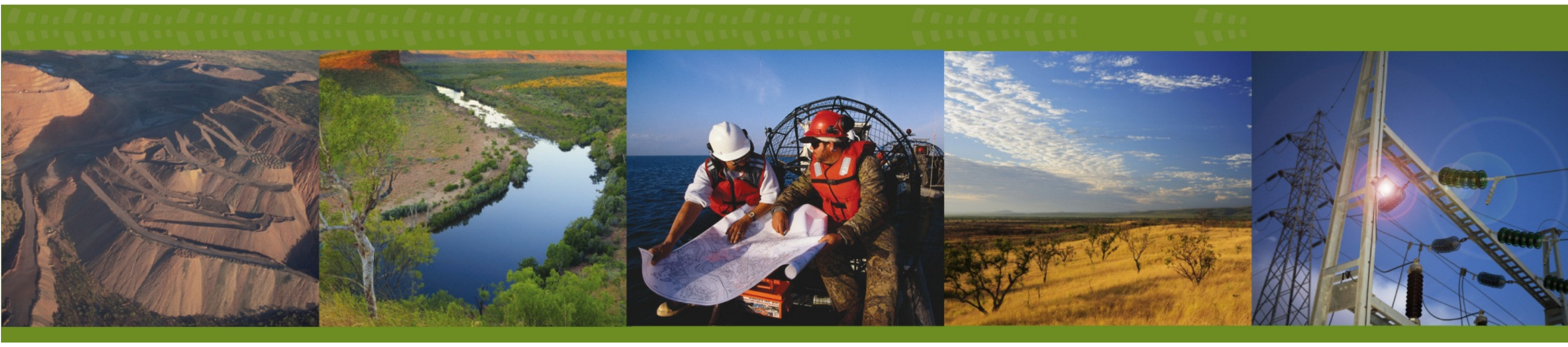

Ocean Reef Marina

EP Act Referral Supporting Document

Prepared for
City of Joondalup
by Strategen

May 2014

STRATEGEN
environmental consultants

Ocean Reef Marina

EP Act Referral Supporting Document

Strategen is a trading name of
Strategen Environmental Consultants Pty Ltd
Level 2, 322 Hay Street Subiaco WA
ACN: 056 190 419

May 2014

Limitations

Scope of services

This report ("the report") has been prepared by Strategen Environmental Consulting Pty Ltd (Strategen) in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Strategen. In some circumstances, a range of factors such as time, budget, access and/or site disturbance constraints may have limited the scope of services. This report is strictly limited to the matters stated in it and is not to be read as extending, by implication, to any other matter in connection with the matters addressed in it.

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The report is based on conditions encountered and information received at the time of preparation of this report or the time that site investigations were carried out. Strategen disclaims responsibility for any changes that may have occurred after this time. This report and any legal issues arising from it are governed by and construed in accordance with the law of Western Australia as at the date of this report.

Environmental conclusions

Within the limitations imposed by the scope of services, the preparation of this report has been undertaken and performed in a professional manner, in accordance with generally accepted environmental consulting practices. No other warranty, whether express or implied, is made.

Client: City of Joondalup

Report Version	Revision No.	Purpose	Strategen author/reviewer	Submitted to Client	
				Form	Date
Preliminary Draft Report	A	Client Review	A Welker; K Britza / L Taylor; I LeProvost	Electronic	24-Apr-14
Final Draft Report	B	Client Review	L Taylor	Electronic	19-May-14
Final Report	0	Agency submission	L Taylor	Electronic and hard copy	22-May-14

Filename: COJ13066_01 R004 Rev 0 - 21 May 2014

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1. Introduction

1.1 Proposal overview and location

The City of Joondalup (the City) proposes to develop a world class recreational, residential, boating and tourist development, referred to as the Ocean Reef Marina Development at Ocean Reef, Western Australia (the Development). The Development is located in the Ocean Reef locality, approximately 29 km from the Perth central area and 9 km from Hillarys Boat Harbour (Figure 1). The Development is within the City and includes the existing Ocean Reef Boat Harbour.

The Proposal will involve the upgrade and expansion of the existing Ocean Reef Boat Harbour into a mixed use 'working marina' enabling club, service commercial and marine industrial uses in the north; a central retail, tourist and residential precinct; and a southern boating precinct inclusive of ramps (Figure 2).

This referral includes the marine component of the Development only – that part which occurs below High Water Mark (the Proposal). The terrestrial component of the Development is being referred under section 48A of the *Environmental Protection Act 1986* (EP Act).

1.2 Proponent details

Proponent

City of Joondalup
PO Box 21
JOONDALUP WA 6919

Proponent contact

Garry Hunt
Chief Executive Officer

City of Joondalup
PO Box 21
JOONDALUP WA 6919
Phone: (08) 9400 4000
Email: info@joondalup.wa.gov.au

1.3 Purpose of document

This document has been prepared to provide supporting information for the referral of the Proposal to the Environmental Protection Authority (EPA) under section 38 (Part IV) of the EP Act. The information contained within this document is based on Proposal and study information available at the time of writing.

The document provides background information to the Proposal, describes proposed activities at the development site and key environmental characteristics. In accordance with the EPA EAG 8 (EPA 2013) it identifies the key environmental factors which are considered relevant to assessment of the potential impacts of the proposal and provides a preliminary scoping of impacts and proposed management actions for each factor.

The completed section 38 referral form is provided in Appendix 1.

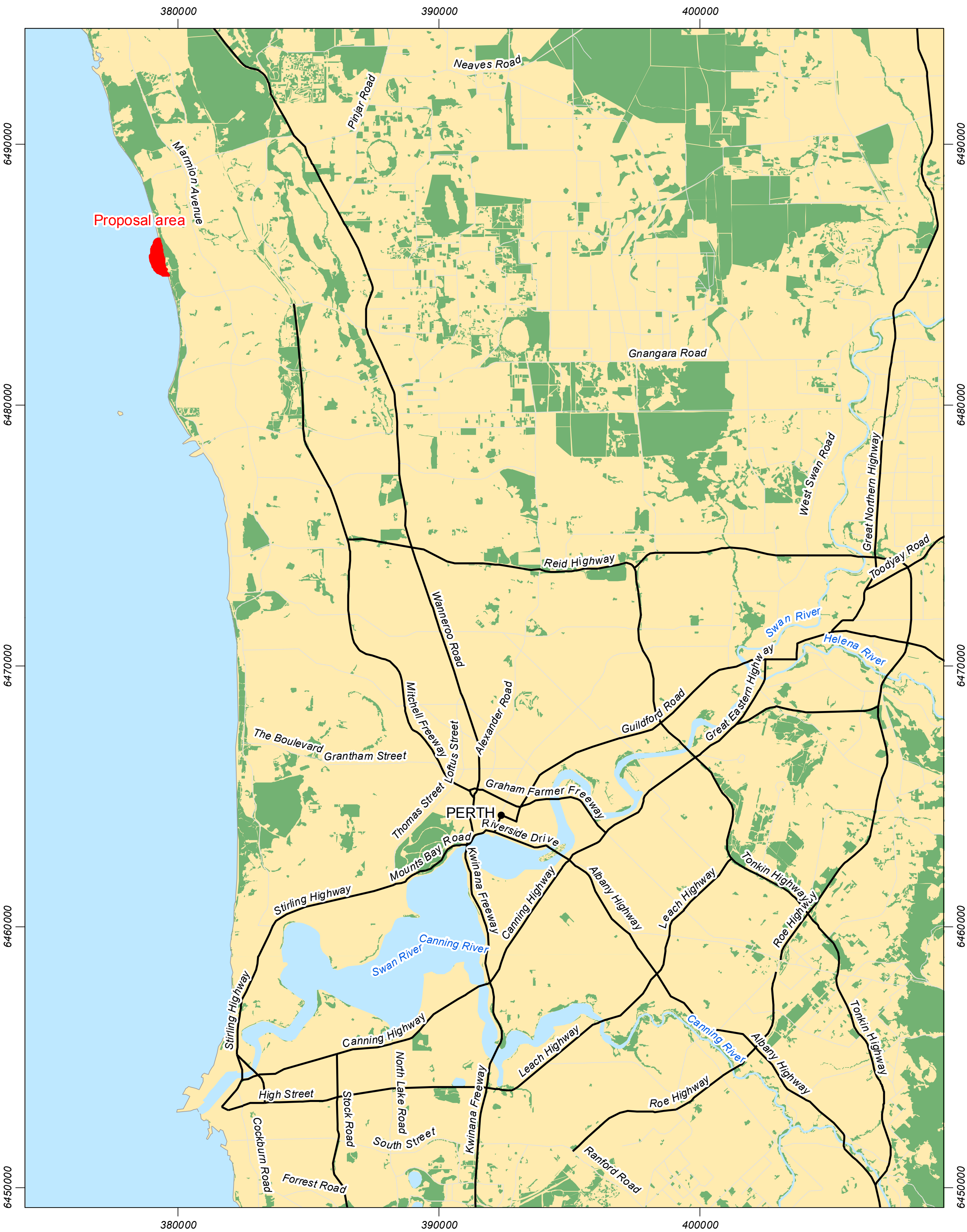

Figure 1 Location of the proposal

Scale 1:200,000 at A4

0 1 2 3 4 5 km

Coordinate System: GDA 1994 MGA Zone 50
Note that positional errors may occur in some areas
Date: 3/04/2014
Author: JCrute
Source: Topography: Geoscience Australia 2011.

Legend

- Town
- Major road
- Minor road
- Major river
- Lakes
- Native vegetation
- Proposal area

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CONCEPT PLAN 7.2A

Ocean Reef Marina MRS Amendment Report Executive Summary

A City of Joondalup Project

0m 50 100m

s: 1:6000@A4
d: 28 March 2014
p: 01/111/076

Taylor Burrell Barnett Town Planning and Design
187 Roberts Road Subiaco Western Australia 6008
p: (08) 9382 2911 f: (08) 9382 4586
e: admin@tbbplanning.com.au

Figure 2 Concept Plan

Date: 24/04/2014
Author: JCrute
Source: TBB 31/03/2014.

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2. Ocean Reef Marina Development overview

The Development has been the subject of debate for over 30 years with a range of plans being considered during this time. Planning for the Development was revitalised in 2004 with the State Government (former Department of Planning and Infrastructure) providing a financial contribution towards the development of a concept plan and structure plan aimed at transforming the Ocean Reef Boat Harbour into a world-class commercial and recreational marina.

The site was also identified as a future development site by the Western Australian Planning Commission (WAPC) in the Perth Coastal Planning Strategy (WAPC 2008) and the Perth Recreational Boating Facilities Study (DoP 2009).

Investigations into the design, feasibility and environmental considerations resulted in the production and Council endorsement of the current concept plan for the Development.

In 2012, the City executed a Memorandum of Understanding (MOU) with the State Government which acknowledges a joint appreciation of the importance of the Development and to set out the roles of each party in resolving ongoing issues related to its delivery. Co-signed by the Minister for Transport and the Minister for Planning, the MOU is an endorsement of the shared commitment of the parties to proceed collaboratively with the Development.

The Development has been identified as a Level 1 project within the State Government's Lead Agency Framework with the DoP identified as the responsible Lead Agency.

In accordance with the MOU, the City will prepare a Structure Plan that will be adopted under Part 9 of the City's District Planning Scheme No 2. The Structure Plan will provide additional detail on the concept plan to guide future development accordingly.

The City's Project Vision for the Development is articulated as:

- world class recreation, residential, boating, and tourist development
- sustainable community amenity
- social and economic benefit to all residents
- balance of public, residential and commercial amenities
- equitable facility for visitors and residents
- social and economic maximisation of land use.

The Development represents a logical advance in the planning for the land, which responds to the changing context of the site, particularly in relation to the planning for the Joondalup City Centre and coastline and the increasing focus on urban infill within the Perth Metropolitan area, while at the same time providing for the enhanced protection of sensitive environmental features on and adjacent to the site.

The concept plan (Figure 2) proposes a mixed use 'working marina' enabling club, service commercial and marine industrial uses in the north; a central retail, tourist and residential precinct; and a southern boating precinct inclusive of ramps, coastal amenities and parking. Specifically, the proposed development includes approximately 700 residential dwellings, 250 hotel/short suites and approximately 6,000 m² of retail/food & beverage, 2,700m² of future retail, 3,500 m² mixed use, 800 m² of commercial space in addition to civic and community uses and up to 750 boat pens/boat storage spaces.

3. Proposal

3.1 Proposal overview

The Proposal the subject of this referral involves the upgrade and expansion of the existing marina facilities at the Ocean Reef Boat Harbour. The high tide mark on the coast represents the boundary between the land-based component of the Development and the marine-based component to which this referral relates. The approximate high tide mark boundary is shown in Figure 3.

Facilities associated at the existing Ocean Reef Boat Harbour consist of:

- one large and one small limestone groyne
- eight boat launching ramps
- extensive car and boat trailer parking
- public toilets
- coastal recreation amenities
- facilities for the Whitfords Volunteer Sea Rescue Group
- facilities Ocean Reef Sea Sports Club
- informal walking tracks.

The upgrade and expansion proposed by the Proposal includes:

- construction of two new outer breakwaters
- removal of the existing breakwaters from the boat launching harbour
- dredging of sand and rock inside the harbour
- disposal of dredge spoil into land reclamations inside the breakwaters
- construction of jetties to support piled boat mooring pens.

The marina when completed will encapsulate approximately 32 ha of nearshore waters and associated marine habitats within Marmion Marine Park. The Proposal area encapsulates the disturbance footprint plus a 100 metre buffer (development envelope). The development envelope for the Proposal is shown in Figure 3.

The key characteristics of the Proposal are outlined in Table 1.

Table 1 Preliminary key proposal characteristics

Summary of the Proposal		
Proposal Title	Ocean Reef Marina Development	
Proponent Name	City of Joondalup	
Short Description	The Proposal includes: • construction of two new outer breakwaters • removal of the existing breakwaters from the boat launching harbour • dredging of sand and rock inside the harbour • disposal of dredge spoil into land reclamations inside the breakwaters • construction of jetties to support piled boat mooring pens.	
Physical elements		
Element	Proposed Location	Proposed maximum extent
Development envelope	Refer to Figure 3	55.32 ha
Marina Waterbody	Refer to Figure 2	32 ha
Reclamation area	Refer to Figure 2	8 ha
Dredging		4.5 ha

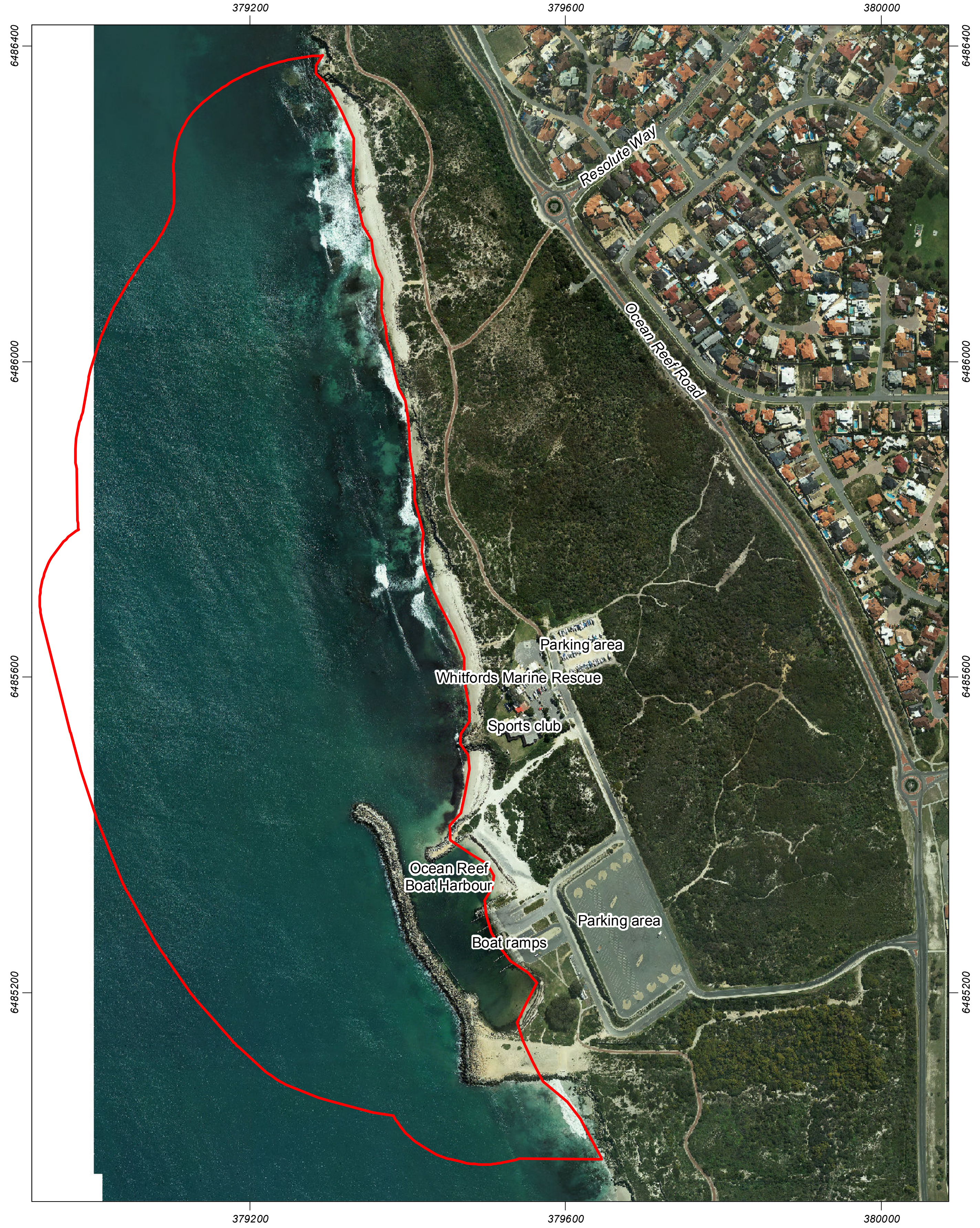

Figure 3 Proposal development envelope

Scale 1:6,600 at A4

0 40 80 120 160 200 m

Legend

Development envelope

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 21/05/2014

Author: JCrute

Source: Aerial image: Landgate 09/2012, downloaded 04/2013. Referral Area: CAD Resources 2013.

Path: Q:\Consult\2013\COJ\COJ13066\ArcMap_documents\R004\RevA\COJ13066_01_R004_RevA_F003.mxd

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3.2 Construction method

Proposed construction methods

Construction of the marina will initially require construction of the two new outer breakwaters, removal of the existing breakwaters from the boat launching harbour, dredging of sand and rock inside the harbour and disposal of dredge spoil into land reclamations inside the breakwaters. Once the land reclamation is completed, jetties will be constructed to support boat mooring pens for a range of vessel sizes.

Preliminary detail on the proposed construction activities has been developed by the project's engineers and is provided below.

Breakwaters

The Proposal includes approximately 1.7 km of rock breakwaters constructed in waters up to 9 m in depth. The proposed construction method is to use trucks to deliver rock to the site and deposit it into the water. The placement of the rock would be controlled by front end loaders and large hydraulic excavators. The rock armour and much of the rock core would come from quarries in the region. Some of the rock core would be obtained from the excavation work on site.

It is anticipated that the breakwaters would take 1 to 1.5 years to construct.

Reclamation

The Proposal includes approximately 8 ha of reclamation generally protected by limestone seawalls. The material used for reclamation will be mainly sand, gravel, and crushed rock excavated and dredged from the site. The proposed method would be to use trucks, front end loaders and hydraulic excavators to form the perimeter bund and seawall by end dumping and trimming with excavators. The remaining reclamation would be completed by dumping from trucks or pumping by dredger into the water behind the perimeter bund and seawall. The reclaimed area would be compacted at a number of stages in the works.

Reclamation is anticipated to take one year to complete and would start several months after the breakwaters have been commenced and provided shelter to the reclamation areas.

Dredging

The Proposal includes dredging over an area of approximately 4.5 ha of seabed within the breakwaters. This work may be done by floating or land based equipment working from temporary bunds. The materials being dredged include sands and rock. Floating equipment suitable for the work include cutter suction and dipper dredgers. Land based equipment would be hydraulic excavators and trucks. All dredged materials would be used for reclamation elsewhere on site.

The dredging works would likely take between 6 months and 1 year depending upon the equipment used by the construction contractor. The dredging works would commence when the main body of the breakwaters are providing substantial shelter to the dredged areas. This will provide suitable sea-state conditions for the dredging.

Piling

The Proposal includes pens for more than 600 boats, a few hundred metres of boardwalk, supported on piles, and several jetties. Initially only about 50 pens will be built by the proponent along with the boardwalks and a couple of the jetties. The remaining pens and jetties will be built progressively by various lease holders and land owners of areas in the Development.

The piling is likely to be predominantly tubular steel piles either driven into the seabed or placed in pre-drilled holes in the seabed. In recent years, there has been a large number of piles for recreational boat pens installed in WA using the drilling method rather than percussion pile driving methods.

3.3 Proposal schedule

The Proposal will initially require construction of two new outer breakwaters, removal of the existing breakwaters from the boat launching harbour, dredging of sand and rock inside the harbour and disposal of dredge spoil into land reclamations inside the breakwaters. It is anticipated that the breakwaters would take 1 to 1.5 years to construct. Once the breakwaters are completed, dredging and land reclamation will proceed for up to 12 months. Once land reclamation works have been completed, jetties and mooring pens will be constructed progressively over 10 years as demand requires.

4. Stakeholder consultation

The Development, in its current state, has been in planning since 2005. Extensive consultation has been undertaken with the community, State Government and other stakeholders.

The Ocean Reef Marina Government Steering Committee was established in 2007 comprising of representatives from the DoP, Department of Transport, Water Corporation, LandCorp and the City The purpose of the group has been to gather information from consultants and State Government agencies on the condition of the site and ownership of land parcels, and to identify possible development constraints and conditions.

Consultation has been undertaken with the following government departments/agencies:

- Minister of Transport
- Minister for Planning
- Representatives for the Minister for Lands
- Department of Premier & Cabinet
- Environmental Protection Authority (EPA)
- Office of the Environmental Protection Authority (OEPA)
- DoP
- WAPC
- Department of Environment Regulation (DER)
- Department of Transport (DoT)
- Department of Lands (DoL)
- LandCorp
- Department of the Environment (DotE) (C'wlth).

In addition, the Ocean Reef Marina Community Reference Group was established in 2008. Comprising local residents and representatives from interest groups, the group was formed to:

- help the City develop a concept design and structure plan for the Development
- ensure the issues and concerns of the community are adequately represented
- represent the interests of the wider community
- act as a conduit to disseminate information and feedback to and from the wider community
- liaise with extended networks and community groups to facilitate information sharing about the Development.

Several community surveys have been conducted to determine support for the Development and provide input into the planning process. Most significant was the community survey undertaken in 2009 from which over 11,000 responses were received by the City with 95.6% of respondents in support of the Development.

Consultation has also been conducted with various key commercial and recreational marine stakeholders including:

- Abalone Association of WA
- RecFish West
- Western Australian Fishing Industry Council (WAFIC).
- Department of Fisheries (DoF)
- Marine Parks and Reserves Authority (MPRA)
- Department of Parks and Wildlife (DPaW).

A summary of the key issues raised in relation to the Proposal during consultation undertaken to date is provided in Table 2.

Table 2 Summary of key consultation outcomes

Stakeholder	Method	Key issues / messages	Proposed approach / response
OEPA	Comments received in response to Ocean Reef MRS Amendment Request Report (TBB 2013)	Key comments included: • impacts to marina environmental quality and flow on effects to the environmental quality of Marmion Marine Park • groundwater inflows, nutrient loads and other contaminants (e.g. heavy metals and hydrocarbons) from drains and stormwater systems, marina flushing rates and resultant environmental quality require further assessment • potential impacts on marine fauna from construction activities such as dredging and piling • alteration of sediment and shoreline dynamics, resulting on localised erosion/deposition • referral of the marine component at the same time as initiation of the proposed MRS amendment would provide for the EPA to assess the marine proposal in parallel • need for ongoing long-term monitoring and management of environmental quality. Liability and ownership of the marina and ongoing environmental responsibilities also need to be addressed.	• detailed groundwater and flushing studies have been undertaken to inform the section 38 assessment process. Key studies will be peer reviewed • additional detail on construction activities is provided in Section 3.2. Marine mammal management plan will be prepared to manage potential construction impacts (refer to Section 11) • coastal process will be considered at a greater level through the section 38 assessment process (refer to Section 10) • the MRS amendment has recently been referred to the EPA under s48A of the EP Act • monitoring and management of the marina will be addressed through the s 38 assessment process (refer also to Section 9).
DPaW	Meeting and comments received in response to Ocean Reef MRS Amendment Request Report (TBB 2013)	Key comments included: • DPaW encourages early engagement in relation to marine survey and impact assessment studies • nutrient concentrations utilised for the Rockwater groundwater modelling report should be referred to the relevant technical branches within DoW and DoH for confirmation that TN and TP concentrations are considered appropriate to inform the modelling.	• a request for meeting with DPaW has been submitted to the MPRA Executive Officer • more recent contemporary groundwater nutrient concentration data will be obtained. The Rockwater report should be referred to the relevant technical branches within DoW and DoH (refer to Section 9).

Stakeholder	Method	Key issues / messages	Proposed approach / response
DoF	Initial meeting Correspondence providing overview of the Proposal.	Key comments included: • nearshore reef at Ocean Reef supports a significant portion of the commercial fishery for Roei Abalone • Fisheries Compensation Fund may not apply and the compensation mechanism has not yet been tested, however compensation value can be calculated • development of artificial reefs for abalone is technically feasible • potential for aquaculture of Roei's abalone exists; however, not yet proven • alternative offset option may be to open access to areas not currently available to commercial fishermen (e.g. Little Island and Waterman's reef) • important to determine offset preferences of Abalone Association, WAFIC and Recfishwest before engaging DoF to undertake work.	Strategen/CoJ agreed to determine position and offset preferences of Abalone Association, WAFIC and Recfishwest before engaging DoF to undertake work.
West Coast Abalone Divers Association (WCADA)	Meeting on 16/12/13 and follow-up correspondence 19/12/13 describing the Proposal and seeking confirmation of minutes of meeting.	Meeting minutes: • initial position is not supportive of the Proposal • nearshore reef between the Ocean Reef Boat Launching facility and Burns Beach is the most productive commercial fishing area for Roei's abalone in WA and provides two thirds of the annual catch • WCADA do not believe that artificial reefs and re-stocking with laboratory reared juveniles is feasible • WCADA preferred offset was financial compensation for loss of commercial stocks, but access to areas not currently open to commercial fishermen should also be considered • concern that the marina will adversely impact on commercial stocks to the north of the marina development footprint via increased sedimentation and reduced wrack accumulation.	Further consultation and engagement with WCADA on proposal. Investigations have into wrack accumulation and sedimentation (refer to Section 10). Commitment to engage DoF to determine value of compensation.
WA Fishing Industry Council (WAFIC)	A meeting held with WAFIC CEO on 20/1/14 where proposed project explained.	WAFIC to consult the WCADA plus other members of WAFIC and respond in May. To date no response has been received.	No response from WAFIC to date.

Stakeholder	Method	Key issues / messages	Proposed approach / response
RecFish West	Meeting with Recfishwest Executive Officer on 17/12/13.	The following advice was received: • supportive of the proposed development • recreational abalone fishermen would not support provision of access to commercial fishermen unless they were restricted to offshore portion of Waterman's reef • preferred offset for loss of nearshore reef fishing grounds is: o access within marina for recreational fishermen o development of artificial reef for finfish production offshore Ocean Reef.	Acknowledged Recfishwest position on proposed marina and offset suggestions.
MPRA	Comments received in response to Ocean Reef MRS Amendment Request Report (TBB 2013)	Key comments included: • current level of technical marine information is inadequate to make meaningful comment on this point • currency and relevance of the technical data that is available in the report was questioned • terrestrial and marine assessment processes should run in parallel to ensure that there is coordination across jurisdictions • if an excision from the current boundaries of the Marmion Marine Park is required for the development, there should be significant opportunities for marine offsets. The ideal outcome for the Marmion Marine Park would be a larger park with larger sanctuary areas.	• further marine studies are proposed to inform the S38 assessment. • the marina based components of the project is being referred pursuant to s 38 now that the MRS Amendment has been referred to the EPA pursuant to Section 48A. • offsets will be further considered and developed through the assessment process.

Consultation with key stakeholders will continue throughout the approvals, detailed design, construction and implementation stages of the Development.

A search of Department of Aboriginal Affairs (DAA) databases was conducted on the 2 April 2013. The site has been subjected to four Aboriginal Heritage surveys. No registered sites have been identified within the site. While consultation with Indigenous groups and stakeholders has not commenced at this stage, this will be undertaken by the City as part of the environmental impact assessment process.

Ongoing stakeholder consultation will continue throughout the life of the Proposal as part of normal business practice, providing updates to relevant stakeholders as required. The list of stakeholders will continue to be developed and revised as required.

5. Regulatory framework and environmental approvals

5.1 Planning context

The Metropolitan Region Scheme (MRS) prepared by the WAPC provides the statutory framework for land use in the Metropolitan Region.

The Development site is currently zoned Parks and Recreation (including Bush forever), Waterways and Public purposes under the MRS. Much of the subject site is identified in the MRS as Bush Forever although parcels of land within Site 325 are currently developed and entirely cleared of all vegetation.

An amendment to the MRS is proposed to rezone and rationalise approximately 76.5 ha in Ocean Reef from 'Parks and Recreation' (including some Bush Forever), Waterways and Public Purpose to Urban and additional Waterways zones and new Parks and Recreation Reserved Lands. The amendment also includes a proposal to exclude a parcel of water from the Marmion Marine Park.

The amendment is consistent with the MOU the City has signed with the Government of Western Australia. In accordance with the MOU, the City prepare a Structure Plan to be adopted under Part 9 of the City's District Planning Scheme No 2. The Structure Plan will provide additional detail on the concept plan to guide future development accordingly.

The terrestrial component of the Development will be referred by the WAPC under section 48A of the EP Act (referral of scheme) and is not discussed further in this document.

5.2 Western Australian environmental impact assessment process

The EP Act is the primary legislation that governs environmental impact assessment and protection in Western Australia. This Proposal, comprising the marine component of the Development only, is being referred to the EPA under s 38(1) of the EP Act (Refer Appendix 1).

State legislation and policies under which approvals will be sought or considered against include the following:

- *Wildlife Conservation Act 1950* (WA)
- EP Act (WA)
- *Conservation and Land Management Act 1984 (WA)*
- *Contaminated Sites Act 2003* (WA)
- *Transport Coordination Act 1966*
- *Local Government Act 1995* (WA)
- Development Control Policy DC 5.3 Use of Land Reserved for Parks and Recreation
- Statement of Planning Policy 2 Environment and Natural Resources Policy
- Statement of Planning Policy 2.6 State Coastal Planning Policy
- Draft Statement of Planning Policy 2.8 Bushland Policy
- ANZECC and ARMCANZ Guidelines for Fresh and Marine Water Quality (2002)
- National Ocean Disposal Guidelines for Dredged Material (2002)
- various EPA guidance statements.

5.3 Australian Government environmental impact assessment process

While the states and territories have responsibility for environmental matters at a state and local level, the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) aims to focus the Australian Government interests on protecting Matters of National Environmental Significance (MNES).

The EPBC Act requires an assessment as to whether a proposed action is likely to have a significant effect on a MNES.

The most relevant matter of MNES is that which aims to protect threatened species and ecological communities. The EPBC Act lists flora and fauna species that are either extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent. Ecological communities are listed that are critically endangered, endangered or vulnerable. An assessment requires determining the presence (either confirmed or likely) of listed threatened species and communities and the likelihood of significant impacts that may be posed by the proposed action.

The Development as a whole will also be referred to the Department of the Environment (DoE) under the EPBC Act. The key MNES relevant to the Development is Carnaby's Black-Cockatoo. While the likely impacts are not considered significant, a small amount (less than 1 ha) of potential foraging habitat may be impacted by the Development. The MNES which relate to this proposal (marine component only) include migratory and threatened marine fauna species such as the Humpback Whale, Great White Shark and Australian Sea Lion which are known to occur within nearshore metropolitan waters at various times of the year.

5.4 Consistency with environmental principles

In 2003, the EP Act was amended to include a core set of principles that are applied by the EPA in assessing proposals. These environmental protection principles listed in section 4A of the EP Act are:

- precautionary principle
- principle of intergenerational equity
- principle of the conservation of biological diversity and ecological integrity
- principle relating to improved valuation, pricing and incentive mechanisms
- principle of waste minimisation.

The City has considered these principles in its design and will continue to do so during implementation of the Proposal (Table 3).

Table 3 Principles of environmental protection

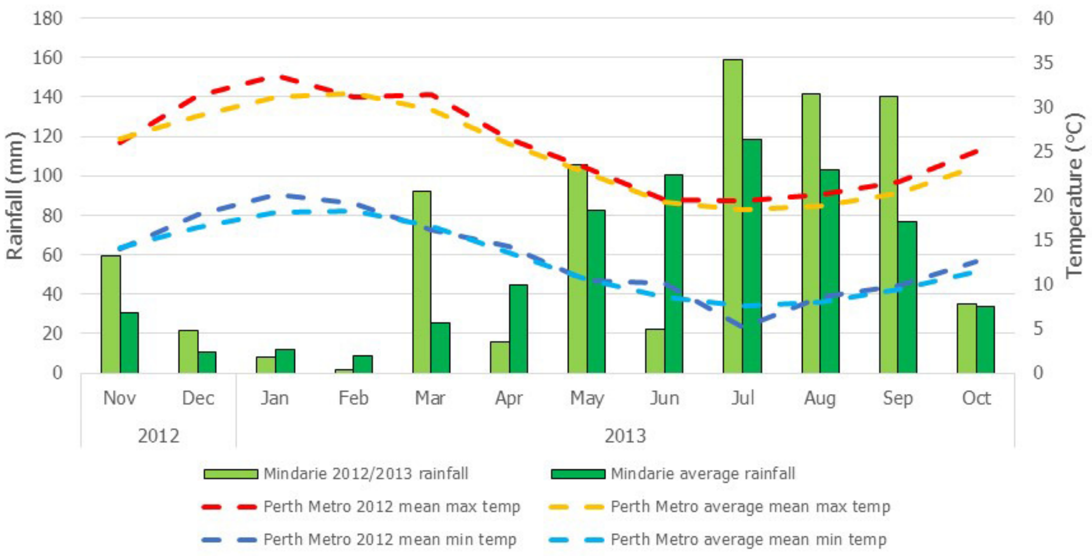
Principle	Consideration
1. Precautionary principle Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation. In the application of the precautionary principle, decisions should be guided by: - Careful evaluation to avoid, where practicable, serious or irreversible damage to the environment - An assessment of the risk-weighted consequences of various options.	Biological and technical studies will be undertaken to ensure that the potential effects of the Proposal have been appropriately identified and assessed. The results of these studies will be used in design and planning to ensure that appropriate management measures have been adopted to avoid, where practicable, and/or minimise potential effects. The current understanding of potential impacts and proposed management has been outlined in this supporting document. Precautionary principles have been applied to environmental impacts related to the Project with the intention of identifying issues early in the process to enable planning to avoid, prevent or manage effects. The Proposal will be designed to minimise potential effects to benthic communities and habitat, marine fauna, marine water quality and coastal processes.
2. Intergenerational equity The present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.	The Proposal will be designed to minimise potential effects to benthic communities and habitat, marine fauna, marine water quality and coastal processes and will ensure that the health, diversity and productivity of the environment is maintained and/or enhanced for the benefit of future generations.
3. Conservation of biological diversity and ecological integrity Conservation of biological diversity and ecological integrity should be a fundamental consideration.	Biological investigations will be undertaken to identify values of environmental conservation significance required to be protected from disturbance. The Proposal will be designed to minimise potential impacts to the key environmental values of the surrounding environment.
4. Improved valuation, pricing and incentives mechanisms Environmental factors should be included in the valuation of assets and services. The polluter pays principle – those who generate pollution and waste should bear the cost of containment, avoidance or abatement. The users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes. Environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentives structures, including market mechanisms, which enable those best placed to maximise benefits and/or minimise costs to develop their own solutions and responses to environmental problems.	The City acknowledges the need for valuation, pricing and incentive mechanisms and endeavours to pursue these principles when and wherever possible.
5. Waste minimisation All reasonable and practicable measures should be taken to minimise the generation of waste and its discharge into the environment.	Waste management will be consistent with the hierarchy of waste minimisation, that is: • avoid and reduce at source • reuse and recycle • treat and/or dispose.

6. Existing environment

6.1 Climate

The Swan Coastal Plain has a typically Mediterranean climate with hot, dry summers and mild wet winters. Annual rainfall ranges from a low of 700 mm to the north and rises to over 1000 mm at the base of the scarp to the south. Winter rains account for the majority of annual rainfall. Figure 4 details rainfall and temperature data from the closest and most representative recording stations to the survey area. Rainfall data was sourced from both Tamala Park (Mindarie) and the Wanneroo recording stations due to gaps in both data sets. Temperature data for 2013 was largely unavailable for surrounding recording stations, therefore the 2012 temperature data from the Perth Metro station are shown. Long term average rainfall and temperature data, together with monthly rainfall data for the period November 2012 to October 2013 are also shown (Mattiske 2013).

Figure 4 Rainfall and Temperature Data for the Tamala Park (Mindarie), Wanneroo and Perth Metro Recording Stations



6.2 Geological setting

The geological setting and subsurface units within the development envelope comprises of:

- Calcareous sands that form sandy beaches
- Tamala limestone outcrops that form the cliffs along the coast.

The presence of rocky coastal formations are characterised by a lack of sediment to form beaches, and are usually being eroded by various physical, chemical and biological processes, such as wind and wave action.

The land/water interface is primarily characterised by limestone cliffs and narrow beaches. Intertidal rocky areas are also present immediately to the north of the Whitfords Volunteer Sea Rescue Building and undercutting of rock faces is also apparent. The foredunes include those adjacent to beach areas and those above the limestone cliffs, and reach elevations ranging from 12 to 18 m AHD. In areas where there have been no modifications to the landscape, the inter-dunal swale between the foredune and secondary dunes is some 6 to 12 m AHD lower. Secondary dunes rise towards the rear of the site to an elevation of around 18 – 22 m AHD.

To the south of the Ocean Reef Sea Sports Club modifications to the topography have occurred as a result of constructing the groyne, boat launching facilities and the car park.

6.3 Overview of coastal processes

6.3.1 Waves

Preliminary investigations by Worley Parsons (2008) found that waves were from the SW, WSW and W sectors 98.5% of the time, and from the WSW sector 76% of the time. Significant wave heights (H_s) ranged between 0.5-1 m 35% of the time, 1-1.5 m 48% of the time and 1.5-2.0 m 12% of the time. The study predicted waves to have periods less than 10 s 9% of the time, 10-12 s 29% of the time, and 12-14 s 53% of the time.

Waves tend to be smaller in summer and predominantly from the SW and WSW sectors. In winter, waves are generally larger and of longer period, encroaching mostly from the WSW and W sectors (Worley Parsons 2008).

Coastal design is generally undertaken for the 50-year return period conditions. The 50-year significant wave height at Ocean Reef is expected to be of the order of H_s=5.0-5.5 m (Worley Parsons 2008).

6.3.2 Wind

The wind climate of the Perth metropolitan coastal waters is controlled at a regional level by annual movement of the anticyclonic belt. At a local level, the wind regime is strongly dominated by the effects of the land-sea interface where offshore land breezes (easterly) are common in the morning and afternoon sea breezes (south-southwest) are common in the warmer months. T he greatest variability in winds generally occurs in winter due to the mobility of the sub-tropical ridge, and a weak land-sea temperature contrast (Worley Parsons 2008).

6.3.3 Water levels

The magnitude of tidal variation in Perth metropolitan coastal waters is small, with a tidal range of typically around 0.5 m. T ides are predominantly diurnal but sea level is also influenced by the passage of pressure systems and associated storm surges (typically 0.3 m up to 0.9 m) The Leeuwin current typically increases water levels in winter by 0.2 m (Worley Parsons 2008).

A common Storm Surge Water Level used in design on the Perth Metropolitan Coastline is +1.9 m CD, equivalent to cyclone Alby, assumed to be the approximate 50-year design condition (Worley Parsons 2008).

6.3.4 Currents

Tidal currents in the Perth metropolitan coastal waters are generally relatively weak due to the small tidal range. Currents tend to be predominantly wind driven, typically reaching speeds of up to 0.2 m/s (Worley Parsons 2008).

6.4 Marmion Marine Park

While the existing Ocean Reef Boat Harbour is located outside the boundaries of the Marmion Marine Park, the Proposal will extend into the boundaries of the Marine Park (Figure 5).

The Marmion Marine Park was reserved on 13 March, 1987, as an 'A' class reserve. It is vested in the Marine Parks and Reserves Authority (MPRA) under the provisions of the *Conservation and Land Management Act 1984*. The MPRA is a statutory body reporting to the Minister for the Environment. Management of the Marmion Marine Park is undertaken by DPaW on behalf of the MPRA.

The Marmion Marine Park Management Plan 1992-2002 (DCLM 1992) was approved in January 1992. The Management Plan identifies the conservation values of the Marine Park as being:

- rich and diverse marine communities that represent a variety of marine habitats
- invertebrate species of special interest (e.g., the cowry shells *Cypraea venusta* and *Cypraea friendii*)
- habitats for marine mammals, such as sea lions, dolphins and whales
- seagrass beds in the shallow lagoons that contribute to energy flows in coastal ecosystems
- natural marine features supplement attractive coastal panoramas
- shipwrecks, such as the historic 'Centaur', are located in Marine Park waters
- a suite of marine species and habitats characteristic of Western Australia's mid-west coast, that contribute to the biodiversity and overall conservation value of the marine reserve estate. The Marine Park has high habitat diversity due to the variation in geomorphology, substrate, water depth, and exposure to wave energy and light. These habitats may be classified into five broad categories:
  - Lagoon Subtidal Sandy Sea Floor
  - Lagoon Subtidal Limestone Pavement
  - Lagoon Intertidal Reefs and Little Island
  - Near shore Reefs and Intertidal Onshore Rock Platforms
  - Offshore Shallow Limestone Reefs.

The distribution of marine habitats within Marmion Marine Park is shown in Figure 7.

