Coastal Management Study
Hallett Cove, SA

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FOREWORD

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Cover photo: Hallett Cove 2011 as viewed from Black Cliff. The conservation area and foredune can be seen in the left-hand foreground. Heron Way Reserve and the Field River entrance are in the centre background. The Hallett Headland and the cliffs south of the Field River to the desalination plant are in the background. Photo is from a similar location to the 1971 photo at Plate 2-4. **Photo**: Coastal Environment Pty Ltd, 27 April 2011

ACKNOWLEDGEMENTS

This project was undertaken for the City of Marion by Coastal Environment Pty Ltd. The work has been jointly funded by the City of Marion and the South Australian Coast Protection Board. Their financial assistance to undertake this assessment is gratefully acknowledged.

The support and input from the residents and property owners at Hallett Cove have been invaluable, a clear demonstration of their passion for the area and their understanding and involvement with their beach. Many individual residents have been consulted and have provided their time, experience and records to assist the study.

The Hallett Cove foreshores, reserves and walking trails are supported by a range of voluntary community groups that work to make these public areas special. They contribute their time and labour to plant regeneration, stabilisation, fencing works and drainage, and in constructing and maintaining the walking tracks that make the area unique. In undertaking this study they have also given freely of their time to assist with the understanding of the issues, and in that regard special thanks are offered to the Friends of the Lower Field River and the Friends of the Hallett Cove Conservation Park who assisted through site meetings and the provision of information.

We also acknowledge and thank Dr Ian Dyson for his assistance with the study. Ian has a special affinity with Hallett Cove, having grown up in the area and completed his PhD studies on the geology of the foreshores of the Gulf St Vincent. Ian gave freely of his time to assist the consultants and the City of Marion staff involved with the project to better understand the history and changes in the area. He was also a source of valuable technical reports on the local geology.

Staff from the Department of Environment and Natural Resources Coastal Branch assisted with technical information and comment on the project, making their records and photographs readily available to the consultants. This technical support was greatly appreciated.

Lastly, the assistance, guidance and support from the staff at the City of Marion is gratefully acknowledged. In particular, the project manager, Renee Pitcher took responsibility for organising consultation, chasing up queries and researching and providing copies of background information. This assistance has greatly benefited the review.

EXECUTIVE SUMMARY

The aim of this study was to assess current and potential future coastal management issues at Hallett Cove and to identify and evaluate alternative management strategies in response to those issues that could be considered in a coastal management plan for the area.

Hallett Cove differs from other beaches along the Adelaide metropolitan coast. It is a product of its unique geology, now preserved in the Hallet Cove Conservation Area, adjacent cliff lines and the shingle beach. The shoreline, while not providing a wide sandy beach for swimming and surfing, is highly valued and enjoyed by many for walking, boating, diving and fishing. The future management of the popular Heron Way Reserve behind the beach will be reviewed through the preparation of a Masterplan that will be, in part, informed by this study. The Coastal Walking Trail which is being formalised and upgraded by the City of Marion and local conservation groups, provides a unique opportunity to explore these metropolitan cliffs with their expansive views of the Gulf and adjacent shorelines. It incorporates the beach area fronted by the regionally unique shingle foreshore deposited by glaciers long ago. The Field River entrance with native vegetation regeneration along the river foreshores and the remnant sand dune cap adjacent to the entrance are also regionally unique. The Hallett Cove Conservation Area and the Hallett Headland Reserve showcase the geology, the flora and fauna and the Aboriginal and European heritage of the area. It is this uniqueness that must be recognised, preserved and enhanced through the management of the area. Perhaps best summed up thirty years ago by the words of Allison Dolling (1981) 'The Hallett Cove area, with its remaining plant life, geological and anthropological relics and historical associations is becoming more widely appreciated as a rich gem in the treasure of our National Estate.'

The future management of Hallett Cove Beach is hampered by the lack of adequate coastal process data and monitoring. This needs to be redressed through the collection and compilation of the nearshore bathymetry and ongoing monitoring of the beach response over time. This would allow a better understanding of the current hazard during storm events and potential impacts of future climate change. The available coastal process understanding which underpins this report of viable management strategies, draws from the detailed studies upon which the Adelaide's Living Beaches strategy has been based. These existing studies and data are discussed in this report.

A key component of the study was community consultation. The level of interest and information forthcoming from the local community is confirmation of the importance that is placed on the beach and open space in the area. This consultation was greatly appreciated and helpful. It is briefly summarised in the report.

In assessing the future impact of climate change and in particular sea level rise on the foreshore areas, this study uses the scenarios put forward in the South Australian Government Coast Protection Board's 'Policy on Coastal Protection and New Coastal Development': 0.3m to 2050, a further 0.7m to 2100 (i.e. total of 1.0m to 2100). For consideration of future hazard within the report, this has been translated to an average recession rate of 25 times the sea level rise, or half what might be anticipated on a fully exposed sandy ocean beach. This equates to approximately 10m recession of the back beach to 2050 and 25m recession by 2100, assuming a sea level rise of 1m is attained. In the absence of site specific information and modelling, these assumed recession values can be applied to forward planning with a view to reviewing the rates within 10 years, based

on survey profiles at key locations and other relevant data. There are currently no major assets (private dwellings, public buildings or roadways) located within 10m of the existing back beach escarpment. The shingle exposed at the surface at present is providing limited protection both to the erosion of the back beach area and the underlying clay. This shingle and the underlying clay are an important feature of the beach and should not be disturbed or exposed unnecessarily.

The foreshores of Hallett Cove present as a slowly receding coastline, starved of sediment. The erosion escarpment at the back of the beach and the shingle and clay deposits exposed across the beach indicate that the beach is now as far landward as it has been since sea level stabilised around the present level approximately 6000 years ago. The available coastal process modelling indicates the potential for sand transport out of the Hallett Beach compartment (100,000m^3/year) is an order of magnitude greater than the natural rate of sand supply along the coastline from the south (5000m^3/year). The perceived reduction in the sand quantity on the beach over time is discussed in some detail throughout this report. While the community perception that the sand cover has reduced over the past 30 years may be true, the likelihood is that over historical times the volume of sand on the beach has always been small and variable, providing a thin sand veneer from time to time over sections of the exposed shingle. While it is acknowledged that additional sand cover on this section of beach is seen as desirable by many in the community, this is unlikely to be a practically achievable outcome. It would require either a significant increase in the alongshore sand supply reaching Hallett Cove or the importation of large volumes of sand to the beach. Even then the retention period for this sand in the embayment would remain short, requiring regular and expensive ongoing replacement.

The recommended approach to management of the Hallett Cove foreshores is to adopt sympathetic and non-confrontational measures for the immediate future. The management actions where possible should be minimal and in keeping with the exceptional natural and heritage values of the area. Current practices of dune management, replanting and minimal use of 'hard' protection should be continued. For much of the beach the preferred management strategy is to accommodate the erosion in the short term and to allow the escarpment to recede, maintaining an accessible beach area. Soft management options may not be sufficient around the Field River entrance and the southern section of Heron Way Reserve in the longer term. On both sides of the river there is residential subdivision and infrastructure located closely behind the beach. In particular, on the northern side of the entrance there are approximately 12 houses along River Parade and the beachfront that are likely to require protection beyond 2050 if they are to be retained. While such works could be implemented now, they are not required at present.

CONTENTS

1. Scope of This Assessment

Coastal Environment Pty Ltd was engaged by the City of Marion in April 2011 to conduct an assessment of current and potential future coastal management issues at Hallett Cove in South Australia and to identify and evaluate alternative management strategies in response to those issues. The project aims as identified in the study brief were:

- Complete a coastal management study addressing coastal process issues for the section of the Hallett Cove foreshore between the southern Council boundary near the desalination plant and the northern end of Hallett Cove Beach at Black Cliff (approximately 2.5km).
- Liaise with the Coastal Management Branch of the Department of Environment and Natural Resources in developing effective coastal management strategies for this section of the Hallett Cove foreshore. Innovative solutions are encouraged and particular consideration is to be given to 'soft' engineering solutions where appropriate (e.g. revegetation, ongoing monitoring etc.) in keeping with the natural character of this unique landscape.
- Identify coastal management issues that require consideration by Council during developmentof a Masterplan for Heron Way Reserve.
- Prepare a report clearly documenting the findings of the study and recommended management strategies. Present findings to Council and elected members through an Interactive Forum or Report including preparation of a presentation and relevant documentation.
- Effectively consult with the community as well as internal and external stakeholders.
- Ensure the Coastal Management Study and its recommendations are consistent with the strategic direction identified in the City of Marion Strategic Plan, Coast Protection Board Policies and other relevant documents.

In assessing the coastal processes as they affect the current and future behaviour of the Hallett Cove foreshore, reliance was placed on the interpretation of existing studies and information to provide a basis for the understanding of the beach behaviour and likely future response to climate change.

The coastal process understanding which underpins this assessment of available management strategies includes the detailed studies upon which the Adelaide's Living Beaches strategy (DEH 2005) has been based. They are the most recent and comprehensive assessment of the regional processes, and little additional value could be seen in re-assessing this understanding, which is widely accepted as defining the coastal processes along the Adelaide metropolitan coast. Specifically, the brief for this study stipulates that 'no new numerical modelling is expected to be undertaken for the purpose of the study' as those previous studies are adequate for providing the level of coastal process understanding required for this management study. These existing studies and data are discussed in this report as required.

In assessing the future impact of climate change and in particular sea level rise, this study uses the scenarios that accord with the State Government Coast Protection Board Policy: 0.3m to 2050, a further 0.7m to 2100 (i.e. total of 1.0m to 2100).

The conclusions reached in this report are based upon the scope of works as outlined and the experience of Coastal Environment Pty Ltd specifically in coastal engineering, coastal processes and coastal zone management.

The approach used to establish an understanding of the regional coastal processes, the issues of concern to the local community and the viable strategies to address those concerns into the future, was based on comprehensive inspections of the site, identification and review of relevant available records, consultation with City of Marion staff and elected members, community groups and community. This took place over a period of six months from April to September 2011 and included:

- an inception meeting with staff of the City of Marion, Department of Environment and Natural Resources and the consultant on 27 April at Council
- discussion with staff from relevant sections within City of Marion
- review of historical information within the Marion City Library
- review of relevant files and records held by DENR relating to previous studies, surveys and reports on Hallett Cove
- review of records on Hallett Cove held by DENR
- comprehensive community questionnaire mailed out to residents and ratepayers with 123 written responses received
- meetings with Friends of Hallett Cove Conservation Park, Friends of Field River and individual local residents
- site inspection in conjunction with City of Marion staff and Dr Ian Dyson
- meeting with staff from City of Onkaparinga, and
- presentation to City of Marion Elected Member Forum on 16 August 2011.

2. EXISTING CONTEXT

2.1 REGIONAL SETTING

The 10km section of the Adelaide coastline between O'Sullivans Beach and Marino, which includes the Hallett Cove foreshore, is aligned north-north-east to south-south-west, while the metropolitan coast of Brighton and Glenelg further to the north is oriented approximately north-south (Plate 2-1). This alignment change is significant, placing the Hallett Cove coastline at a more oblique angle to the predominant ocean swell wave window between the northern side of Kangaroo Island and the southern extremity of the Yorke Peninsula. The waves reaching the shoreline in this area do so at a greater angle and wave height and, hence, have the potential to move significantly larger sand volumes than on the better-aligned metropolitan beaches to the north. This is reflected in the numerical studies of sand transport undertaken for the metropolitan coast (CES 2004, see also Section 3.1). The beach is also exposed to locally generated sea waves within Gulf St Vincent, which approach the Hallett Cove shoreline from directions between north-west and south-west. They may cause sand to move along the beach from south to north or from north to south at different times.

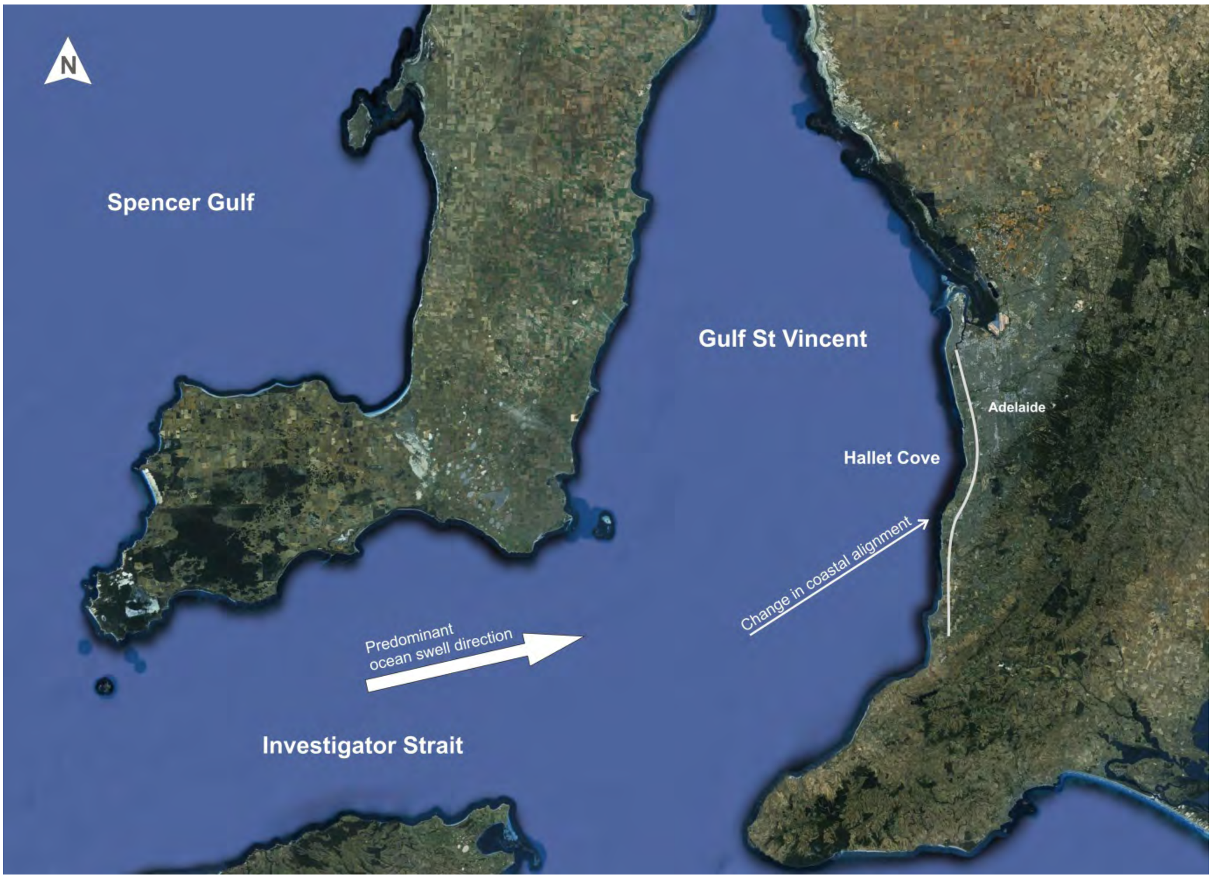

Plate 0-1: The coastal margins of Gulf St Vincent and the Investigator Strait. The arrow at the right indicates the change in coastal alignment through Hallett Cove from O'Sullivans Beach to the south and Marino to the north. Waves that strike this coastal section at an oblique angle cause higher sand transport than on the better-aligned Onkaparinga coast to the south and along the metropolitan coast further north. **Photo source**: Google Earth image 2010

Hallett Cove is located within the City of Marion towards the southern end of the Adelaide metropolitan coast and is approximately 12km south of the Glenelg jetty. The study area is defined in the project brief as 'the section of the Hallett Cove foreshore between the southern border of the Council area and the northern section of the beach directly in front of the Hallett Cove Conservation Park (section approximately 2.5 km)' and is shown in Plate 2-2.

Plate 0-2: The extent of Hallett Cove foreshore in the study area, 2010. Numbered sites refer to notes below. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Significant features of the study area visible in this photograph include:

- The Hallett Cove embayment is contained by high bedrock cliffs to the south and north (**1.**). The entire study area is underlain by a rock/clay shelf, partly visible at low tide and extending approximately 100m seaward of the back beach escarpment (variable width). This shelf is continuous along the cliff and beach areas and is clearly visible in the photograph.
- The ancient bedrock cliffs (**1.**) at Black Cliff (top of photo, see also Plate 2-6) which extend northwards (out of the photo) approximately 4km to Marino.
- The natural 'amphitheatre' contained within the Hallett Cove Conservation Area at the top of the photo (**2.**) which extends approximately 400m south of Black Cliff.
- Heron Way Reserve (**3.**) which extends approximately 400m south of the Conservation Area and the subdivision of Hallett Cove to the east.
- The 'bulge' in the shoreline between the Heron Way Reserve and the Field River entrance at the centre of the photo (**4.**), including the residential development bounded by Marine Avenue and River Parade.
- The Field River entrance (**5.**) and the small entrance sand spit/dune cap on the southern side of the river entrance.

- Residential development and residential land around the Field River entrance and to the south along Beachfront Crescent (**6.**). The concrete boat ramp and deeper boat channel through the clay bed and shingle cover can be seen.
- The emergence of the high cliff line and residential development (**7.**) seaward of Albatross Drive and Burlington Road extending approximately 1.2km south to the desalination plant and City of Marion boundary at the bottom of the photo.

2.2 Aboriginal Settlement of Hallett Cove

Aboriginal settlement of the Hallett Cove region is believed to date back some 40,000 years, making it amongst the earliest in Australia. A brief history of Aboriginal occupation is presented in Dolling (1981) and augmented here with details provided by the Living Kaurna Cultural Centre. It is briefly summarised as follows:

The original inhabitants of the area appear to be the Kartan people (from Karta, the Aboriginal name for Kangaroo Island). Karta is a spirit island where it is forbidden to rest or camp, a place of connection with heaven and earth and no Aboriginal tribe or sovereign nation lived there. The Kartan presence is recorded at Hallett Cove through large stone implements found near the coast and the Waterfall Creek camp site (north of Black Cliff) around 1934 by Harold Cooper, an Honorary Associate in Anthropology at the South Australian Museum. Harold Cooper collected more than 1700 stone implements from the Hallett Cove camp site over a period of 36 years and the breadth of this collection is testament to the long Aboriginal occupation of this site and its importance to these first inhabitants.

More recent settlement of the area was by the Kaurna people from the Adelaide region and their occupation dates back some 2000 years BP (before present). Hallett Cove remains an important place to the Aboriginal community, and the Tjilbruke Dreaming is the predominant dreaming of Southern Kaurna country. Tjilbruke dreaming is an 11,000-year old story and Tjilbruke was a Kaurna man, with neighbouring nations confirming this with their respective dreaming stories. Tjilbruke Dreaming is about the creation of seven freshwater springs along the coast of the Fleurieu Peninsula.

Tjilbruke was an ancestral being of the Kaurna people of the Adelaide plains, whose lands extended from Parewarangk (Cape Jervis) in the south to Crystal Brook in the north and included the freshwater springs along the coast at Ka'reildun (Hallett Cove).

The Tjilbruke dreaming and the important freshwater spring sites at Hallett Cove need to be respectfully considered and discussed with the present-day Kaurna representatives in any changes or works proposed at Hallett Cove.

Information provided by the Department of Premier and Cabinet, Aboriginal Affairs and Reconciliation Division relating to Aboriginal heritage of the area is reproduced in Appendix D.

2.3 European Settlement Pre-1945

Hallett Cove was first explored by Europeans in 1837 when John Hallett visited the area while searching for wandering stock (Dolling 1981). George Sandison Senior had an association with Hallett Cove as early as 1844 when he worked as an overseer on Major O'Halloran's property 'Lizard Lodge'. He subsequently purchased land which he farmed in his own right. This property was passed to his son George upon his death in 1872. In 1900 the property, 'Myrtle Bank' comprised 475 acres, including the amphitheatre at Hallett Cove (Dolling 1981).

The first subdivision at Hallett Cove was in the model estate, opened near the railway line in 1913 (Donley 2001). Mr Allan Sheidow subdivided some land south of Grand Central Avenue. Only four buildings were located on this land by 1949, showing the relatively recent development of the area.

2.4 Development 1945 to Present

Following the end of World War II, holiday shacks were established along the Crown land fronting the present conservation area and Heron Way Reserve.

The surrounding area remained predominantly as farming land through to the 1950s, when the South Australian Housing Trust acquired much of the land for industrial use.

In 1973 Mr Jimmy Sheidow had plans approved for 480 houses on a 150 acre parcel of land to the east of the railway line and behind Hallett Cove Beach. In 1974 approval was given for a further subdivision of 300 acres between the railway line and the Geological Reserve to be developed by the Hallett Cove Development Company. The developer was required to provide a bridge across the railway line to service the 1000 new homes.

The development of the area required removal of the shack development. The extension of the amphitheatre to the south where it joins the beach on the north side of the Field River entrance can be seen in the background of the 1971 photograph (Plate 2-4). This section of the amphitheatre was subsequently filled and levelled by the earthworks undertaken to establish the subdivision at Hallett Cove and the creation of Heron Way Reserve (Plate 2-3).

The Port Stanvac oil refinery (named after the **Stan**dard **Vac**uum Refining Company which built the plant for Mobil) opened on Hallett Headland south of Hallett Cove in 1963. This facility included a jetty (extending 600m from the back beach) and harbour protected by a rock wall (extending 225m from the back beach). The refinery operated for 40 years until its closure in 2003. Details relating to the Port Stanvac maintenance operations are included in Section 4.1.1 and the development is shown in Plates 4-1 and 4-2.

Plate 0-3: Earthworks for the Hallett Cove subdivision, 1976. The two large rocks on the beach (see Plate 2-8) can be seen. The left-hand lower track is the road leading to the present day car park. The Boatshed Café would be approximately at the left-hand side of the photo. All the back beach area has been re-contoured and the outline of what is now Heron Way Reserve can be seen behind the beach. **Source**: unknown, from Matschoss & Mayberry (1993)

In 1975 the South Australian Government purchased 50.48 Ha of land behind the northern end of Hallett Cove, now known as the Conservation Area, so that 'its geological and scientific interest could be preserved in perpetuity' (Dolling 1981).

In 1983 a boat launching ramp and rock breakwater were constructed at O'Sullivans Beach, approximately 4.5km south of Hallett Cove. The southern breakwater is approximately 400m in length, extending 250m from the back beach. The shorter northern breakwater is approximately 160m long. The facility was refurbished in 2000 and now services much of the southern Adelaide area. Details relating to the boat ramp operation are included in Section 4.1.2 and the development is shown in Plates 4-3 and 4-4.

In 1990 the Headland subdivision was approved on Hallett Headland, south of the Field River at Hallett Cove.

In 2003 the Mobil refinery site and harbour at Port Stanvac was effectively closed down, reportedly as a result of poor refining margins and the difficulties faced by Australia's refineries in remaining competitive within the region, particularly in light of the need to invest to meet future fuel standards. The northern portion of this site was subsequently allocated for development of the Adelaide desalination plant which is being constructed on the headland with intake and outfall structures offshore. It was trialled in July 2011 and is scheduled for completion in late 2012. This development forms the southern boundary of the current study area.

Plate 0-4: Hallett Cove, 1971 showing shack development along the front of the present-day Conservation Area. The photo is taken from the beach dune near Black Cliff at the location of the then Surf Life Saving Club which originally operated from one of the shacks. **Photo credit**: Wally Herzfeld as reproduced in Donley 2001, p. 166

The Hallet Cove Surf Club was initially established in one of the shacks at the northern end of Hallett Cove, near Black Cliff (Plate 2-4). The club remained in this location until around 1980 when it relocated to a purpose-built building further south, at the end of Heron Way adjacent to the Conservation Area. The Hallett Cove Surf Club ceased operation in 2003 due to a loss of members to adjacent clubs where the beach conditions were preferred. The City of Marion subsequently considered options for the reuse of the club building which is now leased and operating as the Boatshed Café since 2007.

Erosion of the narrow sand spit on the southern side of the Field River entrance has been a concern since at least the early 1990s. The fragility of this dune is not abnormal for a narrow sand spit located adjacent to a river entrance. In this case, the majority of the dune is in fact a sand cap over the underlying clay substrate. The northern end of the dune is at a lower level, and from time to time is eroded by the river flows, to reform as and when sufficient sand is available on the beach. There is a very small volume of sand incorporated in this spit. On most occasions the wave activity along this southern section of the beach is dissipated against the shingle and larger rock overlying the clay on the nearshore seabed and across the intertidal zone. This shingle layer, which is exposed at a flat slope across the beach, is an effective means of dissipating the wave energy. During the 1990s, periods of storm surge and wave action allowed the waves to reach the back of the beach and undercut the exposed clay underlying the sand cap. This resulted in the formation of caverns

(Plate 2-5) along the back beach which are dangerous and can collapse. The City of Marion took preventative action to collapse these caverns.

Plate 0-5: Undercutting of the dune south of Field River entrance, 1999. The dune is a thin sand cap overlying the clay substrate. During elevated water levels and high waves the clay layer is eroded forming caverns beneath the dune which are prone to collapse. **Photo credit**: A&S Elia, 1999

In late 2004, the City of Marion acted to reduce the frequency and extent of erosion of the face of this dune section by placing imported rock at the back of the beach against the dune face. While contentious, these works have in all likelihood protected the fragile dune cap from further losses due to wave action. This erosion of the dune face during large events is likely to continue, particularly with a long-term prognosis of significant rises in sea level. The continuing efforts by the community in caring for this small dune may retain this isolated and remnant habitat at Hallett Cove for many years to come.

The Hallett Cove foreshore today incorporates valuable and varied public space to service the local and broader community. Residential development is located south of the Hallett Cove Conservation Park and landward of the Heron Way Reserve. Limited residential development is located around the Field River entrance, with existing dwellings located north of the river and undeveloped sub-divided residential land to the south of the river entrance. The foreshore development extends across the Hallett Cove Headland to the south.

The Heron Way Reserve is located along much of the beachfront between the Hallett Cove Conservation Area to the north and the Field River entrance to the south. The reserve was established on cleared and levelled land when the back beach area was subdivided in the mid-1970s (Plate 2-3). It provides a major focal point for local families with easy access, large turfed areas, play equipment and seating. The reserve overlooks the beach and there is a paved walking path across the top of the foreshore escarpment, with panoramic ocean views. The old surf club building and car park adjacent to the conservation area are used as a commercial café which is popular with locals and visitors and the only commercial outlet along the beachfront. The City of Marion is about to commence preparation of a Masterplan for the Heron Way Reserve to enhance the amenity and functional use of the reserve for community and environmental benefits.

