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R608 Rev 1

April 2016

City of Joondalup

Ocean Reef Marina
Coastal Hazard and Risk Management Adaptation Plan

marinas
boat harbours
canals
breakwaters
jetties
seawalls
dredging
reclamation
climate change
waves
currents
tides
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water quality
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Executive Summary

The City of Joondalup (the City) proposes to redevelop the existing Ocean Reef Boat Harbour into a world class marina featuring recreational, boating, residential and tourist precincts. Significant consultation and planning has been completed on the Marina concepts to date.

Specialist coastal and port engineers M P Rogers & Associates Pty LTD (MRA) were commissioned to prepare a Coastal Hazard and Risk Management Adaptation Plan (CHRMAP) for the proposed Ocean Reef Marina.

To date, only conceptual design of the Ocean Reef Marina breakwaters, seawalls and internal edge treatments has been completed. This design work was completed by MRA in 2010 and 2011 to assist with the development of a business case for the Ocean Reef Marina Concept 7.2A. A concept design report was prepared to summarise these conceptual investigations and to provide further information to the CHRMAP process. The concept design report is contained in Appendix A.

Preparation of this CHRMAP is consistent with the requirements of *State Planning Policy 2.6: State Coastal Planning Policy* (SPP2.6) and the CHRMAP guidelines. These documents require that a CHRMAP be prepared by the responsible management authority to cover areas where existing or proposed development could be at risk from coastal hazards over the planning timeframe.

The proposed Ocean Reef Marina is considered a variation to the standard assessment of the SPP2.6. Section 7.4 of the SPP2.6 notes the following.

Industrial and commercial development that is demonstrably dependent on a foreshore location. Such development may include, for example, marinas for tourism and recreational boating facilities, cage based aquaculture operations, and port facilities.

The SPP2.6 does not provide specific guidance on the calculation of coastal erosion or inundation hazards for marinas and instead notes that assessment shall be completed on a case by case basis. External breakwater and seawall structures will be constructed at Ocean Reef Marina to provide wave shelter to the internal Marina waterbody for vessel mooring and other uses. Engineered revetment structures will also be constructed along the internal shoreline of the Marina. These structures provide coastal protection to the key internal assets and will be designed in accordance with contemporary design methods.

It is recommended that the breakwaters and internal edge walls be monitored and maintained on a regular basis to ensure they continue to provide an appropriate level of protection. This approach is in line with the recommendations of the SPP2.6 for coastal works and is an integral component of the CHRMAP for the Marina. This monitoring and maintenance is to be managed by a designated Marina Waterways Manager or harbourmaster of the Ocean Reef Marina. This CHRMAP includes details of a comprehensive monitoring regime for the proposed Ocean Reef Marina.

The CHRMAP process has been completed for both coastal erosion and inundation hazards as per the requirements of the SPP2.6 and the CHRMAP Guidelines (WAPC 2014). This involved calculation of coastal hazard Likelihood and Consequence over a 100 year planning timeframe for a number of key internal and external assets.

Twelve key internal and external assets were identified at the proposed Ocean Reef Marina. Of the twelve key assets, only three were assessed as having intolerable risk levels over the 100 year planning timeframe, as outlined below. Possible risk mitigation strategies that have been developed to reduce the risk are also presented below.

- Large waves are expected outside of the breakwaters during storm or swell events. If people are using the proposed external fishing platforms during these periods, the wave overtopping could lead to injury or loss of life. Therefore, the proposed external fishing platforms have a high to extreme level of risk from wave overtopping from the present day. The platforms should be moved to a safe, appropriate location inside the Marina breakwaters where they are offered protection from wave overtopping.

- Wave overtopping during severe storms in excess of the 5 year ARI event is likely to be dangerous to pedestrians on the breakwaters. The 5 year ARI event has been selected as a cutoff for pedestrian safety as per discussions with DoT on previous breakwater structures. This event is approximately the limit in terms of wind strength for pedestrian safety, therefore it is deemed that it will be difficult for pedestrians to stand in an exposed location. The wave overtopping risk for pedestrian access on the breakwaters during severe storms would just be tolerable now but given the longer exposure period will be intolerable at the end of the 25 year exposure period. Management of pedestrian and vehicular access should be implemented during storm events. This could be through signage and a gate that is closed during periods of storm events. This is similar to how the risk is managed by Fremantle Ports at North and South Moles.

