- Preservation of marine park (50%).

### Table 8.3 Environmental Sub Criteria

| ENVIRONMENTAL | | | |
|---|---|---|---|
| | | | |
| Description | | Preservation of beach environment (beach and vegetated dunes) | Preservation of Marine Park |
| | | Weighting 50% | Weighting 50% |
| Rating Description | | How well the option protects or provides for preservation of the beach environment, including dunes | How well the option protects or provides for preservation of the marine park environment |
| Rating Scale | 1 | Significant loss of beach environment | Significant loss of marine park environment |
| | 2 | Slight loss of beach environment | Slight loss of marine park environment |
| | 3 | No net change in beach environment | No net change in marine park environment |
| | 4 | Slight increase in beach environment | Slight increase in marine park environment |
| | 5 | Significant increase in beach environment | Significant increase in marine park environment |

Similarly to the social sub criteria discussed above, the community engagement process was used to develop the environmental sub criteria. Key success criteria 3 and 8, refer to the preservation of the natural environment, which is associated with maintaining the beach environment and the marine park.

The Reference Group were consulted on each of the environmental sub criteria and provided input to the scales and weightings adopted.

## 8.5 Economic

The economic sub criteria and weightings are summarised below and shown in Table 8.4:

- Capital cost (50%).
- Operating / maintenance cost (50%).

### Table 8.4 Economic Sub Criteria

| ECONOMIC | | | |
|---|---|---|---|
| | | | |
| Description | | Capital cost | Operating/ maintenance cost |
| | | Weighting 50% | Weighting 50% |
| Rating Description | | Capital cost to construct | Ongoing operating and maintenance costs to maintain over 50 year period |
| Rating Scale | 1 | $8.3 million | $15.9 million |
| | 2 | $6.8 million | $15.0 million |
| | 3 | $5.4 million | $14.2 million |
| | 4 | $3.9 million | $13.3 million |
| | 5 | $2.4 million | $12.4 million |

The capital and operating / maintenance scales were developed on a relative basis, based on the highest and lowest cost estimates. The economic sub criteria were rated by MRA, based on the capital and operating / maintenance costs detailed in Section 7 of this report for each of the five adaptation options. These cost estimates are summarised in Table 8.5 for reference.

### Table 8.5 Summary of Probable Capital & Maintenance Costs for the Adaptation Options

| Adaptation Option | Capital Cost (inc GST) | Maintenance Cost (inc GST) |
|---|---|---|
| Sand Nourishment | $2.4M | $12.4M |
| Seawall & Beach Nourishment | $7.9M | $15.9M |
| Groynes / Headland Enhancement & Beach Nourishment | $3.5M | $13.8M |
| Nearshore Breakwaters & Beach Nourishment | $6.7M | $15.2M |
| Submerged Breakwaters (Reefs) & Beach Nourishment | $8.3M | $15.6M |

## 8.6 MCA Assessment

### 8.6.1 MCA Summary & Overall Score

Based on the ratings and weightings assigned in the MCA, overall scores were calculated for each of the five adaptation options. The scores for the broad criteria (technical, social, environmental and economic) as well as the overall scores are detailed in Appendix B and summarised below in Table 8.6. It is noted that these scores have been prepared on the basis of information and assumptions that have been developed for this study. Should details change in the future, this could alter the outcomes of an MCA completed at that time.

**Table 8.6 MCA Summary of Broad Criteria & Overall Score**

| Option | Type | Description | Technical | Social | Environment | Economic | Weighted Score |
|---|---|---|---|---|---|---|---|
| | | | Weighting 25% | Weighting 25% | Weighting 25% | Weighting 25% | |
| 1 | Sand Nourishment | Construction of sand buffer and biennial beach nourishment to protect upland structures while maintaining the current beach amenity. | 3.6 | 2.8 | 3.5 | 5.0 | 3.7 |
| 2 | Seawall & Beach Nourishment | Construction of a vertical seawall directly in front of at-risk assets for protection as well as biennial beach nourishment to maintain beach amenity. | 3.3 | 3.1 | 2.0 | 1.0 | 2.4 |
| 3 | Groynes / Headland Enhancement & Beach Nourishment | Construction of groynes / headland enhancement in combination with biennial beach nourishment to provide usable beach compartments and infrastructure protection. | 2.9 | 1.4 | 2.0 | 3.5 | 2.5 |
| 4a | Detached Breakwaters & Beach Nourishment | Construction of detached breakwaters in combination with biennial beach nourishment to provide a usable beach compartment and infrastructure protection. | 2.6 | 1.6 | 2.0 | 2.0 | 2.1 |
| 4b | Submerged Reefs & Beach Nourishment | Construction of submerged reefs and sand buffer in combination with biennial beach nourishment to protect upland structures while maintaining the current beach amenity. | 2.9 | 3.1 | 3.5 | 1.0 | 2.6 |

### 8.6.2 MCA Sensitivity Analysis

During the Reference Group Workshop 3, the group requested MRA undertake a sensitivity analysis on both the broad criteria and sub criteria to ensure there is no bias associated with the weightings.

A Monte Carlo simulation was conducted on the weightings prescribed by MRA and reviewed and approved by the Reference Group. Monte Carlo simulation is a computational approach used to model complex situations with a high degree of uncertainty.

The following provides a summary of the key assumptions, justifications, and considerations for the probabilistic assessment undertaken:

- Iterations – A total of 10,000 iterations / scenarios have been simulated to provide an appropriate level of accuracy. This number is considered sufficient to capture variability and provide robust statistical insights.

- Ratings – The ratings assigned to each sub criteria were developed by MRA in consultation with the Reference Group. These prescribed ratings form the basis of the assessment and remain constant throughout the Monte Carlo simulation. The sub criteria ratings are detailed in Appendix C.

- Weightings – Criteria and sub criteria weightings are bounded, with the bounds listed in Table 8.7 below. Weightings were generated assuming a uniform distribution within the specified limits of the bounds and were normalized to sum to 1.

### Table 8.7 Summary of Weightings for the Criteria & Sub Criteria

| Criteria | Weightings | | Sub Criteria | Weightings | |
|---|---|---|---|---|---|
| | Lower | Upper | | Lower | Upper |
| Technical | 0.2 | 0.4 | Effectiveness | 0.2 | 0.5 |
| | | | Adaptability | 0.2 | 0.5 |
| | | | Legal / approval requirements | 0.2 | 0.5 |
| Social | 0.2 | 0.4 | Provide beach and active recreation opportunities | 0.2 | 0.4 |
| | | | Provide coastal amenity | 0.2 | 0.4 |
| | | | Ensure the coastline is accessible for all | 0.2 | 0.4 |
| | | | Provide recreational facilities including ablutions and changerooms, shade and shelter | 0.2 | 0.4 |
| Environmental | 0.2 | 0.4 | Preservation of beach environment (beach and vegetated dunes) | 0.4 | 0.6 |
| | | | Preservation of Marine Park | 0.4 | 0.6 |
| Economical | 0.2 | 0.4 | Capital cost | 0.4 | 0.6 |
| | | | Operating/ maintenance cost | 0.4 | 0.6 |

The results of the analysis are presented in Figure 8.1, showing the outcomes for the four broad criteria (technical, social, environmental, and economic) for each adaptation option. Figure 8.2 displays the final weighted scores for each adaptation option.

Each plot depicts the following information:

- Red Line – Represents the mean rating value for each adaptation option.
- Grey Lines – Indicate the outcomes of each individual simulation, highlighting the full range of variability.
- Box and Whisker Plot – Provides a statistical summary, illustrating:
    - Mean: The average score across all simulations.

- Upper and Lower Quartiles: The 25th and 75th percentiles, representing the interquartile range.

- Minimum and Maximum Data Values: The full range of simulated outcomes, showing the most extreme scores generated.

The analysis indicates that regardless of the weighting assigned to the criteria and sub-criteria, beach nourishment remains the preferred coastal adaptation option. Beach nourishment consistently rates highest across three of the four broad criteria.

An interesting observation is that while beach nourishment is often regarded as cost-prohibitive, particularly for large-scale or frequent projects, it emerges as a more cost-effective option when evaluated over the 50-year planning horizon. This is because all proposed adaptation options require ongoing nourishment to maintain the coastline's recreational function and accessibility, a key success criteria. Additionally, the long-term costs associated with maintaining "hard" engineered structures further support the cost-effectiveness of beach nourishment in this context.

If, for any reason, Option 1 (Beach Nourishment) cannot be implemented, the remaining adaptation options show a relatively even performance, noting that Options 3 and 4a (Groyne / Headland Enhancement and Nearshore Breakwaters in combination with Beach Nourishment) are not deemed viable at Mettams Pool. Typically, Option 4b (Submerged Breakwaters & Beach Nourishment) performs better than the Option 2 (Seawall & Beach Nourishment). Nonetheless, adjustments to the weighting of criteria and sub-criteria could result in Options 2 or 4b being the preferred coastal adaptation approach.