The Hallett Cove Conservation Park and the Hallett Headland Reserve showcase the unique and world-renowned geology of the area, including the high cliff line from Marino to Black Cliff, the amphitheatre and sugarloaf within the Hallett Cove Conservation Area, and the high cliffs to the south along Hallett Headland, including the Hallett Headland Reserve. The beach itself is unique, with the exposure of shingle and clay substrate originating from the present-day erosion of the cliffs and reefs and the remnant glacial till. Large isolated rocks (erratics) are exposed along the beach, and occasional thin patches of sand mask the underlying shingle. The Field River entrance across the beach and the unique riparian vegetation along the river banks offer a different experience for passive recreation. Flora surveys have identified important sites of remnant coastal vegetation within these areas. Community volunteer groups work with the City of Marion to protect and enhance these existing areas of coastal vegetation and geological significance. The Council is undertaking a program of conservation, revegetation and weed control projects which include the establishment of bush care sites at Hallett Headland Reserve; dune restoration work at Hallett Cove and revegetation of the cliffs north to Marino .

Much of this public open space is linked by the coastal walking trail which extends from Marino south through Hallett Cove along both sides of the Field River then across the Hallett Headland and cliff line. It is intended this trail will eventually link with the desalination plant at the City of Marion southern boundary. Council has recently appointed a consultant to undertake a full audit of the Coastal Walking Trail. This includes looking at the design (and re-design), change to alignments, structure and ongoing maintenance required throughout.

2.5 Geological and Geomorphological Background

The geological significance of the area was first recognised by Professor Ralph Tate of the newly formed University of Adelaide who in 1877 discovered the visible signs of glaciation along the coastal cliffs (Dolling 1981).

This glaciation, which was evident along approximately 2km of the cliff shoreline, has subsequently been identified as the result of a glacier traversing the area from south to north in the Permo-Carboniferous age (Hasenohr & Corbett 1986), almost 270 million years ago. Striations in the basement rock caused by scratches from rocks embedded in the glacial ice are visible on the rock shelf at the cliff top near Black Rock at the northern end of Hallett Cove (Plate 2-6). The Precambrian surface of these purple siltstones (believed to be some 600 million years old) was polished and scratched by the movement of the glacier. These Precambrian sandstones and siltstones of the Marinoan Series are exposed today as the cliff line reaching north from Black Cliff and as the lower level rocky shoreline platform at the base of the cliffs. They are exposed once more along the cliff line to the south of Hallett Cove (Hasenohr & Corbett 1986).

Plate 0-6: Exposure of 600 million year old Precambrian siltstones at the top of Black Cliff, Hallett Cove. The polished surface and deep scratches caused by the passage of a glacier approximately 270 million years ago were first recognised by Professor Ralph Tate of the University of Adelaide in 1877. **Photo**: Coastal Environment Pty Ltd, 27 April 2011

The significance of these geological finds has been recognised as being of national and global importance. In 1893 an expedition to the site was organised by the Australasian Association for the Advancement of Science and included 150 local and visiting geologists and other interested persons. This expedition was described at the time as the largest scientific expedition ever undertaken in the southern hemisphere.

Following the retreat of the glacier, sediments were deposited along its route, infilling an old river valley that formerly occupied Hallett Cove. The nature of these Permian sediments within the amphitheatre area (Plate 2-7) suggests they were deposited in a lake formed by melt water trapped behind the retreating ice towards the end of the glaciation (Hasenohr & Corbett 1986). 'The soft Permian glacial deposits, overlaid by more recent clays, became in time deeply eroded, gradually carving the formation now known as the "Amphitheatre."' (Dolling 1981).

Plate 0-7: The sugarloaf and amphitheatre within the Hallett Cove Conservation Area 2011. **Photo**: Coastal Environment Pty Ltd, 27 April 2011

The periods of glacial deposition, subsequent sedimentary deposits and then erosion by surface runoff and rising sea levels to the current still stand (about 6000 years BP) are all reflected in the present-day shoreline of Hallett Cove. At the base of the cliffs to the north and south is a narrow wave cut rock platform, visible from the air for about 50m width from the low water line and to an approximate depth of around 3m below mean sea level. This bedrock presumably underlies the beach and much of the remaining sedimentary deposits in the amphitheatre and forms the modern land surface of Heron Way Reserve and the subdivisions landward of the beach to the north and south of the Field River. The depth and continuity of this rock substrate could only be confirmed by drilling or seismic survey.

The shingle comprising much of the beach sediment is in part of glacial origin. 'Visible only at low tide is the lowest of these sediments, called by geologists a lodgement till. It is a bed which extends well out to sea with only the surface exposed at the low water mark. The sediments consist of a very fine grained, compacted grey sandy clay containing unsorted (variably sized) clasts or pebbles of rock. Most of these are angular but a small number are rounded. The majority of the pebbles consist of red siltstones or sandstone torn from the underlying Proterozoic bedrock by the advancing ice, but a small number consist of quartzite granite or rocks of volcanic origin.' (Giesecke 1999). Dating of the pollen in this sediment suggests it is of Permian age.

Towards the southern end of the beach (around the Field River mouth and further south) 'again only visible at low tide, is a layer of sediment known as a flow till. This layer was deposited later and overlies the lodgement till, extending shoreward where it is covered by the sand of the beach. It contains a greater number of rocks than the underlying lodgement till and shows convoluted and contorted, interbedded sands, silts and clays with embedded pebbles. This layer is considered to be a flow till created by debris flowing from the ice into a lake.' (Giesecke 1999).

The beach itself comprises a mixture of shingle and sand overlaying the clay till layers and the rock shelf. This sand cover varies along the beach and from time to time in both composition and quantity. The shingle on the beach is derived from the eroded glacial deposits that overlay the Cambrian bedrock and from the ongoing erosion of the exposed cliffs and rock shelfs. This results in a variety of rocks forming the shingle layer and larger stones on the beach. Notable on the beach face along the shoreline and in the surf zone are large boulders, some of which derive from bedrock located a long way from Hallett Cove. 'Hallett Cove beach is strewn with boulders – erratics which have been eroded from local bedrock or transported by the Permian ice about 280 million years ago and re worked by the sea. Most of the smaller boulders have been eroded from dark sandstone cliffs to the south and tumbled northwards by the waves.' (Giesecke 1999).

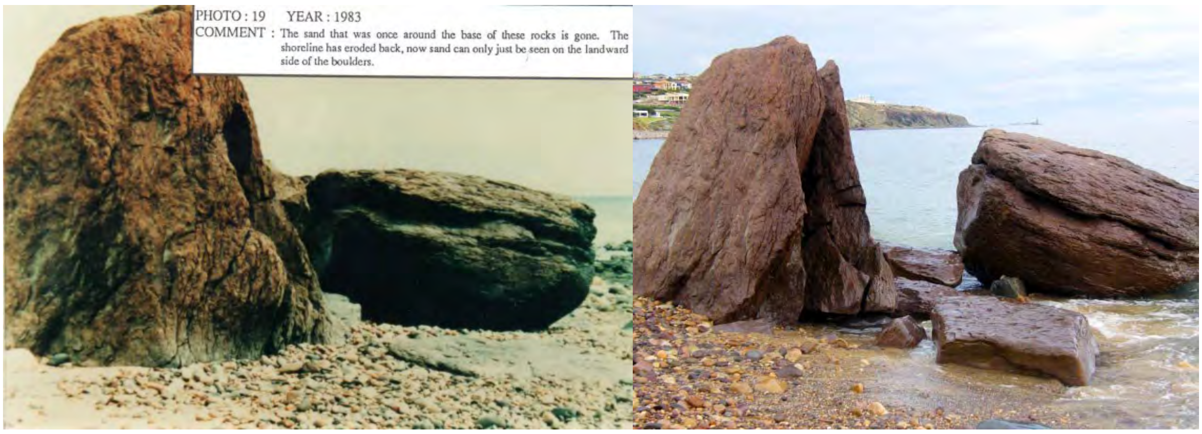

Plate 0-8: Erratics on Hallett Cove Beach. **Photo** (left) taken 1983 (Matschoss & Mayberry). **Photo** (right) taken 29 April 2011 (Coastal Environment Pty Ltd). There appears to be less than 100mm variation in the sediment level around the base of the rocks over a period of almost 30 years

The erratics have been a popular subject for amateur photographers visiting the beach over many years. In particular, there are two large stones about 50m south of the Conservation Park boundary which are clearly visible on the earliest photos of Hallett Cove. These two large erratics (Plate 2-8) are 'composed of red-brown Proterozoic sandstone and siltstone. These were probably stripped from the bedrock south of Hallett Cove and carried deep in the Permian ice' (Giesecke 1999).

Close examination of these two photos and other available photographs dating back to around 1970 shows very little obvious change in the surface level of the beach at this location. There are slight fluctuations and changes in the texture (sand to gravel) at different dates. The more recent photographs of these erratics (1980s to present) all tend to show gravel or shingle rather than sand. This photographic record is consistent with the limited survey data available which suggests a fluctuation in the surveyed levels at this location on the beach of less than 0.5m since 1975 (Section 3.6).

Sea level was significantly lower during the last glacial period and 20,000 years ago would have been about 120m below the present level. During that period of lower sea level, the current Hallett Cove foreshore was inland and elevated. Erosion of the hinterland to the east and the sediments infilling and seaward of the present shoreline would have been eroded, 'forming a vast alluvial plain which in the late Pleistocene ice age extended across the present Gulf St Vincent' (Dolling 1981). During the subsequent Holocene transgression as sea level rose, the Gulf was inundated and the current sea level was achieved approximately 6000 years ago. Since that time the shoreline has continued to be eroded by wind and waves to form the present shoreline.

This geological history is essential to understanding the current structure of Hallett Cove and the way in which it responds to the current-day coastal processes (wind, waves and currents).

2.6 Native Vegetation Background

The vegetation of the coast along Hallett Cove is characterised by the coastal cliff communities that have strong floristic affinities with the vegetation of Coastal Cliff communities found on the Yorke Peninsula, especially locations such as Innes National Park. The other major vegetation type is the coastal sand dunes in Hallett Cove Conservation Park, Heron Way Reserve and at the mouth of the Field River. The coastal cliff bases contain a third vegetation type where the effects of sea spray are noticeably greater.

There are some seemingly obvious patterns to the way the vegetation is distributed along the coast.

On the very front of the coastal cliffs, where the effects of sea spray are noticeably greater there are plants usually associated with salt tolerance. Here Nitraria Billardierei (Nitre Bush), Atriplex cinerea (Grey saltbush), Scaevola crassifolia (Cushion Fanflower), Zygophyllum confluens (Coast Twinleaf), Threlkeldia diffusa (Coast Bonefruit) and Disphyma crassifolium (Round-leaf Pig-face) are common in their abundance and distribution. There are also some very large populations of Lotus australis (Austral trefoil)and the only locations of Nicotiana maritima (Native Coast Tobacco) in the City of Marion.

Inland where sheltered from the salt spray and on rocky south facing slopes there is a greater prevalence of species such as Pomaderris paniculosa (Coast Pomaderris), Hakea rugosa (Dwarf Hakea), Acacia acinacea (Gold-dust Wattle), Dodonaea viscosa (Sticky Hop-bush) and Olearia ramulosa (Twiggy Daisy-bush) with interspersing Lepidosperma viscidum (Sticky Sword-sedge) and Gahnia lanigera (Desert Saw-sedge). These areas often contain small patches of native perennial herbs, lilies such as Arthropodium strictum (Vanilla Lily) and ferns like Cheilanthes austrotenuifolia (Rock Fern).

Vegetation on the cliff tops away from salt spray but on sandy-loam soils normally on north to north-west aspects over calcareous rock is dominated by Beyeria lechenaultii (Pale Turpentine Bush), Acrotriche patula (Prickly Ground-berry) with understorey of Dampiera rosmarinifolia (Wild Rosemary) and Gahnia lanigera (Desert Saw-sedge). Here there are populations of herbaceous plants such as Ptilotus nobilis (Yellow Tails), Velleia arguta (Toothed Velleia) and significant populations of Calostemma purpureum (Purple Garland Lily). This vegetation association is well represented along the southern end of the cliffs such as Headland Reserve.

On the southern end of the Marion Cliffs there are pure stands of Eucalyptus porosa (Mallee Box) and Melaleuca lanceolata (Dryland Tea-tree). Melaleuca lanceolata is restricted to the drainage areas, away from exposed salt spray areas, Eucalyptus porosa prefers areas of shallow sandy soil over calcareous rock where it is associated with Pittosporum angustifolium (Native Apricot) and Rhagodia candolleana (Seaberry Saltbush).

There are some small sections of coastal dune system at the mouth of the Field River, along Heron Way Reserve and in the Hallett Cove Conservation Park; these are composed of an Olearia axillaris (Coast Daisy-bush) +/- Atriplex cinerea (Grey Saltbush) low shrubland with understorey typical of sandy coastal areas such as Ficinia nodosa (Knobby Club-rush), Spinifex sericeus (Rolling Spinifex) and Dianella brevicaulis (Short-stem Flax-lily).

2.7 Recorded Changes to the Beach

While there is a widely held perception within the community that Hallett Cove Beach is eroding and has changed from a sandy beach to a rocky beach over the past 20 years due to a loss of sand over recent years, careful interpretation of the available historical evidence is not clear cut. The beach along its entire length is underlain by a flat rock shelf and/or exposed clay and shingle surface. Large rocks are exposed along the beach and rock cliffs contain the beach area at either end. The earliest photographs do show more sand cover than is evident on the beach today but the perception from these photographs may be misleading as to the extent of the changes. For example, comparison of the cover photo (2011) with the same view in 1971 (Plate 2-4) would suggest only minor changes have occurred over a period of 40 years at this southern end of the beach. On a flat shingle beach of this type, only a relatively small sand volume is required to provide a veneer of sand, hiding the underlying shingle layer and placing a thin sand cover against the dune escarpment. Close examination of the hundreds of early photos available (1960s to present) suggests that from time to time sections of the beach oscillate from predominantly exposed shingle to carrying a thin sand veneer. This is largely dependent on the available alongshore sand supply at the time and the preceding weather conditions. A selection of photographs of the beach on different dates is reproduced here in Appendix B.

Chapter 3 of their field guide (Hasenohr & Corbett 1986), which describes the geology from 'Marino to the Onkaparinga River Mouth' commences: 'The flat sandy metropolitan beaches end at Marino, where the sea washes on to hard rock layers. From here to Port Noarlunga and beyond, cliffs have developed behind rocky or pebbly beaches with occasional sandy bays. … This section of the coastline contains the Hallett Cove Conservation Park where some of the best preserved Permian glacial features in the world can be inspected.'

Records held on file by DENR show that the exposure of shingle and rock along the Hallett Cove foreshore has been an issue for many years and is mentioned in the files over a long time period. For example:

- Extracts on file from a 1975 Hallett Cove Study report 'The Beach is not a particularly high quality one … and is generally deficient in sand, especially at the southern end. An examination of aerial photographs taken in 1949 and subsequently show there have been no substantial changes to the beach over this period.'

- Notes prepared for a question on notice dated 24 August 1981 advise that 'There is no need for the Hallett Cove Beach to be replenished as beach profiles surveyed by the Department of Lands indicate that the beach is stable and does not require protection in the form of sand replenishment.'
- A letter to the City of Marion from the Hallett Cove SLSC dated 8/10/1985 which was forwarded by Council to the Government raising the need for additional sand on the beach states that 'many injuries are sustained from slipping on, or tripping over rocks while entering the water.'
- Internal DENR minutes on file recommending against future nourishment of Hallett Cove Beach dated 5 November 1985 state that 'This beach has always been rocky, and this has been considered one of the attractions of the conservation park.'

While it is recognised that the majority of the photographic evidence and recorded observations date since the construction of the Port Stanvac facility in 1963, the reality is that no detailed and reliable information relating to the beach condition prior to this time exists. The fluctuations in the sand cover are consistent with the expected response of a beach of this type. The geological evidence overwhelmingly points toward an eroding shoreline since the current sea level stillstand, with very old sediments exposed on the sea bed and in the back beach. It is unlikely that a large sand barrier has existed along this shoreline in the recent past as it would have to have been removed by recession between the mid-1960s and mid-1970s when the alongshore sediment transport may have been interrupted.

The beach response and condition over the last 40 years is consistent with a sediment-deficient coast and a low rate of sea level rise.

This shoreline is continuing to evolve and exhibits **all the features consistent with a slowly receding shoreline**. This trend is likely to continue and accelerate into the future under the scenario of an accelerating sea level rise. The clay sediments exposed on the beach (at the southern end around the Field River entrance and in the dune face) and around the low tide zone further to the north, are glacial deposits. Once exposed, the clays will continue to erode and are not replenished. That there is no accretion of modern (Holocene) sands or sediments over them indicates the beach is now as far landward as it has been since the ocean reached its present level around 6000 years ago.

Unquestionably, there is a deficit of sand on the beach, with what little sand arrives down the Field River or alongshore from the south quickly moved by waves to the northern end of the cove and, ultimately, out of the beach compartment to the north.

The shingle exposed at the surface is providing protection both to the erosion of the back beach area and the underlying clay. This shingle and the underlying clay are an important feature of the beach and should not be disturbed or exposed unnecessarily.

3. Coastal Processes

3.1 Studies of the Adelaide Metropolitan Coast

The understanding of the coastal processes as they have been applied in this report to evaluate and develop management strategies is based on the information presented in the existing reports detailing modelling of sand movement through Gulf St Vincent, augmented as appropriate with additional data held by the City of Marion and the community, information provided by the Department of Environment and Natural Resources, historical records, photography and observations.

In 2003 Coastal Engineering Solutions was engaged by the SA Government to update coastal process modelling for the entire metropolitan coast of Adelaide from Kingston Park in the south to Outer Harbour in the north (CES 2004). Their report presents a comprehensive review of the earlier studies of the Adelaide coast dating back to the 1970 Culver Report, produced by the University of Adelaide and funded by the state and local governments. The findings of each of these earlier reports are not presented here as they have been adopted in the more recent modelling and assessment by CES (2004). This study built on earlier work and regional studies using the historical information and process understanding to inform the detailed numerical modelling. It remains the most recent and complete assessment of the coastal processes affecting the Adelaide coast, including Hallett Cove. The information contained within that study has been used to develop and manage the Adelaide's Living Beaches Strategy (DEH 2005) and is supported by the Coast Protection Board.

The fundamental understanding of the current situation in relation to the eastern coast of Gulf St Vincent is well described by CES (2004) based on their modelling. They state that 'The erosion problems being experienced along Adelaide's foreshores can primarily be attributed to a deficiency in the amount of sand being supplied naturally from the south. The volume of sand entering the beach system at Seacliff is of the order of 5,000 m^3/year, whereas the capacity of waves to move sand along the shoreline from south to north is an order of magnitude greater, variously estimated to be in the range of 30,000 m^3/year to 80,000 m^3/year.' They also conclude that 'the rate of longshore sand movement has increased over the last 50 years as a consequence of diminishing nearshore seagrass meadows.' The impact of the loss of these seagrasses is a potential for increasing wave energy at the shoreline. Further losses of sand from the beaches will result from future sea level rise.

In undertaking their assessment, CES (2004) notes that 'The coastal reach in the vicinity of Hallett Cove was also included in the study area to investigate a strategy of possibly exploiting the predominant northerly sand transport processes to naturally supply sand to the downdrift metropolitan beaches whilst improving the beach amenity at Hallett Cove.'

The alongshore sediment transport potential was computed by CES (2004) based on 10 years of hindcast wave data and the results are presented here from that report as Figure 3.1. This computation is based on the existing conditions (2002) including such things as seagrass distribution, shoreline protection works and existing bathymetry. Further computations were also undertaken for the time periods of 100 years BP and 20 years, 50 years and 100 years into the future. This modelling incorporated known changes to the sea bed, seagrass distribution and protection works and for the future projections, the addition of sea level rise based on recent (at the time the report was prepared) CSIRO advice of 0.1m, 0.2m and 0.5m respectively. The historic and forward projections of potential sediment transport rates, result in minimal (local) changes to the overall sediment transport potential through the system over time.

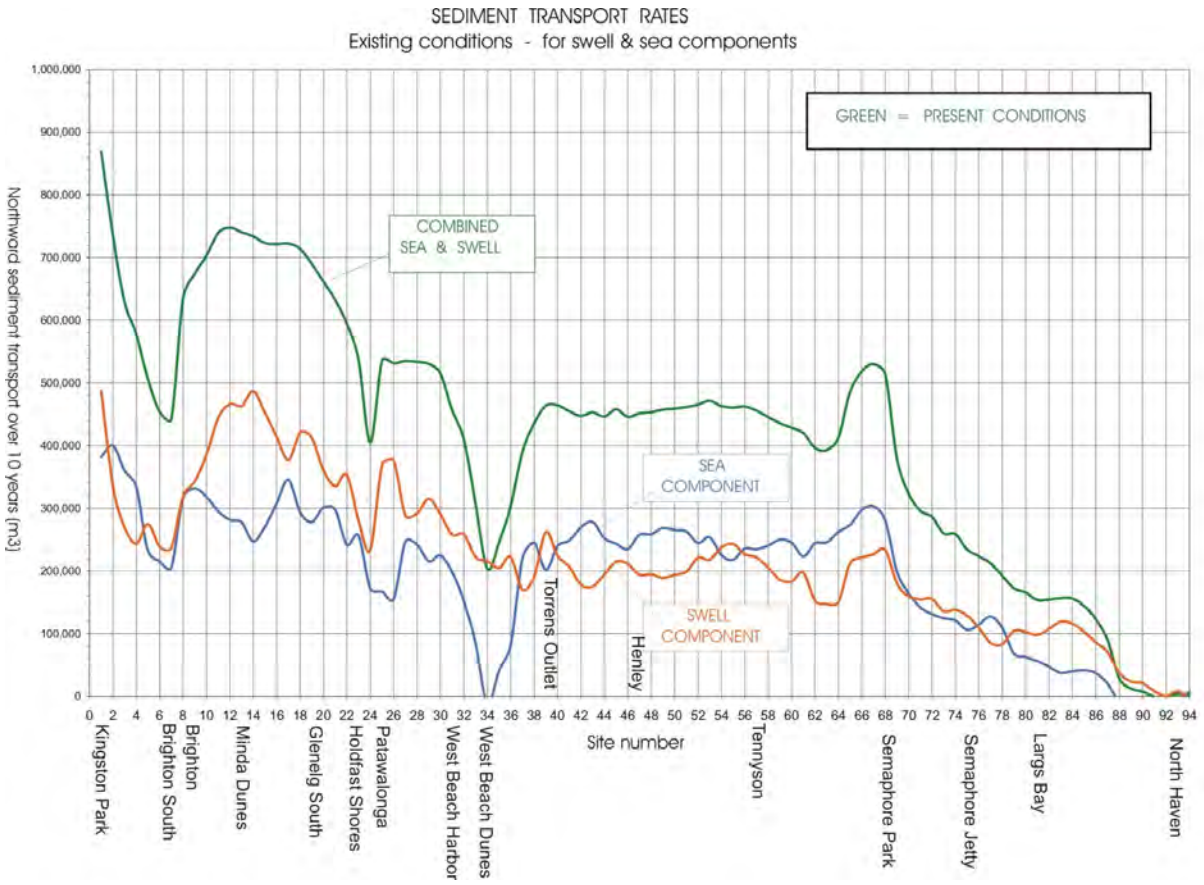

Figure 3.1: Modelled potential net northerly sand transport along the Adelaide metropolitan coast over 10 years. Reproduced from CES (2004), Figure 4

There are significant points to be drawn from this representation in Figure 3.1 that are relevant for the future management of Hallett Cove and which underpin the SA Government metropolitan beach strategy (DEH 2005). The modelling shows that on average the present-day sediment transport along the metropolitan coast is equally a result of ocean swells entering the Gulf and locally generated seas. At the southern end of the system, the sediment transport potential is slightly biased to the ocean swells. Through the system, the potential transport is diminishing to the north, resulting ultimately in deposition of the littoral drift material north of Semaphore Park. While the graph does not stretch south to include the Hallett Cove area, CES (2004) notes that 'There is a rapid diminishing in the sediment transport potential to 450,000 cubic metres (over the 10 years modelled) between Kingston Park and Brighton South.' This equates to a 50% reduction in the annual northerly net sediment transport potential from Kingston Park of around 90,000m^3/year to around 45,000m^3/year at South Brighton. They further note that little sand is supplied from the south, of the order of 5000m^3/year.

The CES (2004) report offers specific advice in relation to Hallett Cove and the concept of nourishing Hallett Cove Beach as part of the broader metropolitan beach management strategy. In effect, the proposal investigated was to return sand to Hallett Cove, changing what they describe as 'composed primarily of a shingle/cobble beach' to become a reservoir of sand, feeding the beaches to the north. Based on their numerical modelling of the overall beach system, CES (2004) advises as follows:

'The longshore sediment transport potential for a sandy beach at this location has been modelled and determined to be in excess of 100,000 cubic metres per year. This suggests that:

- Should a reservoir of sand be placed at Hallett Cove, longshore sediment transport processes would indeed feed the sand towards Adelaide's beaches.
- However, the placed sand would be quickly moved off the Hallett Cove feeder beach (at a rate of at least 100,000 cubic metres per year), and transported alongshore towards the southern metropolitan beaches.
- A significant quantity of sand would need to be placed in the Hallett Cove feeder beach so as to offer several years of sand reserves prior to having to re-charge the replenishment area. Alternatively an annual campaign of placing at least 100,000 cubic metres of sand into the Hallett Cove feeder beach would be necessary.
- Either way of beach nourishment at Hallett Cove would result in a transient beach at Hallett Cove and the end product before a new beach renourishment campaign would be a shingle beach for much of the foreshore. Beach nourishment at Hallett Cove should be considered if it is considerably cheaper to place sand there than at Brighton. However, if costs are similar for renourishment at both locations it is suggested that the sand should be placed at Brighton. Creating a temporary beach at Hallett Cove may raise the public expectation that there should be a beach there all of the time.
- The 100,000 cubic metres yearly rate of sand supply to the southern reaches of the Adelaide beach system is greater than the rate at which sand moves along those beaches. Consequently there would be a transient accumulation of sand at Kingston Park and Brighton South, at least until such time as the sand supply from Hallett Cove ceased. This accumulation would spill over on to the seagrass meadows and may suffocate them. In addition sand would be "lost" from the beach system because the seagrass would catch the sand.
- There is a risk that sand may be lost from the supply due to the steep nearshore seabed which exists between Hallett Cove and Kingston Park. Offshore sand movement during storms may take sand from this sediment pathway into deeper water, where it might no longer be re-mobilised and subsequently moved back onshore by ambient waves. There is no detailed bathymetry off Hallett Cove or for the foreshore between Hallett Cove and Kingston Park. The model SBEACH has been used with the limited bathymetric data which is available to model offshore sand movement during storms. The results imply that there would not be significant offshore sand losses – but this is a tentative conclusion because of the sparsity of the bathymetric data.'