The portion of the Marine Park affected by the proposal is classified as a “general” management zone under the Marmion Marine Park Management Plan 1992-2002 (DCLM 1992).

The Management Plan recognises that future development is planned for the Ocean Reef Boat Harbour and notes that this would change its existing status under the Marine Park. While the Management Plan discourages the construction of marinas in the Marine Park, it does not preclude such development and states that any marina development would be subject to environmental impact assessment in accordance with the EP Act.

The MPRA Audit subcommittee completed a ten year assessment of the implementation of the Management Plan in 2012/13.

The principal findings of the review were:

- despite the urban setting of the Marine Park and the subsequent pressures acting upon it, the Marine Park is generally in good condition with the exception of targeted finfish
- management by DPaW appears to be efficient and effective within the limits of the allocated resources
- the Department of Fisheries receives no funding to undertake marine park specific management activities. Patrols and enforcement is undertaken on an opportunistic basis as part of metropolitan wide compliance activities and this activity focuses on the core Fisheries of recreational and commercial abalone, rock lobster and finfish.

The audit found that the overall condition of the reserves is good, and the management system operates efficiently despite a historical lack of resources.

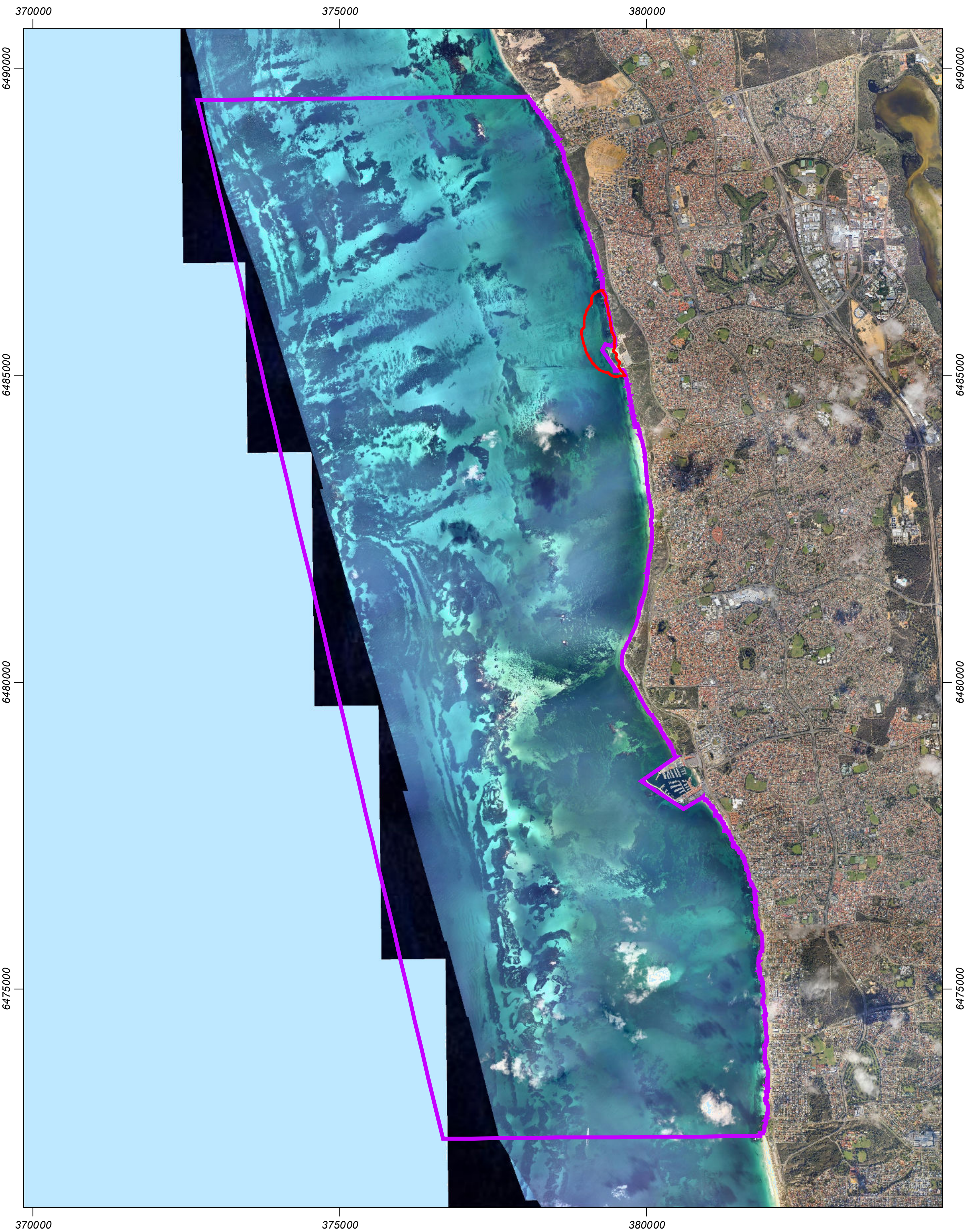


Figure 5 Development envelope within Marmion Marine Park

Scale 1:85,000 at A4

0 0.5 1 1.5 2 2.5 km

N

Coordinate System: GDA 1994 MGA Zone 50
Note that positional errors may occur in some areas
Date: 21/05/2014
Author: JCrute
Source: Aerial image: Nearmap 2012. Referral Area: CAD Resources 2013. Marine Park: DEC 2012.
Path: Q:\Consult\2013\COJ\COJ13066\ArcMap_documents\R004\RevA\COJ13066_01_R004_RevA_F005.mxd

Legend

- Development envelope
- Marmion Marine Park

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info@strategen.com.au
www.strategen.com.au

7. Framework for environmental impact assessment

In reaching a decision as to whether a proposal is likely to have a significant effect on the environment, whether it is likely to meet its objectives for environmental factors and consequently whether a referred proposal should be assessed under Part IV of the EP Act, the EPA may have regard to the following:

- values, sensitivity and quality of the environment which is likely to be affected
- extent (intensity, duration, magnitude and geographic footprint) of the likely impacts
- consequence of the likely impacts (or change)
- resilience of the environment to cope with the impacts or changes
- cumulative impact with other projects
- level of confidence in the prediction of impacts and the success of proposed mitigation
- objectives of the Act, policies, guidelines, procedures and standards against which a proposal can be assessed
- presence of strategic planning framework
- presence of other statutory decision-making processes which regulate the mitigation of the potential effects on the environment to meet the EPA objectives and principles for EIA
- public concern about the likely effect of the proposal, if implemented, on the environment.

This document has been prepared taking into consideration the above criteria.

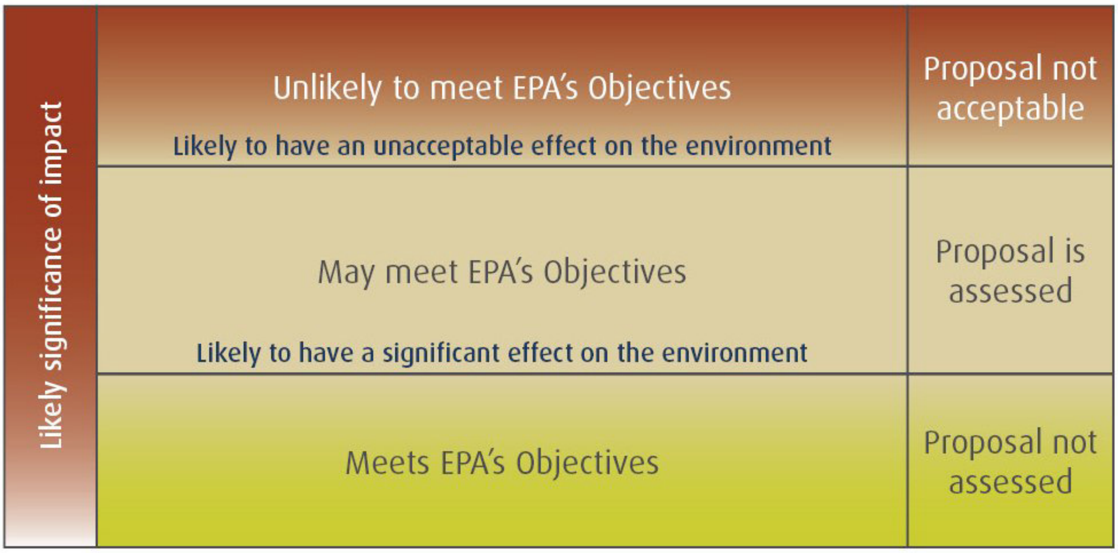
The key potential environmental impacts associated with the Proposal include:

- loss of marine benthic primary producer habitat
- direct and indirect impacts on marine fauna
- effect of the loss of marine benthic primary producer habitat on the conservation values of the Marmion Marine Park, including recreational and commercial fisheries
- reduction in marine water quality as a result of marina construction and operation
- interruption of coastal processes and changes to nearshore ecosystem and foreshore stability.

7.1 Significance framework

In accordance with EAG 9 (EPA 2013b), this referral identifies those aspects and impacts considered likely to be relevant to the Proposal to assist the EPA in determining whether or not the Proposal should be assessed, based on the likely significance of impact of the Proposal on the environment determined against the EPA’s objectives for each environmental factor (Figure 6).

Figure 6 EPA framework for decision-making



Relevant preliminary environmental factors and issues have been identified based on pre-referral consultation and guidance from regulatory agencies such Office of EPA, DoF, DPaW, DoP and DER, the results of relevant studies, as well the experience and advice of the City and the range of environmental consultants engaged to undertake environmental assessments and investigations relating to the Proposal.

The preliminary environmental factors identified as relevant to the Proposal in accordance with EAG 8 (EPA 2013a), include the following:

- benthic communities and habitat
- marine environmental water quality
- coastal processes
- marine fauna
- integrating factor - offsets.

These are discussed in Sections 8 to 12. Given that there are likely to be several key environmental factors relevant to the Proposal, it is anticipated that a Public Environmental Review (PER) level of assessment will be determined. Further studies and investigations are proposed to enable an assessment of the Proposal on those identified environmental factors to support the environmental review documentation.

Other factors and issues recognised as potentially requiring consideration and management as part of the environmental impact assessment process include the following:

- recreational access to the coast
- heritage
- commercial and recreational fisheries.

8. Benthic Communities and Habitat

8.1 Assessment framework

8.1.1 EPA objective

The EPA objective relevant to this factor is:

> *To maintain the structure, function, diversity, distribution and viability of benthic communities and habitats at local and regional scales.*

8.1.2 Relevant legislation, policy and guidance

EPA Environmental Assessment Guidelines No. 3

EPA Environmental Assessment Guideline No. 3 '*Protection of Benthic Primary Producer Habitats in Western Australia's Marine Environment'* (EAG 3; EPA 2009) recognises the fundamental ecological importance of Benthic Primary Producer Habitat (BPPH) and the potential consequences of their loss for marine ecological integrity. BPPHs are defined as seabed communities within which algae, seagrass, mangroves, corals or mixtures of these groups are prominent components and also include areas of the seabed that can support these communities.

EAG 3 identifies a hierarchy of general principles of assessment in relation to the protection of BPPH (EPA 2009):

- Principle 1: Demonstrate consideration of options to avoid damage/loss of BPPH
- Principle 2: Design to minimise loss of BPPH and justify unavoidable loss of BPPH
- Principle 3: Best practicable design/construction/management to minimise BPPH loss.

EAG 3 also defines Ecosystem Protection Categories, based on defined criteria related to perceived conservation value, and provides Cumulative Loss Guidelines (CLG) for each category. The protection category and CLG which apply to Marmion Marine Park are one of the highest = 1%. The CLG is applied to a Loss Assessment Unit which for the purposes of this proposal is the boundary of the Marmion Marine Park.

EPA Environmental Assessment Guidelines No. 7

EPA Environmental Assessment Guideline No. 7 '*Environmental Assessment Guideline for Marine Dredging Proposals'* (EAG 7, EPA 2011) sets out guidance for predicting impacts to benthic communities and habitats due to significant dredging activities, to ensure these are presented in a clear and consistent manner.

8.2 Potential sources of impact

The following aspects of the Proposal may affect benthic community and habitat values:

- **direct removal of benthic habitat** and communities to allow for the construction of the marina waterbody and breakwaters providing access to the marina
- **indirect impacts to benthic habitat and communities** due to altered sediment movement and flows caused by breakwaters
- **alteration in marine water quality** during construction and ongoing operation of the marina
- **increased risk of introduced marine species** due to increased numbers of large recreational vessels berthing in the marina.

Potential impacts on benthic communities and habitat due to altered water quality impacts are discussed in Section 9.

8.3 Overview of existing studies and information

A suite of marine species and habitats characteristic of Western Australia's mid-west coast contribute to the biodiversity and overall conservation value of the marine reserve estate. The Marmion Marine Park has high habitat diversity due to the variation in geomorphology, substrate, water depth, and exposure to wave energy and light. These habitats may be classified into five broad categories:

- Lagoon Subtidal Sandy Sea Floor
- Lagoon Subtidal Limestone Pavement
- Lagoon Intertidal Reefs and Little Island
- Near shore Reefs and Intertidal Onshore Rock Platforms
- Offshore Shallow Limestone Reefs.

Marine habitats in the area include intertidal reef platforms, coastal sand beaches, a high limestone reef about 1 km from the coast, Little Island, and the Centaur Reef/Three Mile Reef system (Marmion Reefs) about 4 km offshore. Of note are complex assemblages of sea floor communities including seagrass meadows and algal limestone pavement communities.

The current known distribution of marine habitats within the Marmion Marine Park is presented in Figure 7. This mapping is over 10 years old and while it is unlikely to accurately represent the present distribution of subtidal lagoonal sand and seagrass habitats in the immediate vicinity of the proposal; however, it does present a reasonably accurate distribution of the various intertidal reef habitat types.

To determine the approximate loss of marine habitat likely to result from the proposed development, the Proposal boundary (Figure 3) was overlaid with existing marine benthic habitat mapping (DEC 2003) in Figure 7.

Preliminary calculations indicate the Proposal may result in a loss of:

- approximately 8.7% of the total near shore reef habitat in Marmion Marine Park
- a very small area of seagrass habitat and some bare sand habitat (<0.1% of available habitat).

The removal of the nearshore reef habitat from the park will require a rigorous assessment of impact on both conservation values and ecosystem function and integrity of the Marine Park. To some extent, lost habitat will be replaced by the breakwaters which enclose the marina. It may also be possible to construct the outside walls of the breakwaters to more accurately replicate this habitat by including intertidally exposed platforms of limestone rock as part of the design. Such a design may not only offset the loss of the habitat, but may also offset the loss of some of the commercially important marine organisms that live on this habitat.

8.3.1 Abalone and lobster stocks

The nearshore reef which occurs immediately north of the existing Ocean Reef Boat Harbour supports commercial and recreational stocks of Roe's Abalone (*Halliotis roei*) and juvenile Western rock lobster (*Panulirus cygnus*). This reef, which runs north to Burns Beach is understood to be the most productive in the metropolitan area (A. Hart, DoF pers comm) and is particularly accessible to recreational fishermen. The DoF State of the Fisheries Report 2012-2013 indicated that the abalone fishery netted approximately 46 tonnes within the west coast region during that period.

The principal commercial fishery in the West Coast Bioregion (including the marine environment from Kalbarri to Augusta) was reported to be the Western rock lobster (DoF 2013). The coastal reef within the development envelope potentially supports juvenile rock lobster habitat however, mapping of the overall Marmion Marine Park indicates there is a very large amount of rock lobster habitat in the region.

8.4 Proposed further studies and investigations

As part of the environmental impact assessment process, detailed marine habitat characterisation and mapping will be undertaken along with a desktop review of all existing water quality data relevant to the study area. Available habitat mapping and aerial photography will be reviewed for comparison with existing DPaW mapping of marine habitat distribution within the Marmion Marine Park to enable a subsequent benthic habitat loss assessment as required under EAG 3 (EPA 2009) and EAG 7 (EPA 2011). A validated hydrodynamic model will be developed to simulate the dispersion of sediment fines during marina dredging and land reclamation activities. Results of the model will also be used to inform the benthic habitat loss assessment (refer Water Quality Section 9).

Available habitat mapping and aerial photography will be reviewed to determine the current adequacy and accuracy of available mapping for a three kilometre seafloor area around the Proposal. Mapping will be compared to the current available DPaW maps, with the finalised habitat map completed to a scale adequate to determine the loss (if any) of benthic habitat within the Marmion Marine Park.

Existing marina breakwaters within and near the Marmion Marine Park are to be inspected and characterised in terms of biotic complement relative to the natural nearshore reef habitat . The study will focus on colonisation by rock lobster and abalone, including identifying the characteristics of nearshore reefs which support the greatest abundance of abalone for incorporation into breakwater design. A professional abalone diver will accompany the dive team during surveys to identify abalone habitats for characterisation on the nearshore reef and existing breakwaters in the region.

The survey will gather microsite habitat characterisation information that may provide useful contextual information for designing artificial reef structures. Characterisation of habitats for both rock lobster and abalone will include the use of towed video surveys.

It is also proposed to engage DoF to determine the importance of the abalone stocks within the development envelope to ensure maintenance of the fishery and the local population of the species. The advice of DoF will also be sought on the value of compensation to commercial abalone fishermen for loss of abalone stocks.

The results of the above studies will be incorporated into the environmental review documentation prepared for the Proposal.

8.5 Proposed management actions

Preliminary management actions proposed to minimise the impacts to benthic communities and habitat from the Proposal include:

1. Preparation of a comprehensive Construction Monitoring and Management Plan that includes relevant baseline information, protocols for monitoring of water quality and benthic habitat during construction and construction management measures.
2. Preparation of a Marine Environmental Quality Management Plan to manage water quality during operation of the Proposal. Dredging and land reclamation activities will only commence once the breakwaters are completed. Experience with other recent marina constructions indicate that it should be relatively unproblematic to contain water turbidity inside the marina and in its immediate locality.
3. Examine opportunities for potential offsetting of nearshore abalone habitat loss through the incorporation of new artificial intertidal reef habitat into the design of the marina breakwaters.
4. Examine opportunities for seed stocking of existing reefs and artificial reefs with artificially reared juvenile abalone.
5. Examine opportunities for compensating commercial abalone fishermen for loss of stocks.
6. Examine opportunities for extending the boundary of the marine park northwards to incorporate additional nearshore reef in the vicinity of Quinns Rocks.

Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.

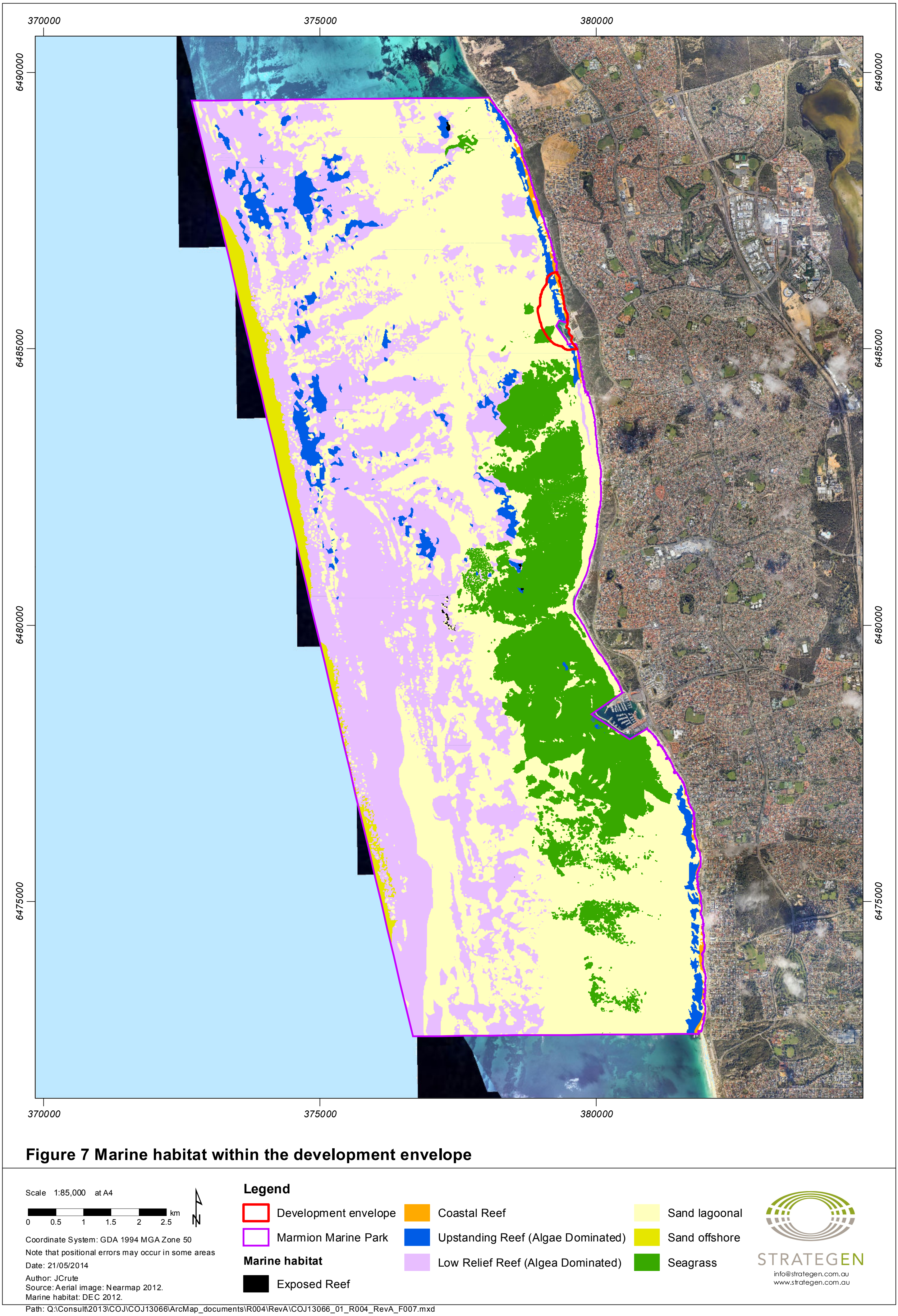


Figure 7 Marine habitat within the development envelope

Coordinate System: GDA 1994 MGA Zone 50
Note that positional errors may occur in some areas
Date: 21/05/2014
Author: JCrute
Source: Aerial image: Nearmap 2012.
Marine habitat: DEC 2012.
Path: Q:\Consult\2013\COJ\COJ13066\ArcMap_documents\R004\RevA\COJ13066_01_R004_RevA_F007.mxd

9. Marine water quality

9.1 Assessment framework

9.1.1 EPA objective

The EPA environmental objective for marine water quality is:

To maintain the quality of water, sediment and biota so that the environmental values, both ecological and social, are protected.

9.1.2 Relevant legislation, policy and guidance

WAPC Policy Number DC1.8

WAPC Policy Number DC1.8 provides general guidelines that apply to artificial waterways and to their adjacent natural waters and/or source water. If the source water does not meet these requirements, a canal estate proposal for that location is considered inappropriate.

National Health and Medical Research Council Guidelines

The aim of the NHMRC Guidelines for Managing Risks in Recreational Water (NHMRC 2008) is to protect the health of the public from threats posed by the recreational use of coastal, estuarine and fresh waters. The guidelines are not mandatory but are a tool to be used by State and Territory Governments to assist in developing legislation, policy and standards appropriate for local conditions. These guidelines therefore support the Cockburn Sound SEP and WAPC Policy Number DC1.8, with a focus on microbial water quality (faecal contamination); cyanobacteria and algae; chemical hazards; and aesthetics.

Contaminated Sites Act 2003

The Proposal will involve the dredging of sediments at Ocean Reef to create navigable water and provide fill for the land reclamation. While considered unlikely, these sediments may contain contaminants from past or present boating activities. Marine sediment contamination in state waters (as well as contamination in terrestrial soils) is addressed under the *Contaminated Sites Act 2003* (CS Act).

National Assessment Guidelines for Dredging (NAGD)

Although sea dumping of dredged material is not planned as part of the Proposal, the NAGD (Commonwealth of Australia 2009) provide a reference for the assessment and management of dredging operations i.e. the potential impacts on the receiving marine environment from the disturbance of the sediment and the sediment metals, nutrients and hydrocarbons. The NAGD criteria for sediment quality are based on the national environmental quality criteria for sediments (ANZECC/ARMCANZ 2000).

9.2 Potential sources of impact

The following aspects of the Proposal may affect marine water quality:

- **dredging** to allow for the construction of the marina waterbody may temporarily affect water quality due to increased turbidity and the release of any nutrients and contaminants in dredged sediments
- **seepage of return water from bunded areas used for temporary storage of dredged sediments** which may temporarily impact water quality due to increased turbidity and the release of nutrients and contaminants in dredged sediments

- **placement of limestone for the marina breakwaters and leaching of fines from the limestone** causing temporary turbidity during and after the limestone is placed
- **outflow of marina waters** into adjacent marine waters may result in changes in turbidity, nutrients and/or contaminants which in turn may adversely affect marine ecology and function
- **increased boat numbers** increasing the potential for pollution.

9.3 Overview of existing information

During the development of the concept plan, marina water quality was identified as a key environmental consideration. Consequently, detailed water quality investigations were completed by coastal engineers, MP Rogers & Associates (2011).

The detailed investigations included the following field measurements at the existing Ocean Reef Boat Harbour:

- flushing characteristics of the existing Ocean Reef Boat Harbour using Rhodamine dye release and monitoring
- measurements of the surface waves, ocean water levels and currents throughout the water column near the existing harbour
- conductivity, temperature and density measurements throughout the existing harbour.

The existing Ocean Reef Boat Harbour was found to have vigorous flushing with typical e-folding times in the order of 2 to 3 days. The main physical mechanisms driving the water circulation and exchange with the adjacent ocean were tidal movements, wind driven currents and density currents primarily driven by the flow of fresh ground water into the saline harbour water. The last of these mechanisms can be very significant in water circulation and exchange in a harbour. The field measurements were used to calibrate and validate the computer modelling of the hydrodynamics and flushing of the existing Ocean Reef Boat Harbour. The validated models were then used to examine the flushing of the proposed marina (Figure 2).

The existing Hillarys Boat Harbour, approximately 7 km to the south of the subject site, is similar in size to the proposed marina. Hillarys Boat Harbour also has a single entrance configuration and investigations into the flushing of the harbour by Imberger & Schwartz (1988 in MP Rogers & Associates 2011) showed that the flushing time was order of five days. This was substantially quicker than the initial estimate of flushing time based on tidal exchange alone which was of the order of 11 days.

The investigation by Imberger & Schwartz (1988 in MP Rogers & Associates 2011) indicated that the flushing of the waterway was also driven by variations in the water density, due to the lower salinity groundwater flowing into the harbour. This density driven exchange was particularly active during calm periods when stratification of the water column could persist and was not broken down due to wind mixing of the water column.

In order to properly account for the inflow of groundwater into the proposed marina, specialist groundwater hydrologists Rockwater were engaged to assess the inflow of groundwater for the pre-existing coast within the Ocean Reef Boat Harbour and also provide computer modelling of the groundwater inflows with the proposed marina in place. The data, methods, computer programs and results of the groundwater investigations are presented in Rockwater (2011) (refer to Appendix 2) and are summarised below.

Ocean Reef is predominantly in an area of Tamala Limestone. Tamala Limestone is karstic in nature and has high permeability. Groundwater is recharged through rainfall infiltration and losses are from discharges to the ocean, evaporation and transpiration from lakes and extraction from groundwater bores.

In the Ocean Reef area, the groundwater table has an elevation of approximately 45 m AHD at Lake Mariginiup and decreases to sea level at the coastline. Previous investigations along the metropolitan Perth coastline have indicated that most of the groundwater flow discharges into the ocean offshore within 20 m to 30 m of the shoreline. Within Tamala Limestone, flow rates are largely controlled by the location and degree of interconnection of solution channels within the limestone formation. Previous studies near Ocean Reef have indicated groundwater flow velocities of between 85 and 355 m/year.

The groundwater model was calibrated to water level changes measured in eight representative groundwater monitoring bores that have been monitored from 1987 to 2010 and gave a good spread over the model domain. The calibrated model was then used to determine groundwater flows to the existing Ocean Reef Boat Harbour, the ocean along the section of coast proposed to be enclosed by and within the proposed marina once it has been constructed.

The groundwater model estimated that the small existing boat harbour has between 1,200 and 2,300 m^3/day of groundwater inflow throughout the year. The existing coastline that would be enclosed by the proposed marina would have between 4,700 and 8,100 m^3/day of groundwater flow throughout the year. The construction of the proposed marina would only slightly affect the groundwater inflow to the coastal waters. The model results were for between 4,900 and 8,300 m^3/day of groundwater inflow. In each case, the lowest groundwater inflow would be at the end of summer / beginning of autumn and the maximum groundwater inflow would be at the end of winter / beginning of spring.

These are significant groundwater inflows and would be a very important contribution to the water circulation and flushing of the proposed marina. Rockwater (2011) also provided estimates of the Nitrogen and Phosphorous in the groundwater inflows for end of summer and end of winter. The total influx of nutrients to the proposed marina was estimated to vary between 16 and 28 kg/day for Total Nitrogen and 0.4 and 0.7 kg/day for Total Phosphorous. The larger values would be during the larger groundwater flows, i.e. end of winter / early spring. The groundwater flows and nutrient loads provided by Rockwater (2011) were then used in the hydrodynamic and water quality modelling.

Supporting information provided to MP Rogers & Associates by Asia-Pacific Applied Science Associates (APASA) set up and calibrated the Delft 3D Flow hydrodynamic model of the existing Ocean Reef Boat Harbour to match the results of the field measurements of the water levels, water currents, and dye dispersion. The groundwater inflows for the model were those calculated by Rockwater (2011).

The calibrated model was then used to examine the performance of the proposed marina. In total, six cases were modelled – two for summer, autumn and winter metocean conditions. The maximum flushing rates from the modelling was about four days. The modelling clearly showed the benefit of the groundwater inflows creating density currents that quickly flushed the proposed marina. During periods of strong winds, the density structure in the water column would be reduced due to the wind mixing of the water column. However, the same strong winds would tend to mix the entire water body and enhance effective flushing by the tidal exchange. Consequently, different mechanisms would dominate the mixing and flushing for the various metocean conditions. The effective flushing time of about four days is comparable to that measured by Imberger & Schwartz at Hillarys Boat Harbour.

Nitrogen and phosphorus were modelled as conservative tracers, a simple approach which is typically used for short to medium term water quality modelling. This approach does not account for release of nutrients from sediments and decaying organic matter or for the uptake by biological processes. This methodology is generally used for initial water quality risk assessments.

ANZECC (2000) provides default trigger values for inshore marine ecosystems in south west Australia. These are:

- Total Nitrogen (TN) 0.23 mg/L annually
- Total Phosphorus (TP) 0.02 mg/L in summer; 0.04 mg/L in winter.

ANZECC suggests that these values should be compared against the 80th percentile as a default. The worst case 80th percentile results for TN and TP within the proposed marina were:

- TN 0.15 (mg/L) winter
- TP 0.0037 (mg/L) winter.

Even under the worst nutrient loading conditions at the end of the winter months, the predicted concentration values within the proposed marina are less than the guideline trigger values. Therefore, the effect of the proposed marina on the wider nutrient concentrations of Whitfords lagoon is expected to be minimal. These levels could be put into context further by measuring seasonal background levels of nutrients within the groundwater bores and surrounding Whitfords Lagoon.

The concentrations of TN and TP provided are due to the groundwater contribution only. It is possible that other sources may produce inputs of TN and TP to the marina area. Best practice management of stormwater runoff, water birds, irrigation, and fertiliser techniques should be undertaken within the development to minimise additional TN and TP inputs to the proposed marina. In addition, a reticulated sewerage system is required in conjunction with banning all sullage discharges from visitor and moored boats into the waterbody.

The water quality investigations have been extensive and the calibrated and verified hydrodynamic modelling shows that the proposed marina would have good flushing characteristics and the flushing time would generally be in the order of four days or less. This is similar to that experienced at Hillarys Boat Harbour. In addition, the nutrients in the groundwater inflow would be effectively flushed out of the marina and the resultant concentrations would be generally less than the ANZECC suggested trigger values.

9.4 Further studies and investigations

Rigorous mathematical modelling investigations have been undertaken which are described above. While this information is considered adequate for impact assessment purposes, it is proposed to confirm the reliability of the findings by:

1. Obtaining contemporary groundwater nutrient samples from the site to confirm that concentrations used in the model are indeed representative of present day concentrations.
2. Obtaining a peer review of the modelling investigations and findings.

Hydrodynamic modelling will also be undertaken to determine the temporal and spatial scale of turbidity impacts on adjacent BPPH arising from dredging and land reclamation and occasional maintenance dredging associated with the construction and operation of the proposed marina. The scope of works for these additional investigations includes the following:

- review all existing water quality data for the study area including Beenyup outfall, Ocean Reef Boat Harbour, Hillary's boat harbour and Mindarie Marina
- develop a mathematical hydrodynamic model that simulates circulation within the marine park and can be used to determine dispersion of fine sediments
- validate model against measured data
- undertake modelling of worst case dispersal conditions and assess potential impacts of water discharges from the marina during construction (land reclamation turbidity).

9.5 Proposed management actions

Management actions proposed to minimise the impacts to water quality from the Proposal include:

1. Preparation of a Construction Monitoring and Management Plan addressing baseline information, protocols for monitoring of water quality during construction and construction management measures.
2. The proposed marina will have good flushing and acceptable nutrient levels. The Marine will be designed and managed to prevent any other nutrients or pollutants from entering the waterbody. A Water and Sediment Quality Monitoring and Management Plan will be established and implemented to ensure that the water quality meets the intended uses and guidelines.
3. Preparation of a Marine Environmental Quality Management Plan to manage marine water quality during operation of the Proposal.
4. Maximising circulation and exchange (design factors), managing discharges from vessels and support services and minimising stormwater contaminant inputs to protect water quality within the proposed marina.
5. Use of 'best practice' measures and strict regulations to ensure minimal inputs of contaminants to the marine environment.

Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.

10. Coastal processes

10.1 Assessment framework

The EPA environmental objective for coastal processes is:

To maintain the morphology of the subtidal, intertidal and supratidal zones and the local geophysical processes that shape them.

10.2 Relevant legislation, policy and guidance

Planning and Development Act 2005

The *Planning and Development Act 2005* (PD Act) provides for a system of land use planning and development in the State and for related purposes.

The purposes of the PD Act are:

- consolidate the provisions of the Acts repealed by the *Planning and Development (Consequential and Transitional Provisions) Act 2005* (the *Metropolitan Region Town Planning Scheme Act* (1959) , the *Town Planning and Development Act* (1928) and the *Western Australian Planning Commission Act* (1985) in a rewritten form
- provide for an efficient and effective land use planning system in the State
- promote the sustainable use and development of land in the State.

Government and industry guidelines

The WAPC guidelines require development of coastal facilities to take into account coastal processes including erosion, accretion, storm surge, tides, wave conditions, sea level change and biophysical criteria to ensure sustainable use of coastal areas for maritime industry, commercial and other activities. The two overarching WAPC policies are:

- Statement of Planning Policy No. 2.6 State Coastal Planning Policy
- Sea Level Change in Western Australia – Application to Coastal Planning.

10.3 Potential sources of impact

The following aspects of the Proposal may potentially impact on coastal processes:

- **construction of the marina entrance breakwater and marina waterbody** may alter wave dynamics and interrupt longshore sediment transport
- **construction of the breakwaters** may trap sediment and cause further loss of near shore benthic communities and habitat
- **construction of the breakwaters** may trap algae and seagrass wrack both inside and adjacent marina.

10.4 Overview of existing information

The following reports provide information on coastal processes within the vicinity of the Proposal:

- SMEC (2009) *Additional Environmental Information - Ocean Reef Marina*
- Worley Parsons (2009) *Ocean Reef Marina: Coastal Sediment Transport Assessment*
- MP Rogers & Associates (2009) *Ocean Reef Marina - Coastal Processes*
- MP Rogers & Associates (2012) *Hillarys to Ocean Reef Coastal Vulnerability*
- Rogers & Associates (2014) *Ocean Reef Marina - Seagrass Wrack Management*.

Combined, these reports provide initial estimates of coastal processes and the likely impact of the proposed marina and a preliminary assessment of longshore sediment transport dynamics along the shoreline.

10.4.1 Alongshore Sediment Transport

The existing Ocean Reef Boat Harbour development presently interrupts the movement of sand along the coastline. Worley Parsons (2009) undertook a comprehensive desktop and preliminary modelling assessment of the longshore sediment transport dynamics along the shoreline in the vicinity of the existing Ocean Reef Boat Harbour as the basis for assessment of the potential impacts from the Proposal. This work suggested that waves were the main driver of sand movement along the shore and that the net longshore transport of sand near the proposed marina is likely to be less than 10 000 m^3/yr.

It was estimated that the seasonal movements would be much larger in magnitude and would occur to the north in summer and generally to the south in winter. Inter-annual variations in the occurrence of key wave events could also have a large impact on the sediment movement in the development envelope. Given the shoreline at the marina site is generally rocky, the actual movement of sand is very dependent on the availability of sand to be moved (Worley Parsons 2009).

This preliminary assessment was subsequently peer reviewed by MP Rogers & Associates (2012). MP Rogers & Associates concluded that the Proposal would trap a small amount of sand moving along the coast and require ongoing maintenance dredging. Initial assessments indicated that the frequency of dredging would be similar, but slightly more extensive, than presently undertaken for the existing Ocean Reef Boat Harbour.

More recently, the City commissioned MP Rogers & Associates (2012) to complete a coastal assessment of the coastline between Hillarys Boat Harbour and Ocean Reef Boat Harbour (study area). A copy of this report is provided in Appendix 3. This coastal assessment involved:

- a site inspection by coastal engineers of the subject site noting the condition of the beaches and presence of limestone rock
- updating existing shoreline movement plans and analysis of the shoreline movement in the subject site
- creation of a conceptual sediment budget for the subject site
- modelling of the potential severe storm erosion at key sectors in the subject site
- assessment of the coastal vulnerability of the subject site to sea level rise (SLR)
- conceptual coastal management options for vulnerable areas
- budget cost estimates for conceptual management options and a priority plan for these works.

The existing harbour entrance is monitored and managed by periodic dredging. Typically about 5,000 m^3/year of sand is trapped to the north of the harbour and is removed by dredging most years (Oceanica, 2009). This sand may be moving south from the beaches to the north of the harbour during winter storms. The sand could deposit on the beach in the lee of the harbour entrance breakwater. As this area is largely sheltered from the effects of the sea-breeze waves, the sand becomes trapped and eventually affects the navigation of the harbour entrance. Consequently, the DoT manages the harbour entrance by removing the accumulated sand from time to time using a backhoe excavator and trucks.

The study area was broken into a number of study cells to facilitate the assessment. Of the five cells, Hillarys, Whitfords, Kallaroo and Mullaloo were predominantly sandy shoreline cells, while the Ocean Reef cell consisted entirely of rocky cliffs. No evidence of rock was observed in the cells south of the Ocean Reef cell.

Due to the construction of the Hillarys and Ocean Reef Boat Harbours in the 1970s to 1980s, analysis of the historical shoreline movement was focused on the period 1987 to 2010. The analysis showed that there has been a general pattern of recession in the southern cells and accretion of the northern cells of the study area, i.e. around Mullaloo Beach.

A sediment budget and conceptual sediment model were developed from the shoreline movement analysis. The sediment budget included a net transport of sediment northwards from Hillarys Boat Harbour. It was estimated that there had been about 10 000 m^3/yr accretion at Mullaloo Beach over the period from 1987 to 2010. This sand is believed to have mainly originated from the ongoing erosion of the beaches immediately north of Hillarys Boat Harbour.

10.4.2 Seagrass Wrack

MP Rogers & Associates (2014) have recently completed an investigation to determine the potential for wrack accumulations to occur at the proposed marina. The investigation primarily involved:

- review of benthic habitat mapping in coastal waters adjacent to existing Metropolitan marinas and boat harbours
- discussions with waterway managers to determine the scale and timing of wrack accumulations and management requirements.

The key findings of the investigation included:

1. Seagrass wrack is routinely and regularly removed from most marina and boat harbours along the Perth Metropolitan coast.
2. Small volumes of wrack (~500 m^3) currently accumulate on the southern beach inside the existing Ocean Reef Boat Harbour and on the shoreline adjacent to the development (~5,000m^3) over winter. The accumulation breaks down and is naturally dispersed over summer. These volumes are based on typical years and metocean conditions. Abnormal conditions with increased frequency of NW storms may result in larger volumes.
3. Discussions with waterway and beach managers for Hillary's Marina, Ocean Reef Boat Harbour and Mindarie Marina indicate that seagrass wrack accumulations are currently not a major management problem.
4. During occasional abnormal metocean years, larger wrack accumulations may need to be physically removed. Proven techniques exist for removing the volumes likely to be involved and include use of weed collection barges (for floating wrack) and bob-cat or small excavator on beaches for stranded wrack.

10.5 Further studies and investigations

Construction of the Proposal would continue the present day interruption of the movement of the sand along the shore that occurs due to the Ocean Reef Boat Harbour. The Proposal would have larger breakwaters in deeper waters which could increase the extent of the wave shadows and has the potential to change the dynamics compared to that presently experienced. Additional investigations will include:

- beach monitoring profiles along the sandy beaches between Hillarys Boat Harbour and the Proposal
- detailed analysis of the shoreline movement plans and beach profiles to better estimate the areas and quantities of accretion and erosion and then refine the sediment budget
- setting up and calibrating a detailed wave model for the area to provide inputs to a high quality beach evolution model. The models would examine the existing situation and then evaluate the impacts of the Proposal
- examining the need (if any) for coastal structures to the north and south of the Proposal to properly mitigate the impacts of the wave shadows that would be caused by the breakwaters
- designing and implementing a comprehensive beach monitoring and management program to manage the beaches and avoid adverse impacts. This would include ongoing bypassing of the net movement of sand along the coast towards the Proposal.

The results of the above studies will be incorporated into the environmental review documentation prepared for the Proposal.

10.6 Proposed management actions

Management actions proposed to minimise the impacts to coastal processes from the development include:

1. Preparation of an Operational Environmental Management Plan addressing ongoing monitoring of sediment movement and management of accumulations that impair navigation by maintenance dredging and monitoring and management of wrack accumulations.
2. Design of the marina entrance to minimise ongoing management requirements.
3. Establishment of sufficient buffers to allow for natural variability or designing structures to maintain access as the beach level changes in response to varying conditions.

Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.

11. Marine fauna

11.1 Assessment framework

11.1.1 EPA objective

The EPA environmental objective for marine fauna is:

To maintain the diversity, geographic distribution and viability of fauna at the species and population levels.

11.1.2 Relevant legislation, policy and guidance

State Protection

The preservation and conservation of fauna is covered by the following Western Australian legislation:

- *Wildlife Conservation Act 1950*
- *Conservation and Land Management Act 1984.*

The DoF is responsible for managing the State's finfish and crab stocks to ensure long-term sustainability and sustainable use of resources; this is done on the basis of sustainability assessments i.e. ensuring that fishing does not cause long-term decline of the resident population. The DoF is also responsible for coordinating Western Australia's Introduced Marine Species (IMS) control and management actions.

Commonwealth Protection

The EPBC Act protects species listed under Schedule 1 of the EPBC Act. In 1974, Australia became a signatory to CITES. As a result, an official list of endangered species was prepared and is regularly updated. This listing is administrated through the EPBC Act. The current list differs from the various State lists; however some species are common to both.

The EPBC Act also protects a range of shorebirds listed under the JAMBA and CAMBA Migratory Bird Agreements. Most of these are associated with saline wetlands or coastal shorelines. However, some migratory birds not associated with freshwater wetlands are also listed on these international treaties.

11.2 Potential sources of impact to be managed

The following aspects of the Proposal may affect marine fauna:

- **construction activities** may cause temporary displacement of marine fauna through noise impacts, vessel strikes and entanglement
- **increased public access** resulting in increased interactions between humans and fauna and littering
- **increased boat numbers** causing increased fishing pressure and the potential for boat strikes.

11.3 Overview of existing environment

The original Marmion Marine Park Management Plan 1992-2002 (DCLM 1992) identifies the conservation values of Marmion Marine Park as including habitats for marine mammals, such as sea lions, dolphins and whales.

11.3.1 Conservation significant species

A search of the EPBC Act Protected Matters search tool identified 11 marine fauna species listed as threatened under the EPBC Act as having the potential to occur in the development envelope (Table 4). These species are also of conservation significance under the *Wildlife Conservation Act, 1950*.

Table 4 Fauna species of Conservation Significance with the potential to occur in the development envelope

Species Name	Common Name	EPBC Status	Wildlife Conservation Act Status	Likelihood of occurrence/impact
Mammals				
Balaenoptera musculus	Blue Whale	Endangered	Threatened - Endangered	Unlikely. No NatureMap records in the Northern Perth area (DEC 2013). Unlikely to occur in development envelope.
Eubalaena australis	Southern Right Whale	Endangered	Threatened - Vulnerable	Unlikely. One record at Mullaloo Beach (over 1 km from shore) (DEC 2013); however species is not a regular visitor to Perth Metropolitan waters and is unlikely to occur in the development envelope.
Megaptera novaeangliae	Humpback Whale	Vulnerable	Threatened - Vulnerable	Possible. Species regularly migrates through Perth metropolitan waters, but is unlikely to occur in the development envelope due to the nearshore location and the existing boat harbour traffic; however, temporary dislocation impacts outside the development envelope are possible during construction.
Neophoca cinerea	Australian Sea-lion	Vulnerable	Other specially protected fauna	Possible. Temporary dislocation impacts outside the development envelope possible, but unlikely during construction, given the nearest rest area is on Little Island , approximately 6 km from the Proposal.
Reptiles				
Caretta caretta	Loggerhead Turtle	Endangered	Threatened - Endangered	Unlikely. The Proposed Action area is located outside the normal distribution ranges of this species which is predominantly in tropical waters.
Chelonia mydas	Green Turtle	Vulnerable	Threatened - Vulnerable	Unlikely. The Proposed Action area is located outside the normal distribution ranges of this species which is predominantly in tropical waters.

Species Name	Common Name	EPBC Status	Wildlife Conservation Act Status	Likelihood of occurrence/impact
Dermochelys coriacea	Leatherback Turtle, Leathery Turtle, Luth	Endangered	Threatened - Vulnerable	Unlikely. The Proposed Action area is located outside the normal distribution ranges of this species which is predominantly in tropical waters.
Natator depressus	Flatback Turtle	Vulnerable	Threatened - Vulnerable	Unlikely. The Proposed Action area is located outside the normal distribution ranges of this species which is predominantly in tropical waters.
Sharks				
Carcharias taurus (west coast population)	Grey Nurse Shark (west coast population)	Vulnerable	Threatened - Vulnerable	Unlikely to occur due to nearshore location of the Proposal.
Carcharodon carcharias	Great White Shark	Vulnerable	Threatened - Vulnerable	Potential. Recorded within the Perth metropolitan area (DEC 2013). Species known to occur along coastline. Only temporary dislocation impacts likely.
Rhinocodon typus	Whale Shark	Vulnerable	Other specially protected fauna	Unlikely. No NatureMap records in the Perth area (DEC 2013). Unlikely to occur due to location of the Proposed Action (known aggregating area off Ningaloo Reef).

Marine species such as the Humpback Whale, Great White Shark and Australian Sea Lion are known to occur within nearshore metropolitan waters at times and may experience temporary dislocation impacts as a result of the project during the two year construction period when breakwaters are being constructed and piling for jetties and boat pens is undertaken. These works will create underwater noise that may discourage marine mammals from entering the locality of the works. It is important to note that jetty piling, the major source of underwater noise will not be undertaken until the breakwaters have been completed, thereby providing a substantial noise buffer to waters outside the marina.

In addition, a number of recognised marine noise management actions exist that will minimise potential for adverse impact on listed marine mammals which do venture close to the marina during construction period. Given jetty piling will be undertaken gradually in stages of project development after the breakwaters have been completed and that there are recognised underwater noise management actions available in the event that animals are spotted in the vicinity of piling works, it is considered that the proposed action poses little to no risk to the maintenance of regional populations of any of the above listed protected marine fauna.

11.4 Proposed management actions

Preliminary management actions proposed to minimise the impacts to marine fauna from the development include:

1. Preparation of a comprehensive Construction Environmental Management Plan that includes measures for marine fauna protection and contingency actions for incidents of fauna injury and death.

Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.

12. Integrating factor - offsets

The City is aware of the need to provide environmental offsets for possible significant residual environmental impacts to high value environmental assets remaining after on-site efforts to avoid, minimise and rectify impacts have been applied.

12.1 Relevant policy and guidance

12.1.1 State offsets policy and guidance

Offsets are actions to address significant residual environmental impacts of a development or activity. Where a significant residual environmental impact has been identified, the State Government Environmental Offsets Policy 2011 (Offsets Policy) aims to achieve a net environmental benefit, or at a minimum maintain environmental values (Government of Western Australia 2011). There are two categories of environmental offsets:

- direct offsets are those actions that provide a measurable conservation gain related to the significant residual impact that has been identified and provide for restoration or rehabilitation of existing degraded ecosystems, improved management, implementation of agreed recovery plans for species and/or conservation of habitat
- indirect offsets or 'other compensatory measures' are actions aimed at benefiting the affected environmental asset through improving scientific knowledge or community awareness and may include research, management planning or education that leads to the improved understanding of management of the environmental value.

When considering proposed environmental offsets, the EPA is guided by the following principles as outline in the Offset Policy:

- environmental offsets should only be considered after all other reasonable attempts to mitigate adverse impacts have been exhausted
- an environmental offset package should address both direct offsets and contributing offsets
- environmental offset and impact should ideally be "like for like or better"
- positive environmental offset ratios should apply where risk of failure is apparent
- environmental offsets must entail a robust and consistent assessment process
- environmental offsets must meet all statutory requirements
- environmental offsets must be clearly defined, transparent and enforceable
- environmental offset must ensure a long lasting benefit (Government of Western Australia 2011).

The State Government has recently released a draft WA Government Environmental Offsets Guideline (Offset Guidelines) that are intended to complement the Offsets Policy by clarifying the determination and application of environmental offsets in Western Australia (Government of Western Australia 2014). The Offset Guidelines outline the methodology for determining an appropriate offset by identifying the key elements which should be considered to ensure that decisions made on environmental offsets are consistent and accountable under the EP Act.

The Offset Guidelines outlines the framework for consideration of offsets required under the environmental approvals process, including demonstrated application of the mitigation hierarchy and assessment of the residual impacts in relation to relevant EPA environmental factors (Government of Western Australia 2014).

EPA guidance is that offsets should aim 'to counterbalance any significant residual environmental impacts and risks of a proposal' (EPA 2012). Environmental offsets represent the 'last line of defence' for the environment, ensuring that adverse impacts are counterbalanced by an environmental gain somewhere else (EPA 2006). Environmental offsets should be a component of the environmental impact assessment procedure and the EPA expects proponents to put forward commitments for offsets as part of their Proposal.

12.1.2 Australian Government offsets policy

DSEWPaC has released an EPBC Act Environmental Offsets Policy (EPBC Act Policy) (DSEWPaC 2012b) that defines two types of offsets

- **direct offsets**: measures that have on-ground, tangible benefits that improve the viability of the protected matter
- **other compensatory measures**: any other measure that contributes to the overall conservation outcome of the protected matter.

Principles guiding the EPBC Act Policy are that offsets:

1. Deliver an overall conservation outcome.
2. Be efficient, effective, transparent, proportionate, scientifically robust and reasonable.
3. Be built around direct offsets but may include indirect (i.e. compensatory) offsets.
4. Be of a size and scale proportionate to the impacts being offset.
5. Be in proportion to the level of statutory protection that applies to the affected species or community.
6. Effectively manage the risks of the offset not succeeding.
7. Be able to be readily measured, monitored, audited and enforced.

12.2 Net conservation benefit

As part of the assessment process, offsets will be developed in accordance with relevant guidance to address any significant residual impacts to biodiversity values associated with the Proposal. Potential residual impacts associated with the Proposal have been identified at this stage to include loss of benthic communities and habitat within Marmion Marine park. Other potential residual impacts may be identified during future stages of the environmental impact assessment process.

As part of the EIA process, an offsets strategy will be developed and refined, and will include related mitigation strategies developed with input from the State and Australian agencies. The mitigation package will include accurate details regarding potential impact and the proposed offset measures to achieve a net conservation benefit for the area.

13. Conclusion

This section summarises the content discussed above regarding the key and other environmental factors and issues potentially relevant to the assessment of impacts of this Proposal (Table 5). It provides a summary of the potential impacts, proposed management measures to be addressed in detail during the anticipated assessment process as well as the further studies proposed to support the assessment.

Table 5 Preliminary summary of environmental factors, impact, management and proposed studies for the Proposal

Environmental factor	EPA objective(s)	Existing environment	Potential impacts	Proposed management	Proposed studies
Benthic communities and habitat	To maintain the structure, function, diversity, distribution and viability of benthic communities and habitats at local and regional scales.	Marine habitats in the immediate area include intertidal nearshore reef platforms, coastal sand beaches, largely barren shallow lagoonal sand flats and a small area of seagrass meadow. The nearshore reef which occurs immediately north of the existing Ocean Reef boat launching facility supports commercial and recreational stocks of Roe's Abalone (*Halliotis roei*) and juvenile Western rock lobster (*Panulirus cygnus*).	The following aspects of the Proposal may affect benthic community and habitat values: • direct removal of benthic habitat and communities to allow for the construction of the marina waterbody and breakwaters providing access to the marina • indirect impacts to benthic habitat and communities due to altered sediment movement and flows caused by breakwaters • alteration in marine water quality during construction and ongoing operation of the marina • increased risk of introduced marine species due to increased numbers of large recreational vessels berthing in the marina • potential impacts on benthic communities and habitat due to altered water quality impacts are discussed under marine water quality.	Preliminary management actions proposed to minimise the impacts to benthic communities and habitat from the development include: 1. Preparation of a comprehensive Construction Monitoring and Management Plan that includes relevant baseline information, protocols for monitoring of water quality and benthic habitat during construction and construction management measures. 2. Preparation of a Marine Environmental Quality Management Plan to manage water quality during operation of the Proposal. Dredging and land reclamation activities will only commence once the breakwaters are completed. Experience with other recent marina constructions indicate that it should be relatively easy to contain water turbidity inside the marina and in its immediate locality. 3. Examine opportunities for potential offsetting of near shore abalone habitat loss through incorporating new artificial intertidal reef habitat into the design of the marina breakwaters. 4. Examine opportunities for seed stocking of existing reefs and artificial reefs with artificially reared juvenile abalone. 5. Examine opportunities for compensating commercial abalone fishermen for loss of stocks. 6. Examine opportunities for extending the boundary of the marine park northwards to incorporate additional nearshore reef in the vicinity of Quinns Rocks. Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.	The following additional studies are proposed to support the impact assessment for this factor: • detailed marine habitat characterisation and mapping • desktop review of all existing water quality data relevant to the study area • hydrodynamic modelling to simulate the dispersion of sediment fines during marina dredging and land reclamation activities • inspection and characterisation of breakwaters within and near the Marmion Marine Park in terms of biotic complement relative to the natural nearshore reef habitat . The study will focus on colonisation by rock lobster and abalone, including identifying the characteristics of nearshore reefs which support the greatest abundance of abalone for incorporation into breakwater design • characterisation of habitats for both rock lobster and abalone will include the use of towed video surveys • engage DoF to determine the importance of the abalone stocks within the development envelope to maintenance of the fishery and the local population of the species.
Marine Water Quality	To maintain the quality of water, sediment and biota so that the environmental values, both ecological and social, are protected.	Detailed water quality investigations have been undertaken, including: • flushing characteristics of the existing Ocean Reef Boat Harbour using Rhodamine dye release and monitoring • measurements of the surface waves, ocean water levels and currents throughout the water column near the existing boat harbour • conductivity, temperature and density measurements throughout the existing harbour. Groundwater modelling by Rockwater (2011) shows that even under the worst nutrient loading conditions at the end of the winter months, the predicted concentration values within the proposed marina are less than the guideline trigger values. The water quality investigations have been extensive and the calibrated and verified hydrodynamic modelling shows that the proposed marina would have good flushing characteristics and the flushing time would generally be in the order of four days or less. In addition, the nutrients in the groundwater inflow would be effectively flushed out of the marina and the resultant concentrations would be generally less than the ANZECC suggested trigger values.	The following aspects of the Proposal may affect marine water quality: • dredging to allow for the construction of the breakwaters and marina waterbody may temporarily affect water quality due to increased turbidity, and the release of any nutrients and contaminants in dredged sediments • seepage of return water from bunded areas used for temporary storage of dredged sediments, which may temporarily impact water quality due to increased turbidity and the release of nutrients and contaminants in dredged sediments • placement of limestone for the marina breakwaters and leaching of fines from the limestone causing temporary turbidity during and after the limestone is placed • outflow of marina waters into adjacent marine waters may result in changes in turbidity, nutrients, and/or contaminants, which in turn may adversely affect marine ecology and function • increased boat numbers increasing the potential for pollution.	Management actions proposed to minimise the impacts to water quality from the Proposal include: 1. Preparation of a comprehensive Construction Monitoring and Management Plan that includes relevant baseline information, protocols for monitoring of water quality during construction and construction management measures. 2. Even though the proposed Marina will have good flushing and acceptable nutrient levels, it is acknowledged that it is important to design and manage the development to prevent any other nutrients or pollutants from entering the waterbody. There will need to be an ongoing Water and Sediment Quality Monitoring and Management Plan established and implemented. This will ensure that the water quality meets the intended uses and guidelines. 3. Preparation of a Marine Environmental Quality Management Plan to manage marine water quality during operation of the Proposal. 4. Maximising circulation and exchange (design factors), managing discharges from vessels and support services and minimising stormwater contaminant inputs to protect water quality within the marina. 5. Use of 'best practice' measures and strict regulations for the Proposal, to ensure minimal inputs of contaminants to the marine environment. Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.	The following additional studies are proposed to support the impact assessment for this factor: • obtaining contemporary groundwater nutrient samples from the site to confirm that concentrations used in the model are indeed representative of present day concentrations • obtaining a peer review of the modelling investigations and findings • hydrodynamic modelling to determine the temporal and spatial scale of turbidity impacts on adjacent BPPH arising from dredging and land reclamation and occasional maintenance dredging associated with the construction and operation of the marina.

Coastal processes	To maintain the morphology of the subtidal, intertidal and supratidal zones and the local geophysical processes that shape them.	A number of studies relating to coastal processes have been commissioned. The most recent study (MP Rogers &Associates (2012) noted that the existing harbour entrance is monitored and managed by periodic dredging. The analysis showed that there has been a general pattern of beach recession to the north of the existing marina and beach accretion to the south, i.e. around Mullaloo Beach. A sediment budget and conceptual sediment model were developed from the shoreline movement analysis. The sediment budget included a net transport of sediment northwards from Hillarys Boat Harbour. It was estimated that there had been about 10 000 m3/yr accretion at Mullaloo Beach over the period from 1987 to 2010. This sand is believed to have mainly originated from the ongoing erosion of the beaches immediately north of Hillarys Boat Harbour.	The following aspects of the Proposal may potentially impact on coastal processes: • construction of the marina entrance breakwater and marina waterbody may alter wave dynamics and interrupt longshore sediment transport • construction of the breakwaters may trap sediment and cause further loss of near shore benthic communities and habitat.	Management actions proposed to minimise the impacts to coastal processes from the development include: 1. Preparation of an Operational Environmental Management Plan that will address ongoing management of sediment movement and maintenance dredging. 2. Design of the marina entrance to minimise ongoing management requirements. 3. Establishment of sufficient buffers to allow for natural variability or designing structures to maintain access as the beach level changes in response to varying conditions. Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.	The following additional studies are proposed to support the impact assessment for this factor: • beach monitoring profiles along the sandy beaches between Hillarys Boat Harbour and the Proposal • detailed analysis of the shoreline movement plans and beach profiles to better estimate the areas and quantities of accretion and erosion and then refine the sediment budget • setting up and calibrating a detailed wave model for the area to provide inputs to a high quality beach evolution model. The models would examine the existing situation and then evaluate the impacts of the Proposal • examining the need (if any) for coastal structures to the north and south of the Proposal to properly mitigate the impacts of the wave shadows that would be caused by the breakwaters • designing and implementing a comprehensive beach monitoring and management program to manage the beaches and avoid adverse impacts. This would include ongoing bypassing of the net movement of sand along the coast towards the Proposal. The results of the above studies will be incorporated into the environmental review documentation prepared for the Proposal.
Marine fauna	To maintain the diversity, geographic distribution and viability of fauna at the species and population levels.	The original Marmion Marine Park Management Plan 1992-2002 (DCLM 1992) identifies the conservation values of the Marmion Marine Park as including habitats for marine mammals, such as sea lions, dolphins and whales. A search of the EPBC Act Protected Matters search tool identified 11 marine fauna species listed as threatened under the EPBC Act as having the potential to occur in the development envelope (Table 4). These species are also of conservation significance under the *Wildlife Conservation Act, 1950*. Of these, three are considered likely to occur within the development envelope and may be affected by temporary dislocation impacts.	The following aspects of the Proposal may affect Marine fauna: • removal of benthic habitat • construction activities may cause temporary displacement of marine fauna, noise impacts, vessel strikes and entanglement • increased public access resulting in increased interactions between humans and fauna and littering • increased boat numbers causing increased fishing pressure and the potential for boat strike.	Preliminary management actions proposed to minimise the impacts to marine fauna from the development include: 1. Preparation of a comprehensive Construction Environmental Management Plan that includes measures for marine fauna protection and contingency actions for incidents of fauna injury and death. Other management measures will also be developed in consultation with agencies during detailed impact assessment to address specific impacts.	A number of recognised marine noise management actions exist that will minimise potential for adverse impact on listed marine mammals. Given jetty piling will be undertaken gradually in stages of project development after the breakwaters have been completed, and that there are recognised underwater noise management actions available in the event that animals are spotted in the vicinity of piling works, it is considered that the proposed action poses little to no risk to the maintenance of regional populations of any of the listed protected marine fauna.

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Appendix 1 – s38 referral form

Environmental Protection Authority

GOVERNMENT OF WESTERN AUSTRALIA

EPA REFERRAL FORM

PROPONENT

Referral of a Proposal by the Proponent to the Environmental Protection Authority under Section 38(1) of the *Environmental Protection Act 1986*.

PURPOSE OF THIS FORM

Section 38(1) of the *Environmental Protection Act 1986* (EP Act) provides that where a development proposal is likely to have a significant effect on the environment, a proponent may refer the proposal to the Environmental Protection Authority (EPA) for a decision on whether or not it requires assessment under the EP Act. This form sets out the information requirements for the referral of a proposal by a proponent.

Proponents are encouraged to familiarise themselves with the EPA's *General Guide on Referral of Proposals* [see Environmental Impact Assessment/Referral of Proposals and Schemes] before completing this form.

A referral under section 38(1) of the EP Act by a proponent to the EPA must be made on this form. A request to the EPA for a declaration under section 39B (derived proposal) must be made on this form. This form will be treated as a referral provided all information required by Part A has been included and all information requested by Part B has been provided to the extent that it is pertinent to the proposal being referred. Referral documents are to be submitted in two formats – hard copy and electronic copy. The electronic copy of the referral will be provided for public comment for a period of 7 days, prior to the EPA making its decision on whether or not to assess the proposal.

CHECKLIST

Before you submit this form, please check that you have:

	Yes	No
Completed all the questions in Part A (essential).	×	
Completed all applicable questions in Part B.	×	
Included Attachment 1 – location maps.	×	
Included Attachment 2 – additional document(s) the proponent wishes to provide (if applicable).	×	
Included Attachment 3 – confidential information (if applicable).	×	
Enclosed an electronic copy of all referral information, including spatial data and contextual mapping but excluding confidential information.	×	

Following a review of the information presented in this form, please consider the following question (a response is optional).

Do you consider the proposal requires formal environmental impact assessment?		
☒ Yes	☐ No	☐ Not sure
If yes, what level of assessment?		
☐ Assessment on Proponent Information	☒ Public Environmental Review	

PROPONENT DECLARATION (to be completed by the proponent)

I, GARRY HUNT, *(full name)* declare that I am authorised on behalf of the CITY OF JOONDALUP (being the person responsible for the proposal) to submit this form and further declare that the information contained in this form is true and not misleading.

Garry Hunt	GARRY HUNT
CHIEF EXECUTIVE OFFICER	CITY OF JOONDALUP
23 MAY 2013	

PART A - PROPONENT AND PROPOSAL INFORMATION
(All fields of Part A must be completed for this document to be treated as a referral)

1 PROPONENT AND PROPOSAL INFORMATION

1.1 Proponent

Name	City of Joondalup
Joint Venture parties (if applicable)	Not applicable
Australian Company Number (if applicable)	Not applicable
Postal Address (where the proponent is a corporation or an association of persons, whether incorporated or not, the postal address is that of the principal place of business or of the principal office in the State)	PO Box 21 JOONDALUP WA 6919
Key proponent contact for the proposal: • name • address • phone • email	Garry Hunt Chief Executive Officer City of Joondalup **A:** PO Box 21 JOONDALUP WA 6919 **P:** 08 9400 4000 **E:** Info@joondalup.wa.gov.au
Consultant for the proposal (if applicable): • name • address • phone • email	Darren Walsh Chief Executive Officer and Senior Principal Strategen Environmental Consultants **A**: PO Box 243 SUBIACO WA 6904 **P**: (08) 9380 3100 **E**: d.walsh@strategen.com.au

1.2 Proposal

Title	Ocean Reef Marina
Description	The City of Joondalup (the City) proposes to develop a world class recreational, residential, boating and tourist development, referred to as the Ocean Reef Marina Development at Ocean Reef, Western Australia (the Development). The Development is located in the Ocean Reef locality, approximately 29 km from the Perth central area and 9 km from Hillarys Boat Harbour. The Development is within the City and includes the existing Ocean Reef Boat Harbour. The Proposal will involve the upgrade and expansion of the existing Ocean Reef Boat Harbour into a mixed use 'working marina' enabling club, service commercial and

	marine industrial uses in the north, a central retail, tourist and residential precinct and a southern boating precinct inclusive of ramps . The Proposal the subject of this referral involves the upgrade and expansion of the existing marina facilities at the Ocean Reef Boat Harbour. The high tide mark on the coast represents the boundary between the land-based component of the Development and the marine-based component to which this referral relates (the Proposal). The terrestrial component of the Development is being referred under section 48A of the *Environmental Protection Act 1986* (EP Act).
Extent (area) of proposed ground disturbance.	The Proposal development envelope is approximately 55.32 ha.
Timeframe in which the activity or development is proposed to occur (including start and finish dates where applicable).	The timeframe for commencement of the Proposal is dependent on completion of the required Western Australian planning and environmental approvals.
Details of any staging of the proposal.	It is envisaged that construction of the Proposal will be staged over a ten year period.
Is the proposal a strategic proposal?	No.
Is the proponent requesting a declaration that the proposal is a derived proposal? If so, provide the following information on the strategic assessment within which the referred proposal was identified: • title of the strategic assessment; and • Ministerial Statement number.	No.
Please indicate whether, and in what way, the proposal is related to other proposals in the region.	Yes. The Proposal relates to the terrestrial component of the Development which is being considered under section 48A of the EP Act (Metropolitan Regional Scheme (MRS) Amendment).

Does the proponent own the land on which the proposal is to be established? If not, what other arrangements have been established to access the land?	The Proposal will occur within the Marmion Marine Park vested in the Marine Parks and Reserves Authority (MPRA) under the provision of the *Conservation and Land Management Act 1984*.
What is the current land use on the property, and the extent (area in hectares) of the property?	Refer above.

1.3 Location

Name of the Shire in which the proposal is located.	City of Joondalup
For urban areas: • street address; • lot number; • suburb; and • nearest road intersection.	The address of the proposed development site is: 362 Ocean Reef Road Ocean Reef WA 6027. The nearest road intersection is Hodges Drive / Ocean Reef Road.
For remote localities: • nearest town; and • distance and direction from that town to the proposal site.	Not Applicable.
Electronic copy of spatial data - GIS or CAD, geo-referenced and conforming to the following parameters: • GIS: polygons representing all activities and named; • CAD: simple closed polygons representing all activities and named; • datum: GDA94; • projection: Geographic (latitude/longitude) or Map Grid of Australia (MGA); • format: Arcview shapefile, Arcinfo coverages, Microstation or AutoCAD.	CD attached.

1.4 Confidential Information

Does the proponent wish to request the EPA to allow any part of the referral information to be treated as confidential?	No.

If yes, is confidential information attached as a separate document in hard copy?	Not Applicable.

1.5 Government Approvals

Is rezoning of any land required before the proposal can be implemented? If yes, please provide details.	Yes. An amendment to the MRS is concurrently being sought from the Western Australian Planning Commission (WAPC). The purpose of this amendment is to rezone and rationalise 76.5 ha in Ocean Reef from Parks and Recreation, (including some Bush Forever), Waterways and Public Purpose to Urban and additional Waterways zones and new Parks and Recreation Reserved Lands. The amendment also includes a proposal to exclude a parcel of water from the Marmion Marine Park. The City's District Planning Scheme No. 2 will also require amending to align with the MRS amendment.		
Is approval required from any Commonwealth or State Government agency or Local Authority for any part of the proposal? If yes, please complete the table below.	Yes		
Agency/Authority	Approval required	Application lodged Yes / No	Agency/Local Authority contact(s) for proposal
Department of the Environment (DotE)	Consideration under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).	Yes	Environmental Assessment and Compliance Division
Western Australian Planning Commission and Department of Planning	Metropolitan Region Scheme amendment	Yes	Anthony Muscara (Department of Planning)

PART B - ENVIRONMENTAL IMPACTS AND PROPOSED MANAGEMENT

2. ENVIRONMENTAL IMPACTS

Describe the impacts of the proposal on the following elements of the environment, by answering the questions contained in Sections 2.1-2.11:

- 2.1 flora and vegetation;
- 2.2 fauna;
- 2.3 rivers, creeks, wetlands and estuaries;
- 2.4 significant areas and/ or land features;
- 2.5 coastal zone areas;
- 2.6 marine areas and biota;
- 2.7 water supply and drainage catchments;
- 2.8 pollution;
- 2.9 greenhouse gas emissions;
- 2.10 contamination; and
- 2.11 social surroundings.

These features should be shown on the site plan, where appropriate.

For all information, please indicate:

- (a) the source of the information; and
- (b) the currency of the information.

2.1 Flora and Vegetation

2.1.1 Do you propose to clear any native flora and vegetation as a part of this proposal?

[A proposal to clear native vegetation may require a clearing permit under Part V of the EP Act (Environmental Protection (Clearing of Native Vegetation) Regulations 2004)]. Please contact the Department of Environment and Conservation (DEC) for more information.

(please tick) ☐ Yes — **If yes**, complete the rest of this section.

✔ No — **If no**, go to the next section

2.1.2 How much vegetation are you proposing to clear (in hectares)?

2.1.3 Have you submitted an application to clear native vegetation to the DEC (unless you are exempt from such a requirement)?

☐ Yes ☐ No — **If yes**, on what date and to which office was the application submitted of the DEC?

2.1.4 Are you aware of any recent flora surveys carried out over the area to be disturbed by this proposal?

☐ Yes ☐ No **If yes**, please attach a copy of any related survey reports and provide the date and name of persons / companies involved in the survey(s).

If no, please do not arrange to have any biological surveys conducted prior to consulting with the DEC.

2.1.5 Has a search of DEC records for known occurrences of rare or priority flora or threatened ecological communities been conducted for the site?

☐ Yes ☐ No If you are proposing to clear native vegetation for any part of your proposal, a search of DEC records of known occurrences of rare or priority flora and threatened ecological communities will be required. Please contact DEC for more information.

2.1.6 Are there any known occurrences of rare or priority flora or threatened ecological communities on the site?

☐ Yes ☐ No **If yes**, please indicate which species or communities are involved and provide copies of any correspondence with DEC regarding these matters.

2.1.7 If located within the Perth Metropolitan Region, is the proposed development within or adjacent to a listed Bush Forever Site? (You will need to contact the Bush Forever Office, at the Department for Planning and Infrastructure)

☐ Yes ☐ No **If yes**, please indicate which Bush Forever Site is affected (site number and name of site where appropriate).

2.1.8 What is the condition of the vegetation at the site?

2.2 Fauna

2.2.1 Do you expect that any fauna or fauna habitat will be impacted by the proposal?

(please tick) ✔ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

The construction of the marina and associated breakwaters may impact marine and migratory species and their habitat.

2.2.2 Describe the nature and extent of the expected impact.

The following aspects of the Proposal may affect marine fauna:

- removal of benthic habitat
- construction activities may cause temporary displacement of marine fauna, noise impacts, vessel strikes and entanglement
- increased public access resulting in increased interactions between humans and fauna and littering
- increased boat numbers causing increased fishing pressure and the potential for boat strike.

Refer to Section 11 of the supporting document.

2.2.3 Are you aware of any recent fauna surveys carried out over the area to be disturbed by this proposal?

☐ Yes ✔ No

If yes, please attach a copy of any related survey reports and provide the date and name of persons / companies involved in the survey(s).

If no, please do not arrange to have any biological surveys conducted prior to consulting with the DEC.

2.2.4 Has a search of DEC records for known occurrences of Specially Protected (threatened) fauna been conducted for the site?

☐ Yes ✔ No (please tick)

A search of the *Environment Protection and Biodiversity Conservation Act 1996* (EPBC Act) Protected Matters search tool identified 11 marine fauna species listed as threatened under the EPBC Act as having the potential to occur in the Proposal area. These species are also of conservation significance under the *Wildlife Conservation Act 1950*.

2.2.5 Are there any known occurrences of Specially Protected (threatened) fauna on the site?

✔ Yes ☐ No

If yes, please indicate which species or communities are involved and provide copies of any correspondence with DEC regarding these matters.

Of the species identified from the Protected Matters search, only three are considered to have the potential to be impacted by the Proposal. Impacts to these species can be avoided through appropriate monitoring and management.

Refer to Section 11 of the supporting document.

2.3 Rivers, Creeks, Wetlands and Estuaries

2.3.1 Will the development occur within 200 metres of a river, creek, wetland or estuary?

(please tick) ☐ Yes **If yes**, complete the rest of this section.

✓ No **If no**, go to the next section.

2.3.2 Will the development result in the clearing of vegetation within the 200 metre zone?

☐ Yes ☐ No **If yes**, please describe the extent of the expected impact.

2.3.3 Will the development result in the filling or excavation of a river, creek, wetland or estuary?

☐ Yes ☐ No **If yes**, please describe the extent of the expected impact.

2.3.4 Will the development result in the impoundment of a river, creek, wetland or estuary?

☐ Yes ☐ No **If yes**, please describe the extent of the expected impact.

2.3.5 Will the development result in draining to a river, creek, wetland or estuary?

☐ Yes ☐ No **If yes**, please describe the extent of the expected impact.

2.3.6 Are you aware if the proposal will impact on a river, creek, wetland or estuary (or its buffer) within one of the following categories? (please tick)

Conservation Category Wetland	☐ Yes	☐ No	☐ Unsure
Environmental Protection (South West Agricultural Zone Wetlands) Policy 1998	☐ Yes	☐ No	☐ Unsure
Perth's Bush Forever site	☐ Yes	☐ No	☐ Unsure
Environmental Protection (Swan & Canning Rivers) Policy 1998	☐ Yes	☐ No	☐ Unsure
The management area as defined in s4(1) of the *Swan River Trust Act 1988*	☐ Yes	☐ No	☐ Unsure
Which is subject to an international agreement, because of the importance of the wetland for waterbirds and waterbird habitats (e.g. Ramsar, JAMBA, CAMBA)	☐ Yes	☐ No	☐ Unsure

2.4 Significant Areas and/ or Land Features

2.4.1 Is the proposed development located within or adjacent to an existing or proposed National Park or Nature Reserve?

☐ Yes ✔ No **If yes**, please provide details.

2.4.2 Are you aware of any Environmentally Sensitive Areas (as declared by the Minister under section 51B of the EP Act) that will be impacted by the proposed development?

☐ Yes ✔ No **If yes**, please provide details.

2.4.3 Are you aware of any significant natural land features (e.g. caves, ranges etc) that will be impacted by the proposed development?

☐ Yes ✔ No **If yes**, please provide details.

2.5 Coastal Zone Areas (Coastal Dunes and Beaches)

2.5.1 Will the development occur within 300metres of a coastal area?

(please tick) ✔ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.

2.5.2 What is the expected setback of the development from the high tide level and from the primary dune?

The Proposal is the marine component of the Development and as such there is no setback from the high tide level and dunes.

2.5.3 Will the development impact on coastal areas with significant landforms including beach ridge plain, cuspate headland, coastal dunes or karst?

✔ Yes ☐ No **If yes**, please describe the extent of the expected impact.

The Proposal will impact on the landform along the coastal foreshore at Ocean Reef. As part of the Development, reclamation and alteration of the coastline will be required to form the marina. Refer to Section 3.2 of the supporting document.

Construction of the Proposal will continue the present day interruption of the movement of the sand along the shore that occurs due to the existing Ocean Reef Boat Harbour. The Proposal will have larger breakwaters in deeper waters. This could increase the extent of the wave shadows and has the potential to change the dynamics compared to that presently experienced. The potential impact of the new larger breakwaters is recognised and the following range of studies is proposed:

- beach monitoring profiles along the sandy beaches between Hillarys Boat Harbour and the Proposal area

- detailed analysis of the shoreline movement plans and beach profiles to better estimate the areas and quantities of accretion and erosion and then refine the sediment budget
- setting up and calibrating a detailed wave model for the area to provide inputs to a high quality beach evolution model. The models would examine the existing situation and then evaluate the impacts of the Proposal
- examining the need (if any) for coastal structures to the north and south of the Proposal area to properly mitigate the impacts of the wave shadows that would be caused by the breakwaters
- designing and implementing a comprehensive beach monitoring and management program to manage the beaches and avoid adverse impacts. This would include ongoing bypassing of the net movement of sand along the coast towards the Proposal area.

  Refer to Section 10 of the Supporting Document.

2.5.4 Is the development likely to impact on mangroves?

☐ Yes ✓ No **If yes**, please describe the extent of the expected impact.

2.6 Marine Areas and Biota

2.6.1 Is the development likely to impact on an area of sensitive benthic communities, such as seagrasses, coral reefs or mangroves?

✓ Yes ☐ No **If yes**, please describe the extent of the expected impact.

Marine habitats in the immediate area of the proposal include intertidal reef platforms and sand beaches, largely barren shallow lagoonal sand flats and a small area of seagrass (refer to Figure 7 in supporting document).

The following aspects of the Proposal may affect benthic community and habitat values:

- direct removal of benthic habitat and communities to allow for the construction of the marina waterbody and breakwaters providing access to the marina
- indirect impacts to benthic habitat and communities due to altered sediment movement and flows caused by breakwaters
- alteration in marine water quality during construction and ongoing operation of the marina
- increased risk of introduced marine species due to increased numbers of large recreational vessels berthing in the marina.

Refer to Section 8 of the supporting document.

2.6.2 Is the development likely to impact on marine conservation reserves or areas recommended for reservation (as described in *A Representative Marine Reserve System for Western Australia*, CALM, 1994)?

✓ Yes ☐ No **If yes**, please describe the extent of the expected impact.

While the existing Ocean Reef Boat Harbour is located outside the boundaries of the Marmion Marine Park, the Proposal will extend into the boundaries of the Marine Park (refer Figure 7 of supporting document).

The Marmion Marine Park was reserved on 13 March, 1987, as an 'A' class reserve. It is vested in the MPRA under the provisions of the *Conservation and Land Management Act 1984*. The MPRA is a statutory body reporting to the Minister for the Environment. Management of the Marmion Marine Park is undertaken by the Department of Parks and Wildlife on behalf of the MPRA.

2.6.3 Is the development likely to impact on marine areas used extensively for recreation or for commercial fishing activities?

✔ Yes ☐ No **If yes**, please describe the extent of the expected impact, and provide any written advice from relevant agencies (e.g. Fisheries WA).

The nearshore intertidal reef which occurs immediately north of the existing Ocean Reef Boat Harbour supports commercial and recreational stocks of Roe's Abalone (*Halliotis roei*) and juvenile Western rock lobster (*Panulirus cygnus*). This reef, which runs north to Burns Beach is understood to be the most productive in the metropolitan area and is particularly accessible to recreational fishermen. The Department of Fisheries Status of the Fisheries Report 2012-2013 indicated that the abalone fishery netted approximately 46 tonnes within the west coast region during that period.

The principal commercial fishery in the West Coast Bioregion (including the marine environment from Kalbarri to Augusta) was reported to be the Western rock lobster. The coastal reef within the Proposal area potentially supports juvenile rock lobster habitat however, available habitat mapping of the overall Marmion Marine Park indicates a large amount of rock lobster habitat in the region (refer Figure 7 of supporting document).

Refer to Section 8 of the supporting document.

2.7 Water Supply and Drainage Catchments

2.7.1 Are you in a proclaimed or proposed groundwater or surface water protection area?

(You may need to contact the Department of Water (DoW) for more information on the requirements for your location, including the requirement for licences for water abstraction. Also, refer to the DoW website)

☐ Yes ✔ No **If yes**, please describe what category of area.

2.7.2 Are you in an existing or proposed Underground Water Supply and Pollution Control area?

(You may need to contact the DoW for more information on the requirements for your location, including the requirement for licences for water abstraction. Also, refer to the DoW website)

☐ Yes ✔ No **If yes**, please describe what category of area.

2.7.3 Are you in a Public Drinking Water Supply Area (PDWSA)?

(You may need to contact the DoW for more information or refer to the DoW website. A proposal to clear vegetation within a PDWSA requires approval from DoW.)

☐ Yes ✔ No **If yes**, please describe what category of area.

2.7.4 Is there sufficient water available for the proposal?

(Please consult with the DoW as to whether approvals are required to source water as you propose. Where necessary, please provide a letter of intent from the DoW)

☐ Yes ☐ No (please tick)
Not applicable – this referral is for the marine component of the Development only.

2.7.5 Will the proposal require drainage of the land?

☐ Yes ☐ No **If yes**, how is the site to be drained and will the drainage be connected to an existing Local Authority or Water Corporation drainage system? Please provide details.
Not applicable – this referral is for the marine component of the Development only.

2.7.6 Is there a water requirement for the construction and/ or operation of this proposal?

(please tick) ☐ Yes **If yes**, complete the rest of this section.

☐ No **If no**, go to the next section.
Not applicable – this referral is for the marine component of the Development only.

2.7.7 What is the water requirement for the construction and operation of this proposal, in kilolitres per year?

Not applicable – this referral is for the marine component of the Development only.

2.7.8 What is the proposed source of water for the proposal? (e.g. dam, bore, surface water etc.)

Not applicable – this referral is for the marine component of the Development only.

2.8 Pollution

2.8.1 Is there likely to be any discharge of pollutants from this development, such as noise, vibration, gaseous emissions, dust, liquid effluent, solid waste or other pollutants?

(please tick) ✔ Yes — **If yes**, complete the rest of this section.

☐ No — **If no**, go to the next section.

No long term discharge of pollutants will result from this Proposal. However, short term emissions during the construction phase of the project will occur, including dust, noise and vibration from piling, dredging and construction of breakwaters.

2.8.2 Is the proposal a prescribed premise, under the Environmental Protection Regulations 1987?
(Refer to the EPA's *General Guide for Referral of Proposals to the EPA under section 38(1) of the EP Act 1986* for more information)

☐ Yes ✔ No — **If yes**, please describe what category of prescribed premise.

2.8.3 Will the proposal result in gaseous emissions to air?

☐ Yes ✔ No — **If yes**, please briefly describe.

2.8.4 Have you done any modelling or analysis to demonstrate that air quality standards will be met, including consideration of cumulative impacts from other emission sources?

☐ Yes ✔ No — **If yes**, please briefly describe.

Not applicable.

2.8.5 Will the proposal result in liquid effluent discharge?

☐ Yes ✔ No **If yes**, please briefly describe the nature, concentrations and receiving environment.

The marina may be a 'non-point' source for a range of contaminants and therefore the outflow of marina water has the potential to affect water quality in Marmion Marine Park. Contaminants are inherently associated with the use of boats and management will be in place to minimise these contaminants in the marina. Refer to Section 9 of the supporting document.