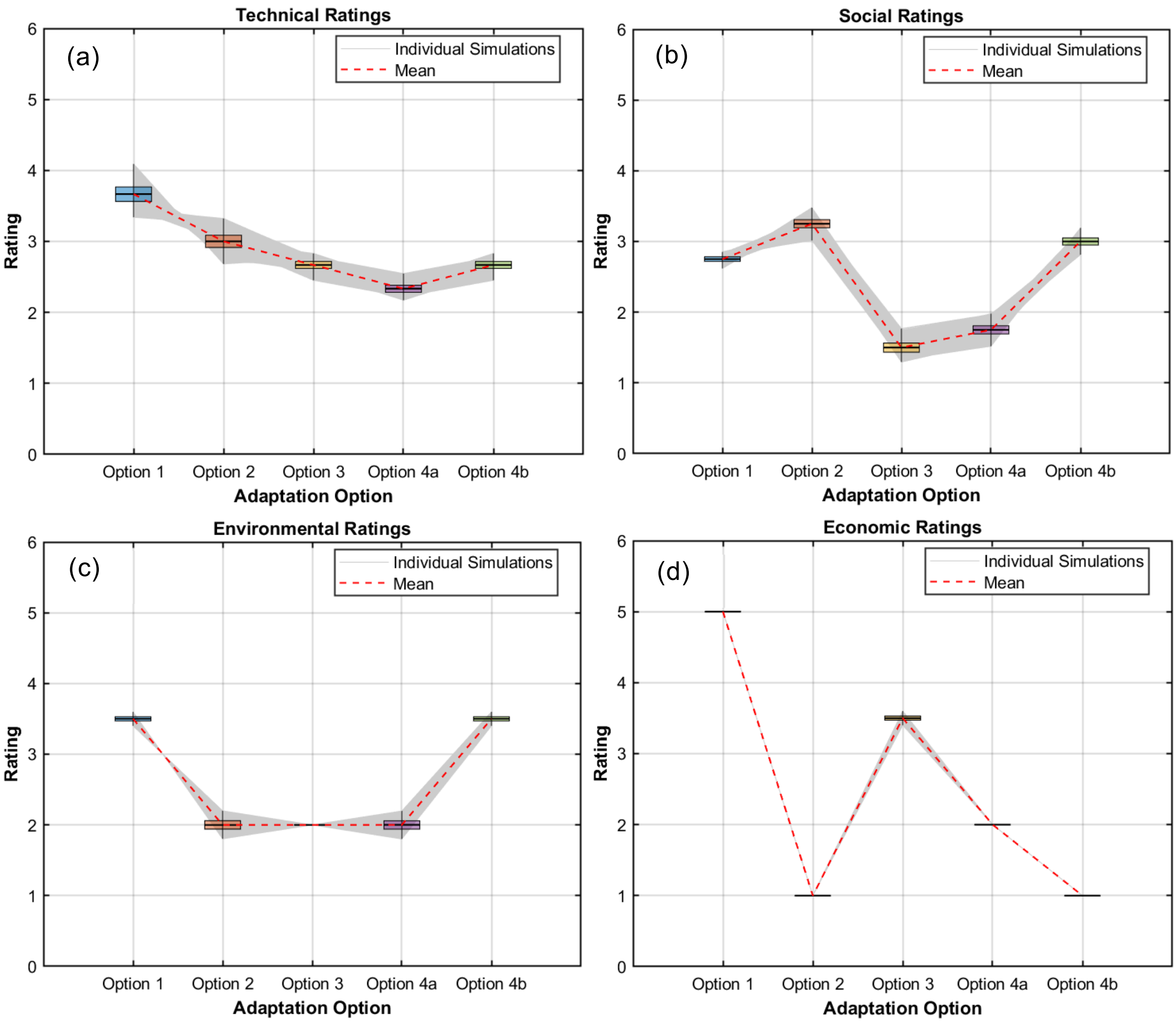



**Figure 8.1 Monte Carlo Simulation (a) Technical Sub (b) Social Sub (c) Environmental Sub & (d) Economic Sub Criteria**

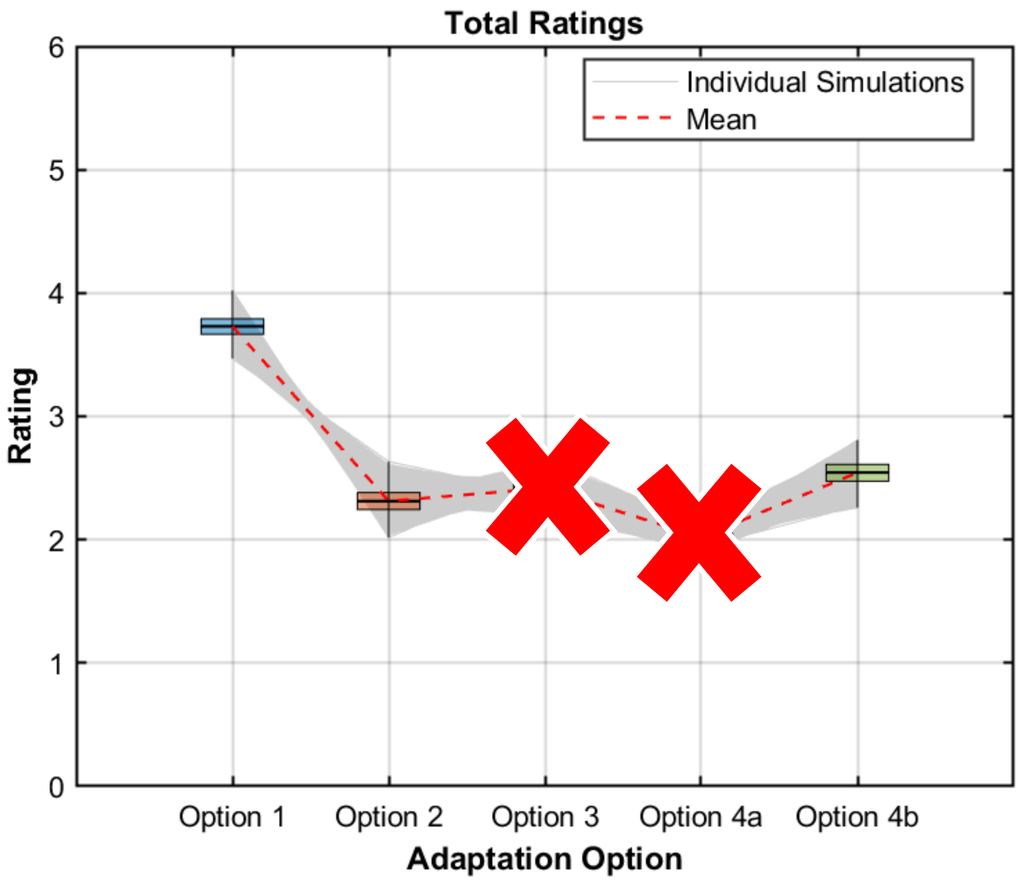



**Figure 8.2 Monte Carlo Simulation (Final Ratings)**

As outlined earlier, while developed, the Groynes (3) and Nearshore Breakwaters (4A) options were not considered to appropriately meet the success criteria and was not considered further.

# 9. Adaptation Option Progression

## 9.1 Highest Ranking Adaptation Option

Based on the MCA assessment and sensitivity study detailed in Section 7, the adaptation options which are deemed to be suitable at Mettam Pool have been ranked and are listed below:

- Option 1 – Beach Nourishment (3.7).
- Option 4b – Submerged Breakwater (Reef) & Beach Nourishment (2.6).
- Option 2 – Seawall (Vertical) & Beach Nourishment (2.4).

It is important to highlight that the outcomes of the MCA process are based on key success criteria developed through the community engagement process, which has significantly influenced the requirements of each adaptation option. Should community values change in the future, both the adaptation options and the MCA process can be revisited, as these changes could alter the preferred option.

As demonstrated, Beach Nourishment ranks as the highest-scoring option. It is recommended that this option be further evaluated for progression into future design phases. A developed version of the Beach Nourishment concept plan is presented in Appendix D.

## 9.2 Key Considerations for Further Evaluation & Progression

The key considerations for the further evaluation of Option 1 (Beach Nourishment) and implementation, if selected, have been summarised below to assist with the process.

### 9.2.1 Placement Methodology

It has been considered that sand will be transported and placed at the site using heavy land-based machinery. This method has been successfully used for similar projects at Watermans Bay and Mettams Pool. However, this is not the only method of transporting sand to the site.

The City has indicated that in the long term, trucking sand to the site is not the preferred option due to its heavy demand on the WCD, especially considering the large quantities required for capital works. Therefore, it is worth investigating all forms of transporting sand to the site, briefly discussed below:

- Trucking – Sand is brought to the site using heavy plant and machinery. The sand can be sourced from Suppliers or beach sand traps. This is the current methodology used by the City to nourish Mettams Pool. This is also how the City of Joondalup bypasses sand around HBH.
- Pumping System – Sand is transported to the site through a permanent or semi-permanent pipeline network. The pumping infrastructure can be located at the sediment source or another accessible location. Sand can be sourced from Suppliers, sand traps, or dredged from offshore sources. This strategy has been used for bypassing works at Port Coogee in the City of Cockburn.
- Dredging – Dredging involves extracting sediment from offshore sediment sources via a dredge. There are many types of dredges and approaches to placing the extracted material on the coastline, as depicted in the figures below. Dredging via rainbowing was used as the nourishment technique at Port Beach in the City of Fremantle.

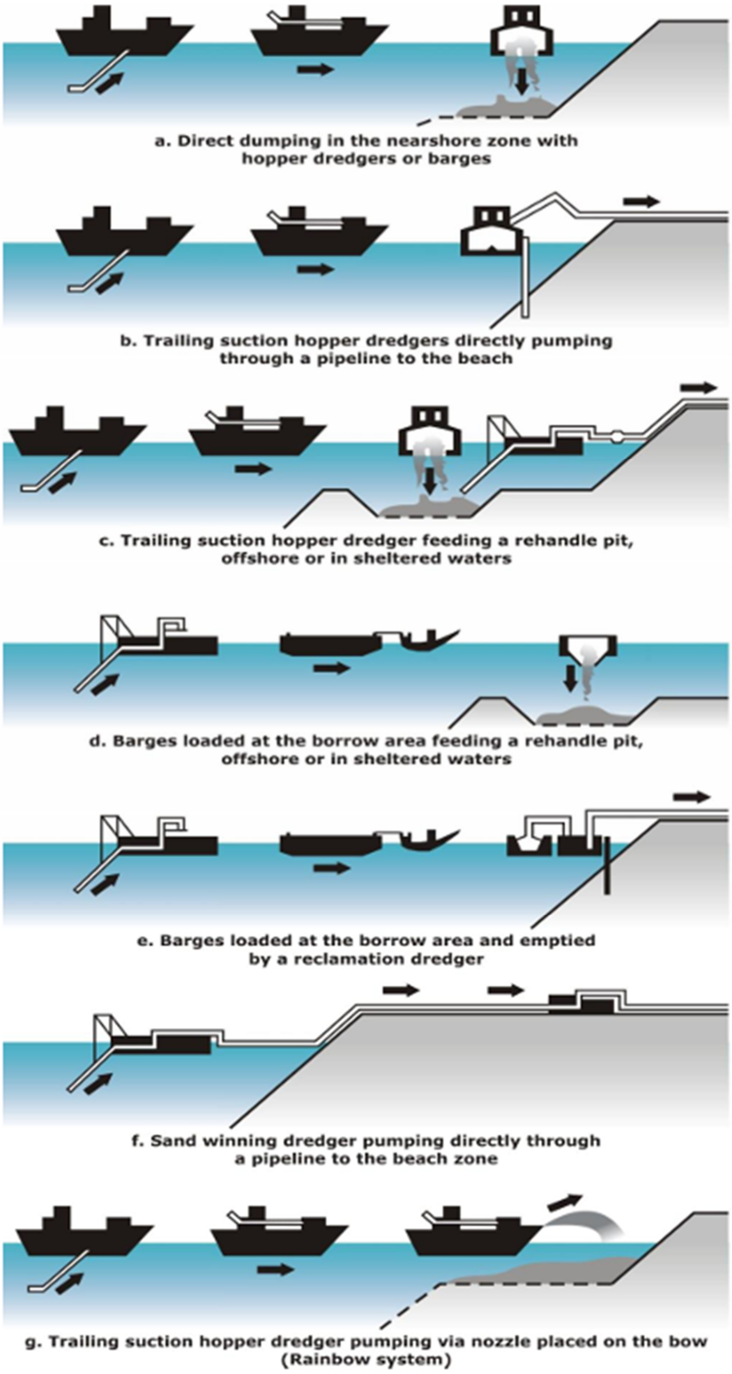



**Figure 9.1 Methods of Dredge Nourishment**

The advantages and disadvantages of each option are given in the table below.