This assessment effectively rules out the inclusion of the Hallett Cove Beach in the metropolitan strategy and the concept of massive nourishment of the cove to change the beach to a sandy beach embayment, similar to those found at Brighton and further north. Sand availability, the excess in potential sediment transport in relation to the remaining metropolitan beaches and the existing alongshore supply, together with the lack of a suitable nourishment source and cost considerations, all rule this option unlikely.

While the CES report advises a current alongshore supply rate to the metropolitan coastal system of around 5000m^3/year, it does not discuss the possibility or potential impact of that sand supply having been interrupted from time to time by construction works (dredging and beach protection) and other port and harbour works over the last 50 years. The estimates of the alongshore supply rate would appear to be based on measurements of sand build-up against the O'Sullivans Beach boat harbour. This is addressed further in section 4.1.

3.2 Tides

The Adelaide coast experiences a tidal range which varies from about 2.4m on spring tides to approximately 0m on neap tides (DEH 2005). Within the Gulf St Vincent, tidal currents along the east coast are aligned approximately north-south with speeds of up to 0.2 to 0.3m/s. At the surface or in shallow water these may also be affected by local wind conditions. A table showing the tidal constituents, reduced to both chart datum and Australian Height Datum (AHD), is reproduced here as Table 3.1. Chart datum is defined here as the Lowest Astronomical Tide (LAT) measured at the outer harbour in 1991, which is approximately 1.452m below AHD.

While these tidal currents have the potential to entrain and move bare sand on the sea bed which is stirred by waves, they do not contribute significantly to the alongshore sediment transport rates at the shoreline.

Table 3.1: Tide Levels for Outer Harbour, Adelaide
(Reproduced from CES 2004, Table 1.1)

Level	Chart Datum (m)	AHD (m)
Lowest astronomical tide	0.00	-1.45
Mean Sea Level	1.30	-0.15
Australian Height Datum	1.45	0.00
Mean High Water Neaps	1.30	-0.15
Mean High Water Springs	2.40	0.95

3.3 Winds

Coastal winds tend to be variable in strength, direction and duration. They are one of the key drivers of coastal processes, effectively modelling and shaping the coastline in a variety of ways.

Onshore winds are responsible for moving sand off the beach and blowing it inland at locations where there is a constant sand supply and wide beach (a dune blowout). This used to be quite common along the Adelaide metropolitan coast prior to European settlement and the stabilisation of the back beach sand by either development or vegetation. Where vegetation is maintained at the back of the beach, this wind-blown sand may be trapped building dunes, providing a buffer against future wave erosion during storms. These dunes are recognised as environmentally significant habitat and define the character of many of our beaches. In urban locations, concerted works to maintain the coastal vegetation and the dunes reduce the likelihood of further wind-blown sand losses and provide a temporary sand store to satisfy storm erosion.

Distant winds are responsible for generating large ocean swells with long wave periods (typically 8 to 18 seconds). These ocean swells contain enormous energy and may travel thousands of kilometres to reach and break on the coast. The energy from the winds stored in the swell wave is then responsible for erosion of the beach during elevated ocean levels and high swells, frequently associated with coastal storms. Low swells have the opposite effect and lengthy periods of regular waves of low steepness (height) tend to move sand onshore and towards the back of the beach, aiding beach recovery following storms. While the erosion during storms is rapid, the period of recovery in contrast can be very slow, taking weeks or even years.

Local winds generate sea waves which are usually short period waves (typically 2 to 6 seconds), steep but with lower wave heights than the more powerful swell. The size of the sea waves is limited by either the area of the available water over which the wind can blow (called fetch-limited waves) or by the water depth for very shallow water bodies (called depth-limited waves) within the water body over which the wind is blowing. For a semi-enclosed waterway such as the Gulf, seas reaching the eastern shore may be generated by winds blowing from all directions from south-east through west to north-west. Those seas approaching the shore from the north-west quadrant can cause sand movement along the metropolitan coast from north to south, unlike the swell waves which always cause sand to move south to north along this coast.

Onshore winds are also responsible for elevating water levels against the shoreline. This is called wind setup. The wind blows the surface water against the land and elevates the water level at the beach. This setup of the water surface is balanced by offshore currents, returning water offshore. Wind setup can add significantly to the ocean water levels at the beach during storms, permitting waves to travel further up the beach and erode the dunes.

DEH (2005) describes the predominant winds affecting the Adelaide coastline using a description by Culver (1970) as follows: 'There appears to be a relatively regular pattern evidenced each year. In January, February and March the predominant wind pattern is primarily south-west with some south-east and north-east wind. Late March and April shows a well distributed wind pattern (right round the compass). In May, north-west and south-west winds begin to show longer durations and higher velocities. This pattern continues into June and July often with stronger north-west winds predominating (with some north-east activity). West to south-west winds begin to blow stronger in August and continue into September with increasing velocities. The equinox is traditionally squally and the September–October period shows strong winds between the north-west and south-west quarters. The distribution in November is again well round the card but with longer duration west-south-west winds evident. In December, wind velocities are lower with south-west winds predominating with some north-east activity closely paralleling the January and February pattern.'

Detailed wind data over a 10-year period was used by CES (2004) to hindcast both the sea and swell conditions for the Adelaide coast using numerical models. This data formed the basis for their assessment of the sediment movement along the Adelaide coast, as discussed here in section 3.1.

3.4 Waves

3.4.1 Swell waves

Swell waves are long period ocean waves, generated in deep water by strong winds often at distances of many hundreds of kilometres from the shoreline where they eventually make landfall. For the Adelaide metropolitan coast, ocean swell waves are generated outside of the Gulf St Vincent in the southern ocean. They reach the west coast of the Fleurieu Peninsula after passing through the narrow wave window of Investigator Strait between Kangaroo Island and the Yorke Peninsula. Less significantly, they may approach through the Backstairs Passage on the eastern side of Kangaroo Island. These relatively narrow swell windows and subsequent wave transformation as the waves refract, diffract and attenuate due to bottom friction, result in considerable reduction in the wave heights as they approach the shoreline of Hallett Cove.

A detailed assessment of the prevailing swell wave conditions along the metropolitan coast is included in CES (2004) based on 10 years of wave hindcasting from 1993 to 2002. Ten years of ocean swell data was hindcast at a deepwater, offshore location and compared with several other model results as well as a brief record of wave buoy measurements off Kangaroo Island between 2000 and 2002. This 10-year period was chosen as it included the 1994 storm which was the most severe on record, with an estimated offshore wave height in excess of 11m.

The Adelaide's Living Beaches report advises that 'swell waves that propagate to the southern metropolitan beaches have 12-16 second periods, heights below 1 m and directions close to 260°'. (DEH 2005).

3.4.2 Sea waves

Sea waves are those waves generated by winds associated with local storms, in this case occurring within the Gulf St Vincent. They are generally of short wave period and quite steep, frequently with white caps as partial breaking occurs. They approach the shoreline from the direction of the wind. These sea waves generally contain less energy than the longer ocean swells and at the shoreline the impact of the two separate wave conditions is combined. Often they will be approaching from different directions resulting in a confused surf at the shore. Because of the consistent approach direction of the swells and their greater energy, the net resulting sediment movement under these combined waves will usually be from south to north along the coast.

A detailed assessment of the local sea wave along the metropolitan coast is included in CES (2004). This was based on hindcasting of wind data measured for the same 10-year period at Adelaide Airport (1993 to 2002). Sea conditions were assessed at 34 individual locations along the metropolitan coast to allow for the varying shoreline exposure and fetch lengths applicable. Individual results by location are not reported. The sea and swell wave climates derived by CES (2004) were then modelled at the shoreline, using wave transformation models to allow for the wave processes from deep water to the shoreline and used as input to drive the sediment transport modelling of the Adelaide metropolitan coast (see Section 3.1).

The Adelaide's Living Beaches report advises that 'Sea waves reaching the metropolitan beaches are mostly generated by west-south-west winds. Together with swell entering Gulf St Vincent through Investigator Strait and wave refraction, the resultant net wind-wave direction is northward. Strong wind-waves in Gulf St Vincent have been recorded with periods of 4–6 seconds, heights up to 2.6 m and directions ranging from 250º to 310º, depending on wind direction'. (DEH 2005).

3.5 Storm Surge

Storms can cause most damage to a beach or dune when they occur in conjunction with storm surges and high tides that elevate the water level above that which would otherwise occur. This allows waves to break directly on the beach and to erode the escarpment on the dune face at the back of the beach.

Storm surges are additional to the high tide level and are added to the maximum predicted tide. They may result from a combination of:

- barometric surge - low pressure systems elevate the ocean surface above the average level, commonly associated with intense low pressure systems such as tropical cyclones
- wind setup – winds blowing towards the shoreline will pile the water against the shoreline, until the wind subsides
- other causes such as coastally trapped waves, currents and temperature differences.

The storm surge components are not readily estimated as the different mechanisms may not occur in any single event. They are independent of the wave conditions. For design purposes, estimates of storm surge at a particular location are based where possible on historical occurrence, using water level measurements from a tide gauge or water level recorder located outside the surf zone. This allows a peak water level to be nominated for design purposes. DEH (2005) advises that 'storm surges of over 1.5 m have been measured in Adelaide, a significant size compared with the normal tidal cycle.'

In addition to the tides and storm surge during storms is the action of the waves themselves. While not included as a component of the storm surge, wave setup occurs at the beach inside the breaker zone and is often included in the community perception of surge. As waves break and convert their kinetic energy to potential energy, they elevate the water against the shoreline. Each individual wave as it breaks will then run up the beach slope to a level in excess of the ocean storm surge level. This wave runup is the dynamic component of the inundation process and can result in waves overtopping dunes or seawalls and causing inundation of the land behind.

DEH (2005) advises that for the Adelaide coast 'Storms surges are most pronounced if winds persist in a north-westerly to westerly direction. These winds force water into Gulf St Vincent, by deflection from Kangaroo Island, significantly raising water levels. This is called wind set-up.

'Most significant storms on the Adelaide coast occur during May and June, with approximately half as many occurring during July and August. The few major storms in spring and early summer are rare events. January, February and March are the calmest months and obviously the best months for coastal works.'

3.6 Bathymetric and Survey Data

The broad bathymetry of the Gulf St Vincent offshore area is presented on the Admiralty Charts. Aus 780 and AUS 781 include bathymetry of the Gulf St Vincent and eastern shoreline and nearshore from Port Adelaide to Backstairs Passage at a scale of 1:150,000.

In compiling the survey grids for their sediment transport assessment, CES (2004) also obtained and used detailed surveys for the metropolitan coastline from Kingston Park to Outer Harbour undertaken in 2002 by the Coastal Protection Branch of the Department of Environment and Heritage. These provide detail from the shoreline to about the 10m depth contour and are plotted at a scale of 1: 17,500. In synthesising the available survey data CES (2004) notes that 'the recent survey (completed in 2001 and presented at a scale of 1:17,500) did not overlap with the seabed depicted on the Admiralty Chart Aus 781 (presented at a scale of 1:75,000). Unfortunately the resolution of the nearshore data in Aus 781 is quite poor, consequently considerable estimation and manual "smoothing" of contours had to be undertaken to link these two survey data sources.'

The CES (2004) report also notes that there is limited detailed bathymetric survey available of the Adelaide metropolitan coast generally and of the Hallett Cove embayment in particular. They state that 'between Hallett Cove and Kingston Park … accurate bathymetry does not exist.'

Some long-term monitoring of shore-normal beach profiles is undertaken by the Coast Protection Board along the metropolitan coast. This includes high precision, repeat survey along two shore-normal lines through Hallett Cove. This data set was provided by DENR for this study. The locations of the survey profile lines within Hallett Cove are shown here as Figure 3.2 and the overlying profiles are graphed on Figure 3.3.

Survey profile 200041 (Figure 3.3) is along the alignment of the boundary fence along the southern side of the Conservation Area, adjacent to the north side of the Boatshed Café. The figure shows six overlying surveys from 1975 to 2007 that extend from the path, across the slope and beach into the water, a total profile length of 150m. The offshore extent of the survey is to a depth of approximately -1.5m AHD. The cross-section represents a time span of approximately 32 years. A number of observations can be drawn from this single cross-section:

- the location of the erosion escarpment at the back of the beach has not changed over the period of record from 1975 to 2007 (i.e. has not receded)
- the maximum change in level of the beach seaward of the erosion escarpment (approximate chainage 45m) is less than 0.5m
- in 1975 the back of the beach for a distance of 20m from the erosion escarpment was up to 0.5m higher than in 2007.
- Below mean sea level (0m AHD, approximate chainage 85) there is no discernible change in the level of the beach profiles for a distance of 65m offshore to a depth of -1.5m AHD.
- The total volume variation in the envelope of profiles between the erosion escarpment (approximate chainage 45) and the mean water mark (0m AHD, approximate chainage 85) is less than 20m^3/m.

Figure 3.2: Hallett Cove Survey Profile Locations. **Source**: SA Coast Protection Board

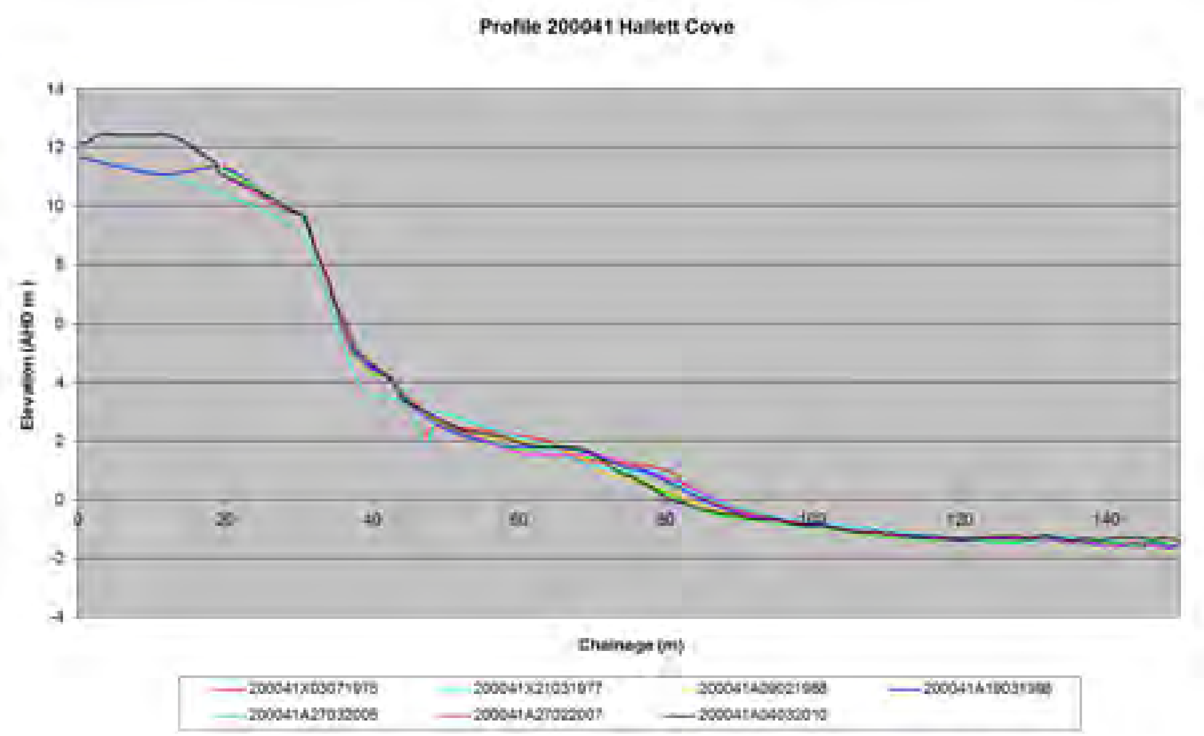

Figure 3.3: Hallett Cove Beach Profile #200041, adjacent to the Boatshed Café. Profiles shown from 1975 to 2010. **Source**: SA Coast Protection Board

While caution has to be placed on the interpretation of the beach response at a single location, the survey shows that at this location any changes to the level of the beach or the width of the beach are extremely small over a period of 30 years. Any additional sand cover on the beach above mean sea level in 1977 represented a very small volume and depth. The stability of the beach at this location can be attributed to the underlying bedrock/clay layer and the protective shingle layer that covers it. The slope of the beach from the base of the escarpment (chainage 45 at a level of approximately 3m AHD) to the base of the profile (chainage 150 at a level of -1.5m AHD) is approximately 1-in-23. The steepest section of the profile around mean sea level is approximately 1-in-10. At these steeper slopes, the shingle beach is very efficient in absorbing wave energy, limiting the frequency and extent of wave action reaching the back beach escarpment.

3.7 Climate Change Impacts

3.7.1 Current knowledge

The science of climate change is well known and documented over recent years. It has long been accepted in coastal management, policy and practice across Australia. Definitive information on all aspects of climate change is published within the most recent IPCC Fourth Assessment Report (AR4) released in 2007 (IPCC 2007) which is due for review in 2014.

The consideration of climate change and, in particular, sea level rise has been a fundamental component of coastal zone management in Australia since the early 1990s. In 1991 the South Australian Government recognised the future impacts of sea level rise in their Coastal Protection Board sea level rise policy which required future development to make an allowance for 0.3m of sea level rise to the year 2050. The policy also requires that the development of any future protection strategy must be capable by reasonably practical means, of being able to withstand a further 0.7m of sea level rise to the year 2100. This policy, which has informed coastal management in South Australia since that time, effectively removed the uncertainty of any sea level rise arguments from the decision-making process by the adoption of these sea level rise benchmarks. In the intervening 20 years the other Australian states have adopted similar policies with allowance for similar benchmark rises in sea level to 2050 and 2100.

At about the same time, the Institution of Engineers Australia, through their National Committee on Coastal and Ocean Engineering published in 1991 their *Guidelines for responding to the effects of climate change in coastal engineering design* (NCCOE 1991). These guidelines summarised the most recent science in relation to climate change generally and sea level rise in particular. They included a risk-based approach to the consideration of all aspects of potential climate change in coastal engineering design. They have been updated twice and are currently being revised to reflect the most recent information. The latest version of the guideline can be accessed from the Engineers Australia web site.

Other specific information on climate change and the likely impacts on the City of Marion and adjacent coastlines has been prepared recently for local government (e.g. AECOM 2009, Caton 2007)

In May 2011 the Local Government Association of South Australia published a detailed update of recent climate change science with specific application to South Australia. That review is available from their website (LGASA 2011) and includes a comprehensive reference list including new research published since the release of the IPCC AR4. In respect of future trends in sea level rise this report advises as follows:

'The AR4 projections for global sea level rise were between 0.20 and 0.59 m by 2090 – 2099 across the range of climate scenarios (IPCC 2007). These estimates included thermal expansion from oceans and freshwater contributions from glaciers, Greenland and Antarctica, but did not include uncertainties pertaining to changes in ice sheet flow. It has been estimated that if the West Antarctic Ice Sheet were to collapse (i.e. the currently grounded ice), sea levels could be expected to rise by between 4 – 6 m (Oppenheimer 1998). Research since AR4 suggests that there is a "considerable body of evidence now that points toward a sea level rise of 0.5 – 1.0 m by 2100" and that "sea level rise … towards 1.5 m cannot be ruled out" (Steffen 2009). There is certainly no credible research that predicts sea levels to be less than that predicted in the AR4 (Garnaut 2011).

'It should be noted that even moderate increases in sea level rise can result in extreme sea level events associated with high tides and storm surges to occur hundreds of times more frequently than they currently do. As an example, an event that now occurs once every 100 years could be expected to occur two or three times every year by the end of the century (Steffen 2009). In Australia more than 85% of the population lives in coastal regions and so the impacts of sea level rise may be significant (Garnaut 2011).'

The SA Government in their submission to the Commonwealth inquiry into climate change and the coast (Aust. Govt. 2009) states that 'The South Australian Government recognises the serious threat that climate change poses to South Australia, Australia and the world and is committed to engaging with all levels of government on climate change policy. The South Australia Government has a long-standing commitment to tackling climate change - through both mitigation and adaptation - as an essential part of its environmental sustainability agenda, documented in 'South Australia's Strategic Plan' and 'Tackling Climate Change: South Australia's Greenhouse Strategy'. Central to its efforts is the 'Climate Change and Greenhouse Emissions Reduction Act', introduced in July 2007.' (SA Govt. 2008).

In considering the climate change impacts on the coast they advise also that 'The likely impacts of climate change will increase the challenge of sustainable management of the coastal zone. Current coastal development patterns may be increasing coastal vulnerability to climate change. There is potential for considerable damage to low lying coastal settlements and infrastructure, affecting large and growing populations, tourism and capital investments, as well as sensitive ecosystems, such as mangroves, saltmarshes and sand dunes, from sea level rise, flooding, rising groundwater with increased salinity and erosion.' (SA Govt. 2008).

In the face of rising sea levels and other climate change implications, the submission advises the State Government's intent to revise development plans to, amongst other things, 'Allow for the sea level rise induced erosion of beaches and retreat of mangroves and saltmarshes.' Further, in respect of the protection of existing development the submission advises that 'investigations as to where and when protection works are required, and the subsequent design, assessment construction and maintenance of those works, has cost implications for present and future landowners, councils and State agencies.' (SA Govt. 2008).

3.7.2 The impact of sea level rise on beach recession

The effect of sea level rise on a natural sandy beach is to cause lowering of the beach profile and landward movement of the waterline and the erosion escarpment over time. Effectively the beach retreats landward, following each storm event. The difficulty is to establish now the rate at which this beach movement will occur in the future, given the uncertainties and assumptions. For an open coast sandy beach exposed to full ocean swells, there are various modelling techniques used to establish the likely extent of the erosion.

The most commonly applied is the Bruun rule (Bruun 1962). In its simplest form the Bruun rule relates the sea level rise to the slope of the active beach profile, extending from the onshore limit of wave action to the offshore limit of sediment movement. The key assumption underpinning the approach is that the beach profile is in equilibrium. This condition is clearly not applicable at Hallett Cove, with the profile constrained by the exposure of clay, shingle and rock in the active profile. Further, the material behind the beach is unknown. It is unlikely that the back beach area is comprised of unconsolidated sand, but rather is likely to be some combination of clay and rock with a sand cap. Further, the depth to bedrock is not known, the offshore bathymetry is not well defined and the local wave climate is derived. All of these are essential to the computations.

Other methods used rely on numerical modelling, such as SBEACH or more complex proprietary 3D models. These approaches are beyond the scope of this assessment and would require much more detailed information (including nearshore bathymetry and bedrock exposure) than is currently available to provide a reliable answer.

Typically on an exposed (open coast) sandy beach, the extent of shoreline relocation is estimated in the range of 50 to 100 times the sea level rise, equating to about 50m to 100m recession by 2100 for a 1m rise in sea level. For a constrained and sheltered beach such as Hallett Cove, the impact is likely to be significantly less as the shingle substrate limits the lowering of the profile and the back beach erosion during storm events. The available evidence shows that long-term recession of the beach due to other causes is occurring at very low or negligible rates over recent years. An alternative approach for coping with sea level rise may be to monitor the beach changes against an assumed benchmark rate to ascertain how quickly the back beach is retreating as sea level rises into the future.

It is likely that a conservative assumption for sea level rise recession would be an average recession rate of 25 times the sea level rise, or half what might be anticipated on a fully exposed sandy ocean beach. This would equate to approximately 10m to 2050 and 25m recession by 2100, assuming a sea level rise of 1m is attained. There are currently no major assets at risk in Hallett Cove located within 10m of the existing back beach escarpment. These assumed recession values can be applied to forward planning, with a view to reviewing the rates within 10 years based on annual survey profiles at selected locations and other relevant data.

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4. Project Site Impacts

4.1 Variability in Alongshore Sand Supply

4.1.1 The impact of Port Stanvac

Following the construction of the rock breakwater to provide sheltered berthing within Port Stanvac harbour, sediment movement alongshore from south to north under the prevailing swells was intercepted by the shore-normal rock wall constructed to provide a sheltered anchorage. Sand accreted on the south side of this wall until it would then start to bypass the breakwater, passing underneath the trestle jetty, and would again be pushed onshore by the waves. Here it preferentially settled out within the sheltered harbour area (See Plate 4-1).

Plate 4-1: Port Stanvac Refinery site showing the harbour infrastructure. Note the difference in the sand build-up south of the main breakwater and within the harbour, compared with the rock shelf to the north. **Photo source**: Google Earth image based on aerial photography 25 March 2010

The progradation of the beach within the harbour and the reduction in berthing depths necessitated maintenance dredging works from time to time. While the frequency and volumes of sand removed during these maintenance operations were not available for this study, we are informed that the dredged sand was placed to the north of the harbour on the rock shelf where it could continue under wave action alongshore to Hallett Cove and the metropolitan beaches beyond. This interrupted sand flow around the harbour since the early 1960s would have resulted in variable amounts of sand moving towards Hallett Cove, rather than a slow, quasi-steady supply that is likely to have occurred prior to the works being installed. However, it is not likely to have resulted in a significant net loss of sand from the Hallett Cove beach system. There is a possibility that sand was also diverted offshore from time to time in moving around the rock breakwater, thus being lost from the littoral system to deeper water. However, there are no records or detailed survey information available to support such an assertion.

Since the closure of the port operations around 2003, it has not been possible to establish whether any maintenance dredging of the site has continued under the existing interim management arrangements. However, it appears this is unlikely. The aerial photo (Plate 4-1) and photo from O'Sullivans Beach boat ramp (Plate 4-2) show a substantial sand build-up on the rock shelf to the south, on the southern side of the breakwater and within the Port Stanvac harbour. In contrast, there is very little visible sand along the rock shelf and shoreline north of the harbour (Plate 4-1).