2.8.6 If there is likely to be discharges to a watercourse or marine environment, has any analysis been done to demonstrate that the State Water Quality Management Strategy or other appropriate standards will be able to be met?

✔ Yes ☐ No **If yes**, please describe.

Water quality is recognised as a key environmental factor to be considered for both construction and operational aspects of this Proposal.

Hydrodynamic modelling has been undertaken to determine the extent of the likely operational water quality impacts (refer to Section 9 of the supporting document). The flushing characteristics of the proposed Ocean Reef Marina have been investigated by Worley Parsons (2009b), whose findings have been peer reviewed by MP Rogers & Associates (2009). MP Rogers & Associates concluded that a single entrance marina design was likely to be adequate and would most likely perform in much the same manner as the Hillary's Boat Harbour which has been shown to flush within five days thanks largely to baroclinic circulation induced by fresh groundwater inflow (Schwartz and Imberger 1988).

MP Rogers & Associates (together with Rockwater and APASA) was subsequently engaged by the City to undertake additional modelling studies (MP Rogers & Associates 2011; Rockwater 2011; APASA 2011) which concluded that the proposed marina would flush well and was most unlikely to contribute to nutrient related water quality problems in the adjacent Marmion Marine Park (refer Section 8.3 of the supporting document).

It is proposed to collect contemporary groundwater nutrient data from the site vicinity to confirm that the historical data used in these studies are still representative of nutrient concentrations today and confirm the validity of the modelling conclusions. It is also intended to obtain a peer review of the modelling studies.

However hydrodynamic modelling of the dispersal of fines during construction dredging, excavation and land reclamation works, and maintenance dredging works will be required to determine scale of impacts (if any) on adjacent seagrass beds and nearshore reef platforms arising from the resulting turbidity. This work will be undertaken in accordance with guidance provided in EPA EAG 7 for Marine Dredging Proposals (EPA 2011) and will be used to inform the marine habitat loss assessment in accordance with guidance provided in EPA EAG 3 for Protection of Benthic Primary Producer Habitats in Western Australia (EPA 2009).

2.8.7 Will the proposal produce or result in solid wastes?

☐ Yes ✔ No **If yes**, please briefly describe the nature, concentrations and disposal location/ method.

The Proposal will involve dredging or excavation over an area of approximately 4.5 ha. Dredge spoil is expected to be used for reclamation elsewhere within the footprint of the Development. Hence, no offsite waste rock disposal is anticipated.

2.8.8 Will the proposal result in significant off-site noise emissions?

☐ Yes ✔ No **If yes**, please briefly describe.

Noise will be generated onsite during the construction phase as a result of use of earthmoving machinery and perhaps pile drivers.

The Proponent will ensure that:

- construction equipment is the quietest reasonably available
- construction work will be carried out in accordance with Section 6 of the Australian Standards 2436-1981 "Guide to noise control on construction, maintenance and demolition sites"
- screens, enclosures and other noise mitigating devices shall be used where there is a risk of unacceptable noise levels.

2.8.9 Will the development be subject to the Environmental Protection (Noise) Regulations 1997?

☐ Yes ✔ No **If yes**, has any analysis been carried out to demonstrate that the proposal will comply with the Regulations?

Please attach the analysis.

2.8.10 Does the proposal have the potential to generate off-site, air quality impacts, dust, odour or another pollutant that may affect the amenity of residents and other "sensitive premises" such as schools and hospitals (proposals in this category may include intensive agriculture, aquaculture, marinas, mines and quarries etc.)?

☐ Yes ✔ No **If yes**, please describe and provide the distance to residences and other "sensitive premises".

2.8.11 If the proposal has a residential component or involves "sensitive premises", is it located near a land use that may discharge a pollutant?

☐ Yes ☐ No ✔ Not Applicable

If yes, please describe and provide the distance to the potential pollution source

2.9 Greenhouse Gas Emissions

2.9.1 Is this proposal likely to result in substantial greenhouse gas emissions (greater than 100 000 tonnes per annum of carbon dioxide equivalent emissions)?

☐ Yes ✔ No **If yes**, please provide an estimate of the annual gross emissions in absolute and in carbon dioxide equivalent figures.

2.9.2 Further, if yes, please describe proposed measures to minimise emissions, and any sink enhancement actions proposed to offset emissions.

2.10 Contamination

2.10.1 Has the property on which the proposal is to be located been used in the past for activities which may have caused soil or groundwater contamination?

☐ Yes ☐ No ✔ Unsure **If yes**, please describe.

It is unlikely that contaminants would be present in marine sediments at Ocean Reef from the current boat harbour facilities - the current facilities are for trailer boats only. There are no moored vessels and no hull cleaning is undertaken at present. Monitoring and management measures will be in place to ensure that relevant marine water quality objectives and criteria are achieved.

2.10.2 Has any assessment been done for soil or groundwater contamination on the site?

☐ Yes ☐ No **If yes**, please describe.

Not applicable.

2.10.3 Has the site been registered as a contaminated site under the *Contaminated Sites Act 2003*? (on finalisation of the CS Regulations and proclamation of the CS Act)

☐ Yes ☐ No **If yes**, please describe.

Not applicable.

2.11 Social Surroundings

2.11.1 Is the proposal on a property which contains or is near a site of Aboriginal ethnographic or archaeological significance that may be disturbed?

☐ Yes ✔ No ☐ Unsure **If yes**, please describe.

2.11.2 Is the proposal on a property which contains or is near a site of high public interest (e.g. a major recreation area or natural scenic feature)?

✔ Yes ☐ No **If yes**, please describe.

The Proposal will extend into the boundaries of the Marine Park, an ‘A’ class reserve.

The nearshore reef which occurs immediately north of the existing Ocean Reef Boat Harbour supports commercial and recreational stocks of Roe's Abalone (*Halliotis roei*).

2.11.3 Will the proposal result in or require substantial transport of goods, which may affect the amenity of the local area?

✔ Yes ☐ No **If yes**, please describe.

The proposal will require the transport of quarried rock (limestone and granite) to the site to form the core and armour of the breakwaters. The source of the rock has not yet been identified but will be from an existing commercial quarry within reasonable transport distance of the site.

3. PROPOSED MANAGEMENT

3.1 Principles of Environmental Protection

3.1.1 Have you considered how your project gives attention to the following Principles, as set out in section 4A of the EP Act? (For information on the Principles of Environmental Protection, please see EPA Position Statement No. 7, available on the EPA website)

1. The precautionary principle.	✔ Yes	☐ No
2. The principle of intergenerational equity.	✔ Yes	☐ No
3. The principle of the conservation of biological diversity and ecological integrity.	✔ Yes	☐ No
4. Principles relating to improved valuation, pricing and incentive mechanisms.	✔ Yes	☐ No
5. The principle of waste minimisation.	✔ Yes	☐ No

Refer to Section 5.4 of supporting document.

3.1.2 Is the proposal consistent with the EPA's Environmental Protection Bulletins/Position Statements and Environmental Assessment Guidelines/Guidance Statements (available on the EPA website)?

✔ Yes ☐ No

3.2 Consultation

3.2.1 Has public consultation taken place (such as with other government agencies, community groups or neighbours), or is it intended that consultation shall take place?

✔ Yes ☐ No **If yes**, please list those consulted and attach comments or summarise response on a separate sheet.

The Development (in its current form) has been in planning since 2005. Extensive consultation has been undertaken with the community, State Government, and other stakeholders.

Ongoing stakeholder consultation will continue throughout the life of the Proposal as part of normal business practice, providing updates to relevant stakeholders as required. The list of stakeholders will continue to be developed and revised as required.

Refer to Section 4 of the supporting document.

Appendix 2 - Rockwater (2011)

Rockwater
PROPRIETARY LIMITED
76 JERSEY STREET, JOLIMONT, WESTERN AUSTRALIA, 6014
PO BOX 201, WEMBLEY, WESTERN AUSTRALIA, 6913
TELEPHONE: (08) 9284 0222 INTERNATIONAL: 618 9284 0222
FACSIMILE: (08) 9284 1785 EMAIL: consult@rockwater.com.au
A.B.N. 43 008 804 653

1 BACKGROUND

Rockwater carried out numerical flow and solute transport modelling in 2011 to calculate flows and nitrogen loadings to the planned new marina at Ocean Reef. The modelling was based on rainfalls and groundwater recharge continuing with a similar dry climate to that which has occurred since the 1970's.

MP Rogers and Associates has been asked to consider the impacts on the marina of further climate change (less rainfall and higher ocean levels), and has requested that Rockwater considers the groundwater aspects. These are covered below.

2 IMPACT OF REDUCED RAINFALLS

Lower rainfalls would reduce groundwater levels, and hence groundwater throughflow and discharge to the ocean. They would be offset, at least in part, by increased infiltration to groundwater from runoff from roofs and roads with further urbanisation in the area inland, and reduced extraction of groundwater for irrigation of market gardens. Lowering of groundwater levels on the Gnangara Mound (upgradient of Ocean Reef) has resulted in the development of the Gnangara Sustainability Strategy (2009). Based on the strategy, the Government is planning reductions in private and public groundwater extraction; and the clearing of pine plantations that prevent groundwater recharge.

The future climate in Perth could be wetter, similar or drier than at present, although it has been widely predicted to be drier. For example, Sadler (2007) cited in DoW (2009) predicted that rainfall could decrease by 15 percent to 2030 compared to the 1980–1999 baseline, together with a -5% to -25% natural variability.

The CSIRO (2009) has assessed groundwater availability in the South-West of Western Australia at year 2030 for a number of climate scenarios using 15 global climate models, including a dry extreme future climate scenario. The Perth Regional Aquifer Modelling System (PRAMS) was run to predict future groundwater levels for these scenarios, and for the dry extreme future climate case predicted that groundwater levels in 2030 would be similar near the coast at Ocean Reef and 3 m lower inland on the flanks of the Gnangara

Mound. The modelling did not allow for the impacts of urbanisation, or for reductions in extraction and increased recharge to the Gnangara Mound.

The 2011 Rockwater model constructed for the Ocean Reef project was re-run with 20 percent lower recharge rates to give approximately 3 m lower groundwater levels inland of the planned marina. In that case calculated flow rates to the planned new marina after 10 years with the drier climate are indicated to average 7,900 kL/d in winter and 4,600 kL/d in summer; 93 to 95 percent of the flows calculated for the current climatic conditions. The flows would continue to decline at a gradually decreasing rate until a new equilibrium was reached.

3 IMPACT OF HIGHER OCEAN LEVELS

Higher ocean levels will change the configuration of the coastline and cause the coastal saltwater wedge in the aquifer to move further inland.

Groundwater levels will rise to match the rise in base level (ocean level) and so there will be little change in hydraulic gradients. As a result groundwater discharge rates will, therefore, also remain largely unchanged.

4 CONCLUSIONS

In conclusion:

- The 2011 modelling was based on the climate since the 1970's which has been drier than the climate in the long term record.
- It is uncertain whether the climate will continue to be dry, or even drier.
- On the basis of a drier future as predicted by the CSIRO, the groundwater levels would decrease by about 3 m inland but remain at around current levels near the coast. Also, groundwater flow to the planned marina could decrease by up to 10% over the coming decade, and by more in subsequent decades.

Dated: **19 July 2013** **Rockwater Pty Ltd**

P H Wharton
Principal

REFERENCES

CSIRO, 2009, Groundwater yields in south-west Western Australia. Report to the Australian Government from the Sustainable Yields Project.

DoW, 2009, Perth-Peel regional water plan 2010–2030, responding to our drying climate. Draft for public comment.

Government of Western Australia, 2009, Gnangara sustainability strategy. Draft for public comment.

Appendix 3 - MP Rogers & Associates (2012)

July 2012

City of Joondalup

Hillarys to Ocean Reef Coastal Vulnerability

m p rogers & associates pl
marinas boat harbours canals breakwaters jetties submarine pipelines seawalls dredging reclamation

Job J961, Report R316 Rev 1

July 2012

City of Joondalup

Hillarys to Ocean Reef Coastal Vulnerability

Job J961, Report R316 Rev 1 Record of Document Revisions

Rev	Purpose of Document	Prepared	Reviewed	Approved	Date
A	Draft for MRA review	D Hamilton	T Hunt	T Hunt	08/05/12
0	Issued for Client use	D Hamilton	M Rogers	T Hunt	14/05/12
1	Client & DoT comments incorporated and re-issued as final report	D Hamilton	T Hunt	T Hunt	17/07/12

Form 035 12/02/07

m p rogers & associates pl
waves currents tides flood levels water quality siltation erosion rivers beaches estuaries climate change

t: +618 9444 4045
f: +618 9444 4341
e: admin@coastsandports.com.au
Unit 2, 133 Main Street, Osborne Park WA 6017, AUSTRALIA

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Executive Summary

The City of Joondalup commissioned M P Rogers & Associates (MRA) to complete a coastal assessment of the coastline between Hillarys Boat Harbour and Ocean Reef Boat Harbour. This coastal assessment involved:

- A site inspection by coastal engineers of the study area noting the condition of the beaches and presence of limestone rock;
- Updating existing shoreline movement plans and analysis of the shoreline movement in the study area;
- Creation of a conceptual sediment budget for the study area;
- Modelling of the potential severe storm erosion at key sectors in the study area;
- Assessment of the coastal vulnerability of the study area to sea level rise (SLR);
- Conceptual coastal management options for vulnerable areas; and
- Budget cost estimates for conceptual management options and a priority plan for these works.

The study area was broken into a number of study cells to facilitate the assessment. Of the 5 cells, the Hillarys, Whitfords, Kallaroo and Mullaloo, cells were predominantly sandy shoreline cells, while the Ocean Reef cell consisted entirely of rocky cliffs. No evidence of rock was observed in the cells south of the Ocean Reef cell.

Due to the construction of the Hillarys and Ocean Reef Boat Harbours in the 1970's to 19080's, analysis of the historical shoreline movement was focused on the period 1987 to 2010. This analysis showed that there has been a general pattern of recession in the southern cells and accretion of the northern cells of the study area.

A sediment budget and conceptual sediment model were developed from the shoreline movement analysis. The sediment budget included a net transport of sediment northwards from Hillarys Boat Harbour in the order of around 11,000 m^3/yr for the 1987 to 2010 period. Inter-annual variations in the frequency of occurrence of key wave events was suggested to have a large impact on the sediment movement in the study area.

The coastal vulnerability to storm erosion, trends in shoreline movement and sea level rise for each of the shoreline sectors was assessed over the short term and the longer 50 and 100 year time frames. The vulnerability was assessed in line with the principles of the SCPP, but using a more realistic method of including historic shoreline movement trends and per Bruun assessment of sea level rise.

The vulnerability assessment showed that:

- The immediate vulnerability risk for the Hillarys to Ocean Reef coastline is erosion caused by severe storm events.

- Beach access ways and dune fencing comprise the majority of the vulnerable infrastructure over the short term. However, the Mullaloo SLSC may be vulnerable to scouring during the severe storm event.

- Significant sections of public infrastructure are estimated to be at risk over the 2060 and 2110 time frames. This includes sections of Whitfords Avenue, Northshore Drive, residential infrastructure, parks, car parks and the Mullaloo SLSC.

- Sections of the shoreline may require active coastal management in the coming 100 years in response to SLR, shoreline recession and severe storm erosion risks.

Subsequently, several recommendations have been proposed to manage the potential vulnerability risk over both the short term and the longer term. The proposed coastal management to address the vulnerability of the coastline includes:

- Active management of beach access ways located on the eroding shoreline at Pinnaroo Point. This involves lowering the beach access point to reduce the effects of erosion and scour.

- Allowances for reinstatement and repairs to the dune fencing and beach access ways located along the shoreline.

- Investigate the adequacy of protection provided to the Mullaloo SLSC by the associated retaining walls and install additional protection if required.

- Setting up a beach monitoring program utilising existing beach profiles, to monitor shoreline movement and provide greater information for future planning.

- Where possible, a policy of planned retreat for all non essential public infrastructure located in close proximity to the shoreline. This includes car parks, parks and DUP networks.

A recommended program and cost estimate for works to be undertaken in the short term was provided. The main priority of the works program was the protection of the Mullaloo SLSC and to allow for the reinstatement and repair of the numerous beach access ways and dune fencing along the shoreline.

The works program does not recommend the wholesale protection of beach access ways or dune fencing due to the high cost of protecting this infrastructure. Instead, the City should allow for the probability of required repairs and reinstatement to the vulnerable infrastructure in future budgets. The total cost of works to repair the dune fencing and beach access ways following the estimated 100 year ARI storm event was estimated at $200,000 excl GST.

Over the longer term it was proposed that due to the existing buffer to critical infrastructure, the City should monitor the effects of sea level rise and shoreline movement on the Hillarys to Ocean Reef coastline in coming years before committing to hard protection works.

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Glossary of Key Terms

Accretion: The buildup or accumulation of land, on a beach primarily by deposition of water or air-borne material. Can be natural or artificial (opposite of erosion).

Australian Height Datum (AHD): Datum for altitude (height) measurement across Australia, approximately mean sea level.

Average Recurrence Interval (ARI): A statistical estimate of the interval of time between events, in years. For example a 100 year ARI water level is a water level that occurs on average every 100 years.

Climate Change: Any change in climate over time, whether due to natural variability or as a result of human activity.

Coastal Processes: The action of natural forces on the coast or shoreline.

Cross-shore: Perpendicular to the shoreline.

Erosion: The process of wearing away or removing material by natural forces (the opposite of accretion).

Event: An occurrence of a particular set of circumstances.

Extreme Event: Infrequent meteorological phenomena that surpasses a defined threshold.

Horizontal Setback Datum (HSD): The datum for assessing a physical processes setback. Considered the leading edge of vegetation on an accreting coastline, it may be permanent or temporary.

Longshore: Parallel to the shoreline.

Mean Sea Level (MSL): The average height of the surface of the sea.

Nearshore: A general area extending from the breaking zone seaward to the start of the offshore area

Offshore: The zone beyond the nearshore zone, generally where wave induced sediment motion is negligible.

Physical Process Setback (PPS): From the State Coastal Planning Policy, the summation of the allowances determined for S1, S2 and S3 and allowing for natural fluctuations in the coastal processes. Designed to protect development and infrastructure from the effects of physical coastal processes over the development timeframe.

Recession: See erosion.

S1- Severe Storm Erosion Allowance: An allowance to account for the impact of a severe storm on the beach profile of a shoreline.

S2 – Historical Shoreline Movement Allowance: An allowance to account for the historical shoreline movement trends of a coastline.

S3 – Sea Level Rise Allowance: An allowance for sea level rise.

Sea Level Rise: A long term increase in mean sea level.

Setback: A required open space, measured horizontally and perpendicular to the HSD.

Shoreline: Commonly, the line that forms the boundary between the land and the water, it can fluctuate with coastal processes.

Storm Surge: An increase above normal water level caused by wind stress on the ocean surface (wind stress), or a reduction in atmospheric pressure.

Water Level: The elevation of still water relative to some datum.

Wave Setup: The elevation of water level due to the action of waves, commonly occurs near the coastal surf zone.

d_{50}: Median sediment grain size (mm).

H_s: Significant wave height, the average height of the largest one third of waves.

T_p: The peak wave period, ie the wave period with the highest energy. Where a wave period is the time for two consecutive wave crests to pass the same point.

1. Introduction

1.1 General

This is the second study to assess the vulnerability of the shoreline within the City of Joondalup (City) over the coming 100 years. This report focuses on the coastline between Hillarys Boat Harbour and Ocean Reef Boat Harbour. It follows a similar assessment from Marmion to Sorrento completed in 2011 (MRA 2011a).

In general the shoreline between the Hillarys and Ocean Reef Boat Harbours has a greater setback to infrastructure than many other sections of the shoreline in the Perth Metropolitan area. However there are still areas where important public infrastructure and residential development are in close proximity to the shoreline.

The study area extending from Hillarys Boat Harbour to Ocean Reef Boat Harbour is shown in Figure 1.1. The main coastal features for this section of shoreline have been highlighted.

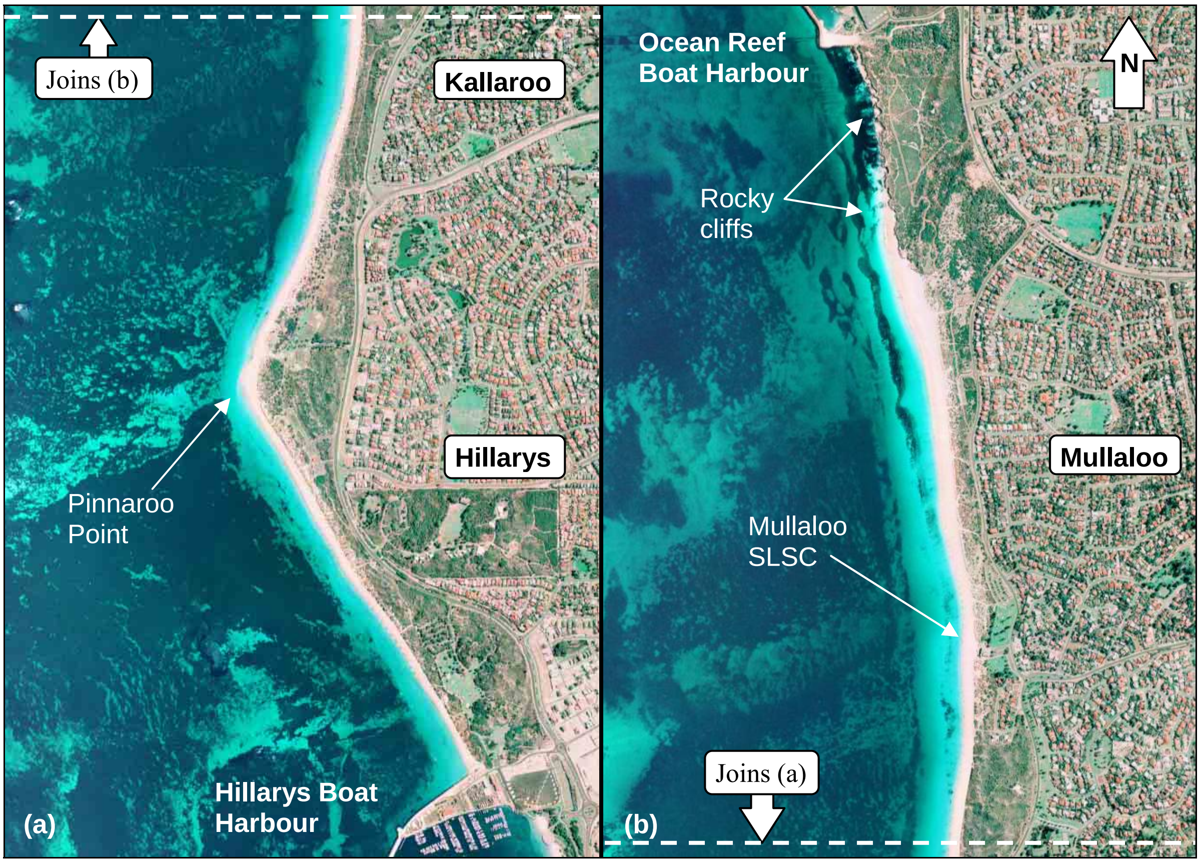

Figure 1.1 – Study Area & Coastal Features

The shoreline in the study area has been significantly modified by human activity, with the construction of Hillarys Boat Harbour and Ocean Reef Boat Harbour altering the coastal processes in the area. Due to the high value of residential development and public infrastructure in close proximity to the shoreline, the City engaged specialist coastal and port engineers M P Rogers and Associates Pty Ltd (MRA) to complete a coastal vulnerability study for this section of shoreline.

The study and assessment includes:

- A site inspection by coastal engineers of the study area noting the condition of the beaches and presence of limestone rock;
- Updating existing shoreline movement plans and analysis of the shoreline movement in the study area;
- Creation of a conceptual sediment budget for the study area;
- Modelling of the potential severe storm erosion at key sectors in the study area;
- Assessment of the coastal vulnerability of the study area to sea level rise (SLR);
- Conceptual coastal management options for vulnerable areas; and
- Budget cost estimates for conceptual management options and a priority plan for these works.

This report presents a summary of the data, methods and findings of the study.

1.2 Background

1.2.1 Study Area

The study area is defined by Hillarys Boat Harbour to the south and Ocean Reef Boat Harbour to the north and includes a range of different shoreline types. While the majority of the shoreline is sandy beach backed by dune systems there are also limestone cliffs and bayed beaches at the northern end.

Investigations by Searle & Semeniuk (1985) and Eliot et al (2005) have classified the Mandurah to Two Rocks coastline in terms of primary sediment cells and secondary sediment cells. More recently Stul et al

(2007) classified the Mandurah to Two Rocks coastline in terms of primary, secondary and tertiary level sediment cells.

In order to assist in the evaluation of the vulnerability of the shoreline and maintain consistency with alternative studies, the study area has been separated into discrete sectors or cells. The determination of these cells is explained in greater detail further on in the report and includes assessments of accretion and erosion, differences in shoreline alignment and changes in shoreline types. The cells and boundaries referred to in this report are presented in Figure 1.2.

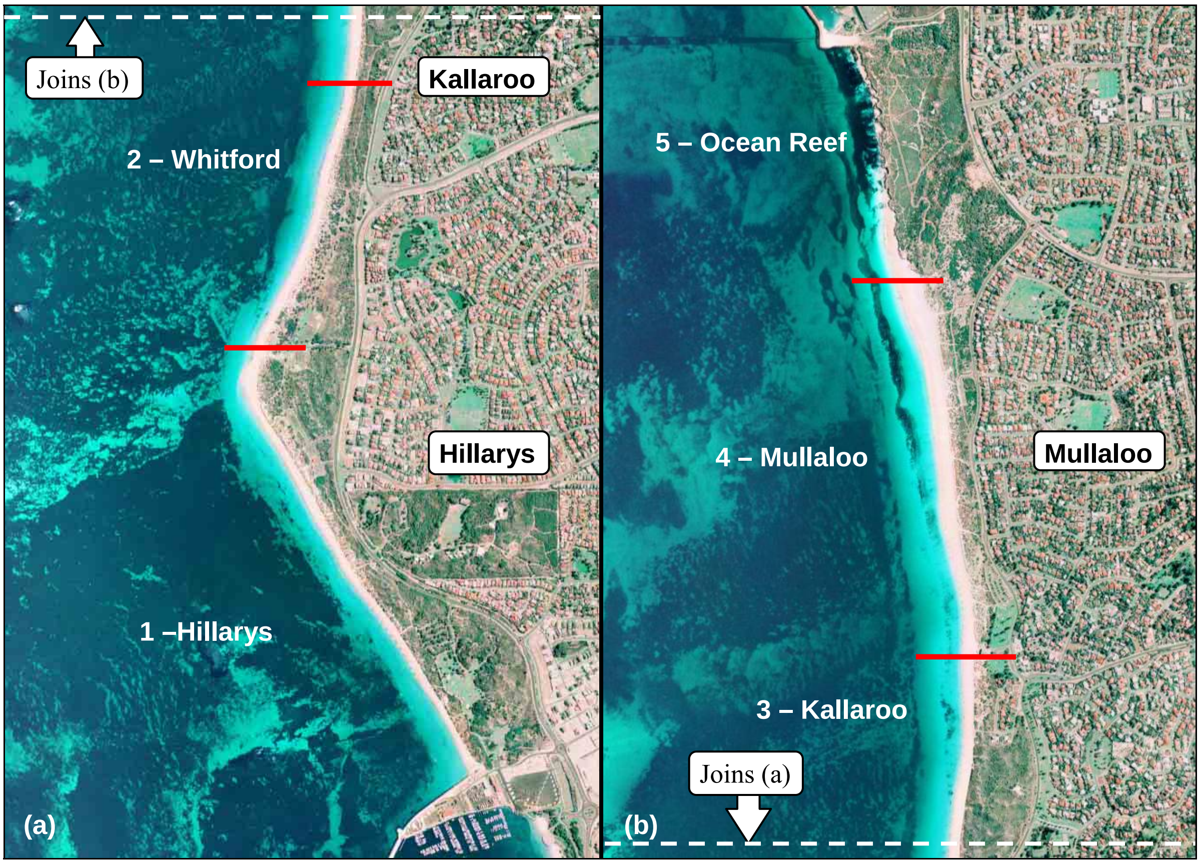

Figure 1.2 – Study Area - Cells & Boundaries

1.2.2 Construction History of Major Coastal Structures

The study area is bound by two significant developments, Hillarys Boat Harbour to the south and Ocean Reef Boat Harbour to the north. The construction of these two developments is likely to have altered the coastal processes in the area.

Hillarys Boat Harbour was constructed in 1987 and consists of southern and northern breakwater arms of 1,200 and 500 m respectively. These breakwater arms extend past the -5 m contour and are believed to prevent the majority of sediment transport past Hillarys Boat Harbour.

The impact of the Ocean Reef Boat Harbour on local nearshore sediment transport began in 1977 with the construction of two groynes out from the shoreline. The remainder of the boat harbour was completed by 1979. The associated breakwaters extend past the -5 m contour and are expected to have substantially reduced any longshore transport past the harbour.

1.2.3 Previous Investigations

A number of previous studies into coastal processes have previously been completed for the study area. The main outcomes are summarised and discussed below.

MRA have previously completed the Northern Perth Metropolitan Coast – Coastal Setback Study (MRA 2005) for the then Department of Planning and Infrastructure (DPI). This report used the State Coastal Planning Policy (SCPP) to determine the required coastal setbacks to development and presented a first pass of areas that may require active coastal management in the coming decade. In general for the study area, MRA (2005) found that little active coastal management would be required in the decade following 2005. One area that was identified as potentially requiring active management was the Mullaloo SLSC.

The current study provides a more detailed assessment of the coastal vulnerability of the study area.

WorleyParsons (2008) completed investigations into the potential shoreline impacts of the redevelopment of Ocean Reef Boat Harbour. MRA (2009) completed a peer review of this work and concluded that a redevelopment of the harbour incorporating deeper breakwaters would further interrupt sediment transport.

In addition, MRA (2009) estimated that for the 1987 to 2010 period:

- Overall a gross net movement of 10,000 m^3/yr was estimated to move north past Ocean Reef Boat Harbour. A proportion of this may be transported along the nearshore reefs.

- Ocean Reef Boat Harbour trapped approximately 5,000 m^3/yr of sediment against the northern breakwater. This is routinely removed and stockpiled by the Department of Transport (DoT).

- The shoreline between Hillarys Boat Harbour and Mullaloo SLSC eroded at around 20,000 m^3/yr and the beaches north of the Mullaloo SLSC accreted at 20,000 m^3/yr.

- Seasonal fluxes along Mullaloo Beach were in the order of 100,000 to 200,000 m^3/yr with sediment movement north in summer and south in winter.

2. Site Setting

2.1 Site Inspection

2.1.1 General

As part of the study MRA completed a site visit to inspect the area, ground truth coastal data and to map the position of exposed rock and reef. As stated previously, the study area has been separated into cells to assist in the analysis of the shoreline. The specific reasoning behind this breakup will be discussed in later sections. A summary of the general inspection for each of these cells is presented below.

2.1.2 Hillarys Cell

The Hillarys cell extends from the northern breakwater of Hillarys Boat Harbour to the northern side of Pinnaroo Point and is shown in Figure 2.1.

Figure 2.1 – Hillarys Cell & Key Features

This section of shoreline is a relatively straight sandy shoreline backed by sand dunes. Figure 2.1 shows that there are several recreational areas, car parks and a section of Whitfords Avenue in close proximity to the shoreline in this sector.

The cell is relatively wide immediately north of Hillarys Boat Harbour and has a flat beach profile. The area north of Hillarys Boat Harbour has recent vegetation growth at the rear of the beach and small foredunes backed by a dune system of increasing height. Figure 2.2 shows the beach profile immediately north of Hillarys Boat Harbour.

Figure 2.2 – Beach North of Hillarys Boat Harbour (18/1/12)

As the beach continues north the beach narrows and backs directly onto the primary sand dune.

Towards Pinnaroo Point the beach appears to transition to a more erosive profile with a narrower and steeper beach profile. Figure 2.3 shows a photograph of this area looking southwards.

Figure 2.3 – Looking South From Pinnaroo Point (18/1/12)

The changing beach profile of the Hillarys cell is also shown in the conditions of the beach access tracks along the cell shoreline. While the access tracks in the southern half of the cell show signs of heavy windblown accretion, the access ways to the north appear to be experiencing scour. This is shown in Figures 2.4a and 2.4b.

Figure 2.4 – Hillary Cell Access Tracks, (a) Windblown Accretion at the South End & (b) Erosion at the North End (18/1/12)

The Hillarys cell also includes Pinnaroo Point, a cuspate headland that has formed in the lee of the Little Island Reef group that lie approximately 2 km offshore (Short 2006). The southern side of Pinnaroo Point has a narrow, relatively flat beach that backs directly onto the primary dune.

As shown in Figure 2.5, the access track located on the southern side of the Point may be at risk from being undercut by wave action in the future.

Figure 2.5 – Pinnaroo Point Access Track (18/1/12)

The beach profile of Pinnaroo Point changes as the shoreline heads north. On the northern side of the point the beach becomes much wider and the crest height of the primary dunes lowers. This is shown in Figure 2.6.

Figure 2.6 – Pinnaroo Point Northern Side (18/1/12)

This area forms the transition shoreline between the Hillarys and Whitfords cells.

2.1.3 Whitfords Cell

The Whitfords cell is a relatively straight section of shoreline on a south-south west to north-north east alignment. This cell extends approximately 1 km from the northern side of Pinnaroo Point. The extent of the Whitfords cell is shown in Figure 2.7.

Figure 2.7 – Whitfords Cell Extents & Key Features

The Whitfords cell has a relatively uniform beach profile along the length of the sector. It is characterised as a flat, wide beach leading to a series of low dunes. This can be seen in Figure 2.8.

Figure 2.8 – Whitfords Cell (18/1/12)

The series of low dunes are heavily vegetated and extend from the rear of the beach right up to a dual use path and continue to Northshore Drive. Old boating signs in the rear dunes and new vegetation growth are evidence of accretion of this shoreline.

2.1.4 Kallaroo Cell

The Kallaroo cell is a relatively straight section of shoreline on a north - south alignment. This cell covers approximately 1 km of shoreline to the south of the Mullaloo SLSC. The extent of the Kallaroo cell is shown in Figure 2.9.

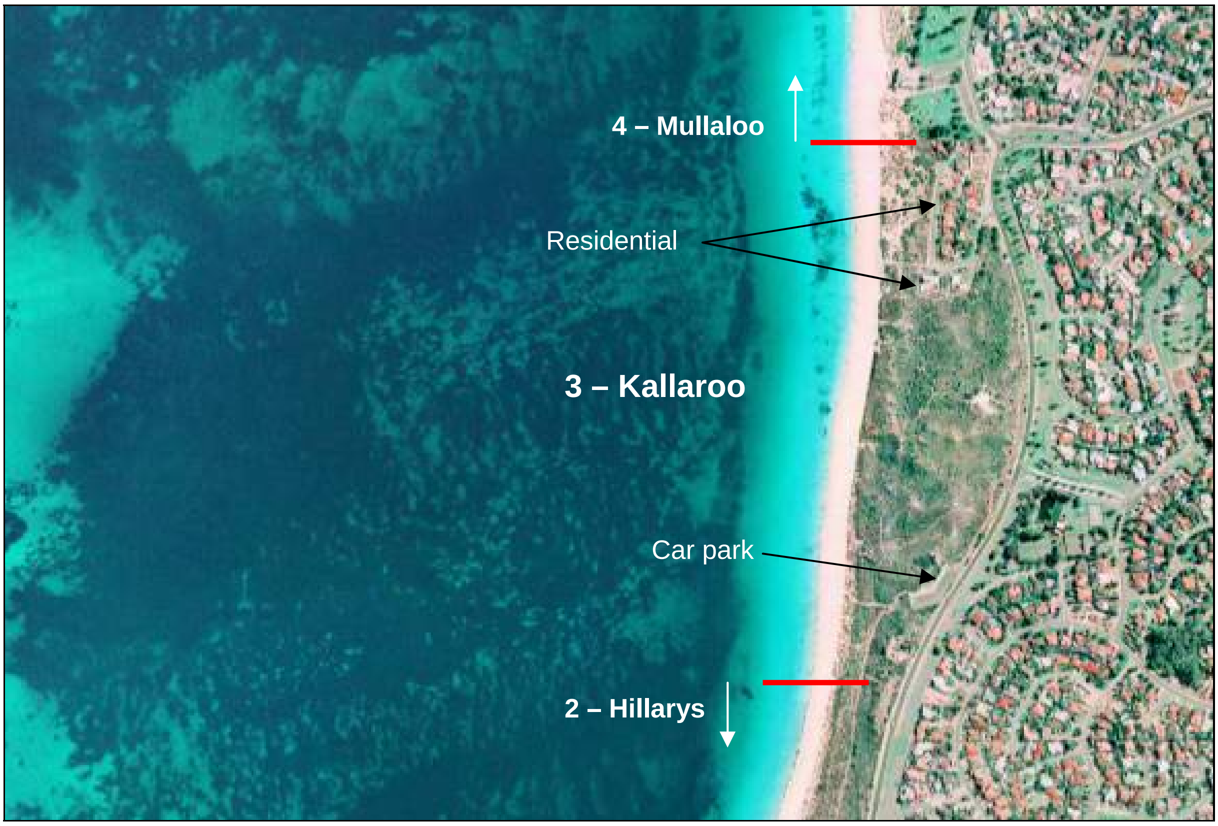

Figure 2.9 – Kallaroo Cell Extents & Key Features

The Kallaroo cell has a relatively uniform flat, wide beach along its length. In the south this beach leads to a series of low dunes, as seen in Figure 2.8.

As the shoreline continues north the dunes increase in height. Figure 2.10 shows the beach at the northern end of the Kallaroo cell looking south.

Figure 2.10 – Kallaroo Cell – North End (Looking South) (18/1/12)

In addition to an increased dune height, the beach also widens as it continues north. The small foredune with new vegetation indicates recent accretion.

2.1.5 Mullaloo Cell

The Mullaloo cell extends from the southern side of the Mullaloo SLSC north to the limestone cliffs that are located south of Ocean Reef Boat Harbour. Figure 2.11 shows the extent of this cell.

Figure 2.11 – Mullaloo Cell Extents & Key Features

The Mullaloo Cell is a relatively straight section of shoreline, with a wide flat beach backed by dunes. Figure 2.12 shows the Mullaloo SLSC at the southern end of the cell.

Figure 2.12 – Mullaloo Cell – Southern End (18/1/12)

Figure 2.12 shows that the SLSC is located in line with the primary dunes in order to serve its functional purpose. The SLSC has a number of associated retaining walls, it is unclear whether these have been designed as seawalls to resist wave action.

Further north the beach increases in width while maintaining a flat slope and consistent dune height. Figure 2.13 shows that the northern end of the cell is a very wide, flat beach with dunes that appear to be experiencing accretion.

Figure 2.13 – Mullaloo Cell – Looking North (18/1/12)

The Mullaloo cell ends at the start of the limestone cliffs that head north towards Ocean Reef and can be seen in Figure 2.13.

2.1.6 Ocean Reef Cell

The Ocean Reef cell covers a section of shoreline that is dominated by limestone cliffs and extends north to the southern side of Ocean Reef Boat Harbour. The extent of the Ocean Reef cell is shown in Figure 2.14.

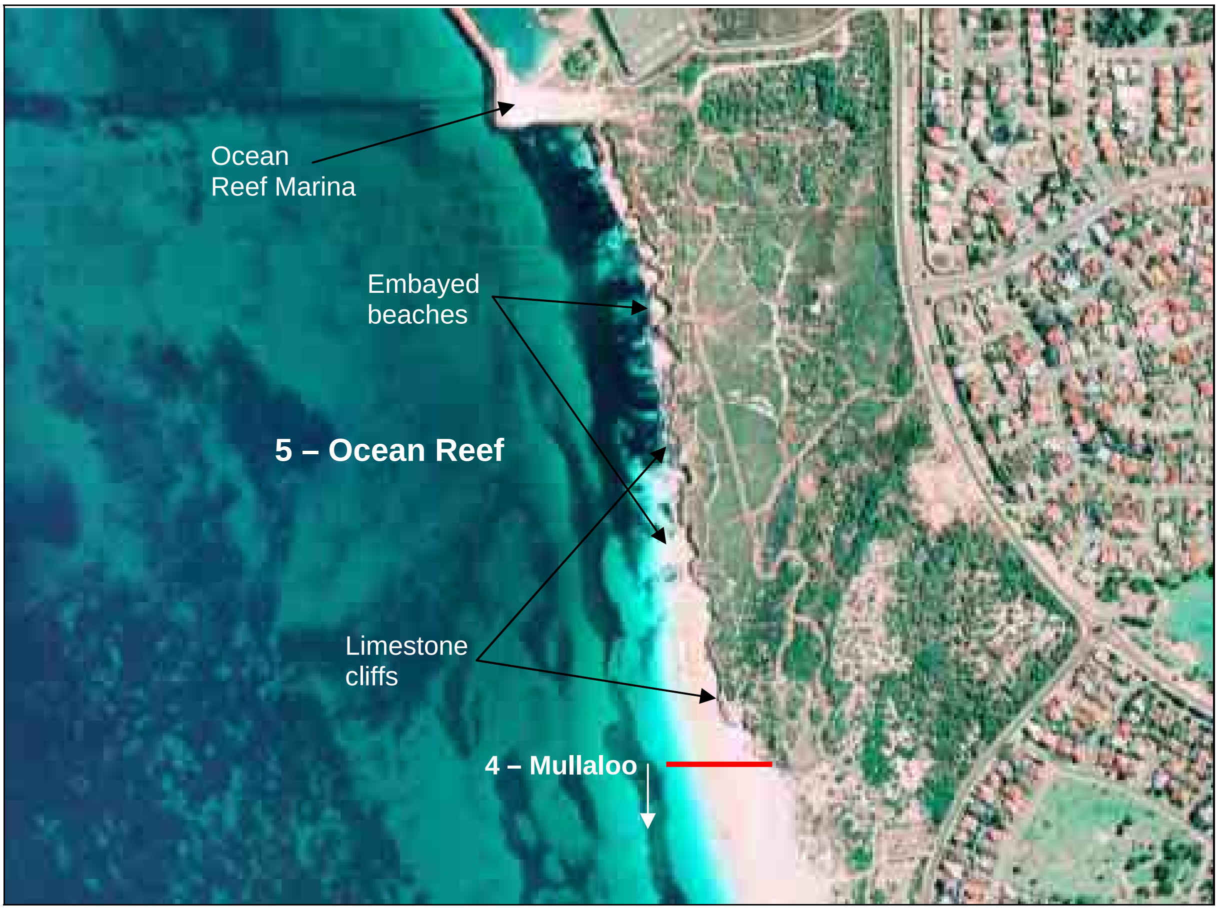

Figure 2.14 – Ocean Reef Cell Extents & Key Features

The shoreline contained within the Ocean Reef cell primarily consists of limestone cliffs with embayed beaches. Aerial images show there can be seasonal movement of sand along the coast. During some summer months sandy beaches can form in front of the cliffs.

