Adelaide Beach Management Review Independent Advisory Panel

Adelaide Beach Management

Scientific review

14 December 2023

Report No: P22272_AdelBeachManagReview_R3.00

Executive summary

This report provides a desktop review of the management of Adelaide’s beaches. It examines available coastal management along Adelaide’s metropolitan beach system the assessment of which was informed by:

- a comprehensive literature review
- analysis of datasets relevant to the understanding of coastal processes and the local environmental setting
- the development of a contemporary coastal sand budget
- a constraints and opportunity analysis of factors that could influence future management.

Coastal management options were developed for the northern Metropolitan beaches from West Beach to North Haven. At West Beach coastal erosion has recently proceeded beyond an acceptable natural sandy buffer (i.e., the buffer does not provide an acceptable level of coastal protection or beach amenity). The main causal mechanism of the long-term erosion observed at West Beach are explained by:

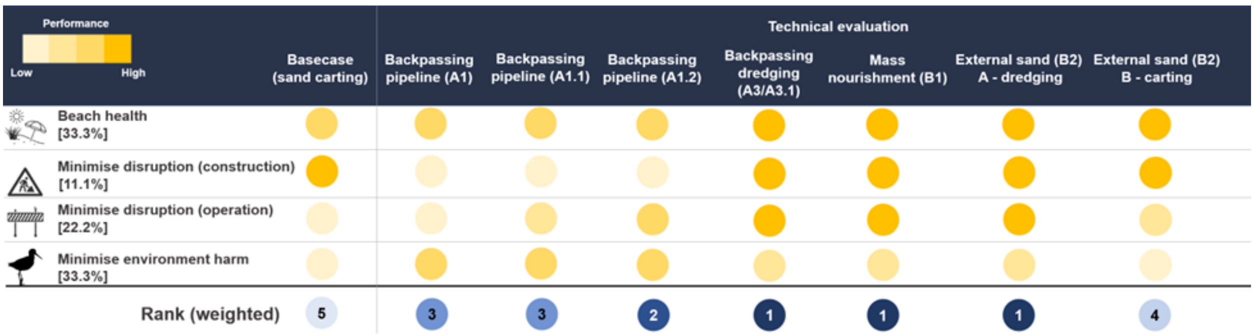
1. the blockage of natural sand supply from the south due to the impact of the Holdfast Shores, West Beach Harbour and the backpassing of sand from Glenelg, and
2. the natural net northward movement of sand that, under the action of waves, acts to move sand out of West Beach towards Largs Bay.

The option development and assessment approach adopted for this review commenced with the identification of a longlist of 24 options that aimed to address the causal mechanisms affecting the northern management area. The selection of a shortlist of four main options with two additional sub-options were justified by the application of a coarse filter approach using three criteria. Shortlisted options all consisted of sand management using various transfer methods (dredging, pipelines or carting).

The shortlisted options were further developed to enable a conceptual description and comparative life-cycle cost estimates over a 20-year period. The shortlisted options were technically evaluated with performance criteria aligned to the three goals of the Adelaide beach management review:

1. maximise the amount of sand on beaches
2. minimise disruption for all communities
3. avoid environmental harm.

The results are summarised in the below table. Life-cycle cost estimate highlighted significant differences between the options. Options that rely primarily on a backpassing pipelines to transfer sand are around $60-70M more than options that primarily rely on dredging to transfer sand. Likewise, options that involve large quantities of sand carting from quarries are expensive.



The result of the scientific review is that options involving beach nourishment using dredging equipment have merit. This is because they transfer sand to where it is needed more efficiently and more economically. This approach is expected to result in significantly less community disruption and be more flexible and adaptive (including to a changing climate). However, there are remaining uncertainties regarding sand sources and environmental planning approvals for these dredging options.

A roadmap forward over the next 12 to 24-months is provided based on a **'no regrets'** approach. The roadmap is focused on the next steps required to understand the quantity and quality of potential sand sources, including their environmental constraints.

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 About this report

This report provides a desktop review of the management of Adelaide's beaches. Informed by the development of a contemporary coastal sand budget, it provides a comprehensive review of available coastal management options for the Adelaide's metropolitan beach system. By doing so, the review aims to equip decision-makers with the technical and scientific information required to select sustainable and effective beach management practices.

The scope of the Adelaide Beach Management Review was to consider:

- How to manage sand on Adelaide's beaches to achieve the following goals:
    i. minimise disruption for all communities
    ii. avoid environmental harm and
    iii. maximise sand staying on beaches.
- A scientific and data-driven review of coastal processes, including a contemporary coastal sand budget of Adelaide's metropolitan beaches and the implications of climate change.
- The Adelaide community's views on sand management options and on the impact of the current sand management approaches including trucking and pipelines.
- Lessons from international examples of sand management on metropolitan beaches.

1.2 Review background

Adelaide's metropolitan beach system spans 28 kilometres from Kingston Park in the south to Outer Harbor in the north. The movement of sand along the coast is primarily influenced by the combined forces of waves and wind, resulting in a northward drift of sand along the coast. This has resulted in the gradual erosion of the southern beaches, with significant accretion of sand in the north.

To address these challenges, the State Government, through the Department for Environment and Water (DEW) and the Coast Protection Board (CPB), has actively collaborated with local councils to manage Adelaide's metropolitan beach system since 1972. The primary objective has been to safeguard the foreshore and coastal development from storms while ensuring that the community can continue to enjoy sandy beaches.

In 2000, DEW, on behalf of the Coast Protection Board, initiated a review of the management of Adelaide's metropolitan beaches. Based on examination of the benefits and costs of a range of strategies, along with the results of a series of modelling and feasibility studies and input from the community, DEW developed *Adelaide's Living Beaches: A Strategy for 2005–2025* (herein referred to as the ALB report). The ALB strategy a fixed sand backpassing pipeline to transport sand from Semaphore to Kingston Park was planned. When tender submissions coming back over budget, the scope was reduced to a pipeline from Glenelg to Kingston Park and a pipeline from Torrens Outlet to West Beach, with the transport of sand by truck to continue from Semaphore to West Beach (Department for Environment & Water, 2021). The Glenelg to Kingston Park and Torrens Outlet to West Beach backpassing pipelines were constructed, with the Glenelg to Kingston Park system operating to backpass up to 100,000m^3/yr of sand since commissioning in 2013. An offshore breakwater at Semaphore South was also built to manage erosion at Semaphore Park and trap sand for recycling back to eroding southern beaches.

In 2019, the South Australian Government committed $48.4 million to the *Securing the future of our coastline* project to 1) construct a sand recycling pipeline from Semaphore to West Beach to backpass sand (i.e. transfer it in opposite direction to the natural alongshore direction of movement), 2) deliver a large quantity of sand (500,000m^3) to West Beach from outside of Adelaide's beach system; and 3) restore sand dunes using best practice techniques and native plants in partnership with local councils and coastal community groups.

The proposed extension of the pipeline from West Beach to Semaphore has been put on hold, pending the outcomes of the Adelaide beach management review.

1.3 Study area

A map of the review's study area is shown in Figure 1. The area is bound by Kingston Park in the south and the Outer Harbour training walls in the north. It is one long sandy beach system that has a few obstacles (or shoreline controls), such as the boat harbours at Glenelg and West Beach, to the net northerly movement of sand. This study examines the behaviour of the beach system at a regional level, as well as smaller local processes and issues that exist particularly around the control structures shown in Figure 1. DEW are responsible for the management of the metropolitan beaches in this region, which spans over four Local Government Areas (LGAs).

1.4 Community engagement

Adelaide's metropolitan coastline is a valued environmental and recreational asset. The management of sand on Adelaide's metropolitan beaches is a highly challenging and topical issue that has generated strong and emotionally charged responses from community and stakeholders.

This independent scientific review has been supported by community engagement undertaken by URPS (URPS, 2023a). Across two main stages, the URP- led community engagement has gathered an understanding of the outcomes and values that are important in relation to sand management (URPS, 2023b), as well as the level of support of community and stakeholders for different options and the reasons behind supporting an option or not (URPS, 2023c).

The information gathered by the community and stakeholder engagement process has supported the identification and assessment of the sand management options put forward for Adelaide's metropolitan beaches.

1.5 Objectives of the review

The objective of this review is to identify and assess options to manage sand on Adelaide's metropolitan beaches in a way that maximises sand staying on beaches, minimises disruption for all communities, and avoids environmental harm.

1.6 Scope and structure of this report

The findings of the scientific review are set out in this report as follows:

- Section 2 provides background information including an introduction to coastal processes, a history of relevant changes to Adelaide's beaches and a summary of the data used in the review.
- Section 3 contains a summary of coastal processes that are most relevant to beach management.
- Section 4 sets out the results of a contemporary sand budget analysis developed to inform the review.

Figure 1: Map of the review study area.

- Section 5 maps constraints and opportunities to inform the identification of a longlist of potential management options. A filtering process is then used to reduce the longlist to a shortlist of options to carry forward.
- Section 6 presents the shortlist of management options including concept layouts and descriptions as well as a comparative assessment of the shortlisted options.
- Section 7 contains recommendations along with a roadmap based on the findings of this report.

2. Background information

2.1 Introduction to coastal processes and coastal hazards

Coastal processes and the evolving and dynamic nature of the shoreline can give rise to a range of risks to the physical landscape and to the social and economic values of coastal communities. Coastal hazards are the physical phenomena stemming from coastal processes that expose a coastal area to such risks. They can generally be classified into erosion-type hazards and inundation-type hazards. Identifying and estimating coastal hazards require a clear understanding of the underlying coastal processes that act singularly or in combination and their evolution in time.

2.1.1 Coastal processes

Movement of water and sediments within and around the coastal profile occurs in three main areas, the shoreline and beach above the mean sea level (MSL) mark (i.e., subaerial beach), in the intertidal swash zone, and in the deeper surfzone and nearshore waters. Sand movements within these areas are governed by several processes that vary on a range of spatial and temporal scales including but not limited to:

- **Regional geology** - influences the structure and orientation of the beach system as well as the sediment available.
- **Local geomorphology** - the coastal topography influences the magnitudes and directions of currents generated in the nearshore zone and the shape of the active beach face.
- **Waves** - in the coastal zone are generated predominately from two primary sources, offshore (swell) and locally generated wind-waves (sea). Within the nearshore zone, waves impact sand transport through three key processes: wave breaking, wave motion and undertow.
    - Infragravity waves have longer periods of 25 to 250 seconds and are formed due to the superposition of two different short-wave trains of similar lengths and frequencies. The waves are often reflected off the coast and the presence of a sandbar may trap infragravity waves between the bar and the beach. Wave breaking and infragravity waves which can dominate the wave motions at the coastline, particularly during storm events, result in radiation stresses and drive cross-shore and longshore currents and are the main driver of sand transport.
    - In addition, wave orbital motions drive mass onshore movement of sediments from differences in shear stress on the seabed leading to onshore sand transport and beach accretion. Undertow can result in transport of sediments offshore due to bottom return currents and rip currents in the surf zone leading to offshore sand transport and beach erosion.

- Variability in the wave climate occurs over both seasonal, interannual and decadal time scales, impacting sand movements over longer time scales. The impact of waves on a given coastline depends on its local setting, including the exposure and local bathymetry, with significantly greater sand transport occurring in the surf zone during high wave events.

- **Tides and water levels** - astronomical tide range is subject to spatial variability due to hydrodynamic, hydrographic and topographic influences. Background sea level can also be affected by other phenomenon such as seasonal fluctuations related to El Niño/La Niña cycles, relative position of ocean currents and eddies to the shoreline, coastally trapped waves and persistent monsoon winds. At many locations sea level rise due to climate change is predicted to result in recession of the shoreline as the beach profile moves landward as well as inundation of low-lying areas.
- **Wind** - wind driven (aeolian) sediment transport occurs over unconsolidated sands above the water level, with the quantity of sand transported increasing with the cube of the wind velocity. Aeolian sand transport can be significant for the overall sand budget at some locations, although is often orders of magnitude lower compared to sand transport below water.
- **Storm surges** - occur mainly due to wind set-up during strong onshore winds pushing surface waters against the coastline. This leads to temporary elevated water levels along the coast above astronomical tides during storm conditions. The rate at which the wind increases in speed also affects water level elevation, with rapid wind speed acceleration leading to larger maximum water levels at the shoreline.
- **Nearshore currents** - generated from differences in waves, tides, water levels and winds and the interactions between the processes and geomorphological landforms.
- **Coastal entrances and river outlets** - river entrances are dominated by the daily ebb and flood tides, while complex interactions between tides, waves, fluvial outflows and modifications to entrance bathymetry can generate complex secondary currents around river and harbour entrances.

The natural coastal processes influencing the supply and movement of sand through the coastal zone is mainly from the combined action of waves, currents and winds as described above. Transportation in the nearshore zone is comprised of alongshore and nearshore transport which act concurrently and interact together:

- **Longshore sand transport** (also known as littoral drift) occurs across the surf zone due to waves approaching the beach from an oblique angle which generates radiation stresses, driving currents along the shore. The direction of sediment transport along the coast is dependent on the prevailing wave direction (i.e., transport north could occur during a south-easterly wave direction). Longshore sediment transport occurs inshore of the surf zone particularly inshore of the wave breaking zone, reducing in strength with distance shoreward and offshore due to a typical increase in depth and therefore reduction in wave breaking.
- **Cross shore sand transport** occurs across the surf zone-nearshore beach profile. Typically, sand is transported onshore during normal swell conditions generating beach accretion and offshore during large storm/swell wave events that cause beach erosion. As waves move into shallow water the waves shoal and the wave orbital velocity becomes asymmetrical, resulting in a net sand transport onshore (the direction of wave propagation). Breaking waves induce sediment transport onshore. Undertow and rip currents within the breaker zone induce mass transport of sediments offshore generated from an offshore directed return flow (from breaking waves) and a longshore variation in wave setup, respectively.

- **Net sediment transport** describes the sum of the transport rates in all positive and negative directions, whereas the gross sediment transport rate describes the total transport disregarding the direction. These processes determine and are in turn influenced by the shape of the shoreline, the alignment of the shoreline and the bathymetry. As wave energy is a function of the square of wave height the amount of sand transported increases exponentially with increasing wave height.

2.1.2 Coastal hazards

Coastal processes have shaped the coastline over thousands of years and will continue to do so. The coast is subject to hazards from waves and rising sea levels that affect recreational use and development along the coastline. These include:

- **Beach erosion**: Beach erosion is the loss of beach and dune material because of changing wave and water level conditions. Beach erosion is commonly caused by increased wave height and energy, higher than usual tides, a storm surge (or elevated water levels as a result of barometric pressure and wind), or a combination of all three. Sometimes these factors do not need to be particularly intense to cause beach erosion which can occur over a period of days, weeks, or months.
- **Shoreline recession:** Shoreline recession refers to a net landward movement of the shoreline over a specified time. Recession is a natural process which occurs whenever the transport of material away from the shoreline is not balanced by new material being deposited onto the shoreline. Shoreline recession can be in response to or increase due to rising sea levels.
- **Coastal inundation:** Coastal inundation occurs when a combination of marine and atmospheric processes raises ocean water levels above normal elevations and inundate low-lying areas or overtop dunes, structures, and barriers. It is often associated with coastal storms resulting in elevated water levels (storm surge) and waves.

2.2 History of Adelaide's beaches

Adelaide's coastline has a long history of human intervention affecting both the shape and health of the beaches. The most significant interventions or events affecting the current management of the beaches are given in the list below with a comprehensive timeline provided in Figure 2 to Figure 4.

- In the late 19th and early 20th century a number of timber jetties were constructed along the coastline for the purposes of amenity, tourism and industry. Around this time, seawalls were also built in these areas.
- In 1937 the Torrens River was redirected to empty into Gulf St Vincent which, while not the intention, caused a hydraulic groyne resulting in sand buildup at the new outlet (DEH, 2005).
- The 1940's to 1970's saw increased development along the coast. Sand from the dunes was used as fill in low-lying regions and for housing development in other areas (DEH, 2005). This effectively removed sand from the beach system reducing the quantity available as a sandy buffer protecting development and providing amenity.
- Several large storms in 1946, 1948 and 1953 caused significant beach erosion threatening coastal properties. This was particularly prevalent in areas with waterfront properties that had previously erected vertical seawalls. Following these storms, a new approach was taken to coastal protection structures with the introduction of sloping rock revetments instead of the vertical concrete or timber seawalls of the past. Existing seawalls were also upgraded.

- Published in 1970, the Culver Report (Culver, 1970) recognised that there was no natural replenishment source of sand to replace that lost from Adelaide beaches due to northerly littoral drift. With properties at risk and beach amenity lost, the report concluded that urgent action was needed to artificially maintain the beach system.
- The Culver Report led to the formation of the Coast Protection Board (CPB) which was legislated under the *Coast Protection Act 1972*. The CPB implemented a range of measures to manage the coast, including beach nourishment, dune restoration, and the construction of groynes to prevent erosion. Since the establishment of the CPB, there has been extensive coastal monitoring to track beach volumes as part of the ongoing sand management strategy.
- The building of the harbours at Glenelg (1964, extended in 1997) and West Beach (1998) caused ongoing downdrift erosion issues to the north of both harbours. Prior to 2005, both sand bypassing (to maintain littoral drift) and maintenance dredging (to maintain channel navigation) were required at these facilities.
- Since 2005, and following several technical reports and reviews in the late 1990s and early 2000s, the Adelaide's Living Beaches (ALB) strategy (DEH, 2005) has been implemented to manage Adelaide's metropolitan beaches.
- When the 2005 ALB Strategy was introduced, sand bypassing of the harbours was abandoned (DEH, 2005). Instead, sand that built up at Glenelg was removed by excavators and carted by trucks 7 to 8km south on public roads to beaches at Brighton and Seacliff. Maintenance dredging to maintain a navigable channel was continued at both harbours, with the spoil disposed of just north of each structure.
- In 2013, a backpassing pipeline was commissioned between Glenelg and Kingston Park to replace the need for trucks in transporting and placing sand in the southern beaches. This has continued to operate to present. A backpassing pipeline was also built between Torrens Outlet and West Beach, it however only operated until 2016 due to 'technical sand management issues' (DEW, 2023).
- In 2016, large storms resulted in extensive erosion at West Beach prompting calls for renewed management plans for the beaches north of Glenelg.
- In 2018, DHI completed a report on coastal processes focussing on West Beach (DHI, 2018), the outcome of which was that the northerly littoral transport rate was significantly higher than previously reported and highly variable year to year. Recommendations for a sustainable solution included mass nourishment and increased annual backpassing from the northern beaches to West Beach.
- An extension of the existing Torrens Outlet to West Beach backpassing pipeline to Semaphore was approved in 2022, then put on hold pending the findings of this review.

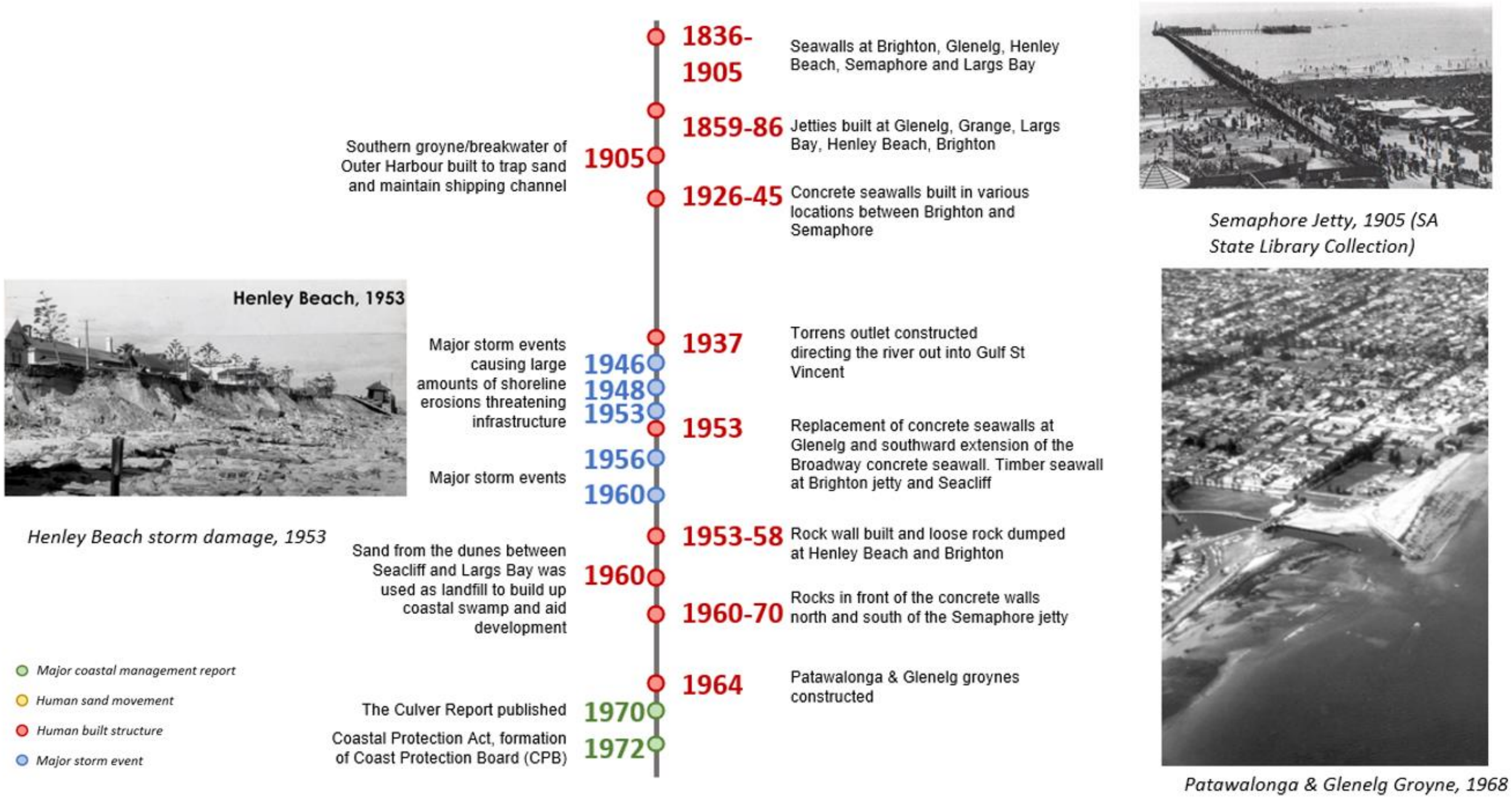


Figure 2: Timeline of major events relating to the management of Adelaide's beaches (Part 1: 1836 to 1972).

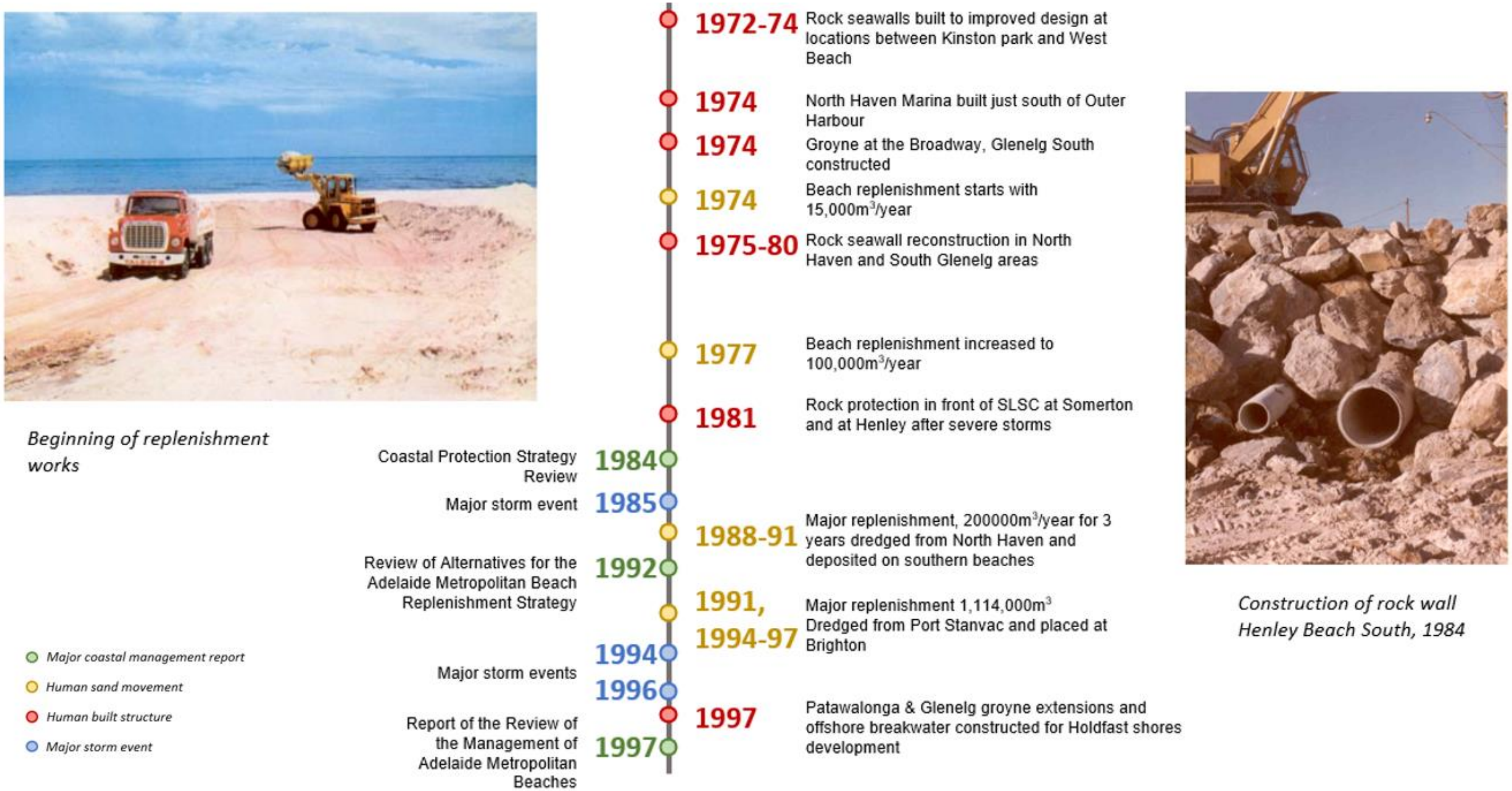


Figure 3: Timeline of major events relating to the management of Adelaide's beaches (Part 2: 1972 to 1997).

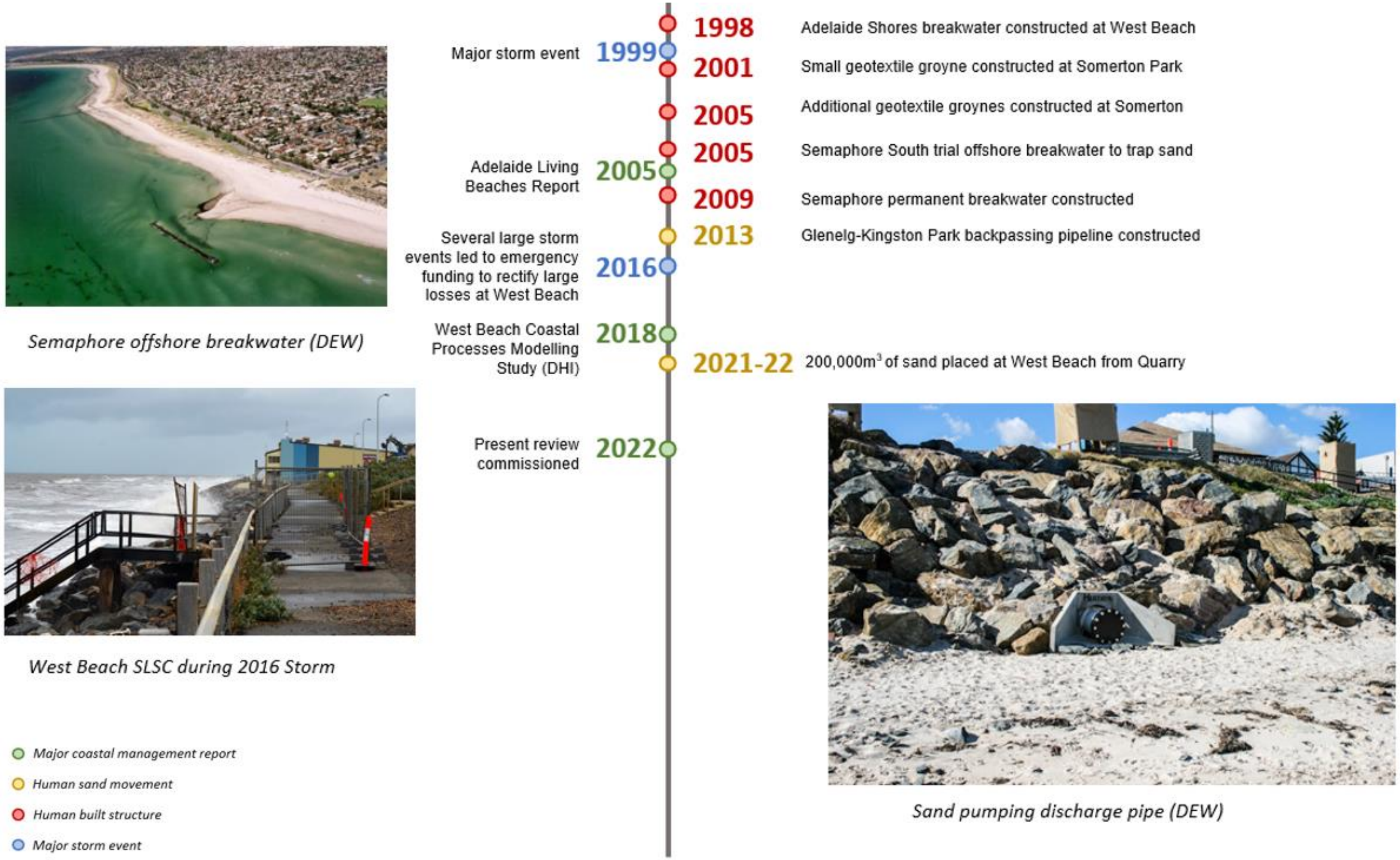


Figure 4: Timeline of major events relating to the management of Adelaide's beaches (part 3: 1998 to present).

2.3 Literature review

A review of previous studies and reports related to the management of Adelaide's beaches was used to inform this review. Previous studies and reports were requested and supplied by DEW, obtained from internet searches, from journals or conference proceedings or other sources. Over 180 documents were reviewed, either partially or in their entirety. The integration of these previous studies ensures that the present review builds on the experiences of the past management, including what has worked and what has not. A proportion of the reviewed studies are included in the reference list (see Section 8), being the studies that required referencing herein.

This includes the following significant reports and studies have guided the protection strategies employed on the Adelaide coast since the 1970s:

- *The Culver Report* (Culver, 1970)
- *Adelaide Coastal Protection Strategy Review* (CMB, 1984)
- *Metropolitan Coast Protection Strategy Review* (CPB, 1985)
- *Review of Alternatives for the Adelaide Metropolitan Beach Replenishment Strategy* (CMB, 1992)
- *Report of the Review of the Management of Adelaide Metropolitan Beaches* (DENR, 1997)
- *Adelaide's Living Beaches: A Strategy for 2005 – 2025* (DEH, 2005)
- *West Beach Coastal Processes Modelling Study* (DHI, 2018)

In addition, the literature is referred to throughout the report wherever relevant to do so.

2.4 Coastal management strategy

2.4.1 Summary of sand management on Adelaide's beaches

Since 1972 and the establishment of the CPB, sand management has been a key strategy for Adelaide's beaches. In the years from 1973, there has been a focus on the transfer of sand around and onto the beaches to replenish what has already been moved by alongshore transport of sand. The anthropogenic movement of sand can be classed as either:

- Internal: where removal and placement of sand is from within the beach system, or
- External: where sand is either imported from a source or exported to a sink outside the beach system.

Historically sand management on Adelaide's beaches has been conducted using the following methods:

- Sand carting: involves sand collection from within the beach system then loading onto trucks to be carted to the target placement beach where the sand is unloaded and spread. Carting is also used to import sand from external quarry sources. When internal (beach) sources are used a 'sand plane' is used to take a layer from the top of the source beach then load it into the trucks for transportation using an excavator or wheel loader.
- Dredging: involves collecting sand from the seafloor of a specified 'borrow area' and placing it in a target location (can be onshore or nearshore). The source material can be internal (e.g., bypassing of Glenelg/West Beach harbours) or external (e.g., mass nourishment from Port Stanvac).
- Pumping: in the Adelaide beaches context, this has involved the collection of sand from the subaerial (or dry) beach for transfer through a sand slurry pipeline and discharge at the placement beach. A backpassing pipeline was commissioned in 2013 between Glenelg and Kingston Park.

Sand is harvested from a thin layer over a wide area of beach using a 'sand plane' (similar to a land plane and pulled by a tractor). The tractor with sand plane deposits the sand nearby an excavator that stockpiles and loads the sand onto a conveyor belt. The conveyor belt feeds a trommel that is used to screen the material of cobbles, seagrass wrack and rubbish. Ocean water is fed into the system, which is used to slurry the sand for pumping through the pipeline before it is discharged at the back of the target placement beach.

When considering the internal sand management only, carting has been adopted as the primary method of transporting sand in the past. However, since the backpassing pipelines were commissioned in 2013, these have been used in favour of trucks where available, see Table 1.

Table 1: Internal sand transfer volumes by method (not including dredging).

Method of sand transport	Volume transferred (m^3)		
	Pre-southern backpassing pipeline (1973 to 2012)	Post-southern backpassing pipeline (2013 to 2022)	Total (1973 to 2022)
Carting	3,156,497	1,392,112	4,548,608
Pumping (via pipeline)	-	1,032,425	1,032,425
TOTAL:	**3,156,497**	**2,424,537**	**5,581,033**

Figure 5 shows a timeseries of the annual volumes of sand transferred around Adelaide's beaches for the post-ALB period. This period, post-2008 is selected because more detailed annual records for both carting and pumping volumes were available. It shows that since 2010, the annual volume of sand transferred around the beach system has been approximately 200,000m^3/year. The majority of these sand transfers are sand backpassing, whereby sand is moved to the south, counter the natural direction of coastal sand movements. The reduction in sand transfer volumes in 2022 coincides with a large nourishment volume delivered to West Beach from quarry sources as shown in Table 2. Harbour sand bypassing, using carting (trucks) and dredging, was undertaken until 2005 to move around 85,000m^3/year of sand to the downdrift beach compartment (i.e., West Beach) (DEH, 2005).

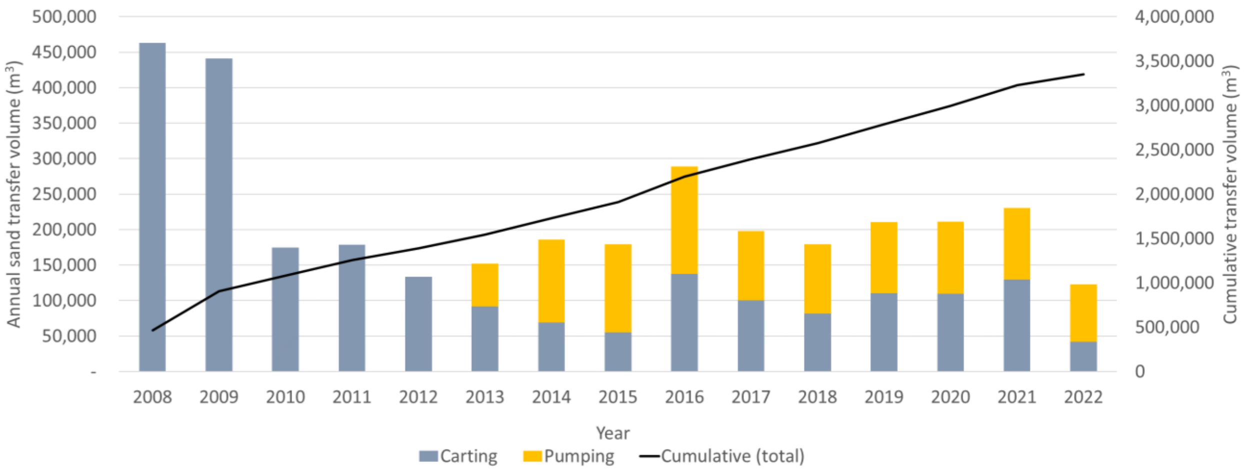


Figure 5: Historical sand transfer volumes from post-ALB implementation.

External sand nourishment campaigns have been conducted since the 1970's when the CPB was formed. This was in response to the recognition that additional sand was needed due to a lack on natural sand supply to the Adelaide beaches. The sand has been sourced from several onshore and offshore locations, with the most significant campaign supplying Brighton with over 1.14 million m^3 from offshore Port Stanvac in a series of campaigns from 1991 to 1997.

Table 2: Major external nourishment campaigns.

Date	Placement volume (m^3)	Placement location	Source
1974-85	158,500	Seacliff	Port Stanvac Beach
1980	1,000	Seacliff	Port Noarlunga Beach
1988-90	187,500	Glenelg North	Torrens Island Sand Dunes
1991	187,169	Brighton	Port Stanvac offshore
1994	172,839	Brighton	Port Stanvac offshore
1995	181,522	Brighton	Port Stanvac offshore
1997	602,712	Brighton	Port Stanvac offshore
1988, 2004	25,000	Seacliff	Quarry (Mount Compass)
2021-2022	200,900	West Beach	Quarry
2023	118,584	West Beach	Quarry
2023	20,354	Henley Beach South	Quarry
Total:	**1,856,080**		
Port Stanvac (dredging)	1,144,242	61.6%	
Quarry (carting)	364,838	19.7%	
Other	347,000	18.7%	

Figure 6 shows a map of how sand management activities since 1973 have been distributed over Adelaide's beaches. This includes both internal sand transfers and sand nourishment from external sources. For each location, it shows the average yearly rate of sand removal and/or sand placements. It demonstrates key areas where sand has been placed and removed, highlighting several insights to historical coastal management:

- Historically, management efforts have been focused on the southern beaches (Kingston Park to Glenelg).

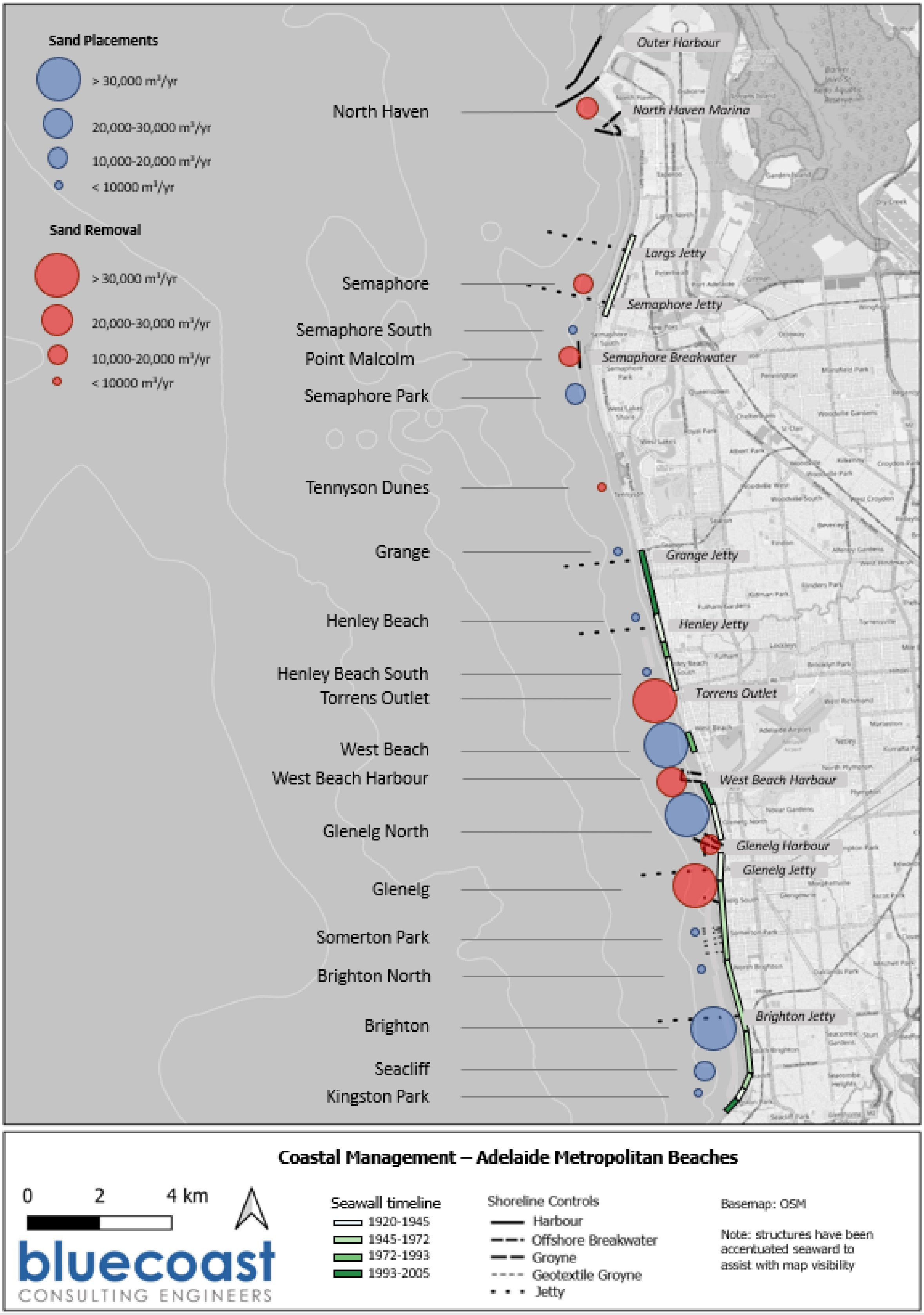


Figure 6: Annualised average rate of sand replenishment activities 1973 – 2022.

- The harbours at Glenelg and West beach are causing disruption to the northerly transport of sand which is requiring significant management by dredging as well as by-/backpassing.
- Compared to the relatively large amount of sand that has moved north naturally into Semaphore and Largs Bay during the time of replenishment records (~99,250m^3/year), there has been only a small amount (~20,000m^3/year) removed from this area of the system and transferred south.
- Areas with coastal structures (e.g., seawalls or shoreline controls) require greater coastal management.

2.4.2 Current coastal management strategy

The current coastal management strategy is based largely on the ALB report (DEH, 2005). This sets out a coastal management strategy for 2005 to 2025 and is the most recent major management strategy review. The ALB report confirmed the continuation of a sand management approach at the core of the management of Adelaide's beaches. The key changes introduced at the ALB report, as illustrated in Figure 7 were:

- <u>Sand bypassing around the boat harbours at Glenelg and West Beach was to be abandoned</u> in favour of sand backpassing. Ceasing sand bypassing was justified as reducing harbour management costs and resulting in more efficient backpassing of sand.
- Sand backpassing (or sand recycling) becomes the main element of the strategy. This was envisaged to be implemented:
  - Using new pipeline transfer systems that would pump sand as a slurry. These would replace sand carting using trucks along beaches and on local roads.
  - Within four (4) or seven (7) coastal management cells defined in the ALB report. This was the four southernmost management cells of (i) Kingston Park to Glenelg (6.5km) (ii) Glenelg harbour to Glenelg North (1.5km) (iii) West Beach to Torrens Outlet (1.5km) and (iv) Henley Beach to West Lakes Shores (9.5km). It was envisaged each cell would have its own sand transfer system, backpassing the nominated alongshore sand transport rates from the northern end of the pipeline to the southern end. The alongshore sand transport/pumping rates were 70,000m^3/year in the cell 1 (Kingston Park to Glenelg) and 50,000m^3/year in other cells/pipelines.
  - Using sand collection for the pipelines via either 'Sand Shifter' or 'Slurrytrak' systems. The Slurrytrak was closest to what has been implemented on Adelaide's beaches to-date as it involved conventional earth moving equipment harvesting sand from the beach. The 'Sand Shifter', which is currently used in Noosa, Queensland, is more hydraulic in nature, being buried beneath the beach level and collecting sand using fluidisation.
- Coarse sand was to be imported to the beach system using carting (i.e., trucks) with the material to be sourced from quarries such as Mount Compass. This was a change from the previous management which had included sand nourishment from nearshore/offshore sources using dredging. The main justification for excluding dredging was that a suitable sand source had yet to be found.
- Shoreline control structures, used to slow the northward movement of sand, like the offshore breakwater at Semaphore were proposed to be included at a few critical locations.

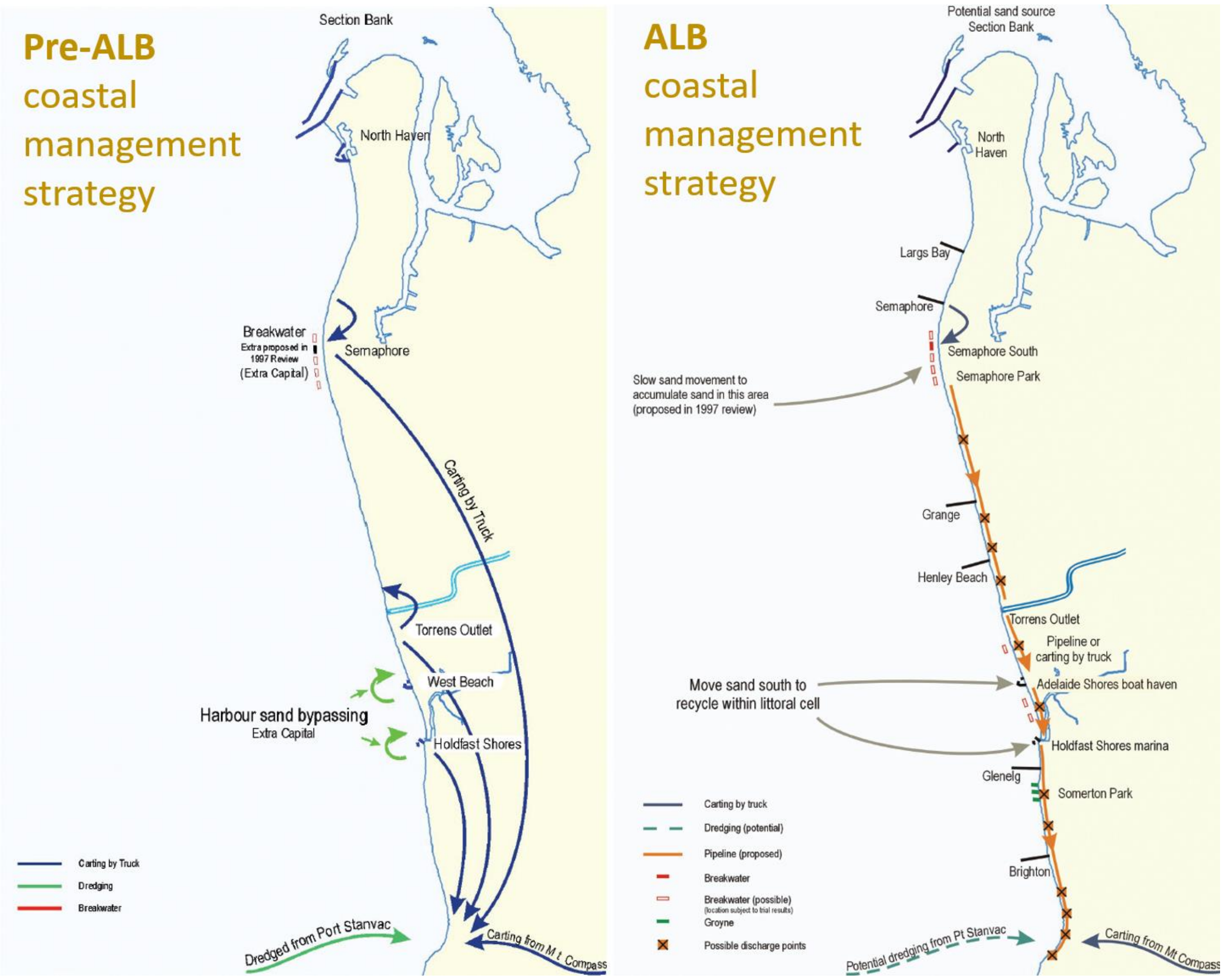


Figure 7: Coastal management strategy prior to (left) and after the ALB report (modified after DEH, 2005).

The elements of the strategy that have been delivered are shown in Figure 8 and described as:

- Sand bypassed of the harbour was discontinued in 2005, after which time, West Beach immediately began eroding in response to the lack of sand supply from the south.
- The four backpassing pipeline systems were subject to further design development, public consultation, a development approval (DA) and construction tendering in 2008. The tenders received were over the budget and a decision was made to reduce the scope rather than increase the budget. This resulted in two of the four proposed sand backpassing pipelines being constructed which were operational by 2013. These were:
  - Glenelg to Kingston Park (cell 1) which as discussed above has continued to operate and pump around 100,000m^3/year of sand collected at Glenelg.
  - Torrens Outlet to West Beach Parks (cell 3) was built but only operated until 2017, after which no further sand pumping occurred via this pipeline. While the pipeline is understood to be operational, this is reported to be due to ‘technical sand management issues’ (DEW, 2023).

- Sand carting operations between beaches continued, as described in Section 2.4.1, with a renewed focus on the northern beaches.
- An offshore breakwater at Semaphore South was built to manage erosion at Semaphore Park and trap sand for backpassing to southern beaches, including West Beach.
- In 2017, DHI was commissioned to investigate the erosion issues at West Beach and investigate options to address the sand loss. The DHI report estimated that the rate of sand loss from the West Beach compartment was 100,000 to 115,000m3/year, which was significantly higher than previous estimated (i.e., 50,000m3/year in the ALB report) (DHI, 2018). The findings were used to inform new investments in beach management – Securing the future of our coastline.
- Following review of the DHI report, the CPB made recommendations to South Australian government, which decided that the Securing the future of our coastline project, which was announced in 2019, would involve:
  - Sand nourishment of 500,000m^3 to West Beach using external sources to restore beach volumes to 2005 levels.
  - Construction and operations of a sand backpassing pipeline from Semaphore to West Beach to restore the sand supply rate to that was naturally supplied to the beach prior to the construction of the boat harbours and the operation of the southern sand backpassing pipeline.
  - While the above two main elements were being planned, there would be an immediate increase to sand carting from Henley Beach South to West Beach.
  - Following the restoration of beach volumes and sand supply, dune stabilisation and revegetation works would be used to help stabilise the sand.

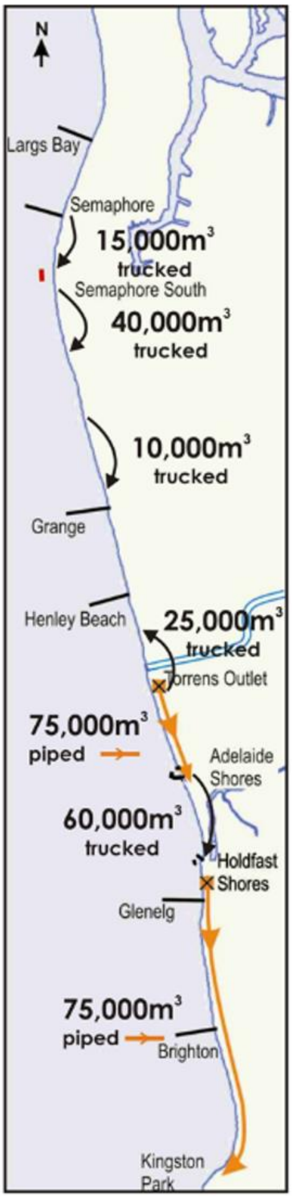


Figure 8: Sand management strategy delivered (Department for Environment and Water, 2021).

The following elements from the *Securing the future of our coastline* project (Figure 9) have been undertaken to date:

- The sand carting was implemented as was further sand sourcing investigations, primarily at Port Stanvac but also some preliminary assessments at the Section Banks.
- Investigations of the Port Stanvac sand source indicated that this was not a suitable source for beach nourishment material (DEW, 2020). The Section Banks source was also dismissed on environmental grounds. This resulted in a return to the ALB strategy of external and coarse sand soured from quarries and delivered by trucks. Because of the much higher cost of quarry sand this

resulted in a reduction of the required 500,000m³ (in 2018) of sand nourishment to a lower volume that could be delivered from quarries for the allocated budget.

- In 2021, a contract was awarded for the design and construction of a sand backpassing pipeline. This contract was halted in 2023 pending the outcomes of this review.