It is likely that the harbour has been a total barrier to alongshore sand movement to the north since that time.

Plate 4-2: Port Stanvac from O'Sullivans Beach boat ramp showing sand accretion on the southern side of the harbour. **Photo***:* Coastal Environment 28 April 2011

4.1.2 The impact of the O'Sullivans Beach boat ramp

The O'Sullivans Beach boat ramp was constructed around 1983, just north of the Christies Beach sewage treatment plant off Galloways Road. The main (southern) rock wall extends offshore a distance of approximately 250m from the back of the beach.

The ramp underwent major refurbishment in 2000 and is now the major recreational boat launching facility south of Adelaide. It is heavily used by the recreational boating community, including local residents, regional visitors and tourists, and is also utilised by the SA Sea Rescue Squadron for the launching of emergency vessels.

The South Australian Department of Transport is responsible for the facility and undertakes maintenance dredging from time to time. Detailed records of the dredging volumes and frequency were not available. Anecdotal evidence suggests that dredging is undertaken about every five years, with a volume of approximately 5000m^3 transferred across the harbour and deposited on the rock shelf to the north of the harbour. From here it continues northward along the coast under wave action to Port Stanvac.

Plate 4-3: O'Sullivans Beach boat harbour and ramp. The construction of the rock harbour walls has intercepted the alongshore sand movement, with accretion to the south and within the harbour. The beach to the north of the harbour is comparatively depleted of sand. **Photo source**: Google Earth image based on aerial photography 25 March 2010

4.1.3 Other changes to alongshore sand supply

Since European settlement there have been many activities undertaken on the foreshore that could have affected the alongshore movement of sand in minor ways, but that are not well documented or quantifiable. However, the cumulative impact of these activities is invariably a reduction in the net alongshore transport rate. For example, such things as river entrance dredging and/or training, changes to river flow regimes, small scale sand removal for one-off projects or maintenance, protection of back beach areas effectively locking up the sand stored in the dune system, can all have short-term or ongoing impact on the sediment balance at any location downdrift.

To the south at Christies Beach, the Onkaparinga Council has addressed issues arising from erosion of the back beach and the subsequent threat to the road and development behind the beach through construction of rock protection works at the back of the beach. They extend approximately 1.5km south from the sewage treatment works, protecting The Esplanade from Gulfview Road in the north to Anderson Avenue in the south. While the beach adjacent to the seawall remains sandy, the high water mark along much of the beach is against the toe of the protection works. A short geotextile container groyne has been constructed near the surf club at the end of Ferris Street, but appears to have had little effect on the alongshore sand movement.

Plate 4-4: View south from O'Sullivans Beach boat ramp showing the sand build-up. The rock protection along Christies Beach and Witton Bluff can be seen in the background. **Photo***:* Coastal Environment 28 April 2011

The City of Onkaparinga is currently finalising a detailed study of management options to secure infrastructure located towards the southern end of the beach around Witton Bluff. The report will include detailed design for a further seawall. The studies, which are being undertaken by CES Pty Ltd for Council, are not yet completed and the information arising from them is not available at this time. It is likely that the report will also incorporate recommendations relating to the management of the sand reserves on the beach.

Prior to developing the Adelaide's Living Beaches Strategy (DEH 2005), the SA Government through the Coast Protection Board had been augmenting nourishment of the metropolitan coast north of Marino Rocks to Glenelg utilising sand trucked from both Mount Compass (onshore) and Port Stanvac (marine) over many years from 1974 to 2000. Additional sand was extracted by dredge from deep water off Port Stanvac during the 1991, 1994, 1995-96 and 1997-98 campaigns. The volumes (in situ) removed during these dredging campaigns totalled approximately 1.15 million cubic metres. DENR advises that this sand was dredged from well outside the littoral zone, in water depths around 15m, and would not have impacted the alongshore sand movement to and past Port Stanvac.

Table 4.1: Sand volumes trucked to the Adelaide metropolitan coast from south of Hallett Cove between 1974 and 2000. **Source**: SA Department of Environment and Natural Resources

Financial Year	Source	Volume m^3 (in situ)
1974/75	Port Stanvac	2,073
1975/76	Port Stanvac	2,216
1975/76	Port Stanvac	3,730
1975/76	Port Stanvac	2,546
1976/77	Port Stanvac	3,634
1977/78	Port Stanvac	8,625
1978/79	Port Stanvac	4,379
1979/80	Port Stanvac	3,750
1980/81	Port Stanvac	11,057
1980/81	Port Noarlunga	990
1981/82	Port Stanvac	11,227
1982/83	Port Stanvac	14,248
1983/84	Port Stanvac	36,480
1984/85	Port Stanvac	2,000
1985/86	Port Stanvac	14,998
1985/86	Port Stanvac	6,543
1995/96	Port Stanvac	10,000
1996/97	Port Stanvac	7,000
1998/99	Port Stanvac	7,000
1999/2000	Port Stanvac	7,000
Total		**159,496**

However, additional sand was also removed on a regular basis from adjacent to the breakwater and within the harbour at Port Stanvac and trucked to the metropolitan beaches. While relatively smaller volumes than the dredging, this sand was removed adjacent to the shoreline from within the active littoral zone. The effect of this sand carting would have been to reduce the build-up of sand at Port Stanvac and, presumably, the volume of maintenance dredging passed across Port Stanvac and into the littoral zone feeding the alongshore supply to Hallet Cove and the metropolitan beaches beyond. In 1980 a small volume was also removed from Port Noarlunga and trucked north; the precise location that this sand was sourced from is not indicated.

These individual sand removals (excluding dredging) as shown on the DENR records are presented in Table 4.1 and total approximately 160,000m^3 over 25 years.

Over the 25 years of the trucking operation the sand volume removed averages approximately 6500m^3/year which is approximately the estimated alongshore supply rate to the metropolitan coastal system of around 5000m^3/year advised by CES (2004).

Since the cessation of the trucking and following the apparent absence of any maintenance dredging since the closure of Port Stanvac in 2003, it is likely that limited sand has bypassed the Port Stanvac works since 2000. DENR staff advise that recent inspections of the Port area indicate the harbour and nearshore areas are filled with sediment and that it is likely that near full bypassing of the facility has once again commenced under natural wave conditions with no obvious offshore sand loss. This means that the effective alongshore sand supply from the south to Hallett Cove and the metropolitan beaches further to the north is not currently interrupted by the Port.

4.1.4 The concept of sand rights

Prior to the European settlement of the Adelaide coast, sand was able to move uninhibited along the eastern shoreline of Gulf St Vincent and through the Adelaide metropolitan area to the northern end of the gulf. This process has continued largely uninterrupted since sea level reached its present stillstand approximately 6000 years BP to at least the early 1900s. Subsequent construction of development and assets along the shoreline resulted in a need to protect those assets as sand supplies depleted and the shoreline continued to retreat, a natural process along an evolving coastline. This protection locked up sand reserves in the now developed dune systems that would previously have fed the alongshore littoral transport demand following storm events. The erosion pressures were effectively passed downdrift with a decrease in sand supply to the north. This interruption to the littoral supply may have been further accentuated through works done to reduce peak flows in the rivers through dam construction and to stabilise their entrances, in some locations potentially reducing the supply of sand from the rivers to the coast. Other works were constructed to facilitate access to the coast and often included dredging works for navigation, entrance training works, construction of harbours sheltered by shore-normal breakwaters, jetties and boat ramps, all of which intersected the active littoral zone. Other works specifically designed to enhance the beach width and improve recreational amenity such as groynes across the beach constructed of rock, timber or geotextiles, and beach nourishment projects, further complicate the issue.

With coastal protection works constructed to defend a receding coastline and with commercial and recreational enhancement projects that intersect alongshore sand supply, it has been increasingly recognised that some legal status needs to be afforded to the body of sand which constitutes the beach. In many parts of the world this has led to the development of the concept of 'sand rights' on a littoral drift coastline. This sand needs to be recognised as transitory and, in the same way that water in a river is recognised as communal property, does not belong solely to the property or local community landward of the beach on which it temporarily resides. This concept has resulted in litigation in certain locations, notably in California, where removal of sand for nourishment of an adjacent area of beach or the construction of structures such as groynes to retain sand on the beach at a particular location, were seen to be to the detriment of the downdrift areas, which may suffer additional beach recession and storm damage.

The issue is complex, as many of the decisions made that affect the natural movement of sand along the coast were taken many years ago and, frequently, in the common interest without full appreciation of longer-term impacts elsewhere. It is not reasonable or logical to try and redress these decisions or to remove the potentially responsible works or activities. Rather, it is important that the value of sand on the beach is more clearly recognised by all stakeholders as a community asset. Responsible decision-makers need to be accountable for their decisions that have the potential to alter the movement of sand from their location to another point downdrift. These decisions need to identify such potential impacts and to fully inform those communities likely to be affected. Likewise, coastal managers and communities need to be aware of proposals updrift that may be outside their local area of control but that have the potential to alter their supply of sand along the coast. Equally, they have a duty to express their position and to ensure the relevant decision-maker is aware of any potential impacts. Such changes can be expensive to remedy and may not become apparent for many years. These issues are likely to occur more often as sea level rises and protection and adaptation strategies are devised and employed.

4.2 Foreshore Management Sections

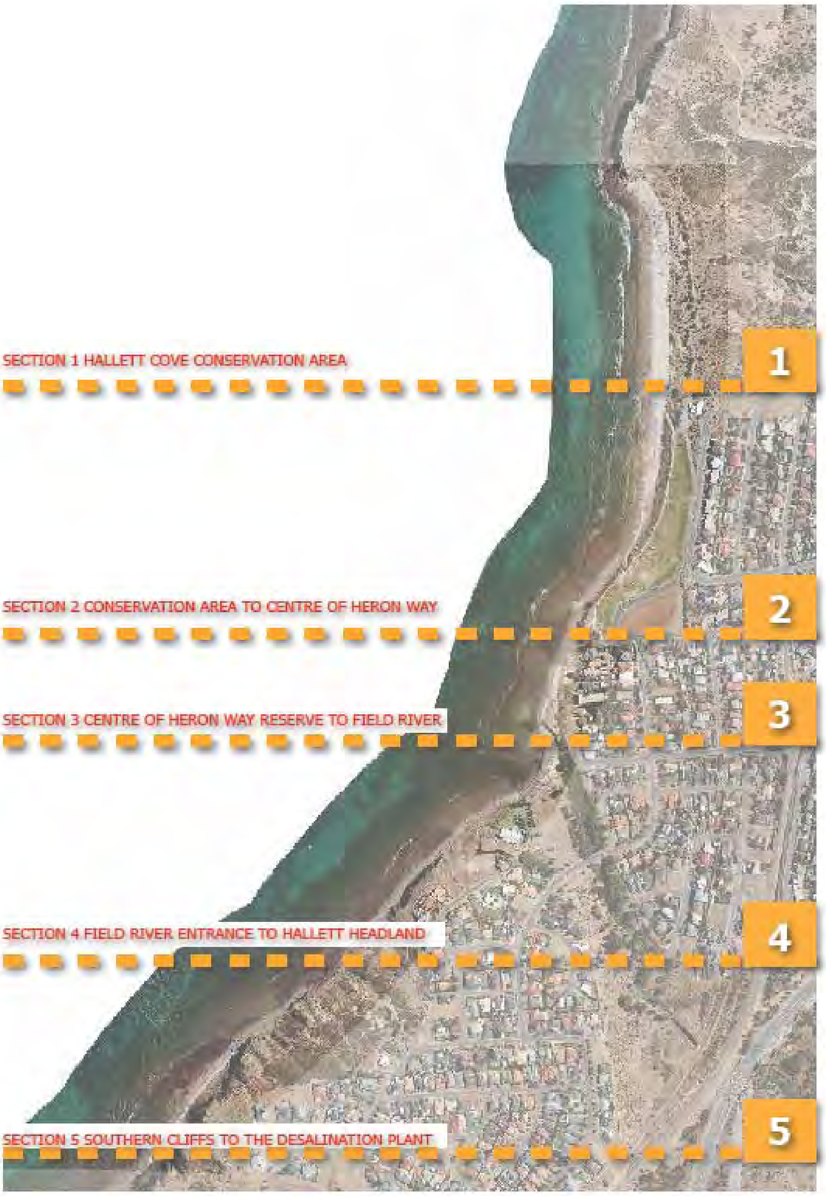

Plate 4-5: The study area has been divided into five sub-areas as described in the following sections.

4.2.1 Section 1 - Hallett Cove Conservation Area

Beach Section 1 extends approximately 400m south from Black Cliffs to the southern boundary of the conservation area at the Boatshed Café. This beach section is underlain by glacial clay and till deposits which extend from the back of the beach offshore to below the low tide limit. The beach is backed by a single low dune which increases in height towards the south.

There is a visible erosion escarpment along the dune face, presumably eroded by waves from time to time when ocean levels are high. The semi-circular low area behind this dune comprises the amphitheatre and includes the sugarloaf. The back beach area was once grazed and almost denuded of vegetation, while the frontal dune was covered with beach shacks. It is now cared for by community volunteers who have revegetated the area, established a series of walkways and signposts highlighting features of cultural and environmental significance. The geology and flora of the area are world-renowned and represent one of the key conservation and tourist attractions within the City of Marion.

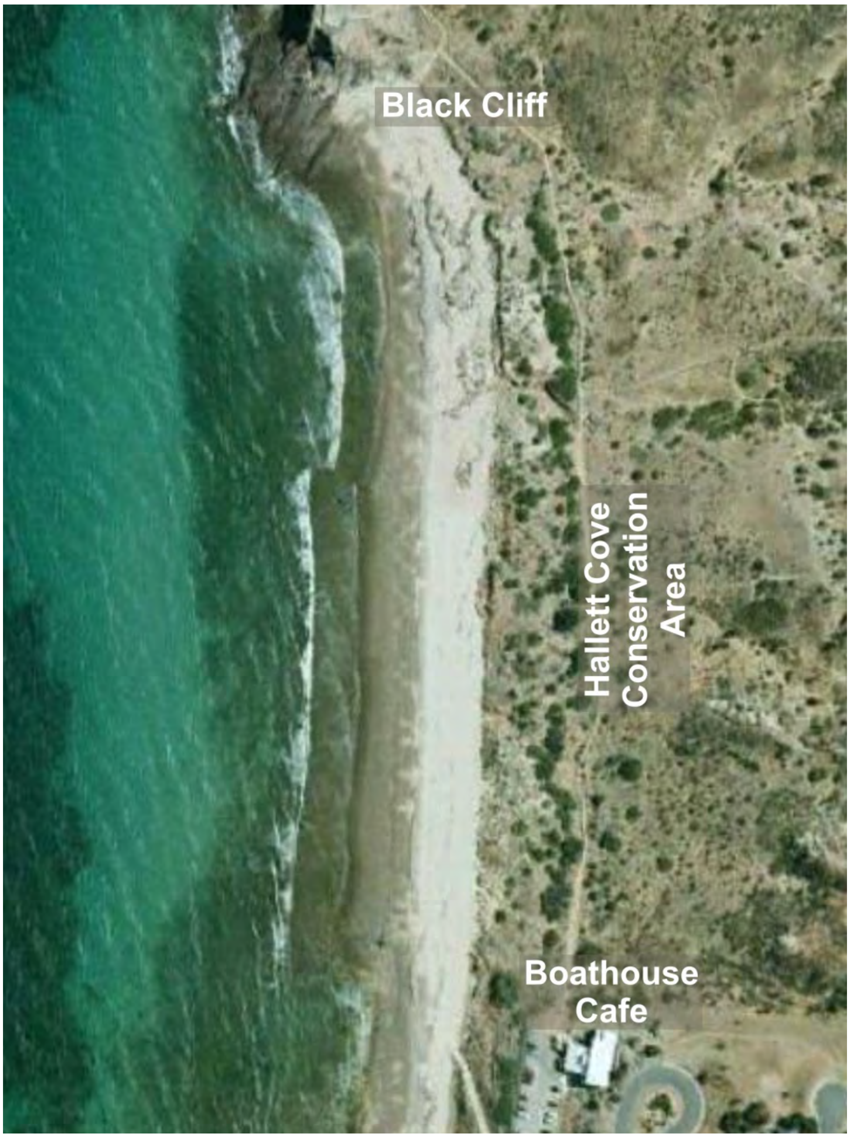

Plate 4-6: Section 1 Hallett Cove Conservation Area. This northern section of the beach extends approximately 400m south from Black Cliff to the southern boundary of the Hallett Cove Conservation Area. **Photo source**: Google Earth image based on aerial photography 25 March 2010

The beach level appears relatively stable over time, although at present there is less sand cover across the shingle beach above high tide than appeared to be the case in the early 1960s. This section of the beach tends to have some sand cover when the beach to the south is denuded and traps the last of the sub-aerial sand before it is eroded by waves to move around Black Cliff to the north during storms.

The back beach escarpment location appears stable, based on the available limited survey information and vertical photography. Erosion of the front of the dune can and does still occur during storm events. At present this periodic erosion is managed and rehabilitated by the community volunteers.

There are no high value developed assets (buildings, stormwater or sewerage) located in close proximity to the back of the dunes and the risk of serious damage during storms is low at present. Using the allowance for sea level rise recession recommended in Section 3.7.2, recession of the foredune by 25m to 2100 would still leave room for establishment of a dune between the beach and the existing shore-parallel access track nearest to the beach.

4.2.2 Section 2 - conservation area to centre of Heron Way Reserve

Beach Section 2 extends approximately 300m south from the boundary of the conservation area to approximately the location of the disused boat ramp near the end of Dutchman Drive. At the northern end, adjacent to the southern boundary of the conservation area, the foredune is high (approximately 10m AHD). The car park and Boatshed Café are located landward of the crest and there is a steep embankment from the dune crest to the beach at a slope of approximately 1V to 3H. At the base of the slope, erosion of the lower bank has left a vertical and unstable slope along sections of the beachfront to the south.

Plate 4-7: Section 2 Conservation Area to centre of Heron Way Reserve. This section of the beach extends approximately 300m south from the southern boundary of the Hallett Cove Conservation Area to the boat ramp seaward of the Dutchman Drive roundabout. **Photo source**: Google Earth image based on aerial photography 25 March 2010

At the southern end of the car park, a concrete access path to the beach runs across the dune face at an angle to the north. From the top of the bank, a concrete pedestrian path extends to the south along the embankment crest to the disused boat ramp approximately 250m to the south. This path forms the seaward edge of the Heron Way Reserve. Seats, play equipment and shelter sheds are adjacent to the path.

The beach narrows to the south as the back beach curves further seaward. The slope of the embankment to the beach becomes steeper and at the southern end (adjacent to the ramp) the slope of the embankment is approximately 1V to 1.5H. This steep section of the slope has been reinforced with rock armour to try and stabilise the slope.

Applying the allowance for sea level rise recession recommended in Section 3.7.2, recession of the foredune by 25m to 2100 would impact assets and facilities behind the beach. At the northern end the access to the beach and the car park would be removed. The Boathouse Café would be at risk. Along Heron Way Reserve, the steep embankment would continue to realign with each major storm, initially undermining the access pathway along the dune crest, and ultimately eroding back into the reserve. At the southern end the disused boat ramp would be lost and the existing rock protection works to the embankment could be expected to fail.

4.2.3 Section 3 - centre of Heron Way Reserve to the Field River entrance

Beach Section 3 extends south from the disused boat ramp in Heron Way Reserve (now converted to provide pedestrian access via stairs to the beach) for a distance of approximately 400m, to the St Vincent Avenue corner with River Parade on the northern side of the Field River, just upstream of the entrance.

Plate 4-8: Section 3 Centre of Heron Way Reserve to the Field River entrance. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Along this section, the beach is very narrow and the back beach protrudes seaward, protected in part by the exposed shingle and rock across the beach and in the swash zone. From the boat ramp, the dune height decreases to the south. The embankment slope remains very steep and erosion at the base has resulted in an unstable slope along this frontage. At Grand Central Drive, the foredune is significantly lower, reverting to a narrow and low sandy dune cap. The foreshore path ends at this location with access provided to the beach. The low dune continues to the south, reducing in height and width until the Field River entrance.

This section of the foreshore is the most heavily developed section of the Hallett Cove foreshore, with development and infrastructure located in close proximity to the beach. Within Heron Way Reserve to the south of the boat ramp there is a stormwater outlet with a gross pollutant trap buried behind the beach embankment. The outlet to the beach is via a low, concrete headwall which has rock protection. The concrete pedestrian path extends along the top of the foreshore embankment to Grand Central Drive at the southern end of the reserve. South of this location the foreshore is subdivided for residential development. There are 12 beachfront properties facing the beach, separated from the beach by the low sand dune. The southern six properties are also landward of River Parade which runs parallel to the beach. Sewerage infrastructure is located on the seaward side of the properties.

Applying the allowance for sea level rise recession recommended in Section 3.7.2, recession of the foredune by 25m to 2100 would impact assets, facilities and the 12 residential properties behind the beach. At the northern end the access ramp to the beach and stormwater outfall and GPT would be removed. The steep embankment would continue to realign with each major storm, initially undermining the access pathway along the dune crest, and ultimately eroding back into the reserve. South of Grand Central Avenue, the front row of residences behind the beach would be at risk, sewerage services may be compromised and River Parade undermined.

4.2.4 Section 4 - Field River Entrance to Hallett Headland

Beach Section 4 extends south from the Field River entrance approximately 300m to the cliff top and the first residential development on the seaward side of Albatross Walk. It includes the sand spit adjacent to the south side of the Field River entrance and the low subdivision north of Beachfront Crescent. The deeper water section known as the boat channel does not appear to be a natural feature, possibly formed in response to the removal of a section of the shingle layer at some time in the past, allowing the underlying clay to erode. It is visible on the earliest photographs. As a consequence, during storms waves at this location do not break on the shingle banks but run up the channel, causing erosion of the dune and the underlying clay layer on which it is situated. Over many years this has resulted in erosion of the back beach causing a small embayment south of the entrance.

There is a concrete boat ramp across the rock on the south side of this boat channel. Further to the south, the back beach area rises rapidly to Hallett Headland. Bedrock is clearly exposed on the beach and in the back beach south of the boat ramp forming a near-vertical cliff along the seaward face of the headland and effectively protecting it from short-term wave erosion.

Plate 4-9: Section 4 Field River entrance to Hallett Headland. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Applying the allowance for sea level rise recession recommended in Section 3.7.2, recession of the foredune by 25m to 2100 would result in the loss of most of the sand dune and spit on the south side of the Field River. Erosion would impact the seaward portion of three currently vacant lots in the undeveloped Beachfront Crescent subdivision. To the north of the boat ramp, the existing dwelling on the lower margin of Hallett Headland is well elevated and appears to be protected by bedrock. It is unlikely to be affected. The headland trail to Albatross Walk is well back from the cliff edge and would not be affected.

4.2.5 Section 5 - southern cliffs to the desalination plant

Beach Section 5 is the Hallet Headland, south from the first residential development on Albatross Walk to the desalination plant boundary, a distance of approximately 1100m. This includes the Hallett Headland Reserve, located along the headland behind the cliff line and seaward of any residential development. The top of the cliff line is approximately 30m AHD along this section. The closest development and subdivision along Albatross Walk is more than 20m from the cliff line. Further to the south all existing development is more than 50m from the cliff line. The walking path follows the cliff line and for the most part is more than 10m from the cliff edge. At several locations, stormwater discharges to deep gullies which discharge across the cliffs.

Plate 4-10: Section 5 Hallett Headland, Albatross Walk to the desalination plant boundary. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Given the cliff elevation, sea level rise is not an issue and is unlikely to impact significantly on this section of the coast. By 2100, it is likely the wave cut platform below the cliff will be inundated more frequently, allowing wave action directly against the base of the cliffs. Routine monitoring of the cliff condition and stability (in particular the discharge of stormwater) should be undertaken.

5. CONSULTATION

5.1 COMMUNITY CONSULTATION

Community consultation has been an integral part of this assessment since the project commenced in April 2011. This consultation was detailed in Section 1 and included:

- meetings with individual residents/groups.
- meetings with key stakeholder groups including:
  - Friends of the Lower Field River, and
  - Friends of the Hallett Cove Conservation Park
- community questionnaire.

A copy of the community questionnaire is included in Appendix A, together with a summary of the key outcomes.

5.2 INTERNAL CONSULTATION

Internal consultation was undertaken within The City of Marion. The purpose of this was to familiarise the consultants with the work currently in progress within Council, providing an opportunity for exchange of information. It also provided the opportunity to access data and information held within the various divisions of Council that were relevant to the project and to identify individual requirements and issues. This consultation included:

- internal meetings with Council staff from various Departments
- meetings with elected representatives
- briefing to the City of Marion, Elected Members Forum.

5.3 EXTERNAL CONSULTATION

As appropriate, meetings were arranged with state government and adjacent local government representatives to access relevant information and data, to familiarise the consultant with current works in progress and to provide an opportunity for exchange of information. This consultation included:

- meetings with Department of Environment and Natural Resources coastal staff
- meeting with City of Onkaparinga coastal project staff
- liaison with local Aboriginal heritage representatives.

5.4 Consultation Findings

The main use identified for public lands along the Hallett Cove foreshore was for passive recreation purposes, including walking coastal trails, walking on the beach and recreation/playing on the beach.

The key issues arising from the community consultation are summarised in Appendix A. These include in order of priority (based on the number of responses):

- lack of sand on the beach
- additional reserve/redevelopment facilities
- coastal walking trails and linkages
- erosion of dunes at Field River entrance
- erosion of the dune face along the beach in general/asbestos management

5.5 Issues and Opportunities

5.5.1 Lack of sand on the beach

The perceived reduction in the sand quantity on the beach is discussed in some detail throughout this report. While the community perception that the sand cover has reduced over the past 30 years may be true, the likelihood is that over historical times the volume of sand on the beach has always been small and variable, providing a thin sand veneer from time to time over sections of the exposed shingle.

The beach has always been a difficult place for traditional surfing activities due to the preponderance of rock within the surf zone and the exposure of the clay and shingle from time to time. The Surf Life Saving Association of Australia gives the Hallett Cove beach a general beach hazard rating of 5, which is described as moderately hazardous. They note that the beach is a 'narrow high tide sand beach fronted by an intertidal gravel rock flat.' They comment further that the beach 'while sandy at high tide is predominantly rock flats and boulders at low tide.' They go on to caution users to carefully choose their time and location for swimming (high tide) and further, that it is not a popular place for surfing due to the dominance of rocks.