The limestone rock in the southern section of the cell typically extends from approximately 0 mAHD to approximately +4 mAHD.

The beach in this section stretches in front of the limestone cliffs for several hundred metres. Further north the shoreline becomes a series of small rock headlands with embayed beaches. Figure 2.15 shows a typical embayed beach for this section of shoreline.

Figure 2.15 – Ocean Reef Cell – Typical Embayed Beach (18/1/12)

The height of the limestone cliffs increase as they head north, with the limestone extending from the waterline to approximately +10 mAHD. This is shown in Figure 2.16.

Figure 2.16 – Ocean Reef Cell – North End Looking South (18/1/12)

The area behind the limestone cliffs is relatively undeveloped for the length of the cell. Noticeable infrastructure is limited to a DUP that is approximately 50 m back from the cliff edge.

The rock observed on site is Tamala limestone, which can offer significant protection from the processes of the ocean. This is the same material which is present on the rocky shorelines of Cottesloe and Halls Head, Mandurah. In Mandurah, surveys of the rocky cliffs from early last century indicate there has been less than 5 m movement of the cliffs in over 100 years. This shows that competent limestone can provide protection and withstand the erosive effects of the ocean.

3. Site Conditions

3.1 Geology & Geomorphology

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

Searle & Semeniuk (1985) broadly classified the coast into a number of sectors, the study area falling at the southern end of the Whitfords to Lancelin sector, which the authors describe as a dominantly straight rocky shore with isolated accretionary cusps. The coast in this sector is generally characterised by rocky coasts and pocket beaches interspersed with straight sandy beaches (Searle & Semeniuk 1985).

This general characterisation of the sector is represented across the study area, with offshore reef platforms located north of Hillarys Boat Harbour, an isolated accretionary cusp at Pinnaroo Point and sandy beaches and dune systems stretching to the north. Limestone cliffs and bayed beaches are also present at the northern end of the study area.

Geosciences Australia's 2005 report (Jones et al 2005) conducted a natural hazard risk assessment that focused on the Perth Metropolitan area and its surroundings. One of the coastal hazards investigated was the potential for recession of the shoreline based on the presence of 'erosion-prone' sand and 'erosion-resistant' limestone (Jones et al 2005).

Using available environmental geology maps which showed the spatial distribution of the surface geology, Jones et al (2005) undertook microtremor, borehole and seismic cone penetrometers test (SCPT) investigations. This allowed Jones et al (2005) to estimate the lithography distribution across depth. Figure 3.1 shows the estimated upper surface of Tamala limestone relative to sea level.

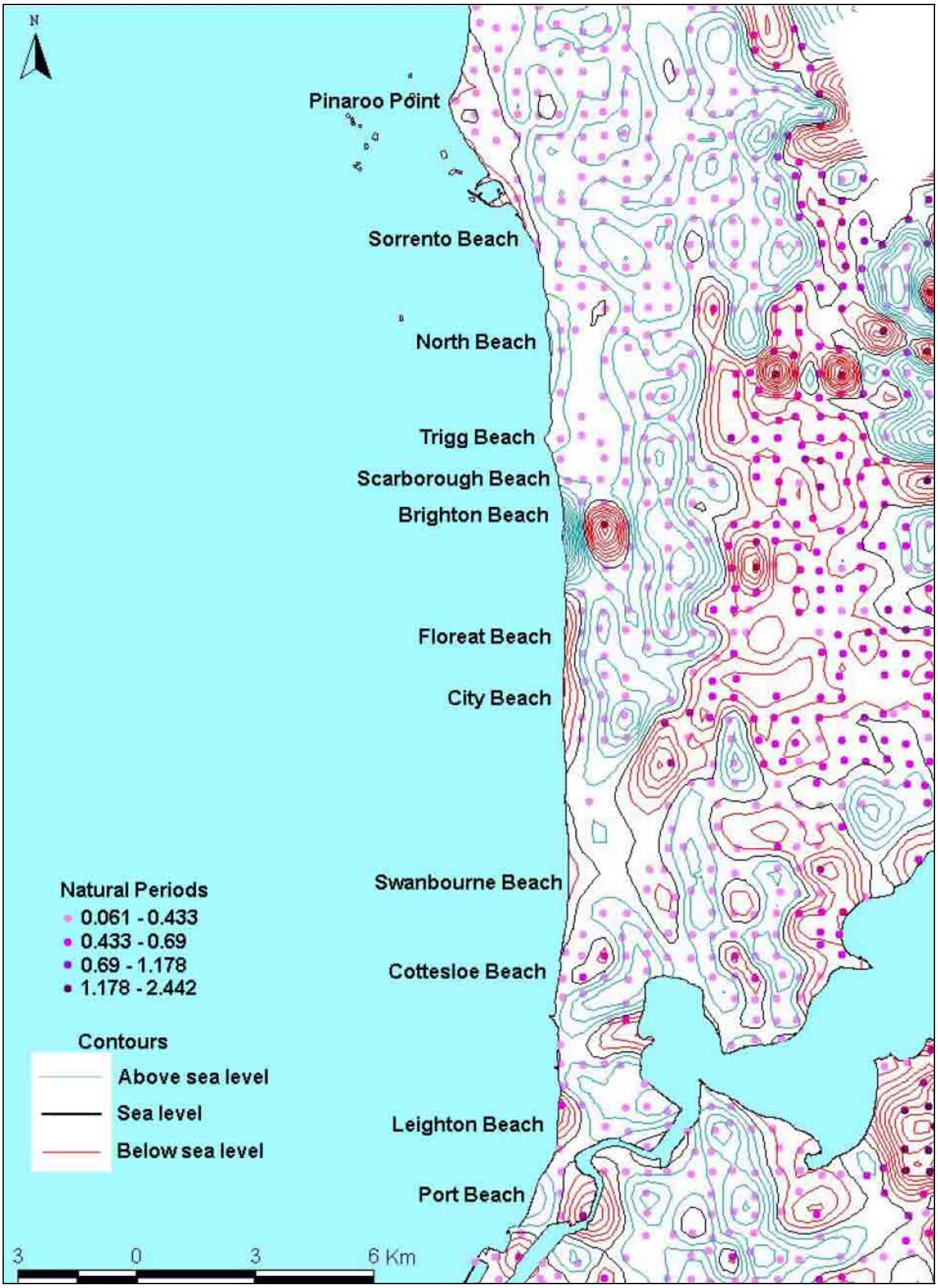

Figure 3.1 – Upper Surface of Limestone Relative to Sea Level (Jones et al 2005)

It can be seen that the assessment did not cover the entire study area of this report, however it does cover the Pinnaroo Point area. The figure indicates that competent rock about Pinnaroo Point was only present below water level.

Jones et al (2005) stated that coastal erosion of the Pinnaroo Point area is possible as competent lithologies are located below sea level. However, it is considered to be the least vulnerable of areas identified as 'potentially prone to erosion' as external sediment input appears sufficient to fill any accommodation space created by sea level rise (Jones et al 2005). Should the availability of external sediment decrease then erosion of the Pinnaroo Point may occur.

The extent of this potential erosion indicated by Jones et al (2005) includes all of the area landward of the limestone below sea level. This does not take into account local conditions, structures or beach profiles. A more detailed analysis of the vulnerability of this section will be presented later in the report.

3.2 Coastal Processes

3.2.1 General

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

- longshore sediment transport;
- cross-shore sediment transport; and
- wind-blown sand transport.

The following sections discuss the fundamental mechanisms for the sandy shorelines, which make up the majority of the study area, as well as the rocky shorelines to the north.

3.2.2 Longshore Sediment Transport

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

However, longshore sediment transport along rocky sections of shoreline, such as that south of Ocean Reef Boat Harbour, is believed to be more complex than the sandy beaches across most of the study area. Figure 3.2 depicts typical longshore transport mechanisms along rocky shorelines.

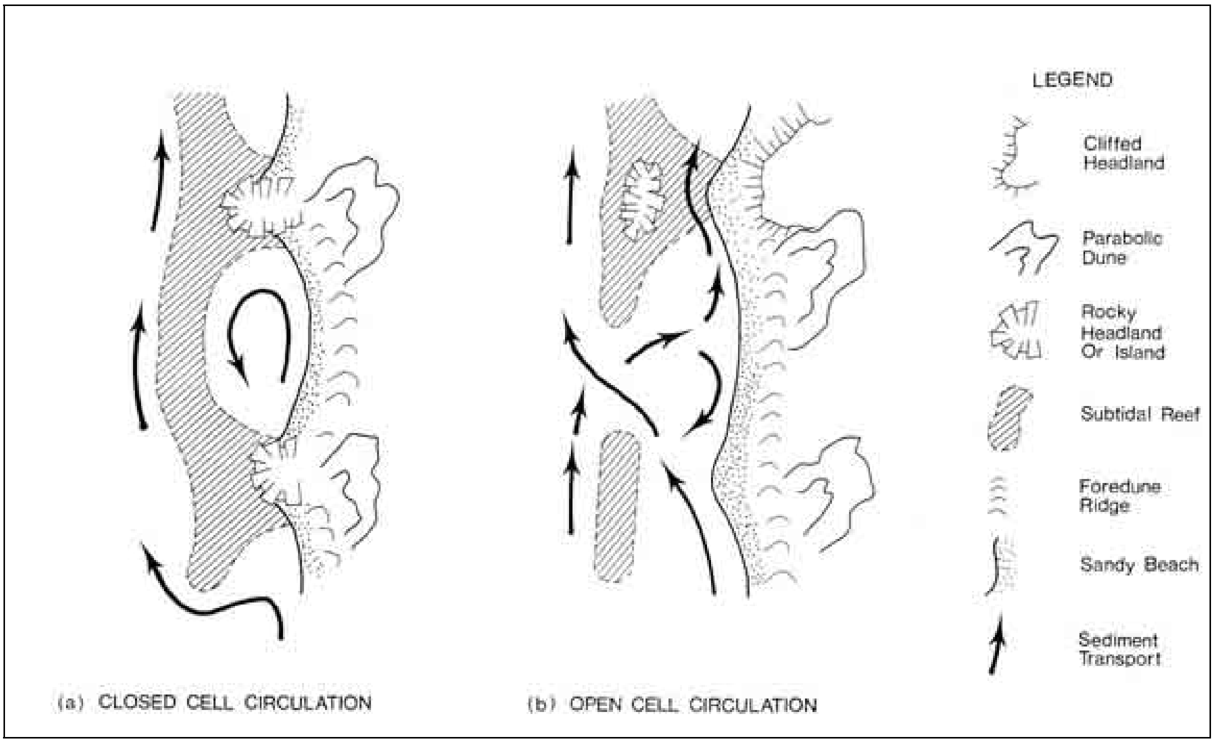

Figure 3.2 – Longshore Transport Along Rocky Coastlines (Sanderson & Eliot 1999)

The shoreline south of Ocean Reef Boat Harbour is most likely the process (b) shown in Figure 3.2. Channels exist through to the open ocean, allowing sediment to be transported offshore between the reefs, while some sediment will be transported adjacent to the coast and some will be transported on the outer edge of the reef.

There can also be considerable variation in magnitude and direction of the longshore transport from season to season and year to year. In Perth, longshore sediment transport is typically north in summer and south in winter. The strong sea breezes blow from the south-west in summer, creating wind waves at an angle to the shoreline. This transports sediment to the north (Masselink and Pattiaratchi 2001). In winter, severe storms generate waves from the north, swinging to the south over their duration.

This typically transports sediment to the south in winter storms (Masselink and Pattiaratchi 2001).

MRA (2010) reviewed the typical wave and water levels at Watermans Bay and Mettams Pool, which are similar to the rocky shoreline south of Ocean Reef Boat Harbour. This indicated that generally the longshore transport would be concentrated in the inshore area to a depth of about 6 m of water.

3.2.3 Cross-shore Sediment Transport

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

For sandy beaches, the initial width of the surf zone is often insufficient to dissipate the increased wave energy of the storm waves. The residual energy is often spent in eroding the beach face, beach berm and sometimes the dunes. The eroded sand is carried offshore with return water flow where it is deposited and forms an offshore bar. Such bars can eventually grow large enough to break the incoming waves further offshore, causing the wave energy to be spent in a wider surf zone. This is shown diagrammatically in Figure 3.3.

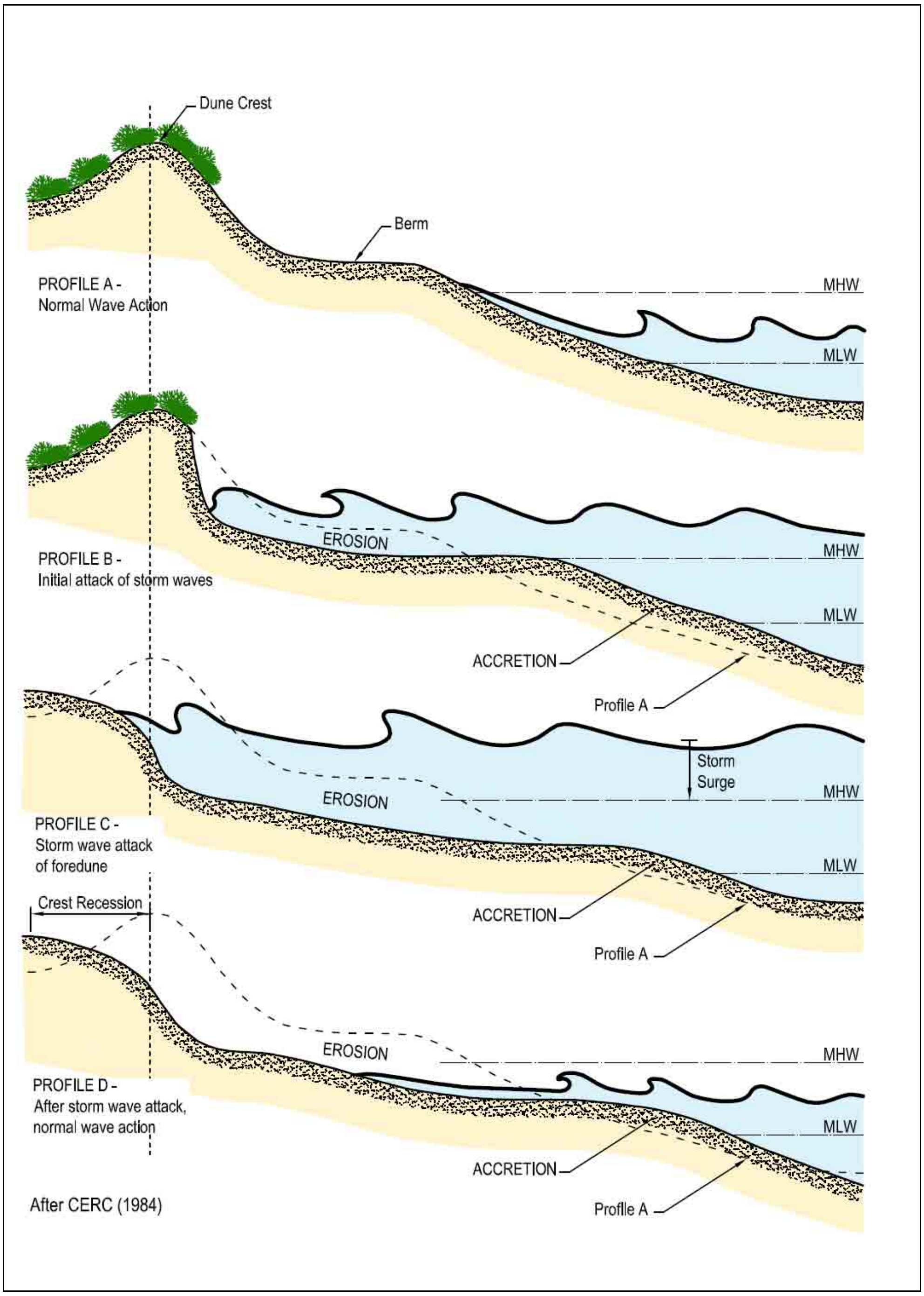

Figure 3.3 – Severe Storm Erosion Mechanism

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

3.2.4 Wind-blown Sand

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

The shoreline north of the Mullaloo SLSC appears to be experiencing significant windblown movement of sand. This was observed while on site in the form of buried fences and vegetation. Figure 3.4 shows a section of beach north of the SLSC that is experiencing high levels of wind-blown sediment transport.

Figure 3.4 – Wind-blown Sediment Transport

3.3 Sediment Cells & Pathways

Sediment cells are used to group sections of shoreline that behave similarly in terms of longshore sediment transport and generally have defined limits such as headlands or structures. They are often used to determine the availability and movement of sediment along sections of shoreline and in the development of sediment budgets.

Stul (2005) uses work from Eliot et al (2005) to describe the Perth Metropolitan shoreline in terms of 5 primary sediment cells stretching from

Mandurah to Yanchep. The study area for this report falls within the fourth primary cell, Whitfords.

Eliot et al (2005) further details secondary sediment cells within these primary cells. The secondary cells for the Whitfords primary cell consist of the Mullaloo and Burns Beach cells. Of these, the Mullaloo cell stretches from Hillarys Boat Harbour to Ocean Reef Boat Harbour and matches the study area.

Potential sediment sinks were also investigated in Eliot et al (2005). This work showed that the main sediment sinks in the Whitfords primary cell are the dunes, dune blowouts and the Pinnaroo Point headland. Of these the dunes and Pinnaroo Point headland are likely to be the main contributors for the study area of this report.

This report will further estimate the sediment movements and pathways in the sediment cell between Hillarys Boat Harbour and Ocean Reef Boat Harbour.

3.4 Wave & Water Level Conditions

3.4.1 General

Any comprehensive study of coastal processes must be done with knowledge of the fundamental driving forces. Consequently, an understanding of the magnitude and variation in the wind, waves and tide conditions are important in assessing the coastal processes.

MRA (2011a, 2011b) provide a comprehensive summary of recent wave and water level conditions. This was based on analysis of offshore wave and wind records and measured inshore water levels. This analysis includes data from 2000 to 2010 and is presented in the following sections.

3.4.2 Bathymetry

The bathymetry of the shoreline between Hillarys Boat Harbour and Ocean Reef Boat Harbour is shown in Figure 3.5. This figure is an extract of the Department of Planning and Infrastructure’s (DPI) Chart WA 957.

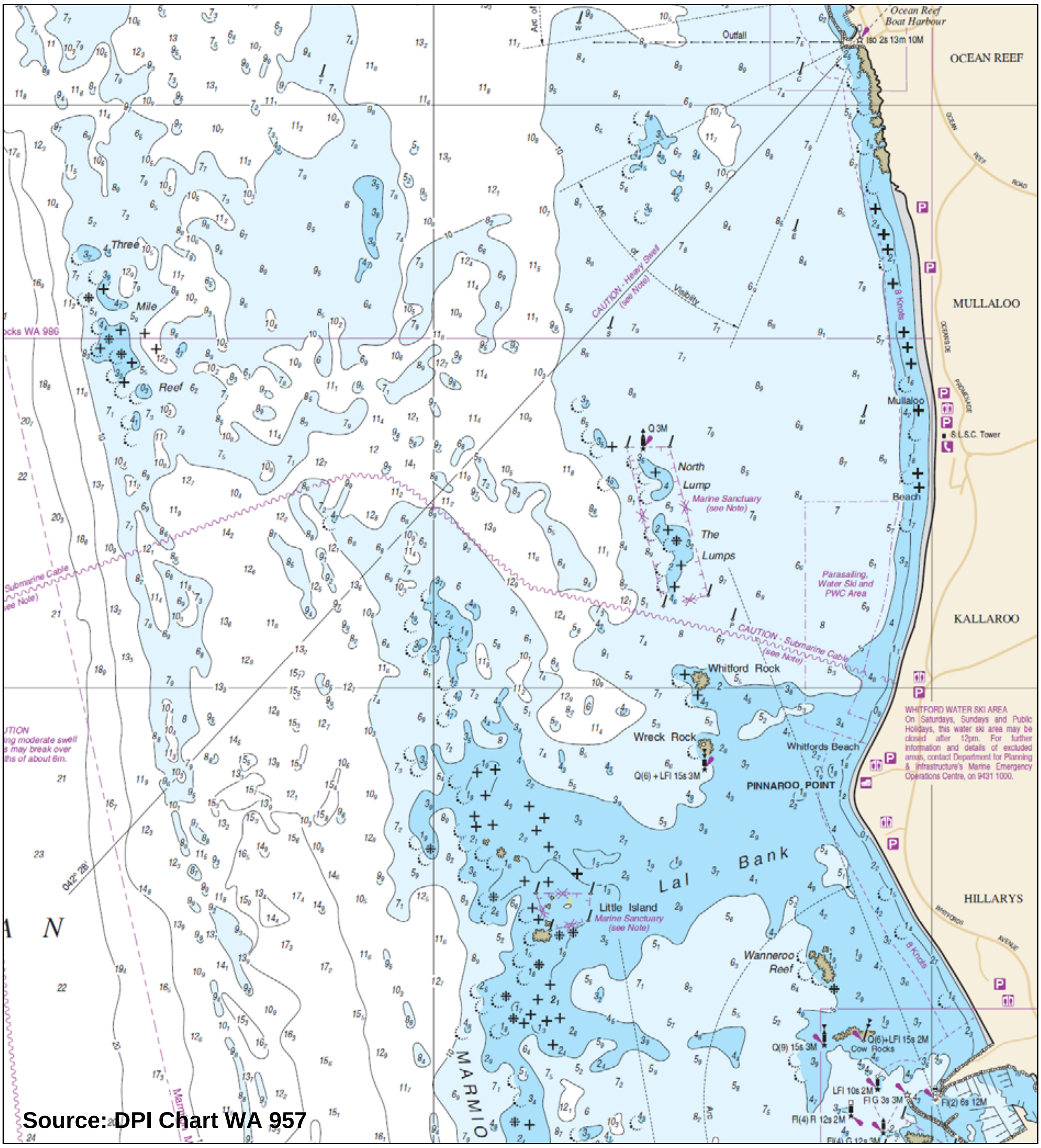

Figure 3.5 – Hillarys to Ocean Reed Bathymetry

This figure shows that a large shoal (Lal Bank) is present north of Hillarys Boat Harbour. This shoal has likely formed as a result of reduced wave energy due to the presence of offshore reefs and rock islands that provide protection from north westerly to south westerly waves. These same reefs and rocks have resulted in the formation of the cuspate headland called Pinnaroo Point (Short 2006).

The water depth of the shoreline stretching from Hillarys Boat Harbour to Pinnaroo Point remains relatively shallow for a much greater distance from the shoreline than the sections of shoreline to the north of Pinnaroo Point.

The 'Lumps' located off Kallaroo and Three Mile Reef off Mullaloo provide a degree of protection to the shoreline from waves approaching from the west. However the shoreline in these regions is much more exposed than the southern sections and the shallow water depths are limited close to the shoreline.

It can also be seen that a band of shallow water continues in front of the limestone cliffs at the northern end of the study area. This may indicate that sediment is being transported along the shoreline at the base of the limestone cliffs.

3.4.3 Wave Conditions & Inter-annual Variability

To investigate inter-annual variations in wave conditions, the frequency of occurrence of the key wave events of swell, sea breeze, moderate and severe storms from 2000 to 2010 were estimated. These key events dominate the movement of sediment along the Hillarys to Ocean Reef shoreline and any changes in the relative occurrence can influence shoreline position. In order to provide a consistent analysis, this data set does not include information after 2010 due to the availability of supporting information such as shoreline movement data.

The Department of Transport (DoT) operates a directional Waverider buoy in approximately 50 m of water south-west of Rottnest Island. Time histories of summary wave conditions from the buoy, as well as wind data from Rottnest Island, were used to estimate the number of occurrences of key events in MRA (2011a). Table 3.1 presents the frequency of occurrence since 2000.

Table 3.1 Annual Numbers of Days for Key Wave Events

Year	Light Swell / Calm (days)	Large Swell (days) [2]	Sea Breeze (days)	Moderate Storm (days) [3]	Severe Storm (days) [4]
2000	91	84	144	45	1
2001	61	113	168	23	0
2002	76	98	147	41	3
2003	96	82	143	41	3
2004	97	106	130	30	2
2005	98	103	129	34	1
2006	82	81	163	38	1
2007	43	119	132	65	6
2008	80	97	147	40	1
2009	58	99	158	46	4
2010	99	73	170	22	1
Avg	**80**	**96**	**148**	**39**	**2**

Notes:

1. The number of days of each event was estimated manually from wind and wave records and is approximate only.
2. Swells greater than 2.0 m in 50 m of water were considered large.
3. Moderate storm events have Hs > 3.0 m in 50 m of water and wind speeds of approx 40 kph.
4. Severe storm events have Hs > 6.0 m in 50 m of water and wind speeds of approx 60 kph.

Table 3.1 shows that there were significantly less moderate and severe storms in 2010 compared to recent history. Combined there was a total of 23 storm days in 2010, compared to an average of 41 since 2000.

The table also indicates 2010 had a low number of swell events and a much greater than average number of sea breeze events.

The net sediment movement observed each year is a balance of these events. However, individual events move sediment in very different manners. In particular, changes to the frequency of sea breeze and storm events can result in large changes to the shoreline. Large numbers of sea breeze events can increase northerly transport of sediment. The low number of storm events in 2010 may also mean this northerly transport is not returned. This is likely to have resulted in:

- increased net northerly transport in 2010;
- wider beaches at the northern end of beach compartments; and
- narrower beaches and erosion pressure on the southern end of beach compartments.

This will be considered in determining the sediment budget for the region.

3.4.4 Water Level Conditions & Inter-annual Variability

Higher water levels allow waves to attack the higher portion of the beach that is not normally vulnerable. Sustained high water levels may therefore contribute to increased beach erosion.

Water levels have been recorded at Fremantle for more than a century. This provides a comprehensive record of water levels for extreme analysis and is believed to be applicable for the study area due to their close proximity. MRA has previously estimated the most reliable data in this period has been measured since approximately 1950. Therefore only data since 1950 has been used in this report.

MRA (2011b) analysed the extreme water levels, as well as calculating the annual mean water levels between 1950 and 2010. Figure 3.6 presents the annual mean water level at Fremantle between 1950 and 2010, with the linear trend superimposed. The trend indicates an increase in water level of around 1.1 mm/year for the period.

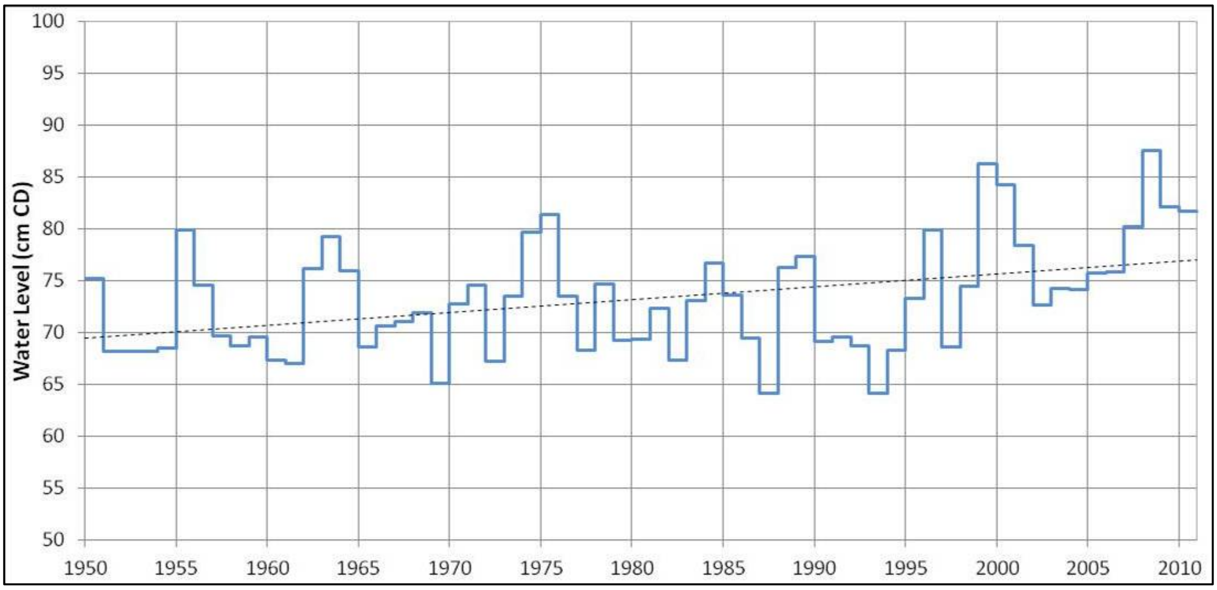

Figure 3.6 – Annual Mean Water Level at Fremantle

Notably, 2008 had the highest mean water level at Fremantle over the period shown. This high mean water level is most likely due to long term trends in sea level rise combined with medium term El Nino oscillations and tidal cycles.

Total water level variability is due to a number of influences which vary at timescales of hours, days years etc. The combination of peaks in these cycles can elevate the mean observed water level. Eliot (2010) states that the peak in an 18.6 yr lunar nodical tidal cycle was in 2007, resulting in elevated mean water levels. Figure 3.6 also shows that the rate of increase in sea level rise appears to have been greater over the past 15 years than the period prior, possibly as a result of the combination of inter-annual cycle peaks and increasing global sea levels.

In general the period between 2004 and 2010 is shown to have an elevated mean water level compared to the longer term record. This increases the potential for storm erosion.

This longer term increasing trend in mean water levels is expected to continue. It is likely that future mean water levels will be higher than those in the recent past, increasing the erosion pressures on vulnerable shorelines.

3.5 Coastal Data

A summary of the available coastal data used in this assessment for the Hillarys to Ocean Reef coastline is given in Table 3.2. This list is not a comprehensive guide to all available data but details some of the more useful and readily available data to the City.

Table 3.2 Available Coastal Data

Available Data			
Type	**Reference**	**Data Period**	**Comment**
Nautical Charts	AUS 754 – Lancelin to Cape Peron	July 2002	Offshore and nearshore bathymetry
	DPI WA 957 - Trigg	March 2002	Offshore and nearshore bathymetry
	WA001 – Ocean Reef to Cape Peron		
Wave Data	Directional Waverider Buoy RDW47	From 1991	DoT operated buoy in approximately 48 m of water, south west of Rottnest Island.
Tidal Data	Fremantle Boat Harbour Tide Gauge	From 1897	Operated by DoT
	Hillarys Boat Harbour Tide Gauge	From 1991	Operated by National Tidal Centre
Wind Data	Site No. 009225	From 1993	Perth Metro wind gauge
	Site No. 009215	From 1985	Swanbourne wind gauge
	Site No. 009193	From 1983	Rottnest Island wind gauge
Survey Information	LiDAR (DPI)	2009	Hydrographic survey from Two Rocks to Cape Naturaliste
	Ocean Reef Investigation Survey Drawing No 96402mp-001 and 96402mp-002	May 2010	Hydrographic and topographical survey by MAPS for 7 profile locations within the study area
	City of Joondalup 2004 Topographical Survey	2004	2004 Topographical surveys at 1 m intervals

4. Climate Change

4.1 Climate Change Variables

Climate change is defined by the Intergovernmental Panel for Climate Change (IPCC) as "a change in the state of the climate that can be identified by changes in the mean (and/or the variability), and that persists for an extended period, typically decades or longer" (IPCC, 2007).

The National Committee on Coastal and Ocean Engineering (NCCOE) detail 6 key climate change variables and 16 secondary variables that are applicable to the coastal region (NCCOE 2004). NCCOE (2004) provides guidelines for the assessment of these variables to enable a project to be assessed for the impact that changes in key environmental variable may have.

These climate change variables have been assessed for their impact on the vulnerability of the shoreline located between Hillarys Boat Harbour and Ocean Reef Boat Harbour. This assessment primarily focused on potential changes in the local nearshore and meteorological conditions of the area as they are likely to have the largest impact on the vulnerability of the coastline within the study area.

The climate change variable interactions were assessed to the following criteria:

- Variables which may impact the shoreline in the study area were indentified and highlighted in the table. These highlighted variables are discussed in more detail in coming sections.

- Where potential changes may be likely to occur but are assessed as having a limited impact on the vulnerability of the coastline they have not been assessed in further detail.

- Where one climate change variable dominates another, the dominating variable was investigated in detail. An example would be the controlling aspect of wind over the local wave climate. Therefore, changes in the wave climate for the study area were considered in the context of changes in wind climate and were not assessed separately.

Although both potential and likely changes in the nearshore conditions were considered in the context of this report only those changes considered likely were investigated further. For the remaining potential changes, a short description of the possible changes were included in the table. The results of this assessment are presented in Table 4.1.

Table 4.1 Interaction Matrix of Climate Change Variables for Hillarys to Ocean Reef Shoreline (from NCCOE (2004))

Primary / Secondary	Mean Sea Level	Ocean Currents & Temperatures	Wind Climate	Wave Climate	Rainfall/Runoff	Air Temperature
Local Sea Level	Substantial effect, assessed in detail	Minor changes, potential seasonal variations.	Potential seasonal & extreme changes, assessed in detail	Minor changes to wave setup possible	Possible coinciding of extreme flood & storm events	Minor changes
Local Current	May affect nearshore currents	Minor changes in study area, may affect nearshore currents	Potential changes to prevailing longshore current direction. Assessed in detail	Potential effect on wave driven currents	Unlikely to directly affect	Minor changes
Local Winds	Unlikely to affect	May affect sea breeze patterns	Potential impact on sea breeze, storms. Assessed in detail	Unlikely to affect	Unlikely to directly affect	May affect existing sea breeze patterns
Local Waves	May affect nearshore wave conditions	Unlikely to affect	Potential impact on sea breeze, storms. Assessed in detail	Potential impact on wind generated , swell and severe storm waves	Unlikely to directly affect	May affect sea breeze & wind waves
Effects on Structures	Direct impact on SLSC & coastal structures. Assessed in detail	Unlikely to directly affect	Likely to affect future design requirements for coastal structures	Likely to impact on coastal structures & design of future structures	Unlikely to directly affect	Unlikely to directly affect
Coastal Flooding	Direct impact due to inundation. Assessed in detail	Unlikely to directly impact	Potential impact, assessed in detail	Potential impact from increased wave run up	Unlikely to directly affect	Unlikely to directly affect
Beach Response	Impact likely, assessed in detail	Unlikely to directly affect	Potential impact on dune creation, coastal alignment and stability	Potential impact on beach alignment. Assessed qualitatively	Unlikely to directly affect	Unlikely to directly affect
Foreshore Stability	Impact likely, assessed in detail	Unlikely to directly affect	Potential impact on coastal alignment and stability	Potential impact from severe storm erosion, changes in wave patterns	Unlikely to directly affect	Unlikely to directly affect
Sediment Transport	Impact likely, alteration of sediment pathways and changes to sinks	Changes possible to storm currents and offshore deposition	Potential impact on longshore movement	Potential major impact on cross shore sediment transport	Unlikely to directly affect	Unlikely to directly affect

4.2 Assessment of Climate Change Variables

4.2.1 Mean Sea Level

CSIRO (2007) states that climate change is believed to cause an increase in mean sea level as a result of two main processes:

- The melting of land based ice, increasing the volume and height of the ocean waters; and

- A decrease in ocean density through thermal expansion, which increases the volume and thus the ocean height.

Observations of sea levels have been carried out for centuries at some locations, allowing historical trends to be identified. The global mean sea level rose by 0.17 m (between 0.12 to 0.22 m) over the 20^{th} century, which equates to around 1.8 mm/yr (IPCC 2007).

As shown previously in Figure 3.6, Fremantle has experienced a local sea level rise of 1.1 mm/yr since 1950. The Fremantle records indicate that between 1950 and 1991, there was a general levelling out of sea levels, with a rapid increase in sea level experienced between 1991 and 2010.

Research by Church (2006) suggests that since 1993 the global measured sea level rise has been tracking the upper range of the IPCC 2001 climate change scenarios. This research used tide gauge data and satellite altimeter readings between 1993 and 2004 to reach this conclusion (Church and White 2006).

Rahmstorf et al (2007) also found the observed sea levels from tide gauges and satellites are tracking near the upper bound of the IPCC 2001 projections since the start of the projections in 1990 (CSIRO 2008). This research was updated for the March 2009 Copenhagen Conference, with the results shown in Figure 4.1.

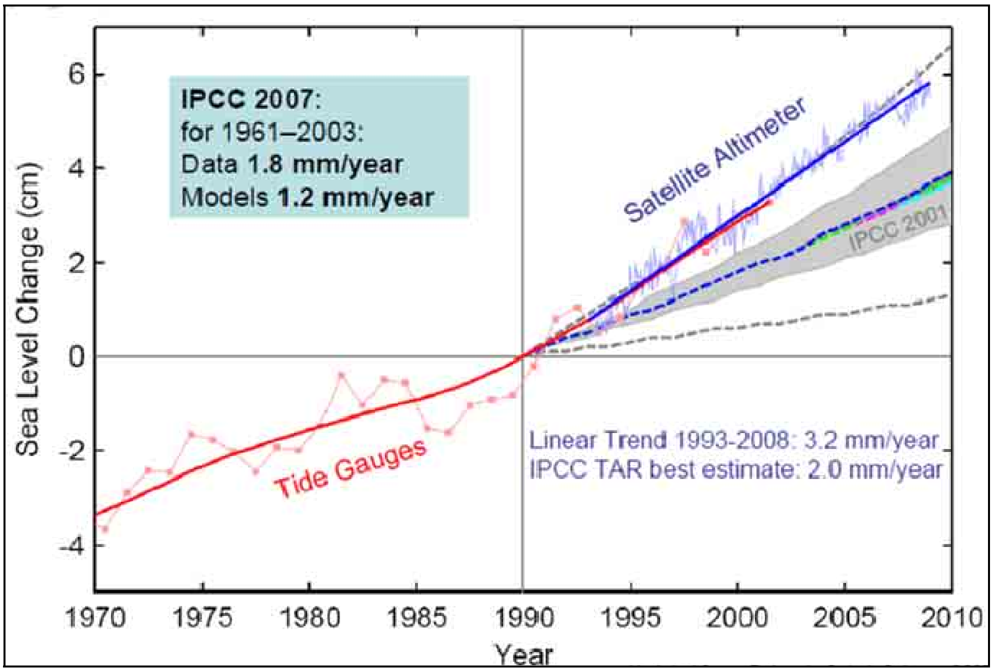

Figure 4.1 – Tide Gauge & Satellite Observations Compared to IPCC 2001 Sea Level Rise Predictions

This upper limit leads to a global-averaged sea-level rise by 2100 of 88 cm compared to 1990 values. However, these observations do not necessarily indicate that sea level will continue to track this upper limit - it may diverge above or below this upper limit (CSIRO 2008). The relatively short time length of these observations makes it hard to predict long term sea level rise, as shorter term fluctuations in mean sea level, such as the El Nino Southern Oscillation, may be contributing to these increased rates.

At this stage it is important to note that extreme sea levels will be influenced by the mean sea level and that it is necessary to investigate changes in the intensity and frequency of extreme sea levels as a result of local storm surges and remote forcings.

The most extreme water levels generally occur when a storm surge coincides with a high tide and large wave climate, as shown in Figure 4.2.

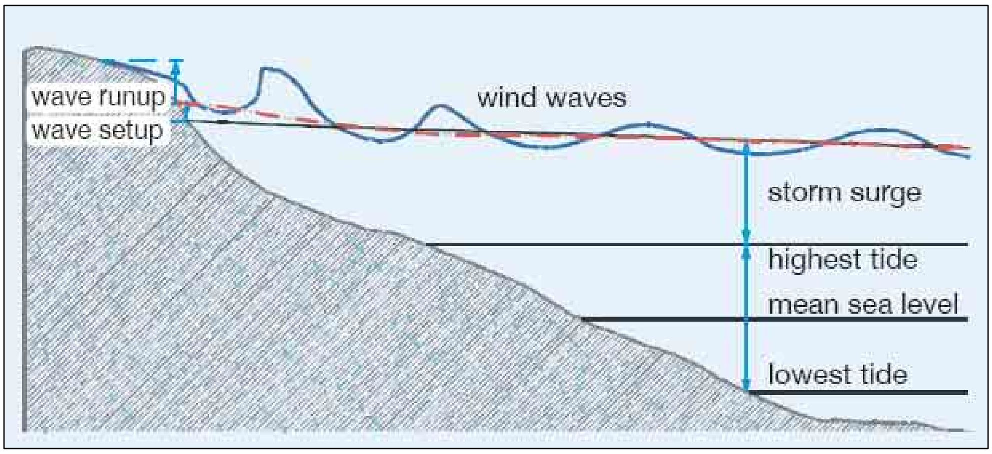

Figure 4.2 – Diagram of Extreme Sea Level

A storm surge occurs when a storm with high winds and low pressures, such as a tropical cyclone or a winter cold front, crosses the shoreline. The strong, onshore winds push water against the shoreline (wave setup) and the barometric pressure difference create a region of high water level against the shoreline. The size of the storm surge is influenced by the following factors:

- wind strength and direction;
- pressure gradient;
- seafloor bathymetry; and
- coastal topography.

The shoreline within the study area is relatively open and is vulnerable to these factors. Therefore, it is important to investigate the likely effects of climate change on sea level extremes, especially with regard to storm surge frequency and intensity.

Over south-west WA there have been fewer troughs, each generally bringing less rainfall, and more high pressure systems since 1975 (IOCI, 2005). Figure 4.3 shows the regions where storm development is favoured (in red). During early decades, south west WA was the preferred region for storm development. More recently, storms are less likely to form and the favoured region of development has shifted east.