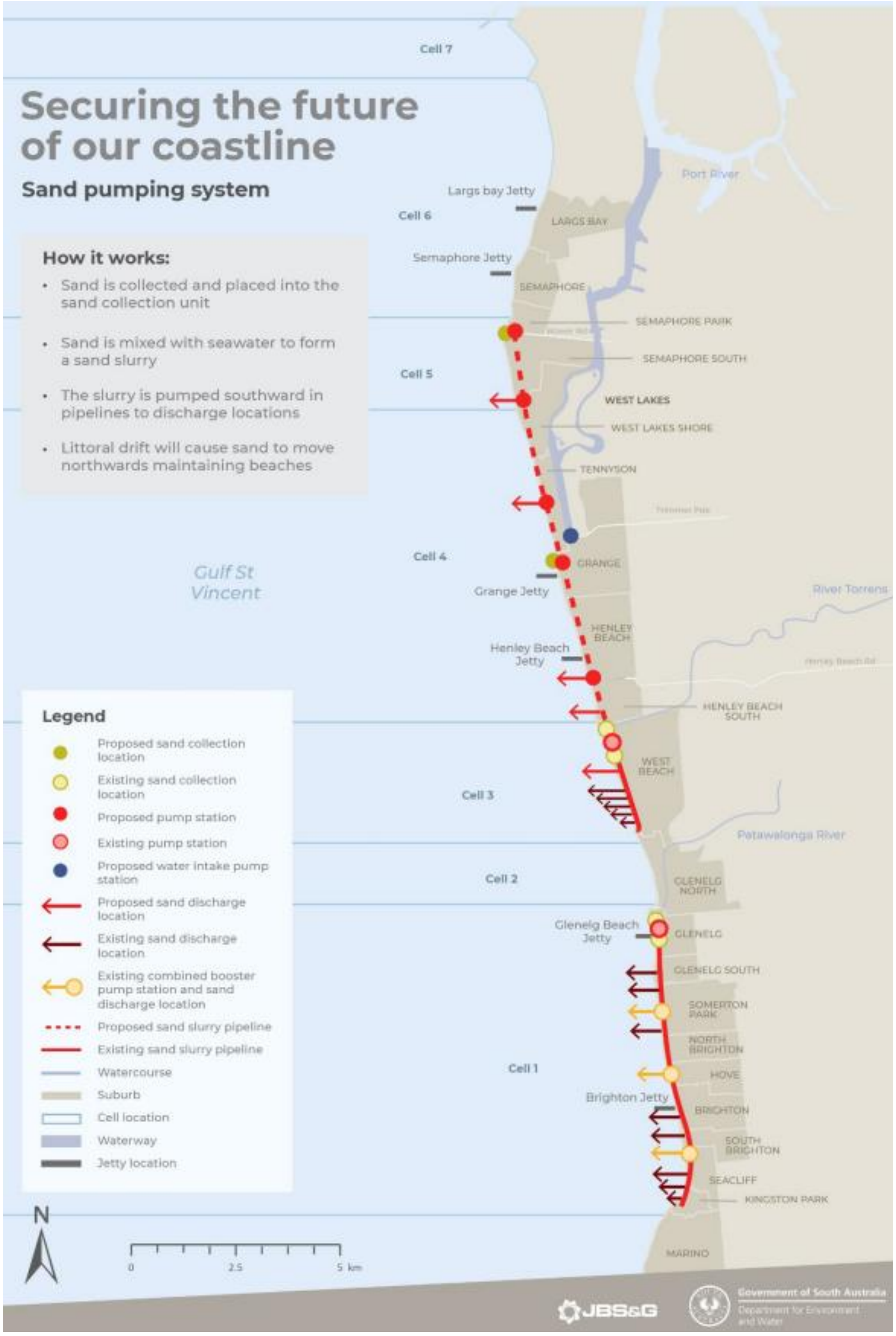


Figure 9: Extended northern pipeline footprint (JBS&G, 2021).

2.5 Review of Australian and international sand management

2.5.1 Overview

A review of relevant sand management projects and practices employed on beaches in Australia and internationally was undertaken. This review places the Adelaide Beach management activities into the context of other Australian and international examples of sand management.

2.5.2 Sand bypassing and backpassing

Sand bypassing and backpassing systems are similar types of coastal engineering projects which are generally designed to manage sediment distribution and mitigate coastal erosion. Sand bypassing systems facilitate artificial transport of sand across tidal entrances (or other significant littoral drift blockages) to help prevent accretion on the updrift side, control downdrift erosion and maintain navigation channels. Backpassing systems facilitate artificial transport of sand back to updrift erosion areas. Both types of systems utilise similar components, with either permanent or semi-permanent sand pumping infrastructure, trucks or dredging vessels used to facilitate the transfer of sand.

Overall, bypassing systems are more common and typically used to transfer larger volumes (i.e., >100,000m^3/year) of material compared to backpassing systems (typically <100,000m^3/year). This is primarily because backpassing is typically only undertaken when the downdrift sand transport rates are less than the rate reaching the bypass system, allowing recycling of some of the sand without causing adverse impacts downdrift (Jackson, 2023).

SwashPD (2023) identified 35 regular sand bypass and backpass systems within Australia, only counting those that transferred greater than 10,000m^3 sand per year (refer to Figure 44 in **Appendix A**). Table 30 in **Appendix A** presents further detail on the most notable projects in Australia, along with several other international examples in South Africa, Brazil and the USA. A summary of the key findings of the sand bypassing and backpassing review is provided below in Table 3.

Several projects in the USA utilise temporary pipelines connected to dredgers to place sand onto the subaerial beach for long (>1km) stretches of beach. This typically involves adding sequential lengths of temporary pipeline to progress along the beach, with earth-moving machinery used to distribute sand as the work advances.

In Europe there are no notable sand bypassing or backpassing systems, with the majority of coastal management in European countries being conducted in the form of large beach nourishments conducted using dredgers using offshore-sourced sand (refer to Section 2.5.3).

Table 3: Overview of sand bypassing and backpassing operations in Australia and around the world.

	System type	Australian examples (m^3)	International examples (m^3)
Bypassing	Fixed	Sand intake jetties part of bypassing systems at Gold Coast: • Seaway (600,000). • Tweed River (500,000).	• Brazil: Barra do Furado sand intake jetty (unknown volume). • South Africa: Ngqura industrial port sand intake jetty (160,000).
	Dredge	• Murray River entrance (1,000,000). • Lakes Entrance: combination of backpassing/bypassing by dredgers inside and outside the entrance (350,000). • Tweed River: In 2023, dredged and bypassed to downdrift beaches (220,000). • Maroochydore: (50,000).	• South Africa: Durban (250-500,000) • US: many examples, notable instances include Port Hueneme (1,700,000), St. Augustine Inlet (212,000), Santa Barbara (180,000), Jupiter Park (80,000), Sebastian Inlet (30,000)
	Other	• Portland: Fixed pipeline with sand shifter intake (50,000). • Dawesville/Mandurah: Sand collection units with earth-moving machinery similar to backpassing system in Adelaide (both transfer approximately 100,000).	US: Novel examples of semi-mobile sand intakes suspended on cranes at South Lake Worth and Palm Beach Inlet in Florida (100-150,000) and Indian River (75,000).
Backpassing	Fixed infrastructure	Surfers Paradise backpassing pipeline: ties into the existing sand bypass system at the Gold Coast Seaway (120,000).	US: Proposed fixed pipeline system for Galveston, Texas (40-75,000).
	Trucking	Existing backpassing practices along northern Adelaide beaches (100,000).	US: Several examples. Notable examples include North Wildwood Beach (200,000), Avalon Beach (21,000), Cape May Beach (50,000) and Ocean Beach (50,000).
	Dredge	• Tweed River: In 2023, sand dredged and placed at updrift beach (40,000). • Lakes Entrance: combination of backpassing/bypassing by dredgers inside and outside the entrance (350,000).	No known examples.

System type	Australian examples (m³)	International examples (m³)
Other	• Southern Adelaide beaches: Backpassing by sand scraping, loading into hopper, and pumping via permanent pipeline (100,000). • Noosa and Woorim: Semi-mobile sand shifter (30-40,000). • Jimmys Beach: Semi-mobile jet pump and permanent pipeline (30,000).	US: One example from Miami Beach, Florida. 65,0000m³ transferred utilising earth-moving equipment for sand scraping, placement into a hopper and pumping along a pipeline.

2.5.3 Beach nourishment using dredgers

Beach nourishment using dredgers is a common method employed globally to restore or expand eroded shorelines. Its prevalence is due to its economic feasibility for the required quantities, along with the relative accessibility and natural suitability of sand that is already on the seabed. Dredging involves the extraction of sand from either:

- Within harbours or coastal inlets. There are many examples of beach nourishment using material sourced from these locations for bypassing/backpassing purposes with several already described in the previous section (Section 2.5.2).
- Offshore sources. There are many examples of beach nourishment by dredge using material sourced offshore. Some key examples in Australia and internationally are described below in Table 4. It is noted that for most European countries (Netherlands, Germany, Denmark, Belgium and Spain), this is the predominant source of nourishment material (Staudt et al, 2019).

Placement of sand for nourishment purposes occurs either by bottom dumping in the nearshore, rainbowing sand to the surf zone, or transporting sand through a pipeline, typically to the beach, where it can then be further distributed by earth moving machinery. Discharge from a pipeline can also be into the nearshore/ surf zone, as shown below in Figure 10 from dredging at Ponce De Leon Inlet (Florida, USA) in 2019.

Figure 10: Dredge slurry discharge in the nearshore at New Smyrna Beach (Florida), 2019. Source: Christian Oehmke.

Table 4: Beach nourishment examples by dredge using sand extracted from offshore sources.

Location	Description
Australia	• Gold Coast: In 2017, City of Gold Coast contracted a specialised offshore dredging vessel to transfer 3,000,000m^3 of sand from offshore reserves and deliver it to the nearshore bar systems to renourish the most vulnerable beaches (Elliot-Perkins et al, 2021). Sand was dredged from offshore sand reserves and distributed nearshore using bottom dumping and rainbowing methods. The sand placement design used an innovative 'design with nature' approach defined by a unique grid system. This allowed for sand delivery flexibility with changing bathymetries, community use of the beach and temporary enhancement of surf amenity. • Maroochydore Beach: Nearshore Nourishment Trial in 2022 placing sand dredged from Moreton Bay just offshore of Maroochydore Beach by rainbowing and bottom-dumping. • Stockton Beach: In 2023, approximately 130,000m^3 of sand extracted from approved maintenance dredging offshore of the Newcastle harbour entrance and placed in the nearshore at Stockton Beach by rainbowing.
USA	• Large beach nourishment campaigns involving >100,000m^3 of sand from offshore undertaken frequently for a large number of beaches.
Netherlands	• The Netherlands have adopted a national strategy of dynamic preservation to maintain the shoreline of 1990 by beach nourishment using sand from offshore sources. Nourishment is typically undertaken every 4-5 years with an average annual nourishment volume of 12,000,000m^3 (Staudt et al, 2019). • 'Mega' nourishments have been tested in recent years with initial volumes of 21.5 and 35 million m^3 and design lifetimes of approximately 20 and 50 years, respectively. The design of these mega nourishment follows the recommendations to nourish very large amounts with long repetition rates in order to avoid frequent disturbances of the ecosystem.
Germany	Total average annual nourishment volume of 1,900,000m^3 provided every year with sand extracted from offshore sources (Staudt et al, 2019).
Denmark	Total average annual nourishment volume of 2,500,000m^3 provided every year with sand extracted from offshore sources (Staudt et al, 2019).
Belgium	Total average annual nourishment volume of 1,300,000m^3 provided every 4-6 years with sand extracted from offshore sources (Staudt et al, 2019).
Spain	Total average annual nourishment volume of 10,000,000m^3 with sand extracted from offshore sources, no regular nourishment program (Staudt et al, 2019).
UK	Total average annual nourishment volume of 4,000,000m^3 provided every 5 years with sand extracted from existing licensed offshore dredging areas (Staudt et al, 2019).

2.6 Data used in this review

An overview of the datasets used in this project are presented in Table 5. Metocean (i.e., wave, water level and wind) monitoring sites are shown in Figure 11. The data was used in a variety of ways, as outlined in the relevant section of the report. Analysis and interpretation of this data has been fundamental to understanding the coastal processes and developing an evaluating the longlist and shortlisted options. Gaps in the available data are discussed in Section 7.

Table 5: Overview of observational data used in this project.

Data type	Description	Source	Date
Waves	Measured wave data at two locations within Gulf St Vincent	SA Waves (Flinders University)	2021 – 2023
Water level	Measured water levels at two locations, Outer Harbour and Inner Harbour	Bureau of Meteorology	1940 – 2022 Outer Harbour 1932 – 2019 Inner Harbour
Wind	Measured wind data at Black Pole	Bureau of Meteorology	2001 – 2023
Topographic, bathymetric and coastal surveys	Coastal profile surveys	DEW	1977 - 2023
	Detailed bathymetric surveys of West Beach	DEW	1990 1995 2017
	Satellite-derived shorelines	Digital Earth Australia (DEA)	1988 - 2021
Coastal management (including sand management)	Sand transfer volumes from carting including: harvesting and placement methodology, transportation, distribution and shaping/adjustment in placement area.	DEW	2008 – 2022
	Sand transfer volume by pipeline including harvest locations and volume at each outlet location.	DEW	2013 - 2022
	Historical and detailed information on sand management costs and operations (pumping, carting and quarry sourcing)	DEW	2020 - 2023

Data type	Description	Source	Date
	Summary of dredging records from Adelaide Shores Boat Harbour and Holdfast Shores marina (incl. dredge and placement areas)	DEW	2012 - 2020
	Details on existing coastal protection structures (rock revetements, seawalls, groynes, breakwaters etc) along Adelaide's managed beaches. Details included things such as seawall alignment, levels, structure type, year of constructions etc	City of Holdfast Bay (Water Technology, 2020) City of Charles Sturt (Wavelength, 2022)	2020 2022
Sediment data	Over 1,000 sediment samples from Kingston Park to Port Gawler	Bone et al. 2008	April 2003 & October 2005
	102 sediment samples from 27 coastal profiles along the metropolitan coast	Environmental Projects 2022a & 2022b	August 2021 & January 2022
Environmental	Benthic habitat mapping including the metropolitan coastline in 2006 and then targeted data for nearshore Largs Bay in 2023	DEW	2006 & 2023

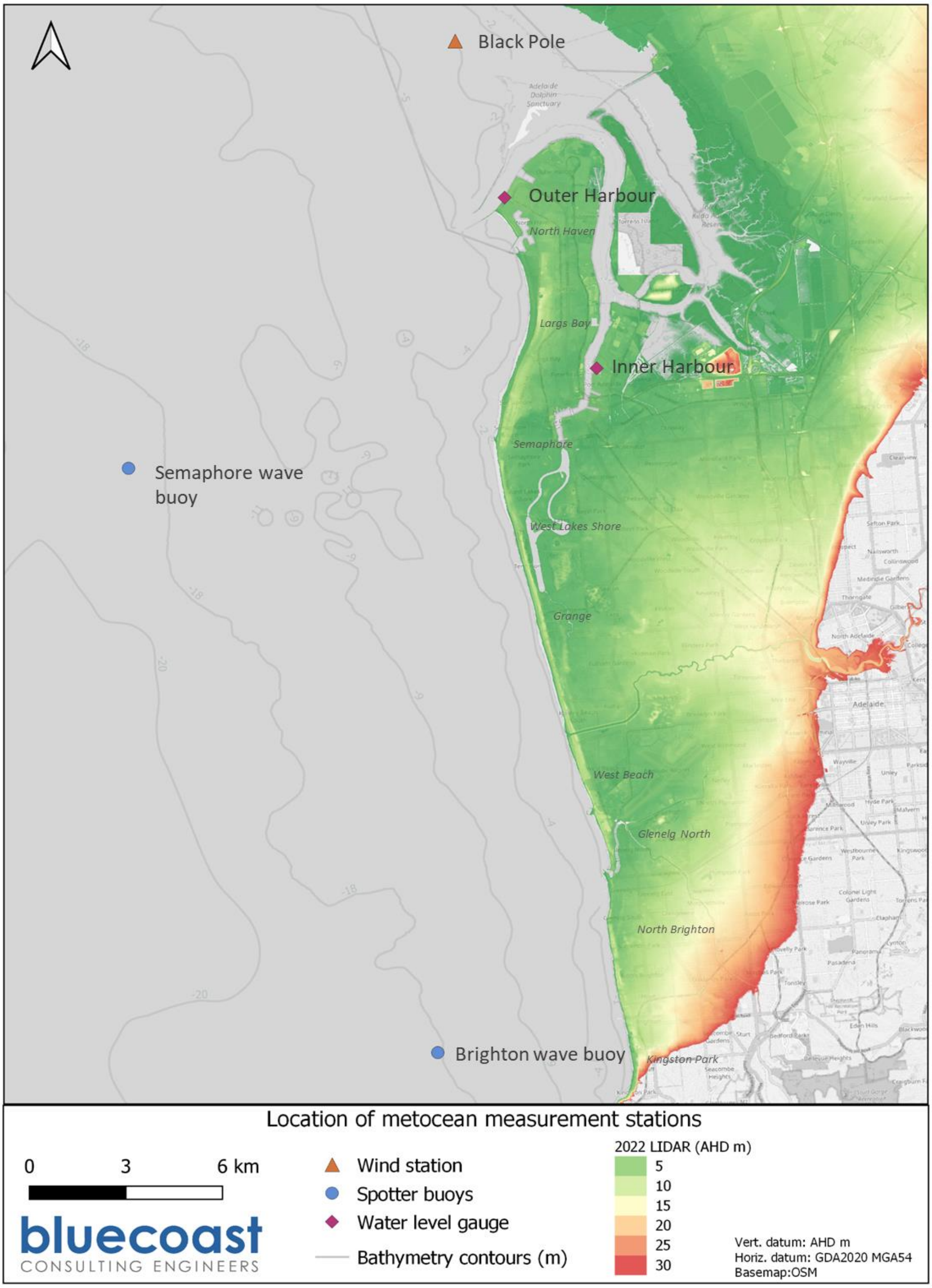


Figure 11: Location of metocean monitoring sites available for this study.

3. Coastal processes

3.1 Geology and geomorphic evolution

3.1.1 Geomorphic evolution

A natural rise in sea level from approximately 18,000 to 6,500 years ago flooded Gulf St Vincent. Sea level rose by about 130m submerging land surfaces. The flooding of the shallow gulf floor reactivated siliceous sediments moving them to and northward along the coast.

Bowman and Harvey (1986) dated the beach and dune ridges of the northern Adelaide coast and reconstructed the Holocene palaeo-shorelines of the LeFevre Peninsula, which occupies the northern 14km of the coast. They observed rapid northern movement of sand between 7.5 and 5.5 ka, followed by a reduced rate of sediment supply and a change in coastline orientation contributing to spit recurvature and a flared beach-ridge pattern. Figure 12 illustrates the northward growth of the coast as a series of both seaward prograding dune ridges and northward prograding recurved spits and ridges. The sand has been transported into an increasingly lower energy environment and terminates in a series of recurved spits that form at the northern (downdrift) end of the peninsula. To the north of the peninsula are extensive low energy tide-dominated tidal flats, mangroves and inner shelly beach ridges. The Holocene produced a series of dune ridges 200 - 300m wide and 10 - 12m high, widening to 1 - 2km along the peninsula.

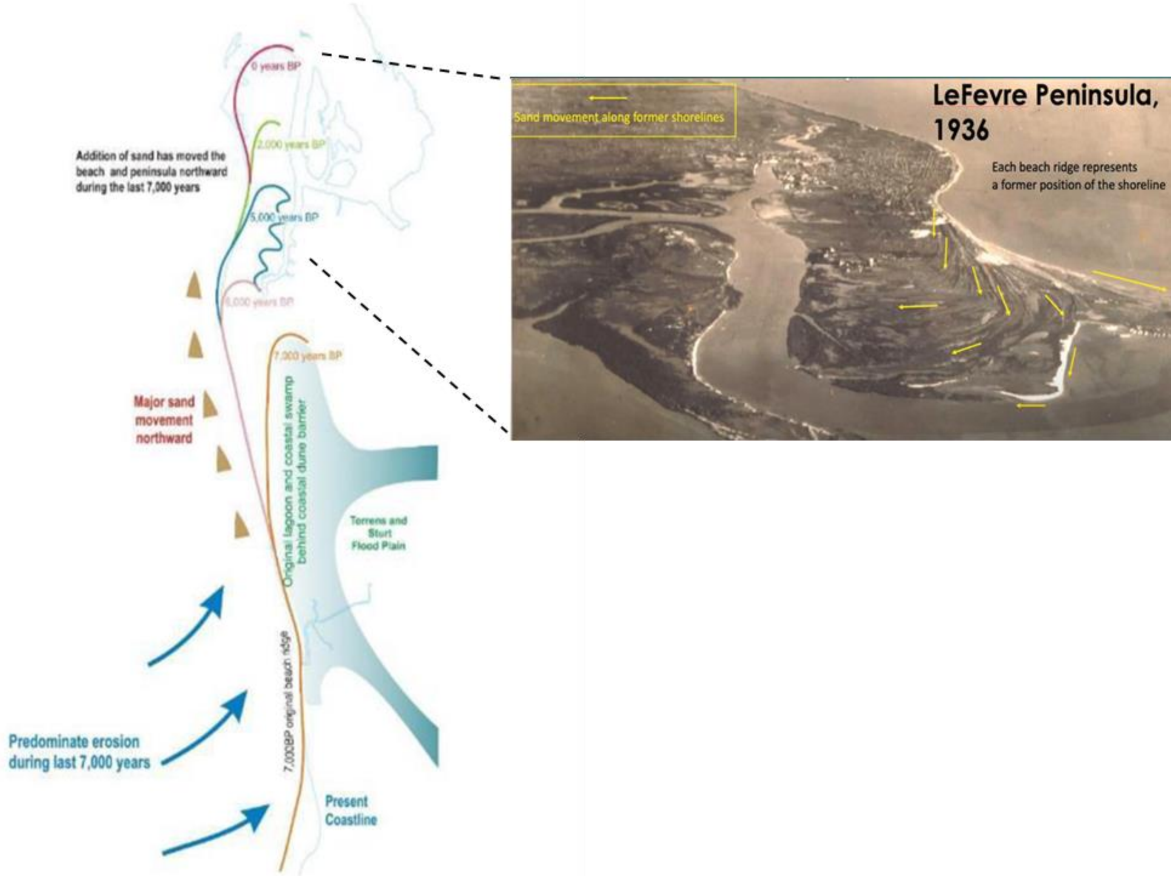


Figure 12: Evolution of the northern Adelaide coastline over the last 7,000 years (left) (source: Bowman and Harvey, 1986) Prograding shoreline at Le Fevre Peninsula (right) (Source: DEW public presentation, 2021).

3.1.2 Regional geology and sediment deposits

The near-surface geology along the coast of the LeFevre Peninsula and further south along Adelaide's beaches is well known and documented (Belperio, 1995). Less well documented is the offshore near surface geology. The known stratigraphy as summarised after Glenn et. al (2001):

- At the base of the Gulf St Vincent, a dominant feature is expected to be the Pleistocene-aged Hindmarch Clay formation, being derived from erosional material from the Adelaide Hills, and deposited at a time of low sea level. The Hindmarsh formation consists of stiff to hard silty and sandy clay, with some sand and gravel layers or lenses.
- A cemented calcrete crust overlying calcareous sand that is known as the Glanville Formation. The calcrete crust maybe relatively thin (0.4m to 1.0m) but hard calcrete or calcareous sandstone layer. Investigations around Port Adelaide River and near the Outer Port have consistently encountered this layer.
- Inland, the Pooraka Formation, a sequence of generally red clays overlies the Glanville Formation. However, the Pooraka Formation is known to decrease in thickness toward the coastline and was not encountered at the borehole locations drilled for the Pelican Point power station.
- Overlaying the Pooraka Formation (if present), sand veneers equivalent to the St Kilda or Semaphore Formation may be expected. The St Kilda Formation is important to potential sand sources and is discussed further below.

The St Kilda Formation, which includes 'Semaphore sand' formed during the Holocene (c. 10,000 year ago to present). Generally, this St Kilda Formation is a thin veneer of sand but a significant build-up of Holocene sediments, with thicknesses of up to 10m, are found in the northern metropolitan beaches around the Lefevre Peninsula. The thickness sediments form a coastal wedge that is thickest (up to 10 m) beneath the contemporary intertidal zone in the Port River estuary. Significant accumulation (>10 m) has occurred beneath Outer Harbor, Torrens Island and the Barker Inlet intertidal marshes (Figure 10). South of Adelaide, much of the shallow sea floor is devoid of Holocene sediment cover and Tertiary strata crop out in a coast-parallel band from Port Stanvac to Sellicks Beach (Belperio et al., 1990).

The quartz grains of 'Semaphore sand' are generally rounded to sub-rounded. Between 3% and 30% of the sand is carbonate material (Culver, 1970) derived from the breakdown of nearshore fauna and flora such as bivalves, bryozoans and red algae. A minor siliceous bioclastic component of the sand is derived from small algae called diatoms (DEW, 2005). Holocene sediments are similarly dominantly biogenic carbonates, with quartzose sands restricted to the littoral zone south of Adelaide.

Other relevant features include:

- In the shallow gulf margins (0-20m), patchy to thick seagrass meadows (dominantly Posidonia) with associated epiphytes and epibenthos dominate the sea floor.
- Mangrove woodlands are well developed in the mid-intertidal zone from Port Adelaide to the Light River. Finer sediment accumulates in this environment, and intensive burrowing by small crabs thoroughly homogenises and oxidises the sediment.

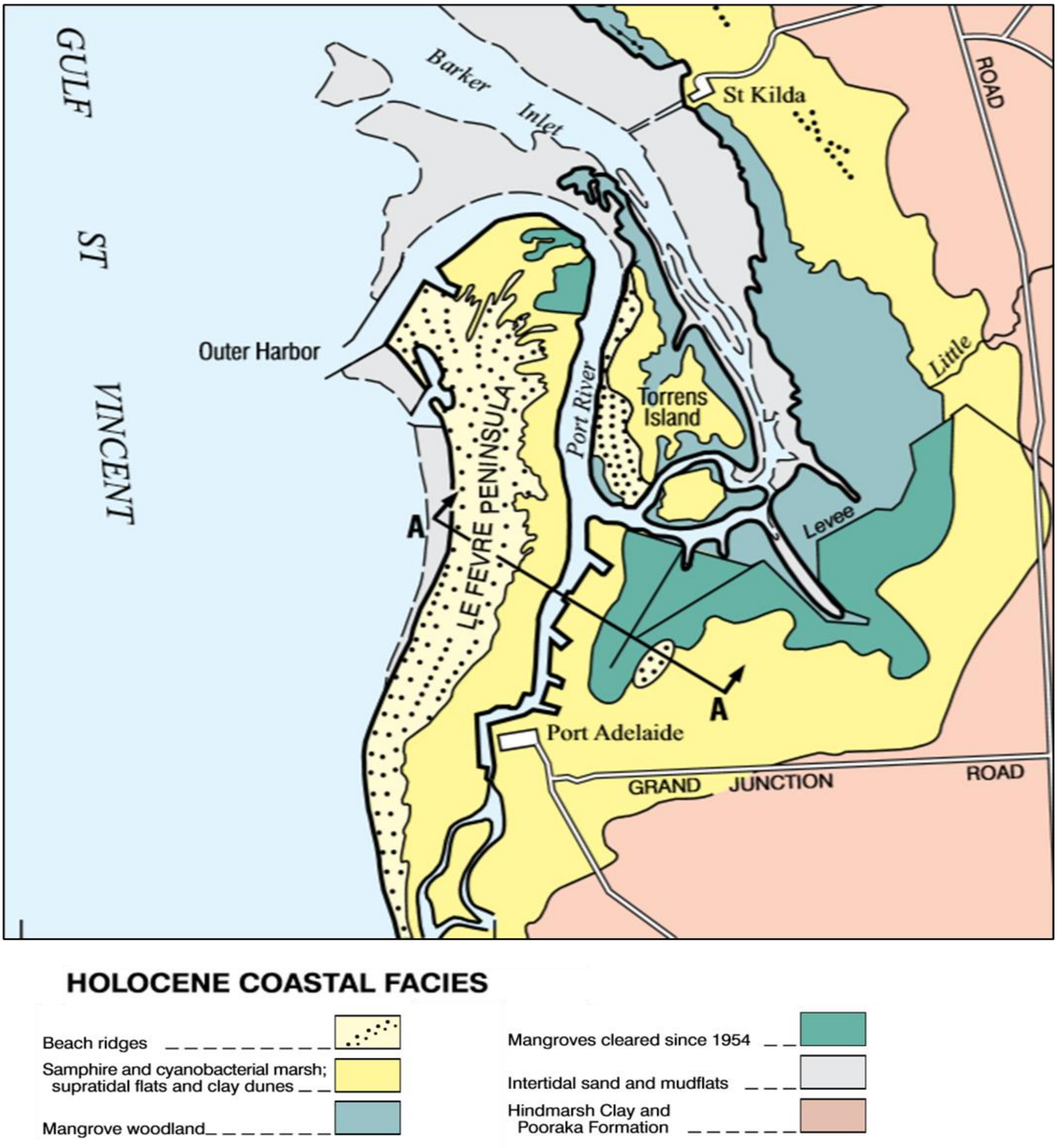


Figure 13: Morphology of the coastal zone north of Adelaide (adapted from Belperio, 1995).

3.2 Modern geomorphic structure

Key features of the modern geomorphic setting of the Adelaide's metropolitan beach are shown in Figure 14.

Adelaide's metropolitan coast is characterised by a long sandy beach in which sand is moved in a net northward direction by waves and currents. Adelaide's beaches are mostly continuous, although the Outer Harbor breakwaters, North Haven marina, Torrens Outlet, Adelaide Shores boat haven and Holdfast Shores marina each cause disruption to sand movement along the coast.

The 28km long beach receives a similar amount of wave energy from Brighton to Semaphore. There is a slight wave height gradient decreasing south to north with distance from the Gulf's entrance, however, this is countered by an increase in wave period toward the north (refer Section 3.3). Sheltering in the lee of the Wonga Shoal and changing shoreline orientation reduces the wave climate in Largs Bay, north of Point Malcom. However, no wave measurements are available to quantify this.

Along much of the southern 20km between Seacliff and Semaphore the beach consists of a wave-dominated low tide terrace which is cut by occasional shallow north skewed rip channels, fronted by one to two shallow sand bars, the crests at times exposed at spring low tide (Cooper and Pilkey, 2012).

North of Semaphore, wave energy decreases and three shore parallel bars gradually dissipate into a wide low gradient inter to sub-tidal terrace, as wave energy becomes insufficient to form and maintain the bar morphology, and tide-modified conditions dominate (Cooper and Pilkey, 2012).

Along the entire coast the individual bars run shore parallel for up to 2–3km and are aligned to the shore. Each bar commences at a point of attachment and gradually moves offshore and dissipates as another inner bar replaces it. In the intervening shallow troughs north-trending mega ripples are maintained by both wave and tide-driven northerly currents. Seaward of the bars bare sand now extends seaward for several kilometre offshore where seagrass meadows of *Posidonia sinuosa*, *Amphibolis antarctica*, *P.angustifolia*, *Heterozostera tasmanica* and *Halophila australis* are encountered from depth of around 5-6m and out to a depth of 18m (Cooper and Pilkey, 2012).

The topography of Adelaide is characterised by a low backshore with dune barrier profile in sections where there is not a seawall, which is mainly along the northern section of Adelaide's metropolitan beaches. The typical dune crest elevations are around:

- 10m AHD at North Brighton.
- 7m AHD at West Beach.
- 8m AHD along Semaphore.
- 4m AHD along Largs Bay.

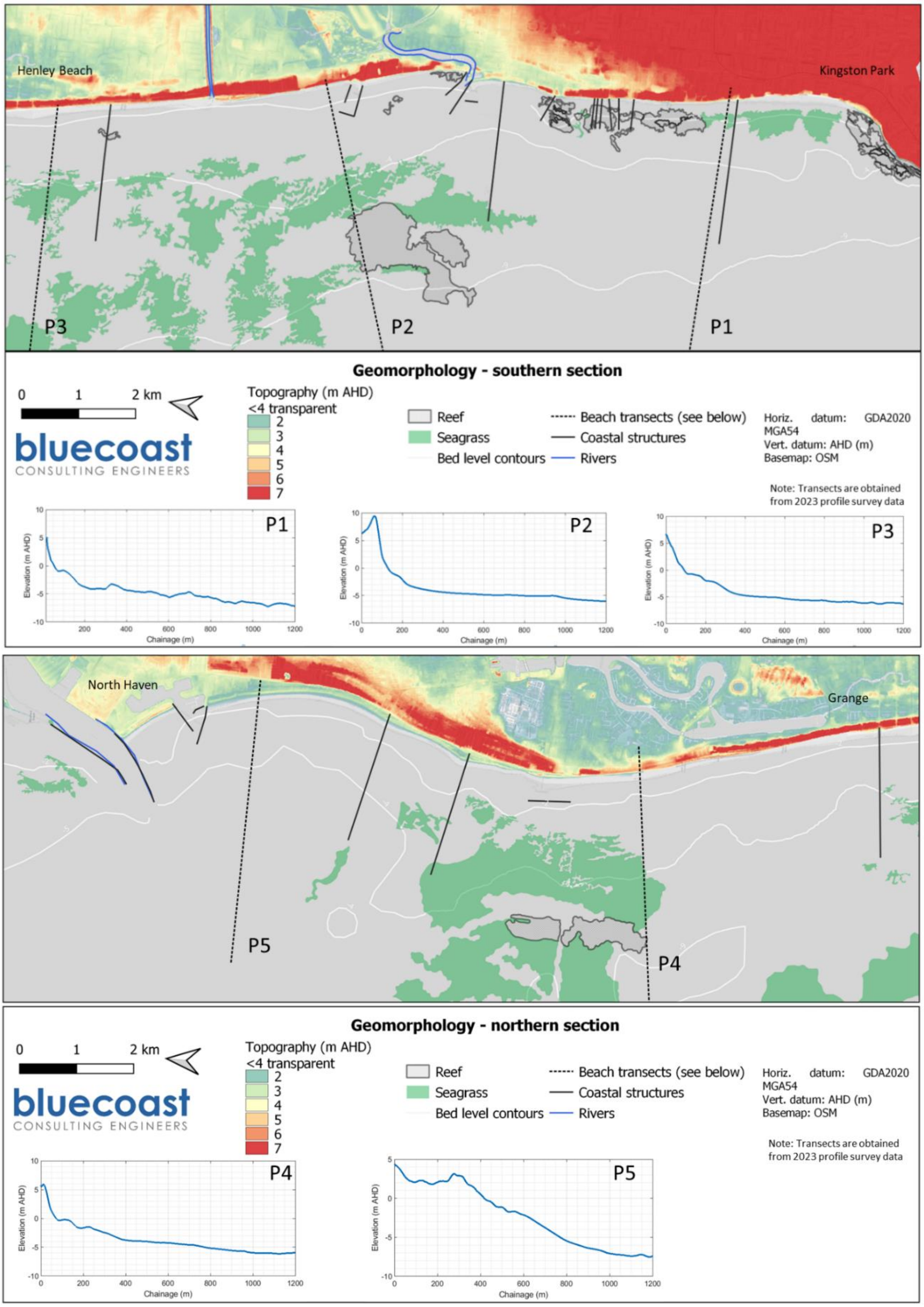


Figure 14: Geomorphic setting at Kingston Park to Henley Beach (top) and Grange to North Haven (bottom).

3.3 Nearshore wave climate

The nearshore wave climate was assessed using the following data:

- Nearshore wave buoy at Brighton. Wave and wind data available from 13 August 2021 to 9 May 2023.
- Nearshore wave buoy at Semaphore. Wave and wind data available from 13 August 2021 to 14 May 2023.

Nearshore wave roses for total, swell (swell waves, Tp >8s) and sea (local sea, Tp <8s) are provided in Figure 15, for Brighton and Semaphore. Average wave statistics for Brighton and Semaphore are provided in Table 6. Wave statistics tables, that include a seasonal breakdown are provided in **Appendix B**.

Adelaide's metropolitan beaches are exposed to waves from the south-west sector dominated by low energy and low period sea waves. Sea waves are predominant around the 75% of the time in Brighton and 60% in Semaphore. Sea waves reaching the metropolitan beaches are mostly generated by west-south-west winds. The wave roses show a narrow band of incoming wave directions. The location of Adelaide 100km into the gulf together with the blocking effect of Kangaroo Island across the gulf entrance results in only occasional low ocean swell reaching the beach. Waves reach Adelaide with around 12–15s periods, heights below 1m, and directions close to 255ºN. Winters sees slightly larger mean wave heights, with longer wave periods more from the north (i.e., likely more refracted swell waves).

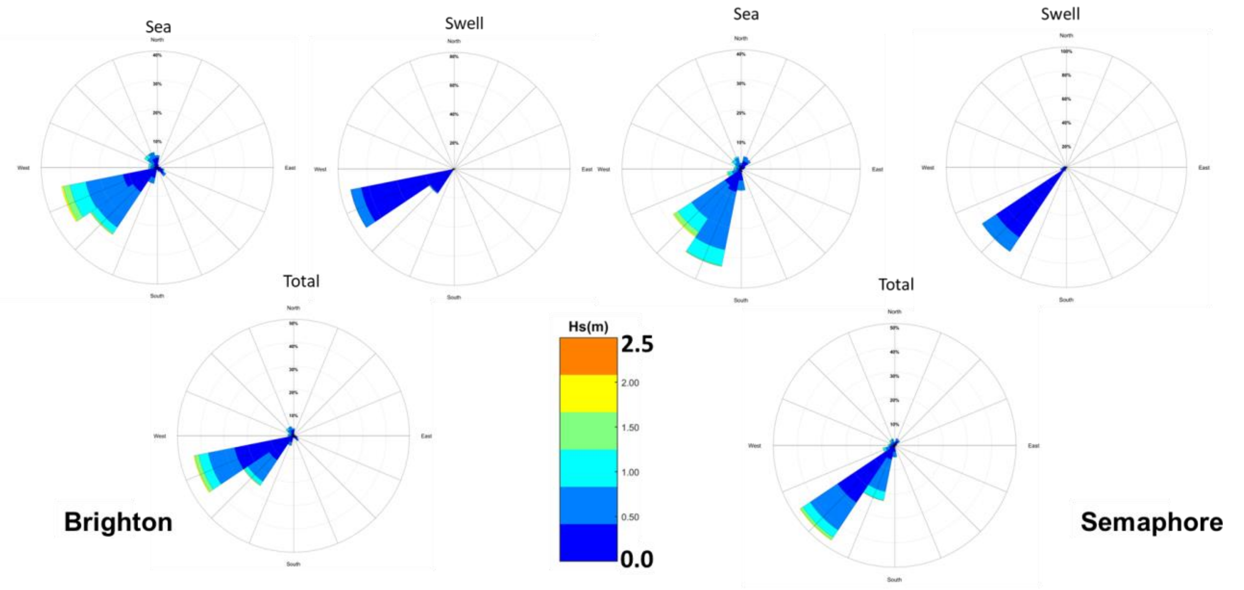


Figure 15: Total, swell and sea wave height and direction roses at Brighton (left) and Semaphore (right).

Table 6: Wave measurement statistics derived from Brighton and Semaphore wave buoys.

Parameters	Statistics	Brighton 3-year record	Semaphore 3-year record
Significant wave height (Hs) [m]	Mean	0.55	0.60
	20%ile	0.26	0.29
	50%ile	0.45	0.51
	75%ile	0.69	0.76
	90%ile	1.07	1.08
	99%ile	1.93	1.81
	99.5%ile	2.10	2.02
	Maximum	3.17	4.27
Peak wave period (tp) [s]	Mean	6.3	7.1
	20%ile	3.2	3.4
	50%ile	4.4	4.6
	75%ile	8.5	12.8
	90%ile	12.8	14.6
	99%ile	20.5	17.0
	% of time sea (Tp<8s)	0.74	0.66
	% of time swell (Tp>8s)	0.26	0.34
Peak wave direction (Dp) [ºN]	Weighted average	249	226
	STD	43	44

3.4 Tides and other water level variations

The tidal range on the Adelaide coast varies from about 2.4m at spring tides to near zero at neap tides. Tidal planes based on the latest 18.6-year tidal cycle at the Port Adelaide Outer Harbour tide gauges are provided in Table 7.

Table 7: Main tidal planes at the Port Adelaide Outer Harbour gauge.

Tidal plane	Outer Harbour (m AHD)
Mean high water springs (MHWS)	0.94
Mean sea level (MSL)	-0.08
Mean low water springs (MLWS)	-1.10
Lowest astronomical tide (LAT)	-1.52

Along the South Australian coast, ocean water levels[1] can also be influenced by other non-tidal variations such as:

- Storm surge – elevated water levels during storm events including both the barometric effect and wind-driven surge.
- Coastal trapped waves – long period waves with periods of days to weeks generated by strong wind events along the southern Australian coastline.
- Seiching – a standing wave oscillation in a body of water (e.g., sloshing back and forth in a bathtub). In Gulf St Vincent, seiching is likely to occur between the west coast (York Peninsula) and east coast (e.g., Adelaide) due to the semi-enclosed nature of Gulf St Vincent.

The water level exceedance curve provided in Figure 16 shows the total water level variation measured at Port Adelaide tide gauges. This is based on long-term water level data from the 82-year period (1940 to 2022) at the Outer Harbour site and the 87-year period (1932 to 2019) at the Inner Harbour site. The highest recorded water level was 2.35m AHD on 9 May 2016, which was during a storm that caused widespread coastal erosion particularly at West Beach.

[1] The term ‘ocean water levels’ is used to refer to water levels offshore of wave breaking. Inshore of wave breaking additional non-astronomical processes can also influence water levels including wave setup and wave runup.

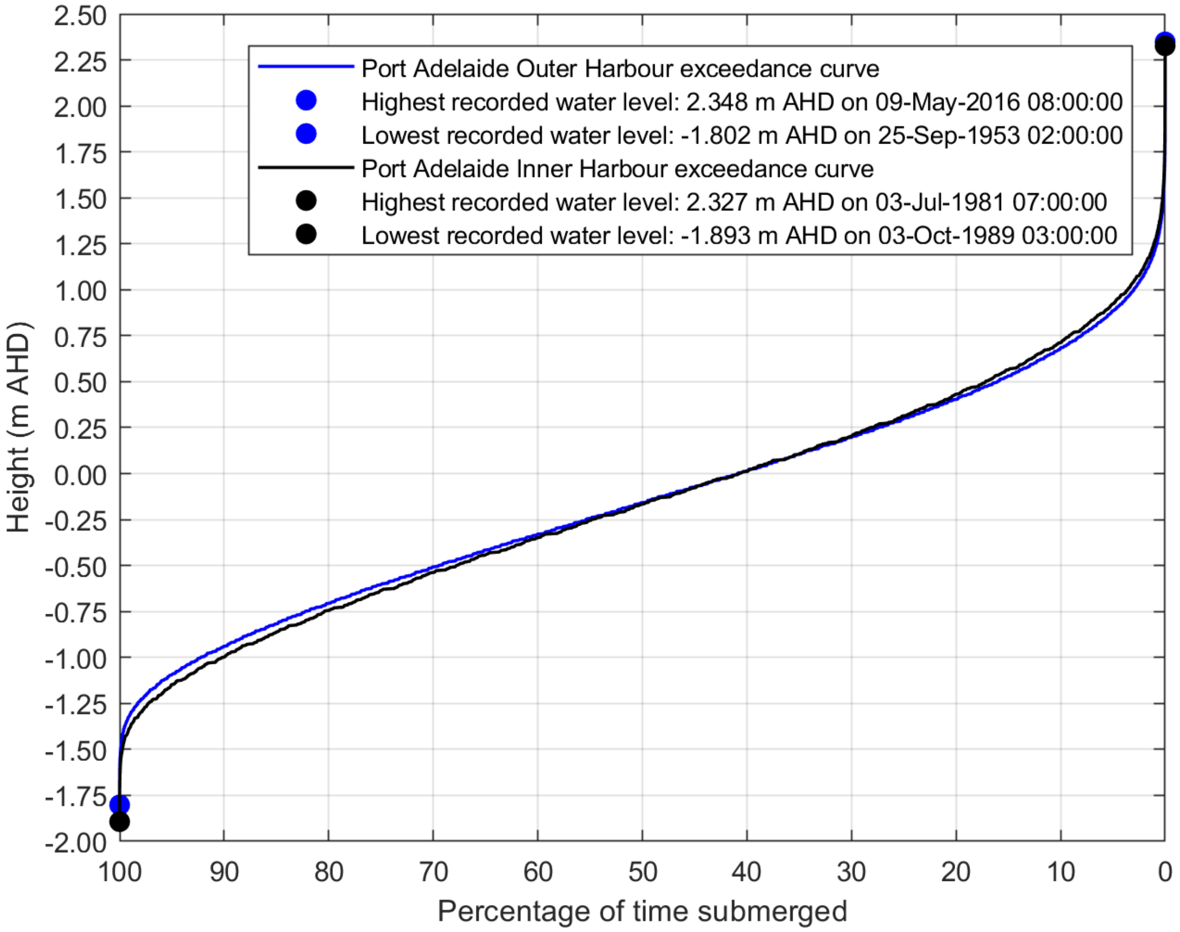


Figure 16: Water level exceedance curve for Port Adelaide tide gauges.

3.5 Climate variability and projections

The latest advice from IPCC (AR6) on sea level rise (SLR) assesses the climate response to five illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate. The report concludes that in the longer term, sea level is committed to rise for centuries to millennia due to continuing deep ocean warming and ice sheet melt and will remain elevated for thousands of years.

In the shorter term, it is certain that global mean sea level will continue to rise over the 21st century. The latest SLR (above 1995 - 2014 baseline) projections for Port Adelaide (Outer Harbour) for the ‘likely' mean SLR ranges (17th to 83rd percentiles) by 2100 are (refer to Figure 17):

- 0.27-0.58m under the very low greenhouse gas (GHG) emissions scenario (SSP1-1.93).
- 0.33-0.65m under the low GHG emissions scenario (SSP1-2.6).
- 0.42-0.78m under the intermediate GHG emissions scenario (SSP2-4.5).
- 0.50-0.92m under the high GHG emissions scenario (SSP3-7.0).
- 0.56-1.00m under the very high GHG emissions scenario (SSP5-8.5).

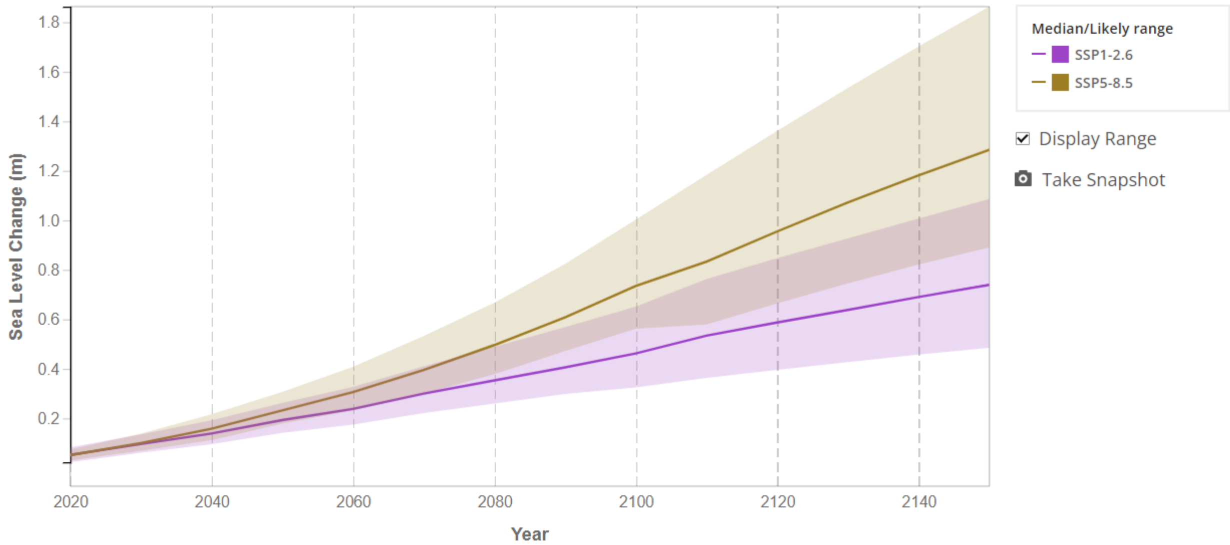


Figure 17: IPCC AR6 sea level rise projections (for Port Adelaide) relative to 1995 - 2014 baseline for the low and very high future greenhouse gas emission scenarios (Garner et al., 2021).

Note: Shaded range represents the respective 17th to 83rd percentile ranges.

4. Sand budget of Adelaide's beaches

4.1 Approach (Overview)

A coastal sediment budget is a quantitative analysis of the movement and distribution of sediment within a coastal region. Along the Adelaide's metropolitan beaches, the predominant sediment is sand. Developing a sand budget involves accounting for the sources of sand, such as erosion from coastal cliffs, discharge from rivers or onshore sand supply, and the processes that transport it, such as wave action or longshore sand movements. The coastal sand budget also includes the sinks or locations where sand is deposited, such as on the beach or within tidal inlets.

Coastal sand budgets are important for understanding the impact of coastal management practices on erosion and accretion patterns in the coastal zone. They can also help to identify areas of the coastline where erosion is occurring and where sand management strategies may be needed to prevent erosion or mitigate its effects. In addition, coastal sand budgets can be used to assess the impact of climate change on coastal processes, such as sea level rise and changes in wave patterns, and to predict how these changes may affect sand movement and distribution in the future.

4.1.1 Methodology

Analysis to determine the Adelaide's metropolitan beach sand budget involved calculating historical sand volume changes in nine (9) sediment compartments (see Section 4.1.2) along the coast. These are used to infer the rates and directions of sand movements. A quantified conceptual sand movement model was then developed to link together the drivers and volumes of annual sand movement (see Section 4.2).

Full coastal survey profiles (i.e., both subaerial and subaqueous part) were analysed to examine sand volume changes along Adelaide's metropolitan beach. DEW and its predecessors have undertaken a continuous and extensive survey profile measurement program of the Adelaide metropolitan coastline since the mid-1970s. These coastal profiles survey data set provides an extremely important resource for understanding the long-term variations in the coastal processes and for quantifying the rates of sediment transport and beach volume changes. Figure 19 shows the cross-shore profiles that were analysed to determine the rate of volume changes across the full coastal profile. Compartment sand volumes from dune to around -5 or -6m AHD were calculated by considering the distance between profiles and the long-term rate of volume change of each profile.

Due to varying data availability/quality and timing of significant human modification of the coastline within the study area, two time periods have been assessed to identify long-term trends. These periods consider all available data between:

- 1977 to 2023 (46 years) – full data period.
- 1993 to 2023 (30 years) –representative of post boat harbour construction/extension at Glenelg and West Beach.

The profile-based approach to estimate compartment volumes was verified using detailed bathymetric surveys available for West Beach. The results suggest that there is up to around 5% difference between the profile-based approach and the volume rates obtained from survey analysis for this compartment. This was considered acceptable for the purpose of the sand budget analysis.

A summary of the profile-based approach is presented in Figure 18.

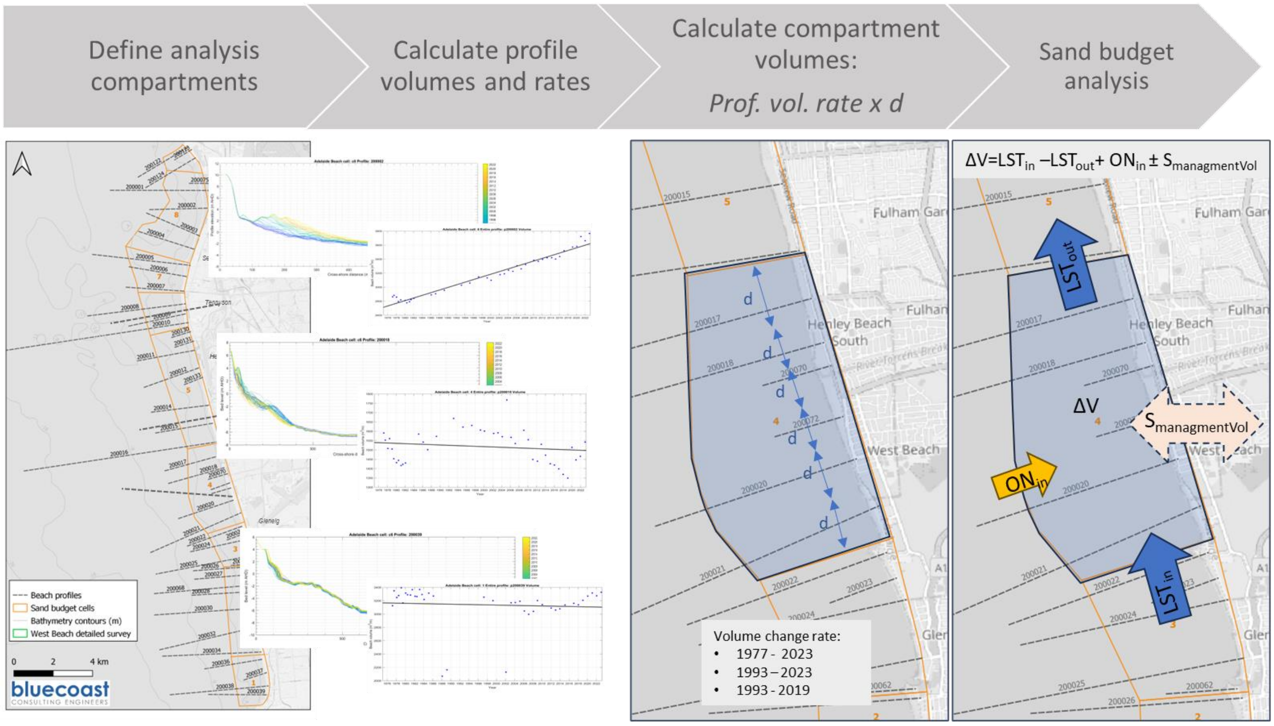


Figure 18: Summary of the sand budget analysis approach.

4.1.2 Sediment compartments

An assessment of the change in the sand volumes within the study area was undertaken adopting the nine (9) analysis cells shown in Figure 19. The alongshore extents and division of the cells were defined based on contemporary shoreline behaviour, based on a review of satellite derived shorelines (see Section 4.1.3). Cross-shore extents of the cell were defined according to the beach profile length from the top of the dune down to around -5 to -6m AHD.