**Table 9.1 Advantages & Disadvantages of Sand Nourishment Techniques**

| Type | Advantanges | Disadvantages |
|---|---|---|
| **Trucking** | ■ No large capital investment required<br>■ Available for use all year<br>■ Largely independent of weather<br>■ Extraction area can be readily shifted<br>■ Required quantity can be sourced and placed relatively quickly<br>■ Large amount of control around the as-constructed beach profile | ■ Dependent on available source of sand<br>■ Access to beaches may be an issue<br>■ Increased truck traffic at the site<br>■ Substantial $/m$^3$ rate for obtaining wash white sand for nourishment |
| **Pumping System** | ■ Once constructed, low $/m$^3$ rate can be achieved<br>■ Once constructed, quantity can be sourced and placed relatively quickly<br>■ Low social impact after construction<br>■ Can conduct works at low use beach times to minimise social impact<br>■ Available for use all year round<br>■ Reduced truck traffic at the site | ■ Large capital investment with ongoing maintenance costs<br>■ Sand is required to accumulate or be transported to the extraction point<br>■ Likely to require a clearing permit for pipeline install<br>■ Minimal amount of control around the as-constructed beach profile |
| **Dredging** | ■ Once mobilised, lower $/m$^3$ rate can be achieved<br>■ Can conduct works at low use beach times to minimise social impact<br>■ Reduced truck traffic at the site<br>■ Low social impact | ■ Large mobilisation / demobilisation costs<br>■ Likely to require EPA approvals at the dredge location as well as at the site<br>■ Significant works required to investigate potential marine sediment sources<br>■ Control around the as-constructed beach profile is dependent on the placement technique<br>■ Largely dependent of weather |

### 9.2.2 Sand Sourcing

It has been considered in the cost estimate that sand will be procured from external Suppliers. Typically, this has not been the case for the City's beach nourishment works, as sand has been sourced from beach sand traps at both Trigg Point and Sorrento Beach. However, this is unlikely to be suitable in the longer term and therefore alternative options have been further investigated.

MRA is in the process of finalising a material scoping study for the Perth and Peel regions and the Southwest Region. Outcomes from the study tend to indicate that there is enough sand in the Perth and Peel regions to support expected coastal adaptation works now and into the future (the project considered a 10 year planning horizon). The largest risk to the supply of BRMs comes from larger coastal developments, such as the recently completed Ocean Reef Marina and the planned Westport project. These developments have the potential to significantly affect the quantity of available BRMs, exceed the annual production rates of suppliers, and result in challenges in supply for additional projects, leading to increased costs.

From discussions with local Suppliers in the Perth and Peel regions, terrestrial sands required to meet specific project requirements, including colour and washing, incur greater costs. Washed white sand was suggested to cost $20 /tonne, whereas unwashed sand was significantly less at $2-4 /tonne. These values are exclusive of cartage costs.

Regarding marine sediment sources, the City, with support from the NBA, is actively investigating potential sources of marine sediment for beach nourishment. Several potential sediment sources have been identified, and the NBA has recently engaged a consultant to ground-truth these sources.

One marine sediment source that has been tried and tested is Fremantle Port's Deepwater Channel. Over 150,000 m$^3$ of a potential 400,000 m$^3$ of sand dredged from Deepwater Channel was used to nourish the beach at Port Beach. The unit cost of dredging sediment from Deepwater Channel and rainbowing it into the swash zone of Port Beach was approximately $10-15 /m$^3$, which is estimated to be a third of the unit cost of sand nourishment via trucking from terrestrial sources. It is important to note that the unit cost of the dredging works was low due to several unique circumstances which may not occur for other projects.

No work has been done to verify potential sources of sediment for beach nourishment at the site. Therefore, it is recommended that further analysis be undertaken of the native material to ensure there is no mismatch between the aesthetic and physical properties of the potential borrowed sediment.

There are also several beach sources in close proximity to the site, including Trigg Point and Sorrento Beach. These beaches are known to be suitable, as they have been investigated and used for coastal protection works along the City's coastline. Although the sand's aesthetic and physical properties may be appropriate, the quantity of sand required for both capital and maintenance works is far greater than what has previously been assessed as sustainably extractable from these sites and unlikely to be appropriate.

### 9.2.3 Approvals

Prior to any beach nourishment being undertaken, the City will need to obtain the required approvals. These requirements will heavily depend on both the sediment source location and the placement methodology. The "Considerations" for Option 1 are based on a land-based construction approach, assuming material is trucked and placed above the waterline, thereby requiring minimal approvals.

Given the logistical challenges associated with transporting and placing sand on-site, this does not appear to be the City's preferred approach. For other placement options where sand may be sourced offshore or placed below the waterline, MRA expects the works to require EPA approval for the extraction location and the placement site to address the following concerns:

- Direct and indirect impacts on benthic communities and habitats.
- Changes to shorelines, bathymetry, and habitats through modified ecological and physical processes.
- Introduction of invasive pest species translocated in dredging (or ancillary) equipment, posing ecological and economic risks.
- Adverse effects of contaminant release and dispersion on marine environmental quality.
- Conflicts with fisheries and impacts on fish, their habitats, and fisheries production.
- Changes to coastal processes and water circulation affecting the environmental values of the coast and coastal waters.
- Impacts on the behaviour and survival of marine wildlife, including specially protected species.

Consultation with the EPA would be required to confirm these approval requirements if beach nourishment via dredging is selected for progression.

### 9.2.4 Staging

MRA was engaged to complete a coastal adaptation options assessment for Watermans Bay and Mettams Pool. From discussions with the City, the works will be staged, with Mettams Pool's design development and implementation expected to be completed prior to Watermans Bay. The staging is based on the assets at Watermans Bay being currently protected by a GSC seawall, which is estimated to have a residual remaining service life until 2030 and therefore is not considered as critical as coastal protection at Mettams Pool.

### 9.2.5 Emergency Works Procedure

The primary function of beach nourishment is to provide improved protection to upland structures and infrastructure from the effects of cross-shore and longshore sediment transport. This involves adding sand to the upper beach profile, which acts as a sand buffer. During storm events, the energy of the ocean is spent eroding the sand buffer rather than the coastline requiring protection. Therefore, the sand buffer is expected to decrease over time, eventually requiring renourishment. The sand buffer can also be eroded completely during severe storm events with high water levels or consecutive storm events that occur in close succession, not allowing the beach berm to build up naturally.

Subsequently, if beach nourishment is developed and implemented at the site, it is also recommended that an emergency works procedure is developed for the coastline. This document should detail key items, including:

- Definition of an extreme or significant storm event that may affect the coastline (including wave height, water level, and frequency of events).
- Shoreline monitoring to document the response of the shoreline to the storm event.

- Identification of emergency work triggers.
- Details of the City's response following triggers being reached, including:
    - Nourishment volumes.
    - Potential sand sources.
    - Construction methodology.
    - Required construction management plans and approvals.

## 9.3 Coastal Monitoring Considerations

The City has recently re-established its coastal monitoring program. The aim of this program is to monitor changes to the shoreline within the study area and assist the City in managing its coastal assets (MRA, 2023).

The coastal monitoring program currently being implemented includes 6 monthly onshore surveys as part of the Northern Beaches Alliance. It is strongly recommended that these surveys are supplemented by:

- Periodic hydrographic surveys.
- Inspections and photographic monitoring of the relevant beaches every six months.
- Mapping of the shoreline every year.
- Analysis and reporting on the monitoring surveys by experienced personnel, highlighting notable variations in shoreline movements and metocean conditions.

It is strongly recommended that the coastal monitoring program continue for future use in the Mettams Pool adaptation project.

## 9.4 Funding Opportunities & Constraints

The responsibility to fund coastal adaptation lies with the relevant beneficiaries, including the land and asset owners and the coastal users that benefit from the approaches implemented. The City has engaged Ricardo to complete the Benefit Distribution Analysis (BDA) for the preferred coastal adaptation options at Watermans Bay and Mettams Pool following the completion of this scope of works. This work is planned to be completed in accordance with SPP2.6.

A list of potential funding opportunities is discussed below. This does not consider local, state, and federal budgets that the City can lobby for the funding required to implement the preferred coastal adaptation option at Mettams Pool.

### 9.4.1 Coastal Management Plan Assistance Program (CMPAP)

The CMPAP is designed to support the Western Australian Planning Commission's SPP2.6, which guides land use and development along the coast. The grant itself provides funding to land managers to prepare and implement strategies and management plans for areas that are, or in the future will be, under pressure from a range of challenges.

Applicants can request funding up to $200,000 to assist with the development of the Coastal Hazard Risk Management and Adaption Plan (CHRMAP), and the following:

- Review of the CHRMAP;
- Implementation and adoption of the CHRMAP; and
- Development or review of the coastal strategy and foreshore management plan.

The funding is available for local governments, Aboriginal corporation / land councils and national resource organisations with responsibility for coastal land management.

Following the completion of a CHRMAP, coastal managers may be able to seek funding through the Coastwest Program and CAP grants to implement the recommendations of the CHRMAP, coastal strategy and management plan.