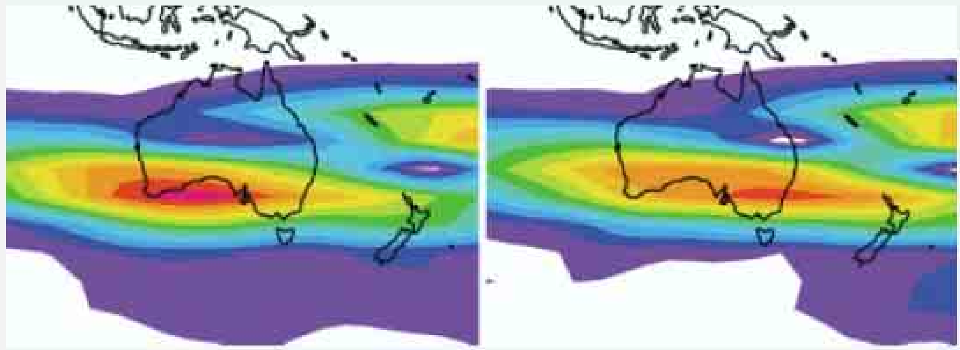

Figure 3: The left panel shows the preferred location of winter storm tracks (in red) over southern Australia 1949–1968. The right panel shows the preferred locations 1975–1994. Data source: NCEP/NCAR reanalyses.

Figure 4.3 – Preferred Location of Winter Storm Tracks

This suggests locally that the number of winter storms influencing the south west may be decreasing.

Recent research by Haigh et al (2009) examined the spatial variability of storm surges and tides around south west Western Australia using a 60 year hindcast of sea levels. Preliminary results from this study suggest that storminess has not increased for the south-west of Australia. A general increase in mean sea level was identified as the most significant factor for extreme water level events in the region.

As mentioned previously, storm surges are partly driven by winds, especially during extreme events. Mean wind speed projections have been carried out by the CSIRO up until 2030. The models show that in winter the winds around the 30°S latitude region (just north of Perth) are likely to have a 2 to 5% reduction in speed. However, in summer the mean wind speed is projected to increase by 2 to 5%.

Winter extreme wind events are more likely to be governed by larger scale systems such as trade winds (CSIRO, 2007). On the other hand, extreme winds in summer are likely to be governed more by small scale systems such as thunderstorms. Unfortunately, neither global climate models nor regional, high-resolution models are able to capture thunderstorms, making it hard to project the effects of climate change on summer storm events.

In general, there is an absence of any real, scientific evidence to suggest that the extreme sea levels **above** the mean sea level (ie storm surge) are being affected by climate change.

A detailed assessment of the specific impacts that SLR is likely to have on the shoreline between Hillarys and Ocean Reef is presented in Section 8. This assessment is based on a continued rise in mean sea level and no change in extreme sea levels such as storm surge due to climate change.

4.2.2 Ocean Currents & Temperatures

The effect of changes in ocean currents & temperatures as a result of climate change are likely to have a minimal impact on the vulnerability of the shoreline between Hillarys Boat Harbour and Ocean Reef Boat Harbour. This is largely due to the dominating effects of alternative coastal processes.

While changes in these two factors could affect the sea breeze system and nearshore currents, the impact would be expected to be relatively minor compared to potential changes in climate variables such as the wind and wave climate.

Therefore potential changes in ocean currents and temperatures have not been investigated further as part of this vulnerability assessment.

4.2.3 Wind Climate

The wind regime influences coastal processes through the generation of ocean waves and currents as well as feeding dune systems with wind-blown beach sand.

The seasonal weather patterns along the Perth metropolitan shoreline are largely controlled by the position of the so called Subtropical High Pressure Belt. This is a series of discrete anticyclones that encircle the earth at the mid-latitudes (20° to 40°). These high pressure cells are continuously moving from west to east across the southern portion of the Australian continent. A notional line joining the centres of these cells is known as the High Pressure Ridge.

In winter this ridge lies across Australia typically between 25° to 30° S, to the north of Perth (located at 32° S). During summer, the ridge moves south and lies between 35° and 40° S. This latitudinal shift in the position of the High Pressure Ridge is fundamental to the seasonal wind patterns experienced in the region.

In addition to these regional scale effects that cause seasonal variations, the meso-scale phenomenon of a land-sea breeze system is commonly experienced along the Perth metropolitan shoreline, causing wind variations on a daily time scale. Offshore breezes are experienced in the morning which swing around to the south-west and south in the afternoon. This is often referred to as the ‘sea breeze’ but is a land/sea breeze system.

As a result of climate change the wind climate for the Perth metropolitan shoreline may be altered from typical patterns. This will be assessed qualitatively as there is insufficient information currently available to make a quantifiable assessment.

Changes in the wind climate may:

- Alter the intensity, duration and prevailing direction of the sea breeze system;

- Affect the average direction of seasonal and extreme events approaching the shoreline;

- Require changes in design requirements for future structures; and

- Affect existing nearshore currents.

Of these changes the factor with the greatest chance to affect the vulnerability of the study area is changes in the sea breeze system.

Should changes in the sea breeze system eventuate, this is likely to affect longshore sediment transport patterns, shoreline alignments, dune creation and beach stability. The majority of the study area consists of sandy beaches that have highly seasonal longshore sediment transport patterns. Therefore, such changes could potentially impact on the vulnerability of the study area.

Sufficient information is not available to make a quantifiable estimate of these potential effects on the vulnerability of the shoreline between Hillarys and Ocean Reef. Therefore the potential impacts will be considered qualitatively when determining the vulnerability allowances for the various cells.

4.2.4 Wave Climate

Changes in the wave climate will likely be the result of changes in the wind climate and increases in the mean sea level. Qualitatively, changes in the ocean and land temperatures may affect the wind climate, i.e. the sea breeze system. In turn, any changes in the intensity, duration and frequency of the sea breeze system is likely to affect the wave climate of the study area.

If these changes to the wave climate did occur than there would be expected to be some change in both longshore sediment transport and cross shore severe storm erosion. Since the local wave climate is strongly linked to the wind climate for the study area, potential changes to the vulnerability of the shoreline due to changing wave climate will be considered in conjunction with changes in the wind climate.

4.2.5 Rainfall & Runoff

The study area does not include any rivers or estuaries subject to river flood waters. Overall, the intensity and frequency of extreme rainfall events is therefore unlikely to affect the coastal vulnerability of the study however it has been included for completeness.

Observations in a number of studies (Li et al 2005 & CSIRO 2007) revealed the following:

- winter extreme daily rainfalls with up to 50 year return periods have decreased since 1965; and
- there is no observable trend apparent in the summer rainfall extremes over time.

As stated previously, over south-west WA there have been fewer troughs, each generally bringing less rainfall, and more high pressure systems since 1975 (IOCI 2005).

A modelling study of the south-west rainfall trends by Timbal (2004) found "*Future trends also suggest reduced rainfall in spring, as opposed to the past decades, and a reduction of extreme rainfall events, i.e. heavy rainfall days and long wet spells*." Further to this, CSIRO (2007) noted "*Decreases in extreme values tend to occur where there is a strong decrease in mean precipitation, such as south-west Australia in winter*." Figure 4.4 reinforces this statement, showing a general decrease in precipitation intensity in the south-west region.

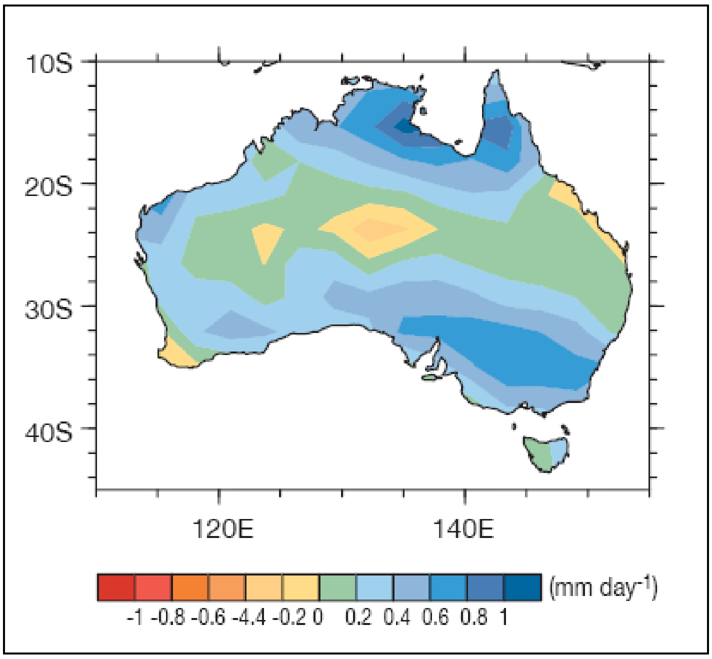

Figure 4.4 – Mean projected changes (2080-2099 minus 1980-1999) in precipitation intensity (mm/day) for the A1B scenario (CSIRO 2007)

Neither global climate models nor regional, high-resolution models are able to capture thunderstorms. Hence, it is difficult to infer the impact of climate change on summer thunderstorms using a modelling approach (CSIRO 2007).

The following was the general consensus at the recent Greenhouse 2009 conference in Perth on the 23rd to 26th March 2009 (Pers Comm, Jim Davies JDA Hydrology)

- winter and annual rainfall in the south-west WA has trended down since about 1975 and is likely to continue to fall by a further 10% by 2030; and

Extreme **floods** are believed to have decreased in intensity and frequency as a result of the following factors:

- reduced antedecant catchment wetness; and
- general decreases in regional groundwater levels in uncleared catchments.

In general, there is an absence of any scientific evidence to suggest that the long-term extreme rainfall and flooding events are being affected by climate change. Subsequently, the present-day climatic return periods for storms and flooding will be used in this vulnerability assessment.

4.2.6 Air Temperature

Changes in the air temperature, presumably warming, are likely to have a similar impact to changes in the ocean temperature in regards to the vulnerability of the shoreline within the study area over the next 100 years.

Any change in the air temperature could affect the intensity, duration and direction of the sea breeze system similar to that of changes in the ocean temperature. However for this report these potential changes are considered to be part of changes in wind climate and will not be assessed separately.

5. Coastal Vulnerability Assessment Process

5.1 State Coastal Planning Policy

One method of determining the vulnerability of a shoreline is to assess the buffer between the shoreline and existing infrastructure using the State Coastal Planning Policy (SCPP). The SCPP provides guidance on the citing of new development, including subdivision and strata subdivision, on the Western Australian shoreline (WAPC 2003). Schedule One of the SCPP outlines the recommended criteria for use in determining the appropriate Physical Processes Setback (PPS) to freehold development. The standard setback assessment should provide a very low level of risk to the development from coastal erosion over a **100 year** planning horizon.

For the general case of freehold development on an undeveloped sandy shoreline, the SCPP recommends using the following criteria to calculate the appropriate PPS:

- Acute Storm Erosion Allowance (S1) - Allowance for short-term erosion caused by a series of severe storms, with elevated water levels and an Average Recurrence Interval (ARI) of approximately 100 years.

- Historic Shoreline Movement Allowance (S2) - allowance for chronic long-term trends caused by the local coastal dynamics. This needs to provide a buffer for the coming 100 years.

- Sea Level Change Allowance (S3) - Allowance for possible recession of the shoreline as a result of anticipated sea level rise in the coming 100 years.

The total setback distance is calculated by adding the allowances and is measured from the Horizontal Setback Datum (HSD). This is defined as the toe of the erosion scarp on an eroding coast or the seaward edge of the ephemeral vegetation on an accreting coast (WAPC 2003).

The SCPP is primarily intended for locating new development and is therefore used only for guidance in this vulnerability assessment. Currently the SCPP is undergoing a revision and a draft copy of the updated policy has been released for public comment. Some of the changes proposed to this policy may affect the viability of the recommended management options presented later in the report.

The key objective of this assessment is to provide the City with a vulnerability assessment of the study area shoreline for the coming 100 years. The City also requested that the vulnerability assessment for the

Hillarys to Ocean Reef shoreline be carried out over short-term and 50 year (2060) time frames. This will provide an estimate of the potential vulnerability of existing infrastructure and allow for a planned response over the short and long term.

The vulnerability will be determined in the following sections through an assessment of:

- Severe storm erosion;
- Historical shoreline movement;
- Shoreline recession due to sea level rise; and
- Inundation due to sea level rise.

6. Vulnerability to Severe Storm Erosion

The State Coastal Planning Policy (SCPP) recommends using a computer model such as SBEACH to estimate the severe storm erosion by modelling three repeats of a storm experienced in Western Australia in July 1996. Three repeats of this storm are believed to conservatively represent the 100 year ARI event in relation to beach erosion. The duration of the storm with elevated water levels and high waves is important in determining the severe storm erosion.

The SBEACH computer model was developed by the Coastal Engineering Research Centre to simulate beach profile evolution in response to storm events. It is described in detail by Larson & Kraus (1989). Since then the model has been further developed, updated and verified based on field measurements (Wise et al 1996). Primary input to the model includes time histories of wave height, period, water elevation, pre storm beach profiles and median sediment grain size (Wise et al 1996).

SBEACH profiles were chosen to reflect each of the cells nominated along the Hillarys to Ocean Reef shoreline. These profiles were extended out perpendicular to the shoreline in order to model the beach response for each type of beach. The locations of these profiles are shown in Figure 6.1.

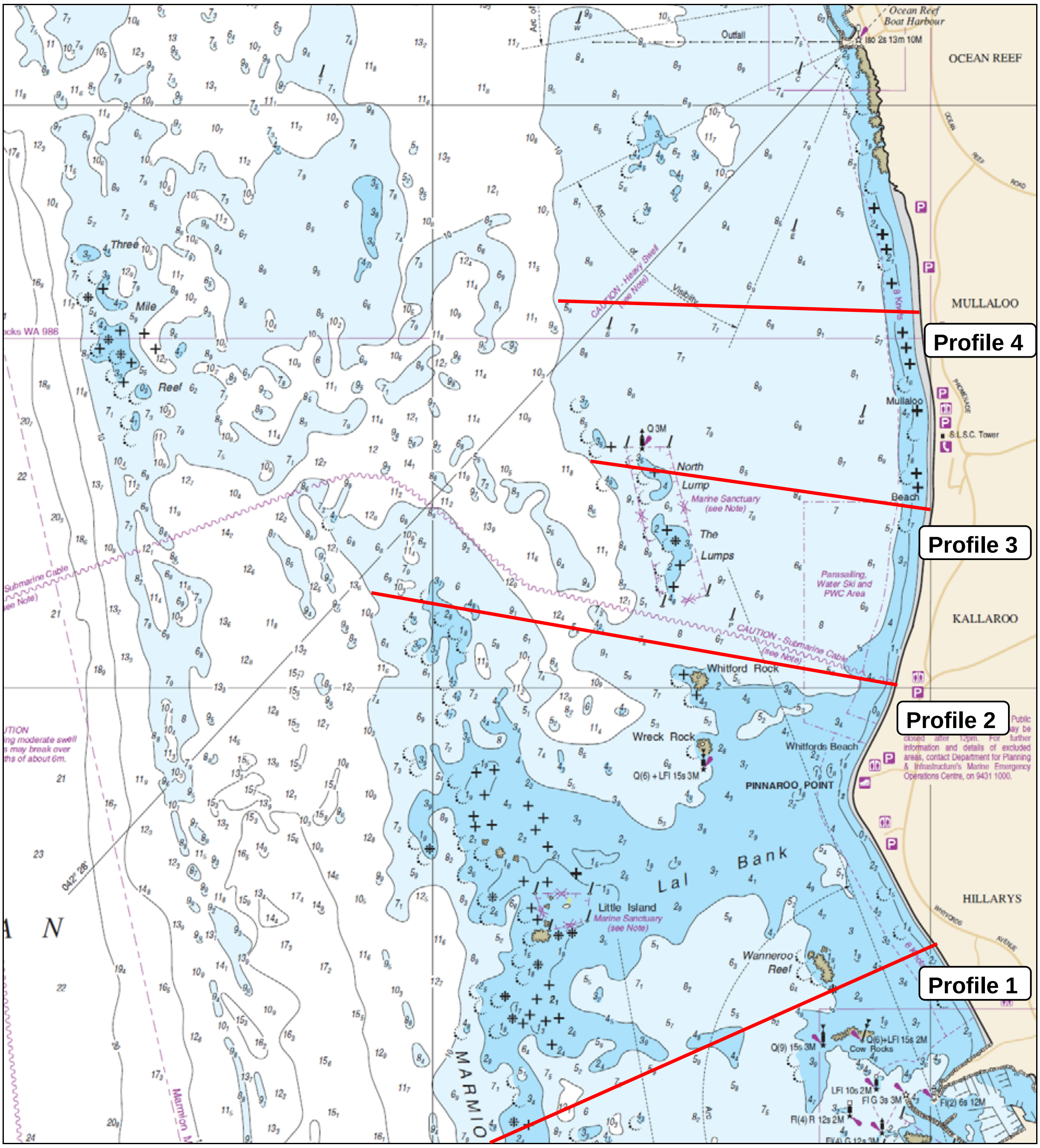

Figure 6.1 – SBEACH Profile Locations

The profiles were compiled using Department of Planning and Infrastructure (DPI) nautical charts (WA 957 and AUS 754) and a series of beach profiles completed for MRA by McMullen Nolan Surveyors in 2010. No SBEACH profile was created for the Ocean Reef Cell as the shoreline is dominated by limestone cliffs.

The sediment size required for SBEACH analysis was determined from on-site sampling performed by MRA. A composite sample from the waterline, beach berm and dune was analysed for particle size distribution (PSD), to obtain the representative d_{50} grain size required. The results of the PSD analysis are provided in Appendix A along with the location of each sample.

The duration of the July 1996 storm was approximately 110 hours. Three repeats of this storm bring the duration to approximately 330 hours.

The wave conditions during the July 1996 event were recorded by DoT in approximately 48 m of water, with a peak significant wave height of 7.8 m. MRA have previously modelled the wave climate of the northern Perth metropolitan shoreline for DPI using 2GWAVE (MRA 2005). Using the results of this modelling the significant wave heights and periods were attenuated to reflect the local wave climate at 10 m of water. These attenuation factors are presented later on in the report and were previously accepted as appropriate for use by DPI (MRA 2005).

Water levels during the 110 hours of the July 1996 storm were also recorded by DoT in approximately 5 m of water at Fremantle. These water levels were input into SBEACH with a peak water level of +0.99 mAHD.

The potential severe storm erosion is measured from the HSD of each cell. The HSD was estimated for each of the SBEACH profiles through the use of on-site observations, aerial photographs and 2010 beach profile surveys. The height of the HSD ranges from approximately +2.2 mAHD for the Hillarys cell to approximately +3.6 mAHD for the Mullaloo cell.

The results of the SBEACH run for the Hillarys cell are presented in Figure 6.2. MRA (2005) provides attenuation factors of 32% and 60% for the H_s and T_p respectively at the Hillarys SBEACH profile location. The Hillarys cell has a d_{50} of 0.29 mm and a HSD of approximately +2.2 mAHD.

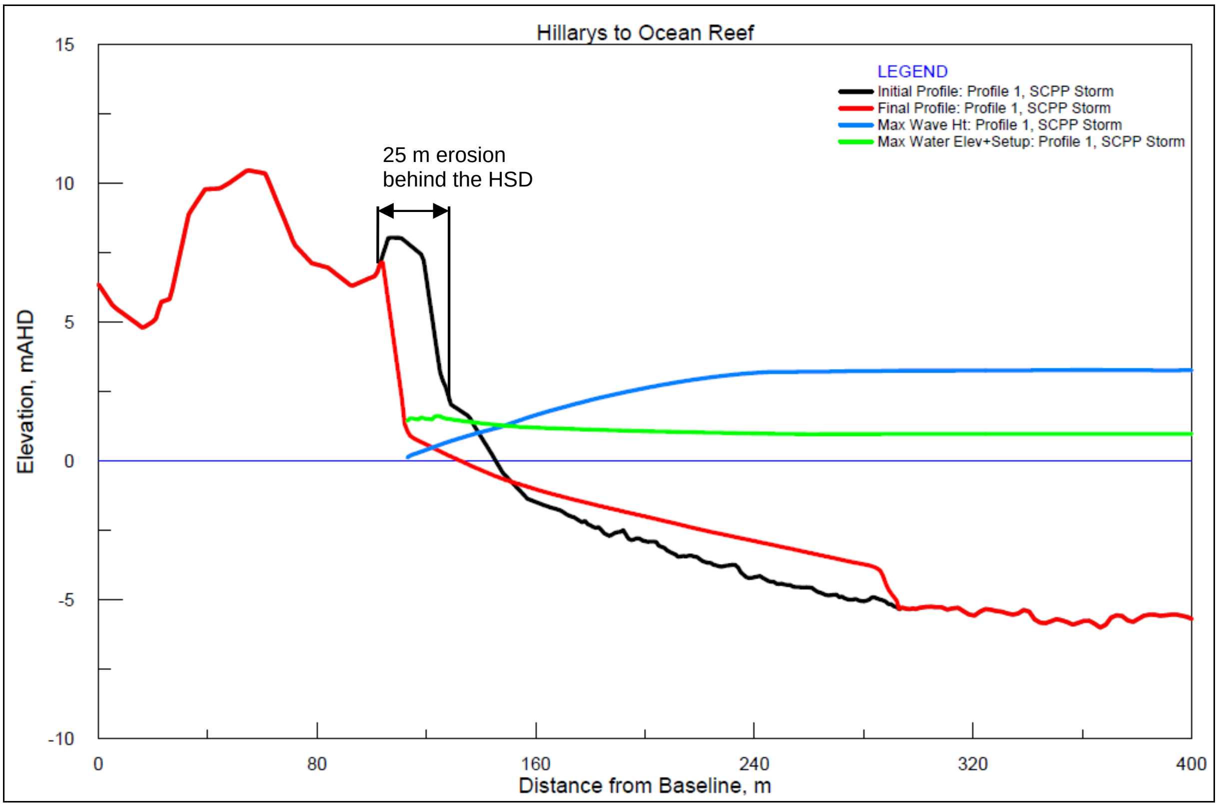

Figure 6.2 – Hillarys Cell Severe Storm Erosion (Profile 1)

Figure 6.2 shows the extent of erosion behind the HSD would be 25 m. The current SCPP recommends that the recession of the mean sea level (MSL) contour be used to determine the extent of severe storm erosion. MRA believe that the erosion behind the HSD is the best representation of the vulnerability of a shoreline to severe storm erosion and will be used in this assessment.

Therefore, the severe storm erosion allowance for the Hillarys cell will be 25 m.

The second profile modelled was the Whitfords cell. The attenuation factors used for this SBEACH profile for H_s and T_p are 37% and 40% respectively. The Hillarys cell has a d_{50} of 0.28 mm and a HSD of approximately +2.4 mAHD.

The results of the SBEACH run for the Whitfords cell are presented in Figure 6.3.

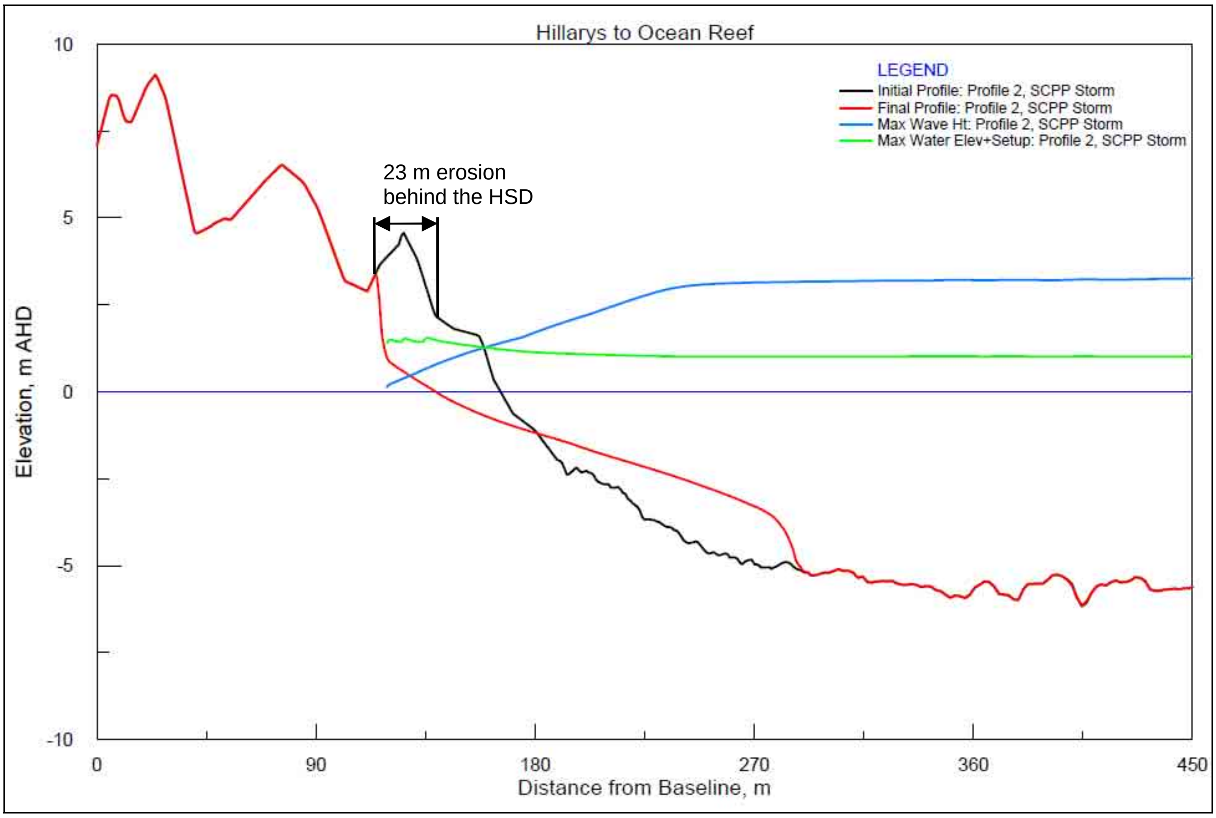

Figure 6.3 – Whitfords Cell Severe Storm Erosion (Profile 2)

Figure 6.3 shows 23 m of erosion behind the HSD. Therefore, the severe storm erosion allowance for the Whitfords cell will be 23 m.

The Kallaroo cell was modelled with attenuation factors of 43% and 54% for H_s and T_p respectively. The Kallaroo cell has a d_{50} of 0.28 mm and a HSD of approximately +2.8 mAHD.

The results of the SBEACH run for the Kallaroo cell are presented in Figure 6.4.

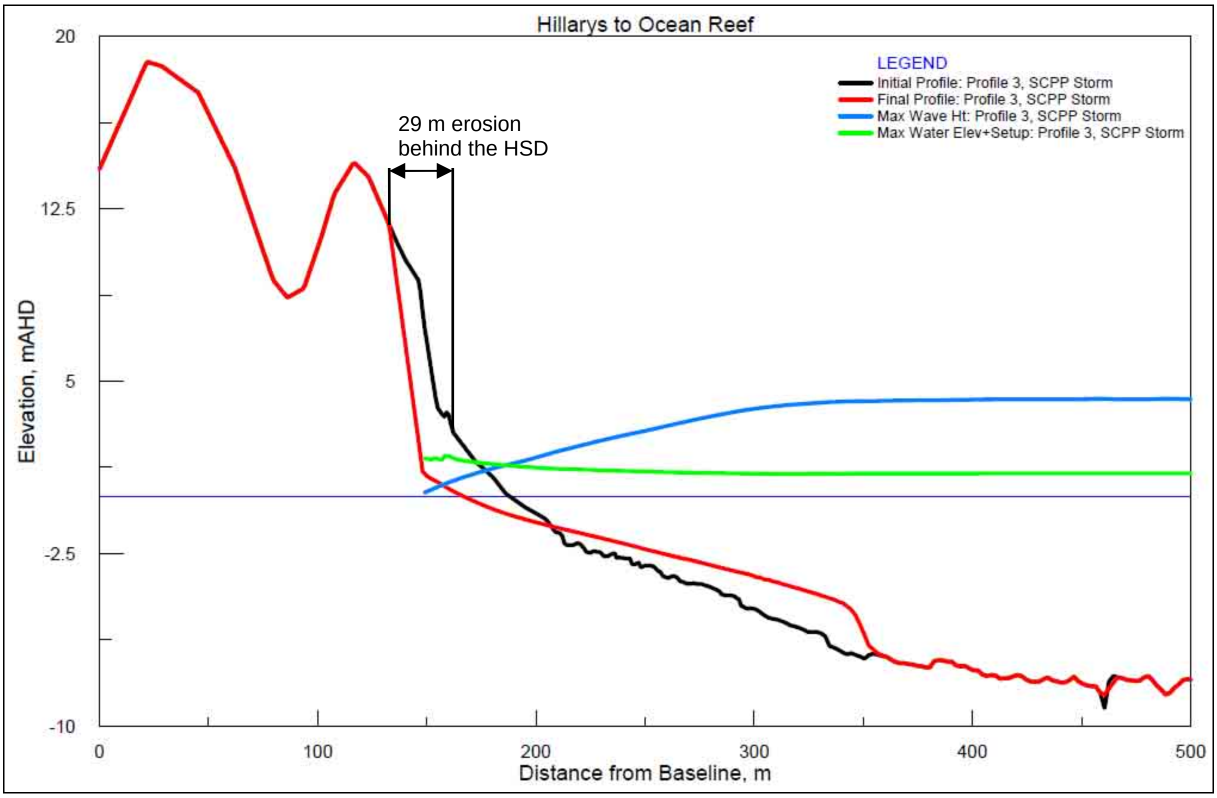

Figure 6.4 – Kallaroo Cell Severe Storm Erosion (Profile 3)

Figure 6.4 shows 29 m of erosion behind the HSD. The severe storm erosion allowance for the Kallaroo cell will be 29 m.

The Mullaloo cell was also modelled with attenuation factors of 43% and 54% for H_s and T_p respectively. The Mullaloo cell has a d_{50} of 0.21 mm and a HSD of approximately +3.6 mAHD.

The results of the SBEACH run for the Mullaloo cell are presented in Figure 6.5.

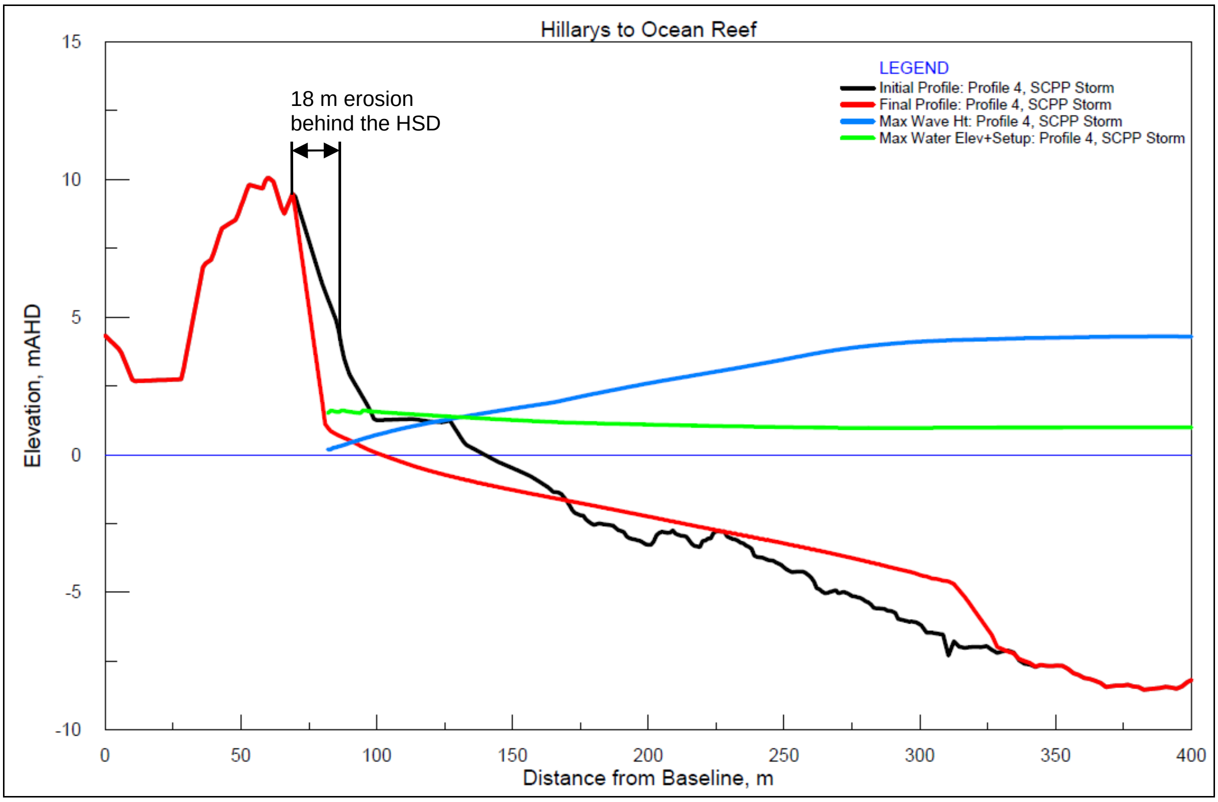

Figure 6.5 – Mullaloo Cell Severe Storm Erosion (Profile 4)

Figure 6.5 shows 18 m of erosion behind the HSD. The wider beach in this profile is likely to assist in the dissipation of wave energy and result in the lower severe storm erosion extent. The severe storm erosion allowance for the Mullaloo cell will be 18 m.

As stated previously, the Ocean Reef cell shoreline consists of limestone cliffs. This rock was assessed to be competent and there would be no severe storm erosion behind the HSD. Therefore, no SBEACH modelling was conducted for the Ocean Reef cell.

A summary of severe storm erosion allowances is given in Table 6.1.

Table 6.1 Severe Storm Erosion Allowances

Study Cell	Severe Storm Erosion Allowance
Hillarys	25 m
Whitfords	23 m
Kallaroo	29 m
Mullaloo	18 m
Ocean Reef	0 m due to Limestone Cliffs

The severe storm erosion allowances for each shoreline cell were combined to form a line showing the extent of the severe storm erosion for the length of the study area. These are presented in a Severe Storm Vulnerability Plan, included as Appendix B. This plan shows areas that are currently vulnerable to a severe storm event.

In general there is very little infrastructure along the shoreline from Hillarys to Ocean Reef that is at risk from severe storm erosion. In the majority of cells the only infrastructure at risk consists of beach access ways and dune fencing.

MRA have been advised that existing dune fencing is founded to 2 m below the natural surface (Keith Armstrong, pers comm 2012). However, the estimated extent of the severe storm erosion indicates that these fences may still experience damage or displacement in the estimated 100 yr ARI storm event.

The exception to this is the Mullaloo cell where the SLSC is shown to be at risk from severe storm erosion. While onsite it was observed that the SLSC has associated retaining walls. It is unknown if these retaining walls have been adequately designed to resist wave action or have toe protection installed. The foundations of the structure and the SLSC are not known. The structure is therefore considered to be at risk from severe storm erosion.

In a severe storm event, the beaches along the length of the coast would also lose a large amount of sand. This may affect the amenity and recreational value of the areas that are heavily used by the public.

7. Vulnerability to Historical Shoreline Movement

7.1 Historical Shoreline Movement

Shoreline movement analysis uses the historical position of the vegetation line to determine the movements of the shoreline over time. The vegetation line is often used as an indicator of the long-term shoreline position, as it is less sensitive to changes in water levels such as tides and storm erosion than indicators like the water line.

MRA mapped the shoreline position in the study area for a number of years between 1942 and 2010. This shoreline position data was obtained and extracted from a number of sources. These sources include:

- DPI vegetation lines extracted from rectified aerial photography from MRA (2005);
- Vegetation lines extracted by MRA from rectified aerial photographs provided by the City of Joondalup.

A shoreline movement plan for use in this study was created from the extracted vegetation lines and is attached in Appendix C. The accuracy of the position of these vegetation lines is believed to be ± 5 m depending on the resolution of the photographs and the rectification process.

The position of the shoreline was determined at 100 m intervals along the length of the study area. Figure 7.1 shows the chainage locations.

Figure 7.1 – Chainage Locations

From these recorded shoreline positions, the relative shoreline movement was calculated. It should be noted that while vegetation lines are available as far back as 1942, the construction of Hillarys Boat Harbour and Ocean Reef Boat Harbour have made any reference to 1942 irrelevant. These developments have altered the local sediment transport dynamics. Therefore the shoreline movement was assessed relative to the next most recent shoreline positions following the construction of these coastal structures.

The shoreline movements have been taken relative to 1987 for the shoreline south of Mullaloo SLSC and 1996 for the shoreline north of the SLSC due to limitations in available information. The relative movements for these two periods are shown in Figure 7.2.

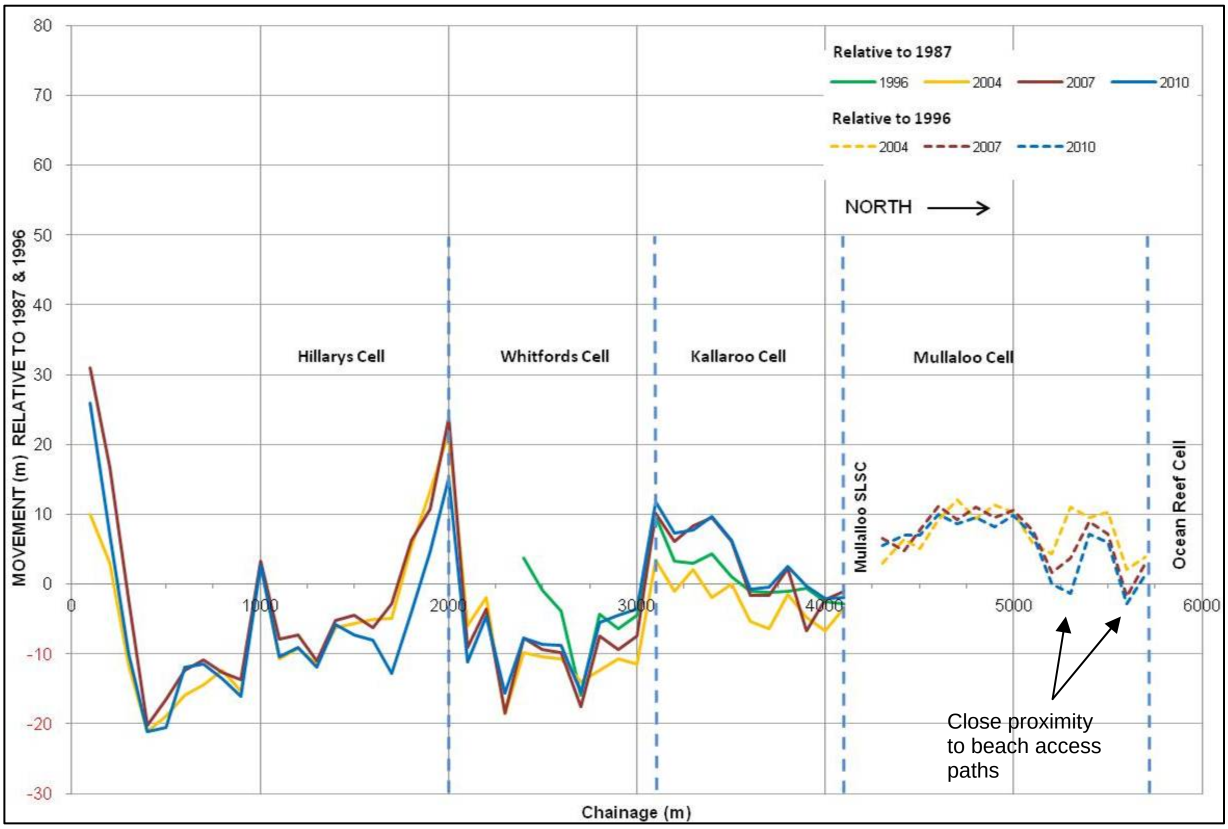

Figure 7.2 – Shoreline Movement Plot Relative to 1987 & 1996

Shoreline movement trends can be compared to changes in fundamental driving forces such as meteorological effects, climate change and coastal structures. This aims to identify potential contributors to the shoreline changes observed across the study area.

The shoreline movement analysis indicates that:

- Typically the shoreline south of Pinnaroo Point (chainage 1,800 to 2,000 m) has eroded since 1987.
- Pinnaroo Point has receded by approximately 10 m since 2007.
- The Whitfords cell has generally receded while the Kallaroo cell has fluctuated between recession and accretion.
- The Mullaloo cell has generally accreted since 1996 and been relatively stable since 2004. Several areas that show recession of the shoreline have been noted as being in close proximity to beach access paths. It is likely that anthropological causes are behind the local ‘recession’ of the vegetation line in this area as a visual inspection of aerial photographs shows a substantial beach width in these areas.

It should also be noted that the vegetation line for the majority of the study area is heavily influenced by human activity and some areas constrained by fencing. This can affect the calculated shoreline movement in these areas by limiting vegetation growth.

7.2 Historical Shoreline Movement Allowance

Historically, changes in shorelines occur on varying timescales from storm to post storm, seasonal and longer term (Short 1999). The severe storm erosion component accounts for the short-term timescale of beach change. Historical shoreline movement is intended to account for the longer term movement of the shoreline that may occur within the relevant timeframe. To determine the shoreline movement allowance, historical shoreline movement trends are examined and future shoreline movements predicted.

The SCPP recommends a minimum “safety” allowance of 20 m on all sandy shorelines, except where a chronic accretion rate greater than 0.2 m/yr is present. In such a case no allowance is made for shoreline movement. In the presence of chronic erosion, it is recommended that the shoreline movement allowance be taken as the predicted annual rate of erosion multiplied by 100 years.

In order to determine the appropriate shoreline movement allowance the shoreline movement rates have to be determined.

The 1987 to 2010 period was chosen for determining the average shoreline movement rates as the construction of Hillarys Boat Harbour and Ocean Reef Boat Harbour greatly changed the shoreline dynamics. As stated previously the 1987 data does not cover the full length of the study area, therefore the shoreline north of the Mullaloo SLSC uses the 1996 to 2010 period. There was sufficient overlap of the 1996 and 1987 vegetation lines south of the SLSC to suggest that this is appropriately accurate.

Average shoreline movement rates for the periods spanning 1987 and 1996 to 2010 were obtained for each chainage along the shoreline. Figure 7.3 shows the average shoreline movement rates for each cell.