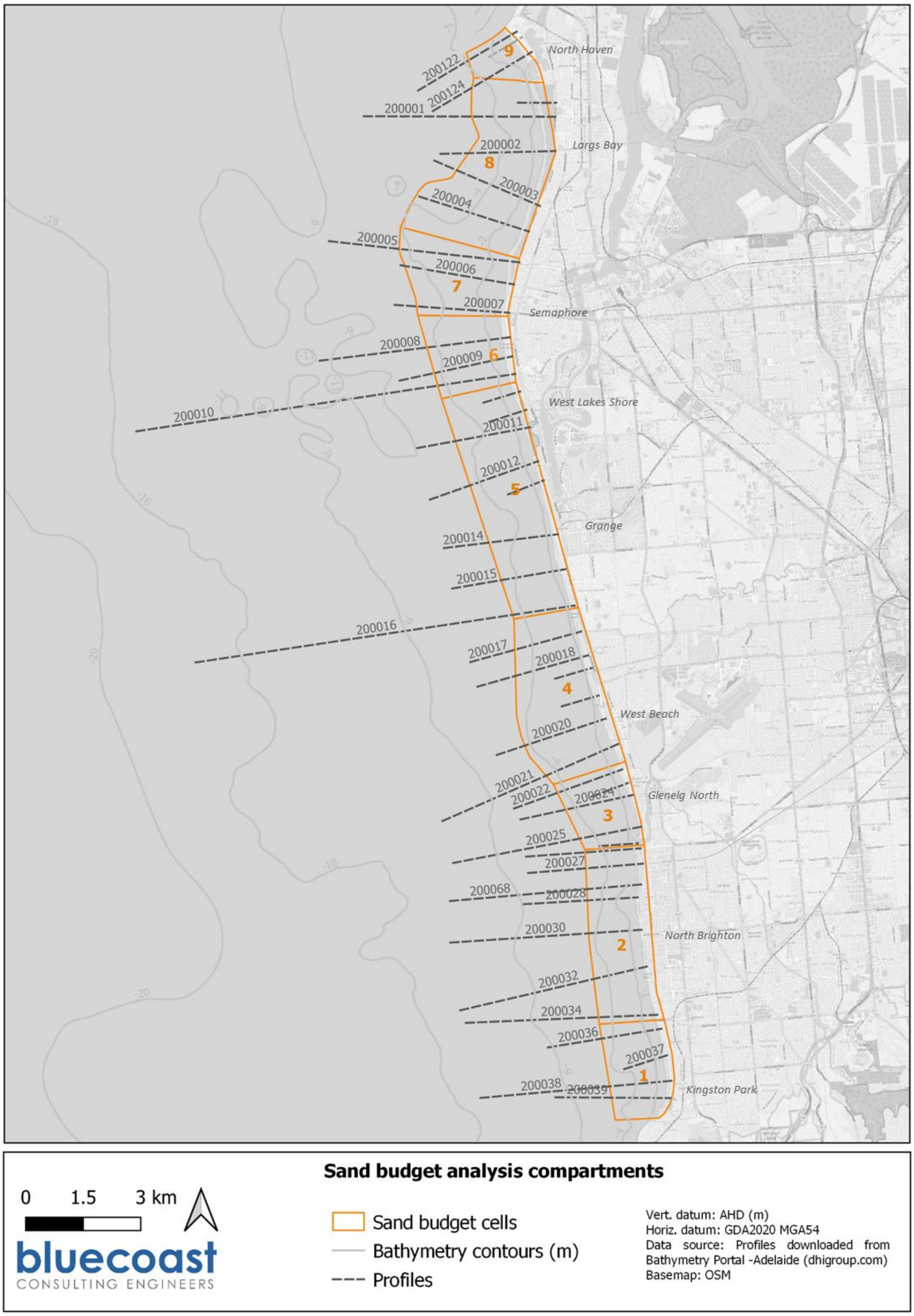


Figure 19: Sand budget analysis beach compartments.

4.1.3 Shoreline behaviour

Mean annual shoreline positions are available from Digital Earth Australia (DEA), a continental dataset that currently includes satellite derived shorelines along the entire Australian coastline from 1988 to 2022. The derived shoreline positions are shown in Figure 21. The annual rate of shoreline change is presented in Figure 22.

4.1.4 Time scale for change

The beaches along the Adelaide's metropolitan coast experience change over various time scales. This is illustrated in Figure 20 and described as:

- Long term changes occur over decades to centuries (and beyond) and are driven by persistent changes to sand budgets (e.g., reducing/increasing sand supply) and sea level rise.
- Medium term changes occur over years to decades and are driven by climatic cycles like ENSO and IPO, link to shifts in the wave climate or a result of anthropogenic changes resulting in changes to erosion and accretion patterns.
- Short term changes can occur over days, weeks, months or years and are linked to storms, seasonal variations and ENSO fluctuation.

In the context of the sand budget analysis, it is important to understand these fluctuations. Profile surveys are undertaken at a point in time with the morphology captured reflecting the preceding conditions. Short to medium term influence may thus mask longer-term trends and care must be taken in interpreting the sand volume changes.

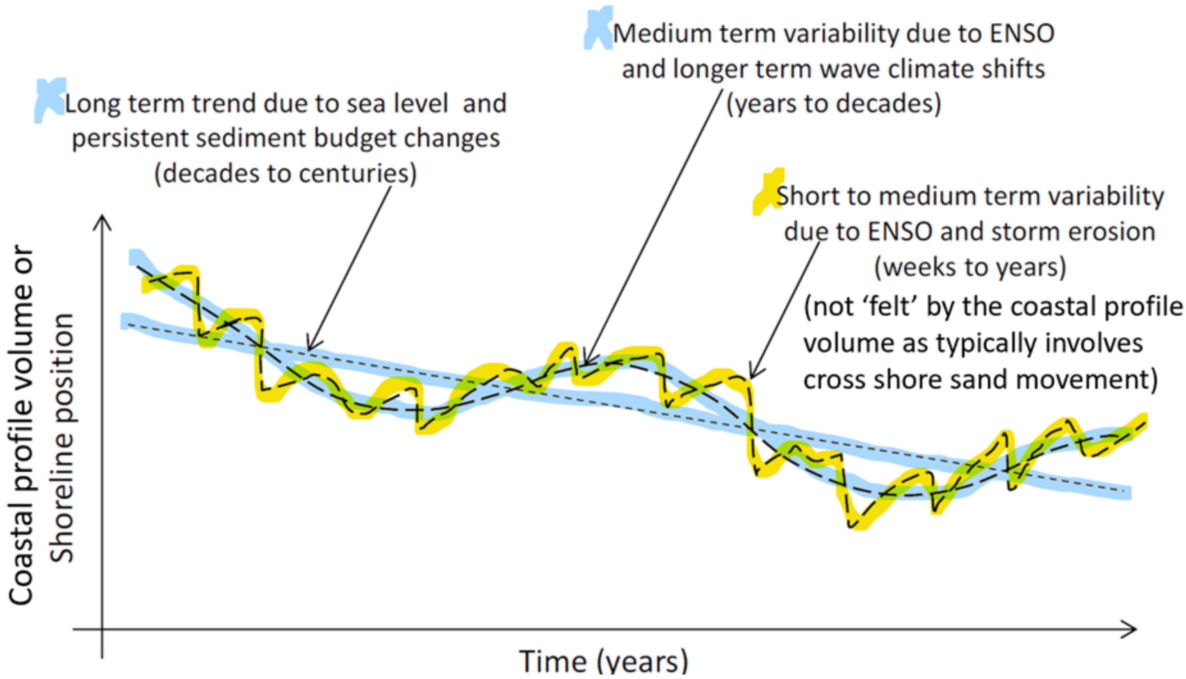


Figure 20: Conceptual illustration of time scales for beach changes (adapted from BMT WBM, 2013).

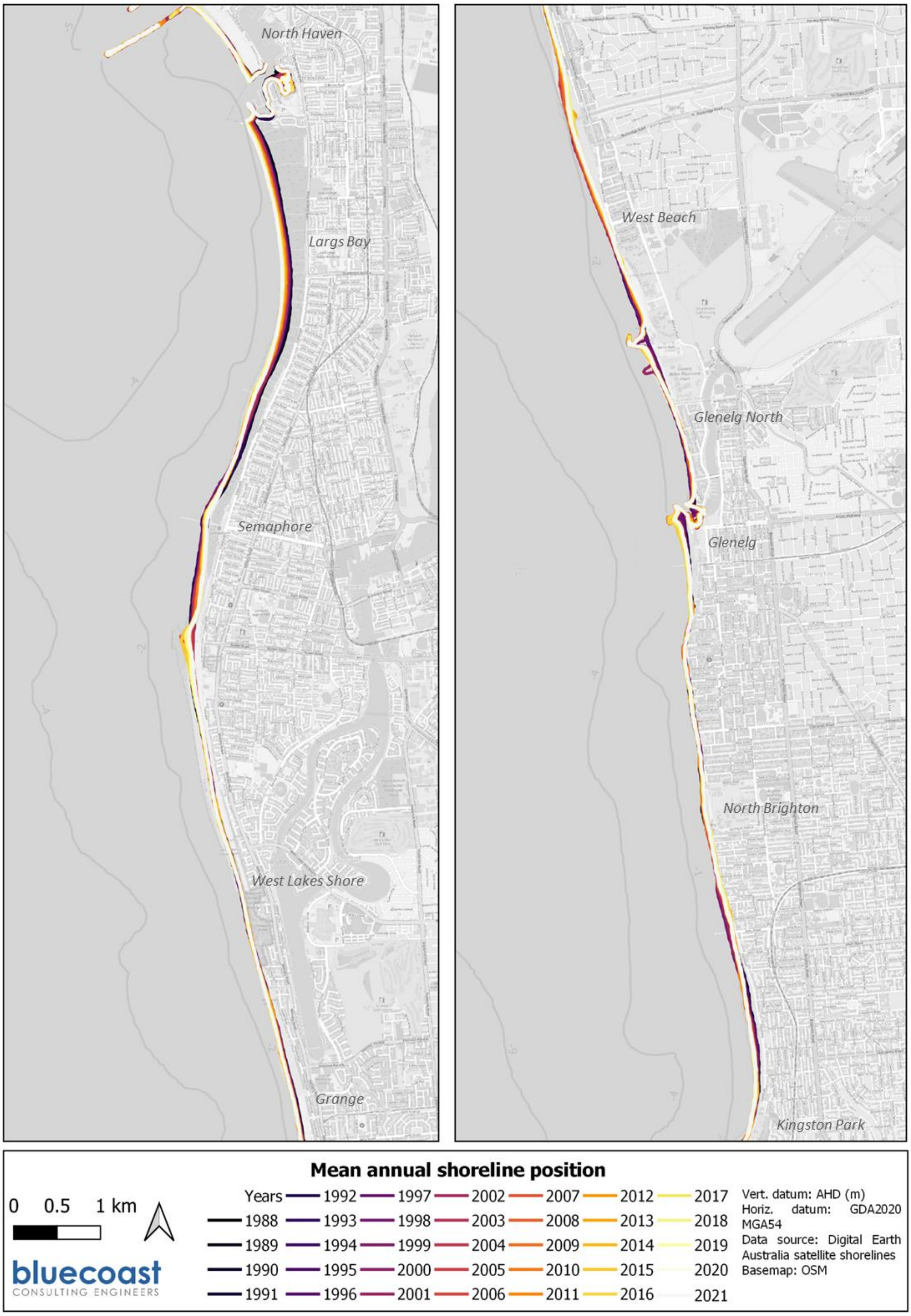


Figure 21: Mean annual shoreline from 1988 to 2021 along Adelaide's metropolitan beaches.

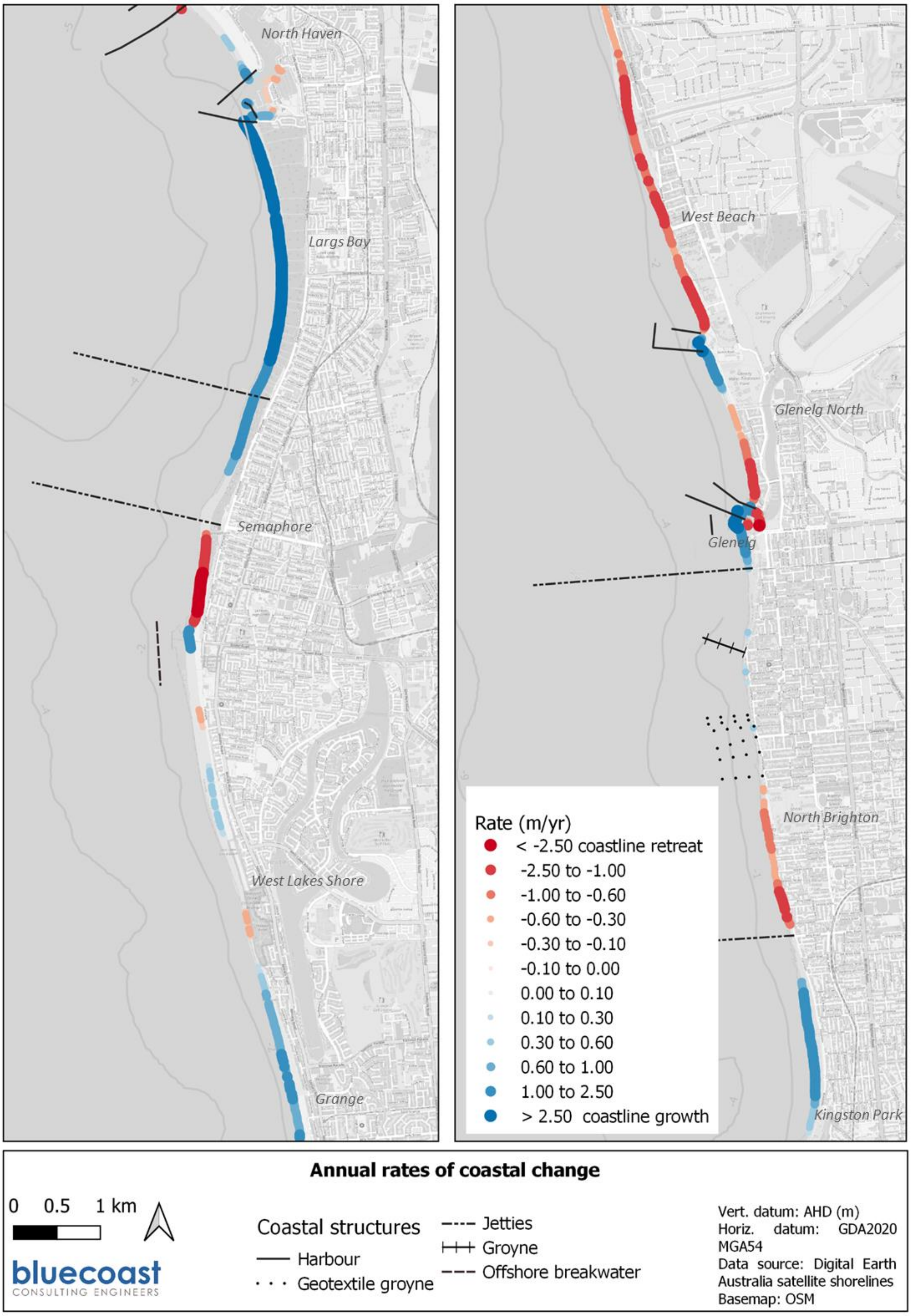


Figure 22: Rates of shoreline change along Adelaide's metropolitan beaches.

4.2 Observed beach volume changes

Table 8 provides a summary of the profiles used in each beach compartment and the rate of change observed for the two analysis periods. Figure 23 and Figure 24 present the volume change time series of all profiles in each of the compartments. The beach section is defined as the section represented by each profile. The beach section volume is calculated by multiplying the beach profile volume with the alongshore length between the profiles (see '*d*' in Figure 18).

The derived longshore sand movement rates along the study area are presented in Figure 25.

Table 8: Summary of the volume rate of change of each beach compartment.

Beach compartment	Alongshore length (m)	Profiles	Rates of change (m^3/year)	
			Long-term 1977 to 2023	Since harbour construction 1993 to 2023
1 (South Brighton)	2,669	200036, 200037, 200038, 200039	12,100	13,900
2 (North Brighton to Glenelg)	4,594	200026, 200027, 200028, 200030, 200032, 200034, 200068	-3,800	-9,600
3 (Glenelg North)	2,146	200022, 200023, 200024, 200025	170	37,900
4 (West Beach to Henley South)	4,286	200017, 200018, 200020, 200021	-15,600	-37,900
5 (Henley to West Lakes Shore)	6,676	200011, 200012, 200014, 200015, 200130, 200131, 200132, 200133, 200016	12,100	26,248
6 (Semaphore Park)	1,864	200008, 200009, 200010	-6,900	2,630
7 (Semaphore)	1,887	200005, 200006, 200008	0	1,458
8 (Largs Bay)	4,582	200001, 200002, 200003, 200004	70,700	50,043
9 (North Haven)	1,235	200122, 200123, 200124	14,100	18,015

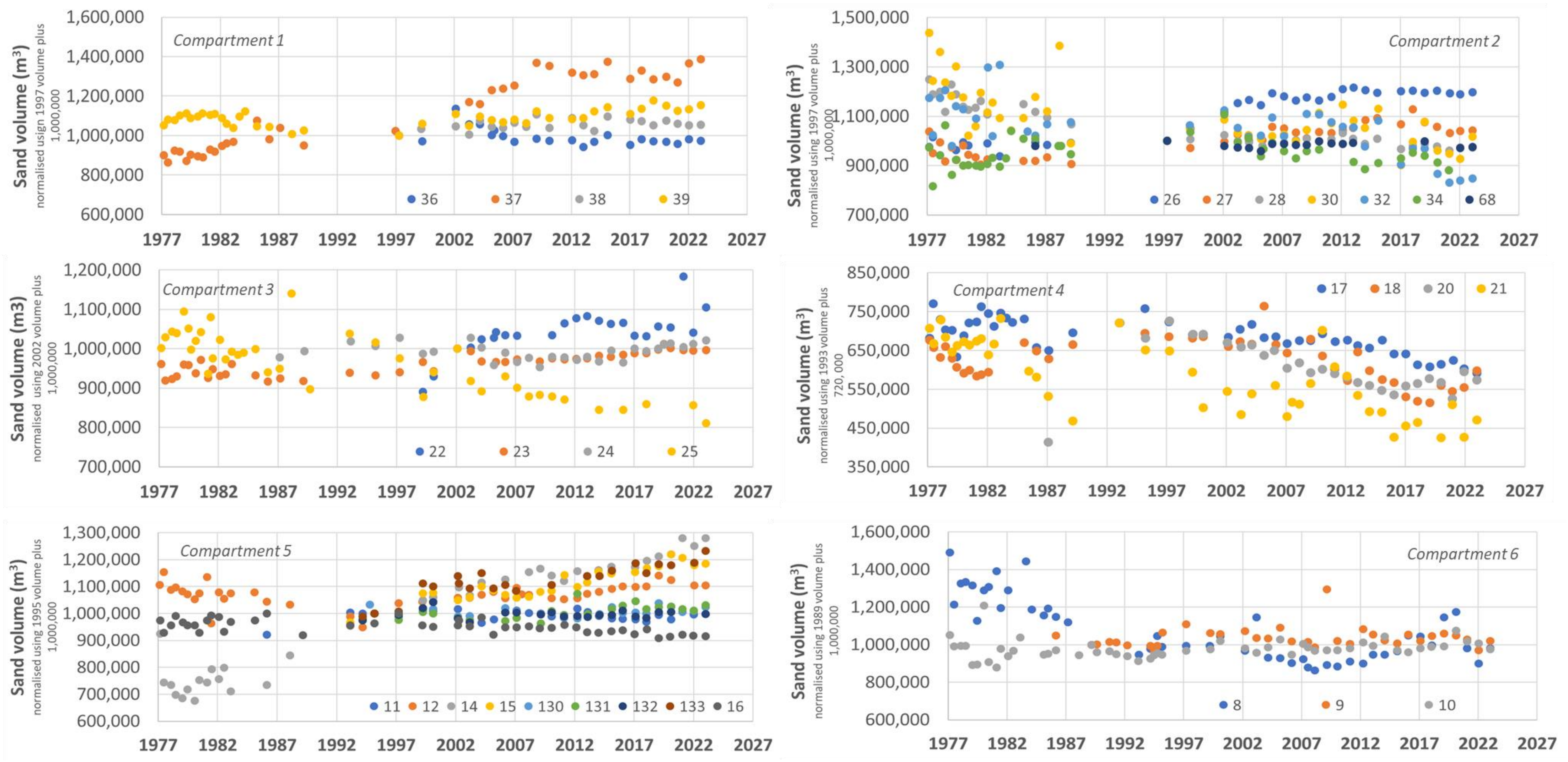


Figure 23: Beach section sand volume timeseries (profile volume per distance between profiles).

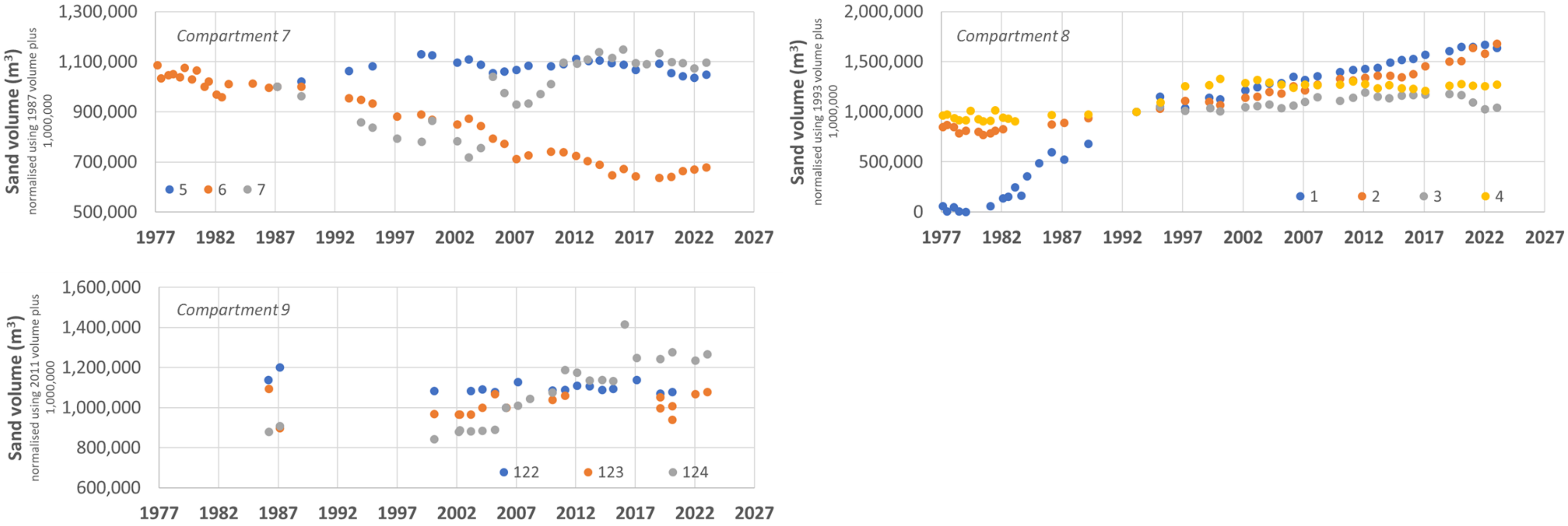


Figure 24: Beach section sand volume timeseries (profile volume per distance between profiles).

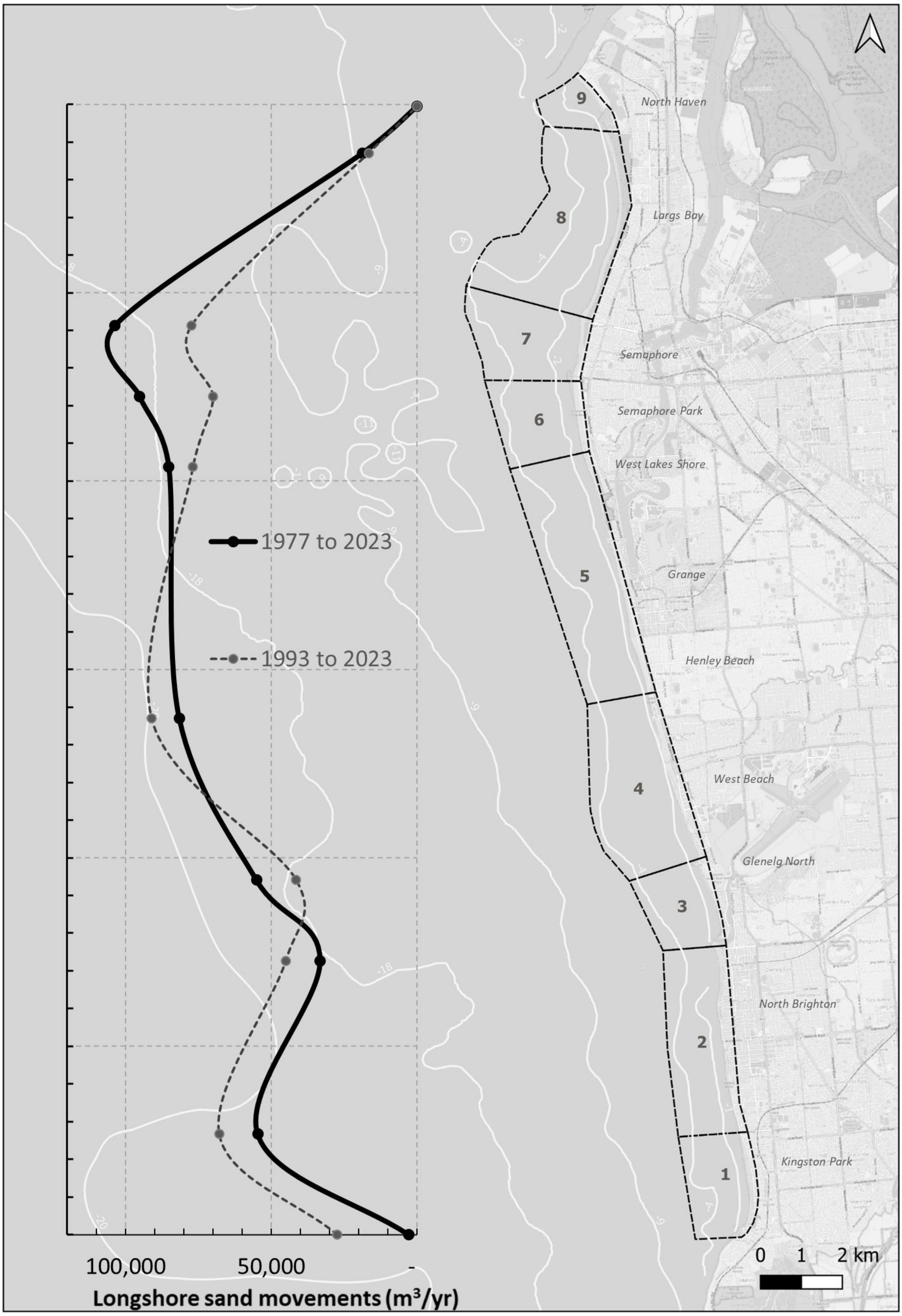


Figure 25: Longshore sand movement rates along Adelaide metropolitan beaches.

4.3 Sand budget outcomes

4.3.1 Quantified conceptual sand movement model

Figure 26 provides graphical overview of the quantified conceptual model of sand movements (quantified model) across the study area. This quantified model is based on the sand budget analysis and the assessment of each of the sand movement pathways for the period 1993 to 2023. All alongshore sand movement rates have an estimated accuracy of ±30%.

Based on historical data, previous literature and/or coastal processes knowledge, key factors that influence the observed sand volume changes and sand movements have been distilled. Wherever possible, multiple lines of evidence have been used to cross-check, validate and provide greater confidence in the findings. The key factors are summarised as:

- Past and current coastal management interventions and their interactions with the study area's natural sand movements. For example:
  - The mass sand nourishment of Brighton area (some 1.4M m^3) worked to provide a good supply of sand to the Adelaide beach system.
  - The building of the harbours at Glenelg (1964, extended in 1997) and West Beach (1998) form barriers to the natural net northward longshore sand transport pathway. Following construction, this northward longshore sand transport was artificially maintained via sand bypassing, using carting and dredging, to move around 85,000m^3/year of sand to the downdrift beach compartment (i.e., West Beach) until 2005 (DEH, 2005). Since 2005, sand accumulating at the southern side of the harbours was largely backpassed to the south at around 90,000 to 100,000m^3/year (first via sand carting then via southern backpassing pipeline). This resulted in a reduction of the sand supply to West Beach which in turn resulted in a net loss of sand of around 38,000m^3/year (when averaged over 1993 to 2023) from the beach compartment. This net loss of sand from West Beach was partially offset by sand placements sourced from the northern end of the beach system and quarries (see below). Without these sand placements, the sand loss from the West Beach compartment would have been closer to the net longshore sand transport rate out of the beach compartment at around 91,000m^3/year.
  - Importing coarse grained sand from quarries has added sand to the beach system and appears to modify the sand sizes found on some metropolitan beaches. More detailed analysis of shorter-time periods would be required to quantify the effect of coarse sand on alongshore transport rates.
- There is a general increasing gradient in the alongshore sand transport rates from Brighton (in south) to Point Malcolm/Semaphore in the north. Further north into Largs Bay, the transport rates decrease rapidly (i.e., suggesting accreting beaches with more sand coming in than going out). This outcome fits well with the generally understanding of eroding beaches along much of metropolitan shoreline with significant accretion in Largs Bay and North Haven compartments. When considering the 1993 to 2013 period, there is a notable reduction in transport rates around Point Malcom and Semaphore, which may be explained by the offshore breakwater.
- There has been a net gain in sand across the beaches, with an onshore sand supply assumed to exist. The adopted rate of onshore sand supply (1.1m^3/m/year) balances the sand budget. Over geological times the Lafevre Peninsula is known to have been supplied sand to sustain its growth but that this rate had slowed or stopped in modern times. However, the sand budget suggests that there is still some residual onshore supply. Mechanisms for this could be (i) calcareous sand

generation over seagrass meadows and Pinna beds (ii) sand eroded from the seabed in areas of seagrass loss. Any available sand would be expected to slowly move onshore under the action of long period waves. It is noted that the sand budget and conceptual sand movement model assume a zero net loss landward of the dunes. The 1970 Culver report had estimated a landward sand loss. If a net landward loss exists this would imply a higher onshore sand supply rate.

- At the southern end, the sand budget analysis estimated that on average less than 30,000m^3/year of sand is moving into the beach system from south. Based on the available evidence, it was assumed that no sand is transported out of the beach system northward beyond the Outer Harbour breakwaters.

4.3.2 Have Adelaide's beaches gained or loss sand?

The sand budget can be used to answer this question based on high quality measured data, without the need for numerical modelling. Table 9 presents the surveyed rate of net volume change, the net volume of sand imports based off the CPB's sand management records and the assumed rate of onshore sand supply which is calculated to balance the sand budget.

These values show that there has been an overall gain in the amount of sand on Adelaide's beaches of about 80,000m^3/year. Slightly more than half of this increase has been due to sand imports from management actions, while the remainder was likely to be naturally supplied from the gulf waters below -5m AHD.

While this has been relatively consistent between the long-term (1977 to 2023) and more recent times (1993 to 2023), there is a significant variation between the southern beaches (Brighton to North Glenelg) and the northern beaches (West Beach to North Haven). Without the imported sand, the southern beaches would have eroded, with a long-term sand loss rate (sand deficit) of some 26,500m^3/year calculated. In the northern management area, however, when sand import volumes have historically been much lower, the system has naturally gained sand at a rate of around 50,000 to 67,000m^3/year. Most of this net gain has been along Largs Bay, where the Outer Harbour breakwater and North Haven marina traps sand with the accumulation observed along the embayment's shoreline (see Figure 22).

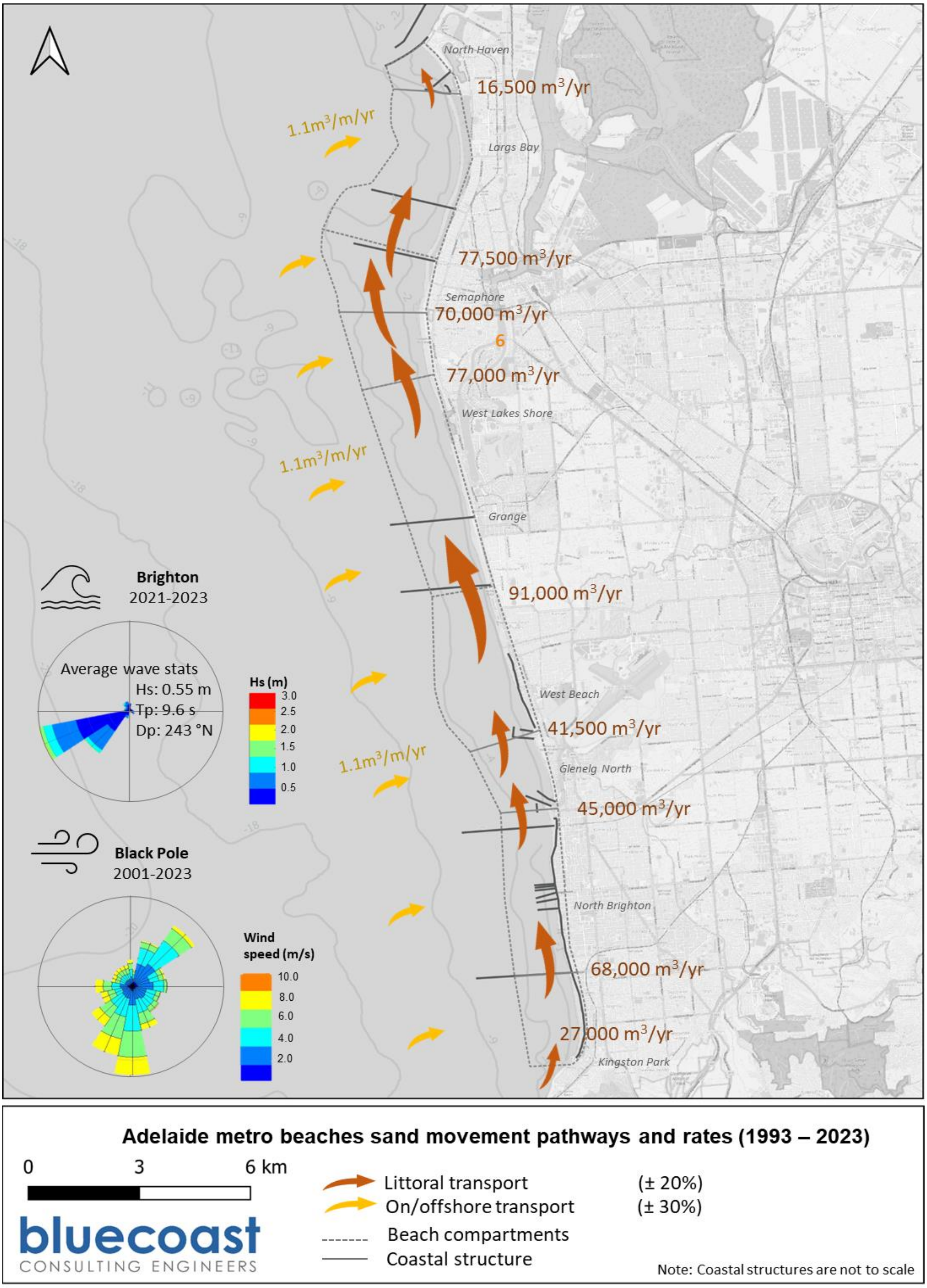


Figure 26: Quantified conceptual model of sand movements along Adelaide's metropolitan beaches.

Table 9: Net sand volume changes across Adelaide's beaches.

Management area	Parameter	Annualised rate of volume change (m^3/year)	
		1977 to 2023	1993 to 2023
Overall metro beach system	**Survey net rate of sand volume change**	**+83,000**	**+78,700**
	Net sand imported to system from external sources	+42,750	+44,500
	Onshore supply (assumed)	+40,250	+34,200
Southern management area (Brighton to North Glenelg)	**Survey net rate of sand volume change**	**+8,500**	**+18,200**
	Net sand imported to system from external sources	+35,000	+33,000
	Onshore supply (assumed)	-26,500	-14,800
Northern management area (West Beach to North Haven)	**Survey net rate of sand volume change**	**+74,500**	**+60,500**
	Net sand imported to system from external sources	+7,700	+11,500
	Onshore supply (assumed)	+66,750	+49,000

4.3.3 Considerations for northern management area

Further review of the sand budget results and survey analysis was undertaken to help inform future beach management along the northern management area. The northern management area extents between West Beach (north of West Beach Boat Harbour) to North Haven Beach (southern Outer Harbour breakwater).

The calculated sand volume change for the West Beach compartment (i.e., compartment 4) is presented in Figure 27. The relevant coastal management context is also shown. The following observations are made:

- When considering the period from 1977 to 1984, i.e., prior to significant beach erosion associated with a major storm event in 1985, the average West Beach compartment sand volume was around 775,000m^3. Mass nourishment, delivered to Brighton Beach in the 1990's helped in restoring the West Beach compartment volume to the pre-storm average levels by 1993.
- The West Beach compartment sand volume calculated based on the most recent available survey (21 November 2022) is 176,000m^3. This compartment volume is around 599,000m^3 lower compared to the pre- 1985 storm average volume.

- Between 1993 (when full recovery from the 1985 storm event was reached) and 2023, around 91,000m³ of sand per year (on average) was estimated to have moved net northward out of West Beach towards Largs Bay under the action of waves. As discussed in Section 4.3.1, a net sand loss (i.e., reduction in compartment volume) at West Beach is observed because of the blockage of natural sand supply from the south due to the impact of the Holdfast Shores, West Beach Harbour and the backpassing of sand from Glenelg.

Based on these observations, development of future sand management activities within the northern management area may consider the following:

- To restore the compartment volume to pre-1985 average levels, a total of around 550,000m³ of sand would need to be placed within the West Beach compartment. This volume assumes such sand placements would commence at the start of 2024 and considers the volume of sand already placed at West Beach in 2023 (around 139,000m³). Any delay in restoring the compartment volume would be expected to increase this volume requirement.
- To maintain the compartment volume at the pre-1985 average levels, around 90,000m³ of sand would need to be topped up annually (on average) within the West Beach compartment.

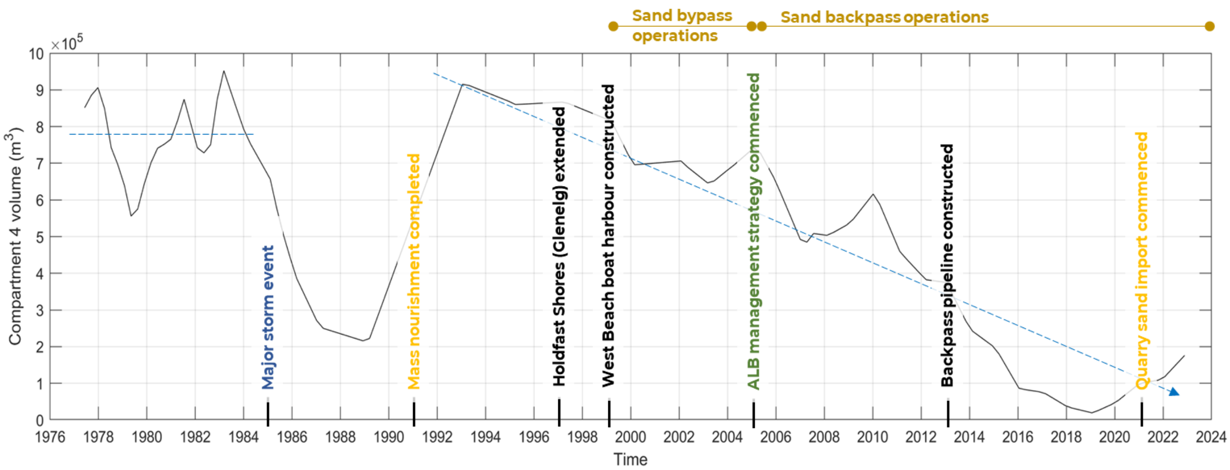


Figure 27: West Beach (compartment 4) sand volume change between 1977 and 2023 and coastal management context.

5. Longlist of management options

5.1 Approach

Building on the overview of historical and current coastal management strategies (presented in Section 2), regional coastal processes (see Section 3) and the sand budget of Adelaide beaches in Section 4, this section presents a longlist of potential coastal management options for Adelaide's northern beaches. In line with this review's terms of reference coastal management options were considered for the coastline from West Beach (north of West Beach Boat Harbour) to North Haven Beach (southern Outer Harbour breakwater), referred to herein as the management area (or northern management area). While options are focused on the northern management area, consideration is given in summary, to pathways forward when the southern sand backpassing pipeline comes to the end of its operational life.

Coarse filtering of options is undertaken with a shortlisting of options presented. The approach used to identify a longlist of options and then shortlist the most feasible involved:

- Initially key **constraints and opportunities** relevant to coastal management of Adelaide's metropolitan beaches were established. Information on these constraints was used to inform option identification and feasibility including assessing longlist options against the assessment criteria used in the coarse filter.
- A **longlist of options** was then identified based on:
  - coastal management options previously used along the study area's beaches or identified in the comprehensive set of previous literature
  - coastal management options that emerged from this review
  - suggestions by the community gathered during the engagement (UPRS, 2023b)
- Each longlist of options was then briefly described. The longlist consists of discrete options (i.e., sand backpassing <u>or</u> seawall), it does not consider specifically considered combination of options (e.g., sand backpassing <u>and</u> seawalls). Combining options to form an integrated coastal management scheme or strategy is considered when developing the selected shortlist of main options (refer to Section 6).
- A **coarse filter assessment** was then used to eliminate and rank options using a set of three criteria. The draft assessment criteria were presented at a public workshop in May 2023 where feedback was sort. The filter process was used to arrive at a shortlist of the **five** most feasible coastal management options that were carried forward for further develop and comparative evaluation as coastal management schemes for the northern management area.

5.2 Constraints and opportunities

Key coastal management practices that could constrain the development of options for future management options are listed in Table 10 below. The constraints and opportunities are broadly broken down into the following categories:

- Existing (fixed) coastal management.
- Assets, land management and development.
- Environmental constraints.
- Community values (amenity).

Table 10: Constraints and opportunities relevant to coastal management of Adelaide's beaches.

Category	Item	Constraint (black) and/or opportunity (green)
	Existing backpassing pipelines	Existing backpassing pipelines have already been constructed with significant CAPEX. The southern backpassing pipeline has been successfully operated for several years. It has been assumed to continue to operate to the end of its design life. A second shorter pipeline from Torrens Inlet to West Beach was more recently constructed and represents an opportunity for future management options for the northern area.
	***Securing the future of our coastline* (proposed pipeline)**	Existing designs and a DA approval for a 10km extension of the Torrens to West Beach pipeline have been developed and a contract commenced for its construction. This work was halted in response due to a lack of support from community. Utilising the work completed on project planning as well as a continuation of current and planned management practice represents an opportunity.
Existing coastal management (**Figure 28**)	**Sand sources**	Terrestrial sources of sand (quarries) are relatively expensive and limited. Based on the available information, no nearshore of offshore sand sources for the quantities of nourishment material required have been identified. This is explored in **Appendix C**. There is an opportunity to locate a suitable source of sand within the system or external to the system to increase the sand management options available.
	Harbours at Glenelg and West Beach	The harbour structures disrupt the northerly longshore sand transport. Sand is not effectively bypassed around these structures. While they may be opportunity for more efficient bypassing activities to restore sand supply, this must be considered in the context of the ongoing operation of the southern backpassing pipeline. Subject to Harbors and Navigation Act 1993 and consultation with SA Department for Infrastructure and Transport.
	Existing timber jetties	Could be utilised in future management and monitoring options.

Category	Item	Constraint (black) and/or opportunity (green)
	Existing seawalls	Seawalls, or vary standard and design, have been built over recent history to protect coastal assets. These coastal structures are managed by different local councils and range of their condition. They typically protect landward assets and can not be relocated without also relocating the protected assets. Could be utilised in management options.
	Existing groynes	There are existing groynes at Glenelg South (the Broadway) and Somerton (6 x geotextile). Now mostly buried. Provides insights into effectiveness of such structures as part of a management strategy.
	Port	Opportunity for use by construction plant/ dredgers if part of management strategy. Local marine contractors and services, including monitoring.
Assets, land management and development (**Figure 29**)	**Local Government Area (LGA) boundaries**	The northern management area covers four LGAs. Each Council is responsible for the coastal structures within their boundaries. These assets impact future management strategies, coordination required. The Councils are important stakeholders in coastal management.
	Coastal Protection Board (CPB)	The CPB has the power carry out works, remove sand, acquire coastal land (with the approval of the Minister) and deal with its land (with the approval of the Minister).
	SARDI water intakes	There are four sea water intakes / outlets offshore of West beach with the closest around 450m from the shoreline and the deepest being around 1.45km offshore (see Figure 31). These are used to supply seawater to the South Australian Aquatic Sciences Centre (SAASC) at West Beach. The intakes are sensitive to water quality parameters. Water quality data is collected at the intakes.
Environmental constraints (see **Figure 30** & **Figure 31**)	**Seagrass and wrack**	Extensive seagrass meadows exist in the nearshore of the management area. In South Australia, seagrass is protected under the *Native Vegetation Act, 1992*, which is administered by the Department for Environment and Heritage, as well as *Environment Protection (Water Quality) Policy 2015* under the *Environment Protection Act 1993*. Consultation with the Native Vegetation Council would be required should areas with seagrass be considered for dredging. Seagrass wrack drifts ashore from the meadows and accumulates in the intertidal, beach berm and other areas. It

Category	Item	Constraint (black) and/or opportunity (green)
		can be a significant component of sand composition in some areas. The wrack presents challenges and potentially some opportunities for future management options. Additional background information and management context is given in Section 5.2.1.
	Marine Parks	There is a small marine park noted as 'Habitat Protection Zone 8' outside the entrance to the Patawalonga River subject to the *Marine Parks Act 2007*. A Habitat Protection Zone is defined as being a zone primarily established so that an area may be managed to provide protection for habitats and biodiversity within a marine park, while allowing activities and uses that do not harm habitats or the functioning of ecosystems.
	Dolphin sanctuary	The Adelaide Dolphin Sanctuary covers Port Adelaide River and Barker Inlet with its offshore boundary just seaward of the Outer Harbour breakwaters and encompassing North Haven Marina. Subject to the *Adelaide Dolphin Sanctuary Act 2005*.
	Shipwrecks	There are various known shipwrecks, particularly around the Outer Harbour subject to the *Heritage Places Act 1993*. These may have heritage significance and their locations are noted for dredging permits.
	Dunes	Threat to dunes and dune vegetation during nourishment works, pipeline construction as well as machinery operating on beach adjacent to dunes (flattening and flora destruction). Increasing the sand buffer could support dune growth/ rehabilitation.
Community values (**Figure 29**)	**Beach width**	Some community members wish the beaches maintained to historical levels (SquareHoles, 2020). Particularly important in areas of high dog-walking traffic. Can be used to determine the required ongoing nourishment volumes and placement strategy.
	Harbours and marinas	Used for recreational and commercial boating.
	Jetties	Provides recreational amenity.

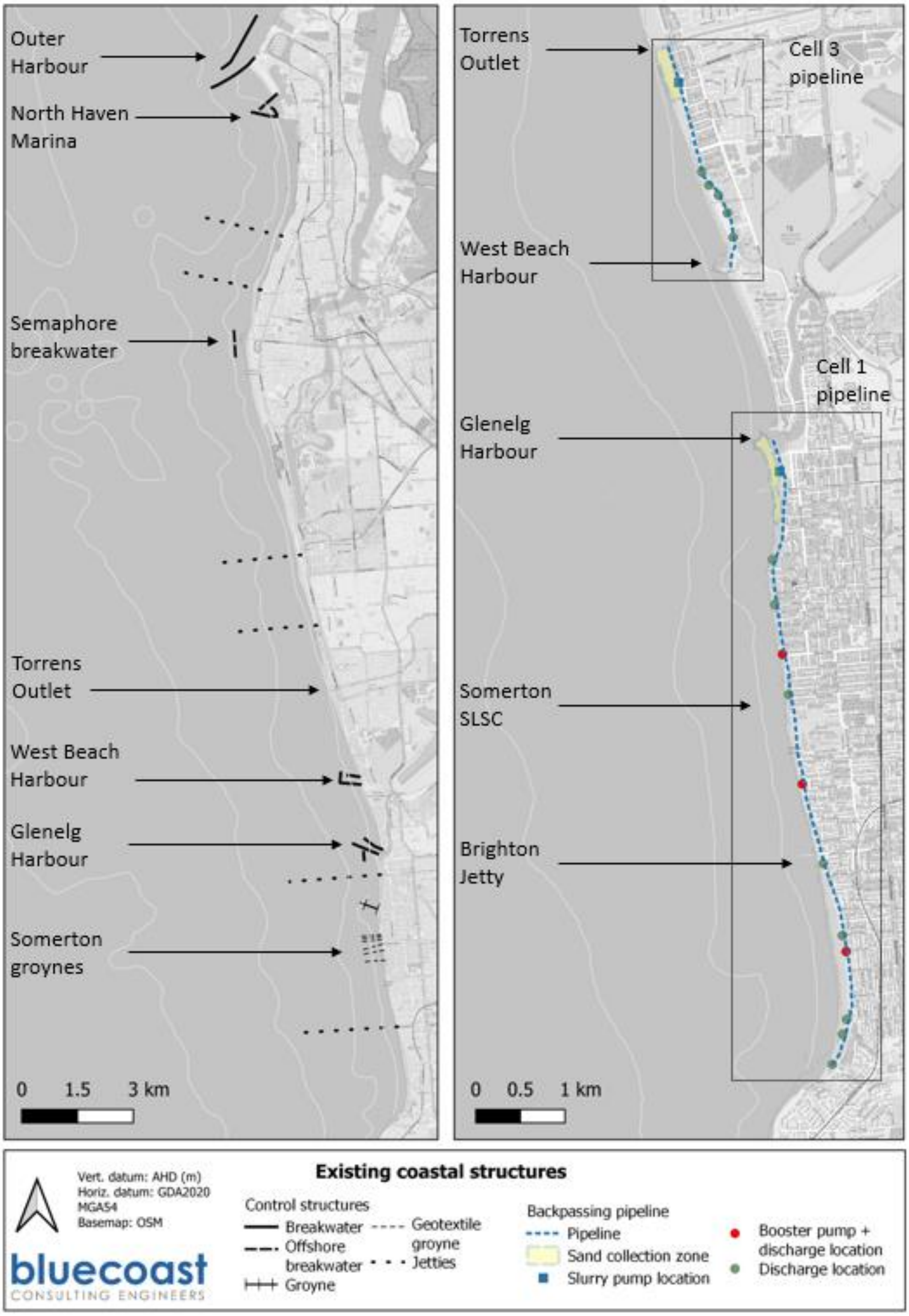


Figure 28: Existing coastal management structures that effect the management of Adelaide's beaches.

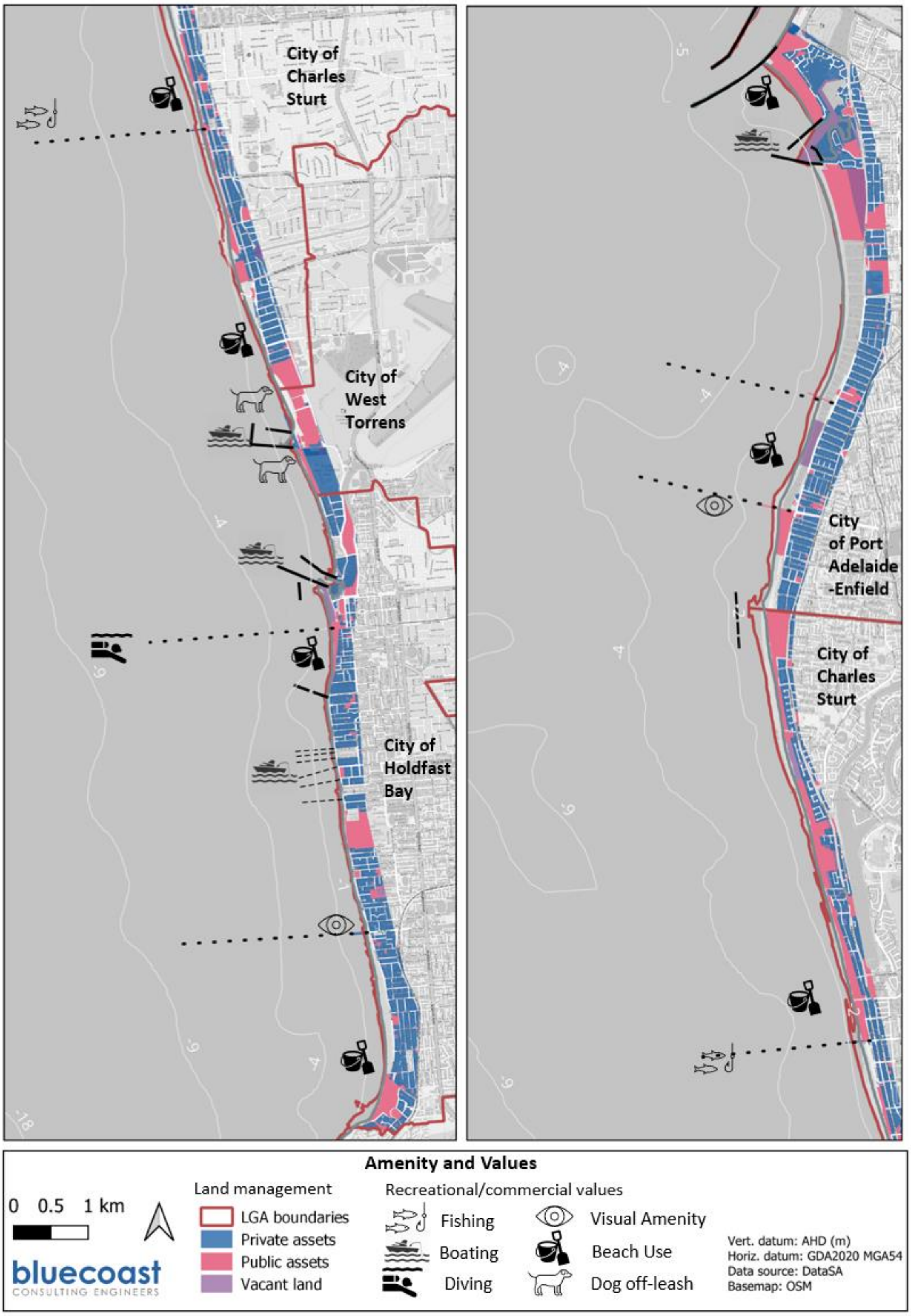


Figure 29: Land management boundaries and community values along Adelaide's beaches.