### 9.4.2 Coastal Adaptation & Protection (CAP) grants

CAP grants are primarily given for coastlines immediately adjacent to the oceans of WA. CAP grant funding is given to coastal managers to implement the recommendations of the CHRMAP, coastal strategy and management plan and therefore are available for the same public bodies.

The funding available ranges between a minimum of $15,000 to a maximum of $400,000 and is considered to be up to 50% of the total cost of the project. Projects that are supported by the CAP grants include:

- Monitoring – Development and implementation of a monitoring program.
- Investigation – Determine the cause of the existing coastal hazard and the likely impacts of climate change, hazard assessments, vulnerability assessments, and the development of adaptation/management solutions.
- Adaptation – Design and / or implementation of managed retreat or the construction of 'soft' foreshore protection and 'hard' foreshore structures.
- Asset Management – Condition inspections of existing coastal protection infrastructure or the development of asset management plans, maintenance programs, etc.
- Maintenance – The maintenance or removal of existing coastal protection structures.

The City may be eligible for CAP grants and it is recommended that DoT are consulted to determine the likelihood of success.

### 9.4.3 Disaster Ready Fund (DRF)

The DFR is run by the Australian Government's National Emergency Management Agency (NEMA). Applications for round one and two have already closed however the design for round three is currently being worked on.

Round three is said to provide up to $200M in funding over the 2025-26 period. The DFR is run with state and territory governments to deliver locally driven projects, with states and territories expected to contribute 50% towards the cost of the project.

The purpose of the DRF is to help curb the devastating impacts of natural hazards by investing in important disaster prevention projects. This includes investing in flood levees, floodways, seawalls, firebreaks, constructed wetlands and reefs.

### 9.4.4 Coastwest

DPLH Coastwest grants are designed to support land managers and community organisations through projects that manage, rehabilitate, restore and enhance coastal sites.

Funding for the grants ranges from $5,000 to $60,000. Projects must be ready to commence on a specified date and must be delivered within 12 months of signing a grant funding agreement.

To be eligible:

- The project must be in a location which is consistent with the definition of coast or coastal zone as defined in SPP 2.6.
- The projects must be undertaken on publicly owned or managed coastal environments within the jurisdiction of the Western Australian Government.
- The following applicants cannot apply however can participate as project partners:
    - State Government departments or agencies;
    - registered businesses; or
    - individuals.

Typically, Coastwest grants support “softer” treatments.

### 9.4.5 Natural Resource Management (NRM) Program

The Natural Resource Management (NRM) program is managed by the Department of Primary Industries and Regional Development (DPIRD) and has been created to sustainably manage the land, water, atmosphere, and biodiversity resources.

The program achieves this by supporting community groups with information and grant funding. One such grant is Community Stewardship Grants which is designed to support local community groups to undertake stewardship of natural resources in their local area. The grants are directed at community-based projects that help conserve, restore, rehabilitate or enhance a local natural area, conserve WA’s biodiversity and maintain or build the capability of NRM community groups across the State.

## 9.5 Next Steps

This project has identified the highest-ranked coastal adaptation option through a detailed MCA informed by key stakeholders and the community. The options, including the highest-ranked option, are presented at a conceptual level. As a result, further, more detailed work is required to advance coastal protection at Mettams Pool. It is recommended that the future stages of the project be completed in several phases:

1) Present the preferred concept option to the council for approval.

2) Present the preferred concept option to the community to receive their input.

3) Resolve outstanding assumptions, gaps, potential funding sources and consider the community's response, to arrive at a final concept design.

4) Progress the design to a detailed design stage.

Depending on the placement methodology and where the borrowed sediment is sourced (onshore or offshore), the timeline for approvals will change. If, for instance, sand is sourced from suppliers or beach sand traps, approvals will be similar to the City's beach nourishment works. Otherwise, if sand is sourced from marine sediment sources, approval requirements for dredging are likely to take 12 to 18 months.

Furthermore, considering the time required for design development, placement methodology, and sand sourcing, it is likely that implementation of the adaptation option at Mettams Pool will be at least 2-3 years away. Consequently, given the risk posed to existing assets, it is recommended that the following interim protection measure be implemented to maintain the coastline:

- Maintain the volume of nourishment placed at Mettams Pool.

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# 11. Appendices

**Appendix A Shoreline Movement Chainage Locations**

**Appendix B Concept Adaptation Options**

**Appendix C Multi-Criteria Analysis**

**Appendix D Developed Beach Nourishment Concept**

# Appendix A Shoreline Movement Chainage Locations

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LOCALITY PLAN

NOT TO SCALE

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| REV | DATE | APPROVED | AMENDMENT |
|---|---|---|---|
| A | 18.07.24 | TSH | PRELIMINARY ISSUE |

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CLIENT: City of Stirling — City of Choice

| DESIGNED | CHECKED | APPROVED |
|---|---|---|
| | | |
| DRAWN: R BORJA | CHECKED: T HUNT | |

PROJECT: METTAMS & WATERMANS ADAPTATION OPTIONS ASSESSMENT

TITLE: CHAINAGE PLAN LOCALITY PLAN

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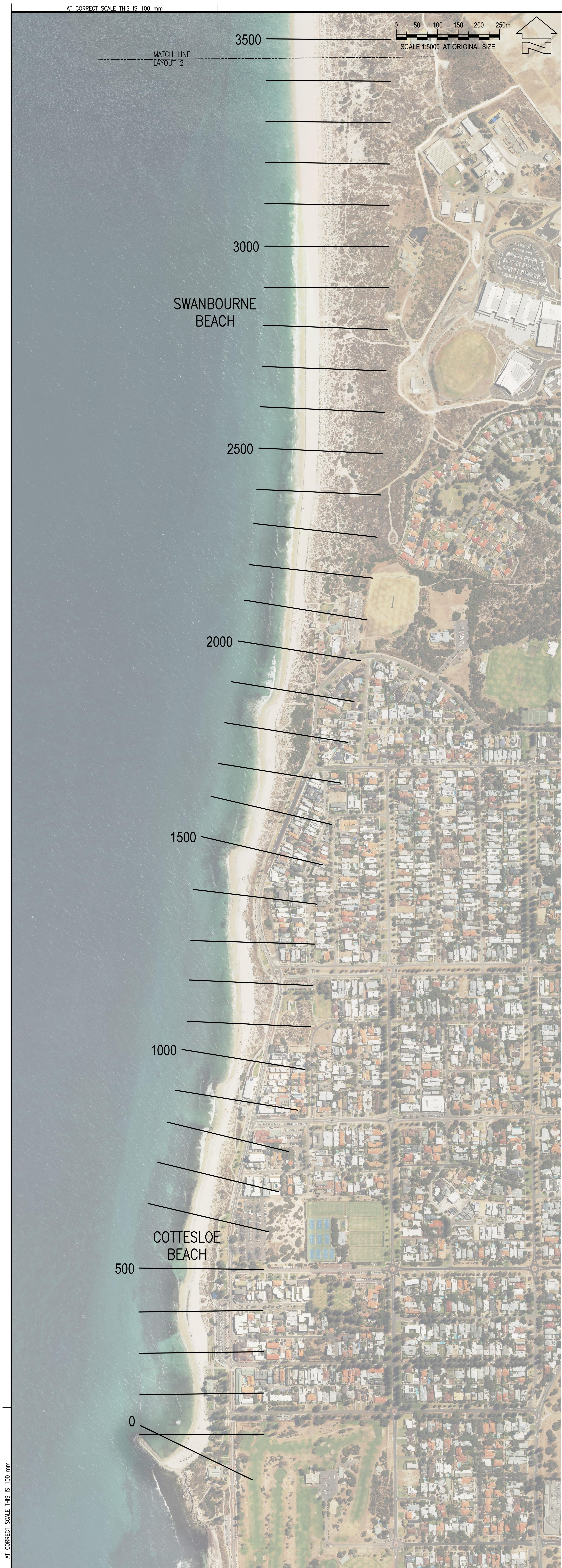


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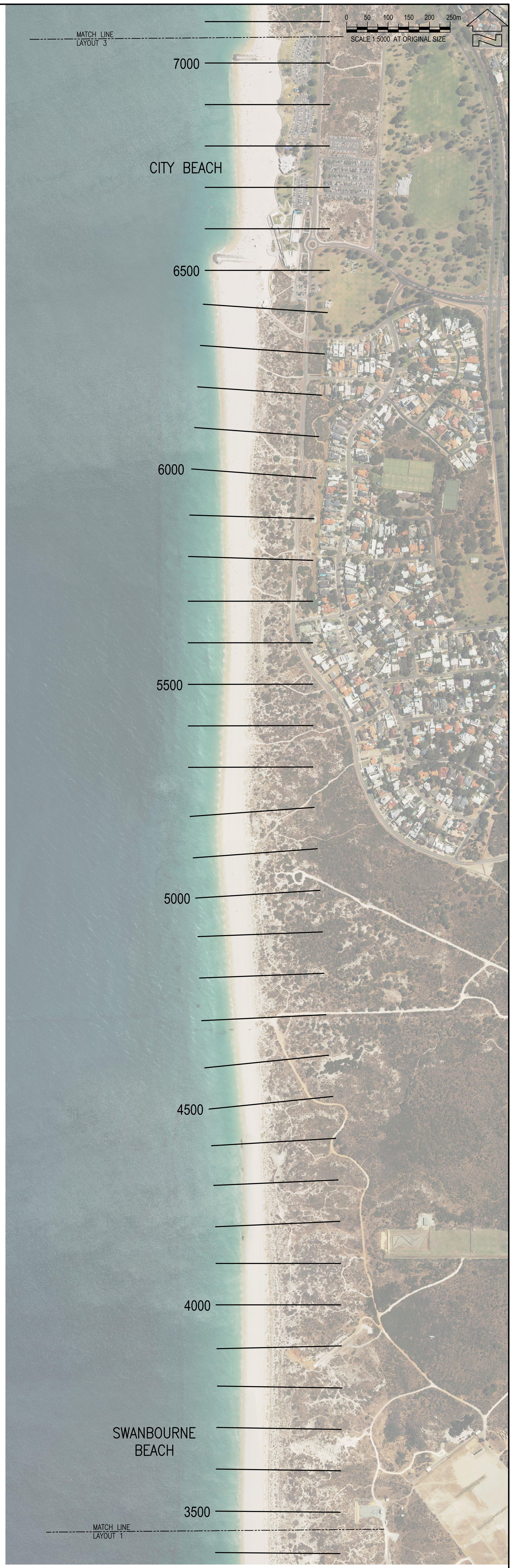