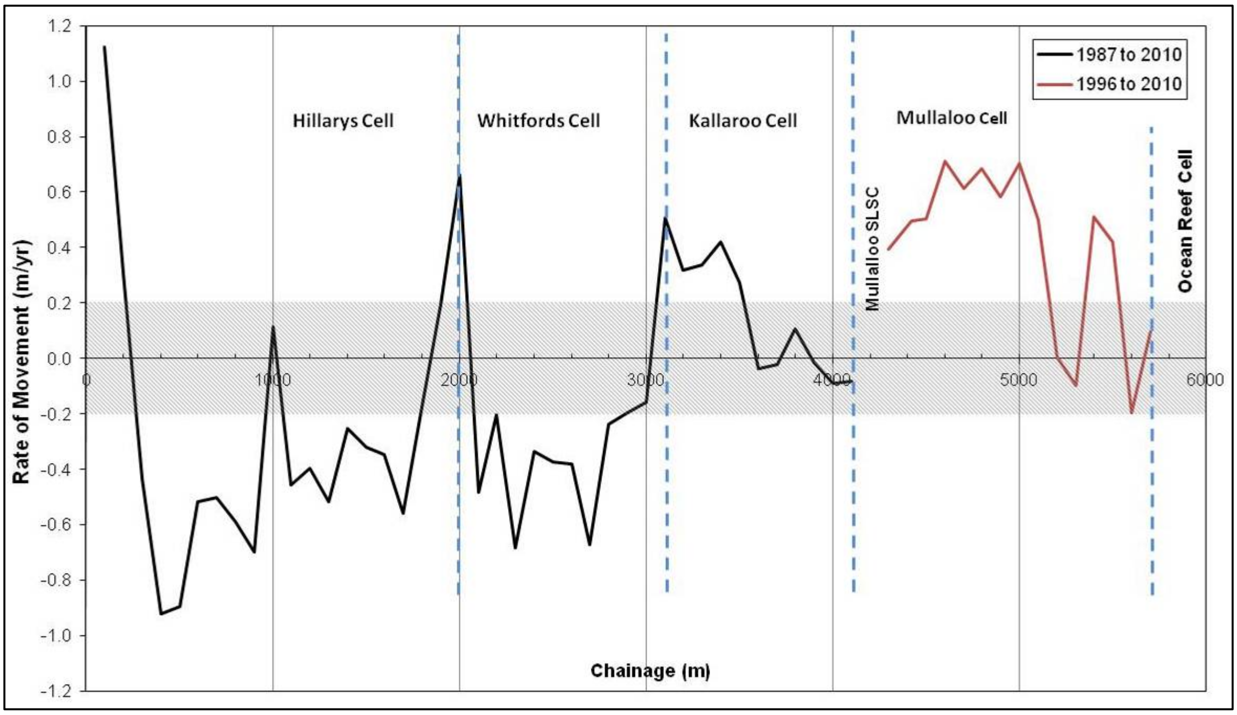

Figure 7.3 – Shoreline Movement Rates 1987/1996 to 2010

The highest erosion rate or lowest accretion rate for each cell will be used to determine the shoreline movement of that cell to 2060 and 2110. This will provide a level of conservatism in the estimates and provides a buffer against unknown variables.

The shoreline rates determined for the 1987/1996 to 2010 periods were:

- Hillarys Cell (Chainage 0 m to 1,000 m), erosion of 0.92 m/yr;
- Hillarys Cell (Chainage 1,000 m to 2,000 m), erosion of 0.56 m/yr;
- Whitfords Cell, erosion of 0.68 m/yr;
- Kallaroo Cell, Safety Allowance Rate of 0.2 m/yr;

- Mullaloo Cell, (Chainage 4,100 to 5,000 m), accretion of 0.39 m/yr;
- Mullaloo Cell, (Chainage 5,000 to 5,700 m), Safety Allowance Rate of 0.2 m/yr; and
- Ocean Reef Cell (Limestone Cliffs), 0.05 m/yr.

An allowance of 0.05 m/yr was used as the shoreline movement allowance for Ocean Reef based on surveys of the rocky cliffs in Mandurah that indicate there has been less than 5 m movement of the limestone cliffs in over 100 years.

Although the Mullaloo cell between chainages 4,100 m and 5,000 m show a minimum accretion rate of 0.39 m/yr this has been discounted in the vulnerability analysis as it relies on an uninterrupted sediment supply from the south over the period. As this can't be guaranteed, the shoreline between chainages 4,100 m and 5,000 m will have a shoreline movement allowance of 0 m. This may be conservative in this area.

A summary of the historical shoreline movement vulnerability allowances for the 2060 and 2110 time frames are presented in Table 7.1.

Table 7.1 Historical Shoreline Movement Allowances

Study Cell	Historical Shoreline Movement Allowance (m)	
	To 2060	To 2110
Hillarys (0 m to 1,000 m)	46	92
Hillarys (1,000 m to 2,000 m)	28	56
Whitfords	34	68
Kallaroo	10	20
Mullaloo (4,100 m to 5,000 m)	0	0
Mullaloo (5,000 m to 5,700 m)	10	20
Ocean Reef	3	5

The shoreline movement allowances from above will used in the estimates of vulnerability of the shoreline in 2060 and 2110.

Due to the construction of the Hillarys and Ocean Reef Boat Harbours the shoreline movement analysis was conducted with approximately 20 years of relevant shoreline movement data. This introduces uncertainties into the erosion rates predicted, as short term data does not have the ability of long term data to compensate for short term fluctuations in the shoreline position (Crowell et al 1993).

The SCPP recommends that shoreline movement rates over a 40 year data set should be considered when determining the shoreline movement allowance. As only 20 years of relevant data is available to date, future shoreline movement data could be obtained when available to verify or update the current shoreline movement allowances.

MRA also assessed the coastline between Hillarys and Ocean Reef for likely changes in the nearshore conditions over the predicted timeframes. It was determined that there was unlikely to be any significant interruption of sediment transport from the south, introduction of new sediment sources or significant changes in longshore transport.

7.3 Sediment Budgets

7.3.1 Indicative Sediment Budget

A sediment budget was estimated for the Hillarys to Ocean Reef shoreline using the shoreline movements and sediment cells identified in previous sections. Net changes in sediment volume along the shoreline were calculated from shoreline movements. This approach assumes that the entire profile accretes or erodes similarly over the entire active zone and that the shape of the profile does not change. In preparing the sediment budgets, MRA reviewed available beach profiles and hydrographic surveys in this area and believe that this provides a reasonable method of developing an indicative sediment budget.

As stated previously, the construction of Hillarys Boat Harbour and Ocean Reef Boat Harbour preclude the use of shoreline movement data prior to 1987. Additionally, due to continuity issues with the shoreline movement data the shoreline was analysed over two different time frames.

The Hillarys Boat Harbour to Mullaloo SLSC shoreline was analysed over the 1987 to 2010 period while the shoreline north of the Mullaloo SLSC was analysed over the 1996 to 2010 period. There was sufficient overlap of the

1996 and 1987 vegetation lines south of the SLSC for comparison to show the two time periods were reasonably consistent.

Note that the sediment budgets presented here are indicative only and represent average values across the measurement period. Sediment transport fluxes and volumes are difficult to estimate and likely to change from year to year depending on the prevailing weather conditions.

The estimated sediment budget for 1987/1996 to 2010 is shown in Figure 7.4. While all calculated values are approximate, those with more limited accuracy are denoted by *****.

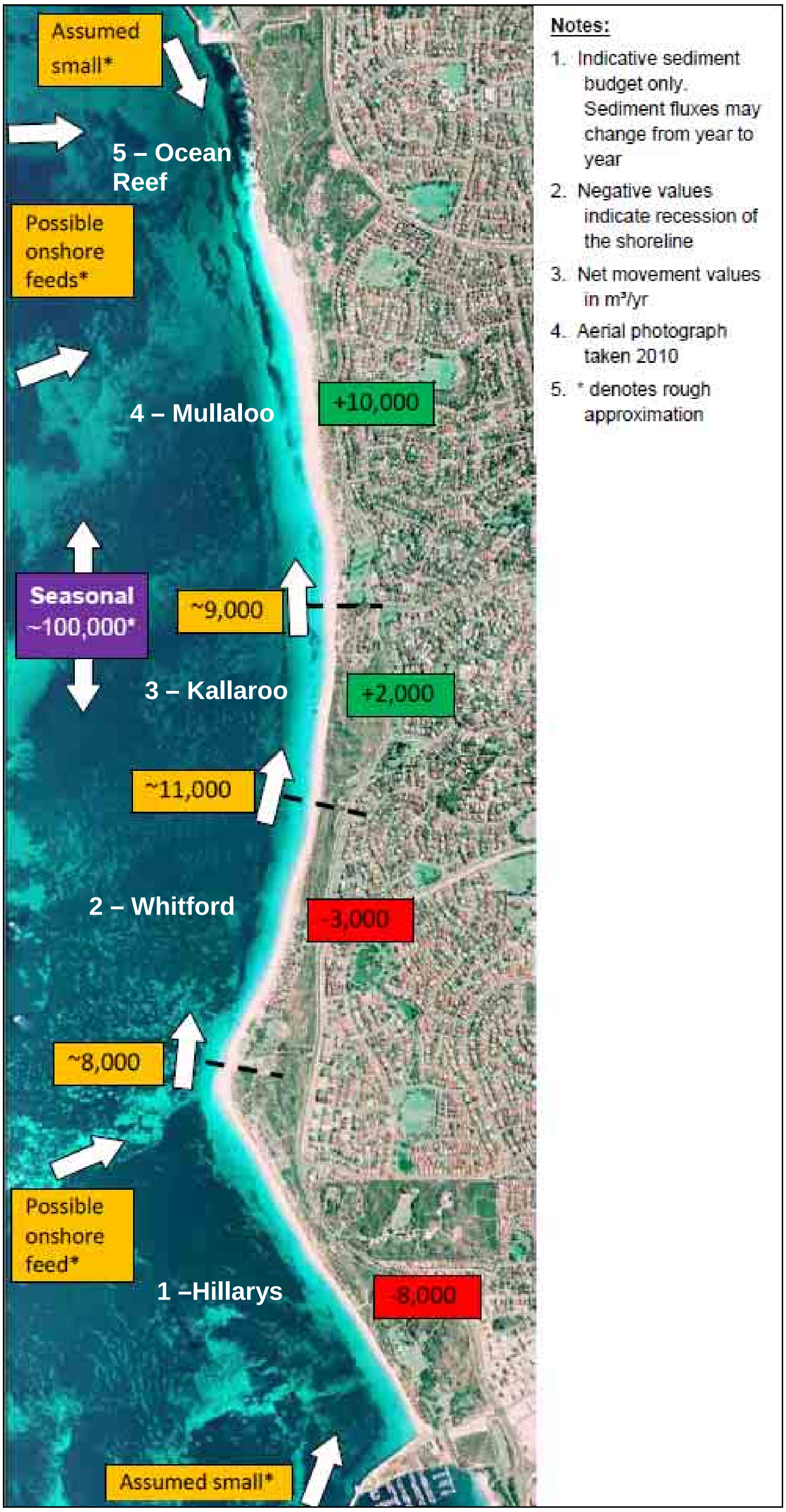

Figure 7.4 – 1987/1996 to 2010 Indicative Sediment Budget

It can be seen in Figure 7.4 that the Mullaloo cell appears to have much wider beaches than the other cells. The dune fencing and public use in this area may be preventing the movement of the vegetation line. This artificial constraining of the vegetation through dune fencing and public use may underestimate the accretion in this area and affect the sediment volumes obtained above.

The potential for onshore feed from the Lal Bank (refer to page 29) at Pinnaroo Point has been included in the sediment budget.

In general the indicative sediment budget shows:

- There has been a net erosion of the shoreline north of Hillarys Boat Harbour since construction was completed in 1987. This is believed to be due to the interruption of the northward sediment transport from the beaches south of Hillarys Boat Harbour.

- There is a net sediment transport to the north in the order of 11,000 m^3/yr. This is highlighted by the substantial accretion of the northern Mullaloo cell against the limestone cliffs. This net northerly sediment transport was also determined in previous reports (MRA 2009, WorleyParsons 2009 and Stul & Eliot 2005).

Overall, the net movement to the north of 11,000 m^3 is relatively small in terms of longshore sediment transport volumes when compared to other coastlines and the seasonal movements of the Hillarys to Ocean Reef coastline.

The City of Joondalup is proposing to redevelop the Ocean Reef Boat Harbour. This redevelopment would see an extension of the Ocean Reef breakwaters from their current extents at the -5 mAHD contour to the -9.5 mAHD contour. This is substantially deeper than the existing breakwaters and it is likely that the majority of the remaining longshore sediment transport past the harbour will be blocked.

7.3.2 Effect of Inter-annual Variability on Sediment Budgets

The frequency of occurrence of swell, sea breeze and moderate/severe storm events has a large influence on the beach profile and dominates the movement of sediment along the Hillarys to Ocean Reef shoreline. Using the wave data that was presented in Section 2.4, the effects of inter-annual variability on the longshore transport of sediment within the study area were investigated.

The timeframe selected for analysis was the 2004 to 2010 period. This was further broken into two separate sediment budgets, 2004 to 2007 and 2007 to 2010. This breakdown was based upon the availability of shoreline movement data being available for 2004, 2007 and 2010.

Over the 2004 to 2007 period it was observed that:

- There was above average number of swell, winter storm and severe storm events and a below average number of sea breeze events. This resulted in a net southerly transport of sediment within the study area.

- The Hillarys and Kallaroo cells showed a combined accretion of approximately 50,000 m^3/yr.

- The Mullaloo cell experienced erosion over the period of 7,000 m^3/yr.

The inter-annual variations, accretions and recessions of the Mullaloo cell are believed to be subject to under estimation due to the restraining effects of public use and dune fencing on the vegetation line position. While this is less pronounced in the longer term sediment budgets of 1987 and 1996 to 2010, it may have a more pronounced effect on the inter-annual variability time frames of 2004 to 2007 and 2007 to 2010 due to the shorter time frames and increase in use.

Over the 2007 to 2010 period it was observed that:

- There was an average/below average number of swell and winter storms events, average number of severe storm events and above average number of sea breeze events. This is likely to have resulted in a net northerly transport of sediment within the study area.

- The Hillarys cell experienced erosion of approximately 30,000 m^3/yr.

In the 2007 to 2010 assessment the Mullaloo cell did not show the large accretions through the period that would be expected from a net northerly transport of sediment. This may be the result of beach works which saw the creation of dune fencing in 2008 to 2009 and may be artificially holding back the vegetation line. Previous investigations on beaches with heavy public use have shown the movement of the vegetation line can be restricted to the fenceline.

This may cause the volume of sand contained on the Mullaloo beach to be underestimated through the analysis methods used in this report. Visual analysis of aerial photographs show evidence of erosion scarps in the dune areas following the above average number of winter and severe storms in 2007. The fencing installed in 2008 and 2009 followed this erosion scarp and may be preventing the vegetation line from recovering to previous extents.

This analysis shows that inter-annual variability in the relative occurrence of key events has a substantial impact on the shoreline within the study area. The 2004 to 2007 period was associated with above average swell and storms and was associated with recession of the northern sectors and accretion of the southern sectors. The 2007 to 2010 period had an above average number of sea breeze events that resulted in net accretion of the northern sectors and recession of the southern sectors in the period.

With climate change potentially affecting the relative frequency, intensity and duration of sea breeze events, changes in the existing longshore sediment transport trends may occur. Specifically, this may affect the long term net movement of sediment northwards along the Hillarys to Ocean Reef shoreline. In turn, this change in sediment transport is likely to affect the rate of shoreline movement within each of the cells in the study area. This is an additional reason for applying the worst recession or accretion rate within a cell to that entire cell instead of an average.

7.4 Summary of Shoreline Movement & Sediment Budgets

A large amount of information was presented in this section. The key outcomes of the shoreline movement and sediment budget analysis are:

- Hillarys Boat Harbour and Ocean Reef Boat Harbour have changed the local sediment dynamics of the region. Both structures have interrupted the longshore transport of sediment in the study area. In particular, Hillarys prevents the northward transport of sediment from the beaches south of Hillarys.

- The Hillary and Whitford cells have a net recession over the 1987 to 2010 period.

- Pinnaroo Point receded in the 2007 to 2010 period.

- The shoreline position in the Kallaroo cell has fluctuated since 1987 but has relatively little net movement.

- The Mullaloo cell accreted from 1987 to 2004 but has remained relatively stable since. Given the wide beach in the area, the vegetation line may be artificially constrained by public use and dune fencing, and the accretion underestimated.

- The net sediment transport in the study area over the 1987 to 2010 period is to the north. This net sediment transport is in the order of 11,000 m^3/yr and is relatively small compared to other coastlines and the magnitude of the seasonal movements in the area.

- Inter-annual variability in occurrence of key wave events can have a substantial impact on the movement of sediment along the Hillarys to Ocean Reef shoreline.

- Increases in the frequency and strength of sea breeze events may continue to put erosive pressure on the beaches south of Pinnaroo Point.

- The proposed redevelopment of the Ocean Reef Boat Harbour is unlikely to have a significant impact on the shoreline position or sediment budget within the study area.

8. Vulnerability to Sea Level Rise

8.1 Shoreline Recession Due to Sea Level Rise

Climate change scenarios are used to predict future trends in greenhouse gas emissions and thus future climate change effects. The complex nature of the climate and of the global population trends leads to uncertainties in predictions, requiring a number of scenarios to cover the wide range of future possibilities in global emissions. For example, it is unknown whether the world population will continue to grow at the same rate and whether third-world countries will begin to use more advanced and efficient technologies to control current emissions.

The atmospheric and oceanographic processes involved in climate modelling are complex and numerical modelling of these processes is far from perfect. Due to these uncertainties, there are a wide range of predictions for global sea level rise in the coming century.

These predictions are shown in Figure 8.1.

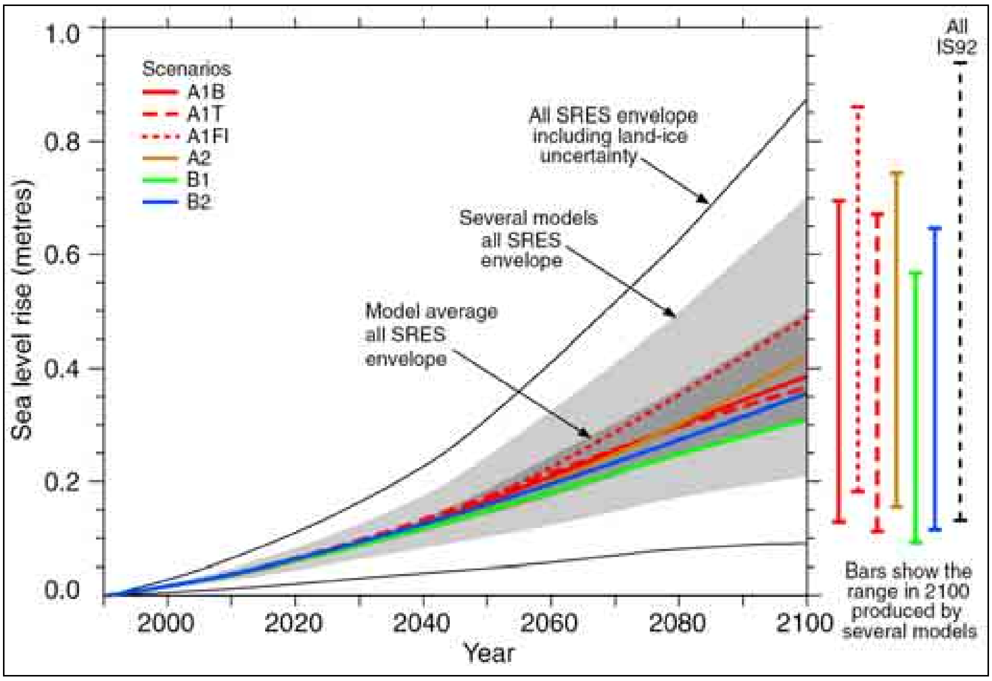

Figure 8.1 – IPCC Scenarios for Sea Level Rise (IPCC 2001)

DoT (2010) extrapolates work by Hunter (2009) to provide sea level rise values based on the IPCC (2007) A1F1 climate change scenario projections to the year 2110. Based on this, the West Australian Planning Commission (WAPC) has released a position statement indicating that the allowance for sea level rise (SLR) to 2110 be increased from 0.38 m to 0.9 m. This is based upon the IPCC AR4 (scenario A1F1) and CSIRO (2008).

Using the A1F1 scenario the expected SLR to 2060 and 2110 is 0.31 m and 0.90 m respectively.

The effect of sea level rise on the coast is difficult to predict. Komar (1998) provides a reasonable treatment for sandy shores, including examination of the Bruun Rule (Bruun 1962). The Bruun Rule relates the recession of the shoreline to the sea level rise and slope of the nearshore sediment bed:

$$R = \frac{1}{\tan(\theta)} S$$

where: R = recession of the shore;

θ = average slope of the nearshore sediment bed; and

S = sea level rise.

Using the Bruun Rule, the shoreline recession for each cell in the study area was calculated for the 2060 and 2110 timeframes.

The shoreline slope in each of the cells was obtained using 2010 beach profile surveys. Analysis conducted using the Bruun Rule provided the following recessions of the shoreline due to the A1F1 SLR scenario.

Table 8.1 Bruun Rule Recession (A1F1)

Study Cell	Recession to 2060 (m) (SLR = 0.31 m)	Recession to 2110 (m) (SLR =0.90 m)
Hillarys	9.3	27.0
Whitfords	29.5	85.5
Kallaroo	17.1	49.5
Mullaloo	14.0	40.5
Ocean Reef	0 due to Limestone Cliffs	

Komar (1998) suggests that the general range for a sandy shore is R = 50S – 100S. The R values calculated by MRA for the cells within the study area ranged between 30S and 95S.

The shoreline recession values shown in Table 8.1 will be combined with the severe storm erosion and historical shoreline movement allowances shown earlier to estimate the vulnerability of the coastline later in the report.

8.2 Inundation Due to Sea Level Rise

In addition to the impact of SLR through recession of the shoreline position the vulnerability of the shoreline to inundation of low lying land during severe storm events was assessed.

MRA have completed an extreme water level analysis on the long term record at Fremantle. For all practical purposes this analysis is applicable to water levels at Hillarys to Ocean Reef. MRA have estimated the 100 year ARI level as approximately +1.2 mAHD. On average, this level will occur once every 100 years.

Table 8.2 presents the estimated 100 year ARI water levels for the study area using the A1F1 scenario for sea level rise.

Table 8.2 Estimated 100 Year ARI Water Levels in 2110

100 yr ARI Water Level 2010	+1.2 mAHD
Sea Level Rise	0.9 m
100 yr ARI WL 2110	+2.1 mAHD

These water levels are applicable to locations in around 5 m of water. Closer to the shoreline, wave setup results in local increases in the water level. The wave setup was determined from severe storm modelling using SBEACH and estimated at approximately 1.1 m in the 100 year ARI conditions.

The estimated shoreline level below which there could be increased coastal inundation risks is outlined in Table 8.3.

Table 8.3 Estimated Inundation Level in 2110

Inundation Components	Inundation Level
Upper-range (2010 100 yr ARI WL + SLR + wave setup)	3.2 mAHD

These have been determined for the end of the planning period and will provide an appropriate level of protection from coastal inundation. These components are graphically illustrated in Figure 8.2.

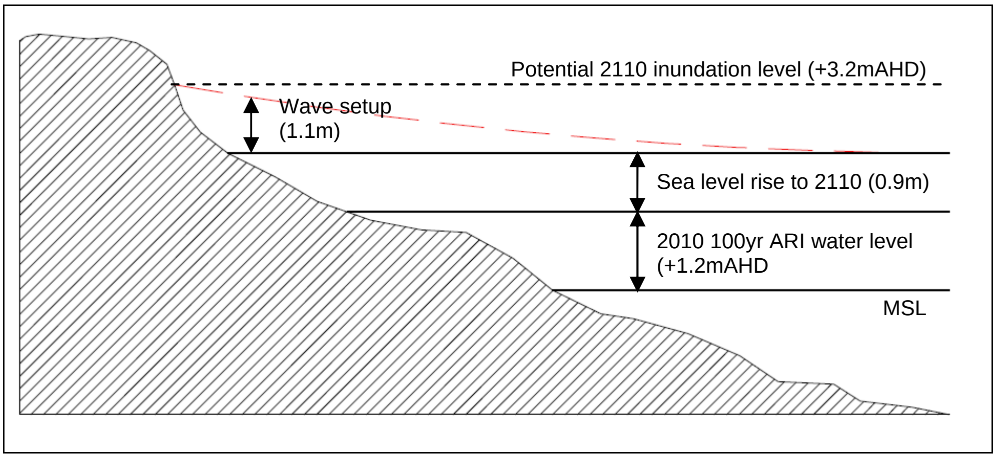

Figure 8.2 – 2110 Inundation Components

The method of inundation used in the assessment assumes that the water level of +3.2 mAHD will continue over land until a contour of equal height is reached. This does not take into account the lessening of wave energy as a result of distance over land. However, given the extent of the nearshore wave setup and the close proximity of the +3 m contour to the shoreline this is believed to be appropriate.

The potential for inundation due to the 2110 100 year event was assessed for:

- Inundation to the Hillarys to Ocean Reef coastline resulting from the current shoreline position;
- Inundation as a result of the shoreline position receding to that previously estimated for 2060; and
- Inundation as a result of the shoreline position receding to that previously estimated for 2110.

Topographical surveys from 2004 were provided to MRA by the City for use in this assessment. The survey data contained contours at 1 m intervals.

Analysis of these contours indicates that the majority of the shoreline has a minimal risk of inundation to 2110 using the above water levels. However, the following items were flagged for consideration:

- Several low lying areas containing dual use paths in the northern section of Mullaloo may potentially be vulnerable to inundation at the end of the planning period (2110).

- Localised inundation about the Mullaloo SLSC may occur.

- If the dunes in the Kallaroo area are breached, inundation in front of Whitfords Avenue may occur.

- Localised inundation about John Wilkie Turn may occur due to an access way through the dune.

- The parks north of Hillarys Boat Harbour are at risk of inundation if the dunes are breached due to shoreline recession.

The areas potentially vulnerable to inundation in severe storm events to 2110 are shown in Figures 8.3 to 8.5.

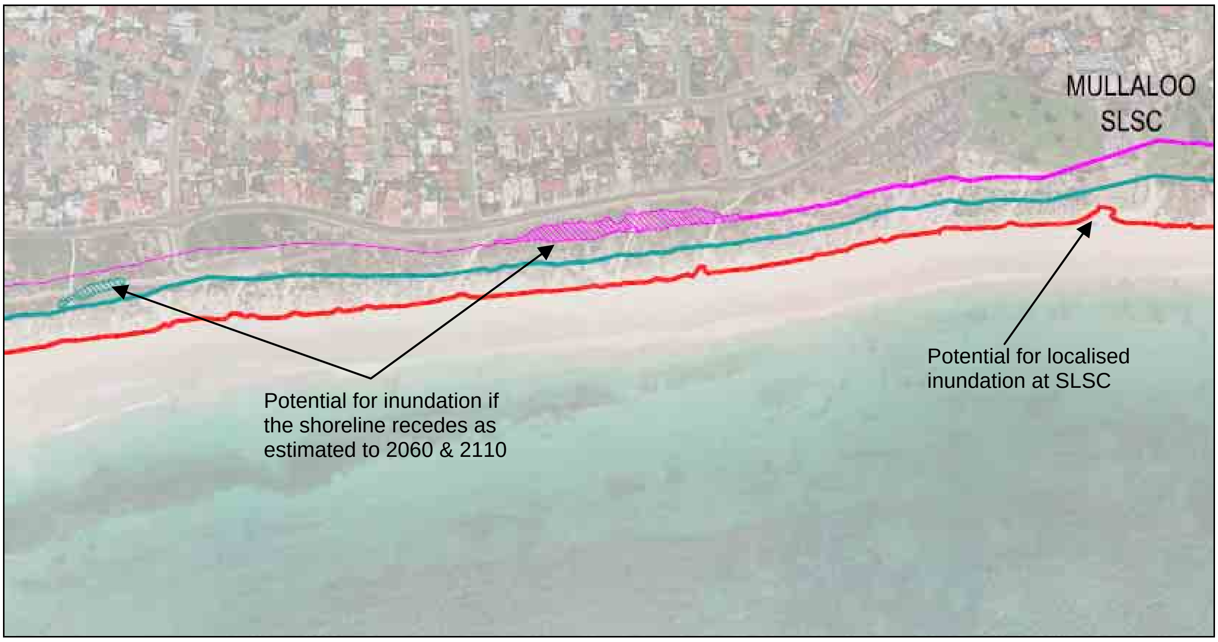

Figure 8.3 – Inundation of the Mullaloo Cell

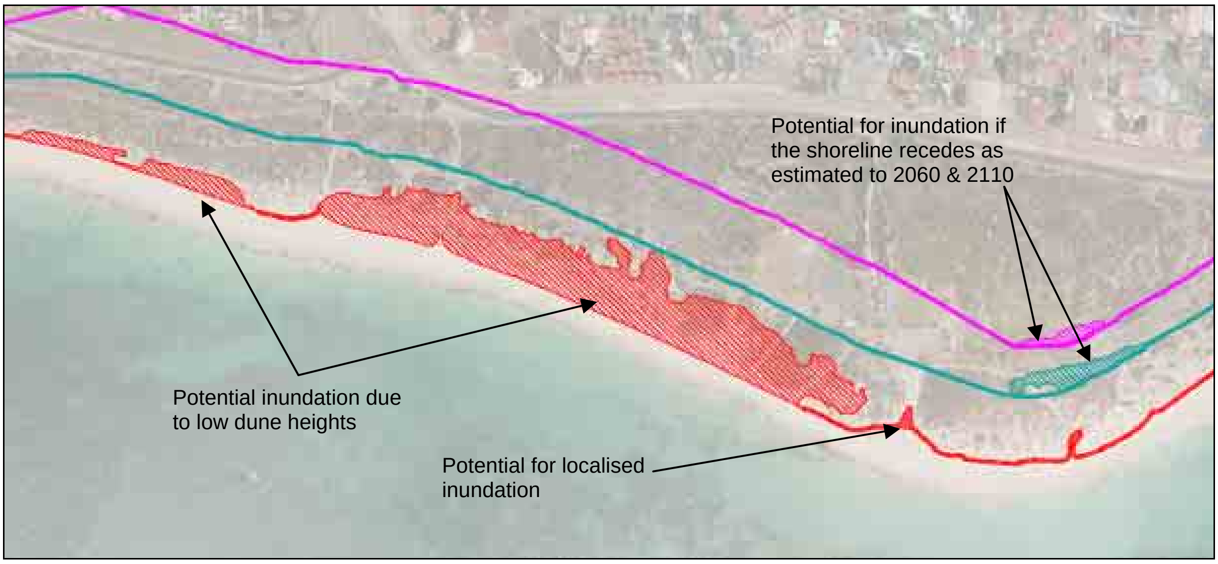

Figure 8.4 – Inundation of the Whitfords and Kallaroo Cells

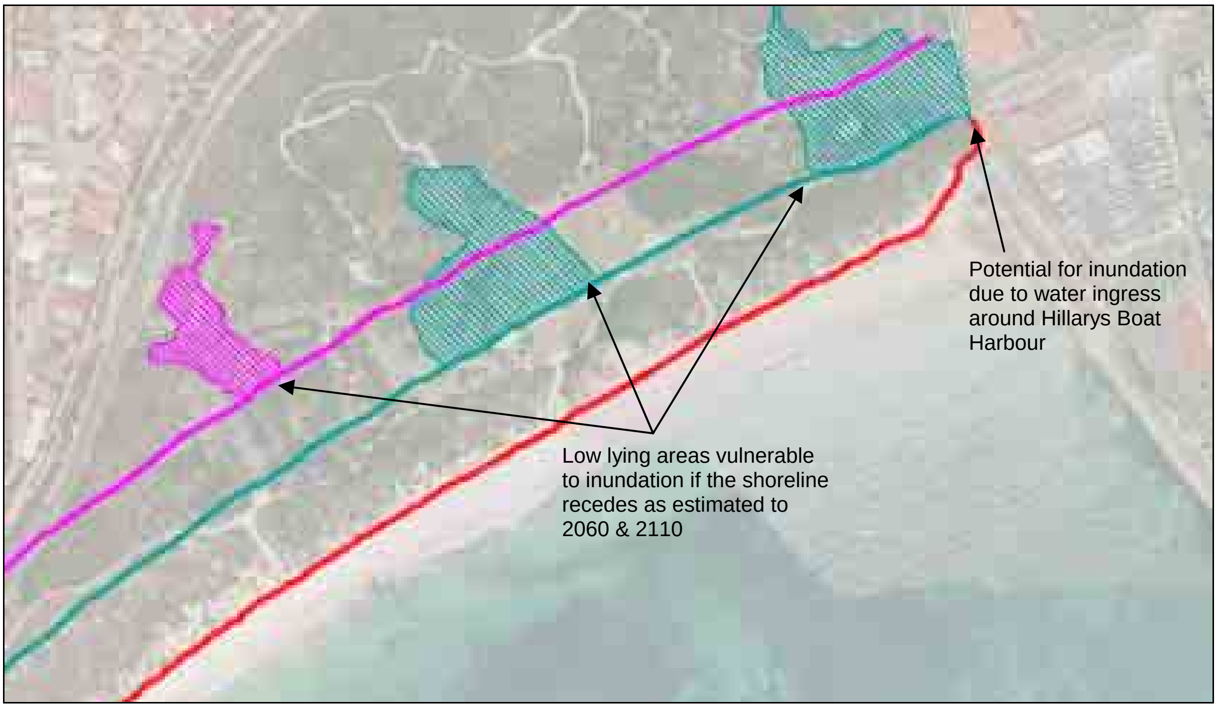

Figure 8.5 – Inundation of the Hillarys Cell

It was also observed from the survey information that the infrastructure on the northern side of Hillarys Boat Harbour was below the 2110 inundation level and may be vulnerable to 2110.

In the Ocean Reef cell, direct inundation of the shoreline as a result of increased mean sea level is considered to be very unlikely due to the limestone cliffs that run the length of the shoreline. There may be some loss of bayed beaches amongst the cliffs in the Ocean Reef cell as the sea level rises, however the cliffs will maintain the shoreline position in that area.

This inundation assessment outlines areas that may be at increased risk of inundation from severe storm events, following sea level rise. This inundation would still be temporary in nature (ie during storm events) and the highlighted areas would not be permanently inundated. There are no areas seaward of the HSD in the study area which would be permanently inundated following sea level rise.

It should be noted that this inundation assessment was conducted with estimated dune heights from 2004 and extreme water levels from 2110. Changes in the dune levels and extents have likely occurred since the survey was taken and will continue to occur into the future. This should not be an issue prior to approximately 2060.

9. Assessment of Coastal Vulnerability

A vulnerability assessment has been conducted using a logical application of the SCPP methodology. This vulnerability assessment is designed to determine the vulnerability of the public and private infrastructure along the Hillarys to Ocean Reef shoreline for the coming 100 years.

Table 9.1 presents the estimated allowances that would be required to limit the vulnerability of infrastructure from severe storm erosion, shoreline movement and SLR. It should be noted that the vulnerability allowance has been measured from the 2010 HSD. Planning horizons used in this assessment include a present day, 50 year and 100 year vulnerability analysis.

Sections where the existing buffer to infrastructure is less than the calculated vulnerability allowance are considered vulnerable to coastal erosion in the management timeframe. These areas may need active coastal management and are shaded in the table.

Table 9.1 Estimated Coastal Vulnerability Allowances

Cell	Time frame	Severe Storm Erosion (m)	Historical Shoreline Movement (m)	Recession Due to Sea Level Rise (m)	Allowance (m)	Existing Buffer to Infrastructure (m) [4]
Hillarys (0 m to 1,000 m)	2060	25.0	46.0	9.3	81	38 to 100
	2110		92.0	27.0	144	
Hillarys (1,000 m to 2,000 m)	2060	25.0	28.0	9.3	63	32 to 70
	2110		56.0	27.0	108	
Whitford	2060	23.0	34.0	29.5	87	67 to 87
	2110		68.0	85.5	177	
Kallaroo	2060	29.0	10.0	17.1	57	98 to 271
	2110		20.0	49.5	99	
Mullaloo (4,100 m to 5,000 m)	2060	18.0	0[2]	14.0	32	15 to 91
	2110		0[2]	40.5	59	
Mullaloo (5,000 m to 5,700 m)	2060	18.0	10.0	14.0	42	56 to 109
	2110		20.0	40.5	79	
Ocean Reef	2060	0.0[1]	5[3]	0[1]	5	15 to 97
	2110		5[3]	0[1]	5	

Notes:

1. Ocean Reef shoreline consists of limestone cliffs and pocket beaches. The HSD is therefore not expected to erode due to severe storm erosion or sea level rise and hence no vulnerability allowances have been shown.
2. Due to accretion greater than 0.2 m/yr, a shoreline movement allowance of 0 was used.
3. An allowance of 5 m for shoreline recession of limestone cliffs was used for the Ocean Reef cell.
4. Buffer is taken to the seaward edge of existing infrastructure.

A plan showing the estimated areas of vulnerability to 2060 and 2110 is contained in Appendix D. From this vulnerability plan it can be seen that:

- All cells except Ocean Reef have infrastructure that could be vulnerable in the 2060 and 2110 timeframes.

- In the southern part of the Hillarys cell substantial sections of the dual use path (DUP), parks and car parks could be at risk in the 2060 period. In addition approximately 100 m of Whitfords Avenue may be threatened as it is in close proximity to the 2060 vulnerability line. In the 2110 period substantially more parks, car parking areas and DUP could be at risk. Approximately 300 m of Whitfords Avenue may also be vulnerable.

- For the northern part of the Hillarys cell a number of car parks, park areas, public amenity blocks and DUP sections could be at risk to 2060. To 2110, the extent of parks, car parks, public amenities and DUP that could be at risk is greatly increased. Approximately 300 m of Whitfords Avenue could also be at risk in the 2110 period.

- Vulnerable infrastructure to 2060 in the Whitfords cell consists of approximately 900 m of DUP, sections of the John Wilkie Turn near Pinnaroo Point and several public amenity blocks. In the 2110 period a much larger amount of public infrastructure could be at risk. This includes car parks, public parks, approximately 600 m of Northside Drive and approximately 250 m of residential infrastructure.

- For the Kallaroo cell, vulnerable infrastructure to 2060 is much less than adjacent cells due to the greater setback to development in the area. Approximately 250 m of DUP could be at risk and residential housing south the Mullaloo SLSC is in close proximity to the vulnerability line. To 2110 the additional infrastructure that could be at risk is approximately 250 m of residential infrastructure south of the SLSC, 250 m of Merrifield Parade and the public areas on the south side of the SLSC.

- For the southern Mullaloo cell the infrastructure at risk to 2060 is generally limited to the infrastructure associated with the Mullaloo SLSC. This includes the SLSC itself, adjacent parks and the associated amenity blocks. To 2110 the infrastructure that could be at risk also includes sections of the DUP, car parks, as well as threatened infrastructure such as the Warren Way roundabout and Korella St.

- For the northern Mullaloo cell the infrastructure at risk is relatively minor. It is generally limited to look out stations and beach access ways. To 2110, vulnerable infrastructure includes approximately 500 m of DUP, car parks and their associated access roads.

The above method of assessing vulnerability discounts the measured shoreline movements of the Mullaloo cell between 4,100 m and 5,000 m. This may be conservative.

The extent of the limestone cliffs in the Ocean Reef cell were obtained from a 2004 DoT analysis of the area. This information indicates that the cliffs within the Ocean Reef cell are continuous and have been assumed as such for the purposes of this vulnerability assessment.

Overall the infrastructure that could be at risk along the Hillarys to Ocean Reef shoreline to 2060 is believed to be mostly non critical. The infrastructure in this region is restricted to public spaces such as parks, car parks and the DUP. However one communication tower that was located near a park in the Hillarys cell is also within the vulnerable area. This indicates that significant coastal management will not be required for some time.

The possible risk to infrastructure to 2110 is more significant. In addition to the infrastructure listed above, sections of major roads and residential housing may be at risk. The extent of public spaces, car parks and DUP that could be at risk is also much greater.

Potential management options to minimise these losses are explored further in the following section.

10. Coastal Management Options

10.1 General

The vulnerability assessment determined that some infrastructure along the Hillarys to Ocean Reef coastline is at risk from severe storm events, shoreline recession and SLR. In order to counter these effects coastal management options were investigated.

The coastal management options were investigated in three primary categories:

- Mitigation & Accommodation Options
- Retreat Options
- Protection Options

Coastal management options were applied to an immediate short term timeframe and the longer 2060 and 2110 timeframes. The short term period takes into account severe storm erosion vulnerability and details coastal management options that may be required anytime from the present.

The longer term periods take into account the combined effects of severe storm erosion, historical shoreline movement trends and SLR vulnerability.

These timeframes will be analysed separately in order to determine the most effective coastal management options for each period.

10.2 Short Term Coastal Management Options

The main risk to infrastructure along the Hillarys to Ocean Reef coastline in the short term period is erosion caused by severe storm events. This is due to the short time span under consideration which reduces the impact of anticipated SLR and shoreline movement.

The Severe Storm Erosion Vulnerability Plan attached as Appendix B shows there is very little infrastructure along the shoreline from Hillarys to Ocean Reef that is at risk from severe storm erosion.

In the majority of the cells the only infrastructure at risk consists of beach access ways and dune fencing. The exception to this is the Mullaloo cell where the SLSC could be at risk from severe storm erosion.

In a severe storm event, the beaches along the length of the coast would also lose a large amount of sand. This may affect the amenity and recreational value of the areas that are heavily used by the public.

Options for managing the infrastructure at risk in the short term as well as management options that may assist the City in regards to future planning are given below.

10.2.1 Mitigation & Accommodation Options

These options attempt to manage for the risks of the short term vulnerability without requiring substantial expenditure by the City. These types of options are of greatest benefit when infrastructure of little value is at risk or preparations can be made to mitigate future risks.