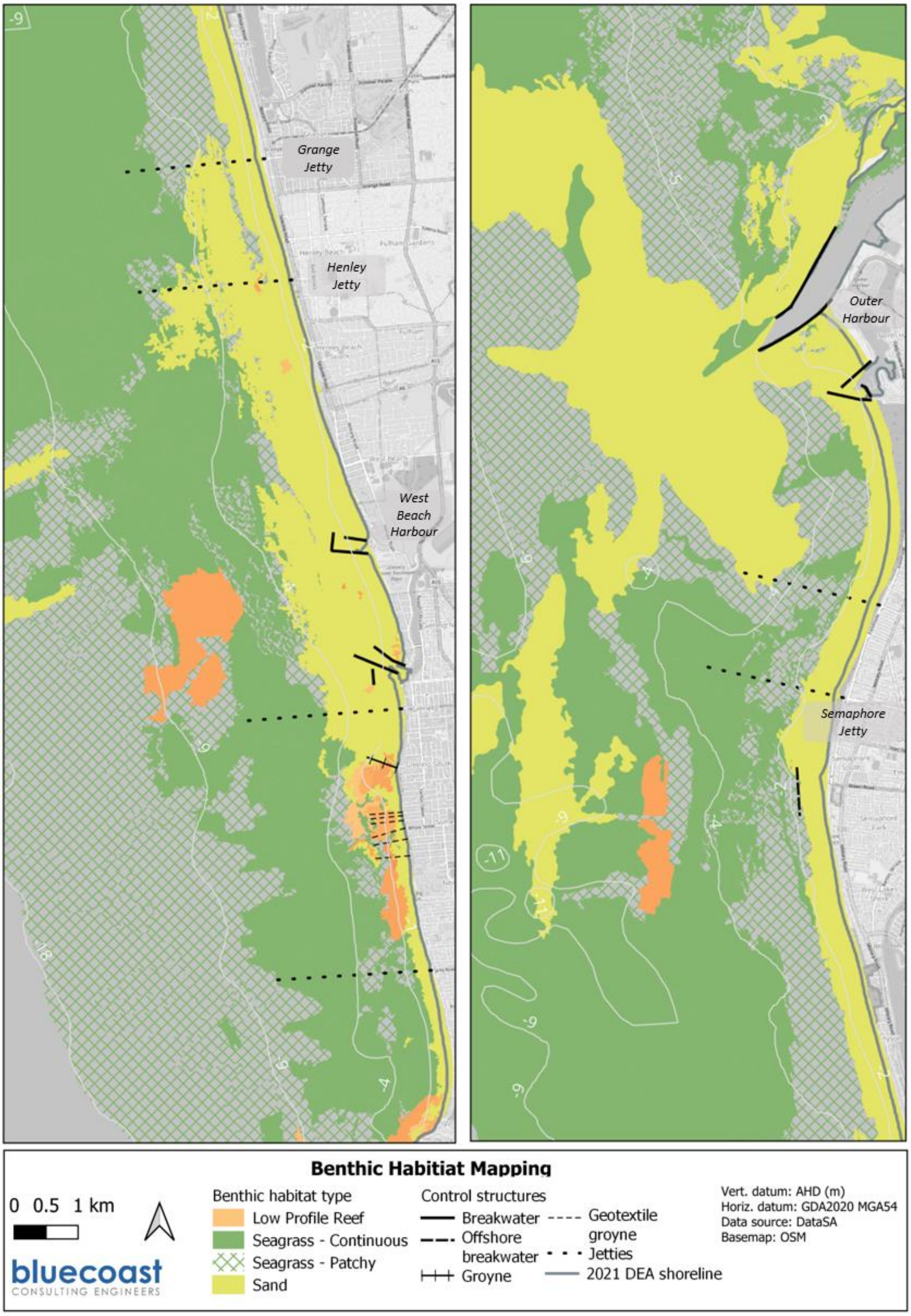


Figure 30: Seabed type mapping along Adelaide's beaches.

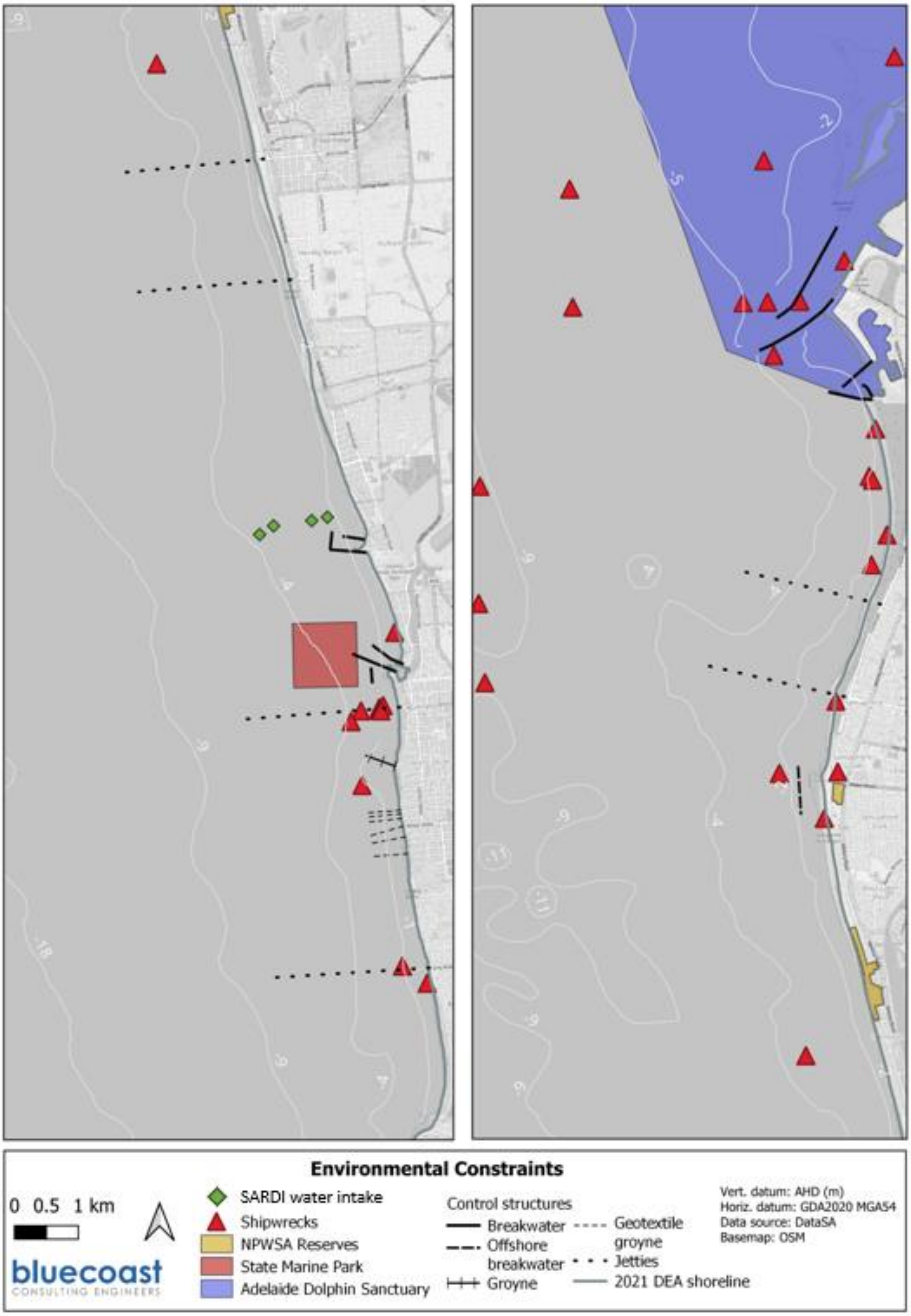


Figure 31: Environmental constraints applicable to Adelaide's beaches.

5.2.1 Seagrass along the Adelaide coastline

Seagrass along Adelaide's coastline plays an important role in providing habitat for marine life (EPA, 2006). However, human activity over the past century has led to substantial decline (Tanner et al. 2014). Key factors in this decline include sewage outfalls, stormwater runoff pollution, infrastructure development and boating impacts.

Dredging activities are also believed to have had direct and indirect turbidity impacts of Adelaide's seagrass meadows (EPA, 2000). Dredging remains necessary at ports, marinas, and boat harbors in Adelaide to maintain safe navigational access. The South Australian EPA has developed a Dredge Guideline that is intended to assist dredging proponents and licensees in meeting their general environmental duty under section 25 of the *Environment Protection Act 1993* (EPA, 2020). This guideline has been referred in this review to better understand anticipated licencing requirements for beach nourishment using a dredger. For example, source quality, timing of works, and employment of environmental best management practices provide pathways for sustainable dredging. A preliminary meeting with EPA staff was also attended.

Recent management efforts have focused on restoring Adelaide's seagrass. Initiatives to reduce runoff pollutants are helping water quality and clarity to improve growth conditions (Gaylard et al., 2013). Replanting trials have also been attempted in degraded areas (Seddon, 2004). It is believed that healthy seagrass meadows will better enable the stability of Adelaide's beaches.

There are seabed areas adjacent or nearby the Adelaide metropolitan coast that are bare sand or isolated or sparse seagrass cover (less than 5-20%). For example, the nearshore area immediately of northern Largs Bay to the Port River outlet at Outer Harbour are presently bare sand (see Figure 30). This is likely due to the turbidity and nutrient load discharged by the Port River as well as the deposition of northerly littoral sand from the metropolitan beaches.

While areas of bare sand offer potential as sand sources, they require further investigation as sand sources. Some areas are known to contain layers of seagrass root matte and seagrass fibres. This is discussed further in **Appendix C**.

5.3 Identification of options

Coastal management options were developed for the northern Metropolitan beaches from West Beach in south to North Haven in the north. The main causal mechanism of the long-term erosion observed at West Beach is explained by:

1. The blockage of natural sand supply from the south due to the impact of the Holdfast Shores, West Beach Harbour and the backpassing of sand from Glenelg, and
2. The natural net northward movement of sand that, under the action of waves, acts to move sand out of West Beach towards Largs Bay.

As a result, the erosion at West Beach has proceeded beyond an acceptable natural sandy buffer (i.e., the buffer does not provide an acceptable level of coastal protection or beach amenity). Sand nourishment would act to reinstate an acceptable sandy buffer which would then need to be maintained, as described in Section 4.3.3. Various other options could be implemented to influence shoreline behaviour or to accommodate the expected shoreline and beach change. The net northward movement of sand ends at Largs Bay and North Haven where littoral sand accumulates against the Outer Harbour and North Haven Marina.

The potential management options are characterised into categories by the way they address the northward transport of sand within the system. These categories are:

- **'Keep sand moving'** – these solutions work by reinstating the natural supply of sand into the West Beach compartment and the northern management area. That is, they remove the causal mechanism number 1. Regular and on-going supply of sand to the management area will maintain the sandy buffer and when delivered in combination with nourishment to restore and maintain the buffer to acceptable levels. To maintain the sandy buffer the sand supply rate should match the natural sand supply rate. Sand backpassing, i.e., recycling of sand in an updrift (southerly) direction is included under this theme. With the exception of backpassing, no downdrift erosion impacts would be expected as these solutions are aimed at 'keeping sand moving' (i.e., they work with nature).
- **'Keep sand in the system'** – these solutions work by retaining sand in the management area by (locally) slowing down northward longshore sand transport rates. That is, they reduce or reverse causal mechanism number 2. The options to 'keep sand in the system' involve either shoreline control structures or nearshore control structures. None of these options introduce new sand into the management compartment and all the structural solutions will be required to be combined with nourishment. While these options have high capital costs, they would reduce the need for ongoing sand renourishment in the southern compartment and/or move the erosion problem to the north. Due to the obstruction created in the northward flow of sand, these solutions would all have a downdrift impact (i.e., they would realign the northern shoreline landward to a degree). This downdrift impact would be reduced/eliminated if the southern compartment is filled and regularly topped up with enough sand to offset downdrift sand movements.
- **'Hold the line'** – these solutions do not address the causal mechanisms of sand loss in the management area. Instead, they act as a last line of defence against coastal erosion irrespective of sand movements. Without any extra supply, northward sand movements will continue to erode the sand seaward of the protection works until the sandy buffer is exhausted. If well designed the options will protect the land and built assets landward of the structures from erosion. These options will also have downdrift impacts and ultimately shift the erosion problem further north.
- **'Avoid'** - these solutions do not address the continual northward transport of sand along Adelaide's beaches. Instead, they act as a last line of defence against coastal erosion irrespective of sand movements. Without any extra supply, northward sand movements will continue to erode the sand on the southern beaches until there are only protective structures as a buffer to infrastructure. Alternatively, managed retreat could increase the buffer between the encroaching shoreline and public/private assets.

Lastly, a fourth management theme (i.e., **'complementary management'**) was considered which comprises options that are complementary to the above list and do not provide adequate benefits or are not feasible/acceptable on their own.

5.4 Longlist of options

A brief description of each coastal management option on the longlist is provided in Table 11.

Table 11: Longlist of coastal management options for Adelaide's northern beaches

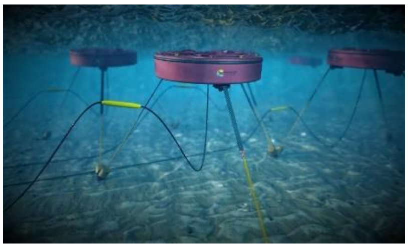
ID	Option	Example
'Keep sand moving' (sand management approaches)		
A	**Backpassing**	

ID	Option	Example
A1	**Backpassing pipeline** Permanent underground pipeline used to transfer sand from suitable updrift areas to downdrift locations requiring nourishment. Sand will be placed on the upper beach at predetermined outlet locations. This option has previously been developed as part of the *Securing the Future of our coastline project*. Technical details have been assumed from that project. A key element is the sand intake. There are various ways sand can be collected and slurred so it can be pumped via the pipeline. This A1 option assumes land-based collection with a sand collection unit (SCU) placed on the beach for the duration of a pumping exercise and earth moving equipment (sand planes, excavators, dozers, Moxy truck etc) used to harvest beach sand and supply it to the SCU. This configuration is as per the proposed northern pipeline.	 Outlet of Glenelg to Kingston Park pipeline (source: DEW).  Sand collection using sand plane (source: DEW).
A1.1	**Nearshore fixed sand intakes for backpass pipeline** This is a key sub-option involving an alternative sand intake for a backpassing pipeline. Under this sub-option jet pumps (or similar) would be lowered into the nearshore seabed and used to harvest sand and supply it directly into a backpass pipeline. Multiple intakes would be required and could be fixed or semi-mobile. It is envisaged, subject to further assessments, that intakes could be located on the existing Semaphore and Largs jetties. Could be used in conjunction with A1.2. If successful it would remove the need for sand harvesting for the visible (subaerial) beach.	 Sand Shifter fixed sand collection pump (source: Slurry Systems Marine).
A1.2	**Nearshore mobile sand intake for backpass pipeline** Like the A1.1 sub-option, this is an alternative sand intake for a backpass pipeline. This alternative would involve using a small to medium sized cutter suction dredge (or similar) to collect sand from the nearshore area in locations where sand accretes (e.g., between Semaphore South and Largs jetty). The sand would be pumped directly into a backpassing system. Could be used in conjunction with A1.1. If successful it would remove the need for sand harvesting for the visible (subaerial) beach.	 Small cutter section dredge (source: IHC Dredging).

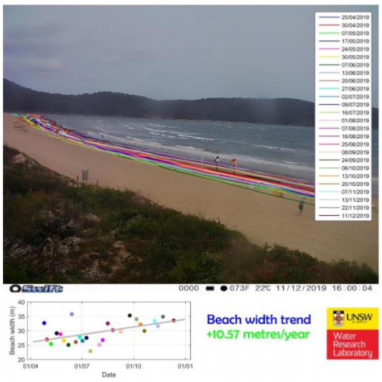
ID	Option	Example
	Alternatively, and to improve operability a custom designed barge could be used to temporarily install a jet pump (or submersible (dop) pump) in nearshore locations, pumping the sand directly into a backpassing system.	
A2	**Sand carting** The option involves using trucks to backpass sand south from suitable downdrift areas where sand accretes to updrift areas where coastal erosion is occurring. Trucks would access the beach to be loaded using earthmoving equipment (like land-based sand harvesting discussed for A1). Trucks would cart the sand via local roads before reassessing the beach to place sand in piles along the upper (subaerial) beach. The sand would need to be reprofiled using earthmoving equipment. Sand can be placed flexibly in locations where the erosion has most occurred in the preceding period.	  Sand carting on Adelaide beaches (source: DEW).
A3	**Backpassing using a dredge** Undertake ongoing dredging of suitable northern nearshore sand deposits and deliver it to West Beach or other southern beach within the management area in need of sand. It is envisaged, subject to further assessment, that a small and manoeuvrable trailer suction hopper dredger (TSHD) would be used. Such a method would not require any earthmoving equipment on the beaches at the northern part of the management area. Placement of the sand would be either via pump ashore (to subaerial beach) or by rainbowing or bottom dumping to the nearshore. The pump ashore method would require earth moving equipment on beach.	 A TSHD rainbowing sand into nearshore area (source: City of Gold Coast).
B	**Beach nourishment (importing external sand)**	

ID	Option	Example
B1	**Mass nourishment (sand engine) using external sand** Large (>1,000,000m^3) one-time mass nourishment aimed to provide a sandy buffer using material from an external source. Northerly transport rates would ensure that this material is distributed along the beach system over time.	 'Sand Engine', Netherlands (source: deltares.nl).
B2	**Ongoing nourishment using external sand** Regular ongoing sand placements using dredged sand from a source outside of the beach system. Nourishment volumes and placement locations to align with observed sand loss rates and natural littoral drift.	 Brisbane TSHD (source: Port of Brisbane).
B3	**Coarse (quarry) external sand** Nourishment of the beach system using externally sourced sand with a larger grain size than the native beach sand. This would reduce the transport rate requiring less nourishment activity.	 Quarry sand (source: Tegra Australia).
C	**Sand bypassing**	
C1	**Fixed bypassing systems** Fixed sand bypass system perpetually transferring sand across the major control structures via pipeline to reinstate natural sand bypassing rates.	 Sand bypass system, Southport (source: City of Gold Coast).

ID	Option	Example
C2	**Removal of existing control structures** Structural modification or removal of the existing control structures aimed at reinstating the natural rate of sand transport.	 Existing control structures at Glenelg (source: DEW).
'Keep sand in the system'		
Shoreline control structures		
D1	**Artificial headland(s)** Barrier to longshore sand transport aimed at retaining sand on the updrift beach to maintain the sandy buffer in those areas. Planform of the structure can provide foreshore amenity and resemble a more natural rounded headland shape compared to a groyne assisting in a more consistent alongshore flow of sand around the structure. Can be designed as multiple smaller or single larger structure	 Artificial headland, Townsville (source: Nearmap).
D2	**Groynes** Barrier to longshore sand transport aimed at retaining sand on updrift beach to maintain the sandy buffer in those areas. Can be designed as multiple smaller (i.e., groyne field) or single larger structure. A single terminal groyne has not been considered as it was deemed to be unfeasible along such a long sandy drift aligned coast. It is further noted that there is already a single terminal groyne, the southern Outer Harbour breakwater.	 Shore normal rock groyne, Palm Beach (source: Nearmap).

ID	Option	Example
Nearshore control structures		
E1	**Offshore breakwater(s)** Nearshore emergent structure to block wave energy arriving at the beach, largely reducing longshore sand transport rates and promoting formation of salient on beach (localised widening of beach).	 Offshore breakwater at Semaphore South (source: DEW).
E2	**Artificial reef(s)** Nearshore submerged structure reducing the wave energy arriving at the beach, reducing longshore sand transport rates and promoting sand build-up in the lee of the structure. May be multi-purpose, providing coastal protection, ecological and recreational amenity benefits.	 Artificial reef construction at Palm Beach (source: City of Gold Coast).
E3	**Reduction of wave climate** This includes several large-scale options that would reduce the incoming wave climate and therefore reduce the longshore transport rate. Specifics include offshore islands, shaped dredging and wave energy converter arrays.	 Wave energy converter array (source: Carnegie Clean Energy).

ID	Option	Example
'Hold the line'		
F1	**Seawalls** Vertical or sloped structure providing terminal protection against erosion. Structure would be strategically located to ensure existing amenity is maintained and designed to sufficiently protect from wave action.	 Seawall on the Isle of Wight, England (source: Wikimedia).
'Avoid'		
G1	**Planned relocation** Compensated removal or relocation of individual private or public assets when the impacts of coastal hazards place the assets at unacceptable risk. Land made available by the growth of the Le Fevre peninsula can be used as location of new development/relocation.	 Potential south to north relocation.
G2	**Do nothing** No further sand management or coast protection works. Remove seawalls, roads, pipelines, other infrastructure and houses when damaged by erosion.	 North Brighton during 2016 storm (source: DEW).
'Complementary management'		

ID	Option	Example
H1	**Dune rehabilitation and revegetation** Re-building and/ or stabilisation of dune to increase natural coastal protection function. Requires sufficient sand on beach and does not provide terminal protection against erosion.	 Dune stabilisation (source: southernhabitat.com.au).
H2	**Seagrass restoration** Restoration of the seagrass habitat that has been lost over the past century by planting out areas that have been lost. Artificial seaweed could be used to encourage colonies to grow. This would reduce wave climate at the shoreline.	 Seagrass off Adelaide beaches (source: SA EPA).
H3	**Smart coastal monitoring** Utilisation of a range of smart monitoring methods to inform ongoing management practices more effectively. This monitoring may capture information about beach widths, metocean conditions, beach use and sand transport rates.	 Beach width monitoring (source: WRL).
H4	**Coastal beneficial reuse** Beneficial reuse of dredge material for beach nourishment from dredging operations. This can be cost-effective and sustainable way to increase the buffer along beaches with dredged material. The source material and its suitability for coastal beneficial reuse and the associated planning approvals and work	 Outer Harbour dredging (source: Boskalis).

ID	Option	Example
	methods (processing, transport and material placements) require detailed assessment.	

5.5 Coarse filtering (longlist to shortlist)

5.5.1 Approach

This step involved filtering the longlist to provide a shortlist, selected using an evidence-based process, to carry forward for further development and evaluation. The coarse filter assessment helps identifying options that can be dismissed early in the process so that available effort can be focused on a shorter list of more feasible options. Importantly, the process provides justification as to why options were not carried forward.

The three coarse filter assessment criteria are discussed below. These three assessment criteria are a sub-set of the more detailed assessment criteria used in the later evaluation of the shortlist. As outlined in Table 12, the filter applied a traffic light type assessment where ‘Go’, ‘Slow’, ‘Stop’ ratings were assigned 3, 2, 1 numeric point(s), respectively. The total score was calculated as the sum across the three assessment criteria.

Table 12: Assessment criteria used in the coarse filter.

Rating	Individual criteria		Aggregated
	Score	Description	
Go	3	Deemed to be effective, practical or acceptable.	**If the total score was six (6) or less, the option was not progressed.**
Slow	2	Additional investigation(s) required to understand if option is effective, practical or acceptable.	
Stop	1	Deemed to be ineffective, impractical or unacceptable. **Option not progressed.**	

5.5.2 Assessment criteria

The mandatory assessment criteria adopted for the coarse filter review each management options’ performance based on accepted coastal engineering research and understanding. In addition to its ability to compliment other management strategies or work in combination with other management options. The coarse filter answers the following key questions:

3. **Is the option effective? (Will it work?)**
    - Does it provide coastal protection?
    - Does it provide beach amenity?
    - What is the level of confidence in the option?

- Is the option adaptable to climate change?

This criterion focuses on the ability of each longlist option to achieve the overarching management objective of providing a level of coastal protection and preserving beach amenity. The effectiveness of each option is assessed in terms of its ability to provide adequate protection to coastal assets and maintain or enhance recreational beach use. The level of confidence in the option is considered inline of scientific evidence supporting its efficacy and past successful implementations in similar coastal settings. Another aspect of this criterion is its adaptability to a changing climate. Given the potential impacts of climate change, including sea-level rise and increased storm events, the ability of the selected approach to respond to these changing conditions is important for ensuring long-term coastal resilience and sustainable management practices.

4. Is the option practical? (Can it be done?)

- Is the option feasible from an engineering and/or constructability perspective?
- Does the option align with overall strategy for the management of Adelaide's beaches?
- Does the option owner have the financial capacity to deliver it?

This criterion assesses the feasibility and practicality of longlist options. The engineering and construction feasibility of the proposed approach is assessed with consideration of available technology and techniques as well as the context of northern Adelaide's beaches including the existing infrastructure and environmental conditions. The strategic alignment of the option with the broader strategy for the management of Adelaide's beaches is considered. The financial capacity of the option's owner, which in this case will be the Government of South Australia, to deliver and sustain the option. The availability of adequate funding and resources is vital to ensure the successful execution and maintenance of the option over time.

5. Is the option acceptable? (Should it be done?)

- Would the option be expected to have acceptable environmental impacts?
- Is it legal? Could planning approvals be sought for this option without legislative change?
- What is the expected level of community support for this option?

This criterion examines the expected social or environmental impacts of the options to answer the question, should this be done? Potential environmental impacts of the option are considered with specific reference to the constraints and sensitivity receptors identified in Section 5.2. Options that are permissible under existing regulations and have a clear pathway for planning approvals are more likely to succeed. Therefore, the legality and ability to seek and obtain the necessary approvals for the option is considered. Based on recent project specific community engagement, the expected level of community support for the option is considered. This is a significant consideration for any project, particularly coastal management projects that are largely community driven.

For the two sub-options (A1.1 and A1.2) related to the sand intake component of a backpassing pipeline system (A1), the first two questions of the effectiveness criterion were not applicable. These were replaced with 'Does the option provide an effective sand intake for a backpassing pipeline?' For the complimentary management, the criteria were considered in their ability to compliment other options.

5.5.3 Coarse filter assessment

A summary of the coarse filter assessment for the longlist of the potential coastal management options is provided Table 12.

Table 13: Coarse filter assessment results for coastal management options along northern Adelaide's beaches.

ID	Option	Suitability			Assessment outcome (total score)
		Is it effective?	Is it practical?	Is it acceptable?	
A1	**Backpassing pipeline**	Yes. Backpassing of sand using a pipeline would effectively redistribute sand to effectively provide a sandy buffer across the management area. Concerns regarding the suitability of northern littoral sand (i.e., grain sizes are fine) can be avoid by limiting sand collection south of Largs Jetty.	Yes. Sand slurry pipelines are achievable as demonstrated by other such pipelines within or adjacent to the management area. Construction costs are well understood.	53% of the 119 submissions during the Stage 1 engagement were strongly against a northern pipeline. One of the key reasons was concerns around disruptions to beach access and amenity from sand management vehicles as well as plant and equipment on the beach. In terms of approvals, the northern backpassing pipeline was previously approved demonstrating that the environmental impacts, particularly the dunes, were considered by regulators to be manageable.	Go (8)

ID	Option	Suitability: Is it effective?	Is it practical?	Is it acceptable?	Assessment outcome (total score)
A1.1	**Nearshore fixed sand collection**	Fixed or semi-mobile jet pumps would be an effective and efficient sand collection technique for a backpassing pipeline if technical constraints regarding seagrass wrack can be overcome. The lower level of confidence justifies the slow rating.	Previous trial in intertidal zone found that seagrass wrack disrupted operation with manual clearing required. Subtidal trials in the nearshore would be required. Capital cost of having fixed or semi-mobile plant likely to be higher but maybe offset by operational efficiencies.	Reduces the number of vehicles and equipment on the northern beach, which would improve access and amenity and may be expected to be more acceptable to the community.	**Slow (7)**
A1.2	**Nearshore mobile sand collection**	Yes, when operational a cutter suction dredger (or barge mounted submersible pump) is an effective and efficient sand collection technique for a sand backpassing pipeline in shallow waters. Mobility of plant adds flexibility to sand extraction location.	Operational wave heights, which would be dependent on dredger specifications, likely to be limited to small waves reducing production capacity. More detailed bathymetry survey required to identify suitable locations.	Sand taken from shallow water to avoid seagrass meadows. Minimises vehicles and equipment required on the beach. Approvals expected to be obtainable given this type of dredging already undertaken in management area for harbour maintenance.	**Go (8)**

ID	Option	Suitability			Assessment outcome (total score)
		Is it effective?	Is it practical?	Is it acceptable?	
A2	Sand carting	Has been somewhat effectively used in the past for backpassing on Adelaide's beaches, however, volumes required to maintain the sandy buffer along the coast has not consistently been achieved. With limited additional fixed infrastructure required, it is adaptable to climate change.	The road network in the northern management area has historically been able to accommodate the required truck movements but additional congestion is resulting in reduced efficiency of sand carting. Costs for volumes carted are well understood.	Less likely to be an acceptable backpassing method due beach access and amenity disruptions as well as the impact on dunes and heavy vehicle traffic on residential roads.	Slow (6)
A3	Backpassing using a dredge	Yes. A suitable sandy buffer could be delivered by using dredgers to backpass. It is an approach commonly used for beach nourishment / sand management projects (including backpassing). High level of confidence with a high level of flexibility given less fixed infrastructure.	Shallow depths, seagrasses and suitable sand sources limit borrow areas, with further investigations required at those identified herein. Good alignment overall beach management strategy and comparative costs. Location of sand within the system that is reachable by dredge to be located. Cost	Approvals can be sort and have previously been given for similar activities at Brighton in the 1990's. Nearshore seagrasses are a key constraint. Significant benefit in terms of beach access and amenity (no equipment required on management area's northern beaches while on southern beaches disruption would be	Go (9)

ID	Option	Suitability Is it effective?	Is it practical?	Is it acceptable?	Assessment outcome (total score)
			relatively low compared to permanent infrastructure.	relatively short duration during placement works).	
Beach nourishment (with sand from external sources)					
B1	**Mass nourishment (sand engine)**	Previous mass nourishment (1.1M m^3 over 6-year period to Brighton) was effective in supplying sand along the beach system (DHI, 2018). Added benefit of facilitating dune stabilisation along southern beaches. Sand budget has shown that additional sand is not required. Over the long term additional sand will continue to accumulate at Largs Bay.	Source of sand large enough has not yet been identified. High cost if source not nearby and/or not accessible with available techniques.	The effect of large quantities of nourishment sand placed at West Beach on the adjacent Torrens Inlet will require further investigation. Would be expected to be acceptable to community as it involves nourishment without harvesting sand from other beaches within the system.	Go (7)

ID	Option	Suitability			Assessment outcome (total score)
		Is it effective?	Is it practical?	Is it acceptable?	
B2	**Ongoing external nourishment**	Yes. Provides adequate buffer nourishing required beaches at the rate of longshore transport. Sand budget has shown that additional sand is not required. Over the long-term ongoing additions to the system will continue to accumulate at Largs Bay.	Source of sand large enough has not yet been identified. High cost if source not nearby and/or not accessible with available techniques.	Effect of Torrens Inlet will be more predictable with smaller incremental volumes. Would be accepted to have a level of community support as it involves nourishment without harvesting from other beaches within the system.	Go (8)
B3	**Ongoing sand with coarse (quarry) sand**	As with other forms of nourishment, addition of quarry sand can be effective at providing a sandy buffer if sufficient volumes are placed. While the coarser grain sizes will reduce longshore losses and provide improved resistance to storm erosion a noticeably steeper beach will form over time. A steeper beach can present other issues along with a different texture of the coarser grains.	Terrestrial sources with sufficient volumes yet to be identified. Ongoing costs will be moderate-high and increase over time.	Does not require sand harvesting from the northern beaches with a level of expected community support expected. Grain sizes may have an expanding impact on the beach morphology.	Slow (6)

ID	Option	Suitability Is it effective?	Is it practical?	Is it acceptable?	Assessment outcome (total score)
Sand bypassing					
C1	**Fixed bypassing pipelines at structures**	Restoration of natural and adequate sand supply to West Beach would be an effective means of maintaining a sandy buffer. Initial nourishment would be needed to restore the sandy buffer. May reduce maintenance dredging requirements for the West Beach Harbour entrance.	This option was deemed to be impractical because the southern backpassing pipeline means there is insufficient sand available to bypass Holdfast Shores and West Beach Harbour and supply the management area considered herein. The represents a misalignment to the adopted and operational management strategy for the southern beaches. However, should a future solution for the northern beaches allow a reassessment of the ability to re-commence bypassing then this option would be a 'GO'. Seagrass wrack, shallow depths and equipment	While this would increase beach access and amenity at Glenelg North, West Beach and further north with little visual impact the following installation.	**Stop (7)**

ID	Option	Suitability Is it effective?	Is it practical?	Is it acceptable?	Assessment outcome (total score)
			limitations are further constraints on practicality.		
C2	**Removal of Holdfast Shores and West Beach Harbour**	Like sand bypassing removal of these shoreline control structures would restore sand supply and remove one of the causal mechanisms. Initial nourishment would be needed to restore the sandy buffer.	While it would be feasible to physically remove these structures, for the same reason as sand bypassing this option has been deemed impractical (i.e., not compatible with southern backpassing operations).	While the removal of these structures would be expected to be acceptable from a coastal management perspective, there would be expected to be strong and broad opposition to such as options from recreational and commercial boating stakeholders.	**Stop (5)**
'Keep sand in the system'					
Shoreline control structures					
D1	**Artificial headland(s)**	Like groynes, these are effective at retaining sand on the updrift side with corresponding downdrift	Several large coastal structures would be required. Long-term planning commitment as well as large	Change in beach shapes and identities will impact the acceptability by the community. Including built-in	**Slow (6)**

ID	Option	Suitability Is it effective?	 Is it practical?	 Is it acceptable?	Assessment outcome (total score)
		erosion. Artificial headlands have a more natural (curved) shape which can avoid increase in rip currents during storms.	investment. Single headland could be combined with additional sand management.	public amenity (e.g., ocean pools) would increase acceptability.	
D2	Groynes	Effective in retaining sand buffer over large area, can exacerbate erosion during major storms due to increased rip currents. Causes downdrift erosion, potentially requiring protection works in this area.	Several large coastal structures would be required. Long-term planning commitment as well as a large investment required. Single groyne unlikely to be practical along this longy sandy coastline.	84% of respondents answered walking or running on the beach as the reasons they visit the beaches. Groynes would disrupt walking or running on the beach and would decrease the visual amenity of the beaches. Permanent plant, equipment or infrastructure hat impact on beach or ocean views was ranked as most disruptive in the recent survey (URPS, 2023)	Stop (5)

ID	Option	Suitability Is it effective?	Is it practical?	Is it acceptable?	Assessment outcome (total score)
Nearshore control structures					
E1	**Offshore breakwaters**	Effective in retaining sand buffer, reducing inshore wave energy reducing erosion hazard. Causes downdrift erosion, potentially requiring protection works in this area. Ultimately, they do not address the underlying problem which is the land of sand supply and would need to be supplemented with nourishment.	Relatively simple coastal protective structure. Long-term planning commitment as moderate investment required. Several structures would be required, DHI 2020 modelled two structures between West Beach and Torrens Inlet.	Provides increased beach width (in lee area) and no impact on connectivity, some visual/ recreation impacts.	**Slow (6)**
E2	**Artificial reefs**	If well designed, these could be effective in retaining sand buffer in installed location, reduced inshore wave energy and reducing erosion hazard. Unlikely to slow littoral drift rates sufficiently. Like, offshore breakwater they do not address	Several structures required; significant CAPEX combined with additional options to achieve management goals.	Provides (small) increase in beach width (in lee area). Beach connectivity and amenity maintained due to submerged nature. Possibility to enhance recreation (surfing/ fishing/ diving).	**Slow (6)**

ID	Option	Suitability Is it effective?	Is it practical?	Is it acceptable?	Assessment outcome (total score)
		the underlying problem and would need to be combined with nourishment			
E3	**Reduction in wave climate**	A reduction in wave climate alone will not be enough to reduce longshore transport. Would do little to reduce storm erosion during high tides and storm surge conditions. Other options would be required.	Deemed to be impractical as unlikely to be technically or financially feasible.	All options have significant environmental impacts and barriers with approvals. Community consultation required to assess acceptability.	**Stop (4)**
'Hold the line'					
F1	**Seawalls**	Provides terminal protection against erosion, can be designed to reduce inundation risk. Will protect assets but not provide beach amenity.	Seawalls already exist on much of the coastline, many would require upgrading to current standards. Would require a change to the beach amenity expectations to align with management goals.	Community likely to oppose as would not provide adequate beach width. Progressive loss of dunes as shoreline recedes and end effects worsen. Additional seawalls required overtime. Overtopping and inundation hazard worsening with	**Slow (6)**

ID	Option	Suitability Is it effective?	Is it practical?	Is it acceptable?	Assessment outcome (total score)
				shoreline recession and sea level rise.	
'Avoid'					
G1	**Planned relocation**	Reduces risk from coastal hazards. Reactive to the natural coastal processes. Challenges in retreating while maintaining beach amenity with such a highly developed coastline.	Significant development on southern beaches would need to be relocated. Technically feasible due to significant dune growth in northern areas.	Expected strong opposition from community. CPB have legal ability to enforce.	**Slow (6)**
G2	**Do nothing**	Provides no coastal protection along sandy shoreline resulting in loss of sand from erosion hotspots and damage to coastal assets. Progressive loss of amenity for beaches in southern end of the management area.	No action required other than make-safe of assets when damaged. Does not align with management goals	Will lead to properties being demolished/abandoned	**Stop (4)**

ID	Option	Suitability			Assessment outcome (total score)
		Is it effective?	Is it practical?	Is it acceptable?	
Complimentary management					
H1	**Dune rehabilitation and stabilisation**	Provides (small) increase in erosion resistance and reduces inundation hazard. Compliments sand management options that delivery a health sandy buffer that can support healthy dunes.	Can be implemented as part of any nourishment strategy. Minor increase in cost. Opportunity for community participation.	Expected widespread support.	**Go (9)**
H2	**Seagrass restoration**	The effect of seagrass restoration on the coastal barrier system in the management area is not fully understood.	Previous studies have shown that human attempts to encourage colony growth have had mixed success. Knowledge of the most practical techniques is improving.	Community support has been expressed for support for seagrass projects.	**Slow (7)**
H3	**Smart monitoring**	Implementing smart monitoring to monitor beach health and inform decision making is effective.	Can be implemented with existing technology at a relatively low cost.	Expected widespread support. Community participation and educational benefits.	**Go (9)**

5.5.4 Summary of results

An overview of the identified most feasible options for further consideration are provided in Table 14. As outlined above, any management options that were not assigned a 'stop' against any single criterion and had and aggregated score of seven (7) or above were carried forward for further development and assessment.

Table 14: Summary of coarse filter results.

ID	Option	Rating and aggregated score	Outcome
A1	Backpassing pipeline	Go (8)	**Carried forward**
A1.1	Nearshore fixed sand intakes for backpass pipeline	Go (7)	**Carried forward**
A1.2	Nearshore mobile sand intakes for backpass pipeline	Go (8)	**Carried forward**
A2	Sand carting	Slow (6)	Considered as part of the basecase
A3	Backpassing using dredge	Go (9)	**Carried forward**
B1	Mass nourishment (sand engine)	Go (7)	**Carried forward**
B2	Ongoing nourishment using external sand	Go (8)	**Carried forward**
B3	Ongoing nourishment using coarse (quarry) sand	Slow (6)	Considered as part of the basecase
C1	Fixed bypassing systems	Stop (7)	
C2	Removal of existing harbour structures	Stop (5)	
D1	Artificial headland(s)	Slow (6)	
D2	Groynes	Stop (5)	
E1	Offshore breakwater(s)	Slow (6)	
E2	Artificial reef(s)	Slow (6)	
E3	Reduction of wave climate	Stop (4)	
F1	Seawalls	Slow (6)	Considered as part of the basecase
G1	Planned relocation	Slow (6)	
G2	Do nothing	Stop (4)	

6. Shortlisted management options

6.1 Introduction

The shortlist consists of the four standalone options as well as the two pipeline sub-options, each of which are focused on the northern management area[2]. Each shortlist option has been developed to allow a description, conceptual layout, life-cycle cost estimate and comparative performance assessment, all of which are presented in this section.

Consistent with the early design stage, relatively simple methods were used to develop the shortlisted options. Methods included reviewing available literature, data and precedent projects which were used to inform selected configurations / strategies for each of the shortlisted options. In general, conservative assumptions and approaches have been adopted for the preliminary design of the main elements. More thorough approaches should be used during later design phases to better resolve and optimise the preferred option(s). Option A1 (backpassing pipeline) was an exception. Having been subject to detailed design, environmental assessment and construction tendering it had a highly resolved design available for reference.

While life-cycle costs have been estimated no further economic appraisal, such as a cost-benefit analysis, has been completed.

The comparative assessment considers the relative performance of each option against specific assessment criteria which align with the goals of the Adelaide beach management review i.e.,

1. Maximise the amount of sand on beaches.
2. Minimise disruption for all communities.
3. Avoid environmental harm.

The evaluation approach and results of this comparative technical assessment are provided in Section 6.7. For context, the shortlisted options:

- Are compared to a basecase, which assumes a continuation of the status quo.
- Aim to restore the sandy buffer at West Beach by adding the adopted 550,000m^3 of sand in the short term along with an additional sand top-up requirement of 90,000m^3/year. This sandy buffer at West Beach relates to review goal number one with quantities based on the findings of our sand budget of Adelaide's beaches (see Section 4.3.3).

It is important to note that implicit within the adopted basecase and shortlisted options is the assumption that the coastal processes driving the need for on-going sand management activities will continue.

6.2 Basecase (sand carting)

A business-as-usual basecase was assumed for the comparator as part of the shortlist evaluation. The basecase for the northern management area was assumed based on actual beach management activities over the past three years (i.e., 2020 to 2022), see Figure 32 and Table 15. As such, the basecase includes ongoing implementation of sand carting at a rate of 130,000m^3/year from either internal (i.e., from beaches within the management area) or from external (i.e., quarries) sand sources. It is further

[2] The northern management area extents between West Beach (north of West Beach Boat Harbour) to North Haven Beach (southern Outer Harbour breakwater).

assumed that the nature of future sand management interventions (i.e., sand volumes, sand sources and sand placement locations) would be like those that occurred between 2020 and 2022 (3 years).

The key elements of the adopted basecase are presented in Table 16 and Figure 33.

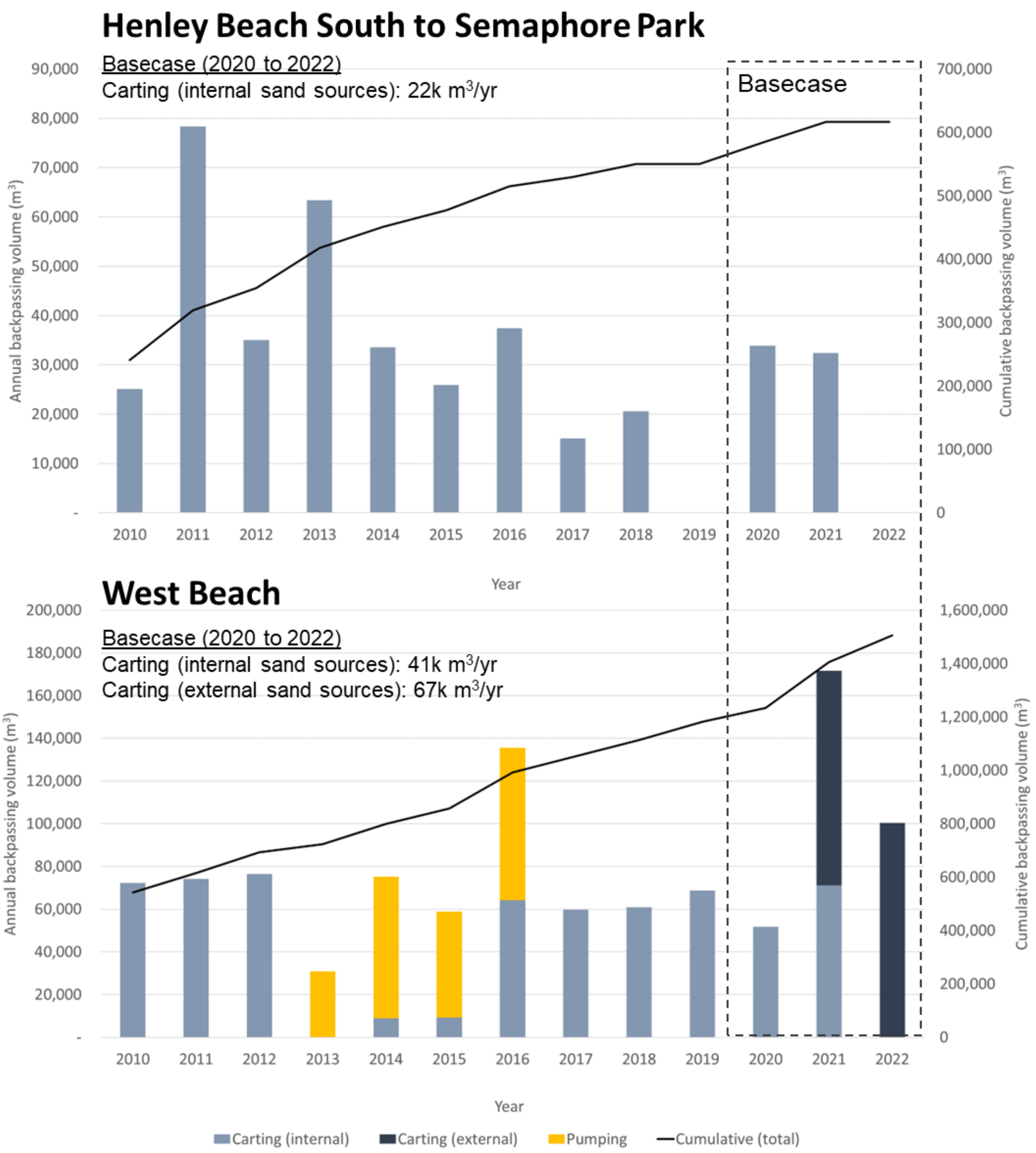


Figure 32: Existing sand management activities and adopted basecase period.

Table 15: Sand management activities over adopted basecase period between 2020 to 2022.

Activity	Annual average sand volume (m^3/year)	Sand source	Placement location	Comment
Sand carting	41,000	Torrens Outlet Semaphore breakwater Semaphore jetty	West Beach	Typically undertaken as annual campaign over two months
	67,000	Quarry (external source)	West Beach	Typically undertaken as two campaigns each year (two to three months per campaign)
	22,000	Torrens Outlet Semaphore breakwater	West Beach Semaphore Park	Typically undertaken as annual campaign over two months
Sand pumping	-	-	-	No pumping undertaken within management area

Table 16: Description of the adopted basecase (sand carting).

Design parameter	Description
Concept and rationale	The basecase involves a continuation of current beach management practices in the northern management area. A continuation of these practices will, over time restore and maintaining the sandy buffer at West Beach through regularly importing sand to the southern (updrift) end of the system. Under the 'keep sand moving' approach (see Section 5.3), the practices will restore and maintain the supply of sand to the West Beach or any other sediment compartment in the northern management area that requires nourishment. For this review, this has been assumed to involve: • Backpass sand south by using trucks from suitable downdrift areas where sand accretes to updrift areas where coastal erosion is occurring. • Importing sand using trucks from external (quarries) sources due to the limited amount of sustainably accessible sand on the northern beaches and to reduce associated disruption to the public along the northern areas. • Minor sand management activities within management area including small scale sand transfer via beach carting from adjacent deposition areas and dune rebuilding (not further described herein).
Sand carting strategy	Sand placements are undertaken annually over two to three campaigns, each typically of two-months duration, in winter each year. A total annual volume of 130,000m^3, comprising 65,000m^3 (50% of total) extracted from within the management area (internal sources) and 65,000m^3 (50% of total) delivered from quarries (external sources), which is based on a continuation of the status quo.

Design parameter	Description
	Adopted daily sand transfer rates: • from northern beaches to West Beach: 1,500m3/day (or 86 x truck loads per day) • from the quarries to West Beach: 1,000m^3 (or 58 x truck loads per day) Based on target placement volumes this requires around: • 3,727 x truck loads each year from the northern beaches (44 days) • 3,727 x truck loads each year from quarries (65 days)
Operational plant and equipment	Sand harvesting (from downdrift beaches) • 1 x tractor with landplane; and/or • 1 x excavator Sand loading • 2 x excavators + 1 x conveyor (if required to transport under Semaphore Jetty) • 1x loader/ excavator • 1 to 2 x dump trucks (to/from temporary stockpiles) • Road transport • 10 to 15 x road trucks (6 axles semitrailers carrying 25 to 29t of sand per load) Re-loading of sand from road truck onto dump trucks at deposition area • 1x 30t excavator • 2 to 4 x dump trucks Shaping of sand placements • 1 x 36t excavator • 1 x bulldozer **Note:** It is assumed suitable beach access ramps are in place and maintained (not costed as part of basecase). Most of these details are based on records of actual sand carting operations supplied to Bluecoast. Where details were missing, aerial photographs were used to supplement the records else assumptions were made.
Implementation	Operations during sand backpassing campaign (refer to Figure 33 for depiction of activities A, B, C1 etc): • Mobilisation (and demobilisation): mobilisation of earth moving equipment and site establishment at beach access points. Signage and traffic management only in place during works. Beach access and beach car parking areas are available to beachgoers and private vehicles without temporal restrictions during works. • Sand harvesting: begins approximately 4 hours to 1 day prior to planned carting. This includes: ○ A – (i) Tractor with landplane (scraper) and/or excavator collects sand within a designated beach strip between the lowest tide level and the base of the dune, with the length of the beach area dependent on the desired quantity of sand. Harvesting depth varies within a range of 300mm to 1,000mm. (ii) Sand is moved to temporary stockpiles at sand

Design parameter	Description
	harvesting area either directly by landplane or by using dump trucks (loaded by excavator). o B – (i) If harvesting sand north of Semaphore Jetty, an excavator is used to load sand from the northern temporary stockpile onto a conveyor to transfer sand under the jetty where it is reloaded onto dump trucks for transfer to temporary stockpile at Point Malcom (Semaphore Park) or directly carted to the Semaphore Park placement area (ii) for further transportation via road, dozer and excavator/loader are used to load road trucks. • Transportation: o C1 – For sand transfer to Semaphore Park placement area dump trucks drive along beach. o C2 – For sand transfer to West Beach, this includes (i) road trucks access the beach ramp at Point Malcom (ii) once loaded they haul the sand via public roads and unload into temporary stockpile area at the beach end of Henley Sailing club and/or Adelaide Sailing Club access ramps at West Beach (iii) reload sand from temporary stockpile onto dump trucks using excavator for transport to final placement area (D1). • Sand placement (D2): (i) Dump trucks distribute sand along upper beach within sand placement area, (ii) excavators and/or dozers used to shape and adjust deposited sand to achieve the desired contours and profiles. • Works are undertaken around the weather and tides with operating hours for beach works between 7:00am and 7:00pm, Monday to Friday. Beach operations during campaign importing sand from quarries: • As above, commencing with road trucks delivering sand at West Beach (see C2).
Complementary management	This option could be complemented by the following additional management actions (see description in Table 11): • H2 Seagrass restoration • H3 Smart coastal monitoring

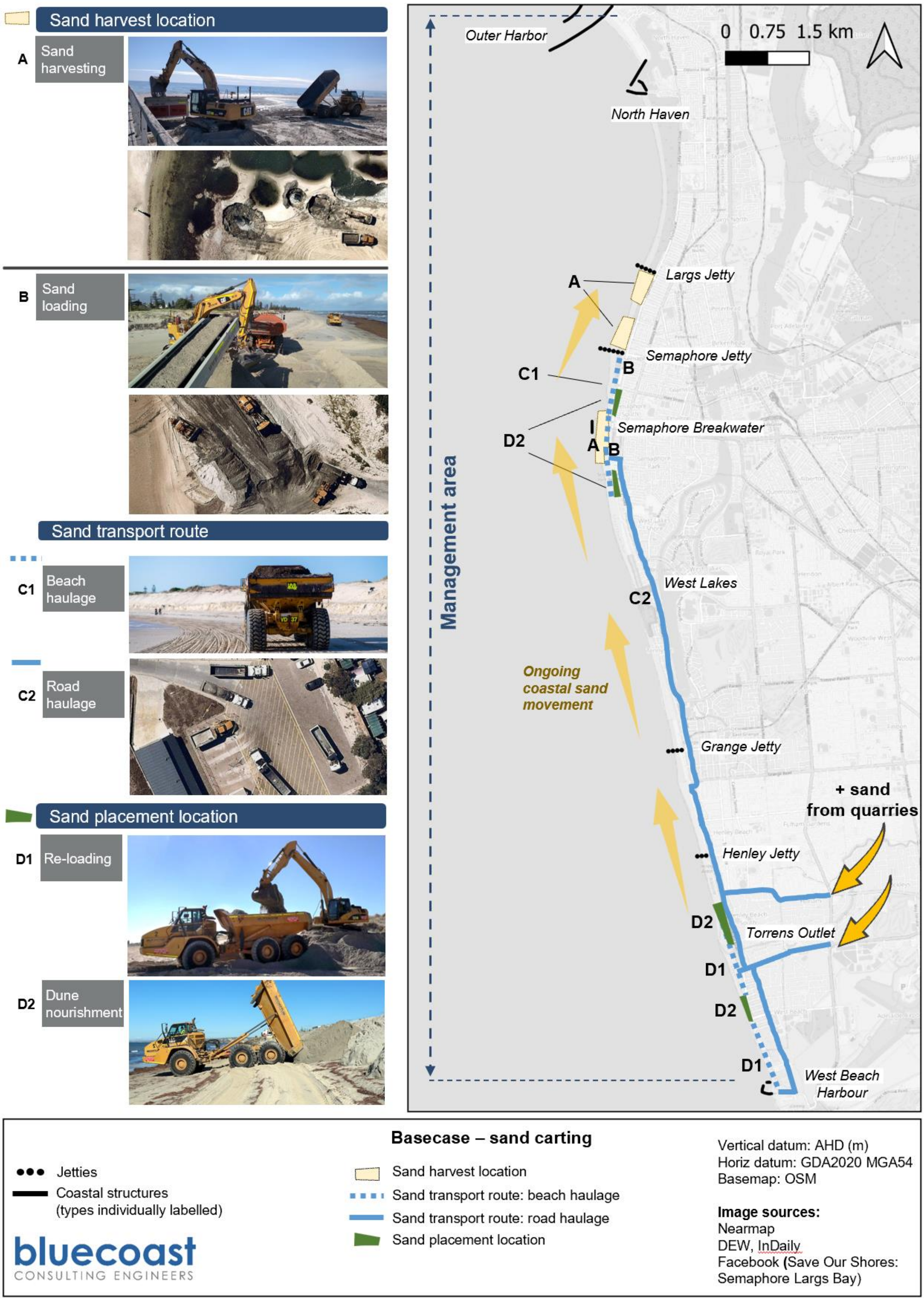


Figure 33: Conceptual layout of recent sand carting activities (basecase).