- At the end of the 100 year planning timeframe, wave overtopping during the 100 year ARI event is likely to be dangerous to pedestrians on the promenade. The promenade level and crown wall could be raised after approximately 75 years to reduce the overtopping risk.

The remainder of the assets were found to have acceptable or tolerable levels of risk over the 100 year planning timeframe. Therefore, risk adaptation and mitigation measures are not required for these assets.

A recommended coastal monitoring and management programme was also developed for the Ocean Reef Marina. Mean sea levels should be recorded and analysed in the future so that observed sea levels can be compared to the projections used in this CHRMAP. The CHRMAP for the Ocean Reef Marina should then be reviewed every decade or so to identify if the assessed risk levels are still appropriate. This will allow adaptation and mitigation strategies to be implemented as new information on climate change comes to light. The integrity of the breakwaters, seawalls and internal revetments also needs to be monitored, as these structures form an integral component of the risk mitigation strategy.

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1. Introduction

1.1 General

The City of Joondalup (the City) proposes to redevelop the existing Ocean Reef Boat Harbour into a world class marina featuring recreational, boating, residential and tourist precincts. Planning for the Ocean Reef Marina development has advanced significantly over the last few years, with a range of planning and engineering studies currently being completed. The proposed Marina layout that is being considered (TBB Concept Plan 7.2A dated 28 March 2013) is provided in Figure 1.1.

To date, only conceptual design of the Ocean Reef Marina breakwaters, seawalls and internal edge treatments has been completed. This design work was completed by MRA in 2010 and 2011 to assist with the development of a business case for the Ocean Reef Marina Concept 7.2A. A concept design report (MRA 2016) was prepared to summarise these conceptual investigations and to provide further information to the CHRMAP process. Concept cross-sections are also provided within the concept design report, which is attached in Appendix A.

Figure 1.1 shows that the majority of the development is protected by two breakwaters. The proposed northern breakwater is approximately 600 m long, while the southern breakwater is approximately 800 m long. These breakwaters are needed to provide wave shelter to the internal waterbody for boat pens and other uses. The shoreline inside the Marina would also be protected by engineered seawall and revetment structures. As a result, the land inside the breakwaters is protected from coastal erosion processes and coastal erosion hazards.

A small section of development is currently proposed to the north of the breakwaters. This development consists of a small, public car-park behind the existing beach to the north of the Ocean Reef Marina. This car-park is proposed to be constructed behind existing, natural rock that is likely to occur along this stretch of coast. The ‘new’ reclaimed beach and the café shown in Figure 1.1 to the north of the Marina are no longer being pursued by the City.

The City engaged specialist coastal and port engineers M P Rogers & Associates Pty Ltd (MRA) to develop a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the proposed Marina. The main components of this investigation are as follows.

- Assessment of coastal erosion to the requirements of State Planning Policy 2.6 (SPP2.6) and the CHRMAP guidelines.
- Assessment of coastal inundation to the requirements of SPP2.6 and the CHRMAP guidelines.
- Develop recommended coastal monitoring and management programmes for the proposed Marina.

This report presents the data, methodology and results of these investigations.

Figure 1.1 Ocean Reef Marina Concept Plan 7.2A (TBB dated 28 March 2014)

2. Site Setting

The existing Ocean Reef Boat Harbour is located on a Calcarenite dominated section of shore. This predominately rocky shoreline extends around 5 km in total length, starting around 1 km south of the Ocean Reef Boat Harbour and extending north to Burns Beach (Short 2006) (refer Figure 2.1). Small transient embayed beaches have formed along the rocky shoreline and are fronted by a mixture of shallow rock platforms, nearshore reefs and rocks. North of the rocky shoreline lies a continuous sandy beach that extends to the Mindarie Marina.

Figure 2.1 Location Plan

The current plan for the Ocean Reef Marina development extends the footprint of the existing Ocean Reef Boat Harbour to the north by approximately 900 m. This study is focussed on the development contained within the new Ocean Reef Marina breakwaters, the external fishing platforms and the shoreline to the north and south of the new Marina.