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PROJECT: METTAMS & WATERMANS ADAPTATION OPTIONS ASSESSMENT

TITLE: CHAINAGE PLAN
COTTESLOE TO CITY BEACH

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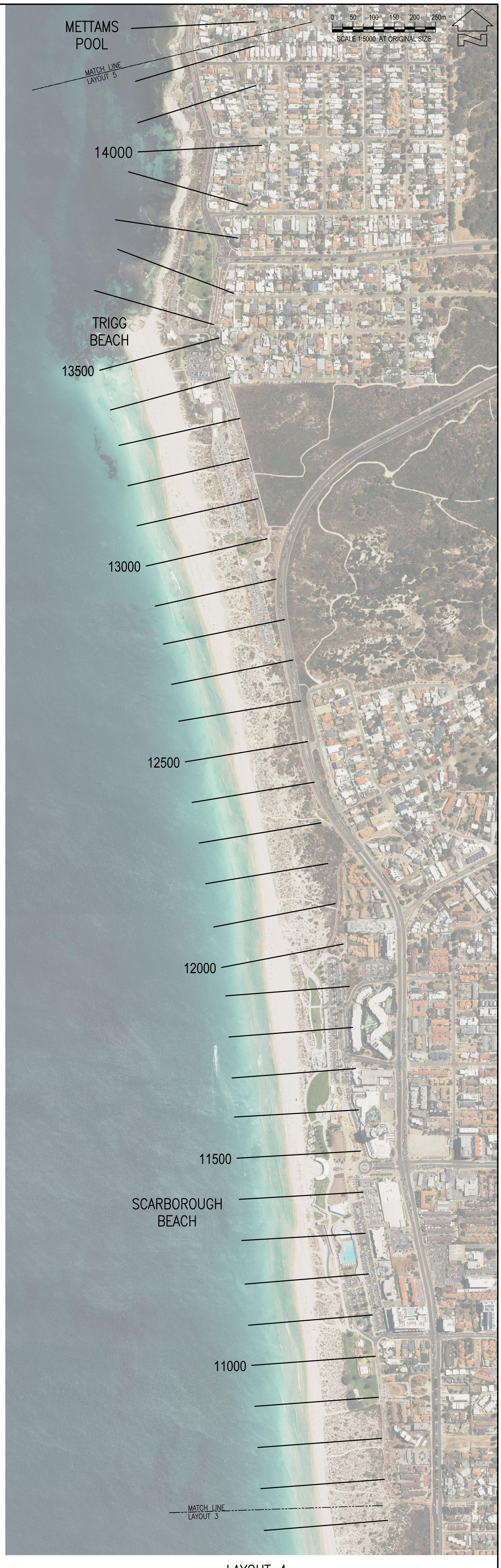


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PROJECT: METTAMS & WATERMANS ADAPTATION OPTIONS ASSESSMENT

TITLE: CHAINAGE PLAN
CITY BEACH TO METTAMS POOL

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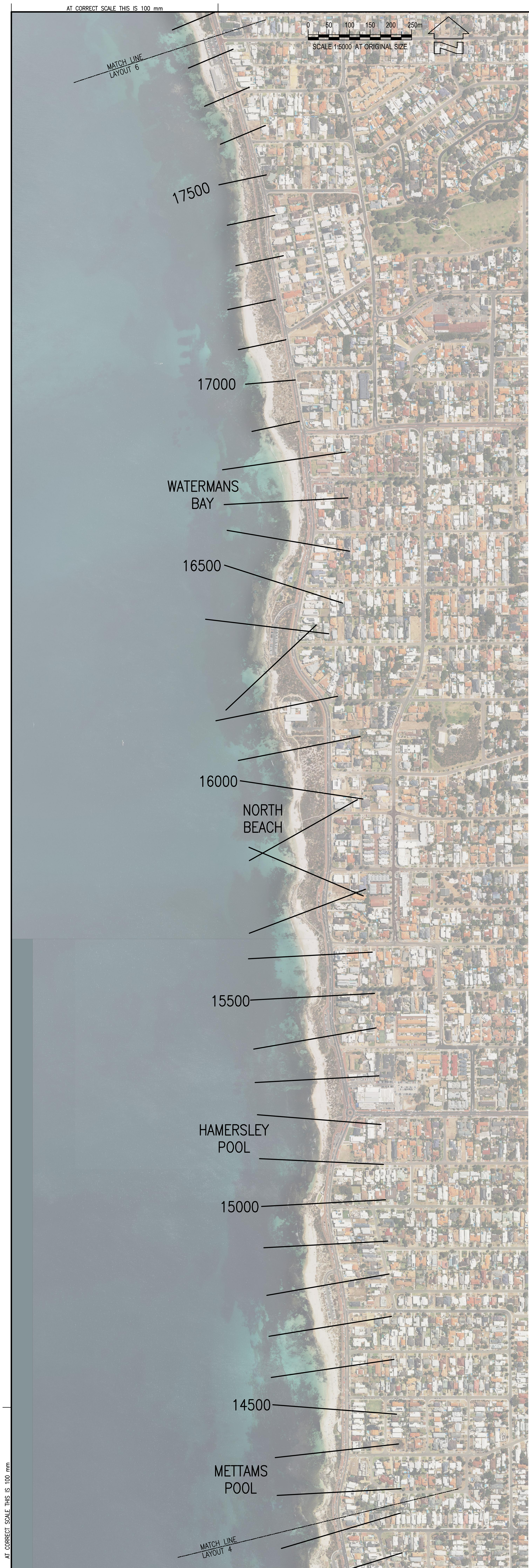


LAYOUT 5
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LAYOUT 6
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| DRAWN: R BORJA | CHECKED: T HUNT | |

PROJECT: METTAMS & WATERMANS ADAPTATION OPTIONS ASSESSMENT

TITLE: CHAINAGE PLAN
METTAMS POOL TO HILLARYS

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# Appendix B Concept Adaptation Options

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## LAYOUT

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## LEGEND:

SUBMERGED REEF

BEACH NOURISHMENT

VEGETATED DUNE

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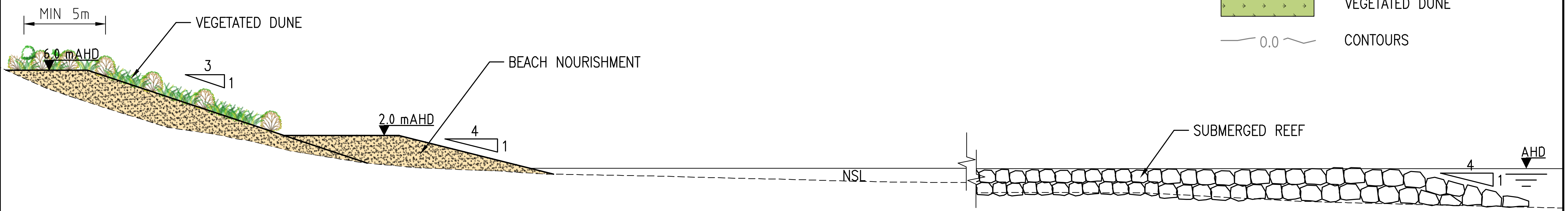


## SECTION A

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| | |
|---|---|
| DRAWN | R BORJA |
| CHECKED | B GARVEY/T HUNT |

OPTION 4B - SUBMERGED REEFS

METTAMS POOL

SCALE AT A3 AS SHOWN

APRIL 2025

SK2107-01-05C

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LAYOUT
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LEGEND:

BEACH NOURISHMENT

VEGETATED DUNE

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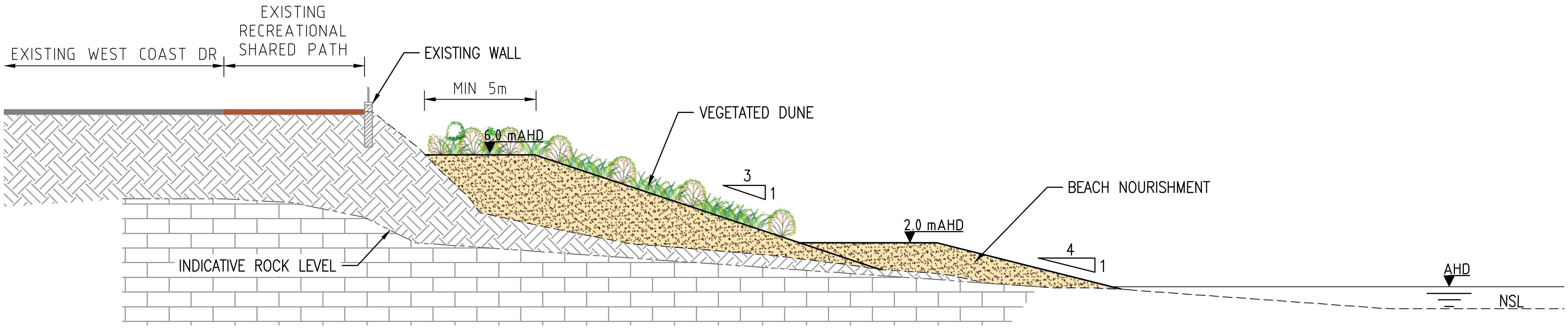


SECTION A
1:200



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| | |
|---|---|
| DRAWN | R BORJA |
| CHECKED | B GARVEY/T HUNT |