6.3 Option A1 Backpassing pipeline

Table 17 outlines key details and describes this backpassing pipeline option (Option A1). Figure 28 presents the conceptual design layout of the option.

Option A1 was developed as part of the *Securing the Future of our coastline project*. Technical details have been taken from 'for approvals' documentation of the proposed backpass pipeline (McConnell Dowell, 2022; SMEC, 2022). Operational aspects are based, in a large part, on the experience from the existing Glenelg to Brighton pipeline to the south of the management area. This southern sand backpassing pipeline began operations in 2013.

Guided by this review's goals, potential opportunities to optimise the design of the proposed backpass system have been identified and could be explored should this option be progressed. Two alternative sub-options for the sand harvesting and intake procedure of the backpass system are described in Section 6.3.1.

Table 17: Description of the backpassing pipeline option (Option A1).

Design parameter	Description
Concept and rationale	This option involves initial nourishment to restore the sandy buffer at West Beach followed by regular and on-going sand top-ups to maintain the buffer. Under the 'keep sand moving' approach (see Section 5.3), it seeks to restore and maintain the supply of sand to the West Beach or any other sediment compartment in the northern management area that requires nourishment. Because the northern management area has a net positive sand budget (i.e., the overall system does not need more sand), sand would be collected from the northern extent of the management area and back passed to the southern beaches. For this review, and for both initial and on-going nourishment exercises, this has been assumed to involve: • Initial (once-off) restorative nourishment at West Beach via sand carting from quarries (see 'C1' to 'D2' basecase elements in Section 6.2 – not further described here). Alternatively, this could be achieved via dredging as described in Section 6.4 (Option A3). Successfully adopting this alternative for the restorative volumes by dredging would result in an estimated $21 million in savings over carting of quarry sand. Moreover, it has been assumed that the backpassing pipeline could not be used for the purpose of supplying this restorative volume. This is because it would exceed the volumes that can be sustainably harvested from the northern beaches (Salients, 2021 and Water Technology, 2020). • Installation and operation of permanent infrastructure including pumping stations and underground pipelines to transfer a sand slurry (i.e., sand and seawater) from beaches where sand is building up, to beaches where sand is eroding. The backpassing pipeline would be connected to the existing pipeline at West Beach (south of Torrens Outlet). The new backpassing system would allow sand collected from dedicated sand harvesting areas using earthmoving equipment between Semaphore Park and Largs Bay to be pumped and discharged as a sand slurry onto the upper beach at fixed pipe outlets throughout the northern management area. Discharged sand would build up the local sand buffer as well as feed sand into the net northward longshore sand transport system, supplying sand to downdrift beaches. When discharged, the sand settles out from the slurry forming a low, wide mound with excess water returning to the sea.

Design parameter	Description
Sand backpassing strategy	As per the other shortlisted options, the sand backpassing strategy is based on achieving: • Initial nourishment volume of 550,000m^3 via sand carting from quarries delivered to West Beach over first five years (commencing 2024). • Sand backpassing via pipeline is undertaken annually over a single campaign of four-month duration in winter each year. Total annual target backpassing volume is 90,000m^3/year with average daily backpass sand transfer rate based on existing sand pumping operations of 1,250m^3/day. For this review, it was assumed all backpass sand is delivered to West Beach.

Permanent and operational backpass infrastructure	<u>Permanent infrastructure</u>
	• 3 x sand intake locations where mobile beach-based sand collection equipment can supply sand to the pipeline at either:
	  o Semaphore South
	  o Semaphore
	  o Largs Bay
	• 13.2km of underground (buried) sand backpassing pipeline (from Largs Bay jetty to south of Torrens Inlet and then West Beach)
	• 7 x permanent electrically powered slurry pump stations and associated components along the foreshore (largely buried) at:
	  o West Beach (Henley Beach Road)
	  o Grange (Terminus Street)
	  o Tennyson (Moredun Street)
	  o West Lakes Shore (Mirani Court)
	  o Semaphore Park (Bower Road)
	  o Semaphore (Hall Street)
	  o Largs Bay (Everard Street)
	• 4 x fixed pipe outlets (discharge points) to discharge slurry at the toe of dune/seawall at:
	  o West Beach (Rockingham Street)
	  o Grange (The Esplanade)
	  o Tennyson (Moredun Street)
	  o West Lakes Shore (Mirani Court)
	• 1 x seawater intake pump station at West Lakes inlet (off Trimmer Parade)
	• 8.5km of seawater supply pipeline from seawater intake pump station to sand intake locations.
	<u>Operational elements</u>
	• Sand harvesting area/ sand intakes:
	  o 1 x tractor with land plane (scraper) for sand harvesting
	  o 1 x 36t excavator for loading

<table>
<tr><th>Design parameter</th><th>Description</th></tr>
<tr><td></td><td>
1 x mobile Sand Collection Unit (SCU) consisting of a hopper, conveyor belt, screening trommel and mobile slurry pump connected to one of the three permanent pipeline intakes
Sand discharge points:
temporary pipeline sections/ diffusers (where required)
5t excavator and/or Hiab crane
</td></tr>
<tr><td>Backpass system capacity</td><td>
<table>
<tr><th>Activity</th><th>Value</th></tr>
<tr><td>Sand placement</td><td>1,500m³/day peak sand transfer rate</td></tr>
<tr><td>Sand collection[1]</td><td>203m³/hr sand transfer rate
2m³/hr seagrass wrack removal rate</td></tr>
<tr><td>Sand pumping[1]</td><td>200m³/hr sand transfer rate, with
235l/s slurry flow rate, and
1.26Sg slurry density</td></tr>
</table>
Note: [1] Assumes sand D50 of 0.26mm (conservative design value, refer to Appendix C) and sand dry bulk density of 1.62 t/m³. Reduced system capacity would be expected for coarser material.
</td></tr>
<tr><td>Backpass system implementation</td><td>
<u>Site investigations, project planning and environmental assessments</u>
The northern pipeline has been approved for construction. It has therefore been assumed this project phase could be completed within 6-months in 2024. During which time on-going sand carting from quarries has been assumed to continue, including commencing delivery of initial restoring nourishment volume (i.e., on top of the common 90,000m³/year sand top-up requirement). The sand carting elements and associated disruption to beach access and local roads for this activity are described in the basecase (see Section 6.2).
<u>Construction (approx. 1-year duration, assumed by mid-2025)</u>
Permanent pipeline installation: Most of the slurry pipeline and seawater supply pipeline (from the seawater water intake station to the three sand intake sites) would be installed underground by trenching.
Booster pump stations: Each pump station is a permanent underground concrete structure founded on screw piles (approximate footprint 15m x 7m for single pump station and 15m x 10m for double pump station). Aboveground vent stacks for air circulation and cooling (approximately 4m tall and 2m x 2m above ground footprint). Each pump station requires services including mains water supply, electrical and communications.
Water intake pump station: Above-ground pump house constructed on an existing carpark. Construction includes water supply pipeline as well as electrical and communications services.
<u>Operation (annual 4-month campaign, from mid-2025)</u>
</td></tr>
</table>

Design parameter	Description

	• Mobilisation (and demobilisation): mobilisation of earth moving equipment, SCU and site establishment at selected sand harvesting site including demarcation of laydown area (approximately 50m x 50m).
	• Sand collection: (i) Tractor with landplane collects sand from beach several hundred metres either side to stockpile immediately adjacent to the SCU. (ii) One 36t excavator is used to directly load sand from stockpile into the hopper of the SCU. (iii) Dozer and excavator are used to load dump trucks for redistribution of screened seagrass wrack.
	• Slurry discharge:
	  ○ Demarcation and installation of signage on beach at selected discharge site(s) and pedestrian management for beach user safety (e.g., redirection or access closure). Typical work area a 20 to 80m stretch of beach (depending on backpassing volume) extending seaward into the water.
	  ○ Ground personnel manage discharge flow where required including making safe of the discharge area at end of pumping event using 5t excavator (where required).
	  ○ Installation/ removal of temporary pipeline sections (where required) and diffusers to connect to permanent pipeline outlets. 5t excavator or Hiab crane is used to handle temporary pipework.
	• Sand backpass operation Monday to Friday between 7.30am and 5.00pm and avoiding summer and school holidays when beach usage is high.

Complementary management	This option could be complemented by the following additional management actions (see description in Table 11): • H2 Seagrass restoration • H3 Smart coastal monitoring

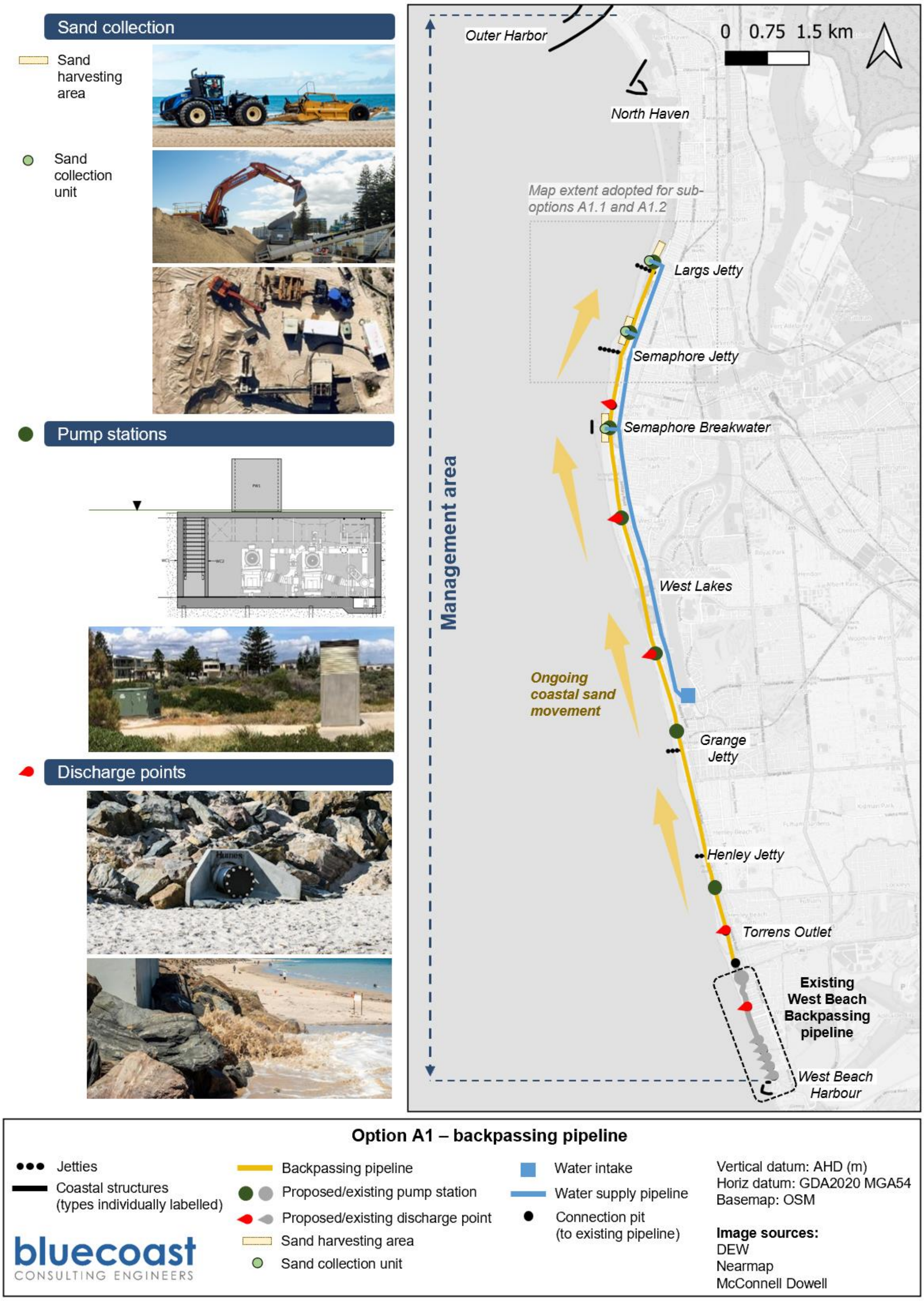


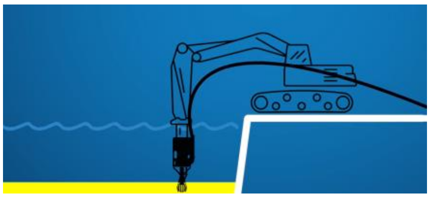
Figure 34: Conceptual design layout of the backpassing pipeline option (Option A1).

6.3.1 Sand intake sub-options (A1.1 and A1.2)

Two sub-options for the sand harvesting and intake of sand into the backpassing system are described in Table 18. Each of the two sub-options (A1.1 and A1.2) would substitute the beach-based sand harvesting elements described for Option A1 in Table 17. Should the backpassing pipeline option (A1) be progressed, the two alternative sand harvesting methods (A1.1 and A1.2) could be considered for further investigation.

If successful, nearshore sand intakes would remove the need for sand harvesting from the visible (subaerial) beach. This would be expected to significantly reduce the associated disruption to coastal communities and beach and foreshore users.

Table 18: Sub-option A1.1 with alternative sand intakes for proposed backpassing pipeline.

Sub-option	Description and value opportunity
Jetty and shoreline based sand intake(s) (Option A1.1)  *Image source: Damen*  *Image source: Damen*	Key elements • Single submersible (DOP) dredge pump attached on Hiab crane or long-reach excavator that can be lowered from existing Semaphore and/or Largs jetties. DOP pumps are powered by a hydraulic power pack attached to crane/excavator and are designed to operate underwater with minimal land-based ancillary equipment. The pumps fluidise surrounding sand at the seabed which will provide a source of sand for the backpassing system. Vegetation cutter blades are used on DOP pump to avoid blockage by seagrass wrack. • Temporary slurry pipeline installed along jetty (or floated across surfzone) and buried under beach to transfer fluidised sand as a slurry to the nearest backpassing pipeline pump station, from which would be as per option A1 above. • Nearest pump station includes hopper, screening trommel and additional seawater supply to allow adjusting slurry density for pumping through backpass pipeline. • Designed to match daily target sand transfer volume of 1,250m^3/day. Possible increased sand transfer rate matching peak backpass system capacity of 200m^3/hr, or around 1,600m^3/day. This could reduce the annual campaign duration from four to three months. Alternatively, fixed or semi-mobile jet pumps operating from the existing jetties could be considered. Further assessment required to determine number, location and spacing of jet pumps if fixed. Value opportunity • Use of existing jetties to access sand in nearshore seaward from seagrass wrack deposition areas. • Reduces heavy machinery and ancillary equipment on beach during operations.

Sub-option	Description and value opportunity
Nearshore mobile sand intake(s) (Option A1.2)  *Image source: Maritime Constructions*	Key elements • 1 x small to medium sized cutter suction dredge (or similar) to collect sand from the nearshore area in locations where sand accretes (e.g., between Semaphore South and Largs jetty). Alternatively, a custom designed barge could be used with an excavator or crane mounted (DOP) pump in nearshore locations. • Temporary pipeline to feed slurry directly to nearest pump station of the backpassing system. Value opportunity • Mobile equipment provides flexibility where sand can be extracted. • Reduces heavy machinery on beach during operations. • Possible increased sand transfer rate matching peak backpass system capacity of 200m^3/hr, or around 1,600m^3/day. This could reduce the annual campaign duration from four to three months.

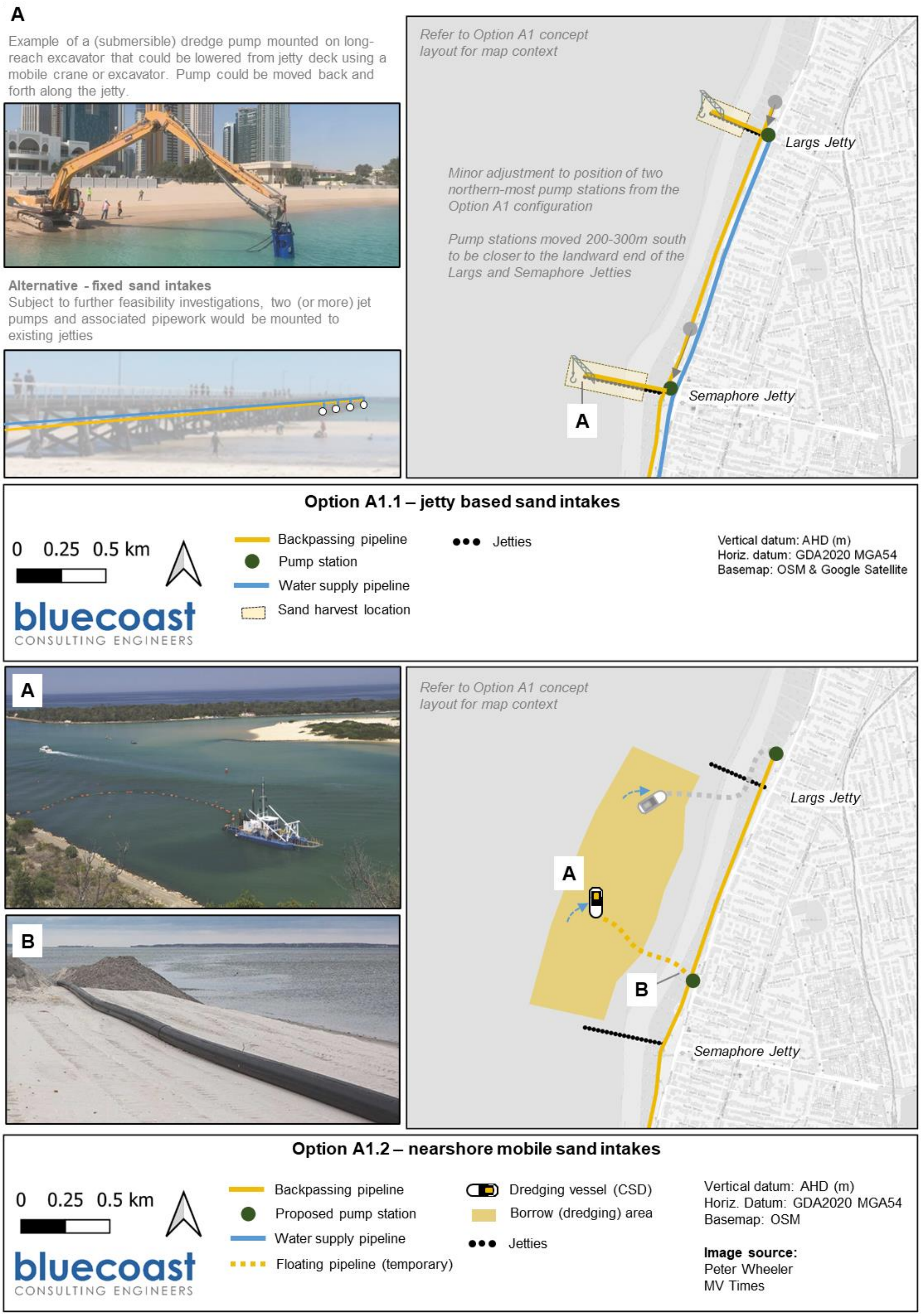


Figure 35: Conceptual design layout for sand intake sub-options (Option A1.1 and Option A1.2).

6.4 Option A3 Backpassing using a dredge

Table 19 outlines key details and describes this backpassing using a dredge option (Option A3). Figure 36 presents the conceptual design layout of the option. An alternative sub-option, Option A3.1, which uses a northern sand source that is inshore of the -5m AHD depth contour is also outlined in **Appendix E**.

Table 19: Description of the backpassing using a dredger option (Option A3).

Design parameter	Description
Concept and rationale	This option involves initial nourishment to restore the sandy buffer at West Beach followed by regular and on-going sand top-ups to maintain the buffer. Under the 'keep sand moving' approach (see Section 5.3), it seeks to restore and maintain the supply of sand to the West Beach or any other sediment compartment in the northern management area that requires nourishment. Because the northern management area has a net positive sand budget (i.e., the overall system does not need more sand), sand would be collected from the northern extent of the management area, in depth accessible to suitable dredgers, and backpassed to the southern beaches. The option achieves this by using floating plant specifically designed to collect, transport and place marine sediments (i.e., dredgers). For this review, and for both initial and on-going nourishment exercises, this has been assumed to involve: • Contracting a small sized trailer suction hopper dredge (TSHD) that would be mobilised to site to perform each exercise. Based on our knowledge of the dredging industry there are suitable dredgers located on the east coast of Australia or New Zealand that could undertake the works. • Dredging would be undertaken to collect suitable sand from a borrow area (i.e., sand source) that has been identified just south and offshore of the southern Outer Harbour breakwater (see **Appendix C**). The dredged sand would be transported in the TSHD's hoppers to the placement site, primarily West Beach which is located 17.8km from the borrow area. • Nourishment sand would be placed at West Beach or other placement site using a modified version of the 'pump ashore' method which would place the sand in the surf zone rather than on the dry beach. Alternative placement methods including standard pump ashore, rainbowing and bottom dumping are available, these are described in **Appendix D**. The 1997 review of the management of Adelaide beaches investigated sand nourishment by dredging. That review investigated a different borrow area and therefore arrived at a different and more costly dredging methodology. However, the report did note that sand nourishment using a method like that proposed herein and as used for Brighton would be significantly cheaper. At the time sand carting was an attractive approach with transport routes and beach access likely to be less restrictive than today. Use of nearshore dredging and nearshore sand placement removes the need for any trucks or other equipment on beaches or on local roads, minimising disruption to coastal communities and beach and foreshore users.
Nourishment strategy	<u>Nourishment frequency, quantities and durations</u> Based on the sand budget outcomes (see Section 4.3.3) with consideration of cost and dredging production estimates, this option is assumed to consist of: • Initial (once-off) restorative nourishment of 820,000m^3 delivered to West Beach using a small (1,400m^3 hopper capacity) TSHD over a 15-week works period.

Design parameter	Description
	• On-going sand top-ups of 360,000m^3 every 4-years delivered to West Beach using a small TSHD over a 7-week works period. Alternative scenarios should be explored in the case this option is progressed. Given the dynamic nature of Adelaide's beaches as well as dredger availability, a degree of flexibility is expected in the nourishment strategy. <u>Sand source, dredging and dredging cycles</u> All sand would be sourced from the nearshore of the northern management area from the 'Offshore of Largs Bay' borrow area discussed in Table 36. When undertaking nourishment works the TSHD will repeat cycles involving loading sand from the borrow area, sail loaded to the placement area(s), unload using the adopted sand placement method and return to the borrow area for loading. A standard sand dredging method will be used with more detailed provided in Table 36. <u>Placement method and areas</u> A modified pump ashore placement method (see Table 44 in **Appendix D**) is proposed. Under this proposed placement method, a floating pipeline would be established in the nearshore at the placement area. The floating pipeline would run from a nearshore mooring (also established for the works) to a floating outlet just seaward of the surfzone (around -2 to -4m AHD). On approach to the placement area, the dredger would manoeuvre to the mooring. Once moored, the floating pipeline will run from the bow of the TSHD to the outlet location. A small support vessel will pass the connecting lines used to pull the male part of the ball joint from the floating line into bow of the vessel to make the connection. The time required to undertake this operation is usually about 15 minutes (25 minutes has been allowed in production estimates). The sand released from the floating pipeline would be placed in specifically designed nearshore mounds. For this assessment, the local bathymetry at West Beach has been checked to confirm the placement concept. For example, 100,000m^3 could be placed in five (5) mounds each of roughly 20,000m^3 by situating the outlet at approximately the -3m AHD depth contour, around 100 to 150m seaward from the shoreline (0m AHD contour). The spacing between mounds would be 150m, resulting in nourishment of around 900m of shoreline. This approach would require moving the floating pipeline outlet a minimum five (5) times and has been depicted in Figure 36. To unload the sand material held in the hopper, a large quantity of water is required to re-fluidise the sand to enable it to be pumped. The water for this will be extracted from the adjacent waters via pumps on board the dredge. For cost estimates completed herein, all sand has been assumed to be delivered to West Beach. However, as shown on Figure 36, placement areas would be flexible and could be established along the northern management area as the need arises. Should this option be progressed, alternative placement methods, including traditional pump ashore, rainbowing and/or bottom dumping, should be further investigated.
Implementation	<u>Site investigations, project planning and environmental assessments</u> Investigations of the borrow area would be required to assess the resource and its suitability for beach nourishment. This would involve bathymetric and geophysical surveys, shallow (vibro-coring) and sediment sampling and analysis. Should suitability be confirmed then concept dredge and placement designs as well as environmental approvals, licences could be progressed. Environmental aspects at this borrow site are discussed in Table 36. Environmental impacts would require assessment and likely to require dredge plume modelling, ecological (seagrass) surveys and baseline monitoring (water quality and possibly noise).

Design parameter	Description
	It has been assumed that this could be completed within a 12 to 24-month period, during which time on-going sand carting from quarries has been assumed to continue. The sand carting elements and associated disruption to beach access and local roads for this activity are described in the basecase (see Section 6.2). <u>Initial (once-off) restorative nourishment (approx. 15-week duration)</u> • Nourishment works would be undertaken on a 24 hour by 7-days a week basis (subject to approval). • Virtually all nourishment works would be undertaken using floating plant with little effect on beach or foreshore access during the works. Swimmer safety would require access to be monitored during sand placement. • The proposed mooring and floating pipeline have been placed at a slightly deeper area off West Beach, which is away from the boat harbour such that navigational access to the harbour would not be restricted during the works. It is further noted that regular maintenance dredging (i.e., every few years) of these harbours, including the use of floating pipelines and nearshore material placements is undertaken already. • Nourishment works are likely to be undertaken in winter or autumn months to avoid impacts on seagrasses. • A range of environmental management activities, including turbidity monitoring and pre- and post-dredging seagrass surveys, will be required during the works. It is noted that recent capital dredging works to widen the Port Adelaide navigation channel adjacent to the identified borrow area removed over 1.5 M m^3 of material and did not adversely affect seagrasses (EPA, 2020). <u>Ongoing sand top-ups (once every 4 years, with each campaign of just under 7-week duration)</u> • As above but for a shorter duration due to relatively smaller target volume.
Complementary management	This option could be complemented by the following additional management actions (see description in Table 11): • H1 Dune rehabilitation and revegetation • H2 Seagrass restoration • H3 Smart coastal monitoring • H4 Coastal beneficial reuse

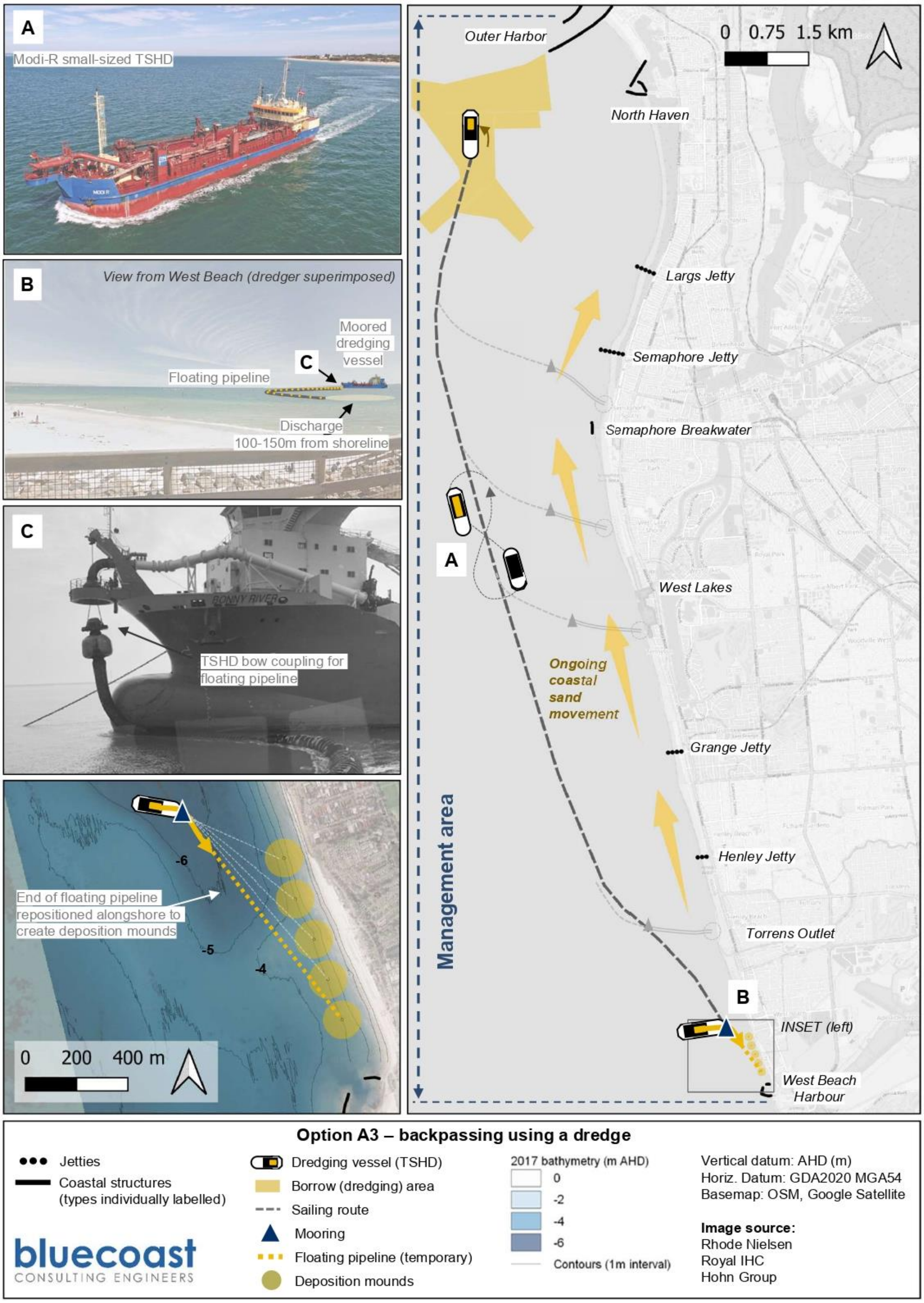


Figure 36: Conceptual design layout of the backpassing using a dredge (Option A3).

6.5 Option B1 Mass nourishment

Table 20 outlines key details and describes this mass nourishment option (Option A3). Figure 37 presents the conceptual design layout of the option.

Table 20: Description of the mass nourishment option (Option B1).

Design parameter	Description
Concept and rationale	This option involves mass nourishment at West Beach which would be designed to place, in a single exercise, enough sand to provide a buffer over a 20-year period. Under the 'keep sand moving' approach (see Section 5.3), it seeks to restore and pre-nourish the supply of sand to the northern management area. The review assumes all sand would be placed at West Beach, the most updrift (southerly) beach in the management area. The option achieves this by using floating plant specifically designed to collect, transport and place marine sediments (i.e., dredgers). For this review, the mass nourishment at West Beach has been assumed to involve: • Contracting a medium sized trailer suction hopper dredge (TSHD) that would be mobilised from to site to perform the exercise. Based on our knowledge of the dredging industry, such a vessel would likely come from the international fleet and need to mobilise to site from another country. • Dredging would be undertaken to collect suitable sand from one or more borrow area(s) (i.e., sand source(s)) that have been identified offshore of Largs Bay, north of the Outer Harbour navigation channel (including the Section Bank) or from Southern sand prospects (see **Appendix C**). The dredged sand would be transported in the TSHD's hoppers to the placement site, primarily West Beach which is assumed to be located 17.8km from the borrow area. • Nourishment sand would be placed at West Beach or other placement site using a 'pump ashore' method. Alternative placement methods including modified pump ashore, rainbowing and bottom dumping are available. This review presents options that are early in the design development stage. There are other construction methodologies and/or sand sources that may be the focus after further investigations and design development. As with any beach nourishment project the final methodology would be delivered by the construction contractor.
Nourishment strategy	<u>Nourishment frequency, quantities and durations</u> Based on the sand budget outcomes (see Section 4.3.3) with consideration of cost and dredging production estimates, this option is assumed to consist of: • Mass nourishment of 2.35 M m^3 (million cubic metres) delivered to West Beach using a medium (6,000m^3 hopper capacity) TSHD over a 15-week works period. Alternative scenarios should be explored in the case this option is progressed. <u>Sand source, dredging and dredging cycles</u> Sand for mass nourishment could be efficiently sourced from several nearshore borrow areas, pending further investigations and approvals. Specifically, this review assumed that dredging to collect sand for mass nourishment could occur from borrow areas at: • Offshore of Largs Bay, detailed of which are discussed in Table 36 • Southern sand prospects, details of which are discussed in Table 40

Design parameter	Description
	Due to environmental constraints and/or marginal suitability, sources at the Section Bank and surrounds as well as Port Stanvac are unlikely to viable. When undertaking nourishment works the TSHD would repeat cycles involving loading sand from the borrow area, sail loaded to the placement area(s), unload using the adopted sand placement method and return to the borrow area for loading. A standard sand dredging method would be used with more detailed provided in Table 36. <u>Placement method and areas</u> A standard pump ashore placement method (see Table 44 in **Appendix D**) is proposed. Under this proposed placement method, a floating pipeline would be established in the nearshore at the placement area. The floating pipeline would run from a nearshore mooring (also established for the works) to: • the subaerial (or dry) beach outlet to nourish the upper profile with earthmoving equipment required to redistribute the pumped sand as well as manage the pipeline and • a floating outlet just seaward of the surfzone (around -2 to -4m AHD) to nourish the surf zone. The coupling process for the dredger to the floating pipeline is like that described for Option A3 (see Table 19). If this option progressed, further consideration should be given to the need for burial or weighting of the pipeline to cross the surfzone. The sand released from the pipeline would be placed along the subaerial beach and within the surfzone to widen the full coastal profile. For this review, the local bathymetry at West Beach has been checked to confirm the placement concept. 2.35 M m^3 could be placed along a 2.2km stretch of shoreline, which would result in an average widening of the beach of around 100-125m. This approach has been depicted in Figure 37. For cost estimates completed herein, all sand has been assumed to be delivered to West Beach. However, additional placement areas could be established along the northern management area if needed. The sand placement design would need to consider impacts on Torrens Outlet linked to sand deposition. Should this option be progressed, alternative placement methods, including modified pump ashore, rainbowing and/or bottom dumping, should be further investigated.
Implementation	<u>Site investigations, project planning and environmental assessments</u> Similar to Option A3, investigations of the borrow area(s) would be required to assess the resource and its suitability for beach nourishment. This would involve bathymetric and geophysical surveys, shallow (vibro-coring) and sediment sampling and analysis. Should suitability be confirmed then concept dredge and placement designs as well as environmental approvals, licences could be progressed. Environmental aspects at the relevant borrow sites are discussed in **Appendix C**. Environmental impacts would require assessment and likely to require dredge plume modelling, ecological (seagrass) surveys and baseline monitoring (water quality and possibly noise). For mass nourishment it has been assumed that this could be completed within a 24-month period (i.e., mass nourishment delivered some time in 2026). During the planning period on-going sand carting from quarries has been assumed to continue. The sand carting elements and associated disruption to beach access and local roads for this activity are described in the basecase (see Section 6.2). <u>Mass nourishment (approx. 15-week duration)</u>

Design parameter	Description
	• Nourishment works would be undertaken on a 24 hour by 7-days a week basis (subject to approval). • Nourishment works are assumed to occur using both pumping to the beach and surfzone. During these works beach and surfzone access would be restricted to all or part of the 2.2km placement area. • Navigation exclusions zones would be required at the dredging and placement sites, with the potential to restrict access to the West Beach boat harbour during part of or all of the placement works. • Nourishment works are likely to be undertaken in winter or autumn months to avoid impacts on seagrasses. • A range of environmental management activities, including turbidity monitoring and pre- and post-dredging seagrass surveys, will be required during the works. It is noted that recent capital dredging works to widen the Port Adelaide navigation channel adjacent to the identified borrow area removed over 1.5 M m^3 of material and did not adversely affect seagrasses (EPA, 2020).
Complementary management	This option could be complemented by the following additional management actions (see description in Table 11): • H1 Dune rehabilitation and revegetation • H2 Seagrass restoration • H3 Smart coastal monitoring • H4 Coastal beneficial reuse

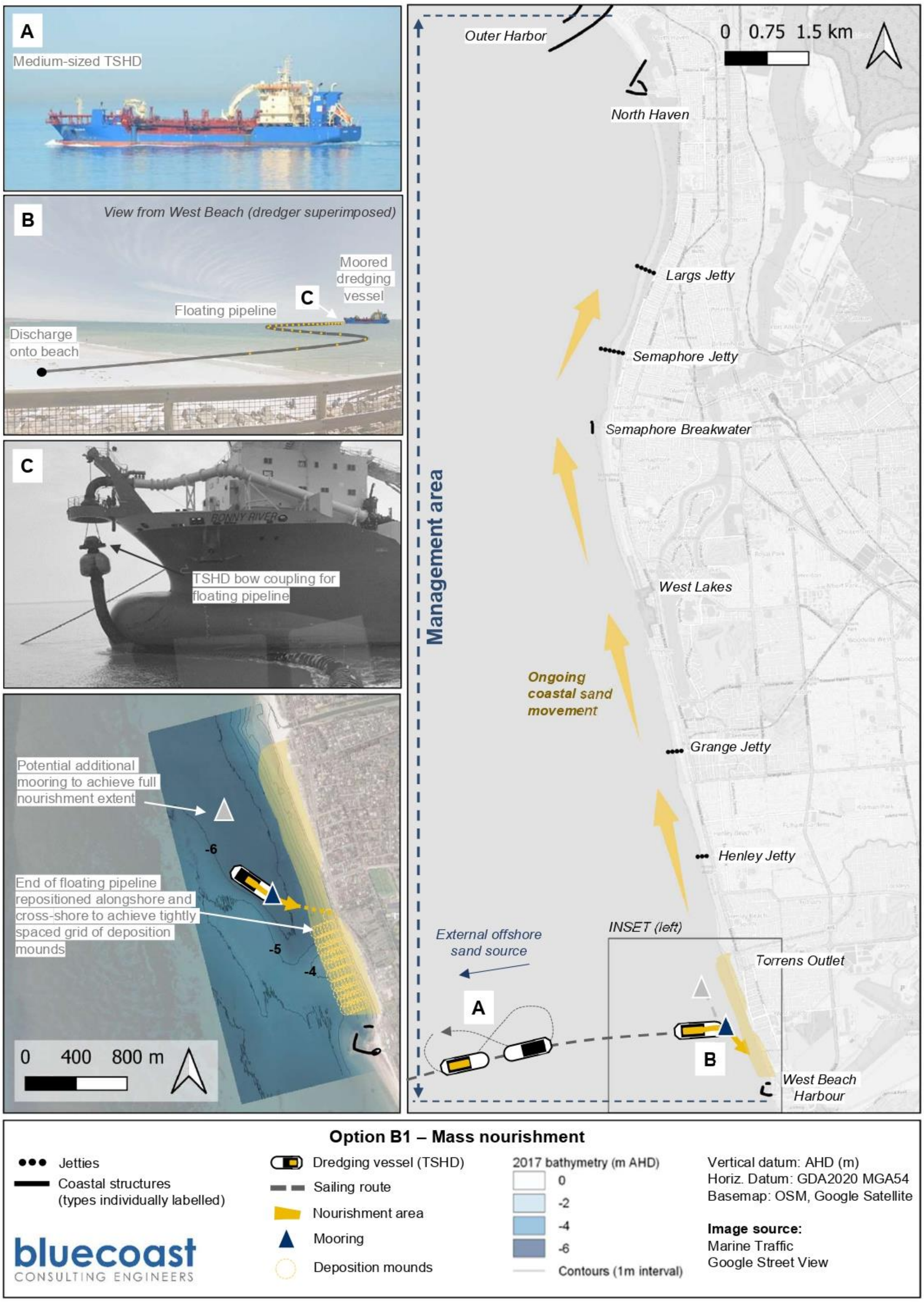


Figure 37: Conceptual design layout of the mass nourishment option (Option B1).

6.6 Option B2 Ongoing nourishment using external sources

Table 21 outlines key details and describes this on-going sand nourishment from external sources option (Option B2). Figure 38 presents the conceptual design layout of the option.

Table 21: Description of the on-going sand nourishment from external sources option (Option B2).

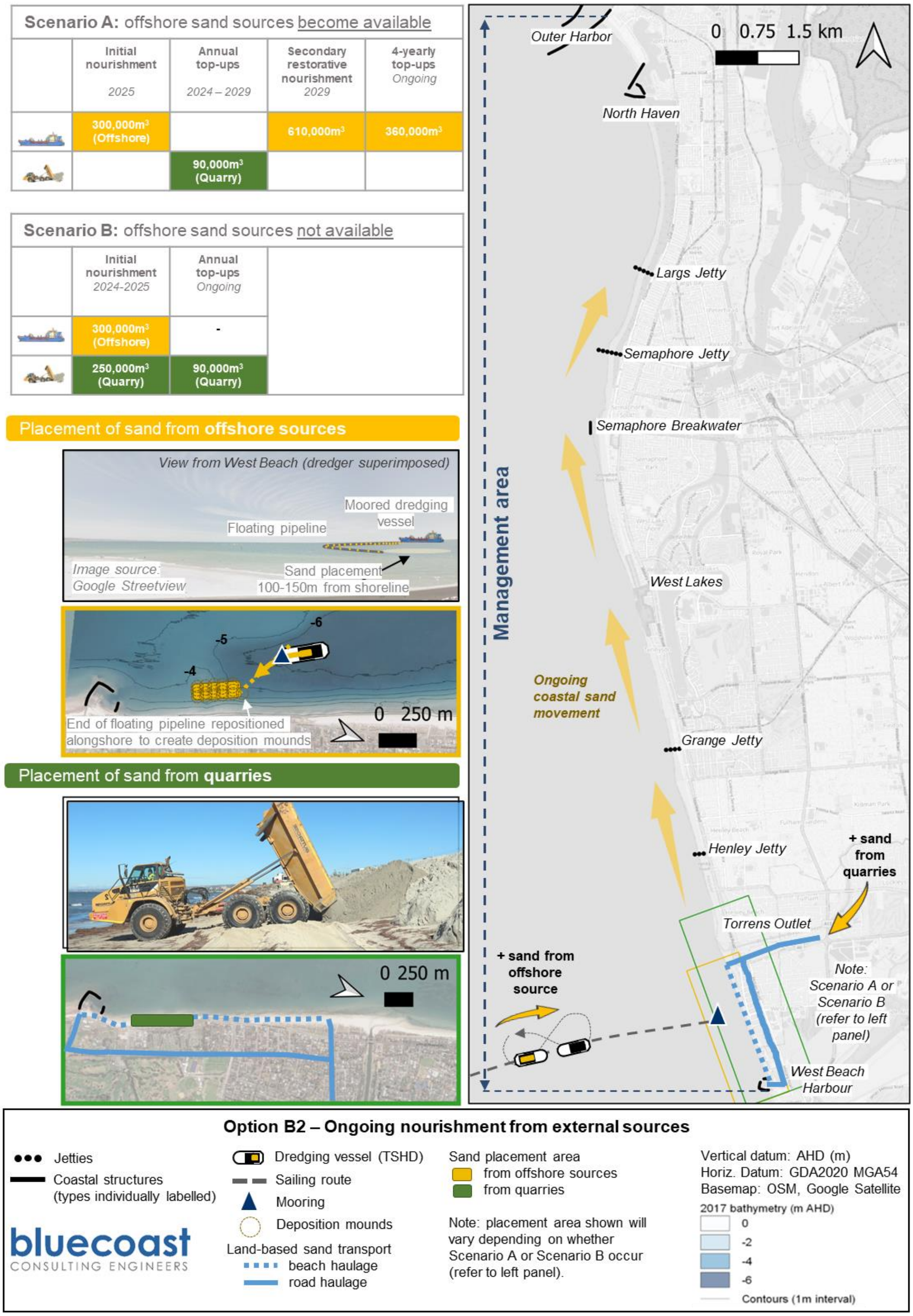
Design parameter	Description
Concept and rationale	This option involves on-going sand nourishment at West Beach using sand from a range of sources (marine and quarries) which would be delivered via a series of nourishment exercises over a 20-year period. Under the 'keep sand moving' approach (see Section 5.3), it seeks to restore and maintain the supply of sand to the northern management area. The review assumes all sand would be placed at West Beach, the most updrift (southerly) beach in the management area. The rationale behind this option is that potential local sand sources prove to be limited and/or can't be accesses because of environmental, social or approval constraints. A range of scenarios, as outlined below, are considered as to how the required sand nourishment at West Beach may be achieved. Internal sand sources, such as collecting sand from the beach berm (i.e., subaerial beach) around Semaphore and Largs Bay have been assumed not to be available due to a lack of social licence to operate into the future. This review presents options that are early in the design development stage. There are other construction methodologies and/or sand sources that may be the focus after further investigations and design development. As with any beach nourishment project the final methodology would be delivered by the construction contractor.
Nourishment strategy	Nourishment frequency, quantities and durations Based on the sand budget outcomes (see Section 4.3.3) with consideration of sand sources (both currently and potentially available in the future), this review, assumes two scenarios for assessment: **Scenario A**: marine sand source(s) in the Gulf (within 20NM of West Beach) becomes available after 5-years in 2029. In the interim, this involves the use of the most cost effective available external sand resources as: • Initial nourishment from nearshore sand source of 300,000m^3 using a small TSHD dredging (i.e., like Option A3) to partially restore the sandy buffer at West Beach in 2025. • Annual nourishments of 90,000m^3 via sand carting from quarries delivered to West Beach for the first five years (commencing 2024). • Secondary restorative nourishment for the remaining 250,000m^3 as well as four years' worth of the annual sand top-up quantity (i.e., 360,000m^3). That is a total of 610,000m^3 to be delivered to West Beach as soon as the marine sand source is approved and dredging contracted (assumed to occur in 2029). This would be completed with a small TSHD taking just under 24-weeks (estimated works duration). • On-going sand top-ups of 360,000m^3 every 4-years thereafter delivered to West Beach using a small TSHD over a 14-week works period. **Scenario B:** no additional (offshore) sand sources become available with all sand to be delivered from already approved sources. This has then been assumed to involve:

Design parameter	Description

	• Initial nourishment from a nearshore or offshore sand source of 300,000m^3 using a small TSHD dredging (i.e., like Option A3) to partially restore the sandy buffer at West Beach in 2025.
	• Initial nourishment volume of 250,000m^3 via sand carting from quarries delivered to West Beach in 2024 and 2025.
	• Annual and on-going sand top-ups of 90,000m^3/year over a single campaign delivered to West Beach over 3-month period in winter each year.
	Sand sources
	Sand for on-going nourishment under this option has been assumed to come from the most convenient sources, such that effort expended on investigations and approvals for additional borrow areas is reduced to a minimum. This includes sourcing the sand entirely from external sand sources, including:
	• Land based quarries, detailed of which are discussed in Table 36
	• Offshore sand deposits in the wider region, specifically:
	  ○ Offshore of Largs Bay, detailed of which are discussed in Table 31
	  ○ Southern sand prospects, details of which are discussed in Table 34
	Due to environmental constraints and/or marginal suitability, sources at the Section Bank and surrounds as well as Port Stanvac are unlikely to viable.
	Placement method and areas
	This option combines dredging and sand carting methods, which have been previously described with detail not repeated here. For dredging the placement method set out for Option A3 (see and Section 6.4) have been assumed to apply. For sand carting from quarry sources, the methods set out in the basecase, see Section 6.2, have been assumed to apply.

Implementation	Site investigations, project planning and environmental assessments Like Option A3 and Option B1, investigations of the borrow area(s) would be required to assess the resource and its suitability for beach nourishment. This would involve bathymetric and geophysical surveys, shallow (vibro-coring), possibly deeper geotechnical boreholes and sediment sampling and analysis. Should suitability be confirmed concept dredge and placement designs as well as environmental approvals, licences could be progressed. Environmental aspects at the relevant borrow sites are discussed in **Appendix C**. Environmental impacts would require assessment and likely to require dredge plume modelling, ecological (seagrass) surveys and baseline monitoring (water quality and possibly noise). For both scenarios, 300,000m^3 of sand from a nearshore/offshore source within 20NM which is assumed to be available for use in 2025. For scenario A, these investigations and approvals processes are assumed to result in at least one additional marine sand source being realised and being available for use as a borrow area within 5-years (i.e., by 2029). During the planning period on-going sand carting from quarries has been assumed to continue. The sand carting elements and associated disruption to beach access and local roads for this activity are described in the basecase (see Section 6.2). For scenario B, no additional marine sand sources are assumed to be realised, with all subsequent sand assumed to be delivered via sand carting from quarries as is currently being undertaken.

Design parameter	Description
Complementary management	This option could be complemented by the following additional management actions (see description in Table 11): • H1 Dune rehabilitation and revegetation (Scenario B) • H2 Seagrass restoration • H3 Smart coastal monitoring • H4 Coastal beneficial reuse (Scenario B)



Scenario A: offshore sand sources become available

	Initial nourishment 2025	Annual top-ups 2024 – 2029	Secondary restorative nourishment 2029	4-yearly top-ups Ongoing
(dredging vessel)	300,000m³ (Offshore)		610,000m³	360,000m³
(truck)		90,000m³ (Quarry)		

Scenario B: offshore sand sources not available

	Initial nourishment 2024-2025	Annual top-ups Ongoing
(dredging vessel)	300,000m³ (Offshore)	-
(truck)	250,000m³ (Quarry)	90,000m³ (Quarry)

Figure 38: Conceptual design layout of the on-going sand nourishment from external sources (Option B2).

6.7 Comparative assessment of shortlisted options

6.7.1 Technical evaluation approach

To compare their expected performance, the shortlisted management options were assessed against non-economic criteria. The assessment criteria used, as presented in Table 22, align with the goals of the Adelaide Beach management review (see Section 1.1). Equal weighting was assigned to each goal, noting that disruption to the community was separated into that associated with construction or operational activities.

The assessment approach was informed by workshopping the approach with the Adelaide Beach Management Review Panel on 16 August 2023. Bluecoast also attended community workshops and the Panel hearing, with feedback received during those consultations incorporated.

Table 22: Shortlist assessment criteria.