The proposed Ocean Reef Marina is located within Tertiary Sediment Cell 28b South of Ocean Reef Boat Harbour to Burns Beach Salient, as identified in Damara (2012) and presented in Figure 2.2.

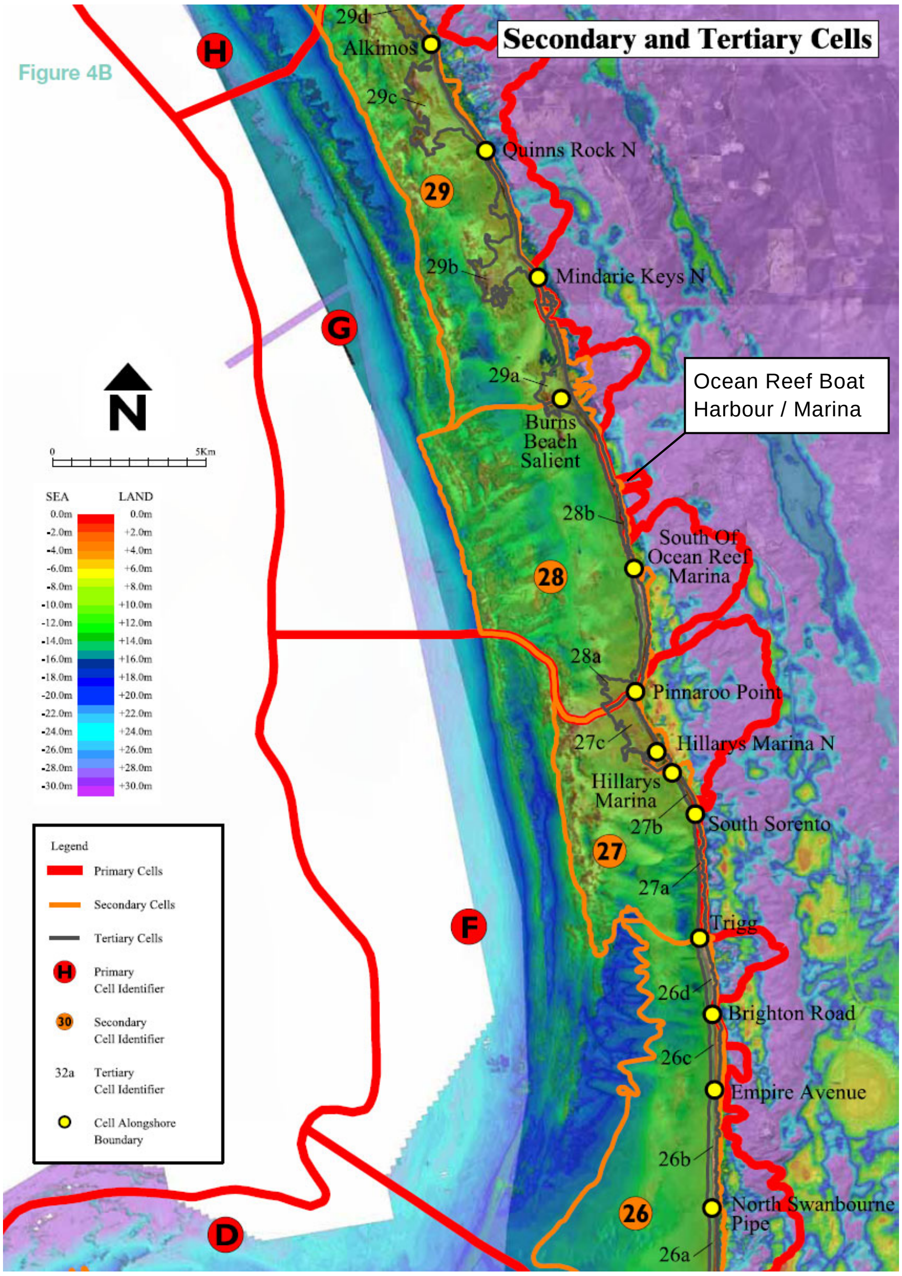


Figure 2.2 Tertiary Sediment Cell 28b (Damara 2012)

The coastal processes assessment completed by MRA (2015a) considers the coastal processes adjacent to the proposed Ocean Reef Marina within the context of this coastal geomorphology and geology, as recommended in the SPP2.6. The findings of MRA (2015a) and the implications to coastal management are detailed further in Section 5 and Section 8.