The sediment transport processes operating along Hallett Cove are capable of transporting sand volumes significantly in excess of those that are supplied to the beach, and the addition of sand to the beach, even in large quantities, is likely to provide only a temporary improvement. Sand sources are difficult to locate and those that have been identified are expensive. For example, dredging of sand from a nearby source and placement on the beach (if a source could be secured) would cost around $\$15/m^3$. The CES (2004) report advises that the potential for sand transport away from Hallett Cove is estimated on average at $100{,}000 m^3$/year. This would give an annual cost to maintain sand on the beach at around $1.5 million per annum. DENR advises that a recent quote for sand purchased from Mount Compass and trucked to a nearby beach is around $\$50/m^3$, giving an annual cost of around $5 million to maintain a sandy beach.

Hallett Cove is a receding beach and the changes observed over recent years are consistent with that assessment. It is not likely to become a sandy beach similar to the metropolitan beaches to the north. While irregular opportunities to return sand to the beach or to re-establish the alongshore sand supply from the south should be pursued as and when they arise, the likely future of the beach is that it will remain similar to the current condition. With the scenario of rising sea level the current low rate of recession of the back beach will increase with time.

The beach in its current state provides opportunities that should not be overlooked. The unique geology and natural heritage of the area are part of the reason the shingle exists on the beach. This provides a beach experience that is unique and different from the nearby sandy coastal compartments. The survey results indicate that the local community is participating in the passive recreation opportunities the beach and foreshore currently provide and this should not be undervalued.

The existence of the bedrock/clay substrate provides protection to the back beach area which does not exist at adjacent sandy beaches without extensive artificial protection works. This will assist in slowing the changes to the beach arising from climate change into the future and limit the landward movement of the beach over time. While there will be a need to address issues arising from sea level rise at particular locations, these will be more easily managed than at many other locations.

5.5.2 Additional reserve/development facilities

While the provision of additional facilities within the various reserves within the study area is not directly a component of this study, the community response in this regard has been noted in the review of the consultation and questionnaires. The enthusiasm for the use of the various reserves for passive recreation, particularly by local residents and families, will support opportunities to further develop these facilities.

Through a separate process, the City of Marion is currently preparing a Master Plan for the Heron Way Reserve that will address many of these concerns in that area. This assessment will inform that process, specifically in relation to the likely hazards and impacts on the reserve from future sea level rise. The questionnaire findings have been discussed with and provided to the relevant Council staff.

Council has recently appointed a consultant to prepare a full audit of the Coastal Walking Trail. This includes looking at the design (and re-design), structure and ongoing maintenance required throughout. Again, the concerns and interest expressed through the consultation process have been provided to the consultant undertaking that work and those concerns will be addressed within that process.

5.5.3 Coastal walking trails and linkages

As outlined in Section 5.5.2 above, the high priority and concerns raised with the linkages relating specifically to the Coastal Walking Trail have been provided to the consultant currently undertaking that review.

5.5.4 Erosion of dunes at Field River entrance

The erosion of the foredune at the Field River entrance is a difficult issue. The remnant dune cap on the south side of the entrance is overlying a clay substrate at a high level. There is very little sand volume remaining within this dune cap and no identifiable source of sand that will naturally replenish this dune. The dune is subject to erosion by river flows during floods and by wave attack along the seaward margin. This wave erosion is exacerbated by the deeper water within the boat channel that allows the waves to reach further up the beach and with greater force than at adjacent locations where the intact shingle banks may dissipate the wave energy.

When eroded by waves, the clay layer is removed and has in the past resulted in the formation of caves into the clay at the back of the beach under the dune cap. These are a risk to public safety and have previously been collapsed by Council to address this risk, further eroding the dune face.

In 2004, City of Marion undertook protection works to limit the erosion by the placement of imported armour stone at the back of the beach. While unpopular, these works have limited the erosion of the dune face, albeit at the cost of adding large stone to the back of the beach. Without this protection work it is likely that the dune would be completely undermined. Erosion pressure on this fragile dune will increase with rising sea level and additional protection may be warranted to maintain the fragile remnant dune in the future.

Various proposals have been brought forward for construction of a reef in the boat channel to limit the wave height and wave approach to the back beach. Construction of a ‘low cost’ structure using, for example, used car tyres is not appropriate. The location is a dynamic environment and would experience high wave energy at times. It is difficult to anchor lightweight units and the risks proposed by such a structure would outweigh any potential benefits. If a reef was to be considered it should be a properly engineered structure which would come at a considerable cost. The width of the boat channel is approximately 30m and a structure of this length would be required. Depending on the final design, location and materials, typical construction costs would vary from $10,000/metre length to as much as $50,000/metre length, giving a minimal likely cost in excess of $300,000.

Nourishment is not an option at this location alone as sand placed on the beach seaward of the dune would simply be eroded with each storm. A similar problem will be experienced on the northern side of the river entrance where the remnant dune fronting the southernmost properties has recently been eroded. The relatively low height of the remaining dune cap and the properties behind, together with an anticipated sea level rise, will require protection of this area in the future if the residential property is to be retained.

5.5.5 Erosion of dunes along the beach in general/asbestos management

Hallett Cove Beach is receding at present and this is likely to be exacerbated by climate change and sea level rise in the foreseeable future. This erosion, which occurs at the toe of the dune slope at the back of the beach, destabilises the slope causing slippage of the steeper sections of the slope which, along much of the beach fronting Heron Way Reserve, is around 8m high (11m AHD). The material behind the dune is of unknown composition as the area was re-contoured during the subdivision of the area in the 1970s. At that time the shack development along the foredune was demolished and some of the debris (including some asbestos product) was buried in the top layer above the escarpment and possibly pushed over the escarpment to establish the new seaward slope. As the slope has been eroded in the past, some of this asbestos material has been disturbed and exposed by the slippage of the slope.

The City of Marion commissioned a report to look at the issues and to provide guidelines as to how it should be handled (Coffey 2007). The report advises that the quantities of asbestos exposed are small and do not pose a risk to public health. They put forward procedures to be followed when/if more asbestos is exposed by recession of the escarpment in the future.

The ongoing erosion of the base of the escarpment and the destabilisation of the slope will be an ongoing issue during future storm events and will need to be managed.

6. Management Options

In developing a management strategy for the shoreline now and into the future, it is essential that the adopted strategy fully considers the current state of the beach, the future aspirations of the surrounding community and the fundamental cost and practicality implications of constructing and maintaining the preferred strategy into the future.

6.1 Physical Attributes Affecting the Beach Management Strategy

The fundamental physical attributes of Hallett Cove that influence the suitability of various management strategies include:

- There is very little development or significant infrastructure located close to the back of the beach and at risk from erosion/recession in the short term.
- Hallett Cove beach is receding and probably has been since the end of the Holocene sea level transgression and reduction/cessation of the onshore supply of sand from the bed of the St Vincent Gulf some 6000 years BP.
- The local alignment of the coastline in the study area and the obliquity of the predominant Southern Ocean swells between Yorke Peninsula and Kangaroo Island result in a high potential transport rate for beach size sand through the Hallett Cove embayment to the north.
- The sand supply to Hallett Cove is substantially less than the potential transport rate of sand away from the embayment to the north under waves. Sand transported to the beach from the south by waves and sand placed on the beach within the active beach system is likely to be short-lived, moving under wave action around Black Cliff and along the cliff coastline to Marino and Brighton Beach beyond.
- The available sand supply from the south has been decreasing for a variety of reasons which include:
    - a reduction/cessation of onshore sand supply from the bed of Gulf St Vincent since sea level reached its current level approximately 6000 years BP
    - decreasing sand supply from the Field River and other rivers to the south along the Fleurieu Peninsula
    - recession of the beaches to the south supplying less sand to the littoral system as their dunes are depleted, developed and protected
    - construction works that intercept the natural flow of sand along the shoreline (such as the Port Stanvac Harbour works 1963, O'Sullivans Beach boat harbour 1983) and the subsequent accretion of sand
    - maintenance dredging potentially resulting in removal of sand from the adjacent active beach system
    - shoreline sand extraction around Port Stanvac to nourish the metropolitan beaches (1980 to 2000).
- Over historical times (20th century to present) the appearance of Hallett Cove Beach has varied, with periods of more or less sand thinly overlying the shingle and rock substrate. The volume of sand on the beach is variable and depends amongst other things on the recent weather/storms and the small and intermittent alongshore sand supply from the south around Port Stanvac.

- Historical evidence suggests that the sand supply from the south has decreased on average. with more frequent periods of exposed shingle and briefer periods of sand cover and extent visible on the beach.
- The beach area is shallowly underlain by a bedrock/clay shelf which is resistant to scour/erosion during storms, also limiting the rate of recession at the back of the beach.
- The beach and nearshore immediately adjacent to the Field River is underlain by clay, protected by a thin layer of shingle. This area is very sensitive to erosion when the clays are exposed or disturbed.
- The small remaining sand dunes adjacent to the Field River entrance (predominantly remaining on the south side) are a remnant feature that will be increasingly at risk from wave erosion and/or river scour. There is little alongshore sediment supply available to naturally replenish this dune cap.
- Much of the back beach has been reworked during the development of the subdivision and Heron Way Reserve. The removal of the old shacks, major earthworks, infilling of natural drainage and levelling of the natural surface, have all contributed to the present-day back beach morphology, particularly to the south of the Hallett Cove Conservation Area.
- The limited available historical survey data suggests there is little change in the location of the back beach escarpment over recent years (low rates of recession) under present day sea levels.
- The rock substrate is overlain by a basal layer of shingle which, while mobile during storms (moving both along the beach and across the beach profile), is resistant to transport offshore into deep water and around the headlands away from the compartment.
- The potential rate of alongshore transport of shingle and coarse sand fractions is significantly lower than that for fine grained sand.
- The shingle is derived from erosion of the glacial deposits and erosion of the local cliffs and rock outcrops
- It is unlikely that significant volumes of shingle are being added to the beach compartment or removed from it by waves at the present time.
- The erosion of the back beach escarpment (fronting Heron Way Reserve and the Conservation Area to the north) is mainly occurring into the relic glacial deposits and clays (some of which have been reworked), providing little sand or shingle to replenish the beach during erosion events.
- The rate of recession of the back beach escarpment and the frequency of erosion events are likely to increase over time as sea level rises.

6.2 Available Management Options

Hallett Cove is well placed to accommodate the impacts that will arise from climate change and, specifically, rising sea level. The range of options is limited by the identified high littoral drift potential and the lack of a consistent sand supply to the beach. It is likely that the beach will become rockier and for longer periods of time as the meagre sand reserve available is eroded and transported to the north.

The natural armouring of the beach already provides some protection and this is evidenced by the relatively minor erosion of the back beach area over recent decades when compared with the sandy beaches to the north and south. A broad shingle slope is very effective in absorbing wave energy. As sea level rises there will be a gradual increase in the frequency and extent of storm events that erode the back beach area. This will occur over an extended time period and will depend on the rate at which sea level rises. It will need to be increasingly managed and, ultimately, may require hard protection structures along some sections of the beach if existing development and infrastructure are to be maintained.

The overarching approach to management of the Hallett Cove foreshores is to adopt a sympathetic and non-confrontational approach over time. Where possible, the management measures should be minimal and in keeping with the exceptional natural and heritage values of the area. Current practices of dune management, replanting and minimal use of hard protection should be continued. For much of the beach the preferred management strategy will be to accommodate the erosion in the short term and to allow the escarpment to recede, maintaining an accessible beach area. Along the foreshores south of the Conservation Area fronting Heron Way Reserve, this may be challenging. Current erosion of the steep escarpment raises safety issues and these will continue to occur as sea levels rise and more frequent wave erosion of the back beach escarpment occurs. It is likely that these events will also release small quantities of the asbestos waste currently buried in the topsoil and fill backing sections of the beach.

Soft management options may not be sufficient around the Field River entrance and the southern section of Heron Way Reserve. On the northern side of the Field River there is residential development and infrastructure located close to the beach on what was once the foredune area. Over time this section of the beach will require some protection works to secure assets on the private properties and in the southern part of Heron Way Reserve. While they could be implemented now, they are not required at present. However, the dune and back beach should be closely monitored and maintained to permit the timely implementation of further works as required. The opportunity should be taken now to further develop appropriate designs (including collection of necessary survey and geotechnical data) and to identify trigger events signalling when such protection should be placed.

Another area of concern is the small remnant sand dune cap on the south side of the Field River entrance which has been eroded in the past and will continue to be at risk. This dune is significant and is the only section of sand dune remaining in Hallett Cove south of the Conservation Area.

At all locations there are options that should be undertaken, irrespective of future actions and decisions These actions include those things that are undertaken as normal business irrespective of climate and hazard uncertainty in the future. They include also those things that might improve decision-making and day-to-day management of the area. They are usually referred to as 'no regret' options.

Where a beach is eroding and receding such as Hallett Cove will be as sea level rises, the options are limited in terms of the movement of the back beach escarpment and assets located on or behind the beach. The only options are to **relocate or to protect/adapt**. These options can be further considered in terms of the approach selected to ultimately lead towards one of these outcomes.

In practice, any management strategy may include a mix of the options outlined below, possibly incorporating elements of the retreat and protect strategies for developed areas. The options will vary from section to section along the beach, depending on the exposure to the coastal hazards, the back beach morphology and local issues. In Section 4.2 the beach has been described in terms of five discrete management sections. The available management options for each section are discussed in section 6.4. A recommended overall suite of management measures is presented in Appendix C as a draft management strategy for consideration.

6.2.1 Do nothing/accept the risk

If no action is taken, over time the beach will respond to the coastal processes and adapt. Inappropriately sited assets and infrastructure would be lost as the beach moves to a new and stable alignment during storm events and following sea level rise.

Table 6.1: Advantages and disadvantages of do nothing option

Advantages	Disadvantages
Do nothing is the benchmark option, requiring no expenditure or particular action to be taken in advance. Ideally suited to stable foreshores, particularly where wave inundation is not considered an issue. May be appropriate where there is little or no built infrastructure and back beach land use (e.g. undeveloped areas, low value public land, dunes). Allows the beach to retreat over time. Natural approach with minimal interference.	Generally not acceptable to communities. Does not provide certainty for users/managers, timing of outcome is dependent on extreme events (emergency management). Ultimately results in loss/damage to dunes and vegetation cover, worsening the situation. Where a beach is receding, may result in gradual loss of public land/infrastructure and development behind the beach over time. Needs to be managed when damage occurs during/after storm events to avoid piecemeal response (such as dumping of rock or loss of dune cover). Minor infrastructure such as access ways, small stormwater outlets etc. may require ongoing reconstruction/repair/removal. Need to advise community if protection or restoration will not be undertaken.

At locations in Hallett Cove where the beach is backed by bedrock and no development is located in geotechnical hazard zones, then this option may be appropriate.

6.2.2 No regrets option

These include those things that can be undertaken irrespective of the uncertainty as they are simply good management practice. They may include such diverse things as beach and dune regeneration works, monitoring, background studies (investigation and design), geotechnical assessment, asset and development planning, recreational enhancement and the like. Many of these activities are part of core business and would need to be done anyway. Others provide data and information that may be useful in future decision-making and implementing options.

Table 6.2: Advantages and disadvantages of no regrets option

Advantages	Disadvantages
Includes those things that may provide benefits, whether projected hazards are realised in the future or not. Facilitates planning to be put in place for future protection or removal of assets. Beach and dune regeneration may slow beach recession and improve environment/habitat. Survey and monitoring may help to identify when protection or relocation of assets is required. Survey and monitoring of existing vegetation, and habitat is essential for ongoing management. Investigation and design for protection works reduces lead time required to implement and assists works budgeting. Geotechnical assessment will improve understanding of future beach response. Removal of barriers to alongshore drift may increase the sand flow through the beach system. Asset management can improve performance of infrastructure and facilitate decisions relating to future relocation or protection.	Requires commitment of time and cost immediately and ongoing. May be seen by the community as non-action (does not solve the long-term problem).

6.2.3 Relocation option

For undeveloped areas and where the impacts of beach recession can be readily accommodated seaward of development/assets, this is a logical approach and allows the beach and dune system to be retained as they move landward over time. For currently developed areas this approach is difficult, requiring development and infrastructure to be removed in advance of the erosion event occurring, rendering the land unusable for its original purpose. It is best suited to new subdivisions where the retreat is planned, with development sited to provide an identified and acceptable period of occupancy with agreed removal triggers identified. For existing development where private assets are deemed to be at risk, retreat requires the abandonment and removal of the development. This may require voluntary or compulsory acquisition and/or rezoning. It has limited applicability within Hallett Cove for the foreseeable future.

Table 6.3: Advantages and disadvantages of relocation

Advantages	Disadvantages
Planned withdrawal is well suited where there is little or no built infrastructure and back beach land use (e.g. reserves, grassed parklands, dunes) offers the opportunity for the beach to retreat over time, retaining the sandy beach amenity. At such locations the loss of the land is outweighed by gains from retaining the economic/recreational values associated with the beach. Ideally suited to stable or slowly receding foreshores, particularly where wave inundation is not considered an issue. Can be planned as a strategy for newly released residential land through rezoning. Where development is already existing, compulsory or voluntary acquisition at significant expense is likely to be required. Obfuscates the need for hard protection works. Regrading and translation of steep dune face provides additional opportunities for revegetation and maintenance of 'natural' dune appearance.	Needs to be managed as erosion occurs during/after storm events (dune reconstruction/regeneration). Careful asset management is required to relocate infrastructure (drainage, access, walking trails etc.) Results in gradual loss of public land behind the beach over time. Provides less certainty for users/managers, as timing of outcomes is dependent on frequency of erosion events

6.2.4 Protection options

Protection options are generally seen as the option of last choice, where a decision is taken to draw a line and limit further landward movement of the beach. Their primary purpose is to protect the land and development located on it, rather than the beach. Where a beach is stable, well sited protection works may allow the retention of the beach while only being exposed (and limiting erosion) during extreme events. More commonly, beach nourishment is needed to maintain a recreational beach.

There are a large variety of protection options that can be used and they provide protection in different ways. They are often used together (e.g. terminal revetment and groynes) to try to limit erosion and trap sand, providing both security to development and a viable recreation beach.

The various approaches have particular advantages and disadvantages. They are not all suitable or effective at any particular location. These protection options can broadly be grouped as:

6.2.4.1 Beach nourishment

Beach nourishment involves the importation of large quantities of sand to establish a broad beach and/or dune buffer capable of accommodating erosion during a severe storm event. It is popular with communities as they can retain a beach amenity while effectively stabilising the beach location. It is not predictable as protection (sand can be removed by a single storm) and requires regular renourishment following storms or over time to maintain an appropriate level of protection. Sand nourishment is ongoing and expensive and requires permanent funding and a readily available and affordable source of suitable sand.

Smaller and irregular nourishment campaigns can be undertaken with short-term and possibly localised impacts. These can be in response to the availability of new or temporary sand sources (such as a dredging or construction project). Such future opportunities may arise and could warrant further assessment at that time. Provided logistics (such as transport and placement) are acceptable and the sand is appropriately assessed for compatibility with the beach sands, then such 'opportunistic' nourishment may be considered. This irregular nourishment does not offer a long-term solution to management of the beach on its own.

6.2.4.2 Shore-normal structures

These include groynes, breakwaters, entrance training works, artificial headlands and the like. They are suited to use on a coastline with a net littoral drift predominantly in one direction and with a reliable alongshore sand supply. They work by intercepting the alongshore sand movement and creating a stable fillet of sand on the updrift side. They must extend from a point above the high water mark (usually the back beach, seawall or dune face) to a distance seaward of the low water mark (typically in a depth of 3m to 10m).

They correspondingly result in erosion on the downdrift side unless sand is imported to initially create the updrift sand fillet and restore full sand bypassing. Downdrift erosion can also recur following storm erosion, which removes the accreted sand fillet that subsequently has to be replaced before the structure recommences naturally bypassing sand under wave action.

Typical construction materials include rock, concrete units, geotextile containers or sheet piles. The effectiveness of the structure in trapping sand is a function of the length of the structure below the low water mark. Major structures (such as river entrance breakwaters) may accrete a sand fillet hundreds of metres in width and extending hundreds of metres or even kilometres updrift. Small structures built between the high and low water mark may result in a beach increase of a few metres and an accretion fillet extending tens of metres updrift.

6.2.4.3 Back beach structures

These include revetments, seawalls, curtain walls, wharves and the like and may be constructed in a large variety of ways and using a broad range of materials. They are fundamentally designed to limit the landward movement of the beach and so protect the assets or land behind. They also provide an armoured crest to limit or stop wave overtopping. They are not designed to protect/retain the beach and can result in accelerated beach loss (seaward and downdrift) and loss of alongshore access using the beach. Used with ongoing beach nourishment, a beach can be maintained seaward of the protection. They are commonly used where the value of assets or back beach activity warrants such protection.

The most common design is in the form of a sloping, armoured rock revetment (as seen along much of the Adelaide metropolitan coast). Earlier seawall constructions tended to favour vertical block walls with a parapet wall and walkway (or promenade) behind imitating the traditional British beachfront treatment (e.g. Glenelg).

Other construction materials include poured and formed concrete, dressed stone, rock, concrete armour units, sheet piling, geotextile sand-filled containers, concrete bored piles, gabions, reno mattresses, etc.

6.2.4.4 Offshore structures and works

These include submerged artificial reefs, shore-parallel breakwaters (submerged and emergent), crenulate bays, configuration dredging, etc. Their purpose is to reduce the wave energy reaching the beach at a particular location, and/or to facilitate the accretion of a sand fillet, spit or salient that provides additional protection and a usable beach amenity. They are more generally suited to beaches with a lower rate of alongshore transport or a reduced wave energy (e.g. Semaphore Beach). Shore-parallel breakwaters can also be used in high wave energy locations with little or no alongshore sand movement. Configuration dredging is used to refract wave energy away from an area being protected and to concentrate it on adjacent more stable areas (usually a nearby rocky shoreline).

Table 6.4: Advantages and disadvantages of protection works

Advantages	Disadvantages
Provide certainty for protection of back beach assets and development. Back beach protection costs may be borne by the property owner. Preferred solution for receding shorelines where development or land is of high value. Can be designed to retain a sandy beach area or can be used with beach nourishment. Can be constructed for a known cost (limited maintenance). Communities often view beach nourishment as a favoured solution (irrespective of expense and need for continual maintenance).	Necessitate interference in the natural processes with the risk of unforeseen adverse impacts. Hard protection structures require high upfront capital expenditure and may result in accelerating the loss of the beach. Soft protection (such as nourishment or sand trapping methods) generally require ongoing funding and a reliable external sand source. These are unlikely to be successful at Hallett Cove given the lack of an alongshore sand supply and the high sand transport potential through the system. Are disruptive during construction and replenishment, closing the beach for use of heavy plant and equipment, dredging etc. Create an artificial environment. May result in a loss of access to and along the shoreline. May alienate residents who see the loss of a public amenity for protection of private assets.

6.2.5 Adaptation options

While not strictly protection options, adaptation measures are employed to prolong the design life of existing structures and development that will be at risk during its design life. Risk from future coastal hazards may be reduced or eliminated by such things as elevated floor levels (inundation), piled foundations (erosion), development setbacks (recession), bunds to limit wave overtopping and the like. They are most commonly used in locations where subdivision already exists and applied to infill development and extensions. Some measures may be retrofitted to existing development or added at a future stage/time as required. The aim is to prolong the useable life of existing land/ development.

Table 6.5: Advantages and disadvantages of adaptation options

Advantages	Disadvantages
Allow the potential life of existing poorly sited development to be extended without major capital protection works. May be relatively cost effective. Can be retrofitted to existing development or added when the hazard threat warrants it (e.g. bunding for inundation). Allow time to confirm the increased hazard without sterilising land (e.g. future sea level rise). Cost may be borne by the property owner.	Don't always provide a permanent solution. May simply prolong the final decision (protect or remove). Are limited in what can be achieved and may not provide equal outcomes for all properties. May require restrictions to what can be done with a property (e.g. setbacks on siting of pools, buildings etc.). May be seen as unnecessary costs by property owners. Need to be monitored and enforced by Council.

6.3 Indicative Unit Costs

6.3.1 Beach nourishment

Beach nourishment is unlikely to provide a viable option for protection of the Hallett Cove foreshore into the future. To establish an adequate sand buffer and maintain it, it is first necessary to nourish the beach across the whole profile, from the back beach to the limit of offshore sediment transport. Normally this is achieved by an initial placement of approximately five years' sand supply to the beach and then ongoing replacement of this initial volume at intervals of two to five years (depending on the frequency and impact of storm events. The CES (2004) report advises that the potential alongshore sand transport through the Hallett Cove beach system is on average 100,000m^3/year. This would suggest an initial sand placement of 500,000m^3 with a further placement of 500,000m^3 in three years time and then ongoing sand supply at an average of 100,000m^3/year into the future. This would equate to the placement of approximately 350m^3/m of beach length over the 1400m of Hallett Cove and then an ongoing additional placement of approximately 70m^3/m of beach every year into the future.

There are obvious difficulties with such a proposal that effectively rule it out.

- Firstly, there are limited available sand sources that could satisfy such a project now or into the future.

- Secondly, the cost of sourcing sand would be prohibitive.
- Thirdly, the logistics of placing and distributing sand are likely to be unacceptable.

No suitable offshore sand reserves have been identified in close proximity to Hallett Cove that would be available for dredging and delivery by sea. Should such sources be identified the cost for the sand extraction and delivery alone would be in the vicinity of $15/m^3 (average $10/m^3 to $20/m^3 depending on volumes and location). This would equate to an initial placement cost of approximately $7.5 million and an average annual cost of $1.5 million per year for the strategy discussed above. Initial investigation, approval and establishment and disestablishment costs for each dredging campaign would be additional. If onshore sources are to be used then the unit cost may increase to around $50/m^3 or in excess of three times the cost (DENR advises unit costs of $52.30/m^3 for trucking sand from Mt Compass to a nearby beach location). Sand would need to be transported to the site by truck and assuming the use of trucks capable of carrying a 40 tonne sand load (approximately 20m^3) the initial campaign would require approximately 25,000 truck trips and an average of 5000 truck trips each year into the future. If the initial nourishment was undertaken over a 12-week period (working 8.00 am to 4.00 pm, 5 days per week) then this would require in excess of 50 truck deliveries (in and out) along the local roads per hour for that 3-month period. Even if the ongoing nourishment of 100,000m^3/year was undertaken continuously over the whole year (assuming 48 weeks and operating 8.00 am to 4,00 pm) this would require in excess of 2.5 truck journeys per hour, every working day of the year. Such an intrusion of large trucks along narrow and quiet suburban streets is not likely to be acceptable or practical.