Criteria [weighting]	Goal	Measure
Beach health **[33.3%]**	Provide and maintain a sandy buffer to provide a level of coastal protection and beach amenity at all beaches.[3]	Average coastal sand volume[4] in the West Beach compartment over a 20-year period. This was assessed against the target beach volume, with the highest performance being equal to or above the target.
Disruption associated with construction **[11.1%]**	Minimise disruption to all communities.	Duration and beach/foreshore area impacted by construction activities.
Disruption caused during operation **[22.2%]**	Minimise disruption to all communities.	Frequency, duration and beach/foreshore area impacted by temporary plant and equipment over a 20-year period. See Table 23 and Figure 40 for more details on how this measure was calculated.
Impacts on environment **[33.3%]**	Avoid environmental harm.	Area of existing sand dunes impacted. Area of seagrass meadow impacted.

As outlined in Table 22, each criteria had a measure by which the relative performance could be evaluated across the options. The 'beach health' and 'community disruption' measures were quantitative in nature being based on:

[3] While beach health of all metropolitan beach was considered in the options development, the option evaluation focusses on the West Beach compartment as an indicator of available sand buffer in line with goal one of the Adelaide Beaches review.
[4] This is measured from the dune crest down to the 'depth of closure', beyond which depth significant movement of sand is not expected and is therefore not relevant to erosion protection.

- Estimates of the future coastal sand volumes at West Beach for each option based on the outcomes of the sand budget (see Figure 39).
- A detailed review of construction and operational activities associated with each option was used to estimate the frequency, duration and extents (beach, foreshore or local roads). Four levels of community disruption were assigned as described in Table 23. For each of the main shortlist categories (carting (or basecase), pipeline and dredging) the conceptual descriptions of each option were used to map the level of community disruption along the coast and the construction and operational sequences were used to assess the frequency and duration of disruption. The results of this spatial and temporal disruption mapping are presented in Figure 40. This information was then used to get a relative measure of performance across all options. A greater weighting was assigned to operational disruptions as these are longer-term in nature.

The 'environmental harm' criterion was assessed in a qualitative manner using the available information. The criteria adopted for the qualitative assessment are described in Table 24.

The non-economic technical evaluation of the shortlisted coastal management options should be considered complementary to the cost comparison presented in Section 0

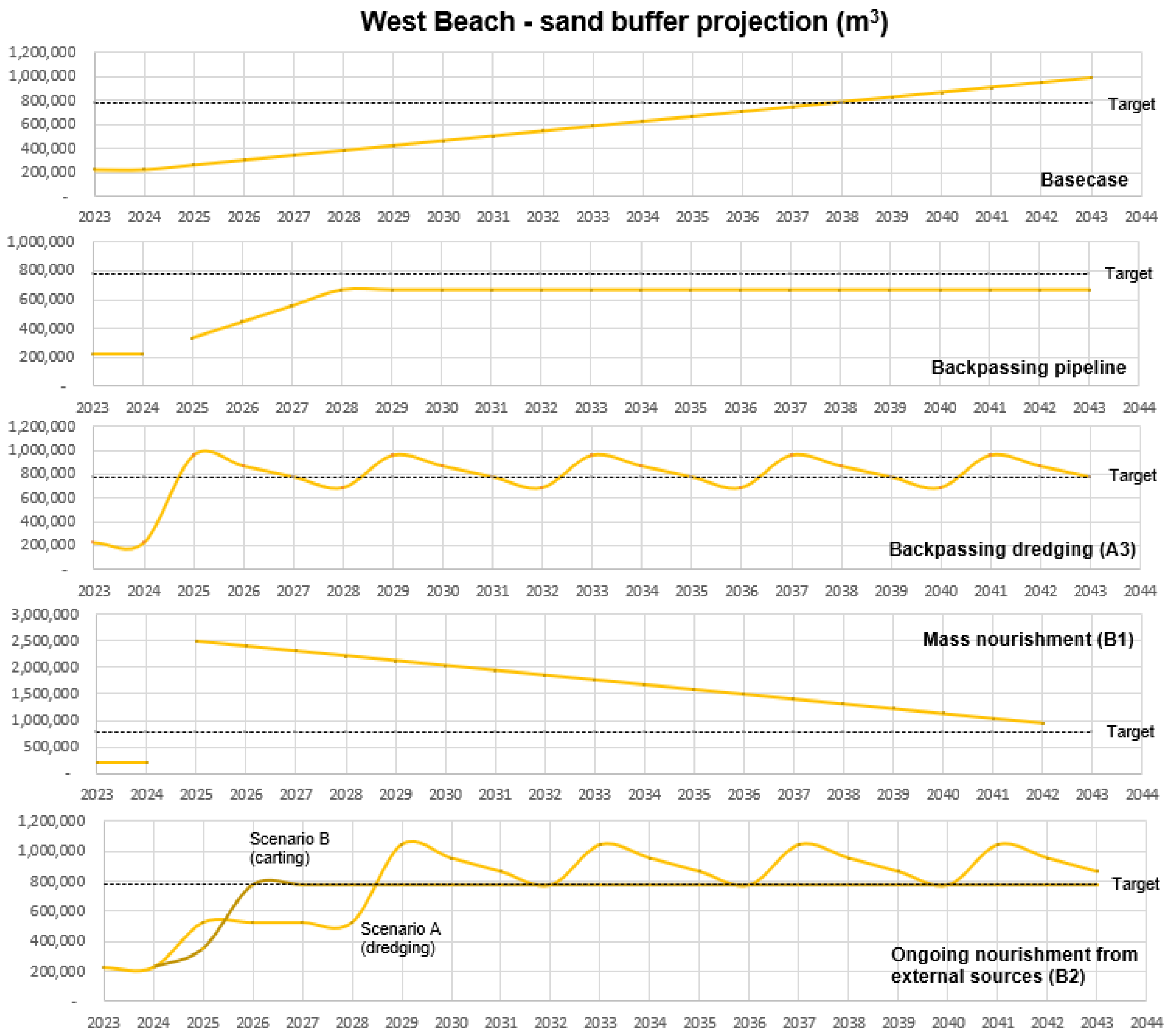
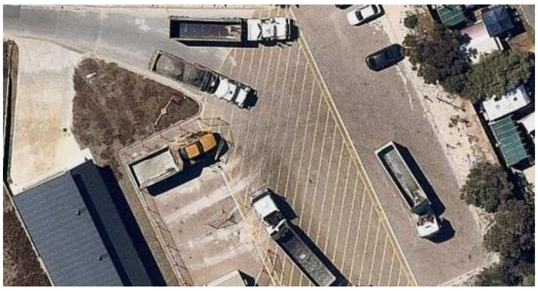


Figure 39: Coastal sand volume estimates within West Beach compartment for each option.

Table 23: Categories of community disruption adopted for the performance assessment.

Category (score)	Community disruption	
	During operation	
None (4)	No anticipated disruption to community caused during activity. Community access to and use of foreshore areas and the beach is uninhibited. Examples are: • dredging sand from sources in the nearshore and offshore areas	
Low (3)	Beach and foreshore access is largely unaffected but operational activities may have minor amenity or usage impacts on the beach, in foreshore areas and local roads. Examples are: • sand carting (trucks) on local roads • occupation of beach carparks by heavy equipment • nearshore (surf zone) sand placements	 
Moderate (2)	Areas closed for public access during operation with only minor presence/use of vehicles/machinery on the beach or in foreshore areas. Closure of the beach (wherein machinery may be located) is limited to a short extent (≈100m) of the beach. Examples include: • sand carting (trucks) on beaches • placement of sand via a fixed or temporary pipeline discharge point (at the back of the beach) • dredge pumping to shore via a pipeline.	 

<table>
<tr><th rowspan="2">Category (score)</th><th colspan="2">Community disruption</th></tr>
<tr><th colspan="2">During operation</th></tr>
<tr><td>High (1)</td><td>Areas closed for public access during operation and would involve extensive presence/use of vehicles/machinery on the beach and foreshore areas (including carparks and roads). Examples include:
construction of backpassing pipeline and associated infrastructure
sand harvesting for carting or pumping
operation of SCU on beaches
truck loading or unloading on beaches
DOP pump extracting sand from intertidal areas</td><td></td></tr>
</table>

Table 24: Adopted scoring framework for ‘environment harm’ criteria.

Category (score)	Impact on environment
Low (1)	Low level of impacts to sand dunes or seagrass meadows with approvals at least partly in place.
Moderate (0.5)	Moderate impact to sand dunes or seagrass meadows with main environmental assessment and approvals still required.
High (0)	Unacceptable risk of impact to sand dunes or seagrass meadows and planning approvals unlikely to be obtained.

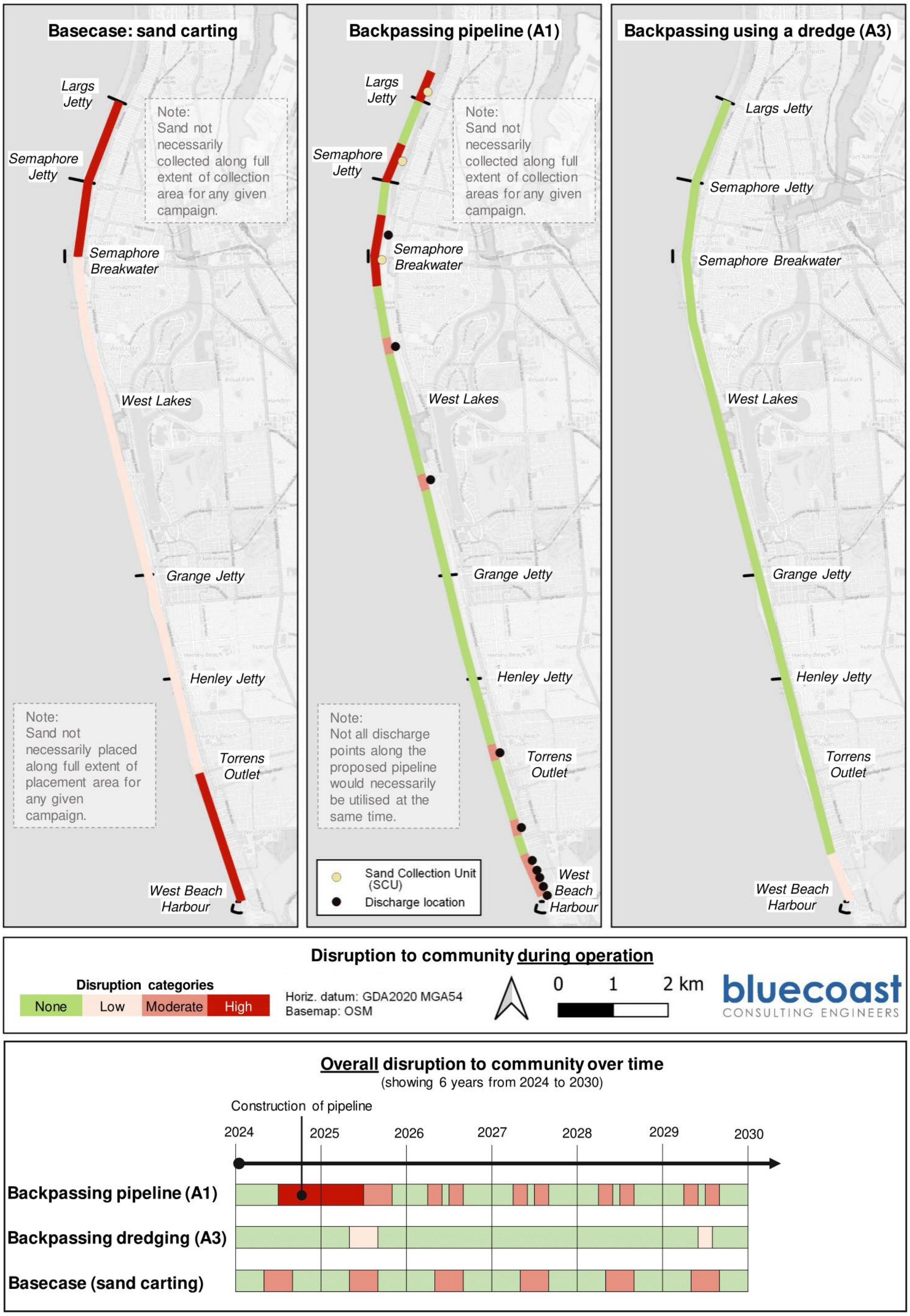


Figure 40: Map of expected community disruption during operations as well as overall (construction and operation) community disruption over time.

6.7.2 Technical evaluation results

The results of the comparative performance assessment of the shortlisted management options along with the rankings are provided in Table 25. Where total weighted score for two options were within 2% of each other, the ranking were considered to be equal (i.e. performance differential was indistinguishable by the methodology adopted). The relative ranking of the coastal management options, against the goals of the review, based on the non-economic factors is:

1. Equally top ranked options:
    - Backpassing using a dredge (A3)
    - Mass nourishment (B1)
    - Ongoing nourishment using external sources (B2, Scenario A 'dredging')
2. Backpassing pipeline with sub-option using nearshore mobile sand intake (A1.2)
3. Equally third highest ranked options:
    - Backpassing pipeline (A1)
    - Backpassing pipeline with sub-option using jetty and shoreline-based intake (A1.1)
4. Ongoing nourishment using external sources (B2, Scenario B 'sand carting')
5. Basecase (sand carting) (A1)

Other substantive issues that could influence decision making are discussed in Section 6.7.4.

Table 25: Summary of technical evaluation results and ranking.

Performance (Low – High)	Basecase (sand carting)	Technical evaluation Backpassing pipeline (A1)	Backpassing pipeline (A1.1)	Backpassing pipeline (A1.2)	Backpassing dredging (A3/A3.1)	Mass nourishment (B1)	External sand (B2) A - dredging	External sand (B2) B - carting
Beach health [33.3%]								
Minimise disruption (construction) [11.1%]								
Minimise disruption (operation) [22.2%]								
Minimise environment harm [33.3%]								
Rank (weighted)	5	3	3	2	1	1	1	4

A sensitivity analysis, whereby the individual scores for each option/criterion are varied within the bounds of uncertainty or subjectiveness to each score, was completed on the evaluation results and rankings. The main outcomes of this sensitivity analysis are:

- The results are **not** sensitive to the beach health or minimising disruption to communities (construction or operations) criteria but are sensitive to the minimise harm to the environment criterion. This is because the beach health and disruption results are fundamental outcomes of the option descriptions and not subject to significant uncertainty or any subjectiveness.
- For any of the pipeline options to rank number one (1), the minimising environmental harm criterion must be considered four (4) times more important than beach health and four (4) times more important than minimising disruption to community. Such a distorted weighting would not be supported by the findings of URPS's community engagement activities (URPS, 2023b). For example, protecting existing sand dunes and coastal habitats were ranked as the most important

environmental protection factors but these features would be most impacted by the pipeline options.

6.7.3 Life-cycle cost comparison

Life-cycle cost estimates, including basic breakdown, for each of the shortlist options are presented in Table 27. Life-cycle costs were estimated over a 20-year project period starting in 2024 and presented as net present values (NPV) using a 7% discount rate. The estimates were based on the conceptual description of the shortlisted options presented in Section 6.2 to Section 6.6, with further assumptions and sensitivity analysis outlined in Appendix F. Results of a sensitivity analysis to the discount rate at 3% and 10% is presented in Appendix F.

Given the conceptual level of design development for most options, the costings are high-level estimates. The infrastructure component of the backpassing pipeline (A1) option, however, has been subject to detailed design and construction tendering and therefore has a higher degree of certainty.

Comparison of the cost estimates highlights significant price differences between the options. For example, options that rely primarily on a backpassing pipeline to transfer sand (A1, A1.1 and A1.2) are around $60-70M more than options that primarily rely on dredging to transfer (A3, B1 and B2-A). Likewise, options that involve large quantities of sand carting from quarries (e.g., basecase and B2.2) are expensive.

The fundamental reason for this can be seen by examining all-inclusive unit rates for each of the key sand management activities, refer Table 26. Comparison of these unit rates highlights:

- The northern pipeline costs $41.8M to construct but the operational sand transfer costs are conservatively ($24.53/m^3) still more than the sand transfer costs from dredging ($18.84/m^3). The reason for the price difference is that the TSHD is a much more efficient technology to transfer sand when compared to the proposed backpassing pipeline with 'manual' sand harvesting.
- The use of quarry sand for the 'restore' volume leads to higher costs. If dredging was used for the restore volume for the backpassing pipeline (A1) costs would be reduced by $29M.

Table 26. Unit rates for sand management activities.

Activity	Rate ($/m^3)
All-inclusive unit rates (including capital cost infrastructure costs where applicable)	
Carting sand from northern beaches[1]	$17.17
Beach nourishment used a TSHD[1]	$18.84
Sand pumping using northern **backpassing pipeline**[2]	$43.10
Carting sand from quarries[1]	$63.74
Operational unit rates (not capital asset costs included)	
Sand pumping using n**orthern backpassing pipeline** (13.2km)[3]	$24.52
Sand pumping using s**outhern backpassing pipeline** (7.0km)[4]	$25.00

Note: 1. Varies, average rate adopted. 2. Includes asset costs. 3. Derived from estimates used in the costings herein. 4. Based on actual sand pumping costs supplied by DEW.

Table 27: Summary of life-cycle cost comparison over 20-year period in millions of dollars ($M).

Item	Basecase (sand carting)	Backpass pipeline (A1)	Backpass pipeline - jetty intake (A1.1)	Backpass pipeline - mobile intake (A1.2)	Backpassing dredging (A3)	Backpassing dredging - Inshore (A3.1)	Mass nourishment (B1)	External sand – dredging (B2 - A)	External sand – carting (B2 - B)
Initial/ construction costs	$0.2	$41.8M	$42.0M	$40.5M	$1.7M	$2.3M	$2.0M	$1.9M	$1.9M
Operating costs	$72.2M	$22.4M	$20.2M	$22.5M	$32.6M	$42.0M	$31.7M	$22.9M	$66.2M
Quarry sand (restore volume)	-	$36.5M	$36.5M	$36.5M	$5.7M	$5.7M	$11.5M	$25.7M	$27.5M
Disposal/ renewal costs	-	-$3.0M	-$3.0M	-$3.0M	-	-	-	-	-
Risk and contingency	$18.1M	$24.4M	$24.7M	$24.7M	$10.0M	$12.5M	$11.3M	$12.6M	$23.9M
TOTAL	**$90.5M**	**$122.1M**	**$120.4M**	**$121.2M**	**$50.0M**	**$62.5M**	**$56.5M**	**$63.1M**	**$119.5M**

6.7.4 Other substantive issues

The technical assessment presented above focused on the performance of the shortlisted options against the goals of the review. There are, however, several other issues that warrant consideration in comparing these coastal management options. These remaining substantive issues are discussed in Table 28. For each issue the anticipated relative performance of each option is provided.

Table 28: Summary of considerations on substantive issues related to shortlisted options but not addressed by the goals of the review.

<table>
<tr><th>Issue</th><th colspan="5">Considerations and quantitative performance</th></tr>
<tr><td rowspan="3">Sand accretion in Largs Bay and North Haven</td><td colspan="5">Due to the trapping effect of the Outer Harbour breakwater, Largs Bay and North Haven have undergone ongoing accretion of the shoreline and shoaling of the nearshore profile. While this has created new low lying dune systems the sand ingress has caused siltation issues for the North Haven Marina, making it more challenging to maintain navigation the marina’s entrance.

As outlined below, options that reduce the rate of or eliminate accretion will assist in reducing this issue. The backpassing pipeline (A1) and backpassing by dredging (A3) would be expected to perform well.

As outlined in Appendix F, the differential entrance dredging costs between the options expected at North Haven Marina have been included in the life-cycle cost estimates presented in Section 6.7.3.</td></tr>
<tr><td>Poor</td><td>Below average</td><td>Neutral</td><td>Above average</td><td>Good</td></tr>
<tr><td></td><td>B1, B2.A & B2.B</td><td></td><td>A1, A1.1, A1.2 & A3</td><td>A3.1</td></tr>
<tr><td rowspan="3">Climate change including sea level rise</td><td colspan="5">Climate change is expected to have an influence on the Adelaide coastline, with possible effects ranging from increased storm intensity, changes in wave climate, changes in rates of alongshore sand movement and a rise in the mean sea level. Options that are most flexible and adaptive will be expected to perform best in a changing climate.

The dredging options, with their much-reduced capital investment requirements and ultimate flexibility in sand placement locations, would be expected to perform best in this regard. In relation to sea level rise, new (or imported) nourishment sand may be needed, and the dredging options would likely be the most effective mechanism to deliver this.</td></tr>
<tr><td>Poor</td><td>Below average</td><td>Neutral</td><td>Above average</td><td>Good</td></tr>
<tr><td></td><td>A1, A1.1, A1.2</td><td></td><td>B1, B2.A & B2.B</td><td>A3, A3.1</td></tr>
</table>

<table>
<tr><th>Issue</th><th>Considerations and quantitative performance</th></tr>
<tr><td>Integrating with the southern backpassing pipeline</td><td>All options would be expected to mitigate the combined downdrift impact of the boat harbours and southern backpassing pipeline (i.e., the erosion at West Beach). History has indicated that carting options (Basecase and B2-Scenario B) have been an ineffective approach to use in synergy with the southern backpassing pipeline. The dredging and pipeline options would be expected to perform better. The northern pipeline options would 'close the loop' on the sand backpassing strategy set out in ALB (2005), which in theory has technical merit. In practice, however, backpassing in cells from Largs Bay to Brighton has been challenging to implement. This is evident by the fact that almost 20-years after the ALB strategy was embarked on only the southernmost cell is backpassed, with the incomplete implementation causing mid-coast erosion at West Beach and North Glenelg.

Dredging would work well with the southern backpassing pipeline, in particular the backpassing by dredging (A3 & A3.1) option. This option adopts the concept underlying the ALB strategy of utilising the sand accumulation in the northern metropolitan areas to nourish the eroding southern beach. Significantly, however, it uses a more efficient sand collection, transportation and delivery mechanism, as illustrated by the lower unit cost for the beach nourishment activity (see Section 6.7.3). The value of using a marine based sand transfer mechanism on a heavily developed Adelaide coastline, where the beaches are highly utilised and valued by the community, is highlighted by the performance about minimising disruption for all communities.

Ultimately, at the end of the southern pipelines' operational life the backpassing by dredging (A3 & A3.1) option could be adapted to deliver sand to Brighton and bypassing of the harbours reinstated, which may well be the least cost Adelaide metropolitan wide coastal management strategy in the long-term.

<table><tr><th>Poor</th><th>Below average</th><th>Neutral</th><th>Above average</th><th>Good</th></tr><tr><td></td><td>B2.B</td><td>B2.A</td><td>A1, A1.1, A1.2 & B1</td><td>A3 & A3.1</td></tr></table></td></tr>
<tr><td>Minimising release of micro and nano plastics into the marine environment</td><td>The pipeline options would be expected to be least performing in this regard. The quantity of plastics particles generated by abrasion of the HDPE pipeline was calculated as part of the project Development Application (DA) (JBS&G, 2021). The calculation of these quantities is subject to some uncertainty and would need to be revised in line with the proposed pipeline extension to Largs Jetty. However, the much shorter pumping distances associated with dredging options would result in much less micro and nano plastics being released. The options involving significant carting would be best performing in this regard.

<table><tr><th>Poor</th><th>Below average</th><th>Neutral</th><th>Above average</th><th>Good</th></tr><tr><td>A1, A1.1 & A1.2</td><td>A3, A3.1, B1 & B2.A</td><td>B2.B</td><td></td><td></td></tr></table></td></tr>
<tr><td>Management of Torrens Outlet</td><td>The shortlisted options are all set out to restore and maintain the sand volumes at West Beach. This in effect will revert the shoreline and beach behaviour back to pre-2005 conditions, and in that regard, would not be expected to have an unexpected effect on the Torrens Outlet.

The exception to this is the mass nourishment option (B1). This option will 'overfill' the West Beach compartment (i.e., mini version of the Dutch sand engine). Introducing such a mass of sand to the system, may have unintended consequences (e.g., impact on flood behaviour, reduce water quality, entrance and/or bank instabilities), on the Torrens Outlet, with a wider beach berm for the flow to discharge</td></tr>
</table>

Issue	Considerations and quantitative performance				
	across. These potential unintended consequences are significant and warrant detailed assessment if this option was to be progressed further.				
	Poor	**Below average**	**Neutral**	**Above average**	**Good**
	B1		A1, A1.1, A1.2, A3, A3.1, B2.A & B2.B		
Implementation challenges	All options are considered to have remaining challenges to implementation: • Dredging options require confirmation of suitable sand sources and extensive environmental planning approvals. • Pipeline options are currently lacking a social licence to operate from all affected communities. This will require further engagement on the option, which is not guaranteed to be successful in gaining wider support, or 'the will of Government' to implement the strategy. The latter is likely to be better received if the Government can demonstrate there are no other viable alternatives. Further environmental planning approvals are also required but these are less extensive in comparison to the dredging options. • Carting options will have similar challenges in terms of social licence but do not require further planning approvals.				
	Poor	**Below average**	**Neutral**	**Above average**	**Good**
		A1, A1.1, A1.2, A3, A3.1 & B1	B2.A	B2.B	
Nearshore and offshore sand source for dredging options including compatibility	Based on the historical information presented to this review it has not been possible to categorically rule out the possibility of suitable sand sources for beach nourishment delivered by dredgers. While there are clearly significant constraints, the review has identified potential sources that are considered more likely than not to be viable. The targeted investigations outlined in Section 7.2 will enable this question to be determined. As outlined in **Appendix C**, insufficient information is available to indicate if the identified sand sources will be more compatible than the pipeline sand source (i.e., northern subaerial beach from Semaphore to Largs). Given pipeline options are around $60-70M more than dredging options any quality differences in sand sources (e.g., grain size, percentage carbonate and/or presence of seagrass fibres) would need to be significant for the life-cycle cost estimates to approach parity.				
	Poor	**Below average**	**Neutral**	**Above average**	**Good**
			B1, A1, A1.1, A1.2, A3, A3.1, B2.A & B2.B		
Greenhouse gas abatement	It is envisaged that the pipeline option would perform well in CO2 abatement. However, detailed analysis, beyond the scope of this review would be required to confirm that. Despite the pump stations being electric the sand harvesting and processing machinery operates on fuel. These operations may be less fuel intense				

<table>
<tr><th>Issue</th><th colspan="5">Considerations and quantitative performance</th></tr>
<tr><td rowspan="2"></td><td colspan="5">but for much longer duration when compared to dredging. It may be that the difference in CO2 abatement is marginal between dredging and pipeline options. Sand carting options would be expected to perform poorly in terms of their CO2 footprint.</td></tr>
<tr><td>Poor
B2.2</td><td>Below average</td><td>Neutral
A3, A3.1, B1 & B2.A</td><td>Above average
A1, A1.1 & A1.2</td><td>Good</td></tr>
<tr><td rowspan="2">Glenelg North</td><td colspan="5">All shortlisted options, as set out herein, largely ignore the coastline between the two boat harbours. Should a sandy beach be desired along this frontage in the future, the dredging options would be the most adaptable and flexible, to deliver this outcome. Sand carting may also be a practical solution if access allows.</td></tr>
<tr><td>Poor
A1, A1,1 & A1.2</td><td>Below average</td><td>Neutral</td><td>Above average
B2.B & B1</td><td>Good
A3, A3.1 & B2.A</td></tr>
<tr><td rowspan="2">Integration with complementary coastal management options</td><td colspan="5">Dredging options would be expected to perform best with each of these complementary management options, including seagrass restoration and dune stabilisation and revegetation. Beneficial reuse of dredged material is a standout example of this.</td></tr>
<tr><td>Poor</td><td>Below average
B2.B</td><td>Neutral
A1, A1.1 & A1.2</td><td>Above average
B2.A</td><td>Good
A3, A3.1 & B1</td></tr>
</table>

7. Summary and next steps

7.1 Summary

This report provides a desktop review of the management of Adelaide's beaches. It examines available coastal management options for the Adelaide's metropolitan beach system, the identification and assessment of which was informed by:

- A comprehensive literature review inclusive of documenting the history of Adelaide's beaches and of Australian and international sand management approaches.
- Analysis of datasets relevant to the understanding of coastal processes and the local environmental setting for the management options.
- The development of a contemporary coastal sand budget.
- A constraints and opportunity analysis to identify factors that could influence future management options.

Coastal management options were developed for the northern Metropolitan beaches from West Beach to North Haven. At West Beach coastal erosion has recently proceeded beyond an acceptable natural sandy buffer (i.e., the buffer does not provide an acceptable level of coastal protection or beach amenity). The <u>main</u> causal mechanism of the long-term erosion observed at West Beach are explained by:

1. the blockage of natural sand supply from the south due to the impact of the Holdfast Shores, West Beach Harbour and the backpassing of sand from Glenelg, and
2. the natural net northward movement of sand that, under the action of waves, acts to move sand out of West Beach towards Largs Bay.

The option development and assessment approach adopted for this review commenced with the identification of a longlist of 24 options that aimed to address the causal mechanisms affecting the northern management area. The selection of a shortlist of four main options with two additional sub-options were justified by the application of a coarse filter approach using three criteria. The shortlisted options were further developed to enable a conceptual description sufficient to allow comparative life-cycle cost estimates over a 20-year period. The shortlisted options were then subject to a technical (non-economic) evaluation of the shortlisted options, with performance criteria aligned to the three goals of the Adelaide beach management review:

1. maximise the amount of sand on beaches
2. minimise disruption for all communities
3. avoid environmental harm.

The results of this technical evaluation are summarised in Section 6.7.2 with life-cycle cost estimates outlined in Section 6.7.3. In addition, remaining substantive issues not specifically addressed by the three review goals were considered and compared across shortlisted options (see Section 6.7.4).

The result of the scientific review is that options involving beach nourishment using dredging equipment, in particular Option A3 (backpassing by dredger) and its sub-option A3.1, have merit. They have merit because they transfer sand to where it is needed more efficiently (i.e., are therefore significantly cheaper) and they do this with significantly less community disruption. However, there are remaining uncertainties regarding sand sources and environmental planning approvals. Understanding the quality of potential sand sources, including the environmental constraints, will reduce both remaining uncertainties. In the case a suitable sand source cannot be confirmed, or some other barrier is found, then the pipeline options, either A1 or A1.2, could be pursued with the additional confidence that due diligence on alternatives had been exhausted.

7.2 Next steps

7.2.1 Short term

The roadmap forward will, beyond the next 12-months, depend on which long-term strategy the South Australian Government decides to take forward. In short-term, all shortlisted options assume a one-to-two-year period for project planning. It is recommended, that a **‘no regrets’** approach be taken that prioritise targeted sand exploration investigations. Figure 41 illustrates the adaptive decision pathways for such an approach whereby the planning for a beach nourishment option using dredging equipment (e.g., A3) is pursued with clear decision points to swap strategies to a pipeline (e.g., A1) if new information justifies the need to adjust.

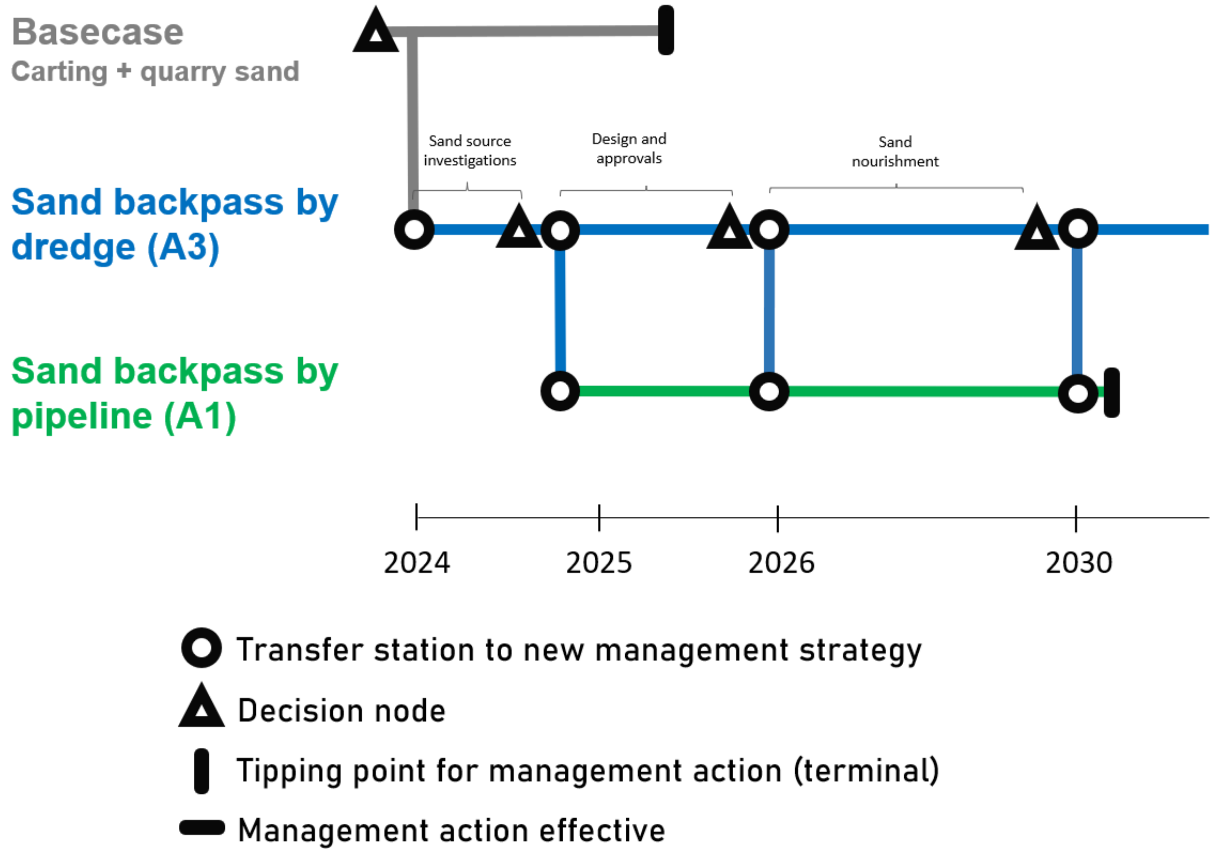


Figure 41. Example of adaptive pathways over the short-term.

The short-term roadmap is further explained by the steps and decision points below. An indicative and comparative schedule for the planning period is shown in Figure 42.

Step 1: Complete targeted sand sourcing investigations taking six to nine months for an estimated cost of $400,000.

Decision point 1: If suitable sand sources are found, a decision informed by the sand sourcing investigations outcomes is then required to continue to invest in dredging option and move onto the design and approvals phase. If no suitable sand sources are identified, a decision is required to swap to the pipeline strategy.

Step 2: Undertaking design, environmental assessment and approvals works for a long-term dredging strategy (or pipeline strategy). This is estimated to take 12 to 18-months and estimated cost of $1.1M.

Decision point 2: If dredging approvals are sought but not granted a decision is required to swap back onto the other coastal management pathway.

Step 3: Implement the strategy, say beach nourishment via A3. At an appropriate future point (say 2030) the strategy would be reviewed. In the case of the beach nourishment using dredging equipment option performing well, a decision to is made to terminate a northern pipeline as an alternative strategy.

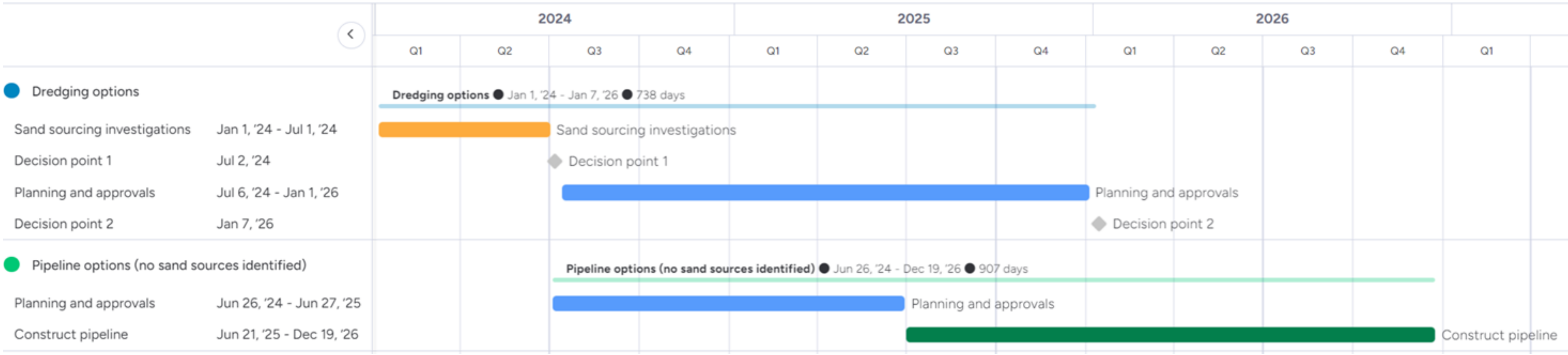


Figure 42. Indicative short-term project schedule for dredging or pipeline options.

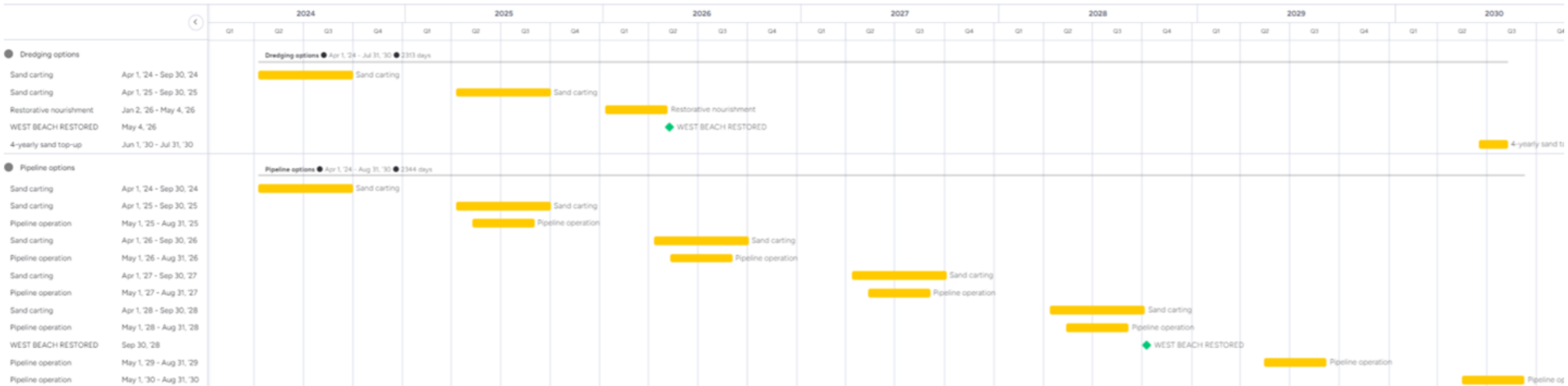


Figure 43. Comparative sand delivery schedule for dredging (A3) and pipeline (A1) options.

Note: The green diamond indicates when West Beach sand buffer would be fully restored.

The beach health at West Beach will remain compromised over the initial planning period of each option and any delay in restoring the sandy buffer comes at significant cost if sand carting from quarries is continued. Due to the high cost of this activity, it should be seen as an interim measure, and it is critical that lead times to implementing the new strategy are kept to a minimum. Sand carting from northern beaches is a viable alternative that is significantly cheaper. This could be considered in the interim but only until the long-term strategy is implemented.

Table 29 provide a basic outline of the scope of the key tasks required for each of the planning steps for the dredging options. The short-term implementation actions for the pipeline options are understood to be well understood and not included herein.

Table 29. Indicative scope of planning tasks required for dredging options.

Option	Description of tasks envisaged to be required
Dredging options (A3, A3.1, B1 or B2.A)	Step 1: Sand sourcing investigations (6 to 9-months) Identification and investigation of borrow area(s) would be required to assess the resource and its suitability for beach nourishment. Based on the desktop review completed herein (see **Appendix C**) it is envisaged this would focus on northern metropolitan sources with a preference for backpassing littoral sand. It would involve: • A comprehensive review and gap analysis of previous sand sourcing investigations (geophysical, coring and sampling data). Preliminary and rapid site investigation may also form part of this task if needed. This would inform the selection of target borrow area(s) and the scoping of the site investigations, including a sediment sampling and analysis plan (SAP). Undertaking a well-designed sediment sampling and analysis program of the native beach sand, which includes the shallow subtidal zone is also recommended. • Borrow site investigations which may include but not be limited to bathymetric survey, seabed surface sampling, geophysical and/or resistivity surveys, vibro-coring, physical and geochemical analysis, magnetometer survey, side scan sonar, video tows for benthic habitat and infauna sampling and analysis. • Consideration of environmental constraints and opportunities including those identified in Table 36, the EPA Dredge Guidelines, required environmental assessments and pathway(s) to all required planning approvals. It is important that the above investigations be overseen by suitable experts with experience in beach nourishment projects of this nature. In a similar fashion to this review, it is recommended that future sand sourcing investigations be undertaken independently of the Coastal Protection Board and that the findings and key data be made publicly available. These measures are to ensure the process is evidence-based, transparent and accepted by the community. Consideration could be given to a panel, comprised of dredging, seagrass/benthic habitat, coastal engineering and environmental planning legislation experts to review and advice Government. Step 2: Design, environmental assessments and seeking of approvals and permits. • Beach nourishment design and work methodology. • Baseline monitoring (water quality and metocean), dredge plume modelling, ecological surveys and other technical investigations. • Environmental assessment required to support planning approvals. • Scoping to be part of Step 1.

7.2.2 Longer term

A longer-term roadmap is considered speculative at this stage as it will depend on the strategy adopted by the South Australian Government. One aspect that warrants consideration is the treatment of the southern backpassing pipeline (Glenelg to Kingston Park) at the end of its operational life. For the northern management area, in the case of successful implementation of:

- A dredging strategy – at the end of the southern pipeline's lifetime it is envisaged there would be the potential to either (i) renew the southern pipeline or (ii) revert to a strategy involving bypassing of the two boat harbours (at Glenelg and West Beach) with beach nourishment placed by a dredger at Brighton/Kingston Park instead of at West Beach.
- A pipeline strategy – given the southern and northern pipeline's asset life cycles would be out of sync it is difficult to envisage anything other than a cycle of asset renewal and backpassing of sand over 20km of metropolitan coastline in perpetuity.

7.3 Key assumptions and uncertainties

The findings set out herein are subject to important assumptions and areas of uncertainty, including:

- No large scale and detailed bathymetry data was available for the Adelaide metropolitan nearshore and offshore area. This is considered a significant data gap.
- Comparative volumetric analysis of available coastal profile surveys has been used to estimate the sand budget and rates of sand movement. These estimates are therefore subject to the accuracy of these surveys as well as spatial and temporal gaps in the survey coverage.
- Consistent with the early design stage, relatively simple methods were used to develop the shortlisted options. In general, conservative assumptions and approaches have been adopted for the design of the main elements. More thorough approaches should be used during later design phases to better resolve and optimise the preferred option(s).
- Native beach material has been characterised by incomplete sediment sampling and is therefore subject to change.
- Assumptions relating to the life-cycle cost estimates are outlined in **Appendix F**.

8. References

Belperio, A.P. 1985. *Department of Mines and Energy Report No. 85/2*. Department of Mines and Energy, Adelaide.

Belperio, A.P. and Cann, J.H. 1990. *Quaternary evolution of the Robe-Naracoorte coastal plain: an excursion guide*. South Australia, Department of Mines and Energy. Report Book, 90/27.

Belperio, A.P. 1995. *Quaternary*. Chapter in 'The geology of South Australia. Volume 2. The Phanerozoic'. Department of Mines and Energy Bulletin 54, 219–280.

BMT WBM, 2013. Byron Shire Coastline Hazards Assessment Update. Report prepared for Byron Shire Council

Bone, Y., Deer, L., Edwards, S. and Campbell, E. 2006. *Adelaide Coastal Waters Study Sediment Budget*. ACWS Technical Report No. 16. Prepared for the Adelaide Coastal Waters Study Steering Committee. University of Adelaide, October 2006.

Bone, Y., Edwards, S., Deer, L. and Campbell, E. 2010. *Sediment sizes and sources in the cool-water, coastal environment of Adelaide, South Australia.* Published in 2010. Vol. 35, pp. 41 - 70, 2010.

Bowman, G. and Harvey, N. 1986. *Geomorphic evolution of a Holocene beach-ridge complex, LeFevre Peninsula, South Australia*. Journal of Coastal Research, pp.345-362.

Cooper, J. and Pilkey, O. 2012. *Pitfalls of shoreline stabilization: Selected case studies* (Vol. 3). Springer Science & Business Media.

Culver, R. 1970. *Final Summary Report on Beach Erosion Studies*. University of Adelaide report to the Seaside Councils Committee and the State Government of South Australia, Adelaide.

Coastal Management Branch. 1984*. Adelaide Coast Protection Strategy Review,* Department of Environment and Planning report to the Coast Protection Board, Adelaide.

Coastal Management Branch. 1992*. Review of Alternatives for the Adelaide Metropolitan Beach Replenishment Strategy.* Department of Environment and Planning, Adelaide.

Coast Protection Board. 1985. *Metropolitan Coast Protection District Management Plan*.

Department of Environment and Natural Resources. 1997*. Report of the Review of the Management of Adelaide Metropolitan Beaches.* Prepared by the reference group appointed by the Minister for Environment and Natural Resources, Hon. David Wotton, MP.

Department for Environment and Heritage. 2005. *Adelade's Living Beaches – A strategy for 2005 – 2025*. Technical report prepared by Natural and Cultural Heritage Department for DEH.

Department for Environment and Water. 2020. *Summary of Investigations: Port Stanvac offshore sand deposits.*

Department for Environment and Water, 2021. *Public presentation on the Securing the future of our coastline project.*

Department for Environment and Water. 2023. *Sand pumping along Adelaide's coast.* Accessed 8 November 2023. <https://www.environment.sa.gov.au/topics/coasts/managing-adelaides-beaches/sand-pumping>

DHI. 2018. *West Beach Coastal Processes Modelling: Assessment of Coastal Management Options.* Report prepared for Department of Environment, Water and Natural Resources.

DHI. 2020. *West Beach Coastal Processes Modelling: Assessment of Structural Options*. Technical memo prepared for Department of Environment, Water and Natural Resources.

Elliott-Perkins, Z., Wharton, C., Colleter, G., Prenzler, P., Woodham, J. 2021. *A Summary of the 2017 Gold Coast Beach Nourishment Project: Implementation and Effectiveness*. Australasian Coasts & Ports 2021 Conference.

Environmental Projects. 2022a. *Metro Coastline Sand Sampling. Report prepared for DEW and dated 31 March 2022.*

Environmental Projects. 2022b. *Metro Coastline Sand Sampling – additional sampling. Report prepared for DEW and dated 31 March 2022.*

EPA. 2000. *Sediment Quality Assessment of Barker Inlet: Effects of Contaminants and Sediment Disturbance on Benthic Infauna.*

EPA. 2006. *Adelaide Coastal Waters Study*.

EPA 2020 *Dredge guideline.* Guideline prepared by South Australian Environmental Protection Authority.

Erftemeijer & Robin Lewis III. 2006. *Environmental impacts of dredging on seagrasses: A review.* Marine Pollution Bulletin.

Frey, A., Morang, A. and King, D. 2016. *Galveston Island, Texas, Sand Management Strategies*, US Army Corps of Engineers, Engineer Research and Development Center.

Garner, G. G., T. Hermans, R. E. Kopp, A. B. A. Slangen, T. L. Edwards, A. Levermann, S. Nowikci, M. D. Palmer, C. Smith, B. Fox-Kemper, H. T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S. S. Drijfhout, T. L. Edwards, N. R. Golledge, M. Hemer, R. E. Kopp, G. Krinner, A. Mix, D. Notz, S. Nowicki, I. S. Nurhati, L. Ruiz, J-B. Sallée, Y. Yu, L. Hua, T. Palmer, B. Pearson, 2021. IPCC AR6 Sea-Level Rise Projections.

Gaylard, S., Nelson, M., & Noble, W. 2013. *Adelaide coastal waters study final report: Summary of study findings.* Environmental Protection Authority.

Glenn, S. 2001. *Deepening of the Outer Harbour Shipping Channel*. Report for Ports Corp South Australia.

Jackson, A. 2023. *Sand Bypassing and Backpassing – Theory and Application*. ICM.

JBS&G 2021 *Securing the future of our coastline project – Development Application October 2021*. Report prepared for DEW.

McConnell Dowell. 2022. *Sand Pumping Project 'For Design Review' drawings.*

Salients. 2021. *Impact Assessment (Phase 2) of Moving Sand from Adelaide's Northern Beaches*. Report prepared for Department for Environment and Water.

Seddon S. 2002. *Issues for seagrass rehabilitation along the Adelaide metropolitan coast: An overview*. In: Seddon S. and Murray-Jones S. Eds. Proceedings of the seagrass restoration workshop for Gulf St Vincent 15-16 May 2001. Department of Environment and Heritage and SARDI Aquatic Sciences, Adelaide, pp. 1-8

Seddon, S. 2004. *Community Ecology: Pattern and Process*. Nature Australia.

SMEC. 2022. *Sand Pumping System Project - Independent Design Certification Report*. Prepared for McConnell Dowell Constructors (AUST) Pty Ltd.

SquareHoles. 2020. *Future of the Coastline Report.* Report prepared for Department for Environment and Water.

Staudt, F., Gijsman, R., Ganal, C., Mielck, F., Wolbring, J. and Hass, C. 2019. *The sustainability of beach nourishments: a review of nourishment and environmental monitoring practice*. Journal of Coastal Conservation (2021) 25:34.

SwashPD. 2023. *Sand bypass and transfer systems around Australia,* accessed 21/11/2023, < https://www.swashpd.com.au/resources/sand-bypass-and-transfer-systems-around-australia/0>

Tanner, J. E., Irving, A. D., Fernandes, M., Fotheringham, D., McArdle, D., & Murray, L. 2014. *Seagrass rehabilitation off metropolitan Adelaide: a case study for recovering a degraded coastal ecosystem.* Marine and Freshwater Research, 65(8), 689-694.

Thomas R. and Clarke S. 2000 *Sedimentology and morphology of clastic seagrass beds in Holdfast Bay, South Australia.* Paper presented at 1st Seagrass Restoration Conference.

URPS. 2023a. *Adelaide Beach Management Review - Engagement Strategy*. Report prepared for Department of Environment and Water.

URPS. 2023b. *Adelaide Beach Management Review - Engagement Summary Report (Part A) - Values and long list engagement*. Report prepared for Department of Environment and Water.

URPS. 2023c. *Adelaide Beach Management Review - Engagement Summary Report (Part B) – Short List engagement*. Report prepared for Department of Environment and Water.

Water Technology. 2020. *Coastal Protection Infrastructure Assessment & Management Strategy: City of Holdfast Bay*. Report prepared for the City of Holdfast Bay.

Wavelength. 2022. *Assets Vulnerability and Risk Assessment: Coastal Hazards Study*. Report prepared for City of Charles Sturt.

Westphalen G, Collings G, Wear R, Fernandes M, Bryars S and Cheshire A 2004, *A review of seagrass loss on the Adelaide metropolitan coastline, Adelaide Coastal Waters Study* Technical Report No. 2, SARDI (Aquatic Sciences), Adelaide, SA

Appendix A: Review of Australian and international sand management

Table 30: Overview of Australian and international sand bypassing and backpassing projects.

Location	Type (bypassing / backpassing)	Average volume transferred (m³)	Description of key elements
Australia			
Murray River (SA)	Bypassing: Dredge and semi-permanent pipeline	1,000,000	The 'Murray River Mouth Sand Bypassing System' utilises a dredge, pipeline and multiple booster pumps. Dredging of the river mouth assists in sustaining the ecology of a Ramsar listed wetland and enables sufficient flushing of salt, nutrients, and suspended sediments to the sea.
Maroochydore (QLD)	Backpassing: Dredge and semi-permanent pipeline	50,000 (100,000 every 2 years)	Installed in 2013. Utilises a CSD operating in the Lower Maroochy River which transfers sand south via a pipeline with 2 booster pumps located along the length of the pipeline. A number of off-take locations allow sand to be discharged at various points along Maroochydore Beach.
Mooloolaba (QLD)	Bypassing: Dredge and fixed pipeline	20,000	Installed in 2012. A CSD operates in the entrance to Mooloolaba boat harbour, transferring sand to downdrift Mooloolaba beach via a permanent pipeline that crosses beneath the navigation channel.
Noosa (QLD)	Backpassing: Fixed sand backpassing system with sand shifter intake	30,000	Trial system installed in 2003 with permanent facility installed in 2013. • 1.6km-long entrenched pipeline with a main pump station and water intake on the Noosa River. A number of off-take locations along the pipeline allow sand to be discharged at various points along Noosa Main Beach. • Sand intake utilises a sand shifter unit which is buried below the beach with jets which fluidise sand for transport. • Small earth moving machines used to redistribute sand at discharge location(s).
Woorim (QLD)	Backpassing: Fixed pipeline	30,000	• Trial system commenced in 2017, pending permanent installation. • 2km-long pipeline with one main pump station and one main discharge location (with 4 additional possible off-take points). • Same intake system as described above for backpassing system at Noosa.