An accommodation or mitigation strategy towards severe storm erosion over the short term should address the following:

a) There are approximately 4 access ways in the Pinnaroo Point area that currently approach the beach at a high level and show signs of scouring due to shoreline recession or wave action. Further shoreline recession in these areas may cause damage to these paths and limit ease of beach access. Therefore, re-contouring of the beach access ways around Pinnaroo Point could be undertaken to land the access paths at a lower level and improve beach access. This is likely to reduce the extent of damage suffered in storm events and improve year round access to the beach.

b) During a storm event, beach access ways along the coastline would likely experience scouring of their seaward extents. This could lead to potential collapse of sections and erosion scarps at the end of walkways. An allowance should be made for the removal of debris and reworking of the access ways to maintain easy beach access. This could be completed by small front end loaders or bobcats. Re-contouring and improvement of the access ways as outlined above could reduce the requirement to manage access following severe storms.

c) Preparations or budgeting for the removal or reinstatement of dune fencing that has been damaged during severe storm events should be made. This may be required over several kilometres, though the extent of repairs required is difficult to quantify.

d) The retaining walls in front of the SLSC should be investigated to determine adequacy of the structures to resist wave action and protect the development. If the existing walls are unsuitable, it is recommended that the City investigate retrofitting appropriate protection or the installation of a seawall.

In addition to the above options a coastal monitoring program could be implemented for the Hillarys to Ocean Reef shoreline. This program could involve monitoring of the shoreline between Hillarys and Ocean Reef through the use of beach and nearshore profiles and mapping of the coastal vegetation line. Such a program could be completed at around 5 year intervals and would:

- Provide guidance on seasonal and annual beach movements over time;
- Assess the effectiveness of any implemented coastal management; and
- Keep track of shoreline movements to update assessments of vulnerability and provide early warnings for vulnerable infrastructure.

As part of the proposed redevelopment of Ocean Reef Boat Harbour, a number of beach profiles were surveyed in 2010 that span the Hillarys to Ocean Reef shoreline. Any future monitoring could use these same profiles as a baseline. A coastal monitoring program would provide the City with information for planning and development as well as providing updates on shoreline movements. This data would also assist in any future updates to vulnerability assessments.

10.2.2 Retreat Option

Given the short time frame, limited vulnerability extents and the possibility that a severe storm could occur at anytime, the option for retreat is not considered to be viable.

10.2.3 Protection Options

It is not recommended that protection options be considered for the beach access ways located along the coastline. The work involved in preparing the access ways to resist the severe storm event is likely to be more costly than that required to repair or rework the access ways following damage.

However, given the value and public amenity of the SLSC, if investigations into the capabilities of the SLSC retaining walls found that they were inadequate then suitable strengthening and protection should be retrofitted. Alternatively, independent protective structures such as a seawall could be installed. Following a severe storm event a structural assessment of the walls should be undertaken.

10.3 Long Term Management

Regardless of the short term coastal management options that are enacted, in the longer term active coastal management of the coastline may be required. The infrastructure most at risk to 2060 and 2110 is shown in Figure 10.1.

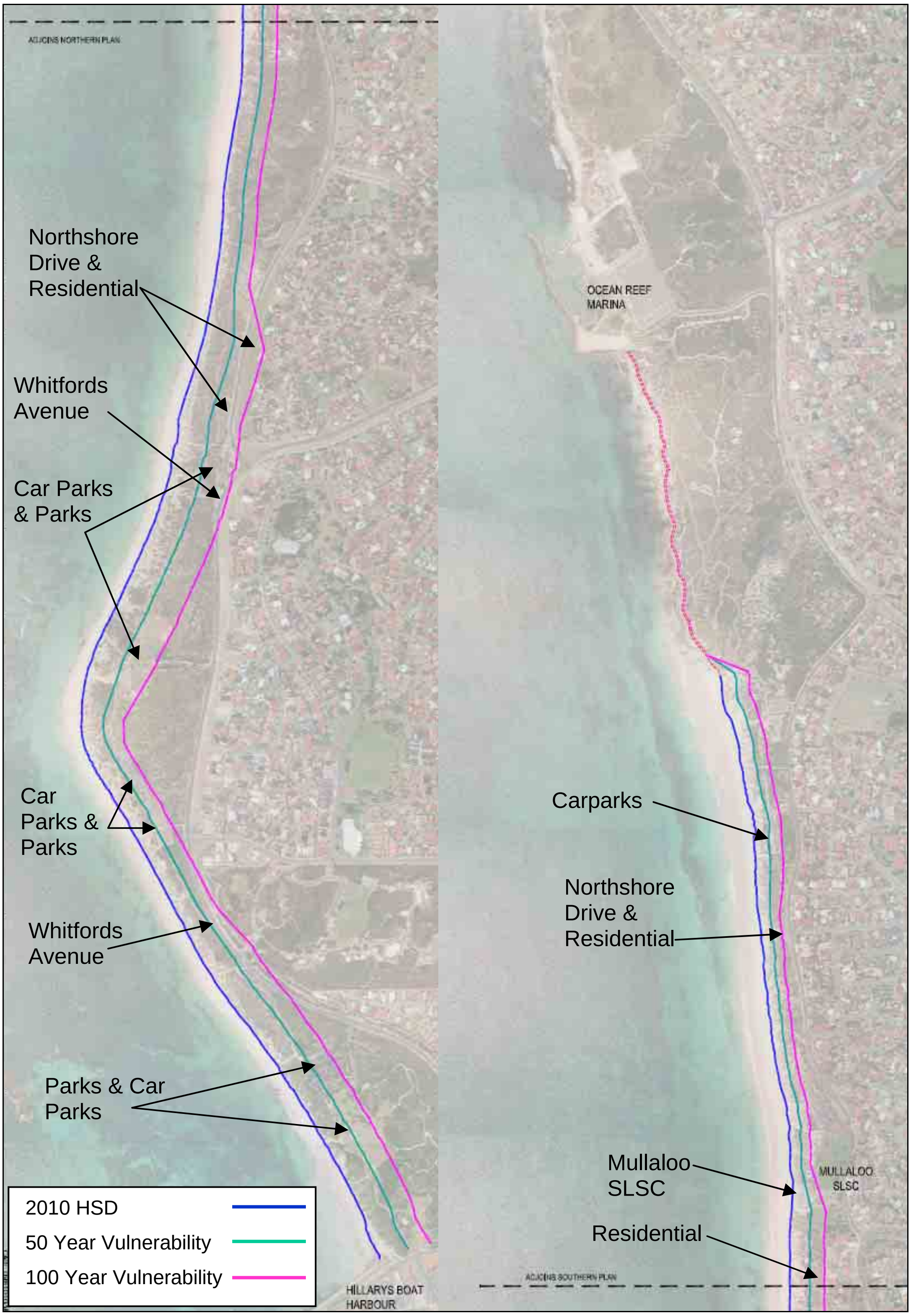

Figure 10.1 – Vulnerable Infrastructure to 2060 & 2110

Figure 10.1 shows that there is a substantial amount of infrastructure possibly at risk in the longer term. While infrastructure such as parks and car parks may be able to be relocated over a number of years, some critical infrastructure such as Whitfords Avenue and Northshore Drive cannot easily be moved. The extent to which this infrastructure is vulnerable can be seen on the Vulnerability Plan contained in Appendix D.

Options for managing the infrastructure at risk to 2060 and 2110 as well as management options that may assist the City in regards to future planning are given below.

10.3.1 Mitigation & Accommodation Options

Coastal Monitoring

Long term mitigation of the coastal vulnerability of the Hillarys to Ocean Reef shoreline could be obtained through the continued application of the 5 year interval coastal monitoring program. Over the long term such a program is likely to provide the City with information that will assist in planning decisions, provide early warning of changes to the coastal vulnerability and guide any required coastal protection works.

Sand Nourishment

One accommodation or mitigation strategy towards long term vulnerability could entail a sand nourishment program.

The addition of sediment to the Hillarys to Ocean Reef sediment cell through a sand nourishment program may reduce the erosion of the southern cells that results from the net northward transport of sediment in the area. This would also assist in retaining a useable beach over the 100 year timeframe. This investigation has found that for the period 1987 to 2010 the net northward sediment transport rate is in the order of 11,000 m^3/yr.

Previous investigations into sand nourishment of coastlines north of Perth have identified that Rocla Quarries are able to provide sand of sufficient quality for beach nourishment. The cost to supply and install sand from quarries north of Perth is in the order of approximately \$60/m^3. To account for the introduction of voids into sediment due to handling and overfill requirements due to potential differences in sediment size between the sediment source site and the destination site, the estimated quantity of trucked sediment required is approximately 15,400 m^3/yr.

A sand nourishment program could also make use of the sediment that builds up against the southern side of Hillarys Boat Harbour and the northern side of Ocean Reef Boat Harbour.

MRA (2011a) estimated that over the 1987 to 2010 period the shoreline south of Hillarys Boat Harbour experienced a net accretion of approximately 4,600 m^3/yr. It should be noted that this net accretion rate had reduced in the 2000 to 2010 period. MRA (2011a) suggested this was a result of reduced sediment feed from the south.

The extraction of sand from the southern side of Hillarys Boat Harbour would have to be done with careful consideration due to the popularity of the beach and the quantity of sediment involved. MRA do not recommend the bypassing of sand from the southern side of Hillarys Boat Harbour until the coastal management options for the Marmion to Sorrento coastline have been determined.

Planning Controls

Potential long term vulnerability could also be mitigated through City planning controls. Requirements to reduce vulnerability of new development as well as the redevelopment of existing infrastructure could be instituted through the City. This could include preventing new development within vulnerable areas or arranging for leasehold agreements for proposed development within the vulnerable areas. This would allow the City to react in the future to changes in coastal vulnerability.

10.3.2 Retreat Option

The planned retreat option investigates the effect on the study area if no action were taken to hold the shoreline position in the face of SLR, severe storm erosion and shoreline movement.

For planned retreat, parks, car parks and associated public infrastructure could be moved back incrementally as they are maintained or refurbished throughout their lifecycles. This would reduce the vulnerability risk while not having to commit a large amount of resources to relocate the infrastructure in one exercise. This approach would also allow these facilities to stay within an appropriate distance of the shoreline to fulfil their purpose.

For example, should monitoring show that the shoreline around Pinnaroo Point was continuing to erode, at the end of their lifecycle the car parks in the area slightly further back from the shoreline to the area which does not appear to be as vulnerable.

This option of planned retreat is not viable for all sections of the shoreline. For example an option of planned retreat would leave large sections of Whitfords Avenue, Northshore Drive, residential housing and the Mullaloo SLSC within the estimated vulnerable area. Therefore retreat for these areas may not be possible or recommended and in the long term management or protection of these assets is likely to be required. It may be possible to relocate the SLSC further back from the shoreline when it approaches the end of its design life. This may enable the SLSC to remain in use without substantial protection works.

It should be noted that there exists residential buildings next to the Mullaloo SLSC that are westward of vulnerable major public infrastructure. The City should consider if any protection should be provided to this residential area in the long term.

The option for retreat will also result in the loss of a substantial amount of foreshore area and the DUP that run the length of the study area, further reducing the amenity of the shoreline.

10.3.3 Protection Options

Figure 10.1 previously showed that several areas of valuable infrastructure were vulnerable over the long term. This includes car parks, Whitfords Avenue, Northshore Drive, Mullaloo SLSC and residential buildings.

If the Mullaloo SLSC remains in its existing location it is highly likely to require protection over the long term. This protection is likely to take the form of hard coastal structures located about the structure. Under the A1FI SLR scenario, the coastline about the SLSC is estimated to recede by approximately 14 m to 2060 and 40 m to 2110. The SLSC currently has an existing buffer of 9 m from the 2010 HSD to the SLSC retaining walls. If the coastline about the SLSC recedes it is likely to leave the SLSC exposed and in front of the future shoreline position.

If the structure were protected by a seawall, it would be difficult to maintain the beach around the SLSC, as wave reflection and shoreline recession act to reduce the beach presence. This loss of beach would result in a large reduction in amenity and may reduce the popularity of the area. Therefore, hard protection of the SLSC may not be the optimal solution.

In general, protection is not recommended for vulnerable car parking areas along the coastline. However, it is likely that protection will be required for critical infrastructure such as Whitfords Avenue and Northshore Drive if they are threatened.

Except for one area located next the Mullaloo SLSC, the residential infrastructure potentially at risk over the long term are located to the east of Whitfords Avenue and Northshore Drive. Therefore, by instituting coastal protection measure for these two items of infrastructure, the vulnerability of the residential buildings is also reduced.

Some coastal protection measures that could be undertaken in the future are presented below:

- Sand nourishment could be placed at areas that experience a net loss of sediment to reduce or stop the shoreline recession. This would be an ongoing cost to the City but would maintain the recreational value and amenity of the beach. As stated previously the net transport of sediment in the area is approximately 11,000 m^3 from south to north.

- Seawalls could be constructed to provide direct protection to vulnerable sections of Whitfords Avenue and Northshore Drive. This may result in the loss of useable beaches in front of these structures, interrupting the continuity of the shoreline.

- Groynes could be used to stabilise the shoreline by retaining sand between consecutive groynes. The use of groynes will have a visual impact and will interrupt the continuity of the beach, however sections of useable beach will be retained.

- Offshore headlands could be used in a similar fashion to groynes in order to reduce shoreline recession due to the transportation of sediment through longshore currents. The use of offshore headlands would provide uninterrupted beaches but would be likely provide less protection during severe storm events.

Given the long time frames of 50 and 100 years under consideration for this part of the vulnerability assessment, no long term coastal protection works are currently recommended as a part of this investigation. Instead the City should consider the mitigation and accommodation measures proposed in order to minimise future coastal vulnerability and protection requirements. This will also allow for monitoring of the shoreline to be undertaken into the future where updated information can be provided, enabling the City to make the most appropriate measures to counteract the coastal vulnerability.

10.4 Priority Plan for Works

An initial step could be to reduce the vulnerability of the beach access ways located about Pinnaroo Point from shoreline recession and wave action. As stated previously, approximately 4 access ways approach the beach at a much higher level than the beach and currently show signs of scour. If these access ways were reworked to achieve a lower landing level then the impact of damage cause by wave action and shoreline recession will be greatly reduced. This would require some re-contouring of the adjacent coastal dunes.

The majority of infrastructure at risk over the short term is limited to dune fencing and beach access ways. The actual value of this infrastructure is relatively minor and preventative measures to protect the vulnerable sections of dune fencing or beach access ways from severe storm erosion would be considerably more than the cost to repair or reinstate them.

For this reason it is not recommended that coastal protection works be undertaken to protect the beach access ways and dune fencing. Instead allowances for the reinstatement and repair of these items of infrastructure could be included in future cost estimates for coastal maintenance and protection works.

Another focus for immediate works could be on the verification of the ability of the Mullaloo SLSC retaining walls to protect the structure from storm damage. Should the associated retaining walls lack the required structural strength, foundations and scour protection then suitable protection should be retrofitted to the structure if possible. If this is not possible then additional protection may be required.

In addition to these works, the City may wish to undertake a coastal monitoring program to observe changes in the shoreline positions along the Hillarys to Ocean Reef coastline. A coastal monitoring program at approximately 5 year intervals would provide the City with greater information on shoreline movement and longshore sediment transport volumes and would assist with future planning decisions and updated vulnerability assessments.

10.5 Program & Potential Costs for Coastal Management Options

The cost of the works undertaken in the immediate futures depends upon the coastal management option determined by the City's short term needs.

A suggested program of works for the Hillarys to Ocean Reef coastline is shown in Table 10.1. Priority has been given to works that seek to reduce the risk of coastal vulnerability, are readily fixed and relatively inexpensive.

Table 10.1 Program of Works & Cost Estimate

Works	Priority	Comment	Estimated Cost [1]	
			Construction	Design/ Consultants
Investigate protection of Mullaloo SLSC	Immediate	Investigates the adequacy of existing protection to severe storm erosion and makes recommendations	None	up to $10,000
Active management of beach access ways	1 to 3 years	Reworking of beach access ways to achieve lower land levels on eroding coast	$10,000 to $40,000 per access way [2]	None, if City manages works
Allowance for reinstatement and repair of dune fencing and beach access ways	As required	Repairs to infrastructure vulnerable to severe storm erosion	In the order of $2,000 to $5,000 an access way per event	None
Coastal monitoring program	~ 5 year intervals	Establish a coastal monitoring program	None	$30,000

Note:
1. The estimated costs above do not include GST.
2. Costs dependent on requirements of access ways (sand, asphalt or concrete).

The City should consider the potential cost of reinstatement and repairs of dune fencing and beach access paths along the shoreline following a severe storm event. A full replacement of the vulnerable dune fencing and beach access ways is estimated to cost approximately $200,000 excluding GST.

11. Future Developments

11.1 Ocean Reef Development

The City of Joondalup, together with other government agencies, is investigating the expansion of the Ocean Reef Boat Harbour to a comprehensive and integrated development including a marina for recreational and small commercial vessels (MRA 2009). The proposed development is called the Ocean Reef Boat Harbour and is shown in Figure 11.1. The southern extent of the existing marina has been indicated on the figure.

Figure 11.1 – Ocean Reef Redevelopment Concept Plan

The Ocean Reef Boat Harbour seeks to expand the development of the coastline and provide a coastal node for the local community. Development close to the shoreline is made possible through the protection provided by the marinas breakwaters and seawalls.

This development will be a key node along the coastline and may provide incentives to develop the area south of Ocean Reef Boat Harbour that is fronted by limestone cliffs. However, as indicated in Figure 11.1 the undeveloped areas have been marked as proposed Bush Forever sites. This may indicate a lack of available land south of the marina for redevelopment.

11.2 Other Development Areas

The City asked that MRA comment on areas within the study area for future development based on potential vulnerability.

Proposed future development should take into account the vulnerability extents estimated in this report as well as potential changes to planning requirements such as the SCPP, which is currently undergoing revision.

One of the proposed changes to the SCPP is to require full width foreshore reserves at the end of the planning horizon should the physical processes impacts be realised over the planning timeframe.. The future foreshore reserve is required to be wide enough to allow for current day values, functions and uses to occur at the end of the planning timeframe. This would further restrict the potential development areas available.

Future development should be located in those areas that are least vulnerable, such as the areas south of Ocean Reef Boat Harbour which are protected by the presence of competent limestone.

Some areas of the shoreline seaward of Whitfords Avenue and Northshore Drive have been shown to be at a low risk of vulnerability over the 100 year planning horizon. However, development in these areas is not recommended due to the uncertainties involved in climate change and its effect on coastal processes.

Additionally, in order to allow for planned retreat, allowances should be made to keep those areas that are seaward of Whitfords Avenue and Northshore Drive undeveloped. This will allow existing infrastructure such as car parks, parks and pathways to be incrementally moved eastward as they are redeveloped.

If development is proposed within the estimated vulnerable areas, then the possibility of leasehold developments should be investigated.

12. Conclusions & Recommendations

The City of Joondalup commissioned MRA to complete an assessment of the coastal vulnerability of the Hillarys to Ocean Reef coastline. This vulnerability assessment involved:

- A site inspection of the study area noting the condition of the beaches and presence of limestone rock;
- A review of the historical shoreline movement along the coastline, including the creation of a sediment budget and conceptual sediment model;
- Determining the vulnerability of infrastructure along the coastline to severe storm erosion, sea level rise and shoreline movement;
- Investigating coastal management options to mitigate shoreline recession and reduce the risk of damage to existing infrastructure; and
- Budget cost estimates for conceptual management options and provide a priority plan for these works.

An inspection of the study area noted that the beach profiles range in width, steepness and dune heights along the shoreline length.

The study area was broken into a number of cells to facilitate the assessment. Of the 5 cells, the Hillarys, Whitfords, Kallaroo and Mullaloo were considered to be sandy shoreline cells, while the Ocean Reef cell consisted entirely of rocky cliffs with bayed beaches. No limestone rock was observed in the beach or dunes south of the Ocean Reef cell.

Analysis of historical shoreline movement was focused on the 1987/1996 to 2010 period due to the construction of Hillarys Boat Harbour and Ocean Reef Boat Harbour in the 1970's to 1980's. This analysis showed that there has been net erosion along the southern cells and net accretion along the northern cells. This recession of the southern cells is believed to be the result of an interruption in the longshore transport due to the construction of Hillarys Boat Harbour.

A sediment budget and conceptual sediment model were developed from the shoreline movement analysis. The sediment budget estimates that there is a net transport of sediment northwards in the order of around 11,000 m^3/yr for the 1987 to 2010 period. Inter-annual variations in the occurrence of key wave events was estimated to have a large impact on the conceptual sediment budget for the study area.

The coastal vulnerability to storm erosion, trends in shoreline movement and sea level rise for each of the shoreline sectors was assessed over short term and the longer 50 and 100 year time frames. The vulnerability was assessed in line with the principles of the SCPP, but using a more realistic method of including historic shoreline movement trends and per Bruun assessment of sea level rise.

The vulnerability assessment showed that:

- The immediate vulnerability risk for the Hillarys to Ocean Reef coastline is erosion caused by severe storm events;
- Beach access ways and dune fencing comprise the majority of the vulnerable infrastructure over the short term. However, the Mullaloo SLSC may be vulnerable to scouring during the severe storm event;
- Significant sections of public infrastructure is estimated to be at risk over the 2060 and 2110 time frames. This includes sections of Whitfords Avenue, Northshore Drive, residential infrastructure, parks, car parks and the Mullaloo SLSC; and
- Sections of the shoreline may require active coastal management in the coming 100 years in response to SLR, shoreline recession and severe storm erosion risks.

Subsequently, several options have been proposed to manage the potential vulnerability risk over both the short term and the longer term. The proposed coastal management options to address the vulnerability of the coastline include:

- Active management of beach access ways located on the eroding shoreline at Pinnaroo Point. This involves lowering the beach access point to reduce the effects of erosion and scour;
- Allowances for reinstatement and repairs to the dune fencing and beach access ways located along the shoreline;
- Investigate the adequacy of protection provided to the Mullaloo SLSC by the associated retaining walls and install additional protection if required;
- Utilising existing beach profiles a monitoring program could be conducted at 5 year intervals to monitor shoreline movement and provide greater information for future planning; and

- Where possible, a policy of planned retreat for all non essential public infrastructure located in close proximity to the shoreline. This includes car parks, parks and DUP networks.

A recommended program and cost estimate for works to be undertaken in the short term was provided. The main priority of the works program was the protection of the Mullaloo SLSC and to allow for the reinstatement and repair of the numerous beach access ways and dune fencing along the shoreline

The works program did not recommend the wholesale protection for the beach access ways or dune fencing due to the high cost of protecting this infrastructure. Instead the City should allow for the probability of required repairs and reinstatement to the vulnerable infrastructure in future budgets. The estimated cost of works to repair the dune fencing and beach access ways was estimated at $200,000 excl GST.

Over the longer term it was proposed that due to the existing buffer to critical infrastructure the City could observe the effects of sea level rise and shoreline movement on the Hillarys to Ocean Reef coastline in the coming years before committing to hard protection works.

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14. Appendices

Appendix A	**Particle Size Distribution Results**
Appendix B	**Severe Storm Erosion Vulnerability Plan**
Appendix C	**Historical Shoreline Movement Plan**
Appendix D	**2060 & 2110 Coastal Vulnerability Plan**

Appendix A Particle Size Distribution Analysis

Hillarys to Ocean Reef – Sediment Samples		
Sample	Location	D_{50}
1	North of Hillarys Boat Harbour 380,229 mE 6,479,274 mN	0.29 mm
2	North of Pinnarroo Point 379,773 mE 6,480,797 mN	0.28 mm
3	South of Mullaloo SLSC 380,077mE 6,482,294 mN	0.28 mm
4	North of Mullaloo SLSC 379,902 mE 6,483,919 mN	0.21 mm

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Material Test Certificate

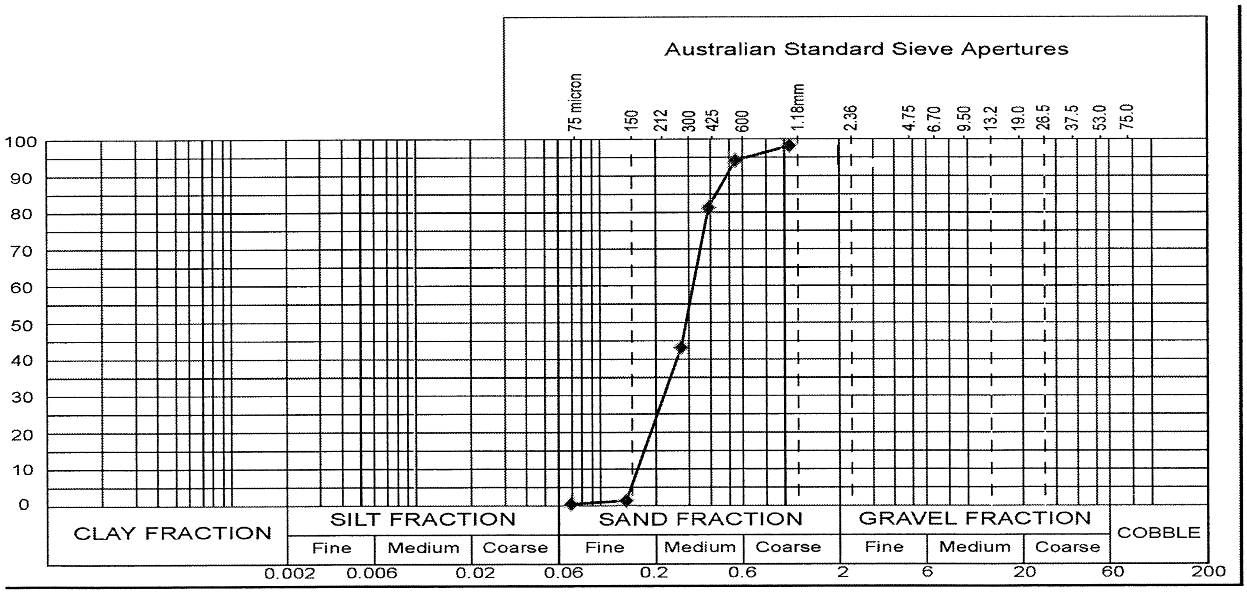
Report No:	15769	**Client:**	m p rogers & associates pl
Job No:	S563515	**Project:**	Hillary to Ocean Reef Coastal Vulnerability

Laboratory Number:	15769
Sample ID:	J961 S1 South/Cnr Cornfield Place & Whitfords Ave
Date Tested:	24-Jan-2012
Material Description:	SAND

Particle Size Distribution & Atterberg Limits of a Soil

Partcle Size Distribution (AS1289 3.6.1)				**Atterberg Limits** (AS1289 3.1.2, 3.2.1, 3.3.1, 3.4.1)	
Sieve Size	% Passing	Sieve Size	% Passing	Liquid Limit (%)	Not obtainable
				Plastic Limit (%)	Non plastic
75.0mm	100	1.18 mm	100	Plasticity Index (%)	-
37.5 mm	100	0.6mm	96	Linear Shrinkage (%)	-
19.0 mm	100	0.425mm	83	Nature Of Shrinkage	-
9.50 mm	100	0.300mm	44	Sample History	Oven Dried
4.75 mm	100	0.150mm	1	Preparation Method	AS1289.1
2.36mm	100	0.075mm	0	**Moisture Content** (AS1289 2.1.1)	
				Moisture Content (%)	

Particle Size Distribution Graph



Remarks: Sampling Method/s - Submitted by client

Authorised Signature:

Colin Gatgens

Date: 25-Jan-2012

1 Erindale Road, Balcatta, Western Australia 6021 PO Box 792, Balcatta, Western Australia 6914
Telephone (+618) 9205 4500 Facsimile (+618) 9205 4501 Email info@structerre.com.au
ABN 71 349 772 837 Zemla Pty Ltd ACN 008 966 283 as trustee for the Young Purich and Higham Unit Trust trading as Structerre

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Material Test Certificate

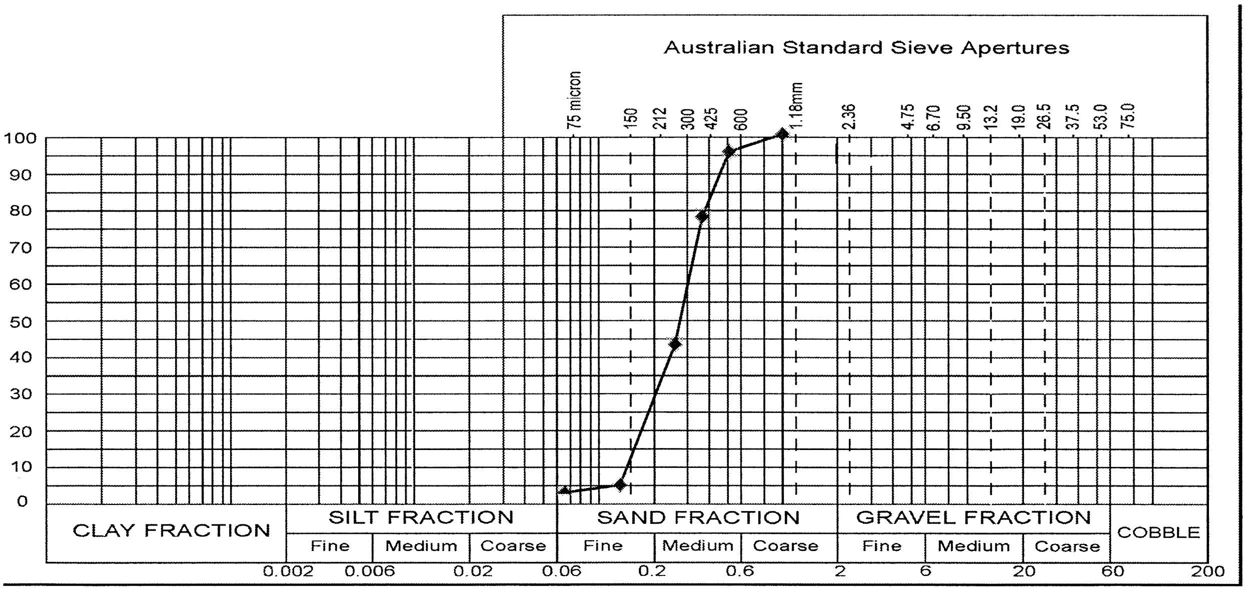
Report No:	15770	**Client:**	m p rogers & associates pl
Job No:	S563585	**Project:**	Hillary to Ocean Reef Coastal Vulnerability

Laboratory Number: 15770
Sample ID: J961 S2 Pinnaroo/Cnr NTh Shore Dr & Whitfords
Date Tested: 24-Jan-2012
Material Description: SAND

Particle Size Distribution & Atterberg Limits of a Soil

Partcle Size Distribution (AS1289 3.6.1)				**Atterberg Limits** (AS1289 3.1.2, 3.2.1, 3.3.1, 3.4.1)	
Sieve Size	**% Passing**	**Sieve Size**	**% Passing**	Liquid Limit (%)	Not obtainable
				Plastic Limit (%)	Non plastic
75.0mm	100	1.18 mm	100	Plasticity Index (%)	-
37.5 mm	100	0.6mm	95	Linear Shrinkage (%)	-
19.0 mm	100	0.425mm	77	Nature Of Shrinkage	-
9.50 mm	100	0.300mm	41	Sample History	Oven Dried
4.75 mm	100	0.150mm	3	Preparation Method	AS1289.1
2.36mm	100	0.075mm	0	**Moisture Content** (AS1289 2.1.1)	
				Moisture Content (%)	

Particle Size Distribution Graph



Remarks: Sampling Method/s - Submitted by client

Authorised Signature:
Colin Gatgens
Date: 25-Jan-2012

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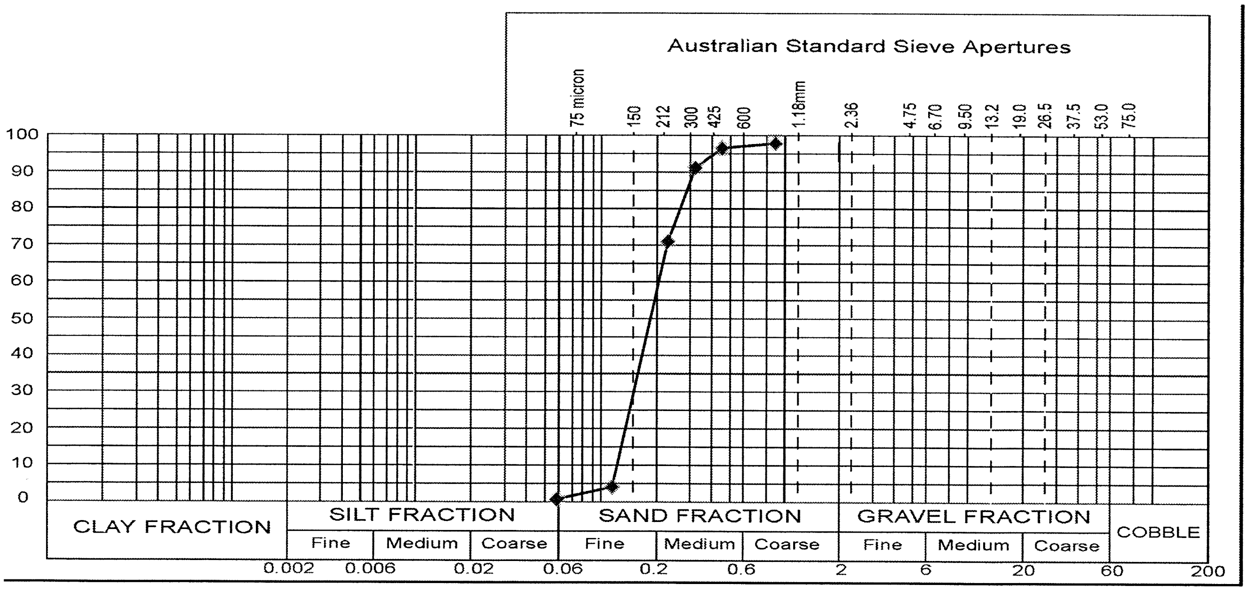
Report No:	15771	Client:	m p rogers & associates pl
Job No:	S563595	Project:	Hillary to Ocean Reef Coastal Vulnerability

Laboratory Number: 15771
Sample ID: J961 S3 Kallaroo/Cnr Mullaloo Dr & Oceanside
Date Tested: 24-Jan-2012
Material Description: SAND trace silt

Particle Size Distribution & Atterberg Limits of a Soil

Partcle Size Distribution (AS1289 3.6.1)				**Atterberg Limits** (AS1289 3.1.2, 3.2.1, 3.3.1, 3.4.1)	
Sieve Size	% Passing	Sieve Size	% Passing	Liquid Limit (%)	Not obtainable
				Plastic Limit (%)	Non plastic
75.0mm	100	1.18 mm	100	Plasticity Index (%)	-
37.5 mm	100	0.6mm	98	Linear Shrinkage (%)	-
19.0 mm	100	0.425mm	93	Nature Of Shrinkage	-
9.50 mm	100	0.300mm	72	Sample History	Oven Dried
4.75 mm	100	0.150mm	4	Preparation Method	AS1289.1
2.36mm	100	0.075mm	1	**Moisture Content** (AS1289 2.1.1)	
				Moisture Content (%)	

Particle Size Distribution Graph



Remarks: Sampling Method/s - Submitted by client

Authorised Signature:

Colin Gatgens
Date: 25-Jan-2012

1 Erindale Road, Balcatta, Western Australia 6021 PO Box 792, Balcatta, Western Australia 6914
Telephone (+618) 9205 4500 Facsimile (+618) 9205 4501 Email info@structerre.com.au
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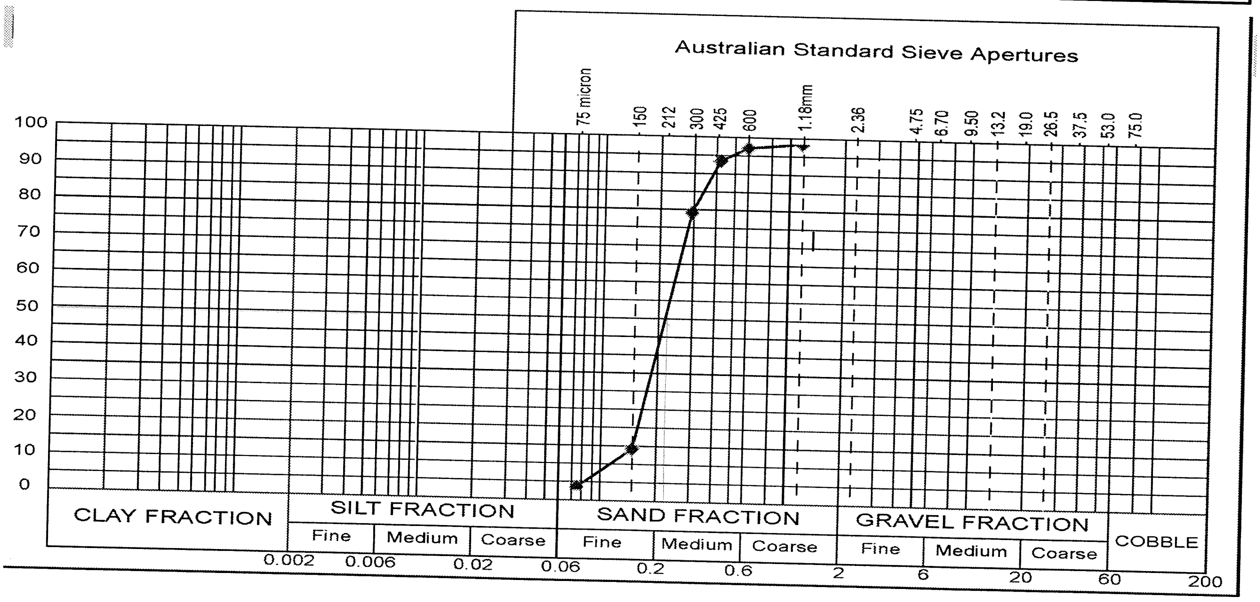
Material Test Certificate

Report No:	15772	**Client:**	m p rogers & associates pl
Job No:	S563597	**Project:**	J961 Hillary to Ocean Reef Coastal Vulnerability

Laboratory Number: 15772
Sample ID: S4 Mullaloo/Cnr Oceanside Pr & Westview
Date Tested: 24-Jan-2012
Material Description: SAND trace silt

Particle Size Distribution & Atterberg Limits of a Soil

Partcle Size Distribution (AS1289 3.6.1)				**Atterberg Limits** (AS1289 3.1.2, 3.2.1, 3.3.1, 3.4.1)	
Sieve Size	% Passing	Sieve Size	% Passing	Liquid Limit (%)	Not obtainable
				Plastic Limit (%)	Non plastic
75.0mm	100	1.18 mm	100	Plasticity Index (%)	-
37.5 mm	100	0.6mm	98	Linear Shrinkage (%)	-
19.0 mm	100	0.425mm	95	Nature Of Shrinkage	-
9.50 mm	100	0.300mm	80	Sample History	Oven Dried
4.75 mm	100	0.150mm	12	Preparation Method	AS1289.1
2.36mm	100	0.075mm	1	**Moisture Content** (AS1289 2.1.1)	
				Moisture Content (%)	



$d_{50} = 0.21$ mm

Remarks: Sampling Method/s - Submitted by client

Authorised Signature:

Colin Gatgens

Date: 25-Jan-2012

Appendix B Severe Storm Erosion Vulnerability Plan

AT CORRECT SCALE THIS IS 100 mm

CAD: D9610102B

AT CORRECT SCALE THIS IS 100 mm

REV	DATE	APPROVED	AMENDMENT	REV	DATE	APPROVED	AMENDMENT
B	17.7.12	TSH	RE-ISSUED FOR REPORT				
A	9.2.12	TSH	ISSUED FOR REPORT				

This plan is not to be used for construction unless issued as Rev 0 and signed below

CLIENT: CITY OF JOONDALUP

DESIGNED	CHECKED	APPROVED
D. HAMILTON	T. HUNT	
DRAWN	CHECKED	
D. HAMILTON	T. HUNT	

m p rogers & associates pl
coastal and port engineers

Unit 2, 133 Main Street
Osborne Park 6017
Western Australia

t: +61 8 9444 4045
f: +61 8 9444 4341
admin@coastsandports.com.au

PROJECT: HILLARYS TO OCEAN REEF COASTAL VULNERABILITY

TITLE: SEVERE STORM EROSION VULNERABILITY PLAN

SCALE AT A1	DRAWING NUMBER	REV
1:5,000	D961-01-02	B

Appendix C Historical Shoreline Movement Plan

AT CORRECT SCALE THIS IS 100 mm

AT CORRECT SCALE THIS IS 100 mm

CAD: D9610101B

REV	DATE	APPROVED	AMENDMENT	REV	DATE	APPROVED	AMENDMENT
B	25.5.12	TSH	AMENDED AND RE-ISSUED				
A	9.2.12	TSH	ISSUED FOR REPORT				

This plan is not to be used for construction unless issued as Rev 0 and signed below

CLIENT: CITY OF JOONDALUP

DESIGNED: D. HAMILTON — CHECKED: T. HUNT — APPROVED:

DRAWN: T. VAN BEEM — CHECKED: D. HAMILTON

m p rogers & associates pl
coastal and port engineers

Unit 2, 133 Main Street
Osborne Park 6017
Western Australia

t: +61 8 9444 4045
f: +61 8 9444 4341
admin@coastsandports.com.au

PROJECT: HILLARYS TO OCEAN REEF COASTAL VULNERABILITY

TITLE: SHORELINE MOVEMENT 1942 – 2010

SCALE AT A1: 1:5,000 — DRAWING NUMBER: D961-01-01 — REV: B

Appendix D 2060 & 2110 Coastal Vulnerability Plan

AT CORRECT SCALE THIS IS 100 mm

AT CORRECT SCALE THIS IS 100 mm

CAD: D9610103B

REV	DATE	APPROVED	AMENDMENT	REV	DATE	APPROVED	AMENDMENT
B	17.7.12	TSH	AMENDED TO INCLUDE INUNDATION AND RE-ISSUED				
A	9.2.12	TSH	ISSUED FOR REPORT				

This plan is not to be used for construction unless issued as Rev 0 and signed below

CLIENT: CITY OF JOONDALUP

DESIGNED: D. HAMILTON | CHECKED: T. HUNT | APPROVED:

DRAWN: D. HAMILTON | CHECKED: T. HUNT

m p rogers & associates pl
coastal and port engineers
Unit 2, 133 Main Street
Osborne Park 6017
Western Australia
t: +61 8 9444 4045
f: +61 8 9444 4341
admin@coastsandports.com.au

PROJECT: HILLARYS TO OCEAN REEF COASTAL VULNERABILITY

TITLE: VULNERABILITY PLAN
50 & 100 YEARS FROM 2010

SCALE AT A1: 1:5,000 | DRAWING NUMBER: D961-01-03 | REV: B