Should the option of simply replacing the original estimated alongshore sediment transport supply of 5000m^3/year be deemed appropriate, it must be recognised that this would not provide protection to the existing back beach area and may only provide some increase in sand cover along the beach at certain times before the sand is lost. Volumes required over time as sea levels rise would increase. Based on a sand placement volume of 5000m^3/year and supply of sand from onshore sources, this is likely to cost approximately $250,000/year (at present) and would require approximately 250 truck deliveries through the suburb. The issues of securing the back beach from future erosion would still need to be addressed.

6.3.2 Fixed protection works

Fixed protection works are expensive, requiring a high capital investment and ongoing maintenance, depending on the frequency and severity of storm events.

Design of a foreshore revetment structure can vary in cross-section and size depending on the materials and design conditions. Typically, costs for an engineered revetment or seawall vary from $2000/metre to $10,000/metre. For example DENR advises the standard design rock wall (sloping revetment, two layers primary armour stone) used in the Adelaide metropolitan area costs approximately $3000/metre to construct. Similar unit costs would be applicable to the Hallett Cove area. Ongoing monitoring and maintenance costs would be approximately 5% per annum or $150/metre/year.

Offshore and shore-normal structures are more expensive to construct as they are exposed to higher wave conditions and are placed in deeper water, requiring larger volumes of construction material as water depths increase. Offshore structures (not joined to the shoreline) are more expensive again due to added difficulties with construction. DENR advises a construction cost of $2 million for the 200m long Semaphore offshore breakwater, or approximately $10,000/metre in 2009. Hallett Cove is exposed to higher swell conditions than Semaphore and costs could be expected to be higher.

These costs are indicative only for various structures and final cost would depend on materials used and the final design.

6.4 Viable Management Options for Hallett Cove Beach

The management of Hallett Cove Beach is hampered by the lack of adequate coastal process data and monitoring for the area. It is fundamental to the future of the management that this be redressed through the collection and compilation of relevant data. While detailed sediment transport modelling underpins the management of the metropolitan beaches to the north and the beaches within Onkaparinga to the south, the available modelling of the Hallett Cove Beach system is less detailed. Specifically, the necessary bathymetric data for detailed models to be developed at a local scale does not exist. Fundamental to this understanding is the collection of base survey data including bathymetry, sediment/reef mapping and shore-normal beach profiles collected at regular time intervals within the embayment. This ongoing monitoring would allow a better understanding of the current beach response during storm events and, potentially, future sea level rise.

This section provides a brief discussion of the likely viable approaches that could be adopted for each beach section discussed in Section 4.2. A suite of recommended options in the form of a draft management plan is presented in Appendix C. It should be noted that this draft plan is the consultant's recommendation and is presented for discussion only. It is not a management strategy endorsed by the City of Marion.

6.4.1 Beach Section 1 - Hallett Cove Conservation Area

The priority within Beach Section 1 is to maintain and promote the natural values of the Conservation Area and the adjacent beach area. Low impact works are preferred.

While it is acknowledged that additional sand cover on this section of beach is seen as desirable by many in the community, this is not a practically achievable outcome. It would require either a significant increase in the alongshore sand supply reaching Hallett Cove or the importation of large volumes of sand to the beach. In the absence of some structure (e.g. rock groynes extending from the back beach across the surf zone or offshore breakwaters) the retention period for this sand would still remain short. Construction of a sand trapping structure is not likely to occur on the grounds of both cost and environmental/aesthetic considerations.

Plate 6-1: Beach Section 1, Hallett Cove Conservation Area. The beach is backed by a low dune which is eroded from time to time during storms. Ongoing recession may be managed with dune revegetation works following storms in the immediate future. **Photo source**: Coastal Environment Pty Ltd 18 August 2011

The recession of the back beach dune escarpment is occurring at low rates and is currently managed through the efforts of volunteers who undertake dune revegetation works within the Conservation Area. These works should be continued and encouraged. It must be recognised that over time, erosion during storm events will continue to erode the face of the dune which will continue to move landward. Typically, a movement of 10m to 2050 and 25m to 2100 should be factored into management strategies until further detailed monitoring of beach response is available. This may require minor realignment of the alongshore access trail over time and management of existing drainage gullies across the beach.

The shingle cover to the beach is an essential part of the natural beach protection and should not be disturbed or removed. It is an integral part of the regional geology. Future erosion of the back beach escarpment could be reduced by the addition of some armouring to the dune face. This is not considered necessary at present and a full engineered revetment is not considered appropriate. The addition of quantities of shingle (compatible with that existing on the beach) could prove beneficial if an appropriate external supply could be found. Quarry stone could also be used but is not preferred along this beach section. Any shingle/rock should be placed at the back of the beach adjacent to the base of the dune to limit the frequency of dune erosion. This option could be investigated further.

Where future erosion results in an unstable dune face or undercutting that is considered dangerous, some manual regrading of the dune face in conjunction with planting may be required from time to time.

The addition of appropriate beach sand from an external source to the beach face (above the high water mark and along the dune face) could be considered if such a source is identified.

Table 6.6: Viable management strategies Beach Section 1

Options	Immediate (0-10 yrs)	Mid-term 10-50 yrs	Long-term 50-100 yrs	Comments
Monitoring	✓	✓	✓	Includes survey and beach profiles
Dune/revegetation management	✓	✓	✓	Ongoing of high value
Regrade dune face/escarpment	✓	✓	✓	As required to stabilise face
Major beach renourishment	?	?	?	Unlikely to be economic
Back beach protection	X	?	?	Minor, sympathetic shingle protection viable
Sand trapping structures	X	?	?	Unlikely to be economic
Minor beach renourishment	?	?	?	Sand placement on beach if appropriate sources are identified
Relocate assets	X	?	?	Access trails, fencing and drainage as required

✓ Recommended measures X Not recommended ? May be suitable

6.4.2 Beach Section 2 - conservation area to centre of Heron Way Reserve

The priority within Beach Section 2 is to maintain and manage the natural dune/slope fronting the reserve. Low impact works are preferred along this section, including dune stabilisation and revegetation.

The relative elevation of the back beach along this section will require regrading of the slope following wave erosion of the toe and removal of any exposed material to ensure slope stability (exposed rock or waste). Rock and shingle removed should be placed at the dune toe. This erosion will gradually result in the loss of the seaward part of the reserve as the slope moves landward. The existing beach access and the shore-parallel path currently along the shoreline at the top of the slope may need to be relocated over time. The car park and the Boatshed Café will also need to be relocated in the long term.

While additional sand cover to this section of beach is seen as desirable by many in the community, again this is not a practically achievable outcome. The importation of large volumes of sand to the beach and construction of sand trapping structures is not likely due to both cost and environmental/ aesthetic considerations. Minor sand placement could be possible if future suitable sources are identified, with maximum benefit gained by placing sand at the back of the beach or on the dune face as and if it becomes available.

The erosion/recession of the back beach dune escarpment is occurring at low rates at present but will occur more frequently as sea level rises. Over time, erosion during storm events will more frequently erode the face of the dune which will continue to move landward. Typically, a movement of 10m to 2050 and 25m to 2100 should be factored into management/planning for the Heron Way Reserve until more detailed monitoring of beach response is available or protection works are placed at the dune toe.

Plate 6-2: Beach Section 2, seaward of Heron Way Reserve. Along this section the beach is narrower and the erosion is forming a high unstable escarpment which needs to be addressed. **Photo source**: Coastal Environment Pty Ltd 18 August 2011

While sections of the face are stable, erosion and slippage is occurring at present along steeper sections, particularly towards the southern end which requires immediate attention. Geotechnical investigations are necessary to determine the nature of the back beach material that will be eroded and to establish guidelines for maintaining a stable slope to the face. This can be managed either by regrading the existing slope and/or the placement of protection at the toe of the slope over time. Current dune revegetation works should be continued and encouraged.

Plate 6-3: Beach Section 2, seaward of Heron Way Reserve. Sections of the escarpment are slipping, with building waste and boulders dislodged on the slope posing a safety risk. **Photo source**: Coastal Environment Pty Ltd 27 April 2011

The existing shingle cover to the beach is an essential part of the natural beach protection and should not be disturbed or removed. Future erosion of the back beach escarpment may be reduced by the addition of some armouring to the dune face through the addition of quantities of shingle (compatible with that existing on the beach) if an appropriate external supply could be found. Compatible quarry stone could also be used but is not preferred along this beach section. This option could be investigated further.

Where future erosion results in an unstable dune face or undercutting that is considered dangerous, manual regrading of the steepened dune face in conjunction with planting would be required with some urgency.

Table 6.7: Viable management strategies Beach Section 2

Options	Immediate (0-10 yrs)	Mid-term 10-50 yrs	Long-term 50-100 yrs	Comments
Monitoring	✓	✓	✓	Includes survey and beach profiles
Dune/revegetation management	✓	✓	✓	Ongoing of high value
Regrade dune face/escarpment	✓	✓	✓	Required at present to stabilise face and will be ongoing
Major beach renourishment	?	?	?	Unlikely to be economic
Back beach protection	X	?	?	Minor protection viable, terminal revetment could be investigated further
Sand trapping structures	X	?	?	Unlikely to be economic
Minor beach renourishment	?	?	?	Sand placement on beach if appropriate sources are identified.
Relocate assets	?	✓	✓	Relocate beach access, in longer term Heron Way Reserve pathway, car park and Boatshed Café

✓ Recommended measures X Not recommended ? May be suitable

6.4.3 Beach Section 3 - centre of Heron Way Reserve to the Field River entrance

This section of the beach is most at risk from coastal processes now and into the future under a scenario of a rising sea level. It includes the southern end of Heron Way Reserve, south of the Dutchman Drive roundabout. Infrastructure located closely behind the beach includes stormwater treatment GPT and outlet, Heron Way Reserve, the alongshore beach path and access to the beach at the Field River, sewerage infrastructure, approximately 12 residential properties and River Parade.

This beach section is proud of the alignment of the beach to the south and north and is sheltered by the exposed shingle and rock substrate at this location. Erosion is already creating a problem and has resulted in the need for rock protection adjacent to the stormwater outlet, erosion of the dune face along the southern part of Heron Way Reserve and loss of much of the fragile remnant sand dune adjacent to River Parade and the Field River entrance. Without substantial intervention into the future, much of the assets and infrastructure outlined will be substantially impacted by future beach recession. Given the value of the assets and infrastructure at risk, protection works are likely to be warranted and can be designed to benefit the remainder of the beach frontage south and north by creation of a protected ‘headland’.

Given the narrow setback to existing infrastructure, the existing morphology of the beach and the proximity to the river entrance, major beach nourishment of the whole embayment would be unlikely to provide increased protection at this location and is not seen as a viable protection strategy, with or without sand trapping structures. Similarly, the value and proximity of assets suggest that the do nothing approach is not appropriate and the relocation of existing development is likely to be prohibitively expensive.

Plate 6-4: Beach Section 3, Heron Way Reserve to the Field River entrance. The escarpment height reduces near the disused boat ramp. The slope adjacent to the access and stormwater outlet and to the south is unstable and requires regrading. **Photo source**: Coastal Environment Pty Ltd 2 June 2011

While an engineered protection structure is not required at the present time, the existing properties are within 20m of the present dune escarpment. Protection works may be warranted by 2050 and the opportunity exists at present to select an appropriate protection alignment and to design an appropriate protection strategy. Detailed geotechnical assessment is also required to determine the substrate and foundation requirements. The total beach frontage requiring protection is approximately 400m (from the stormwater outlet to the southern end of River Parade) and, based on a unit cost of $3000/m, the final protection works may cost in excess of $1.2 million at present-day values. Properties along the beachfront and adjacent to River Parade are low, and potential future inundation issues also need to be addressed.

The erosion/recession of the back beach dune escarpment is occurring at low rates at present but will occur more frequently as sea level rises. Over time, erosion during storm events will more frequently erode the face of the dune which will continue to move landward. Typically, a movement of 10m to 2050 and 25m to 2100 should be factored into management/planning. Existing residences are unlikely to be affected until at least 2050 or beyond, providing opportunity for this likelihood to be addressed.

Plate 6-5: Beach Section 3, Heron Way Reserve to the Field River entrance. Erosion has removed the dune seaward of the Field River entrance in front of the residences facing River Parade. **Photo source**: Coastal Environment Pty Ltd 18 August 2011

In the short term, there is a need to address the erosion of the seaward dune face along the southern end of Heron Way Reserve. Regrading and/or dune revegetation works are required and should continue. Dune works and revegetation should also continue along the seaward side of the private development to the Field River entrance, although little of the remnant dune remains. Sand obtained from external sources could be placed along the beach frontage as and if it becomes available.

While protection works are likely to be required to secure roadways and beachfront properties into the future, it would be opportune to undertake a review of development and planning controls relevant to the existing beachfront properties to minimise any future impacts or risks. These might include the type of development to be approved, setbacks on development from the seaward property boundaries, foundation requirements, minimum floor levels, provision and location of future services and protection works. These could then be applied to future development and redevelopment in the precinct.

Table 6.8: Viable management strategies Beach Section 3

Options	Immediate (0-10 yrs)	Mid-term 10-50 yrs	Long-term 50-100 yrs	Comments
Monitoring	✓	✓	✓	Includes survey and beach profiles
Geotechnical assessment	✓	?	?	Assessment to address slope stability and foundation conditions
Dune/revegetation management	✓	✓	?	Ongoing of high value
Regrade dune face/escarpment	✓	✓	?	Required at present to stabilise face and will be ongoing
Review development and building controls	✓	✓	✓	Future controls to be consistent with level of risk
Back beach protection	✓	✓	✓	Terminal revetment likely to be required by 2050. Investigation could commence now
Sand trapping structures and nourishment	X	X	X	Unlikely to be economic
Minor beach renourishment	?	?	?	Sand placement on beach if appropriate sources become available.
Relocate assets	?	✓	✓	Relocate or protect beach access, sewerage, drainage and roads

✓ Recommended measures X Not recommended ? May be suitable

6.4.4 Beach Section 4 - Field River to the Southern Cliffs

With a potential for increasing sea level, it is likely that the wave erosion and undercutting of the small dune section adjacent to the Field River will continue into the future. The existing rock placement (in 2004) at the back of the beach has provided some protection to this dune face. This rock protection is not adequate to retain the dune cap into the future and may require the addition of further material (at a higher level) and the extension of the future rock/shingle placement further to the north. The quarry rock placed, while not ideal, is serving the purpose at present of limiting undercutting of the dune face. If available, a more sympathetic (shingle) source should be identified for any future additional works. The shingle on the beach seaward of the dune should not be removed or interfered with in any way (as occurred during placement in 2004) as this exposes the underlying clays which will erode and reduce the potential for the wave energy to be absorbed. The only viable alternative to the shingle would appear to be the construction of a fully engineered revetment, which is unlikely to be an economical or ecologically acceptable response.

Plate 6-6: Beach Section 4, Field River entrance to the southern cliffs. The narrow dune cap on the southern side of the river is at the left between the concrete boat ramp and the river entrance. The deeper water in the boat channel on the right allows larger waves to erode further up the beach during storms. **Photo source**: Coastal Environment Pty Ltd 27 April 2011

Proposals to infill the boat channel and/or to construct a submerged reef to block wave action are unlikely to succeed and would prove prohibitively expensive for the limited benefit gained.

The value of the existing dune revegetation works is recognised and should be encouraged and continued both across the dune cap and along the property boundaries to the south abutting the headland. If the opportunity arises to place additional sand along the dune cap from an external source, this should be pursued. This section of dune is the only natural capping dune still remaining within the Hallet Cove embayment.

Infrastructure at risk along this section of beach is limited to dune access fencing and beach access which will need to be managed on an ongoing basis.

An undeveloped residential subdivision is located landward of the dune to the north of Beachfront Crescent and three properties within the subdivision have boundaries to the back of the dune cap. The closest of these property boundaries is located approximately 10m from the present dune scarp. While the erosion/recession of this dune is occurring at low rates at present, without ongoing armouring of the dune face it is likely that erosion during storm events will more frequently erode the face of the dune which will continue to move landward. Typically, a movement of 10m to 2050 and 25m to 2100 should be factored into management/planning. The subdivision is quite low and, as for existing development south of the Field River, it would be opportune to undertake a review of development and planning controls relevant to these existing beachfront properties to minimise any future impacts or risks.

Plate 6-7: Beach Section 4, Field River entrance to the southern cliffs. The narrow dune cap on the southern side of the river has been eroded and is now protected by quarry stone placed at the rear of the beach. As sea level rises this dune cap and the subdivision behind will be increasingly at risk. **Photo source**: Coastal Environment Pty Ltd 18 August 2011

The existing concrete boat ramp servicing the adjacent private property is located on bedrock which is exposed at higher elevations along the beachfront to the south, emerging as the cliff line along the headland. No coastal hazards are identified for the foreseeable future along this section of the coast, with development and infrastructure appropriately sited back from the beach and cliff line. Existing efforts to revegetate the rising coastal margins should be encouraged and continued.

Table 6.9: Viable management strategies Beach Section 4

Options	Immediate (0-10 yrs)	Mid-term 10-50 yrs	Long-term 50-100 yrs	Comments
Monitoring	✓	✓	✓	Includes survey and beach profiles
Dune/revegetation management	✓	✓	✓	Ongoing of high value along the low dunes and rising cliff line
Manage dune cap and escarpment	✓	✓	?	Required at present to retain habitat and stabilise face. Will be ongoing
Review development and building controls	✓	✓	✓	Future controls to be consistent with the level of risk for new residential development
Submerged reef	X	?	?	Unlikely to be economical solution to reducing wave energy
Back beach protection	✓	✓	✓	Existing rock protection to be monitored and possibly upgraded/ extended
Terminal revetment	?	?	?	Unlikely to be economical solution Feasibility study could proceed
Sand trapping structures and nourishment	X	X	X	Unlikely to be economical or effective
Minor beach renourishment	?	?	?	Sand placement on beach if an appropriate source becomes available.
Relocate assets	?	✓	✓	Relocate beach access and fencing as required

✓ Recommended measures X Not recommended ? May be suitable

6.4.5 Beach Section 5 - southern cliffs to the desalination plant

The cliff line from Albatross Walk to the City of Marion boundary at the new desalination plant is at an elevation of 30m AHD. Future sea level rise will elevate the ocean levels over the existing wave cut platform at the base of the cliffs and allow wave action during storms to directly attack the base of the cliff face. Existing development is sited well back from the cliff line and it is not anticipated that erosion or recession of the cliff line will provide any threat to the existing development in the foreseeable future. The existing cliff line and nearshore bathymetry needs to be surveyed to provide a benchmark for ongoing monitoring and management. Regular inspections of the cliff line (annual or following an extreme storm event) should be undertaken and documented to identify any local instabilities, changes or issues that should then be addressed. Drainage lines that terminate at the cliff crest should also be monitored and future flows from these stormwater lines managed. Uncontrolled discharge at the cliff top has the potential to trigger any local instability.

The reserve along the cliff line provides a valuable extension of the natural attributes of the Hallett Cove coastline and is integrated with the coastline via the coastal trails. The revegetation works within the Hallet Headland Reserve provide a unique coastal experience and should be encouraged and continued. The access trail and views of the Gulf St Vincent and coastline to the north further enhance the value of this coastal section which should continue to be promoted as an extension of the natural coastal environment and experience associated with Hallett Cove.

Plate 6-8: Beach Section 5, Hallet Head to the southern City of Marion boundary. The near vertical bedrock cliffs are fronted by a low, wave cut platform with little or no sand at the base of the cliffs. Development is sited well back from the cliff line. **Photo source**: Coastal Environment Pty Ltd 2 June 2011

Table 6.10: Viable management strategies Beach Section 5

Options	Immediate (0-10 yrs)	Mid-term 10-50 yrs	Long-term 50-100 yrs	Comments
Monitoring	✓	✓	✓	Includes survey and regular cliff line monitoring
Headland Reserve revegetation and management	✓	✓	✓	Ongoing of high value along the elevated cliff line
Review and manage assets	?	✓	✓	Relocate trail, viewing platforms fencing and drainage as required

✓ Recommended measures X Not recommended ? May be suitable

Plate 6-9: Beach Section 5, Hallet Head to the southern City of Marion boundary. The trail along the cliff passes through the unique vegetation of Hallett Head Reserve and provides excellent views over Hallett Cove to the north. Residential development is sited well back from the cliff line. **Photo source**: Coastal Environment Pty Ltd 2 June 2011

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7. Conclusions and Recommendations

7.1 Discussion

Perhaps the potential for the Hallet Cove foreshore can be summed up in the words of Allison Dolling (1981): 'The Hallett Cove area, with its remaining plant life, geological and anthropological relics and historical associations is becoming more widely appreciated as a rich gem in the treasure of our National Estate.'

Hallett Cove is different from other beaches along the Adelaide metropolitan coast. It is a product of its unique geology, the story of which is now preserved in the Hallet Cove Conservation Area, adjacent cliff lines and the shingle beach. The shoreline, while not offering a wide sandy beach for swimming and surfing, is enjoyed by many for walking, boating, diving and fishing. The Coastal Walking Trail, which is being formalised and upgraded by the City of Marion and local conservation groups, provides a unique opportunity to explore these metropolitan cliffs and their expansive views of the Gulf and adjacent shorelines. The Hallett Cove Conservation Area showcases the geology, the flora and fauna and the Aboriginal and European heritage of the area. The cove is fronted by the regionally unique shingle foreshore deposited by glaciers long ago.

The developed parkland of Heron Way Reserve between the southern end of the conservation park and the Field River entrance offers a differing recreational opportunity, with the grassed reserve, playground and picnic facilities catering to families. The proposed Masterplan for the Heron Way Reserve, which this study will inform, will further develop those opportunities in an urban setting for the future.

At the southern end, the banks of the Field River and the adjacent entrance dunes and riverfront reserve upstream of Cormorant Drive offer the experience of a riverine entrance environment. This area is readily accessible from the beach and enhanced by native vegetation regeneration works along the narrow floodplain.

At the very southern end the walkway up and across Hallett Headland provides superb vistas of the Gulf and to the north over the cove. Again, this walking experience is enhanced by the regeneration works and significant vegetation within the Hallett Headland reserve.

This combination of magnificent views, geology, local history and unique vegetation all readily accessible from nearby residential areas makes Hallett Cove stand out from, rather than compete with, adjacent beach areas. The focus of the management of the Hallett Cove foreshores within the study area should be on maintaining and enhancing these attributes, rather than trying to change the character of the foreshore to more closely replicate the sandy metropolitan beaches further to the north.

7.2 Conclusions

The assessment of the coastal processes, present-day sediment transport rates and projections of future beach recession are hampered by the paucity of reliable bathymetric survey data to inform detailed wave and sediment transport modelling.

The existing studies covering the area (CES 2004) suggest a sand transport potential of approximately 100,000m^3/year moving through the embayment from south to north. By comparison, the natural sediment supply alongshore from the south is estimated at around 5000m^3/year. This means that any sand reaching the Hallett Cove embayment is quickly remobilised and transported to the north during storm events. While the alongshore movement of sand may give the appearance of a sandy beach from time to time, this is generally little more than a patchy sand veneer overlying the shingle substrate, stranded above the high water mark. Comparison of available aerial photos show a variable sand cover has existed along the beach for over 40 years.

The foreshores of Hallett Cove present as a slowly receding coastline, starved of sediment. The erosion escarpment at the back of the beach and the shingle and clay deposits exposed across the beach indicate that the beach is now as far landward as it has been since sea level stabilised around the present level approximately 6000 years ago.

While the dune face is receding due to infrequent wave erosion, this beach recession is occurring at very low rates at present. This is due in part to the local geology, including the submerged rock shelf along the shoreline and the exposed bedrock and shingle across the beach face. This shingle beach is very effective in reducing wave energy at the back of the beach and limits significant erosion of the beach profile during storms. It is important that this shingle deposit is retained and not disturbed unnecessarily. Where the clay underlying the shingle is exposed it is likely to be eroded by wave action and not replaced, hastening the landward recession.

Erosion of the dune face is into mixed sediments which comprise variously sections of relic dune sands, clays, shingle and fill placed during land clearing for the residential subdivision. This variability makes the projection of the response of the beach to future sea level rise difficult to predict with certainty. The State Government policy requires an allowance for future sea level rise of 0.3m to 2050 and 1.0m to 2100. In this report, the impact of this increase has been translated to an additional erosion of the foredune face of 10m by 2050 and 25m by 2100. These allowances should be refined through further beach monitoring in future revisions of the management strategy.

There is some photographic and anecdotal evidence that the sand cover on Hallett Cove Beach has reduced since the 1960s when various works and activities were undertaken south of Hallett Cove that may have reduced the alongshore sand supply. However, this sand supply was always small and significantly less than the potential of the waves to move sand from the beach and through the beach compartment to the north. At best it provided a thin mantle of sand over the shingle and exposed rock which were present and are visible on some of the earliest photographs of the area. This loss of sand and slow recession of the beach is also consistent with the scenario of a rising sea level which will continue into the future. It is unlikely that the infrastructure that has been constructed to the south of Hallett Cove will be removed, and even if it was, this would not result in a significant or sudden increase in the sand cover on Hallett Cove Beach. Where possible, activities and works that intersect the alongshore sand supply from the south and through the City of Marion coastline should be carefully considered. While these are not the sole cause of ongoing beach recession, the continuation of the interruption to the alongshore sand supply is exacerbating the recession rates at Hallett Cove and also contributing to the shortfall in the alongshore sand supply reaching the metropolitan beaches to the north. Sound coastal management practice does not support the interruption of the alongshore sand supply on a littoral drift coastline.

There is no significant development considered at immediate threat from coastal erosion within the study area. The present erosion rates are low and the projected back beach recession due to sea level rise of 10m by 2050 can be accommodated through soft management works such as dune revegetation and planting, relocation of access ways and fencing when damaged, and possibly minor beach nourishment if the opportunity arises.