Location	Type (bypassing / backpassing)	Average volume transferred (m³)	Description of key elements
Gold Coast Seaway **(QLD)**	Bypassing: Fixed pipeline	500,000	Commissioned in 1986. Comprises a series of fixed jet pumps located along a pumping jetty, transferring sand through an under-channel pipeline to downdrift beaches vulnerable to erosion.
Surfers Paradise Sand Backpassing System **(QLD)**	Backpassing: Fixed pipeline	120,000	• Currently under construction, expected completion 2023-2024. • Intended to recycle a portion of sand captured by the Gold Coast Seaway bypassing system. • 8km-long pipeline with 4 booster pumps and 3 discharge locations, connected to the existing bypassing system infrastructure.
Currumbin and Tallebudgera Creek **(QLD)**	Bypassing: Dredge and semi-permanent pipeline	50,000 (Currumbin) 38,000 (Tallebudgera)	Both creeks dredged using a CSD every year during winter and spring to provide nourishment for nearby (downdrift) beaches.
Tweed River **(NSW)**	Bypassing: Fixed pipeline	500,000	Commissioned in 2001. Comprises a series of fixed jet pumps located along a pumping jetty, transferring sand through an under-channel pipeline to downdrift beaches vulnerable to erosion.
Tweed River **(NSW)**	Bypassing/ backpassing: Dredge	Variable	Maintenance dredging is conducted annually in the Tweed River with sand being placed at a number of available placement areas to the north and south of the river entrance (i.e. bypassing and backpassing, respectively). In 2023, the total volume of sand dredged was approximately 260000m3. Approximately 40,000m3 was placed at updrift locations at Final and Dreamtime beaches (i.e., backpassing).
Jimmys Beach **(NSW)**	Backpassing: Dredge and fixed pipeline.	30,000	• CSD extracts sand from entrance to Myall River, pumping ashore to onshore stockpile. • Excavator with jet pump used to collected sand from the stockpile and transport to permanent transfer pump station, where it is then transferred along a 2km-long pipeline to discharge locations.
Stockton Beach **(NSW)**	Bypassing: Dredge	30,000	Sand from maintenance dredging within the Port of Newcastle, undertaken annually, placed on Stockton Beach.

Location	Type (bypassing / backpassing)	Average volume transferred (m³)	Description of key elements
Gippsland Lakes Entrance (VIC)	Bypassing/ Backpassing: Dredgers and fixed pipeline	350,000	• CSD working within the Inlet itself, transferring sand (typically 120,000m³ p.a.) via a booster pump and pipeline to one of two above-water discharge points, located approx. 1km either side of the entrance. • TSHD operates on the outer bar, collecting sand (typically 250,000m³) and depositing just outside the surf zone via bottom dumping.
Portland (VIC)	Bypassing: Fixed pipeline with sand shifter intake	50,000	• This was the first fixed sand bypass system utilising sand shifters (described above for the sand backpassing system at Noosa). • The system recovers sand from a trap 60 metres offshore on the eastern side of the Main Breakwater. The sand is pumped under the entrance and discharges 3 km North of the harbour at Anderson Point.
Mandurah and Dawesville (WA)	Bypassing: Fixed pipeline with sand collection unit-type intake	100,000 (Mandurah) 120,000 (Dawesville)	Utilises sand collection unit similar to existing backpassing system in Adelaide. An excavator loads sand into a slurrytrak machine which screens sand and pumps it through a pipeline (≈ 1km long) under the navigation channel. Sand is deposited via various outfall arrangements.
International			
Barra do Furado (Brazil)	Bypassing: Fixed pipeline	Unknown	Constructed in 2012. 360m-long jetty with nine jet pumps, two pumping stations and an underwater pipeline to move sand from one side of the river to the other.
Durban (South Africa)	Bypassing: Dredge / fixed pipeline	250,000 – 500,000	A TSHD dredges sand from the southern side of the southern breakwater (sand trap). For delivery of sand to northern beaches, the dredge either: • directly discharges to the beaches via a direct discharge line • connects via a floating pipeline to an onshore sand bypass hopper, which delivers sand directly into the municipality's sand pumping booster station for sand to be distributed to the beaches north of the port's entrance channel. Front loaders used to move sand once deposited on beach.
Ngqura Industrial Port (South Africa)	Bypassing: Fixed pipeline (jetty)	160,000	System was commissioned in 2007 and consists of 6 jet pumps mounted on a 225m long jetty. Sand is pumped

Location	Type (bypassing / backpassing)	Average volume transferred (m^3)	Description of key elements
			3.4km to discharge point with 3 booster stations situated along the pipeline.
St. Augustine Inlet **(USA, Florida)**	Bypassing / backpassing: Dredge and temporary pipeline	212,000	• Material is dredged from Inlet placed in designated critically eroded areas to the north or south of the Inlet. Typically, backpassed to a 6.3km long stretch of beach south of the Inlet. • The bypassing volume objective set out in the Inlet Management Plan (IMP) is 278,000 cubic yards/year (212,000m^3) as determined by Inlet sink analysis. • Transfer campaigns occur every few years with varying volumes. For 2023, planned 610,000m^3 volume.
South Lake Worth **(USA, Florida)**	Bypassing: Fixed pipeline	150,000	• Unique design as a fixed sand intake suspended from a crane on the breakwater. • Dredging of Inlet also undertaken to transfer additional sand if required. • Operates approximately every six years
Palm Beach Inlet **(USA, Floridasan)**	Bypassing: Fixed pipeline	75,000-115,000	• Unique design as a fixed sand intake suspended from a crane on the breakwater. • Dredging of Inlet also undertaken to transfer additional sand if required. • Pipeline crosses under Inlet channel. Problems with pipeline rusting through and becoming non-operational.
Miami Beach **(USA, Florida)**	Backpassing: Truck haul / Earth-moving machinery and temporary pipeline	65,000	• Truck haul backpassing along beach previously conducted in 1996 and 2002 (volumes of 6,000m^3 and 96,000m^3 respectively). • Larger-scale pumping operations in 2007 and 2012 for beach erosion control and hurricane protection. In 2012, 65,000m^3 backpassed a maximum distance of 3.7km. Sand extracted from beach using excavators, stockpiled and loaded into a hydraulic loader via a hopper. Discharged via pipeline onto beach and shaped using earth-moving equipment.
Jupiter/Carlin Park **(USA, Florida)**	Bypassing: Dredge and temporary pipeline with earth-moving	80,000	• According to the Jupiter inlet District's Inlet Management Plan, an average of approximately 50,000m^3 of sand is dredged from the Inlet and navigation channels and pumped via a pipeline to beaches south of the Inlet to counter erosion and

Location	Type (bypassing / backpassing)	Average volume transferred (m^3)	Description of key elements
	machinery at outlet		provide safe navigation. Between 2020 and 2023, annual volumes have been 80-100,000m^3 per year. • Sand is transferred via a 0.5-2km-long pipeline an placed along a 1.6km-long stretch. Additional lengths of pipe are added to the pipeline as the placement proceeds along the beach depositing and distributing sand. Earth-moving equipment used to redistribute sand along the beach.
Sebastian Inlet **(USA, Florida)**	Bypassing: Dredge and temporary pipeline with earth-moving machinery at outlet	30,000 (150,000 every 4-5 years)	• The Sebastian Inlet District is responsible for bypassing sand that migrates into the inlet system, periodic dredging. • Sand transferred via a 1-2km-long pipeline and placed along a 2.4km-long stretch.
Cape May **(USA, New Jersey)**	Backpassing: Dredge and temporary pipeline with earth-moving machinery at outlet	Variable: 53,000 by trucking (backpassin g) 475,000 by dredge from offshore sources	• Periodic beach replenishment using a combination of sand backpassing (along beach via trucking) and dredging from the adjacent inlet/offshore sand sources. • 14 replenishments conducted in total since reconstruction of Cape May Beach in 1991.
North Wildwood **(USA, New Jersey)**	Backpassing: Truck haul / earth-moving machinery	Variable: 2013-2020: 115,000 - 150,000 2020: 230,000 2021: 270,000	Between 2013 and 2021, sand was harvested from Wildwood and transported via on-beach hauling trucks 2-3km along the beach to North Wildwood where it was spread out to form a beach berm. During these backpass campaigns, sections of the beach would often need to be reconstructed to re-establish truck routes along the beach. It is understood that the trucking program is now cancelled after the need to re-construct the beach to facilitate trucking became unfeasibly frequent due to excessive erosion. The backpassing regime was intended as an alternative project to expanding the beach by dredging from nearby Hereford Inlet. This is again being pursued as a solution. Regular trucks were not considered viable due to excessive number of truck loads and the time frame available to complete the works.
Avalon **(USA, New Jersey)**	Backpassing:	21,000 (42,000 roughly	• Sand methodically scraped and trucked to the north end beaches, then graded to an engineered template. Sand transported approximately 2km along the beach, passing beneath jetty.

Location	Type (bypassing / backpassing)	Average volume transferred (m^3)	Description of key elements
	Truck haul / earth-moving machinery	every 2 years)	• Avalon was the first beach community in New Jersey to commit to sand back passing projects as a way to bridge the gap between hydraulic beach fill projects. • Note also: Avalon Beach Fill project (2023). Nearly 460,000m3 of sand pumped to Avalon Beach to “prepare for Hurricane and tourism season”.
Port Hueneme (USA, California)	Bypassing: Dredge and temporary pipeline/ earth-moving equipment	1.7Mm^3 for 2022-2023 campaign	• Periodic sand bypass operation undertaken in large campaigns. Sand that accumulates outside/in the Channel Islands Harbor is moved to downdrift areas near Port Hueneme. Historically, the Army Corps of Engineers (COE) has dredged the Channel Islands Harbor and replenished sand on Hueneme Beach every two years.
Ocean Beach (USA, Califoria)	Backpassing: Truck haul / earth-moving machinery	50,000	• Excavating and trucking excess sand from North Ocean Beach to South Ocean Beach. Coarse sand from other sources placed as a top layer. • Sand trucked along highway using dump trucks, significant impacts on use of highway.
Santa Barbara (USA, Califoria)	Bypassing: Dredge and temporary pipeline with earth-moving machinery	180,000 (550,000 every 3 years)	• Fixed bypassing pipeline installed in 1933 • CSD extracts sand from the entrance to the harbour and pumps along the fixed bypassing pipeline to nourish the downdrift beach.
Corpus Christi Beach (USA, Texas)	Backpassing: Truck haul / earth-moving machinery	Variable: 2016: 20,000 2022: 8,300	• Ad hoc backpassing operations conducted in response to significant erosion events.
Galveston Island (USA, Texas)	Backpassing: Fixed pipeline	40,000-75,000	• Frey et al (2016) describe a permanent sand backpassing system as a design option for coastal management at this location. Average annual volume is the range of their estimates for the required capacity of the system. • Previously, backpassing by trucking had been undertaken at the location.
Indian River Inlet (USA, Delaware)	Bypassing: Temporary pipeline with intake	75,000	• In 1990, the U.S. Army Corps of Engineers constructed a sand bypassing system to mitigate the downdrift beach erosion by transferring sand slurry from the updrift to downdrift side of the inlet. • Sand intake (jet pump) suspended from a crawler crane situated on the beach. Pumped through a single

Location	Type (bypassing / backpassing)	Average volume transferred (m³)	Description of key elements
	suspended from crane		pumpstation, the pipeline crosses the inlet via the highway bridge. • Sand placement area extends approximately 1km along the downdrift beach adjacent to the inlet.

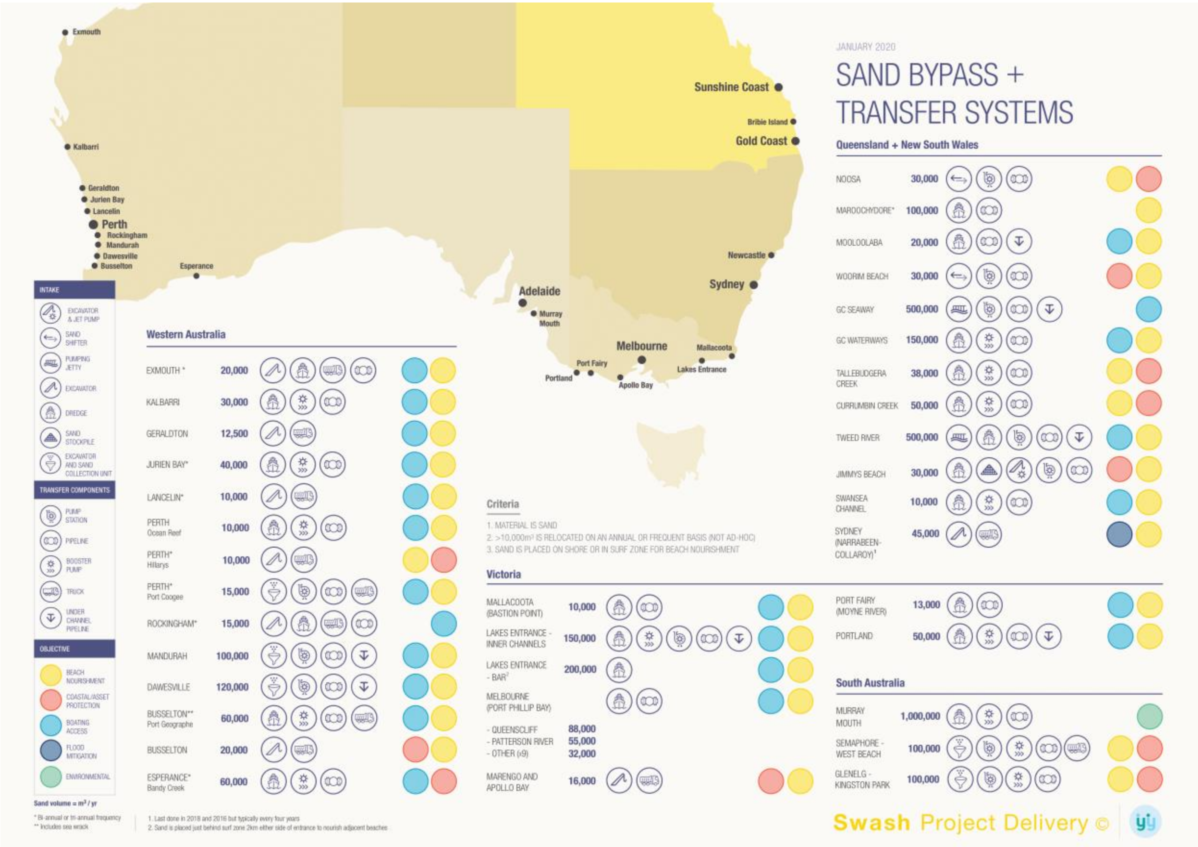


Figure 44: Overview of sand bypass and transfer systems around Australia (SwashPD, 2023).

Appendix B: Wave climate tables

Table 31: Wave measurement statistics derived from Brighton wave buoy.

Parameters	Statistics	LTA (3 years)	Winter	Autumn	Summer	Spring
Significant wave height (Hs) [m]	Mean	0.55	0.61	0.51	0.50	0.59
	20%ile	0.26	0.31	0.23	0.25	0.26
	50%ile	0.45	0.53	0.42	0.44	0.45
	75%ile	0.69	0.76	0.63	0.64	0.75
	90%ile	1.07	1.14	0.96	0.84	1.27
	99%ile	1.93	1.81	1.84	1.69	2.08
	99.5%ile	2.10	2.05	1.96	1.94	2.25
	Max	3.17	2.75	2.81	3.15	3.17
Peak wave period (tp) [s]	Mean	6.3	6.7	6.0	6.0	6.6
	20%ile	3.2	3.6	3.0	3.0	3.3
	50%ile	4.4	4.8	4.3	4.1	4.9
	75%ile	8.5	9.3	7.9	7.9	9.3
	90%ile	12.8	12.8	12.8	12.8	12.8
	99%ile	20.5	17.0	25.6	25.6	17.1
	% of time sea (Tp<8s)	74%	72%	76%	76%	0.72
	% of time swell (Tp>8s)	26%	28%	24%	24%	0.28
Peak wave direction (Dp) [ºN]	Weighted Average	249	266	245	238	248
	STD	43	40	44	42	42

Table 32: Wave measurement statistics derived from Semaphore wave buoy.

Parameters	Statistics	LTA (3 years)	Winter	Autumn	Summer	Spring
Significant wave height (Hs) [m]	Mean	0.60	0.59	0.54	0.62	0.63
	20%ile	0.29	0.33	0.27	0.30	0.29
	50%ile	0.51	0.53	0.45	0.57	0.50
	75%ile	0.76	0.73	0.68	0.82	0.82
	90%ile	1.08	1.04	0.98	1.07	1.27
	99%ile	1.81	1.69	1.66	1.71	2.00
	99.5%ile	2.02	1.91	1.83	1.95	2.17
	Max	4.27	4.01	2.96	4.27	2.94
Peak wave period (tp) [s]	Mean	7.1	8.1	6.9	6.5	7.7
	20%ile	3.4	3.5	3.3	3.5	3.5
	50%ile	4.6	4.9	4.4	4.4	5.1
	75%ile	12.8	12.8	12.8	10.2	12.8
	90%ile	14.6	14.6	14.6	12.8	14.6
	99%ile	17.0	17.1	17.0	25.6	14.1
	% of time sea (Tp<8s)	66%	56%	60%	74%	61%
	% of time swell (Tp>8s)	34%	44%	30%	26%	39%
Peak wave direction (Dp) [ºN]	Weighted Average	226	279	223	211	226
	STD	44	51	42	33	45

Appendix C: Review of sand sources

Introduction

A review of potential sand sources with suitable material for use as beach nourishment was undertaken. The review involved:

- Native beach sand characteristics based on available information the characteristics (physical and geochemical properties) of the sediments along the Adelaide's metropolitan beaches is presented. This information was then used to define acceptance criteria for material suitable for beach nourishment at West Beach or elsewhere along the northern beaches.
- Potential sand sources are then identified, and each source is assessed for suitability as beach nourishment for the northern management area of Adelaide's beaches.

Native beach sand

When selecting sand for beach nourishment projects, it's critical that the imported sand closely matches the native beach sand in terms of grain size, composition, angularity, colour and other relevant characteristics. This is important for both the aesthetic appearance and the long-term performance of the nourished beach.

Sand grains of Adelaide's metropolitan beaches are fine to medium with a median grain size (D50) of 0.22 millimetres (mm) (DEH, 2005). Adelaide beach sand consist predominately of quartz (silica) grains with variable amounts of shell fragments and carbonate content. Silica grains tend to be sub-angular or rounded (rather than angular) while the carbonate fraction consists of soft biogenic material and sharp shell fragments.

The grain size distribution at any given point on the beach is a function of the depositional energy of the cumulative coastal processes (i.e., wind, waves and currents). Usually the coarsest material, with the poorest sorting, is found at the shore break plunge point just seaward of the backrush, an area of high turbulence. A secondary coarse sediment distribution can be found on the top of the summer berm. Finer, better sorted material can be found in the dunes and becomes finer as one moves seaward of the breakers. To define the native beach sand characteristics, a thorough sediment sampling strategy should be implemented. This includes sufficiently dense sampling of the full extents of the planned beach nourishment area (i.e., in the alongshore, cross-shore and vertically) with sufficient analysis to adequately understand the native sediment properties.

There has been a few sediment sampling and analysis efforts that can be referred to for characterisation of the native beach sands along the study area:

- In **2021 and 2022 Environmental Projects (2022a and 2022b)** collected sand sampling along the Adelaide metropolitan coastline, between Kingston Park and Largs Bay. Samples were collected along 27 shore normal profiles with four individual samples taken in the upper profile at: toe of the dune, high-water mark (0.9m AHD), mean sea level and the 'saturated zone' (approximately -0.5m AHD). Importantly, no samples were undertaken in the subaqueous part of the profile. Particle size distribution and the calcium carbonate concentrations were reported. The profiled averaged results are mapped in Figure 45. It shows that the median grain size (D50) generally varies between 0.2 and 0.3 mm (mean D50 of 0.23mm) with the carbonate content less than 10% along much of the coastline. There is:

    - Localised coarser sand from Kingston Park to Glenelg South and then between Henley South and Grange/Tennyson with an average D50 in these areas of 0.25mm. This appears to correlate with a steeper coastal profile slope in these areas.
    - Decrease in grain size north of Point Malcolm (Semaphore breakwater), to the north of the Semaphore breakwater the average D50 is 0.19mm. There is a corresponding increase in the carbonate content, which goes from around 10% at Point Malcolm to just under 30% at Largs Bay north. That is the northward fining is likely a result of finer biogenic (carbonate-rich) sediments that are produced in the dense seagrass meadows moving onshore and mixing with the coarser quartz-rich sand found on the southern beaches.
    - Finer sand at Largs Bay north (D50 = 0.16mm at profile no. 20001) about 950m south of the marina at North Haven.
- The **Adelaide's Living Beaches** (DEH, 2005) technical study presented a similar alongshore sand size distribution plot (reproduced in Figure 46). This was based on sampling in 2002-03 and 1964. The plot shows a similar alongshore grain size and carbonate content distribution as the more recent sampling described above. The ALB (2005) report also states an average D50 of 0.22 mm, which aligns with the 2021 to 2022 sampling of the subaerial beach.
- A third dataset has been used herein because it includes over 1,000 samples taken over a wider alongshore extent with samples to 20m water depth. This dataset was reported in **Bone et al. (2006) and Bone et al. (2010)**. Samples were taken along 23 shore normal transects, with each transect sampled at up to eight elevations being: back of beach, mid-tide and at depths of 1m, 2m, 5m, 10m, 15m and 20m. Unfortunately, full particle size distribution data is not available for this review. Percentage sizes were reported across four categories:
    - Coarse (>2mm): gravels and coarser
    - Medium (2mm to 0.25mm): medium to coarse sand
    - Fine (0.25mm to 0.063mm): fine to medium sand
    - Very fine (<0.063mm): fine sediments (i.e., silts and clays).

  The grain size distribution reported in Bone's sampling does not align with those reported in Environmental Projects (2022a and 2022b) or ALB (2005). The reason for the lack of consistency is unknown but means that only relative comparisons across the Bone sampling are reported herein. Figure 47 and Figure 48 show the locations of the Bone sampling transects along the northern Adelaide's metropolitan beaches and includes plots showing sediment grain size for each sample. A similar pattern with an increase in fines moving northward is noted.

While the above information is useful in defining the native beach characteristics, it falls short of a through sediment sampling strategy to inform a large beach nourishment or backpassing project. Therefore, the information provided herein is preliminary.

Based on the available sediment sampling data completed along the metropolitan beaches Table provides the characteristics of the native beach material. It is important to note, however, that the native beach sampling completed to-date has not covered the cross-shore extent of erosion at West Beach, which extends down to -4m AHD. To fully define the native beach sampling to this depth should be considered. When undertaking such an exercise consideration would need to be given to the large quantities of coarse sand added to West Beach recently. Should this data become available the native beach sand characteristics below would need to be reassessed, which would likely bring down the native D50.

Table 33: Native beach sand characteristics.

Parameter	Metropolitan beaches	Northern management area	West Beach
Grain size [mm]	D10 = 0.13 **D50 = 0.23** D60 = 0.26	D10 = 0.13 **D50 = 0.23** D60 = 0.26	D10 = 0.13 **D50 = 0.23** D60 = 0.26
Carbonate content [%]	10.4	12.3	6.2
Gravel (or coarser) content (%)	1.3	1.0	0.5
Fines (<75µm) content (%)	3.5	3.4	3.4
Uniformity co-efficient	2.0	2.0	2.1

Figure 45: Median grain size (D50) and carbonate content of beach sand along Adelaide's metropolitan beaches (data source: Environmental Project, 2022a and 2022b)

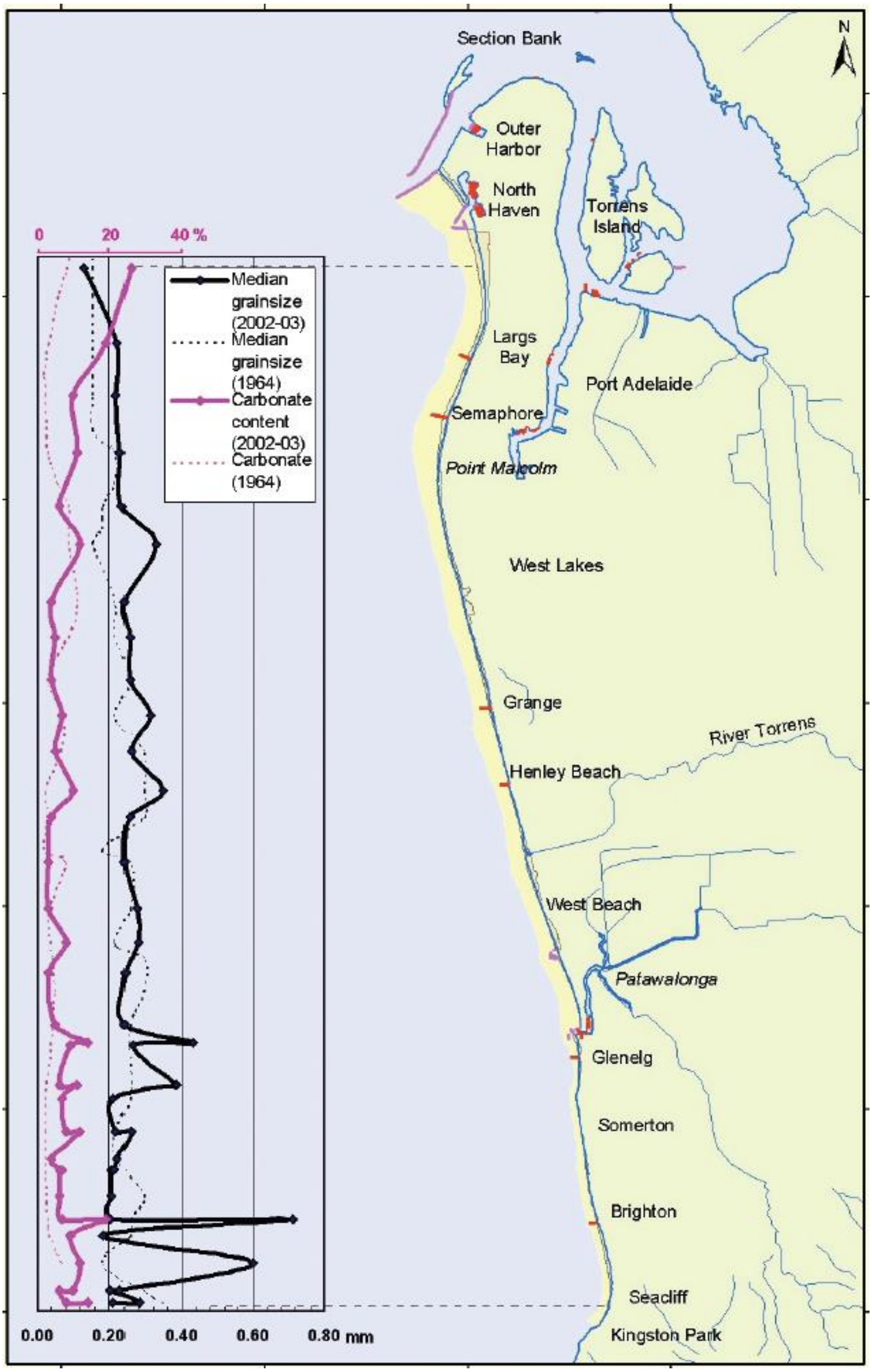


Figure 46: Previously sampled median grain size (D50) and carbonate content of beach sand along Adelaide's metropolitan beaches (source: DEH, 2005).

Figure 47: Representative native beach sand samples from southern Adelaide's metropolitan beaches (data source: Bone et al. 2006 & Bone et al. 2010).

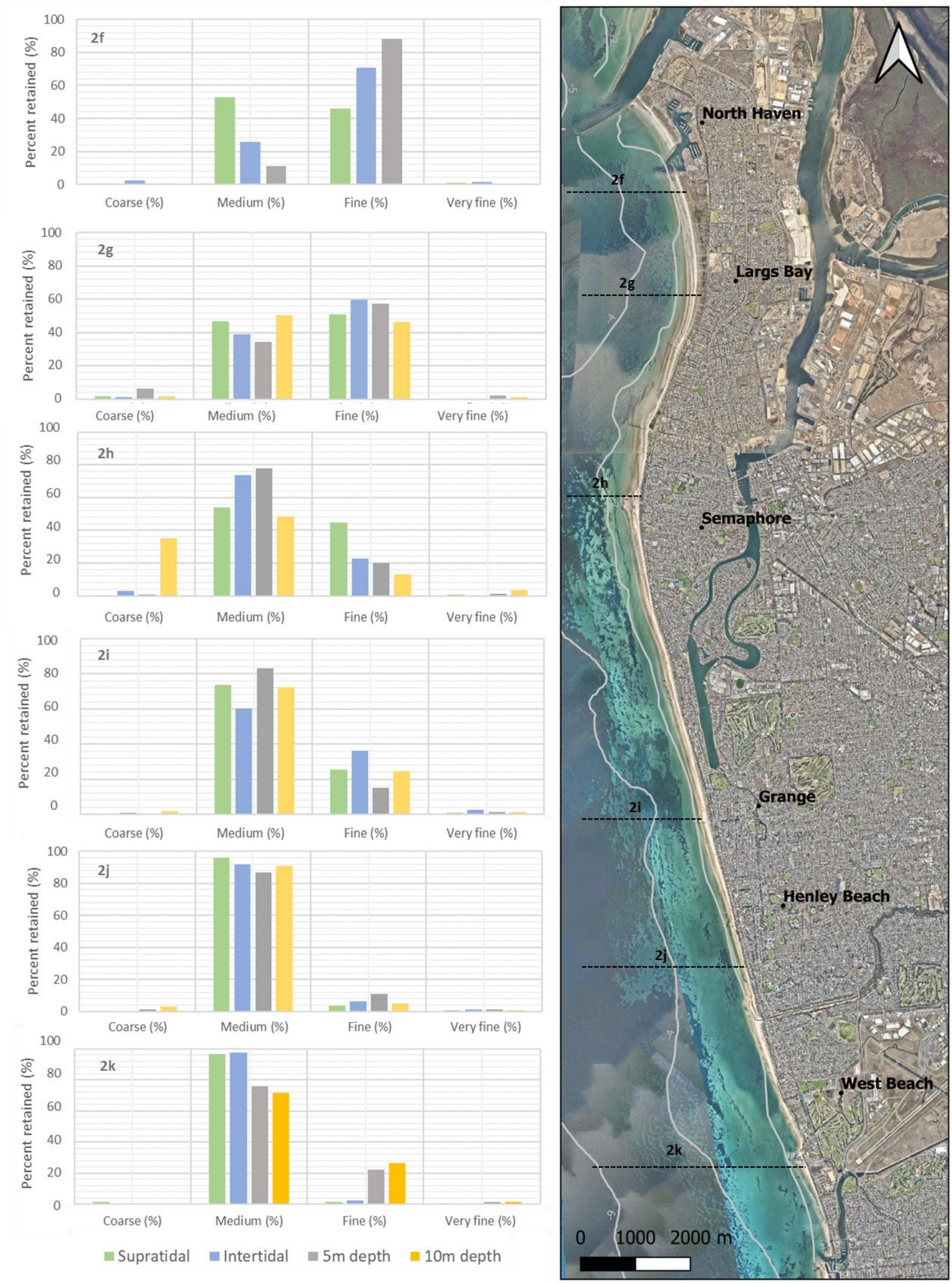


Figure 48: Representative native beach sand samples from northern Adelaide's metropolitan beaches (data source: Bone et al. 2006 and Bone et al. 2010).

Acceptance criteria for compatibility of nourishment material

Not all sand is the same, with potential differences in physical properties such as grain size, composition and colour. Typically, the more similar these properties are to the native beach sand, the more compatible the nourishment sand will be. These properties can influence the likely loss rate of the nourishment sand, the optimum placement location of the nourishment material and/or the acceptability to the community e.g., colour. These properties can be assessed in advance to determine how compatible a potential nourishment source is with the native beach sand.

In considering the acceptability of any sand source for beach nourishment it is recommended that a two-staged assessment be undertaken:

1. **Initial screening** based on the known physical properties of the source material against the acceptability criteria outlined in Table 34. This is intended as a preliminary review of sand source opportunities and is undertaken herein.
2. **Compatibility assessment** to determine if the material could potentially be used for beach nourishment in the northern management area. This assessment would consider targeted sampling undertaken in the borrow area as well as a broader range of factors and how they affect the viability, feasibility and acceptability of the source material. This is not completed herein.

Table 34 provides preliminary specification of the physical parameters based on the review of native beach sand properties presented above together with sand specifications for beach nourishment set out in the ALB (2005) report, DEW's specification for quarry sand as well as other recommended acceptance criteria. It is recommended that these criteria be reviewed following the completion the completion of an appropriated designed sediment sampling program of the native beach material.

The acceptance criteria for nourishment sand varies depending on the location of the sand placement. Sand placed on the subaerial or 'dry' portion of the beach would be required to satisfy a more stringent specification to achieve acceptable beach amenity. For nourishment material placed on the subaqueous or submerged part of the beach, it may be reasonable for the material properties to be outside these tighter specifications. This is because placement in the nearshore allows for rapid natural sorting of the nourishment material by coastal processes (waves and currents) as well as mixing with the native sands at the site.

Table 34: Preliminary specification for acceptance criteria for initial screening of nourishment material.

Acceptability item	Acceptability criteria: Onshore placement (Subaerial beach)	Acceptability criteria: Nearshore placement (Subaqueous beach)
Median grain size (D_{50})	Median grain size should be between 0.21mm to 0.25mm. Material outside of this median grain size range to be considered on a case-by-case basis, with a preference for slightly coarser material. **NOTE:** This grain size should be reassessed based on systematic sampling of the fully extents of the beach profile to be nourished.	
Fines content (fines have particle sizes less than 75µm)	Fines fraction to be less than 5% by weight.	Fines fraction to be less than 10% by weight (desirable). However, fines fraction greater than 10% may be acceptable on a case-by-case basis following compatibility assessment.
Gravel content (Gravels have particle sizes greater than 2mm)	Gravel fraction to be less than 2% by weight.	Gravel fraction to be less than 5% by weight (desirable). However, gravel fraction greater than 5% may be acceptable on a case-by-case basis following compatibility assessment.
Mineralogy	Sand is to be quartz sand with a carbonate content of less than 25%. Shall not contain excessive amounts of organic matter, demolition material or other debris. Seagrass wrack is an exception to this as would be expected that a proportion of the material is native seagrass wrack.	
Uniformity coefficient **$Cu = D_{60}/D_{10}$**	Cu values less than two (2) are desirable for creating beaches. Cu values substantially above two (2) will compact more and create a beach which is more “concrete” like and will not freely drain when the tide drops, resulting in a “swampy” feel.	
Colour	The beach nourishment material should have a colour, following placement and exposure to the elements, like the existing beach sand in the placement area.	Ideally, nourishment material should be of similar colour to the native beach sand. In practice, this may not be achievable (e.g., where nourishment sand is sourced from deeper water). This would not be a significant issue while the sand remains in the subaqueous beach zone where it is not visible but may become noticeable once the sand is transported onto the subaerial beach although this would likely be minor due to mixing with the native sand. Once darker nourishment sand is transported onto the subaerial beach, it may lighten in colour due to bleaching by sun, leaching by rain, wetting/drying and further mixing with the native sand.

Acceptability item	Acceptability criteria: Onshore placement (Subaerial beach)	Acceptability criteria: Nearshore placement (Subaqueous beach)
Angularity	Desirable that sand be well rounded, rounded or sub-rounded	
Contamination	Sand should be free of contaminants in accordance with: • Environmental Protection Authority's Dredge Guidelines 2020 • National Assessment Guidelines for Dredging 2009 (NAGD, 2009) • National Ocean Disposal Guidelines for Dredged Material (Commonwealth of Australia, Canberra, 2002) • Australian Guidelines for Fresh and Marine Waters (ANZECC, 1992 and 2000).	For sediment to be considered suitable for Adelaide's beaches, the 95% upper confidence limit of the mean concentration of all contaminants must be below the screening levels in the 2009 National Assessment Guidelines for Dredging (NAGD).

Sand sources for beach nourishment

This section provides an assessment of each of the identified potential sand sources. Potential sand sources were initially identified through a literature review with additional sources identified through the added review process. The sources cover external, internal (i.e., beaches within management area), marine (or offshore), beach, terrestrial and beneficial reuse material. Figure 49 shows the location of the potential sand sources assessed herein, which are listed in the table below. It is noted that these sources are not considered extensive and instead as based on the desktop review considered herein. It is recommended that a targeted gap analysis be completed as part of preparing further borrow area specific investigations.

The assessment of sand sources considers:

- compatibility of the source material with the native beach sand using defined acceptance criteria.
- available sand volume (or resource).
- environmental or social impacts, planning approvals or any other constraints.
- methodologies and costs for extracting and transporting sand from the source for use as beach nourishment.

Table 35. Summary of sand source assessed for beach nourishment

Name	Internal/external	Distance from West Beach	Method
Offshore Largs Bay and nearby areas	Internal	17km	Very small, small or medium TSHD
Semaphore to Largs Jetty Beach	Internal	11km	Heavy machinery will remove the sand and load into the trucks.
Section Banks	External	22km	Small to medium TSHD. The estimated cost is \$15-25/m^3.
Port Stanvac	External	20km	Small to medium TSHD
Murray Mouth	External	70km	Dredge sand could be transported by a suitable dredge from the Mouth to West Beach or trucks could move the sand from Hindmarsh Island to West Beach. By way of comparison, Coastal and Marine Section of the Environment Protection Agency in 1999 estimated the cost of renourishing Brighton between \$72 and \$92 per cubic metre
Quarries	External	Golden Grove Quarry to 30km, Glenshera Quarry to 55km, Tooperang Visy Quarry to 70km	Transport by trucks It is estimated that it costs approximately \$70/m^3 (supplied, transported and placed at West Beach)

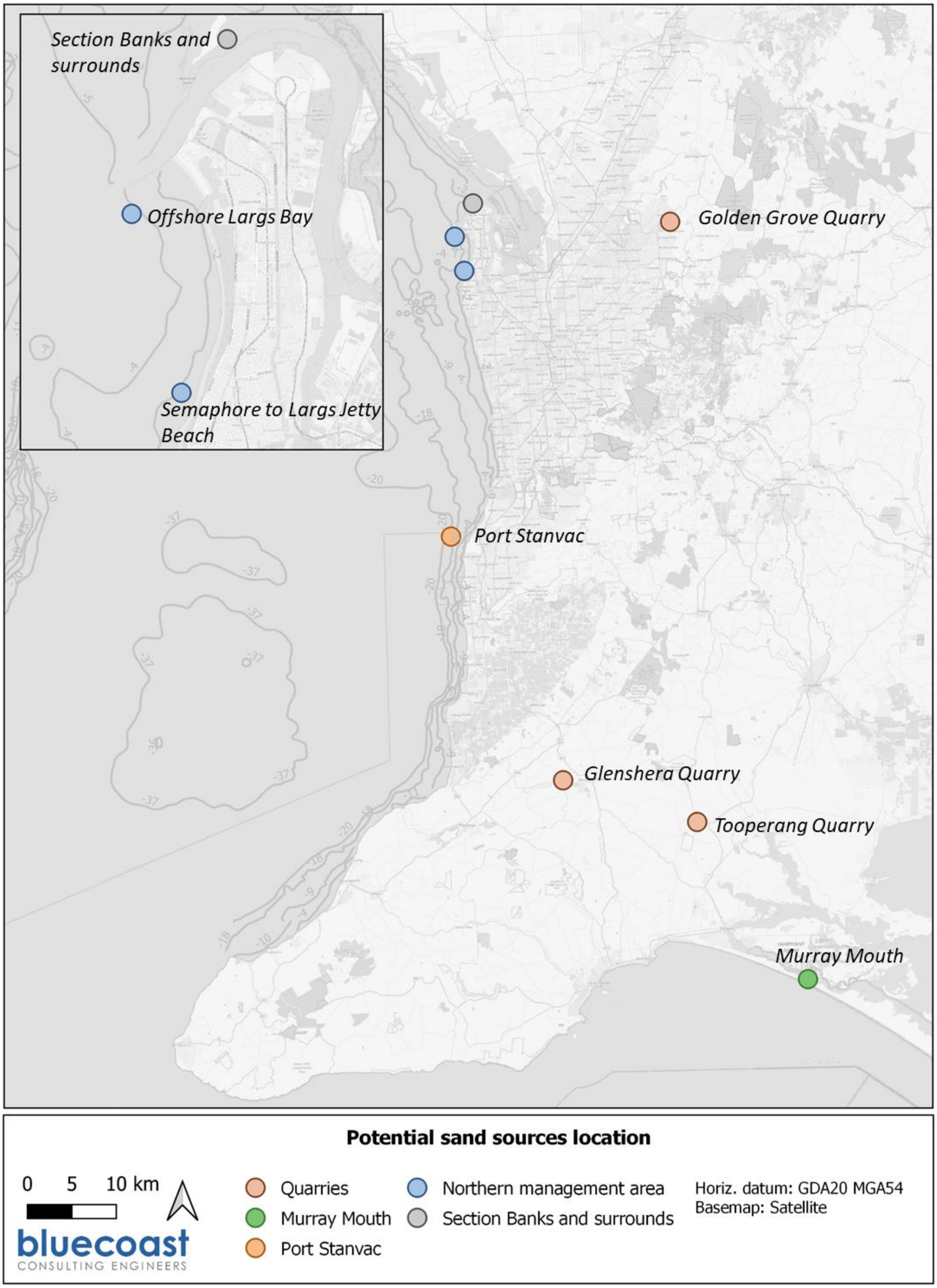


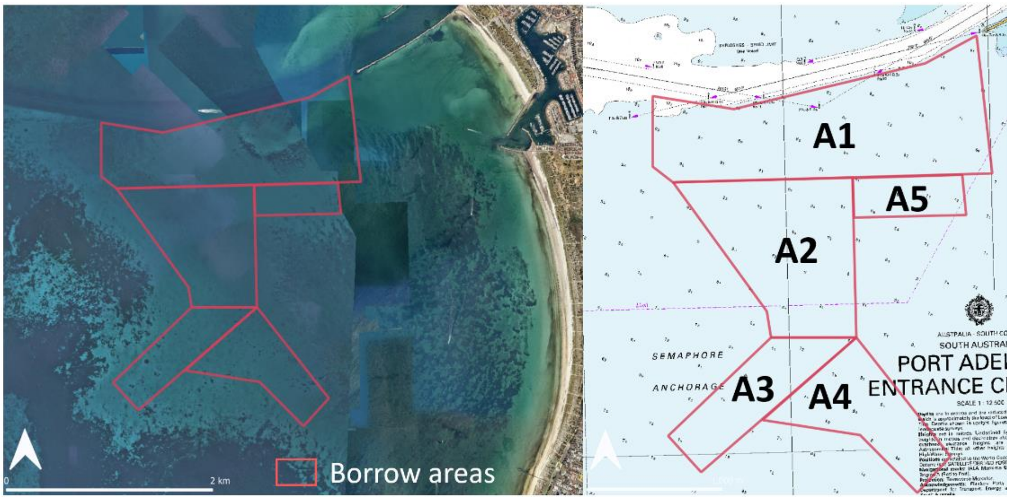
Figure 49: Map of potential sand sources.

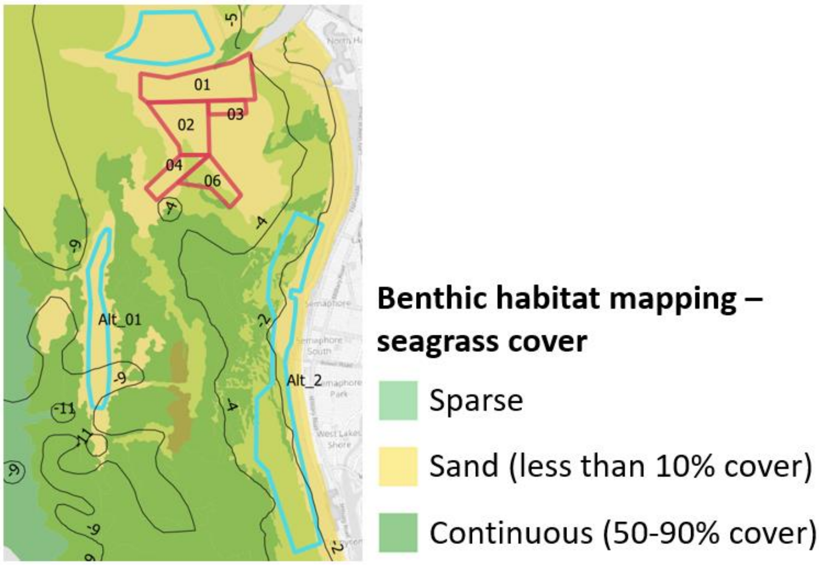
Northern management area: Offshore of Largs Bay

A summary of the Offshore of Largs Bay sand source assessment is provided in Table 36. Information sources used in the preparation of this summary are as follows:

- Belperio, A., Harvey, N., Rice, R., Flint, R. and Gaard, K. 1990. *Offshore Sand Prospects for Metropolitan Beach Replenishment Interpreted from Shallow Seismic Profiles*. South Australia, Department of Mines and Energy. Report Book, 90/13.
- Tucker, R. and Thomas, R. 1985. *Offshore Sand Investigation in the Adelaide Metropolitan Area*. Department of Environment and Planning, Coastal Management Branch, Technical Report 84/2.

Table 36. Assessment of the offshore of Largs Bay sand source.

Parameter	Description
Description	A borrow area has been identified within the nearshore of the northern management area. This area is offshore from North Haven and Largs Bay and south-west of the Outer Harbour southern breakwater (see below map). The water depths are 7 to 10m relative to Chart Datum (or around 8.3 to 11.3m relative to AHD). The total area across the five sub-areas in the borrow is 4.18 million square metres. The subareas shown below are indicative in nature and arranged to avoid seagrasses visible in the aerial photograph and facilitate efficient sand collection.  The above identified borrow area is one possibility of a few potential areas in the nearshore area off the northern metropolitan coastline. Other potential borrow sites are marked as the blue areas in the map below. These include areas south and north of the navigation channel, areas further offshore where seagrass cover has been reduced by historic sewage outfalls and further inshore littoral areas. More targeted information is required for some or all these areas following a detailed review of available information of nearshore sediments.

Parameter	Description
	

Material compatibility

A key reason for selecting this area is that, based on information available, it appears to have coarser sand that would be suitable for beach nourishment. However, only limited sediment data is available to characterise this borrow area. Given the proximity and other favourable attributes further investigations of this borrow area are recommended as priority actions.

The observed cross-shore grain size distribution in Largs Bay is atypical as it shows slightly coarser material at depths. Along the Bone et. al. (2006)'s Largs Bay transect (2g), grain sizes on the beach comprise 68% fine sand and 31% medium sand (or coarser), whereas at depths of 5 to 10m, the results show 52% fine sand and 46% medium sand (or coarser).

The seabed of nearshore area of Largs Bay is known to contain areas where seagrass root matte and seagrass fibres occur (Thomas and Clarke, 2000).

Parameter	Source compatibility
Grain size Guideline suggest D50 between 0.21 and 0.25mm	Insufficient sediment data to adequately assess. Available information suggests source may be compatible. See table note no. 1.
Uniformity co-efficient Cu (D60/D10) is 2 or less	As per the above response.
Mineralogy Carbonate content is less than 25%	23%
Gravel or coarser content • Onshore: less than 2% • Nearshore: less than 5%	4% (suitable for nearshore placement)

Parameter	Description	
	Fines (<75µm) content • Onshore: less than 5% • Nearshore: less than 10% desirable	4.8% (suitable for nearshore and possibly also for onshore placement).
	Angularity/ roundness	Insufficient sediment data available.
	Colour	Insufficient sediment data available.
	Contamination	Insufficient geochemical data, however, recent testing of Outer Harbour entrance channel dredging showed nearby material to be clean.
Available sand volume	**6.27 million cubic metres (see table note 2 below)** This assumes that dredging could be undertaken to a depth of 1.5m on average below the existing seabed. The Outer Harbour navigation channel crosses this sand deposit and is maintained to a depth of 14.2m below chart datum (i.e., 4 to 7 m below the surround seabed levels). Geotechnical investigations of this borrow area would be required to better understand the thickness of the sand layer and what underlays the sand.	
Constraints and considerations Environmental and social impacts, planning approvals and other constraints	The mildly sloping coastal profile (i.e., shallow depths), seagrass meadows and finer sands across much of the northern nearshore area means suitable borrow areas at dredge-able depths are scarce. The known constraints are: • Seagrass: the preliminary borrow area extents have been identified using benthic habitat mapping and recent aerial photography to avoid dense seagrass areas. All dense seagrass is a minimum of 100m away and generally further (2,100m or more). Further surveys of seagrass coverage and density in the area would likely be required to optimise the extents and avoid impacts. DEW recently undertook some towed video to classify the benthic habitat in this area, see table note 2 below. An application to the Native Vegetation Council would be required seeking approval to clear any seagrass in the immediate dredging footprint or the zone of high turbidity impacts. This may require environmental offsetting for the loss of seagrass, this is done through a payment or other offsetting means and is referred to as a significant environmental benefit (SEB). Other sensitive benthic habitat, such as Pinna beds, would also need to be considered. Further consideration has also been given to quantifying losses and actively restoring or offsetting seagrass impacts to achieve positive conservation outcomes from development or maintenance dredging projects. • Water quality: turbidity caused by dredging and placement would require management. Numerical plume modelling would be required as part of the project environmental assessment which along with baseline water quality monitoring would be used to defined turbidity limits. • Dredging of the borrow area may present a risk of Pacific Oyster Mortality Syndrome (POMS) spreading beyond the Port River area. Subject to further investigation this may require the prior removal of razorfish present at the seabed to manage this biosecurity risk.	

Parameter	Description
	• The borrow area is located nearby the Adelaide Dolphin Sanctuary and monitoring for marine mammals (including local dolphin populations) would be required to minimise risk. • Assessment and management of noise (including underwater noise), air quality, waste and hazardous substances required. • A dredge licence from the EPA would be required. In addition to the considerations above, this would require assessment of the project under the EPA's Dredge Guidelines including approval of a Dredge Management Plan and monitoring program. A range of other permits and approvals would also be required.
Methodology and costs	This borrow area is 17km from the main placement site at West Beach and in water depths suitable for safe operations of a small to medium TSHD.

Note: 1. Using the Bone et al. (2006) dataset, the relative sediment size fractions for the native beach material (grey) as well as the offshore of Largs Bay (green) and northern beaches borrow area (rust) are shown in Figure 50. Both borrow areas are finer than the native southern beach sand, however, show a similar comparative composition albeit with a slightly higher portion of gravels and fines in the offshore borrow area.

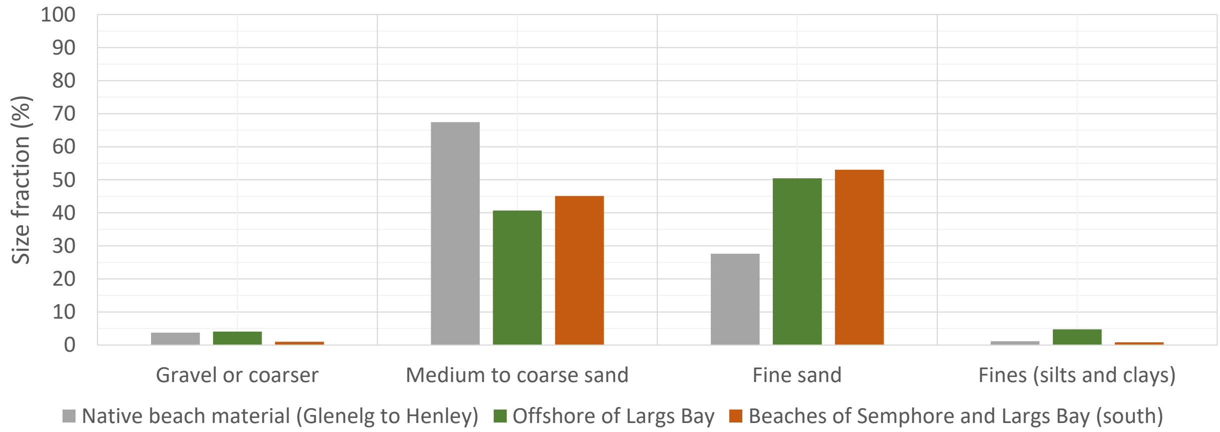


Figure 50: Comparative grain size composition between native beach sand samples and borrow areas offshore of Largs Bay and beaches of Semaphore and Largs Bay (south) (source: Bone et al., 2006).

Note: 2. As part of our review, Bluecoast used aerial imagery and regional benthic habitat mapping to identify an area off Largs Bay. We supplied the extents of this potential borrow area to DEW. DEW undertook 1-2 days of fieldwork (video tows whereby imagery of the seabed is collected and used to classify the benthic habitat). Results were provided to Bluecoast – see Figure 51. They show the average seagrass coverage in the original borrow area to be an average of 14% with 41% of the area 'full sand' and 54% full sand or less than 10% seagrass cover. The borrow area extents were modified to avoid areas of seagrass. This new area:

- Has an average seagrass cover of 9%.
- 54% is full sand, 69% is sand or less than 10% seagrass cover.
- An area of 2.9M m^2.
- Assuming conservative dredging depth of 1.5m, this would equate to a potential sand resource of 4.35M m^3.