3. Context

3.1 Consultation

Throughout the development of the Concept Plan (Figure 1.1), extensive consultation has been undertaken with the community (including community surveys in 2002 and 2007), State Government and other key stakeholders. In addition, the Ocean Reef Marina Community Reference Group (established in 2008) and the Ocean Reef Marina Government Steering Committee (established in 2007), made substantial contributions to the development of the Concept Plan.

At the meeting held on 5 May 2009, Council endorsed the release of Concept Plan 7 for public comment. The City's communication plan included the dissemination of the Ocean Reef Marina Concept Plan Survey to approximately 60,000 properties within Joondalup. Concept Plan 7 and the survey were also advertised through the City's website, community newspapers and at local shopping centres. The overall response to Concept Plan 7 showed that 95.6% of people strongly support or supported the proposal to develop the Marina as presented. 95.5% of North Central Ward respondents supported the development, with 91% of respondents from Ocean Reef indicating their support for the Marina at the site in accordance with the Concept Plan as presented. The amenities receiving the highest levels of support are listed below.

- Food and Beverage Outlets 97.4%
- Public Boardwalk 96.5%
- Public Open Space 95.4%

The Marina berths and facilities, including boat pens, boat stackers, boat launching facilities and boat trailer parking also had very high levels of public support, with an average support of 84.4%. Additionally, the Perth Recreational Boating Facilities Study (DoT 2007) noted that many existing boating facilities are currently fully utilised on good boating days and as such additional facilities are required. The Ocean Reef Marina is one of the public initiatives identified by DoT (2007) to be pursued in order to meet the boating demand to 2025.

Since the release of Concept Plan 7 for community consultation, the City has received a significant amount of positive feedback from the community, particularly with regard to the amendments made to Concept Plan 7, now refined into Concept Plan 7.2A (refer to Figure 1.1). In 2013 the City conducted a series of forums to update the community about the Ocean Reef Marina project and explain its timeline for progression. Open to the public, the forums attracted approximately 600 attendees.

The development of the Concept Plan and the approach to the planning and approvals process for the Marina has been the focus of meetings in 2011, 2012 and 2013 with Department of Planning, Department of Transport, Water Corporation, Department of Lands (formerly Department of Regional Development and Lands), Public Transport Authority, Office of the Environmental Protection Authority, Department of Environment Regulation (formerly Department of Environment and Conservation), Department of Fisheries, Commonwealth Department of the Environment (formerly Department of Sustainability, Environment, Water, Population and Communities) and other significant stakeholders.

The City also maintains an extensive website on the project and regularly informs individual community members, the Community Reference Group and other community stakeholders on the project progress. A table summary of the main consultation completed to date is included in Appendix B. This consultation provides a sound basis for the development of the Concept Plan and the CHRMAP assessment.

3.2 Purpose

The proposed Ocean Reef Marina will be a world class marina featuring recreational, boating, residential and tourist precincts. Recognising the importance of this new, coastally dependent development, the City have commissioned MRA to develop a CHRMAP for the proposed Marina.

Preparation of this plan is consistent with the requirements of the SPP2.6, which requires that a CHRMAP be prepared by the responsible management authority to cover areas where existing or proposed development could be at risk from coastal hazards over the planning timeframe. The main purpose of a CHRMAP is to define areas of the coastline that are vulnerable to coastal hazards and to outline the preferred approach to the monitoring and management of these hazards where required.

A CHRMAP is a powerful planning tool and is used to identify and assess coastal risks for existing and future developers, users, managers or custodians of the coastline. This is done by defining levels of risk exposure, management practices and adaptation techniques that the management authority considers to be acceptable in response to the present and future risks posed by coastal hazards.

Specifically, the purpose of this CHRMAP is as follows.