**OPTION 1 - BEACH NOURISHMENT**
METTAMS POOL

SCALE AT A3: AS SHOWN

APRIL 2025

SK2107-01-01C

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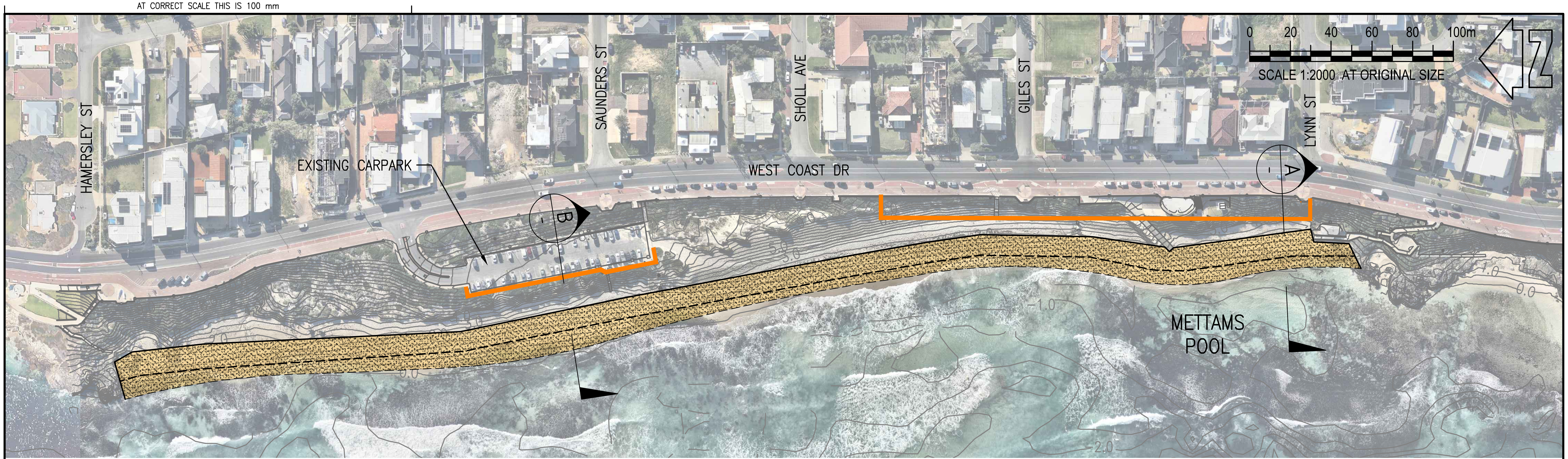


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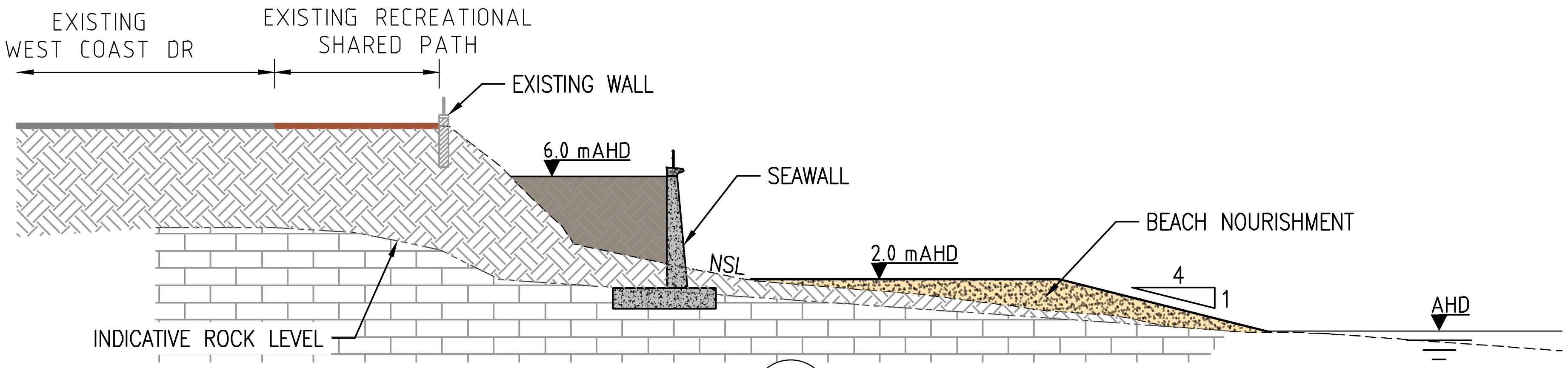
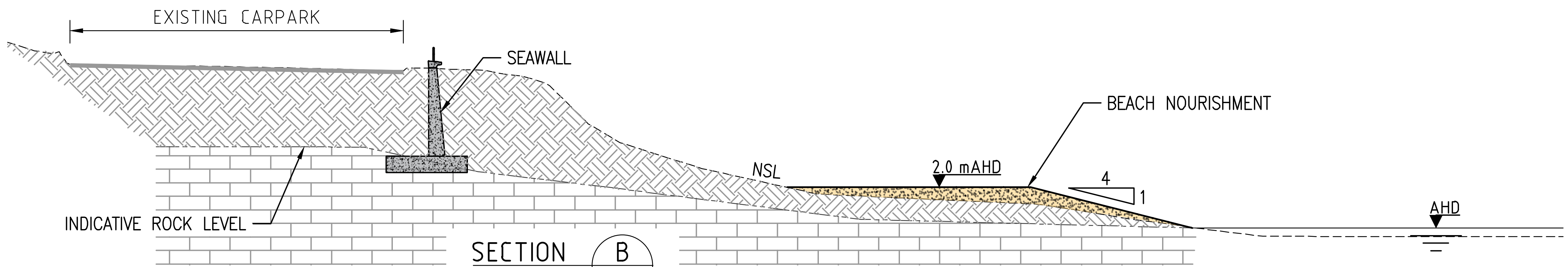



SECTION A
1:250




SECTION B
1:250

## LEGEND:

- SEAWALL
- BEACH NOURISHMENT
- 0.0 CONTOURS



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|---|---|---|---|
| DRAWN | R BORJA | OPTION 2 - SEAWALL | APRIL 2025 |
| CHECKED | B GARVEY/T HUNT | METTAMS POOL — SCALE AT A3: AS SHOWN | SK2107-01-02C |

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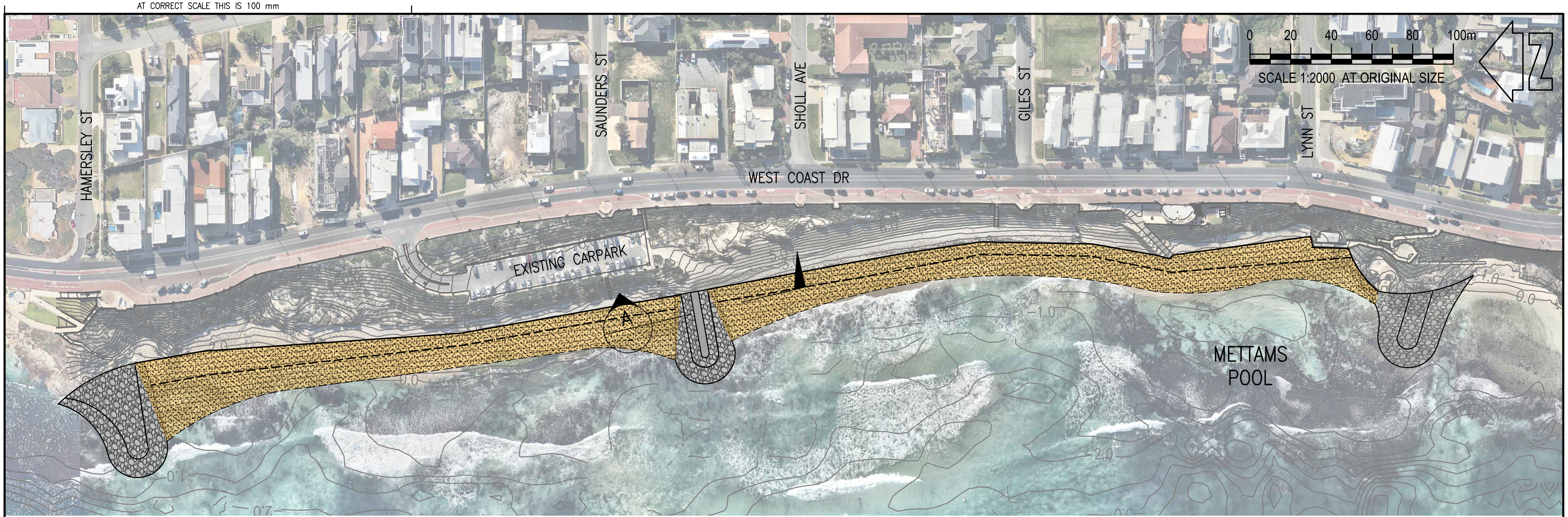
AT CORRECT SCALE THIS IS 100 mm




LAYOUT
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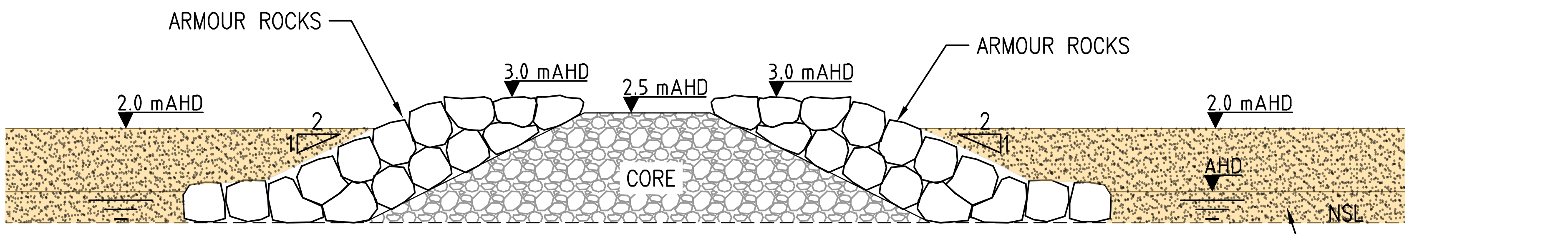
LEGEND:

ROCK GROYNE/HEADLAND ENHANCEMENT

BEACH NOURISHMENT

0.0 CONTOURS




SECTION A
1:200

AT CORRECT SCALE THIS IS 100 mm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DRAWN R BORJA