There are two key areas of concern at present. The first relates to the small sections of unstable dune slope seaward of the Heron Way Reserve, where erosion at the base of the escarpment has resulted in destabilisation of the slope and, in some locations, the partial dislodgement of large rock and rubble in the slope. This may require some regrading to flatten the slope, and geotechnical advice should be obtained at these locations to agree an appropriate strategy (and stable slope) to make the area safe. The material comprising the slope is unknown.

The second area of immediate concern is the erosion of the fragile dune cap on the river entrance spit on the south side of the Field River. While this has been previously undercut by wave erosion in the vicinity of the boat channel, placement of rock by the City of Marion in 2004, together with ongoing vegetation regeneration by volunteers, has reduced this problem. The existing additional rock does not extend far enough to the north to protect that section of the dune, and some consideration should be given to extension of this armouring at the back of the beach. Care should be taken not to disturb the shingle on the beach face seaward of the dune.

By 2050 the dune face could be expected to have moved approximately 10m landward along most of the beach and decisions will then need to be made about the protection of sections of the beach frontage and/or the removal of the existing development. These key areas will include the car park and the Boatshed Café, major beach access ways, the foreshore path along Heron Way Reserve, development between the stormwater outlet at Dutchman Drive roundabout and the Field River entrance. This latter section includes 12 residential properties, River Parade and associated sewerage and stormwater infrastructure. It is likely that an engineered revetment would be required to protect this 400m section of the beach around that time, if the development is to remain. Current consideration of the appropriate alignment and design for any future protection works could be undertaken now.

South of the Field River it is likely that the small entrance dune cap will be increasingly eroded and the potential future risk to currently vacant residential allotments behind the beach should be taken into account. It would be appropriate to canvass likely requirements for development and building approvals for future development and redevelopment within both residential subdivisions adjacent to the Field River entrance, to minimise the associated risks in the future as sea level rises.

The key attribute of the Hallet Cove foreshore lies in its unique geology and natural habitat which are rarely found within residential precincts. The fundamental management strategy suggested is a minimalist approach, accommodating the natural coastal processes and future sea level rise as far as practical. It is fortunate that the geology provides a certain degree of natural armouring to the coast which can be built on over time. Beyond 2050, some key development areas, particularly around the Field River entrance, will be at risk, and decisions will need to be taken either to protect these developments or to relocate them.

A strategy of ongoing management through using minimal intervention works (including dune and vegetation rehabilitation) is not without risk. From time to time the work and effort put in through many volunteer hours will be damaged and need to be redone. This will happen more frequently along the beachfront and over time as sea level rises. Ultimately, it will require some areas to be abandoned and the dune line re-established further landward. The strategy will require strong support and assistance to the community volunteers involved and appropriate recognition of their efforts on behalf of the whole community. Ongoing monitoring is a key element of the approach and the information obtained should be used for regular review and adaptation of the adopted management strategy over time.

7.3 Recommendations

7.3.1 Additional studies and data

1. A high priority is the establishment of a programme and methodology for monitoring changes to the beach along the Hallett Cove foreshore, to determine changes over time. This is essential for assessing the impacts of sea level rise and the rate of retreat of the back beach escarpment, and to identify the need for implementation of elements of the overall coastal management strategy. It is recommended that long-term beach profiles be established in discussion with the Coast Protection Board (CPB) to ensure future monitoring builds on the beach profiling and photographic record they have already established. An additional monitoring program should be developed jointly with the CPB and the community to formally collect and collate data on the beach changes. A likely strategy could include approximately two beach cross-sections (surveyed) within each identified beach section (see section 4.2) to be surveyed at six-month intervals. These could be augmented with more regular annotated photographs of the beach state or specific areas of interest, building a longer-term database of the area.
2. The existing numerical modelling assessment of the Adelaide metropolitan coast recognises the lack of bathymetric data for the region of the coastline from the southern City of Marion boundary through to Kingston Park. This data is essential for any future refinement of the coastal process understanding and beach management. It is recommended that the City of Marion discuss with CPB opportunities for this baseline survey data to be collected from the back of the beachfront dunes to a depth that overlaps the available survey data in deeper water (>10m). If possible this survey should incorporate seabed/habitat mapping including delineation of rock reef, sandy bed and seagrass extent. It is noted that significant information on the nearshore habitat is being compiled by SARDi Aquatic Sciences for current stormwater planning by the City of Marion. This information is currently unpublished but should be taken into account in designing future monitoring of the nearshore.
3. Studies should be initiated and documented to identify suitable available sources of sand, shingle and rock for future repairs and restoration along the Hallett Cove precinct. The assessment should include the appropriate approval procedures for procurement, transport

and placement on the beach, approximate unit costing and timeline for delivery should they be required.

4. Geotechnical advice should be obtained on the appropriate method and slope required to stabilise the currently unstable beach slopes resulting from erosion of the dune toe seaward of Heron Way Reserve.
5. Geotechnical advice should be obtained for the area of back beach between the Dutchman Drive roundabout and the Field River to determine the likely substrate and foundation conditions for a revetment, should that option be considered. This information could then inform the selection of an appropriate alignment for the structure and preliminary design considerations.

7.3.2 Management measures

6. A priority is to determine a strategy and undertake works to stabilise those sections of the foredune slope seaward of Heron Way Reserve that are currently unstable due to erosion of the toe. These works will likely include some flattening of the slope in accordance with appropriate geotechnical advice, removal of exposed rock and rubble from the slope and revegetation of the finished batter.
7. A detailed coastal management strategy/plan needs to be finalised and adopted by the City of Marion, identifying the preferred management approaches for each coastal section and identifying triggers/timelines for implementation. Funding requirements should be identified and included in Council's long-term financial plan. It should aim to provide certainty to property owners and residents, and to assist with Council asset management/maintenance programs. The plan needs to be regularly reviewed (maximum 10 years) to incorporate monitoring. The plan and identified future risks should apply across all areas of Council operations.
8. Consideration should be given to the appropriate development and building controls to be applied to residential development in areas at future risk from sea level rise. This is particularly applicable to existing residential development adjacent to the Field River entrance and to future development and redevelopment of the subdivisions on the north and south side of the Field River.
9. The City of Marion should formulate and implement policy on measures to restore/enhance the natural alongshore littoral processes that supply sand to Hallett Cove Beach. This may include irregular opportunities to place sand on the beach from external sources, the replacement of sand removed from the littoral system to the south during maintenance being returned to the alongshore sediment supply, and ongoing bypassing of existing structures that block the alongshore supply. Such measures would benefit Hallett Cove Beach, from both an amenity and protection perspective, and would also benefit the metropolitan beaches to the north where the sand will ultimately reside.
10. The current understanding of the erosion hazards and threat to the dune/cliff face over time should be incorporated in the Heron Way Reserve Masterplan (about to be commenced) and audit of the Coastal Walking Trail (currently being undertaken) by the City of Marion.
11. A detailed schedule of maintenance works should be agreed with the various volunteer groups undertaking dune stabilisation and revegetation works along the Hallett Cove foreshore. This should include necessary support (technical, equipment and financial) to allow the works to be undertaken as and when required.

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9. Glossary of Terms

9.1 Abbreviations

AHD	Australian Height Datum
AR4	Assessment Report Four
BP	Before Present
CD	Chart Datum
CPB	South Australian Coast Protection Board
DENR	Department of Environment and Natural Resources (South Australia)
ISLW	Indian Spring Low Water
IPCC	Intergovernmental Panel on Climate Change
SARDI	South Australian Research and Development Institute
SLR	Sea level rise
LAT	Lowest Astronomical Tide
SLSA	Surf Life Saving Australia

9.2 Definitions

Accretion - any gradual increase in size/width of a beach or dune area through growth or external addition of material such as sand. Usually applied to the natural build-up of the beach during quiet wave periods.

Active beach - the section of the beach from the offshore limit of onshore/offshore sand movement under waves to the landward limit of wave uprush during storms**.**

Admiralty Charts – nautical charts issued by the UK Hydrographic Office. Over 3000 charts cover the world in various levels of detail. They provide all information necessary for safe navigation. Large-scale charts cover approaches and entrances to harbours and rivers, medium-scale charts cover heavily used coastal areas and small-scale charts are for navigation in more open areas.

Alluvial – deposited by flowing water, e.g. sediment transported by a river or deposited on a floodplain.

Attenuation – reduction in wave energy as the waves travel towards the shoreline, primarily due to friction at the seabed.

Australian Height Datum (AHD) - an assigned sea surface curve based on mean sea level at 30 tide gauges around the Australian coast. Commonly used as the base level for measurement of land elevation. 0m AHD approximates mean sea level.

Bathymetry – the information derived from the measurement of water depths at various locations in a body of water. The earliest bathymetric surveys were undertaken from boats using calibrated lead lines. More recently they have been undertaken from a moving vessel using recording echo sounders and most recently from aeroplanes using laser detection (Lasar Activated Depth Sounding or LADS).

Beach face - the section of the beach normally exposed to the action of wave uprush.

Beach replenishment - a management process to resupply sand to sandy beaches undergoing erosion. Also termed beach nourishment or renourishment.

Before Present - term used in geology to express events over geological timescales, rather than in reference to a precise date.

Breakwater - a structure of rocks and/or other materials usually built in the water normal to the coastline with a seaward portion parallel to the coast. A breakwater provides protected water on the landward side. Breakwaters may also create a physical barrier that slows down or intersects the alongshore movement of sand by waves.

Bypassing - manual movement of sand from one side of a coastal structure to the other to continue sand movement as if unobstructed (e.g. passing of maintenance dredging across the O'Sullivans Beach boat ramp or across Port Stanvac to the north).

Chart datum (CD) - a permanently established surface from which tide heights or chart soundings are referenced, usually Indian Spring Low Water (ISLW) or lowest astronomical tide (LAT); the zero level of tide heights. Generally applied to navigation charts to ensure minimum available water depths.

Clast – a rock fragment or grain formed by the breakdown of larger rocks.

Crenulate bays – small embayed sandy beaches formed between intermittent sections of shore-parallel offshore breakwaters (usually applied to artificial beach protection structures designed for this purpose).

Diffraction – the lateral transfer of energy along a wave crest as it passes an obstruction (e.g. headland) allowing the wave to bend around the obstruction.

Dune blowout – the removal of sand inland from a dune by wind once protective vegetation is lost. This sand is lost to the beach system.

Equilibrium – refers to the relative stability of a beach alignment or beach profile over the usual average range of wave conditions. Implies a zero net alongshore sand transport or no net imbalance in onshore/offshore sand movement.

Equinox – the time that occurs twice each year when the sun is directly over the equator and the length of day and night are equal.

Erratics - glacier-transported rock fragment that may be embedded in till or occur on the ground surface following glacier melting. They range in size from pebbles to large boulders, often varying markedly in composition from the local bedrock where they are deposited.

External sand source – a supply of sand for beach replenishment from a sand source external to the active beach system (usually onshore or deep water offshore).

Fillet - sand that collects (above and below water) on the updrift side of a coastal structure such as a groyne, breakwater or headland due to the interruption to the alongshore sand movement.

Flow till – sediment released by melting of stagnant or slowly moving debris-rich glacier ice and deposited without subsequent transport or deformation. May be divided into sub-glacial melt-out till (melting of debris-rich ice at the bottom of the glacier) and supraglacial melt-out till (melting of ice on the glacier surface).

Gabion – building units composed of rocks, rubble or masonry held tightly together by wire mesh. Used to form retaining walls and other structures.

Geotextile - a permeable geosynthetic sheet comprised solely of textiles, used in geotechnical engineering construction. Commonly geotextiles provide a filter layer under rock armour or can be fashioned into containers filled with sand used as armour units in a structure.

Groyne - structure of rock and/or other materials generally built out from the shore seaward in dynamic environments. A groyne creates a physical barrier that slows down or stops the alongshore movement of sand, trapping a sand fillet on the updrift side.

Holocene – the upper geological epoch which began at the end of the Pleistocene (around 10,000 years ago) and continues to the present, during which sea level finished rising from the last interglacial and has stabilised at about the current level (stillstand).

Indian Spring Low Water (ISLW) - the lowest level, for most practical purposes, to which the tide falls; only in exceptional circumstances will the tide fall lower

Littoral – relating to, or situated on the shore of the sea or a lake (e.g. littoral zone is the zone bounded by the seaward extent of wave breaking and the landward limit of wave action on the coast).

Lodgement till - sediment (clay and rock) which has been deposited by 'plastering' of glacial debris from a sliding glacier bed.

Longshore sediment transport potential - the theoretical sand volume that could be moved along the shoreline by waves, if an unlimited sand source was available.

Lowest Astronomical Tide (LAT) - the lowest level of the tide that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions.

Marinoan – geologic time period of a major global ice age known as the Sturtian/Marinoan glaciation (710 to 640 million years BP), prior to the base of the Cambrian era.

Marine transgression - rising sea level and marine inundation of the land due to geological cycles of climate change and global temperature rise (e.g. post-glacial marine transgression).

Mean High Water Springs (MHWS) - the level that is the average of all the twice-daily high tides at spring periods**.**

Mean Sea Level (MSL) - the average level of the surface of the sea over a long period of time in all stages of oscillation. Also the average level which would exist in the absence of tides. Approximately 0m AHD.

Morphology – study of the shape and composition/origin of the earth's surface.

Neap tide - the tides which happen near the first and last quarter of the moon, when the difference between high and low water is less than at any other part of the month. Opposite to spring tide.

Permian – the final geological period of the Palaeozoic era extending from 280 million years BP to about 225 million years BP.

Permo-Carboniferous Age – dating to the latter part of the Permian period or early part of the Carboniferous period, approximately 280 million years BP.

Pleistocene – the lower geological epoch of the Quaternary period from about 2 million years BP to the commencement of the Holocene.

Precambrian – the earliest geological era, more than about 570 million years BP.

Proterozoic - the later of the two divisions of the Precambrian Eon, from about 2.5 billion to approximately 570 million years BP. The Proterozoic was characterised by the formation of stable continents, the appearance of abundant bacteria and archaea, and the build-up of oxygen in the atmosphere.

Progradation - deposition outward and upward of sediments over time as a result of excess sand supply (alongshore or onshore). Also accretion.

Recession – the landward movement of a shoreline over time (e.g. receding shoreline). Can be caused by erosion resulting in more sediment leaving a coastal compartment than is entering it, or as a result of sea level rise inundating the shoreline over time.

Refraction - the process by which the direction of a wave train moving in shallow water at an angle to the contours is changed to align itself parallel to the shoreline. That part of the wave in deeper water moves faster than that part in shallower water, causing the wave to bend as it approaches the shore.

Reno-mattress - flat wire mesh baskets filled with rocks, used to prevent erosion by water. See also Gabion.

Revetment – in coastal engineering applies to protection structures armouring an existing ground slope or erosion/dune escarpment to prevent further erosion of the slope by waves during storms.

Striations – grooves on exposed rock surfaces caused by the passage of rock fragments embedded in the base of ice sheets and glaciers.

Salient - sand slowed down by a breakwater or reef and trapped nearshore, with the effect of building up the beach in the protected onshore area**.**

Sea – waves generated by winds and which are within the wave generating area, commonly during storms. They are generally of short period and low height and are often confused with irregular surface breaking (whitecaps).

Sea Level Rise (SLR) – a rise in mean sea level when averaged over an extended time period. In terms of climate change is usually used to describe the predicted or projected increase in the mean sea level that will occur to a future date measured above the 1990 mean sea level.

Scarp – (or escarpment) a steep face on the side of a hill, a sand dune or the seabed. Commonly refers to the steep dune face eroded by storm waves.

Shingle – a deposit of coarse gravel or pebbles, particularly on a beach. They can be of varying origin.

Spring tide - the tide that happens at, or soon after, the new or full moon, which rises higher than the common tides**.**

Stillstand - the period of relative constant sea level following the end of the last post-glacial marine transgression about 6000 year BP to the present (Holocene stillstand).

Storm surge – the increase in onshore elevation of the mean ocean level associated with a storm. Primarily comprises a barometric component (low pressure) and wind setup caused by strong onshore winds at the shoreline.

Sub-aerial – refers to sand located adjacent to the ocean but above the waterline. Includes sand on the upper beach face, in the dunes and back beach barrier. The main mechanism for sub-aerial sand movement is by winds, cf. sub-aqueous.

Substrate – an underlying layer upon which the surface sediment is deposited.

Swell - waves generated by winds that have travelled away from the generating area. They may have a uniform or ordered appearance with clearly defined crest lines. They can travel long distances from the generating area and have long wave periods and wave heights compared with sea waves.

Till - unsorted material deposited directly by glacial ice and showing no stratification. Till is sometimes called boulder clay because it is composed of clay, boulders of intermediate sizes, or a mixture of these. The rock fragments are usually angular and sharp rather than rounded, because they are deposited from the ice and have undergone little water transport. The pebbles and boulders may be faceted and striated from grinding while lodged in the glacier (see also lodgement till and flow till).

Wave runup - height to which a particular wave will run up a beach slope or dune face, measured above the still ocean level.

Wave setup - the amount by which the still water level inshore of the breaking wave zone exceeds that outside; in part due to the kinetic energy in the breaking waves being converted into an elevated inshore water level. For the South Australian coast, values are usually less than 0.4m.

APPENDIX A
COMMUNITY SURVEY

A. Community Survey

A1 Survey Process

As part of the community consultation process for this study, a four-page community survey was distributed to residents and ratepayers in the Hallett Cove area seeking identification of issues to be addressed for Hallett Cove Beach. The survey was designed to obtain information to be used in helping Council and the consultant identify the major issues of concern relating to Hallett Cove that could be addressed by Council into the future, and to gain a perspective on the changes that have occurred along the foreshore from the perspective of short- and long-term residents. The questionnaires were distributed along with a prepaid return envelope inviting contributions to reach Council by 27 May 2011. A copy of the survey form is included in this appendix.

A total of 127 completed survey forms were received, indicating the passion of the local community for the beach and their interest and concern in the future management of the beach area. Included in the survey was a request for historical photos and information relating to the beach. A number of residents provided extensive information, well beyond the completion of the survey form, and this included scanned and copies of photos, historical articles and plans and appended statements containing extensive data on the area. This information is greatly appreciated and has proven invaluable in understanding the recent history of Hallet Cove Beach.

All the information gathered from the survey has been collated in a single spreadsheet that will assist both with final recommendations and actions arising from this study and to inform future planning and management of the area. A brief summary of the findings is presented in Section A.2.

A2 Survey Findings

The majority of responses were from permanent residents of Hallett Cove, followed by people who either owned property or used the beach. The following data has been summarised from 123 surveys where a written response was provided.

The main interest in the management of the Hallett Cove Beach study area was the use of the area for passive recreation:

- walking coastal trails
- walking on the beach, and
- recreation/playing on the beach.

When asked about their vision for the area and the one thing that would most improve the area:

- 97 responses mentioned the need for more sand on the beach
- 41 suggested additional/redevelopment of facilities within the reserve
- 27 responses mentioned the coastal walking trail, paths and linkage, and
- 12 responses suggested a need for erosion issues, including asbestos matters, to be managed.

When asking residents which of the following statements did they agree with:

- 90 responses said that the beach now has less sandy area and more exposed shingle area than has been the case previously
- 53 responses agreed that the beach around the Field River entrance is changing
- 51 responses said the bank (dune face or erosion escarpment) at the back of the beach is eroding at increasing rates, but
- 31 responses said the beach has always been variable with sand and rock exposed at different times.

Through the generation of this survey a list of interested parties has been collated that Council will use to contact and inform the community about the outcomes of the final report.

CITY OF MARION

Community Survey - May 2011

The City of Marion and the State Government are undertaking a coastal study of Hallett Cove beach – and we need your help.

The study is focused on the environmental changes to Hallett Cove beach over many years and will look at, for example, water levels, storm surge, sand movement and erosion.

It aims to identify coastal management issues and develop long-term strategies to protect and preserve the beach for future generations.

The study is being undertaken jointly by the City of Marion and the Coastal Management Branch in the Department of Environment and Natural Resources.

Your feedback on how the beach has changed and suggestions for enhancing this important site will feed into the Hallett Cove Coastal Management Study.

It will also provide crucial information to help the City of Marion develop a long-term masterplan for the adjacent Heron Way Reserve, which will include recreational facilities.

Any historic photographs of the area showing how the beach has changed will be useful to the study.

The study is centered on a 2.5km section of the Hallett Cove foreshore between the southern border of Council and the northern section of the beach directly in front of Hallett Cove Conservation Park.

We encourage you to complete the attached feedback form and return it to us in the reply paid envelope by May 27, 2011.

For more information, please contact:
Renee Pitcher
Landscape Project Officer
P (08) 7420 6466 E renee.pitcher@marion.sa.gov.au

Hallett Cove Coastal Management Study

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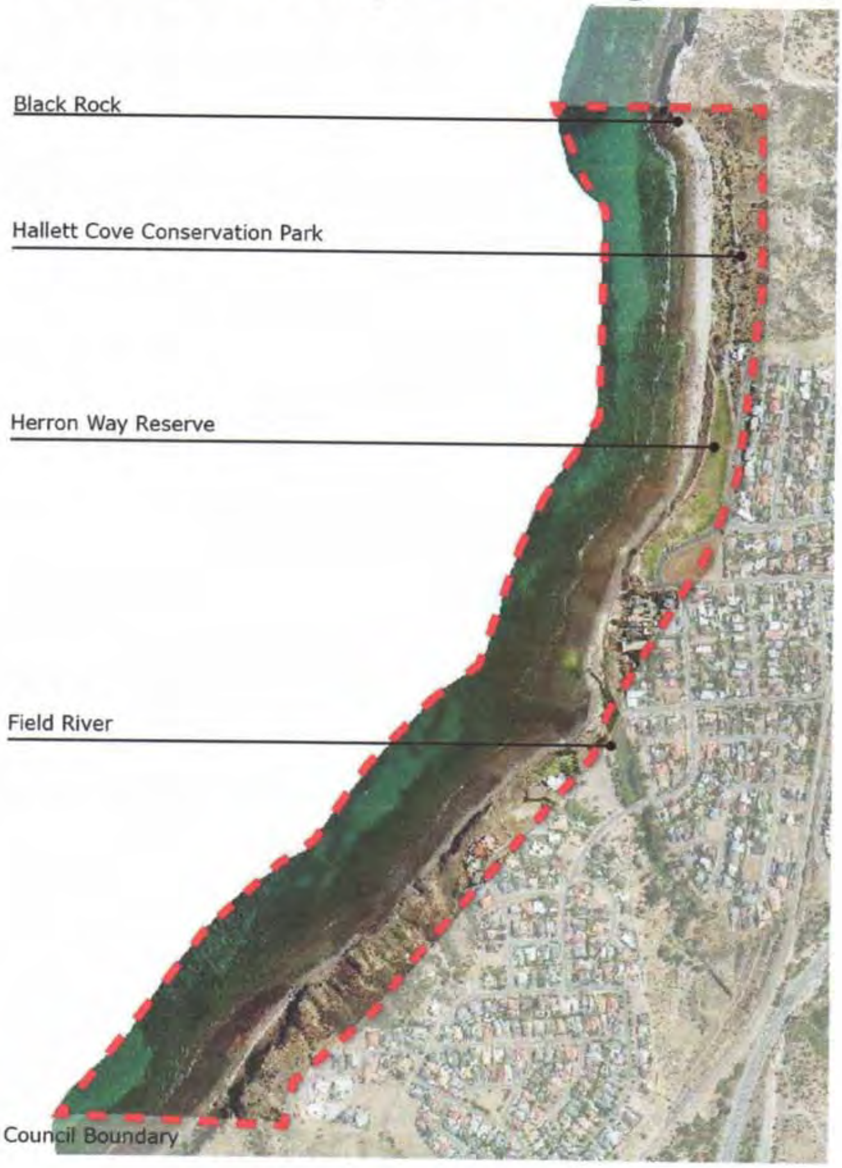
CITY OF MARION

Community Survey - May 2011



Hallett Cove Coastal Management Study

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CITY OF MARION

Community Survey - May 2011

About You

Please provide details if you would like to be kept informed of the progress of the study and of any community consultation meetings (optional).

Name : ____________________

Postal : ____________________

Suburb: ____________________

Email address: ____________________

Which of the following best describes your interest in the Hallett Cove Beach.
(Mark more than one if applicable)

- ☐ Permanent Resident ☐ Property ☐ Owner ☐ Beach User
- ☐ Interested Community Member ☐ Visitor ☐ Other ____________________

Your Interest

What is your main interest in the management of the Hallett Cove Beach study area? (please select from the following, mark more than one if applicable).

- ☐ Active recreation - swimming, fishing, diving, snorkelling, kayaking
- ☐ Passive recreation - walking coastal trail, walking on beach, recreational play on beach
- ☐ Passive use of reserve area - playground, barbeque area, shelters, seating
- ☐ Conservation - involved in local community groups or are a supporter of local groups.
- ☐ Other ____________________

- ☐ Do you have any historical photos that you are prepared to make available should they be required?

Hallett Cove Coastal Management Study

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CITY OF MARION

Community Survey - May 2011

Your Vision

In order of priority please list 5 things that would improve the beach and foreshore in the Hallett Cove Area.

1. ______
2. ______
3. ______
4. ______
5. ______

Your Awareness

Which of the following statements do you agree with (mark more than one if applicable).

- ☐ Hallett Cove beach has not changed significantly over ...... years.
- ☐ The beach now has less sandy area and more exposed shingle area than has been the case previously.
- ☐ The bank at the back of the beach is eroding at increasing rates.
- ☐ The beach area around the Field River entrance is changing
- ☐ The beach has always been variable with sand and rock exposed at different times.

Your Comments

Please explain how you think the beach has changed over the years

______

______

______

What are your ideas for how it could be improved?

______

______

______

Other

______

______

______

Hallett Cove Coastal Management Study

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APPENDIX B
SELECTED HALLET COVE PHOTOGRAPHS

The following photographs are a small selection of those obtained during the investigation or provided by individuals and organisations for use in this study. They are additional to those images included in the body of the report. Photos were provided for the purpose of this investigation and should not be reproduced or distributed without the prior approval of the City of Marion. The original source of the photos is shown below so far as it is known.

Plate B-1 Vertical aerial photograph Hallett Cove study area 1977. **Source**: Department Lands SVY 2854, photo 047. 7 February 1977.

Plate B-2 Vertical aerial photograph Hallett Cove study area 1985. **Source**: Department Lands SVY 3229 photo 112. 24 February 1985.