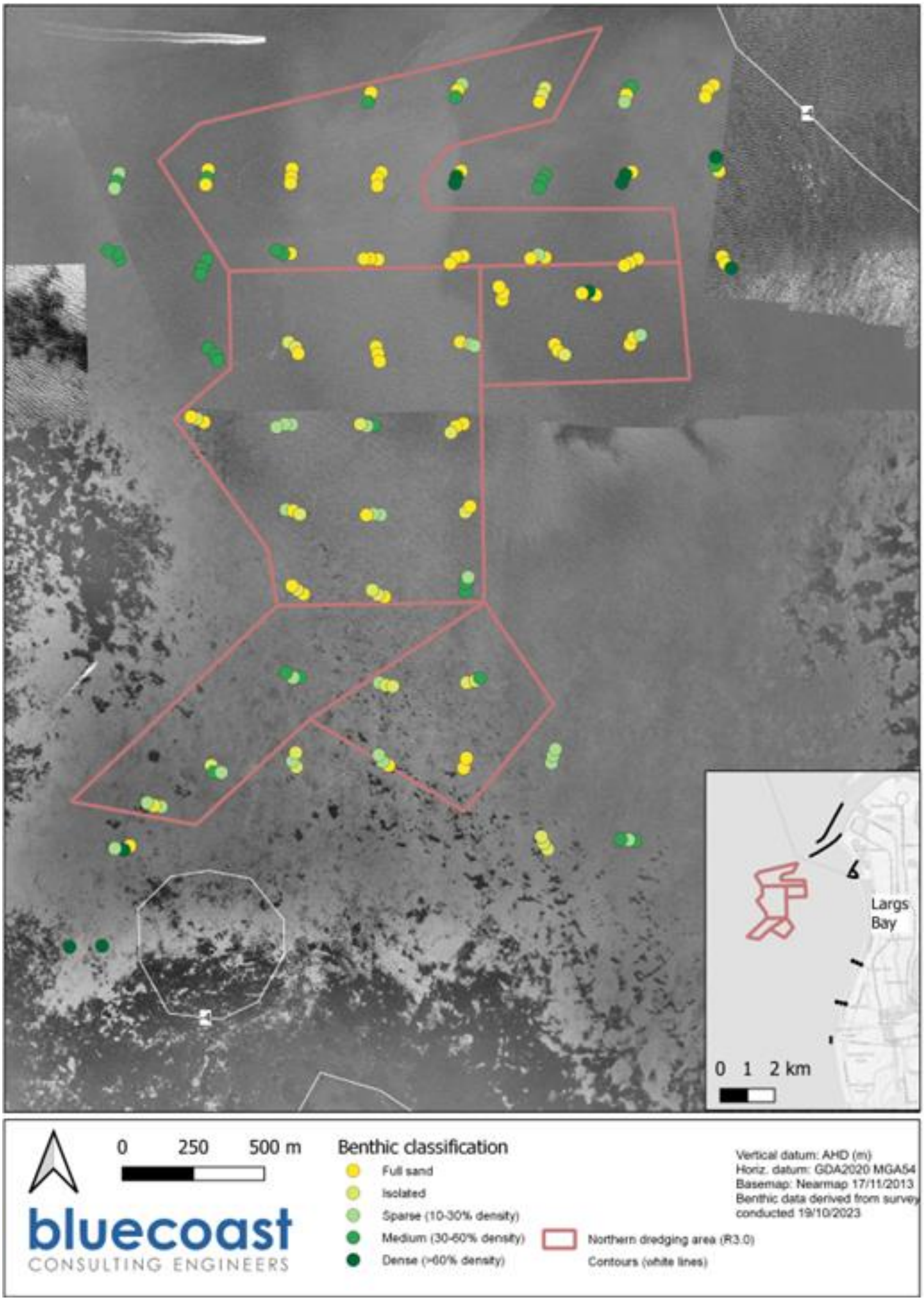


Figure 51. Recent (October 2023) benthic classification completed by DEW in Largs Bay nearshore area.

Northern management area: Semaphore to Largs Jetty beach

A summary of the Semaphore to Largs Jetty beach sand source assessment is provided in Table 37. Information sources used in the preparation of this summary are the same as those used for the northern management area offshore of Largs Bay (previous sub-heading).

Table 37: Assessment of the Semaphore to Largs Jetty beach sand source.

Parameter	Description
Description	This borrow area has been previously identified and is associated with backpassing pipeline and sand carting options. This area covers from Semaphore to Largs Jetty beach. According to the profile survey analysis, Largs Bay sand volume is increasing at 50,000m^3/year (rate of change 1993 to 2023) and north Semaphore at a rate of 13,700m^3/year (rate of change 1993 to 2023). 
Material compatibility	Only limited sediment data is available to characterise this borrow area. Given the proximity and other favourable attributes further investigations of this borrow area are recommended as priority actions. Along the Bone et. al. (2006)'s Largs Bay (2g) and Semaphore (2h) grain sizes on the beach comprise 53% fine sand and 46% medium sand (or coarser).

Parameter	Source compatibility
Grain size Guideline suggest D50 between 0.21 and 0.25mm	D50 = 0.20mm (based on data from Environmental Project 2021 sampling).
Uniformity co-efficient Cu (D60/D10) is 2 or less	1.88

Parameter	Description	
	Mineralogy Carbonate content is less than 25%	18%
	Gravel or coarser content • Onshore: less than 2% • Nearshore: less than 5%	1% suitable for nearshore and onshore placement .
	Fines (<75µm) content • Onshore: less than 5% • Nearshore: less than 10% desirable	0.8% suitable for nearshore and onshore placement.
	Angularity/ roundness	Relevant sediment data not reviewed but assume this would be compatible.
	Colour	Relevant sediment data not reviewed but assume this would be compatible.
	Contamination	Insufficient geochemical data.
Available sand volume	**90,0000 cubic metres/ year** This is based on the sustainable sand harvesting quantities as assessed by Water Technology (2020).	
Constraints and considerations Environmental and social impacts, planning approvals and other constraints	In October 2021 a Development Application was submitted as part of the Securing the Future of Our Coastline project. This DA considered the environmental, heritage and social consideration of sand harvesting from the northern beaches for a pipeline with intakes as far north as Semaphore but did not include a Largs Bay intake/harvesting area. This DA was approved, however, it is noted that the pipeline has since been proposed to be extended to Largs Bay and this may trigger the need for further approvals. The known constraints are: • Dunes and shorebirds: including the removal of dune vegetation and potential impacts on threatened fauna including the Eastern Hooded Plover and the Sooty Oyster Catcher, which were both observed during field surveys in the project area. • Removal of trees and minor potential impacts to the root systems of three significant trees. • Large-scale sand transportation by truck can lead to increase traffic congestion, noise and dust pollution. This can disrupt daily life for residents and businesses. • Assessment and management of noise (including underwater noise), air quality, waste and hazardous substances required. • As some sand is taken from the intertidal zone, it is classified under the EA act and SA EPA Dredge guidelines as ‘dredging’. As such it is likely a dredge licence from the EPA would be required.	

Parameter	Description
Methodology and costs	This borrow area is 11km from the main placement site at West Beach. Heavy machinery, including a tractor and sand plane, excavator, will remove the sand and bring to a stockpile area. This would then be either load into the trucks or into a SCU (for pipeline option) using an excavator. All-inclusive rates for: • sand carting are around $17/m^3$ • pumping via a pipeline are around $40/m^3$

Section Banks and surrounds

A summary of Section Banks and surrounds sand source assessment is provided in Table 38. Information sources used in the preparation of this summary are as follows:

- Johnson Geological Services. 2004. *Section Bank Assessment for Beach Replenishment Sand*. Report for Office of Coast & Marine.
- Letters of advice to CEO of Department of Environment and Water dated 8 December 2020, 11 December 2020 and June 2022 (3 x PDF documents).

Table 38. Assessment of the Section Banks and surrounds sand source.

Parameter	Description
Description	The Section Banks are large deposits of sand to the north of Outer Harbour that were formed through the accumulation of sediments that have been transported northward along the Adelaide metropolitan coastline. These sand deposits have previously been investigated in the 1980s and 1990s, including extensive coring of the sand prospects. These investigations concluded that up to 3.5 million cubic metres of sand suitable for beach replenishment was present.

Parameter	Description
	
Material compatibility	Previous investigations have identified large volumes of medium grain size sand suitable for beach replenishment. Sand sample analysis results from 1979 and 1988 are gathered in a report by Johnson Geological Services (2004). Data presented in that report was analysed to assess the source compatibility.

Parameter	Source compatibility
Grain size Guideline suggest D50 between 0.21 and 0.25mm	D50=0.18mm
Uniformity co-efficient Cu (D60/D10) is 2 or less	Cu=1.82
Mineralogy Carbonate content is less than 25%	No data available.
Gravel or coarser content • **Onshore: less than 2%** • **Nearshore: less than 5%**	Less than 1%, suitable for onshore and nearshore.
Fines (<75µm) content	0.62% suitable for nearshore and for onshore placement.

Parameter	Description		
		• **Onshore: less than 5%** • **Nearshore: less than 10% desirable**	
		Angularity/ roundness	Insufficient sediment data available.
		Colour	Insufficient sediment data available.
		Contamination	Insufficient geochemical data.
Available sand volume	**3.5 million cubic metres** Previous investigations concluded that up to 3.5 million cubic metres of sand suitable for beach replenishment was present.		
Constraints and considerations Environmental and social impacts, planning approvals and other constraints	The known constraints are: • Additional environmental investigations required. • Potential environmental impacts associated with changing the wave climate for the mangrove areas that lie in the lee of the sand bars. Sand deposits are proximate to an important bird nesting area ("Bird Island"), seagrass meadows and mangroves. • Given that the Section Bank is exposed to tidal flows from the Port River, it has been assumed for risk management purposes that POMS is present. Treatment of the sand would therefore be anticipated. • The Section Bank is in close proximity to an existing Aquatic Reserve. The Port River/Barker Inlet may also be declared a dolphin sanctuary, which may influence community perception about dredging. • Water quality: turbidity caused by dredging and placement would require management. Numerical plume modelling would be required as part of the project environmental assessment which along with baseline water quality monitoring would be used to defined turbidity limits. • Assessment and management of noise (including underwater noise), air quality, waste and hazardous substances required. • A dredge licence from the EPA would be required. In addition to the considerations above, this would require assessment of the project under the EPA's Dredge Guidelines including approval of a Dredge Management Plan and monitoring program. A range of other permits and approvals would also be required.		
Methodology and costs	This borrow area is 22km from the main placement site at West Beach and in water depths suitable for safe operations of a small to medium TSHD. The estimated unit cost rate is $18-25/m^3$.		

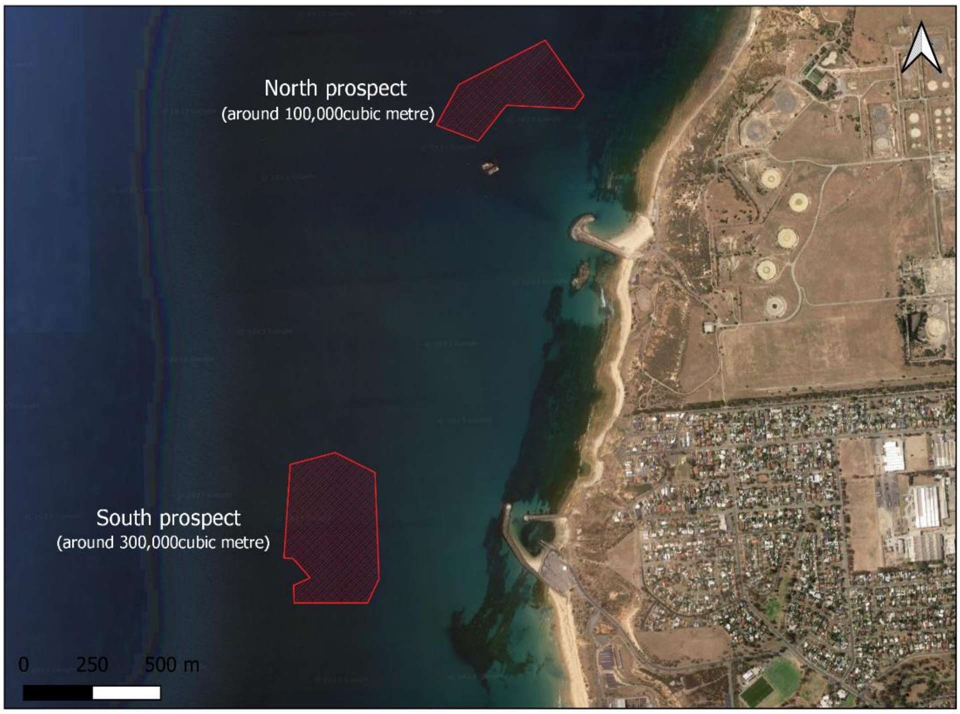
Port Stanvac

A summary of Port Stanvac sand source assessment is provided in Table 39. Information sources used in the preparation of this summary are as follows:

- Acoustic Imaging. 2020. Acoustic Imaging Technical Note: Assessment of Port Stanvac 2020 Seabed Provinces Rev 1.0. Report for Depart of Environment & Water SA.
- Acoustic Imaging (2020) 'Core Results' and 'Sand Volume Estimates' as separate PDF documents.
- Aquatic Biosecurity. 2020. *Sediment Coring of Port Stanvac Waters by Vibrocoring*. Report for Department for Environment & Water SA.
- Deltares. 2020. Sediment dispersion study dredging and beach nourishment West Beach in Adelaide, Australia. Report for Department for Environment & Water SA.
- Environmental Projects. 2020. *Sediment Sampling and Analysis Plan, Port Stanvac South Australia*. Report for Department for Environment & Water SA.
- Gaylard, S. 2004. Ambient Water Quality of the Gulf St Vincent Metropolitan Coastal Waters, Report No. 2: 1995-2002. Environment Protection Authority.
- Precision Hydrographic Services. 2020. *Port Stanvac Multibeam and Sub-Bottom Profiler Survey June 2020*. Report for Department for Environment & Water SA.
- Rice, R. (Geo-Ocean Horizons). 2020. Port Stanvac Offshore Sands Investigation, Vibrocore Land Based Operations & Core Logs. Report for Department for Environment & Water SA.
- Turner, D. 2004. Effects of sedimentation on the structure of a phaeophycean dominated macroalgal community. Department of Environmental Biology, University of Adelaide.

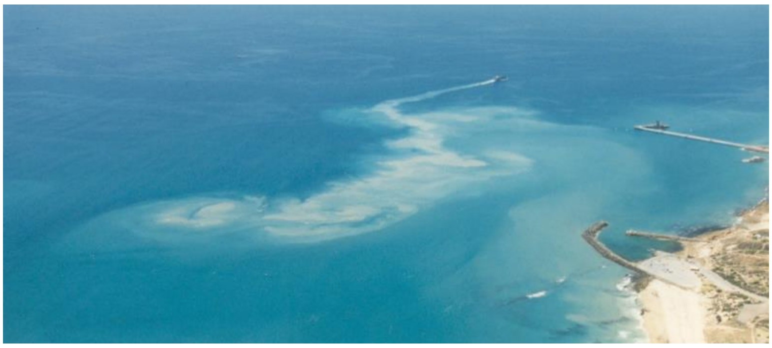
Table 39. Assessment of the Port Stanvac sand source.

Parameter	Description
Description	Port Stanvac is a former port and oil refinery in the suburb of Lonsdale around 20km south of West Beach. Historically, Port Stanvac was primarily known for its oil refinery, which operated from 1963 to 2003. In 1990 more than a million cubic metres of sand was dredged from deposits offshore of Port Stanvac and delivered to Brighton and Seacliff beaches. The water depths are 4 to 19m relative to LAT. Preliminary results

Parameter	Description
	reduced the area of investigation to two main locations (south and north prospects). 
Material compatibility	In 2020 DEW carried out an investigation to assess Port Stanvac deposits suitability to be dredged and relocated to replenish West Beach. Forty two sediment cores were taken across the site with equal numbers in each sand category. The cores were logged, photographed and sampled for contaminant testing and analysis of physical characteristics such as particle size and settling velocity.

Parameter	Source compatibility
Grain size Guideline suggest D50 between 0.21 and 0.25mm	South prospect D50 of 0.17mm North prospect D50 of 0.34mm
Uniformity co-efficient Cu (D60/D10) is 2 or less	South prospect: 2.6 North prospect: 2.2
Mineralogy Carbonate content is less than 25%	South prospect: 18.6% North prospect: 17.9%
Gravel or coarser content • Onshore: less than 2% • Nearshore: less than 5%	South prospect: 2.0% North prospect: 0.9%

Parameter	Description	
	Fines (<75µm) content • Onshore: less than 5% • Nearshore: less than 10% desirable	South prospect: 9.1% suitable only for nearshore. North prospect: 9.4% suitable only for nearshore.
	Angularity/ roundness	Sediment shapes were generally rounded or subrounded. Locations with significant inclusions were angular.
	Colour	Sediment colour generally ranged between brown, grey and olive brown.
	Contamination	Concentrations of all analytes in all samples tested were compliant with the applicable screening criteria except for arsenic, which marginally exceeded the criteria at some samples (SS04, SS09-1, SS18-1, and SS27-1).
Available sand volume	**400,000 cubic metres** The results have found the total volume of the potential sand source at Port Stanvac is approximately 400,000m^3. The total volume is divided between the northern and southern prospects, with approximately 100,000m^3 in the north and 300,000m^3 in the south. The greater volume in the south covers a larger area and is more homogenous, which makes it simpler to dredge in terms of accessibility. The size of the northern prospect and its proximity to rocky and more complex sediments would make it difficult to dredge with the equipment typically used to perform this type of dredging (trailing suction hopper dredges). This means it is likely that only the larger prospect of 300,000m^3 is likely to be feasible for dredging.	
Constraints and considerations Environmental and social impacts, planning approvals and other constraints	The known constraints are: • Water quality: the Port Stanvac source has an average fines content of around 10% and this is not consistent. Turbidity caused by dredging and placement would require management. Turbidity modelling showed that dredging of the Port Stanvac sand deposits would represent a high risk to marine habitats along a significant section of the metropolitan coastline. During previous dredging of this area, some higher fine content layers were encountered, with large sediment plumes occurring as well as smothering of nearby reefs. • sand deposits are geologically complex, with layers of clay and silt material interspersed with the sand. This means that dredging this sand would have an high risk of causing substantial plume events and associated environmental impacts at both the collection (Port Stanvac) and deposition (West Beach) locations. • Assessment and management of noise (including underwater noise), air quality, waste and hazardous substances required.	

Parameter	Description
	• A dredge licence from the EPA would be required. In addition to the considerations above, this would require assessment of the project under the EPA's Dredge Guidelines including approval of a Dredge Management Plan and monitoring program. A range of other permits and approvals would also be required.  • Example of sediment plume generated by dredging at Port Stanvac for beach nourishment in 1990's.
Methodology and costs	This borrow area is 20km south from the main placement site at West Beach and in water depths suitable for safe operations of a small to medium TSHD. All-inclusive cost rate is estimated to be around $18-20/m^3. By way of comparison, the renourishment programme for Brighton in 1997, using sand dredged from offshore Port Stanvac, cost $7.50 per cubic metre.

Southern sand prospects

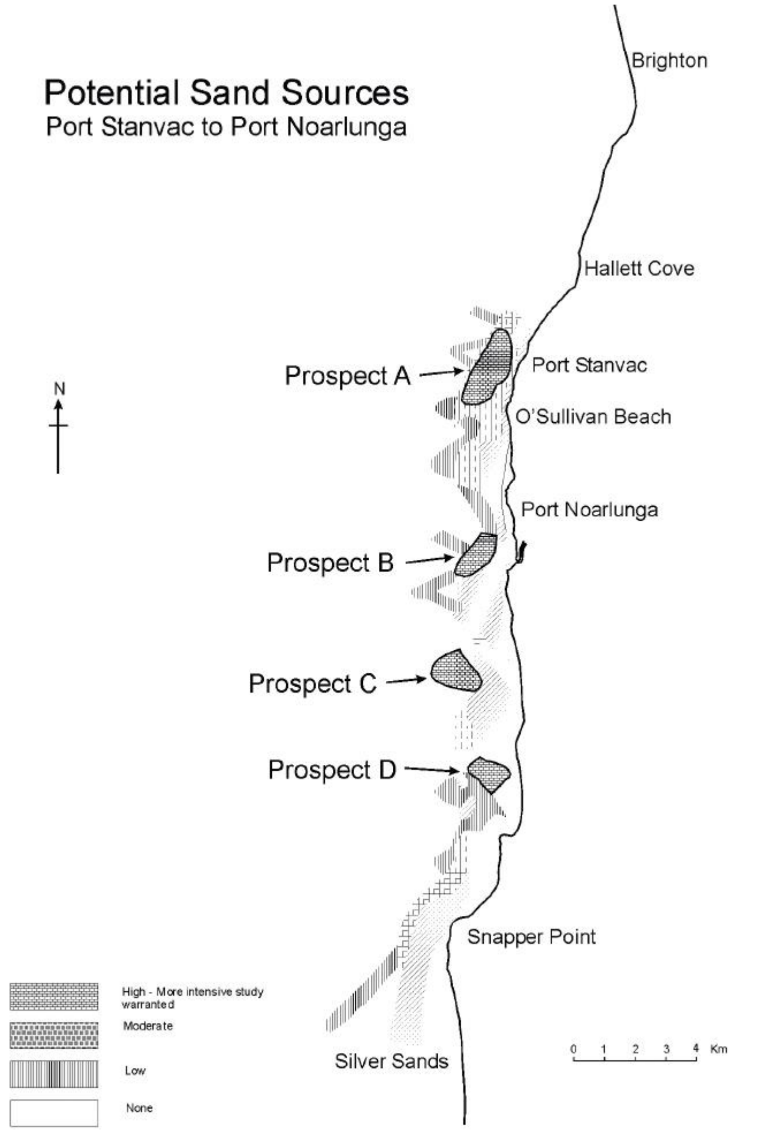
A summary of southern sand sources is provided in Table 39. Information sources used in the preparation of this summary are as follows:

- Rice, R. and Hudson, J. 1998. *Southern Adelaide Offshore Sand Investigation (SAOSI).* Prepared for Coastal Management Branch, Department of Environment, Heritage & Aboriginal Affairs.
- Rice, R. 1999. *Southern Adelaide Offshore Sand Investigation (SAOSI) – Stage 3: Deep Coring Project*, January 1999. Report to Coastal Protection Board & Coast & Marine Section of the Environment Protection Agency (EPA) South Australian Department of Environment, Heritage & Aboriginal Affairs.

Table 40. Assessment of the southern sand prospects.

Parameter	Description
Description	Prospect C and Prospect D, as shown below were identified in Belperio et al., (1990) report as two areas high priority for further investigating. In 1998, sediments offshore from Kingston Park and Maslin Beach were investigated on behalf of the Coastal Management Branch. This was reported in *Southern Adelaide Offshore Sand Investigation* Rice and Hudson (1998) with further investigations in Rice 1999. The Rice 1999 report provide new estimates of up to 630,000m^3 of suitable sand available from Moana Ridge prospect

Parameter	Description
	The Coast Protection Board considered the Ride & Hudson report and the effect that sand extraction would have on the inshore wave climate, as this could lead to significant sediment erosion. If fine sediments were found, the likely formation of a sediment plume during and after the dredging could cause unacceptable environmental impacts in the region. The Board concluded that the deposits were too narrow to be dredged without having impacts on surrounding areas and thus did not warrant further investigation at that stage (DEH, 2005). Given the significant underestimate of the cost of sand pumping via pipelines, it is suggested that it if the potential borrow area along the northern metropolitan coast are found not to be suitable, these southern prospects should be revisited.



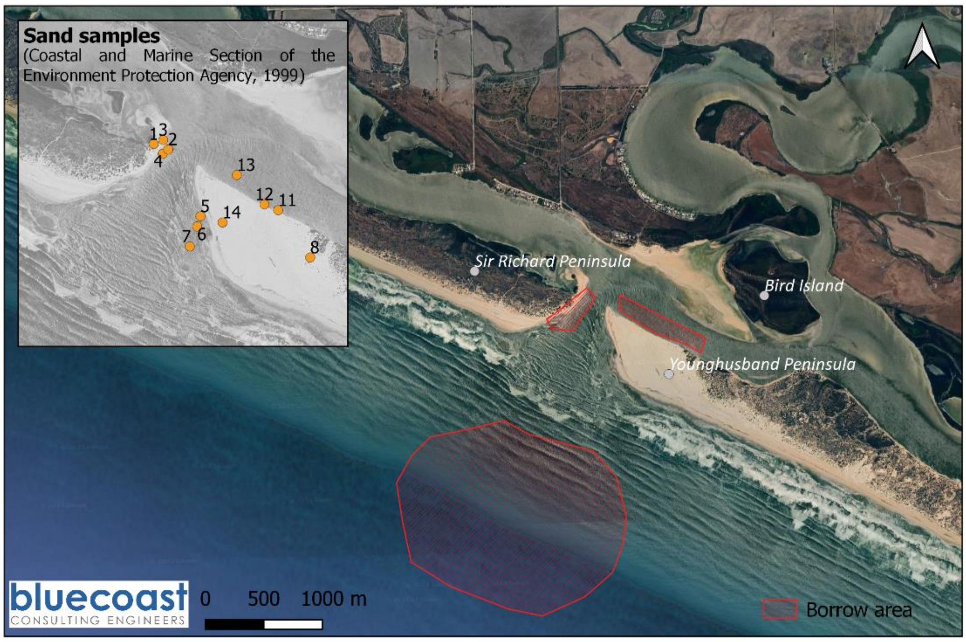
<table>
<tr><th>Parameter</th><th colspan="2">Description</th></tr>
<tr><td rowspan="9">Material compatibility</td><td>Parameter</td><td>Source compatibility</td></tr>
<tr><td>Grain size
Guideline suggest D50 between 0.21 and 0.25mm</td><td>Insufficient information available.</td></tr>
<tr><td>Uniformity co-efficient
Cu (D60/D10) is 2 or less</td><td>Insufficient information available.</td></tr>
<tr><td>Mineralogy
Carbonate content is less than 25%</td><td>Insufficient information available.</td></tr>
<tr><td>Gravel or coarser content
• Onshore: less than 2%
• Nearshore: less than 5%</td><td>Insufficient information available.</td></tr>
<tr><td>Fines (<75μm) content
• Onshore: less than 5%
• Nearshore: less than 10% desirable</td><td>Insufficient information available.</td></tr>
<tr><td>Angularity/ roundness</td><td>Insufficient information available.</td></tr>
<tr><td>Colour</td><td>Insufficient information available.</td></tr>
<tr><td>Contamination</td><td>Insufficient information available.</td></tr>
<tr><td>Available sand volume</td><td colspan="2">630,000m^3
(adopted after Rice 1999, requires confirmation).</td></tr>
<tr><td>Constraints and considerations
Environmental and social impacts, planning approvals and other constraints</td><td colspan="2">The known constraints are expected to be similar to those described for Port Stanvac but the extent and nature of the impacts cannot be considered without a detailed understand of the sand body to be dredged.</td></tr>
<tr><td>Methodology and costs</td><td colspan="2">This borrow area is around 15-20NM south from the main placement site at West Beach and in water depths suitable for safe operations of a small to medium TSHD.
All-inclusive cost rate is estimated to be around $30-35/m^3.</td></tr>
</table>

Murray Mouth

A summary of Murray Mouth sand source assessment is provided in Table 41. The main source of information used in this summary is the following report by Fotheringham et al (2000).

Fotheringham, D., Penney, S., Sandercock, R. and Townsend, M., 2000, Murray Mouth Sand Investigation, Coast and Marine Section Environment Protection Agency, Department of Environment and Heritage.

Table 41. Assessment of the Murray Mouth sand source.

Parameter	Description
Description	The mouth of Murray River is located about 75km south south east of Adelaide city centre. The mouth is an opening in the coastal dune system which separates the river system from the ocean and which extends from near Goolwa in a south-easterly direction along the continental coastline for about 145km. Younghusband Peninsula is part of Coorong National Park and Bird Island is a Ramsar Wetland. Claiming sand from these areas would be difficult. In addition, Sir Richard Peninsula is suffering erosion because of the diversion of sand into Murray Mouth. The are two possible sand sources: the ebb tide delta, which would be accessible to a TSHD, or the inner flood-tide delta surrounding cores 1 to 4 and 11 to 13 (see Figure below). Areas within the entrance are already dregded for environmental reasons, with much of the dredged material placed on the adjacent beaches. The annual dredging quantities are in the order or 1 million cubic metres per year. 
Material compatibility	A sand investigation was carried out by the Coastal and Marine Section of the Environment Protection Agency in 1999 (Fotheringham et al, 2000). 14 cores were taken and analysed the sizing and carbonate content. For this analysis data samples within the National Park and Ramsar Wetland were excluded.

Parameter	Description

Parameter	Source compatibility
Grain size Guideline suggest D50 between 0.21 and 0.25mm	Average D50=0.19mm The range of D50 values varies from 0.16 mm for the finest sample to 0.34 mm for the coarsest sample.
Uniformity co-efficient Cu (D60/D10) is 2 or less	Average Cu=1.84
Mineralogy Carbonate content is less than 25%	Mean carbonate content is 34% The carbonate content of the sand samples ranges from 26% to 50%. The remaining portion of the sample consists of siliceous material.
Gravel or coarser content • **Onshore: less than 2%** • **Nearshore: less than 5%**	0.6% suitable for nearshore and onshore placement.
Fines (<75µm) content • **Onshore: less than 5%** • **Nearshore: less than 10% desirable**	1.4% suitable for nearshore and onshore placement.
Angularity/ roundness	Insufficient sediment data available.
Colour	Sediment colour generally brown.
Contamination	Insufficient geochemical data.

Available sand volume	**1 million cubic metres per year with more likely to be available for a large once-off campaign.**
Constraints and considerations Environmental and social impacts, planning approvals and other constraints	The known constraints are: • Geomorphological considerations: Dredging sand from the Murray Mouth has significant implication for overall management of the Mouth and beaches north-west of the Mouth. The Mouth has effectively acted as a large sediment trap and significant erosion has been occurring north-west of the Mouth for a number of years due to this loss of sediment. The Mouth has shifted north-west more than 2km over the past 10 years because of a negative sediment budget on its north-west side. If the flood deltas are to be dredged, the sand should be returned to the littoral system by being placed on the ocean beach on the north-west side of the Mouth.

Parameter	Description
	Implications for removing the sand from this system for use at Adelaide's beaches would require further investigation. • Environmental considerations: Any sand excavation proposal would need to show that the environmental and ecological values of the wetlands would not be harmed. Excavation of the Bird Island deposit would harm wetland values and it is very unlikely that management authorities would gran approval. • Potential conflicts with the declared conservation status' of the Younghusband Peninsula and Lake Alexandrina. • Water quality: turbidity caused by dredging and placement would require management. • Assessment and management of noise (including underwater noise), air quality, waste and hazardous substances required. • A dredge licence from the EPA would be required. In addition to the considerations above, this would require assessment of the project under the EPA's Dredge Guidelines including approval of a Dredge Management Plan and monitoring program. A range of other permits and approvals would also be required.
Methodology and costs	This borrow area is approximate 95NM from the main placement site at West Beach. Estimates were made using a large TSHD to dredge a mass nourishment volume of sand from the Murray Month and place it at West Beach. This was in the order to $200 million, with consideration of the transport distances and expected wave climate at Murray Mouth. An alternative could be to utalises the existing dredging, which uses cutter suction dredgers working in protected waters inside the entrance. The sand would need to be transfer to a self-propelled barge, likely moored just offshore of the mouth. This barge (or barges) would then transport the sand to West Beach were another mooring and pump ashore facility would be required. No cost estimates has been attempted for such an operations as this is considered to be outside the scope of this review.

Quarries

A summary of the quarries sand source assessment is provided in Table 42. Information sources used in the preparation of this summary are as follows:

- Pre-supply test results of approved quarries prepared by DEW for Glenshera quarry (July 2021), Golden Grove quarry (April 2022) and Tooperang quarry (September 2021).
- PSD test certificates (PDF format) from Earth Testing Services for sand placed on Henley Beach, along with a spreadsheet outlining quarry source, volumes and test results.
- PSD test certificates (PDF format) from Earth Testing Services for sand placed on West Beach along with spreadsheet outlining quarry source, volumes and test results.

Table 42. Assessment of the land-based quarry sand sources.

Parameter	Description
Description	Land-based quarries for beach nourishment refer to the extraction of suitable materials from inland sources. This method involves sourcing and transporting sediment or other

<table>
<tr><th>Parameter</th><th>Description</th></tr>
<tr><td></td><td>suitable materials from inland areas to be deposited on the targeted beach area to restore or enhance its natural characteristics. Land-based quarries for beach nourishment offer an alternative source of sediment when natural sources are limited or insufficient. Three different quarries are typically:
Glenshera quarry is 50km south of Adelaide city centre at Mount Compass and it is managed by Holcim.
Hanson’s Golden Grove Quarry is a wet sand processing facility located at 18 km northeast of Adelaide CBD, within the Golden Grove Extractive Industries Zone (GGEIZ).
Tooperang Visy beach sand</td></tr>
<tr><td>Material compatibility</td><td><table>
<tr><th>Parameter</th><th>Source compatibility</th></tr>
<tr><td>Grain size
Guideline suggest D50 between 0.21 and 0.25mm</td><td>D50=0.30mm</td></tr>
<tr><td>Uniformity co-efficient
Cu (D60/D10) is 2 or less</td><td>Insufficient sediment data available.</td></tr>
<tr><td>Mineralogy
Carbonate content is less than 25%</td><td><5% by weight</td></tr>
<tr><td>Gravel or coarser content
Onshore: less than 2%
Nearshore: less than 5%</td><td>Specification are for 0% gravels or coarser.</td></tr>
<tr><td>Fines (<75µm) content
Onshore: less than 5%
Nearshore: less than 10% desirable</td><td>The specification states a fines content of 0%. All quarries’ samples have less than 1% of fines content.</td></tr>
<tr><td>Angularity/ roundness</td><td>Specification state well rounded, rounded or sub-rounded.</td></tr>
<tr><td>Colour</td><td>Off-white or pale in colour.</td></tr>
<tr><td>Contamination</td><td>All levels below NAGD 2009 screening levels.</td></tr>
</table></td></tr>
<tr><td>Available sand volume</td><td>This assessment has not been completed. Typically, hard limits would relate to the yearly licenced extraction limits of the available quarries. A further consideration is the commercial aspects of introducing such a large demand on the commercial sand market, which may lead to increased prices for nourishment as well as the construction and other sand using industries.</td></tr>
</table>

Parameter	Description
Constraints and considerations Environmental and social impacts, planning approvals and other constraints	The known constraints are: • Large-scale sand transportation by truck can lead to increase traffic congestion, noise and dust pollution. This can disrupt daily life for residents and businesses. • Beach access closures and social impacts as well as environmental impacts on dunes and beach of trucks accessing beaches. • Water quality: turbidity caused by placement would require management. • Assessment and management of noise (including underwater noise), air quality, waste and hazardous substances required. • Quarry sand requires washing during production. High water usage.
Methodology and costs	Carting with trucks is used to transfer sand from quarries to the beach. It is estimated that it costs approximately $63/m^3 (supplied, transported and placed at West Beach). Additional budget allocations may be required (subject to the total volume sourced from quarries).

Appendix D: Shortlisted management options - supporting information

Dredging vessels and placement methods for beach nourishment

Dredge vessels

A review of dredging equipment was undertaken to inform the shortlisted management options involving dredging. The potential marine sand sources available for nourishment for the northern management area of Adelaide's metropolitan beaches would either dredging within the Gulf or another further afield marine or with the estuarine area (e.g., Murray Month). Depending on the source material depth and location the following type of dredge vessel may be suitable:

Trailer Suction Hopper Dredge (TSHD)

- suitable for dredging and transporting material (within hopper)
- suitable for placement via pipeline, bottom dumping or rainbowing
- requires water depth greater than >6-8m for dredging operation
- relatively high mobilisation cost (if suitable local dredge not available)
- relatively low unit rate for dredging/placement
- can operating in conjunction with other vessel traffic without overly affecting each other


Source: Tweed Sand Bypassing

Cutter Suction Dredge (CSD)

- requires relatively sheltered location for operation
- requires the installation of a pipeline to transport and place material at destination (potentially across navigation channel)
- relatively low unit rate for dredging/placement
- is a stationary dredger and can cause delays to for vessel traffic when dredging in a shipping channel


Source: City of Gold Coast

Backhoe Dredge (BHD)

- dredging depth is typically limited to 20 to 30m
- requires relatively sheltered location for operation
- typically requires support barges for transport of material
- relatively high unit rate for dredging/placement
- is a stationary dredger which can cause delays for vessel traffic when dredging in a shipping channel


Source: Napier Port

Given the distances between the sources the most likely and cost-effective method for dredging and transporting sand to the northern beaches from any wave exposed areas (e.g., offshore areas) is by employing a small to medium size TSHD. TSHD's are often used in beach nourishment projects as they can dredge in varying offshore wave climates and can discharge the sand in multiple ways (bottom dumping, rainbowing or through a bow connection and a floating pipeline (i.e., pump ashore)).

It is noted, however, CSD or BHD or other alternative dredging equipment could be explored if an option involving dredging were to progress. The beach nourishment concepts presented herein allows for use of a variety of equipment based on availability at the time and/or contractor preference.

There are around 50 small TSHD (500 to 3,750m^3 hopper capacity) and 22 medium TSHD (3,750 to 6,000m^3) that have been identified for this project. Selection of an appropriate TSHD requires consideration of factors like maximum/minimum dredging depth, geographic location and work commitments and competitive advantages (e.g., loading efficiency). An overview of potentially suitable TSHDs is presented in Table 43.

Table 43: Overview of potentially suitable Trailer Suction Hopper Dredges (TSHD) for sand placements at Adelaide metropolitan's northern beaches.

Vessel	Draught (loaded)	Hopper capacity	Length	Dredging depth (extended)	Sand placement	Photo
David Allan TSHD	3.18m (3.50m)	650m^3	71.5m	15m	Split hopper	
Modi R TSHD	1.5m (3.8m)	1,393m^3	67.1m	20m (24m)	Split hopper/ rainbow 50m	

Vessel	Draught (loaded)	Hopper capacity	Length	Dredging depth (extended)	Sand placement	Photo
Trud R TSHD	2.0m (3.8m)	1,570m^3	75.5m	28m (40m)	Split hopper/ rainbow 50m	
Albatross TSHD	1.85m (3.8m)	1,860m^3	75.0m	30m	Hopper doors/ rainbow 50m	
Brisbane TSHD	3.0m (6.25m)	2,900m^3	84.1m	25m	Hopper doors	
Balder R TSHD	3.8m (7.0m)	6,000m^3	111.3m	35m (65m)	Split hopper/ rainbow 120m	

Placement methods

Table 44 provides a summary of the ways sand may be placed for beach nourishment and the typical work methods used to place material in each area of the coastal profile at Adelaide's northern beaches. To achieve nourishment of the full coastal profile at Adelaide's beaches a combination of the described placement methods would be required.

Table 44: Placement options for beach nourishment with excavated material.

Placement option	Example
Pumping ashore to nourish the visible beach Pumping sand ashore onto the visible beach aims to broaden the existing beach and the existing dune systems (if present/accessible). The process would involve also pumping sand into the surf zone using floating pipe outlets. A typical approach may consist of: • pump sand slurry directly from dredge moving pipe outlets progressively along the beaches. Sand could be pumped from either a TSHD or CSD working in the nearshore. If pumped onto the dry (subaerial) beach distribution of the material with land-based machinery would be needed. • require additional equipment (e.g., pipeline, earth moving equipment on the beach, floating pipe outlet, slurry booster pumps for pumping beyond 1.5km) – pipeline may be buried and kept in place for future nourishment campaigns. • Alternatively sand placement in surf zone via floating pipe outlets to enhance post-nourishment profile for improved (perceived) longevity and improved beach access and amenity • may cause disruption on beach usage during operations • may have potential visual impact as pumping onto subaerial beach is less effective in washing out fines from source material.	  Pump ashore operations for large scale beach nourishment in the USA.
Rainbowing to nourish the surf zone Some TSHD's have 'rainbow' capabilities. This involves a sand slurry being jetted from the bow with the vessel positioned bow-in as close to the shore as possible. The objective is to widen the visible beach by moving the wave breaking zone seaward. The "losses" occur slowly and in a manner more consistent with a natural beach. For Adelaide's beaches, a typical approach may consider: • the shallow profile of Adelaide's beaches would be restrictive to all but the shallowest (smallest) TSHD's to transport material to the site and rainbow, but this still may prove to be too distance from the active beach fluctuation zone. • rainbowing to the surf zone provides some washing out of fines/ mixing with native sediment prior to arriving on the visible beach.	 A medium sized TSHD rainbowing on the Gold Coast (source: City of Gold Coast).

Placement option	Example

Bottom dumping to nourish the nearshore

Bottom dumping of nourishment material is suitable in the outer surf zone and nearshore area depending on vessel draft. After the dredge (or barge) has filled its hopper, it sails to the sand placement area it either opens hopper doors located at the bottom of the vessel or splits its hull (split-hopper). Split hopper is generally preferred as it allows for shallower placements. Nearshore placement aims to emulate a natural storm bar formation. If a storm arrives soon after beach nourishment, wave breaking may be triggered and thereby help protect the coast. However, if no storm arrives, the waves will redistribute the sand onshore. For Adelaide’s beaches, a typical approach may consider:

- the method provides cost-efficient placement and cycle times, however draft restrictions would mean the sand was placed well offshore and take some time to work onshore under the action of waves and currents.
- smaller TSHD with reduced drafts can place material somewhat closer.
- placed material would be ‘washed’ and efficiently sorted by the natural coastal processes with source material mixing with native material and likely to be virtually undetectable at the visible beach.
- where this technique has been used in other Australian locations the beach response has been positive and there are additional recreational benefits if pattern placement is used.
- represented a cost effective and practical option for beneficial reuse sources where the material used for nourishment is generated from nearby capital dredging projects and reuse offers a beneficial alternative to disposal.

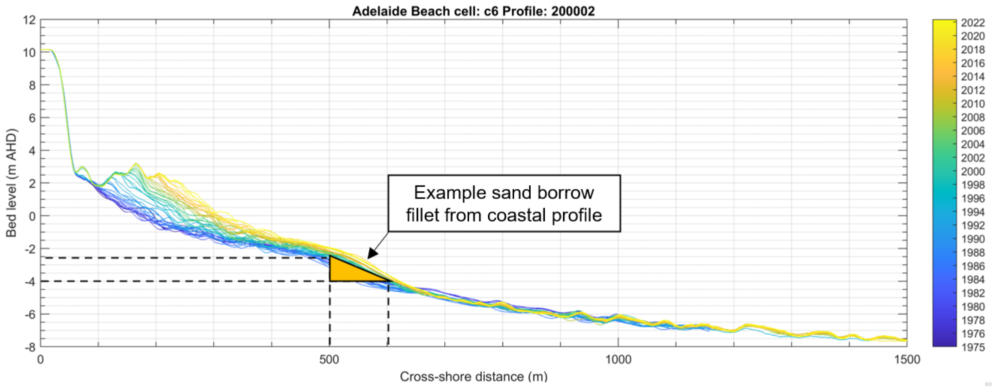
Split hopper TSHD, the David Allan, placing material as beneficial reuse for beach nourishment.

Appendix E: A3.1 sub-option – inshore sand source

Table 19 outlines key details and describes the sub-option to Option A3 that includes obtaining material for ongoing sand top-ups from a northern and inshore sand source.

Table 45: Description of the sub-option for Option A3 – inshore sand source.

Design parameter	Description
Concept and rationale	This sub-option adopts the same approach and rationale as Option A3, including an initial larger nourishment from an offshore source(s). However, ongoing sand top-ups would involve: • Contracting a smaller TSHD to access to shallower borrow areas inshore of the -5m AHD depth contour. For example, the TSHD Tommy Norton is one such TSHD which can dredge with a draft as shallow as 3.5m. It has a hopper capacity of 650m^3. • Dredging suitable sand from northern borrow areas inshore of the 5m depth contour and as far as practically possible away from seagrasses. Preliminary potential borrow areas are indicated on the concept layout for Option A3 (see Figure 36). The dredged sand would be transported in the TSHD's hoppers to the placement site, primarily West Beach, which is located approximately 14.8km from the inshore borrows (conservative estimate assuming sailing from the furthest inshore area to West Beach). The placement method for this sub-option would be the same as Option A3, being predominantly the modified 'pump ashore' method or alternatively standard pump ashore, rainbowing or bottom dumping.
Nourishment strategy	<u>Nourishment frequency, quantities and durations</u> This sub-option adopts the same initial nourishment as Option A3, with 820,000m^3 delivered to West Beach using a small (1,400m^3 hopper capacity) TSHD over a 15-week works period. Ongoing sand top-ups would be 360,000m^3 every 4-years delivered to West Beach using a very small (650m^3 hopper capacity) TSHD over a 15-week works period. This duration takes account of estimated additional environmental and tidal delays anticipated due to dredging in shallow inshore areas. As for Option A3, a degree of flexibility is expected in the nourishment strategy to account for the dynamic nature of Adelaide's beaches as well as dredger availability. <u>Sand source, dredging and dredging cycles</u> Same as Option A3, except that sand for ongoing top-ups to be sourced inshore of the -5m AHD depth contour. <u>Placement method and areas</u> Same as Option A3.
Implementation	<u>Site investigations, project planning and environmental assessments</u> The same investigations listed under Option A3 relating to sediment and environmental characteristics of the borrow area would need to be undertaken before sand can be dredged from either offshore or inshore sand sources. <u>Initial (once-off) restorative nourishment (approx. 15-week duration)</u> Same as Option A3.

Design parameter	Description
	<u>Ongoing sand top-ups (once every 4 years, with each campaign approximately 15-week duration)</u> Ongoing sand top-ups will take longer (15 weeks) than Option A3 primarily due to the smaller dredge hopper capacity. Working with the tides, a very small TSHD could dredge in as shallow as the -2.5m AHD. Continuous (dense) seagrass cover typically starts just seaward of the -4m AHD contour. These depth contours have been considered as the landward and seaward boundaries of the inshore sand borrow areas. In terms of proximity of dredging works to the coastline, the -2.5m AHD contour is situated approximately 500m offshore (on average). Full coastal survey profiles along the coastline (for location refer to Figure 19) show that approximately 80m^3/m of sand would be available between these contours (refer to example below from Profile 200002 located at Largs Bay). Two preliminary inshore borrow areas have been identified which are essentially distinguished as being to the north and south of Semaphore Breakwater (refer to concept layout for Option A3, Figure 36). Adopting the above alongshore rate of 80m^3/m, approximately 230,000m^3 and 300,000m^3 would be available in each of these areas respectively (i.e., 530,000m^3 in total). It is noted that the coastal profile would be expected, under the action of waves and currents, to infill (i.e., smooth out) and will eventually replenished due to northward littoral drift along the Adelaide coastline. 
Complementary management	Same as Option A3.

Appendix F: Life cycle cost estimates

General assumptions

- Cost estimates based on conceptual descriptions of each shortlisted option given in Section 6.
- GST is not included.
- Limits of accuracy on all quantities and rates is ±50%.
- A 15% 'at risk' mark-up as well as a 10% contingency across all estimates.
- Rise and fall not included.
- 7% discount rate used for Net Present Value (NPV) calculations. This was adopted after the Australian Governments, Department of Prime Minister and Cabinets, Office of Best Practice Regulations 2020 Guidance note on Cost-benefit analysis suggests adopting a 7% discount rate with sensitivity testing at 3% and 10%.Reference https://oia.pmc.gov.au/sites/default/files/2021-09/cost-benefit-analysis.pdf.
- Results of a sensitivity analysis to the discount rate at 3% and 10% is presented below. The results show the relative life-cycle cost estimates are largely insensitivity to the discount rate applied (e.g., the cost difference between A1 and A3 is around $71-72M for all discount rates). The exception to this is mass nourishment (B1). Because B1 has larger upfront costs, it moves closer to parity with A3 the lower the discount rate adopted.

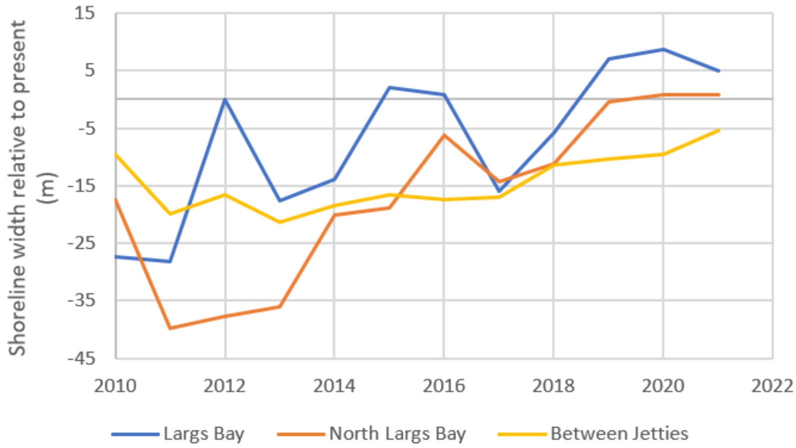
Shortlisted option	Net present value (across 3%, 7% and 10% discount rates)		
	3%	7%	10%
Basecase	$ 114,310,392	$ 90,520,495	$ 78,954,155
Backpass pipeline (A1)	$ 134,261,565	$ 122,075,313	$ 114,906,882
Backpass pipeline - jetty intake (A1.1)	$ 132,295,665	$ 120,428,596	$ 113,511,366
Backpass pipeline - mobile intake (A1.2)	$ 134,096,744	$ 121,221,505	$ 113,816,478
Backpassing dredging (A3)	$ 62,060,107	$ 49,966,154	$ 43,802,890
Mass nourishment (B1)	$ 61,622,408	$ 56,489,386	$ 53,103,062
External sand (B2.A) – dredging	$ 77,118,158	$ 63,089,948	$ 55,726,658
External sand (B2.B) - carting	$ 153,115,071	$ 119,528,069	$ 103,081,452

- Potential differences in the future costs of entrance dredging to maintain navigation to the North Haven Marina (NHM) were included in the cost estimates. Based on data provided by S.A. Department of Infrastructure and Transport, dredging of the NHM entrance channel has increased at a rate of 8.5% per annum. This is correlated with accretion and shoreline advance in Largs Bay (see analysis below). Current annualised rates of entrance dredging are around 23,000m^3/yr, costing around $500,000/yr. The differential costs are therefore $42,500/yr. The Net Present Value (NPV) of receiving $42,500 per year over a period of 20 years at a 7% discount rate is approximately $450,246. This has been added to the non-sand backpassing options.

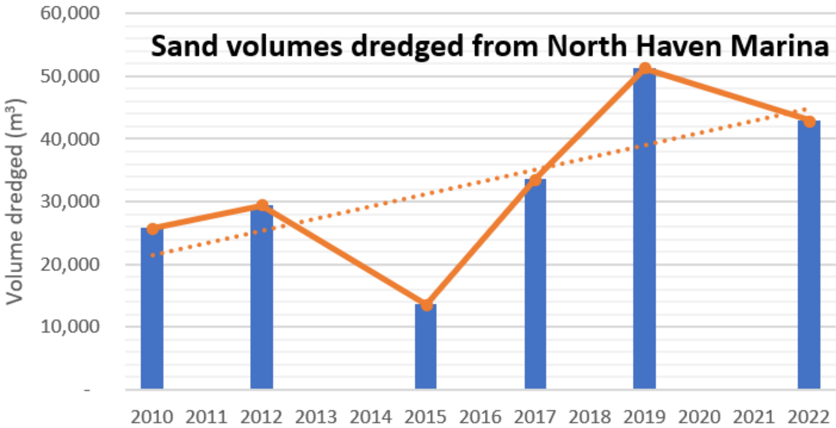
  Non-sand backpassing options that do not alter the future sand budget/shoreline accretion rates within Largs Bay have been assumed to continue to incur these additional management efforts and cost increases (i.e., increases over 20-year period are added to the life-cycle costs). The non-backpassing options are basecase, mass nourishment (B1), external sand (dredging) (B2.A) and external sand (carting) (B2.B). Option that results in a net zero sand budget in Largs Bay and

North Haven (i.e., stabilisation of the Largs Bay shoreline) have been assumed to offset these future increases in harbour dredging costs.

Accretion in Largs Bay and dredging of North Haven Marina entrance



Increase in shoreline width in Largs bay (shown above from DEA Coastlines) aligns with increased dredging requirements of North Haven Marina (shown below)



- Current annualised dredging rate is ~23,000m^3/year
- **Approx. increase in rate of dredging ~1,950m^3/year (8.5%)**

Options specific assumptions

Dredging options	• Cost estimates based on production calculation with mobilisation and demobalisation costs. • Mobilisation and demobilising is from east coast of Australia for small TSHD and from Asia for medium TSHD. • Sea-state delays (calculated from assumed wave height limit and wave buoy measurements), shipping delays (4%) and environmental delays (10%) assumed and included.

	• Production rates are all expressed in cubic meters measured in the hopper well. • Source material is clean compatible sand with no overburden of other borrow site costs or risks.

Pipeline options	• Capital costs derived from SA Government Budget Papers and crossed checked against our estimates including itemised breakdown.
	• Operational costs based on actual southern pipeline sub-component costs supplied by DEW and factored from pipeline length.
	• The residual value of the pipeline asset is included as a negative cost at the end of the 20-year life-cycle period as:
	  ○ Residual value of 80% of asset with 25-year design life: = $6.7M
	  ○ Residual value 20% of asset with 50-year design life: = $5.0M
	  ○ <u>Total residual asset value @ 20-years</u> = 6.7 + 5.0 = **$11.7M**
	• Regular maintenance has been included but no allowance has been made for any (i) upgrades needed to keep the pipeline operating within or beyond the 20-years evaluation period or (ii) end of life costs for the asset. This was at the direction of independent panel. This assumption warrants consideration as there is a reasonably high likelihood such costs will be incurred.

Sand carting	• All rates based on data supplied by DEW.