CHECKED B GARVEY/T HUNT

OPTION 3 - GROYNES/ HEADLAND ENHANCEMENT

METTAMS POOL

SCALE AT A3 AS SHOWN

APRIL 2025

SK2107-01-03C

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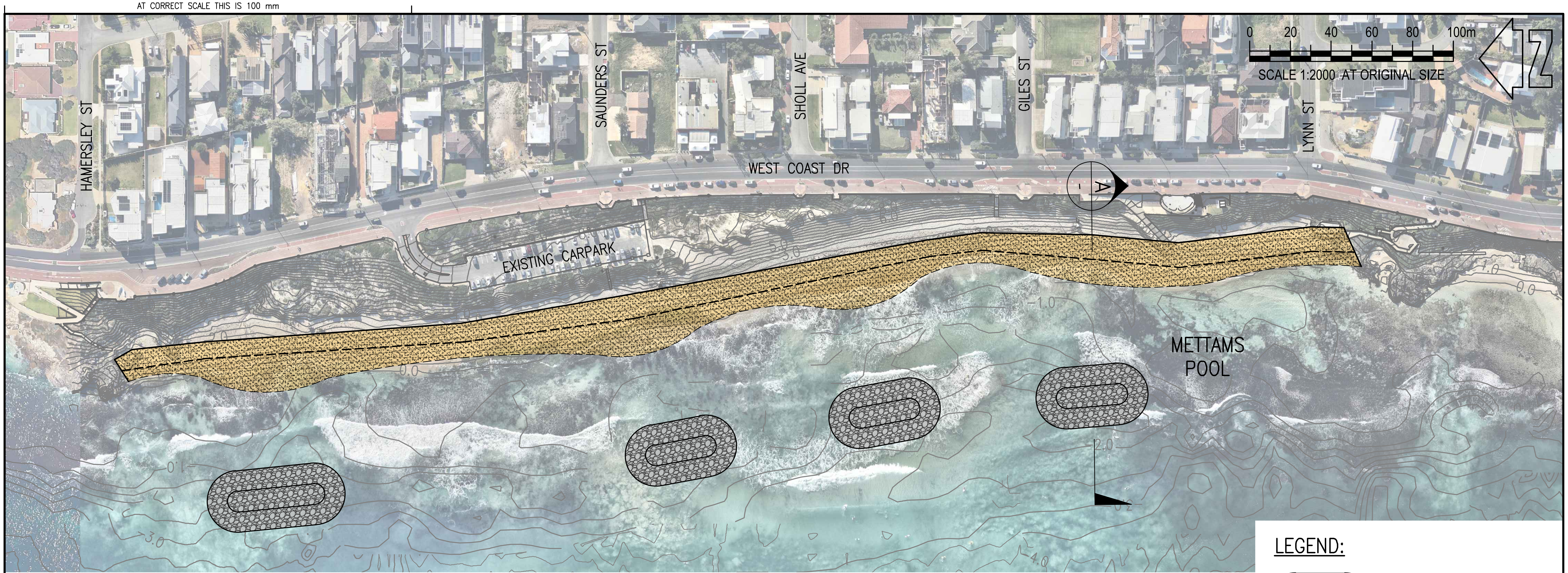
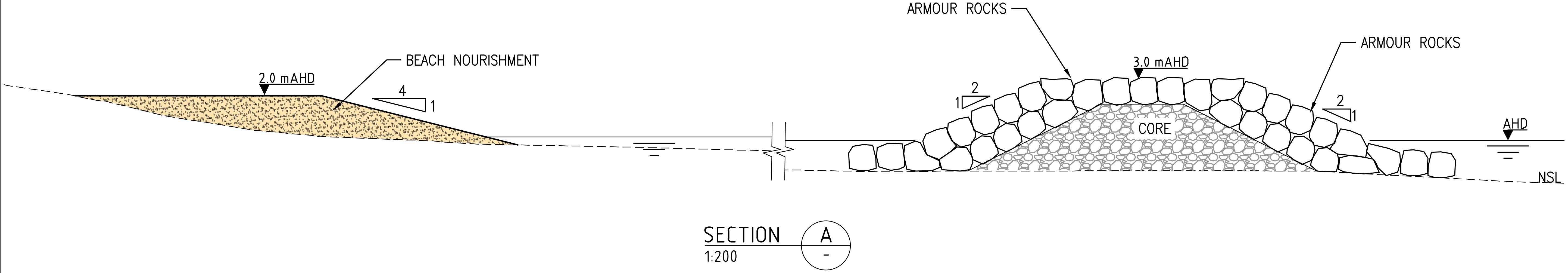



LAYOUT
1:2,000




SECTION A -
1:200

AT CORRECT SCALE THIS IS 100 mm

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|---|---|---|---|
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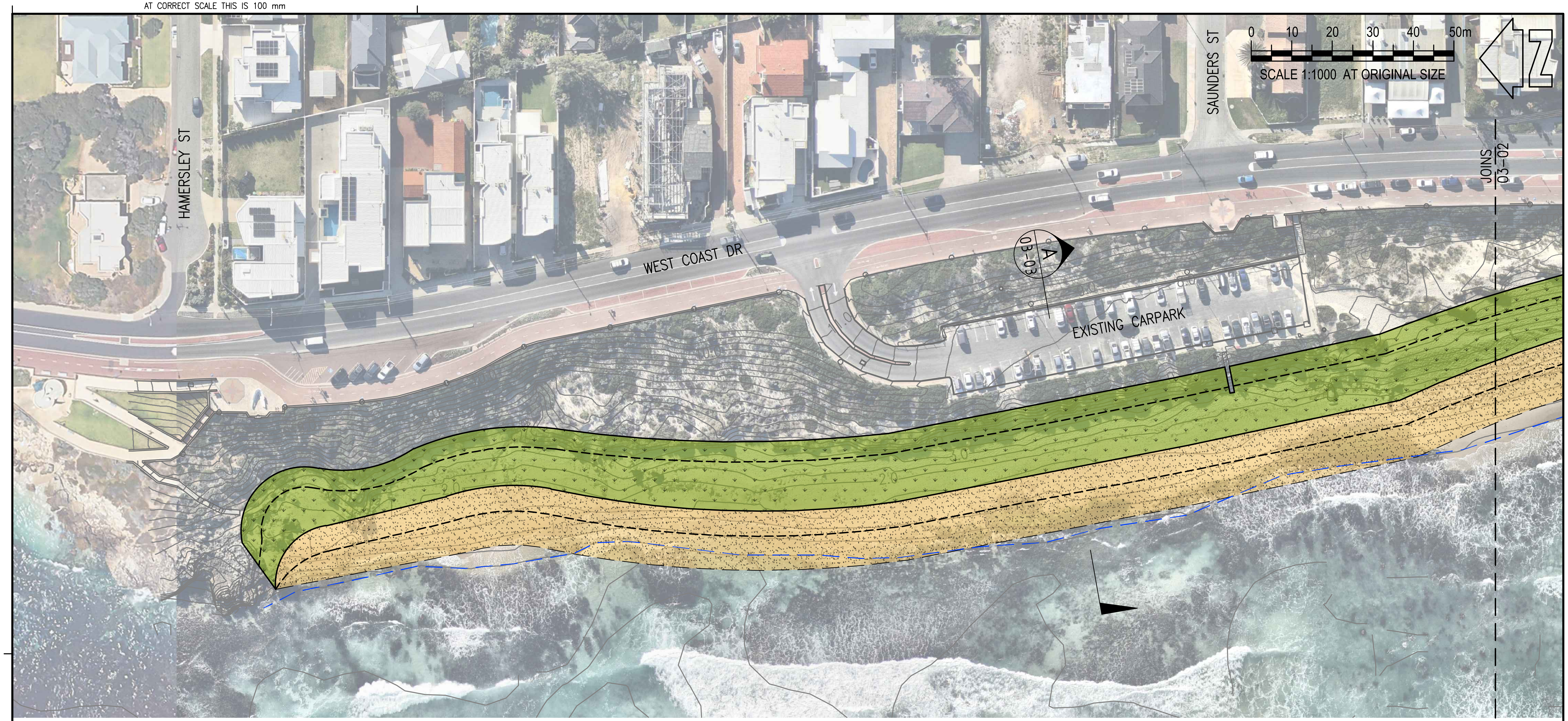
# Appendix C Multi-Criteria Analysis

| | Rating Description | Expected effectiveness of the scheme at achieving the key objectives without ongoing modifications or risks of failure/poor outcomes. | Ease with which option can be modified to account for changes in conditions, etc in the future | Extent of effort and time required to receive approval for option | Extent that the option provides useable beach area and active recreation opportunities | Extent that the option provides opportunities for passive recreation and amenity, such as provision of dual use path, areas to sit and view the water, etc. | Ranking based on provision and likely functionality of access to the beach. | Ranking based on provision and likely functionality of the ablutions, changerooms, shade and shelter. | How well the option protects or provides for preservation of the beach environment, including dunes | How well the option protects or provides for preservation of the marine park environment | Capital cost to construct | Ongoing operating and maintenance costs to maintain over 50 year period |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rating Scale** | **1** | Not expected to be effective | Modification not possible | Extreme effort required - >12 month timeframe for approvals | Significant loss in beach area and active recreation opportunities | Significant loss of amenity and passive recreation opportunities | Access not provided | Ablutions, changerooms, shade and shelter not provided | Significant loss of beach and dune environment | Significant loss of marine park environment | $9.3 million | $16.4 million |
| | **2** | Slightly effective | Only slight modifications possible with large effort | Significant effort required to achieve approvals 6 to 12 month period | Slight decrease in beach area and active recreation opportunities | Slight decrease in amenity and passive recreation opportunities | Access provided but with potential loss of functionality due to change in beach or areas of beach usage | Ablutions, changerooms, shade and shelter provided but with potential loss of functionality due to change in beach or areas of beach usage | Slight loss of beach and dune environment | Slight loss of marine park environment | $7.6 million | $15.4 million |
| | **3** | Effective | Reasonable potential for modification with some effort | Some issues with approvals, but addressed over 3 to 6 month period | No net change in beach area and active recreation opportunities | No net change to amenity and passive recreation opportunities | Access provided within scheme with minimal potential for loss of functionality | Ablutions, changerooms, shade and shelter provided within scheme with minimal potential for loss of functionality | No net change in beach and dune environment | No net change in marine park environment | $5.9 million | $14.4 million |
| | **4** | Very effective | Modifications readily possible with moderate level of effort | Minor issues with approvals, but easily addressed | Slight increase in beach area and active recreation opportunities | Slight increase in amenity and passive recreation opportunities | Access provided with for all most of the time | Ablutions, changerooms, shade and shelter provided with improved functionality | Slight increase in beach and dune environment | Slight increase in marine park environment | $4.1 million | $13.4 million |
| | **5** | Completely effective | Complete modification of option easily achieved | No issues with approvals | Significant increase in beach area and active recreation opportunities | Significant increase in amenity and passive recreation opportunities | Access provided for all at all times | Ablutions, changerooms, shade and shelter ideally situated | Significant increase in beach and dune environment | Significant increase in marine park environment | $2.4 million | $12.4 million |

## Appendix D Developed Beach Nourishment Concept

AT CORRECT SCALE THIS IS 100 mm




LAYOUT 1

1:1,000

LEGEND:

BEACH NOURISHMENT

VEGETATED DUNE

0.0 CONTOURS

WATERLINE

NOTES:

1. SURVEY COMPLETED BY JBA SURVEYS IN MARCH 2024. THE LEVELS AND CONTOURS REFLECT THE SURFACE AT THE TIME OF SURVEY ONLY.