Plate B-3 Oblique aerial photo O'Sullivans Beach boat ramp 2008. **Source**: SA Dept Env and Natural Resources.

Plate B-4 Oblique aerial photo Port Stanvac 2008. **Source**: SA Dept Env and Natural Resources.

Plate B-5 Oblique aerial photo Hallett Cove Beach 1958. **Source**: provided by Friends of Field River, origin unknown.

Plate B-6 Oblique aerial photo Field River April 1997. **Source**: Friends of Field River.

Plate B-7 Oblique aerial photo Field River April 1980. **Source**: SA Dept Env and Natural Resources.

Plate B-8 Oblique aerial photo Field River April 1984. **Source**: SA Dept Env and Natural Resources.

Plate B-9 Oblique aerial photo Field River April 2008. **Source**: SA Dept Env and Natural Resources.

Plate B-10 Oblique aerial photo Black Cliff, Hallett Cove 10-02-1980. **Source**: SA Dept Env and Natural Resources.

Plate B-11 Oblique aerial photo Black Cliff, Hallett Cove February 1995. **Source**: SA Dept Env and Natural Resources.

Plate B-12 Oblique aerial photo Black Cliff, Hallett Cove 2008. **Source**: SA Dept Env and Natural Resources.

Plate B-13 Erratics seaward of the Boatshed Café circa 1970. **Source**: Published in *Hallett Cove – A Field Guide*, Cooper, Kenny & Scrymgour 1970.

Plate B-14 Field River Flood 29 June 2010. **Source**: Friends of Field River.

Plate B-15 Exposed clay, Field River entrance March 2005. **Source**: Brenda and Trevor Westlake.

Plate B-16 Exposed clay, Field River entrance 18 May 2006. **Source**: Friends of Field River.

Plate B-17 Field River entrance 1983. **Source**: Brenda and Trevor Westlake.

Plate B-18 Field River entrance 1992. **Source**: Brenda and Trevor Westlake.

Plate B-19 Hallett Cove Beach January 2003. **Source**: Brenda and Trevor Westlake.

Plate B-20 Hallett Cove Beach December 2004. **Source**: Brenda and Trevor Westlake.

Plate B-1: Vertical aerial photograph Hallett Cove study area 1977

Plate B-2: Vertical aerial photograph Hallett Cove study area 1985

Plate B-3: Oblique aerial photo O'Sullivans Beach boat ramp 2008

Plate B-4: Oblique aerial photo Port Stanvac 2008

Plate B-5: Oblique aerial photo Hallett Cove Beach 1958

Plate B-6: Oblique aerial photo Field River April 1997

Plate B-7: Oblique aerial photo Field River April 1980

Plate B-8: Oblique aerial photo Field River April 1984

Plate B-9: Oblique aerial photo Field River April 2008

Plate B-10: Oblique aerial photo Black Cliff, Hallett Cove 10 February 1980

Plate B-11: Oblique aerial photo Black Cliff, Hallett Cove February 1995

Plate B-12: Oblique aerial photo Black Cliff, Hallett Cove 2008

Plate B-13: Erratics seaward of the Boatshed Café circa 1970

Plate B-14: Field River flood 29 June 2010

Plate B-15: Exposed clay, Field River entrance March 2005

Plate B-16: Exposed clay, Field River entrance 18 May 2006

Plate B-17: Field River entrance 1983

Plate B-18: Field River entrance 1992

Plate B-19: Hallett Cove Beach January 2003

Plate B-20: Hallett Cove Beach December 2004

APPENDIX C
DRAFT MANAGEMENT STRATEGY

C. DRAFT MANAGEMENT STRATEGY

C1 AREA COVERED BY THIS PLAN

This management plan covers the Hallett Cove foreshores within the City of Marion, bounded by the southern end of Hallett Cove Beach adjacent to Black Cliff within the Hallett Cove Conservation area and extending for approximately 2.5 kilometres south to the southern Boundary of the City of Marion, adjacent to the desalination plant on Hallett Headland. It includes the foreshore and foredune of Hallett Cove Beach within the conservation area and seaward of Heron Way Reserve, the Field River entrance and adjacent coastal foreshores; and the cliff line of Hallett Headland.

Plate C-1: The Hallet Cove Study area addressed in this Management Plan

C2 Purpose of this Plan

The nominal life of this plan is ten years. By that time a comprehensive review of the plan incorporating more recent information/monitoring should be completed.

The purpose of this plan is to provide a framework for the future planning and management by the City of Marion of foreshore hazards within the planning area. This should then be incorporated within Council policy and considered across all Council activities within the defined plan area. It identifies:

- additional studies and information necessary for the future management of the area
- recognises and accommodates existing, identified coastal changes and future hazards
- outlines a preferred strategy for the future management of the shoreline by the City of Marion to 2100, in accordance with the South Australian Government policy relating to future climate change and sea level rise,; and
- identifies those actions required within the life of this plan for each foreshore section.

C3 Community Concerns

Community consultation including meetings with key stakeholders and community questionnaires was undertaken in formulating this management strategy. While some of those issues identified are not directly addressed through this management plan, they are being addressed through additional studies and plans being undertaken by the City of Marion which include preparation of a Masterplan for Heron Way Reserve and an audit of the coastal walking trail. The major issues raised by the community were:

- lack of sand on the beach
- additional reserve/redevelopment facilities
- coastal walking trails and linkages
- erosion of dunes at Field River entrance, and
- erosion of the dune face along the beach in general/asbestos management.

C4 Future Issues

Hallett Cove Beach is an eroding beach with the potential for sediment transport to the north under waves exceeding the natural sediment supply from the south. While there has been a reduction in this sand supply from the south over the last 40 years following the construction of harbour works intersecting the alongshore drift and the removal from time to time of sand build-up against those structures for nourishment of the metropolitan beaches to the north, since the current sea level was reached approximately 6000 years ago Hallett Cove has experienced a sand deficit with exposure of the underlying bedrock, clay and glacial shale deposits protecting the back beach from severe erosion. The bedrock and clay exposures confirm that the beach is now at its most landward location.

Based on the limited survey data available, there is no measurable rate of recession of the foredune face over the period of monitoring.

Future sea level rise will result in a decrease in surface sand along the Hallett Cove foreshores and potentially, an increase in the landward movement of the back beach as sea level rises. State Government policy requires the City of Marion to consider a potential rise in sea level of 0.3m by 2050 and of 1.0m by 2100 for future planning and development approval. For Hallett Cove, this is likely to result in a landward recession of any unconsolidated back beach by 10m to 2050 and up to 25m by 2100. For determining likely impacts and actions in this plan, time periods of short term (next 10 years), medium term (10 years to 50 years) and long term (50 years to 100 years) have been arbitrarily selected. These timeframes can be reviewed should rates of sea level rise or foreshore recession vary markedly from current recommended allowances.

There is no major infrastructure or private development at immediate risk from storm erosion within the Hallett Cove embayment. Erosion of the back beach along the elevated areas seaward of Heron Way Reserve has resulted in some steep and unstable slopes along sections of the foreshore that need to be addressed. The sand dune cap south of the Field River entrance and the dune fronting the private development to the north of the entrance have eroded during periods of high water levels and elevated waves and this will continue. There is no natural sand supply to replenish these dunes.

In the future, the recession of the escarpment will result in an increased need for stabilisation and revegetation of the dune face, repairs and relocation of accessways and fencing.

By 2050 there will be an increased risk to some development behind the beach including the Boathouse Café and car park, stormwater and sewerage infrastructure towards the southern end of Heron Way Reserve and adjacent to the residential development north of the Field River entrance.

By 2100 the risk to the Boathouse Café and car park may require their relocation. The southern section of Heron Way Reserve and the residential development on the north side of the Field River entrance (including River Parade) will need to be protected. Additional protection may be required on the south side of the Field River if the currently undeveloped subdivision north of Beachfront Crescent is to be developed.

C5 MANAGEMENT PHILOSOPHY

Hallett Cove has a unique foreshore area within the Adelaide coast, offering a coastal experience different from the nearby sandy beaches to the south and north. The geology of the region and in particular within the Conservation Area behind the northern half of the beach and along the high cliff lines north of Black Cliff to the north and south of the Field River to the south is world-renowned.

The remediation work within the Hallett Cove Conservation Area and the Hallett Headland Reserve and the associated walking trails and interpretive signage have created a world-class facility, preserving the remarkable geology, endemic vegetation and fauna by regenerating what were once cleared pastures. The shingle beach, while not popular for swimming or surfing due to the many exposed rocks, is very well patronised for passive recreation, including fishing and walking.

The management approach to be adopted through this plan is one of minimal interference with this natural system, utilising measures that are compatible with, rather than compromising, these natural environmental and heritage values.

That no significant development or infrastructure is at risk in the short term provides a window of opportunity to gather additional data and undertake focused monitoring to determine appropriate future intervention works. At some locations these are likely to require erosion protection works in the future.

The management philosophy proposed for management of the Hallett Cove foreshore over the foreseeable future is one of monitor, nurture and maintain.

C6 ADDITIONAL STUDIES AND DATA COLLECTION

C6.1 Within the Current Plan

To improve the understanding of future beach response and to facilitate the design and implementation of future management measures, the following additional studies are proposed during the life of this management plan.

1. Obtain geotechnical advice on the appropriate method and slope required to stabilise the currently unstable beach slopes resulting from erosion of the dune toe seaward of Heron Way Reserve (Beach Sections 1, 2 and 3 as appropriate).
2. Implement a beach monitoring strategy to determine changes to the unconsolidated beach areas over time. This is essential for assessing the impacts of sea level rise on the rate of retreat of the back beach escarpment and to identify the need/timing for future implementation of elements of the overall coastal management strategy. Monitoring should incorporate beach profiling along repeat transects with some profiles extended across the nearshore seabed beyond the surf zone, profile locations to be established in discussion with DENR to build on the existing beach profiling. A valuable resource includes photographic records, repeat annotated photographs of the beach area and any significant areas of change (storm damage or construction). An annual summary review of monitoring results should be prepared.

3. Collection of baseline survey data from the back of the beachfront dunes to a depth that overlaps the available survey data in deeper water (>10m) to intersect existing hydrographic mapping. This survey should incorporate seabed/habitat mapping including delineation of rock reef, sandy bed and seagrass extent. Such mapping should be incorporated into the overall database for the Adelaide coastline for use in future studies
4. Internal review of planning and development conditions applicable to development on low-lying areas adjacent to the Field River and in proximity to the beach should be undertaken to identify appropriate development and building controls commensurate with the future coastal risks. As required, amendments should be incorporated in the zonings and local planning instruments.
5. Investigate opportunities to re-establish natural alongshore supply of sand to Hallett Cove from the south.
6. Review available sources of sand, shingle and rock from external sources for future repairs and restoration along the Hallett Cove precinct.
7. Incorporate adequate coastal hazard allowance for climate change impacts in all future Marion City planning, maintenance and works. Specifically allowance for sea level rise of 0.3m to 2050 and 1.0m to 2100 (and associated beach recession) is to be considered in all Council infrastructure design and all building and development approvals.

C6.2 Beyond the Current Plan

1. Beach monitoring strategy should be reviewed and continued, to improve the understanding of beach response to future climate change and extreme storm events.
2. Geotechnical advice should be obtained for the back beach landward of the foredune escarpment to assist with future projections of beach recession and to inform design and implementation of future protection works.

C7 SPECIFIC MANAGEMENT RECOMMENDATIONS

C7.1 Beach Section 1

The primary objective along this beach section is to retain the natural appearance of the beach and the foredune, in keeping with the natural and heritage values of the adjacent conservation area. The beach should be allowed to recede, with storm damage managed through minor regrading, planting and repair of walking trails and drainage as required.

The integrity of the beach face including the shingle and large erratics should be maintained with care taken not to expose the underlying clay or to remove shingle from the beach.

Allowance is to be included in the annual budget to support ongoing dune and revegetation works. This budget allowance should be reassessed over time.

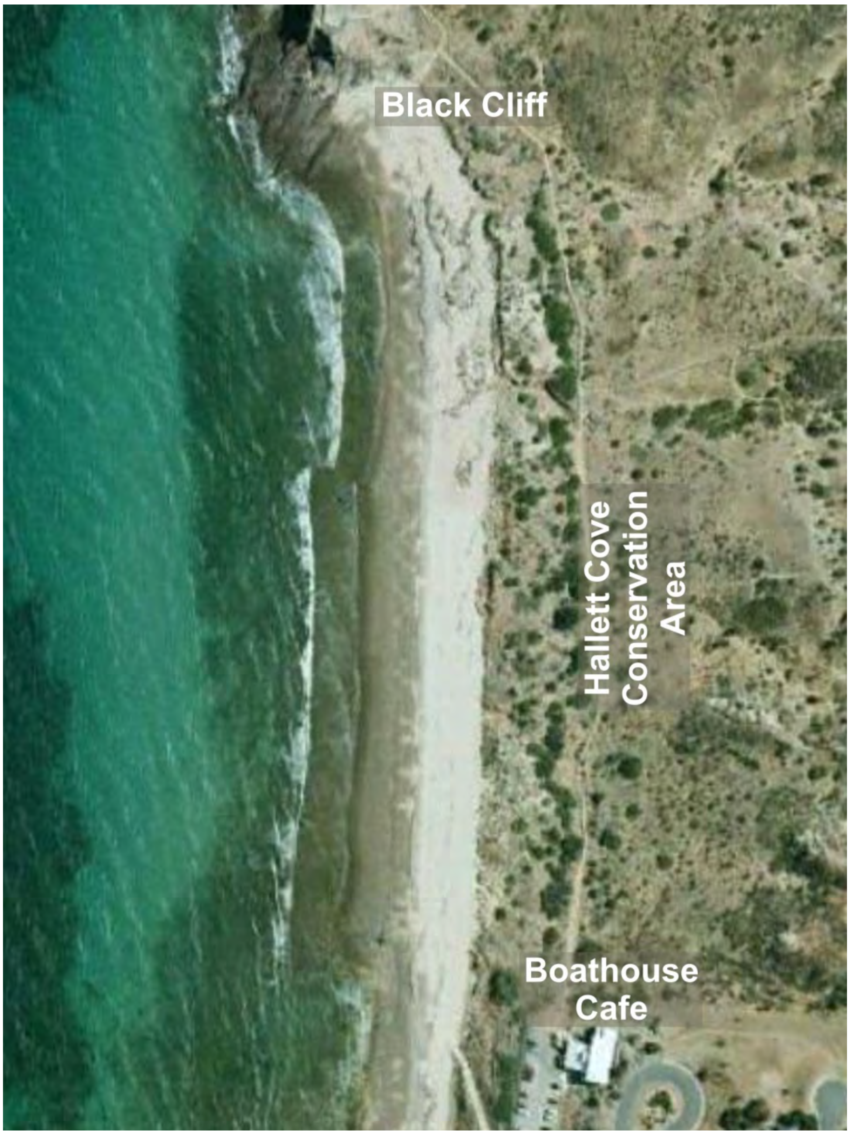

Plate C-2: Beach Section 1 is located along the seaward side of the Hallett Cove Conservation Area. This northern section of the beach extends approximately 400 metres south from Black Cliff to the southern boundary of the conservation area adjacent to the Boathouse Café. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Short term (next 10 years)

- No immediate intervention required (do nothing).
- Dune/revegetation management (ongoing).
- The alignment of access trails should allow for future shoreline recession.

Medium term (10 to 50 years)

- Dune/revegetation management (ongoing).
- Repairs to drainage and access trails as required. The realignment of access trails should continue to allow for future recession.
- Possible addition of shingle (from an external source) to the upper beach face as recession progresses and if warranted to reduce erosion.

Long term (50 to 100 years)

- Dune/revegetation management (ongoing).
- Realign access trails as dune is re-established landward.
- Withdraw drainage and fencing progressively as dune erodes.
- Possible addition of shingle (from an external source) to the upper beach face as recession progresses and if warranted to reduce erosion.
- Longer-term protection strategies may be considered (not recommended at this time).

C7.2 Beach Section 2

The primary objective along this beach section is to manage the natural retreat of the steep dune face in the short term. Additional geotechnical advice is required to determine the safe slope for the dune face and ascertain the material comprising the back beach area. Unsafe areas where rubble and large rocks may be dislodged require immediate treatment.

Repair and/or removal of the beach accessways and in the longer term the northern car park and Boathouse Café may be necessary. The lower section of Heron Way Reserve is likely to be affected beyond 2050, with relocation of the dune top access path and associated facilities likely.

The integrity of the beach face including the shingle and large erratics should be maintained, with care taken not to expose the underlying clay or to remove shingle from the beach.

Initial allowance is to be included in the annual budget to support ongoing dune and revegetation works, geotechnical assessment and regrading of the eroded slope as required. The required budget allowance will increase over time as the beach recedes and remedial works are more frequent.

Plate C-3: Beach Section 2 extends 300 metres from the southern boundary of the conservation area to the centre of Heron Way Reserve at the old boat ramp seaward of the Dutchman Drive roundabout. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Short term (next 10 years)

- Geotechnical assessment and regrading of unsafe dune sections.
- Dune/revegetation management (ongoing).

Medium term (10 to 50 years)

- Dune/revegetation management including regrading dune face following storms (ongoing).
- Repairs/removal of drainage outlets, fencing and beach access as dune erodes.
- Review and if necessary progressively relocate or remove affected sections of northern car park.

Long term (50 to 100 years)

- Dune/revegetation management including regrading dune face following storms (ongoing).
- Realign/relocate access trails as dune face recedes.
- Withdraw drainage outlets on the beach and fencing as dune face recedes.
- Possible addition of shingle or suitable quarry stone (from an external source) to the upper beach face or dune toe.
- Longer-term protection strategies to be considered to slow/limit recession.
- Monitor and relocate car park and Boatshed Café as required.

C7.3 Beach Section 3

The primary objective along this beach section is to retain the flatter southern section of Heron Way Reserve and in the longer term, protect the residential development road and infrastructure on the north side of the Field River which is close to the beach. In the shorter term the natural retreat of the dune face may be accommodated and managed through dune works and revegetation. Additional geotechnical advice is required to determine the safe slope for the dune face and ascertain the material comprising the back beach area. Unsafe areas where rubble and large rocks may be dislodged require immediate treatment.

Repair and/or removal of the beach accessways, walking trail and stormwater assets may be necessary by 2050. Beyond 2050 a protection structure will be required through this precinct to secure existing development and assets. Additional studies to determine the composition of the back beach sediments and identify foundation conditions should be undertaken so an alignment for a revetment can be selected. The integrity of the beach face including the shingle cover should be maintained, with care taken not to expose the underlying clay or to remove shingle from the beach, particularly during works.

Initial allowance is to be included in the annual budget to support ongoing dune and revegetation works, geotechnical assessment and regrading of the eroded slope as required. The required budget allowance will increase over time as the beach recedes. Long-term funding sources will be needed for protection works to be implemented.

Plate C-4: Beach Section 3. This beach section extends 400 metres from the centre of Heron Way Reserve to the Field River entrance and includes the residential development along the beachfront and River Parade between Grand Central Avenue and St Vincents Avenue. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Short term (next 10 years)

- Geotechnical assessment and regrading of unsafe dune sections along south end of Heron Way Reserve.
- Dune/revegetation management (ongoing).
- Review, develop and implement appropriate building/development and planning controls to properties that may be affected.

Medium term (10 to 50 years)

- Dune/revegetation management including regrading dune face following storms (ongoing).
- Realign walking trails and beach access.
- Repairs/removal of drainage outlets, fencing and beach access as dune erodes.
- Possible addition of shingle or suitable quarry stone (from an external source) to the upper beach face or dune toe.
- Identify alignment and prepare designs for protection structure.

Long term (50 to 100 years)

- Dune/revegetation management including regrading dune face following storms (ongoing).
- Construct protection works.
- Monitor and if necessary realign walking trails and beach access.
- Reconstruct drainage and fencing.

C7.4 Beach section 4

The primary objective along this beach section is to manage the erosion around the Field River entrance and specifically, to maintain/enhance the environmental values of the dune cap south of the entrance. In the shorter term, the natural retreat of the dune face may continue to be managed through dune works and revegetation. No major beach or nearshore protecting structures are proposed. Repair and/or relocation of the beach accessways and walking trail may be appropriate following the current audit process.

Additional studies to determine the composition of the back beach sediments and identify foundation conditions should be undertaken so appropriate controls are in place for the residential subdivision behind the dune. In the longer term, additional armouring of the beach face may prolong the viability of this dune area. Importantly, the integrity of the existing beach face must be maintained, with care taken not to expose the underlying clay or to remove or relocate shingle from the beach as has occurred previously.

Initial allowance is to be included in the annual budget to support ongoing dune and revegetation works, geotechnical assessment of the back beach areas and possible armouring/sand nourishment of the beach face and dune cap using imported shingle/rock/sand as required. The budget allowance will increase over time as sea levels rise and erosion of the dune increases.

Plate C-5: Beach Section 4. This section extends from the Field River entrance approximately 300 m south to Hallett Headland and residential development on Albatross Walk. It includes the entrance sand dune cap at the Field River, residential subdivision north of Beachfront Crescent and the emergent bedrock cliff line to the top of the headland. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Short term (next 10 years)

- Dune/revegetation and management (ongoing).
- Continue revegetation of the headland slopes south of the boat ramp (ongoing).
- Geotechnical assessment of back beach areas.
- Review, develop and implement appropriate residential building/development and planning controls to buildings that may be affected.

Medium term (10 to 50 years)

- Dune/revegetation management including regrading dune face following storms (ongoing).
- Realign walking trails and beach access as required.
- Continue revegetation of the headland slopes south of the boat ramp (ongoing).
- Repairs/removal/relocation of fencing, beach access and alongshore walking trails as dune erodes.
- Possible addition of shingle or suitable quarry stone (from an external source) to the upper beach face or dune toe to limit erosion and undercutting.

Long term (50 to 100 years)

- Dune/revegetation management, including replacement and relocation of fencing, following storms (ongoing).
- Continue revegetation of the headland slopes south of the boat ramp (ongoing).
- Assessment of possible long-term protection works for residential properties located landward of the dune cap south of the river entrance.
- Monitor and realign walking trails and beach access as required.

C7.5 Beach Section 5

The primary objective along this cliff section is to retain the environmental values of the native vegetation within the Hallett Headland Reserve and enhance the heritage values of the location while facilitating safe pedestrian access. Residential development and facilities (including access and drainage) should be maintained at a safe distance from the cliff line. Erosion of the cliff face will be slow but may be accelerated as sea levels rise. In the short term the area should continue to be managed through revegetation works and maintenance of walking trails and drainage as required.

Rubbish dumping and rubbish removal need to be actively managed in what are difficult to access clifftop locations and along the base of the cliff on the wave cut platform.

Geotechnical stability of the cliff face should be monitored over time.

Allowance is to be included in the annual budget to support ongoing dune, revegetation and clean-up works. This budget allowance should be reassessed over time.

Plate C-6: Beach Section 5. The cliff line along Hallet Headland extends approximately 1,100 metres south from the residential development on Albatross Walk to the desalination plant at the southern boundary of the City of Marion. **Photo source**: Google Earth image based on aerial photography 25 March 2010

Short term (next 10 years)

- Revegetation and management of public open spaces and access trails (ongoing).
- Rubbish removal strategy to be developed and implemented (ongoing).

Medium term (10 to 50 years)

- Revegetation and management of public open spaces and access trails (ongoing).
- Repairs to drainage and access trails as required.

Long term (50 to 100 years)

- Revegetation and management of public open spaces and access trails (ongoing).
- Realign access trails if required based on cliff line monitoring.
- Withdraw drainage and fencing progressively as cliff face evolves.

APPENDIX D
ABORIGINAL HERITAGE

Government of South Australia
Department of the Premier and Cabinet

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Adelaide SA 5001
DX 56201
Tel 08 8226 3500
Fax 08 8226 3535
www.premcab.sa.gov.au

Physical Id. DPC11D03645
File No. DPC11/0115

Brett Grimm
Landscape Architect
City of Marion
PO Box 21
Oaklands Park SA 5046

Dear Brett

Thank you for your correspondence (email) dated 1 June 2011, regarding the Hallett Cove Coastal Management Study.

I advise that the Central Archive, which includes the Register of Aboriginal Sites and Objects (the Register), administered by the Department of the Premier and Cabinet-Aboriginal Affairs and Reconciliation Division (DPC-AARD), has entries for Aboriginal sites in the area of the project location.

These entries for Aboriginal sites are described as two archaeological sites. The enclosed map identifies the approximate site location. It should be noted however that the site indicator does not reflect the actual area of the site; as this will vary from site to site, depending on the site information contained in the Central Archive.

The Register is not a comprehensive record of all Aboriginal sites and objects in South Australia. The applicant is advised that sites or objects may exist in the proposed development area, even though the Register does not identify them. All Aboriginal sites and objects are protected under the *Aboriginal Heritage Act 1988* (the Act), whether they are listed in the Register or not. Land within 200 metres of a watercourse (particularly the River Murray and its overflow areas) in particular, may contain Aboriginal sites and objects.

It is an offence to damage, disturb or interfere with any Aboriginal site or damage any Aboriginal object (registered or not) without the authority of the Minister for Aboriginal Affairs and Reconciliation (the Minister). If the planned activity is likely to damage, disturb or interfere with a site or object, authorisation of the activity must be first obtained from the Minister under Section 23 of the Act. Section 20 of the Act requires that any Aboriginal sites, objects or remains, discovered on the land, need to be reported to the Minister. Penalties apply for failure to comply with the Act.

It should be noted that this correspondence only addresses Aboriginal heritage matters in the context of the *Aboriginal Heritage Act 1988* and does relate to any native title considerations that may, or may not, be relevant to the land area over which you have requested information.

For further information, please contact the Aboriginal Heritage Branch on telephone (08) 8226 8900.

Yours sincerely

Justin Wearne
SENIOR HERITAGE INFORMATION OFFICER
ABORIGINAL AFFAIRS & RECONCILIATION DIVISION
07 June 2011


ABORIGINAL HERITAGE SITES
Government of South Australia
Department of the Premier and Cabinet
6527 4377
6527 4373
Legend
AARD_Heritage_Sites
Site status
Reported
N
1:10,000
0 50 100 150 200
Metres
Produced by
Heritage Information Team
Aboriginal Affairs and Reconciliation Division
Department of the Premier and Cabinet
Data Source
Projection
Datum
Compiled
Job No