AT CORRECT SCALE THIS IS 100 mm

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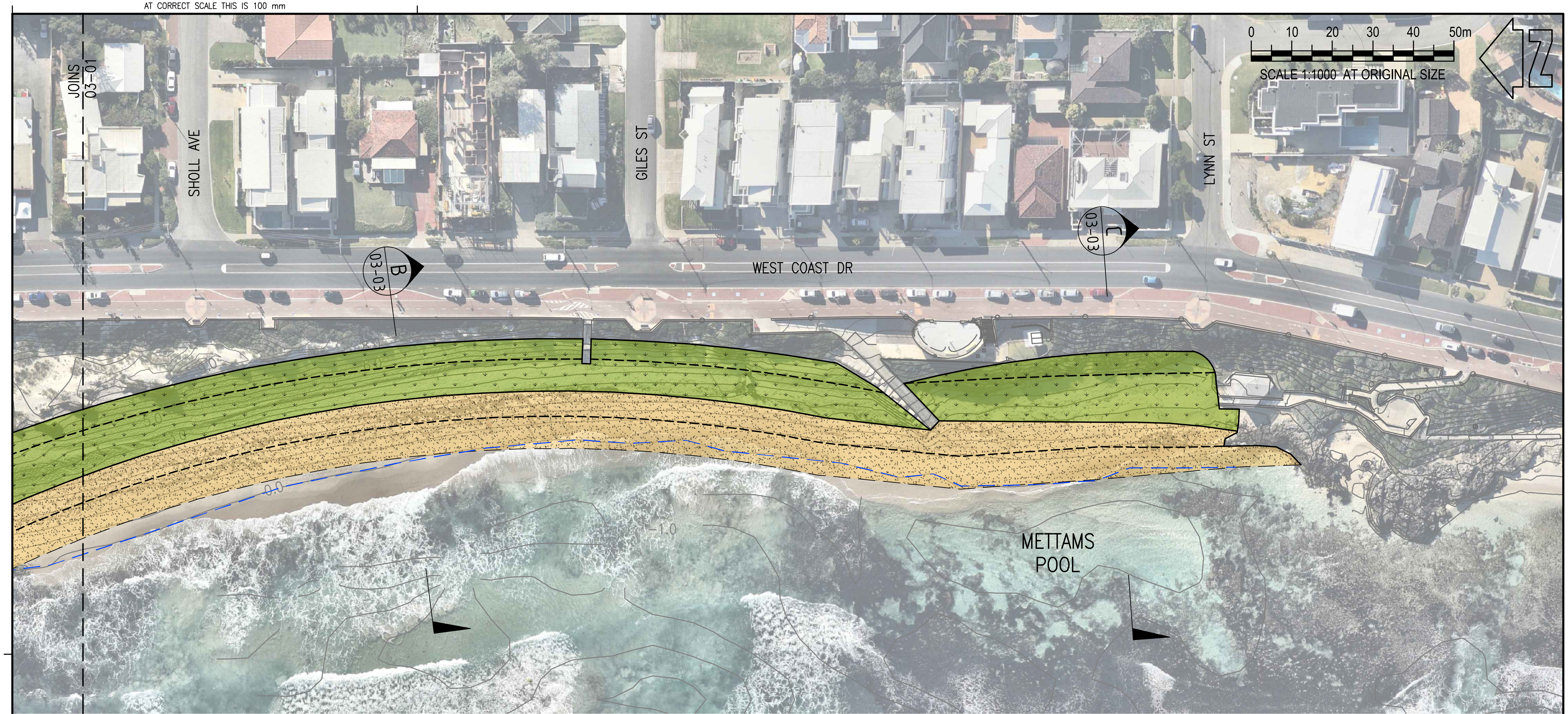


LAYOUT 2

1:1,000

LEGEND:

BEACH NOURISHMENT

VEGETATED DUNE

0.0 CONTOURS

WATERLINE

NOTES:

1. SURVEY COMPLETED BY JBA SURVEYS IN MARCH 2024. THE LEVELS AND CONTOURS REFLECT THE SURFACE AT THE TIME OF SURVEY ONLY.

AT CORRECT SCALE THIS IS 100 mm


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|---|---|
| DRAWN | R BORJA |
| CHECKED | B GARVEY/T HUNT |

BEACH NOURISHMENT CONCEPT - SHEET 2 OF 2

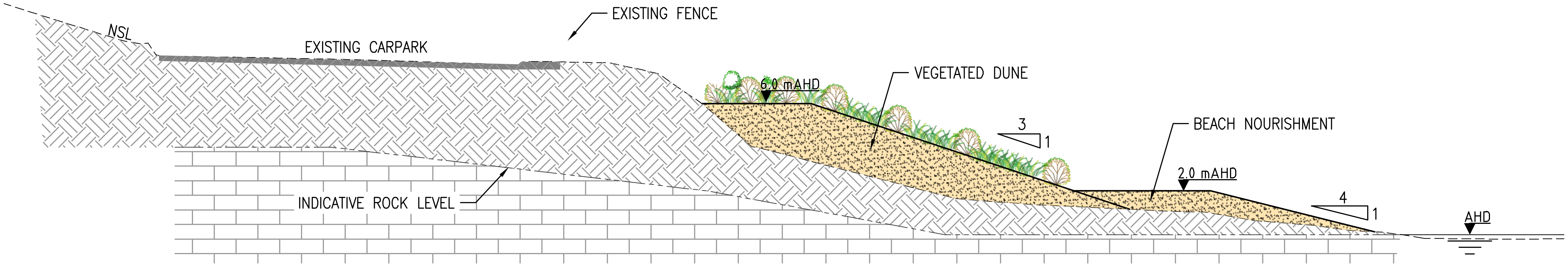
METTAMS POOL

SCALE AT A3 1:1,000

APRIL 2025

SK2107-03-02B

AT CORRECT SCALE THIS IS 100 mm

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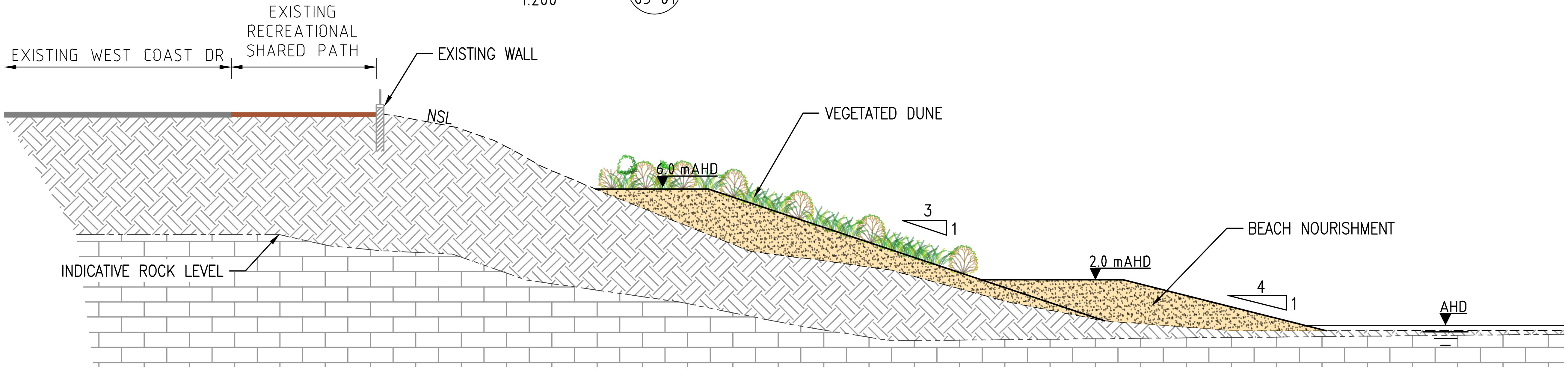


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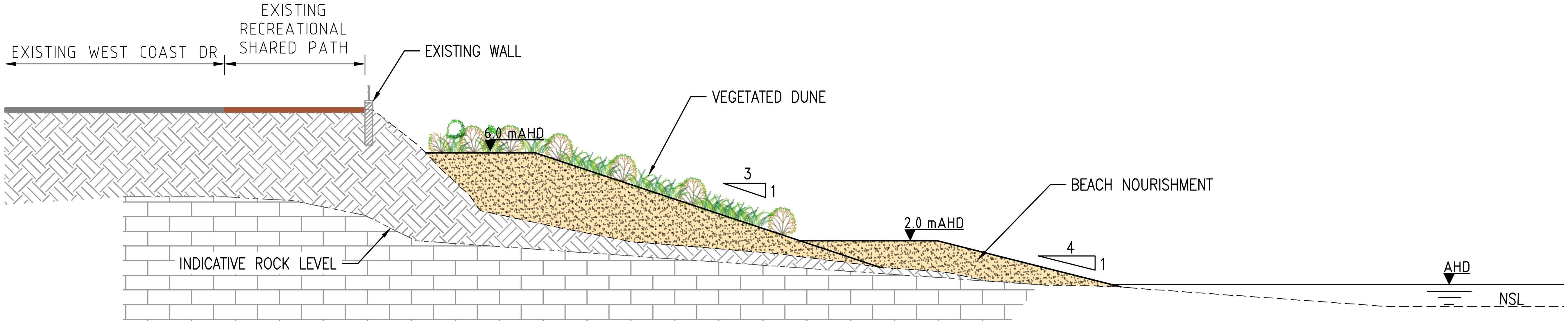


SECTION C
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03-02

AT CORRECT SCALE THIS IS 100 mm


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|---|---|
| DRAWN | R BORJA |
| CHECKED | B GARVEY/T HUNT |

# BEACH NOURISHMENT SECTIONS

METTAMS POOL

SCALE AT A3: AS SHOWN

APRIL 2025

SK2107-03-03B

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