- Confirm the specific extent of coastal hazards for the proposed Ocean Reef Marina and existing coastal areas beyond the Marina.
- Evaluate the risks associated with the proposed Ocean Reef Marina and how this risk may change over time.
- Establish the basis for present and future risk management, mitigation and adaptation.
- Provide guidance on appropriate management, mitigation and adaptation planning for the future, including monitoring.

3.3 Objectives

The key objective of this plan is to assess the risks associated with the development of the Ocean Reef Marina in its proposed location. Once these risks have been assessed, adaptation strategies can be developed to help mitigate the risks where necessary. Whilst the risks of coastal hazards are to be considered for different timeframes, the future behaviour is likely to be variable for a variety of reasons. As a result, the requirement to consider the implementation of future adaptation strategies should be informed by an ongoing monitoring regime and on-going review of this CHRMAP. A recommended monitoring regime is included in Section 8 of this report to address these variabilities over time.

3.4 Scope

In 2014, WAPC released a Guideline document that provides a specific framework for the preparation of a CHRMAP. Figure 3.1 presents a flowchart for the risk management and adaptation process, as outlined within the CHRMAP Guidelines.

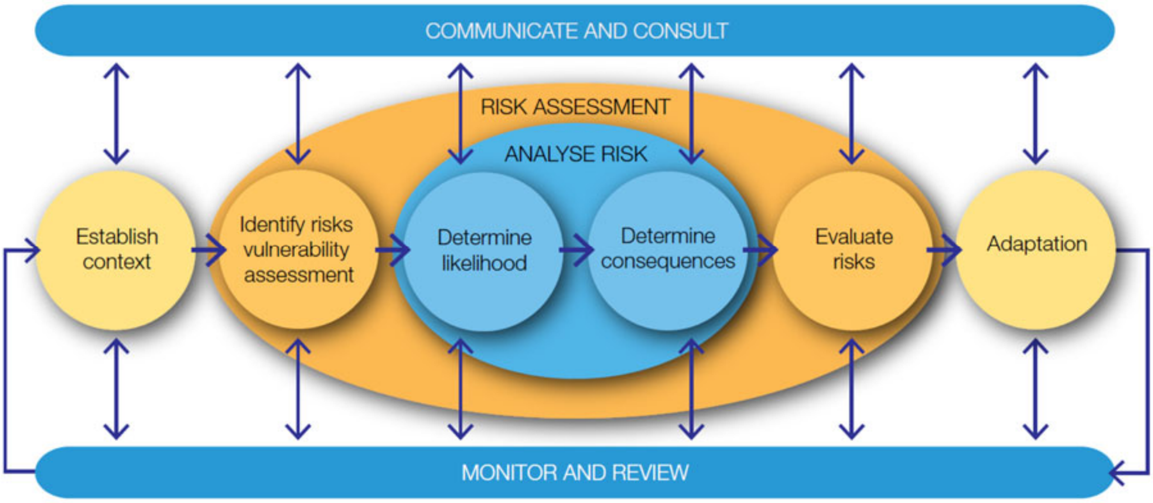


Figure 3.1 Risk Management & Adaptation Process Flowchart (source: WAPC CHRMAP Guidelines, 2014)

As presented in the flowchart, the process for the development of a meaningful CHRMAP requires a number of fundamental inputs. These inputs enable the assessment and analysis of risk, which should ultimately be informed by input received from key stakeholders and the community, to help shape the subsequent adaptation strategies.

This CHRMAP will consider the potential risks posed by coastal hazards over a range of planning timeframes listed below.

- Present day.
- 25 years.
- 50 years.
- 75 years.
- 100 years

In order to provide a framework for future management of the asset, where required, risk mitigation strategies will be developed.

The framework for future risk management strategies should be considered to be a guide of future requirements. The requirement for implementation of these management requirements should ultimately be informed by a coastal monitoring regime. The breakwaters, seawalls and internal revetments structures will be designed with appropriate sea level rise allowances, as outlined in Appendix A. Nevertheless, the integrity of these structures needs to be monitored, as these structures form an integral component of the risk mitigation strategy.

Changes in the extreme events due to sea level rise that could alter the risk exposure of the Marina to coastal hazards also needs to be monitored in the future. This could be achieved through review of the Marina CHRMAP every decade or so. A recommended coastal monitoring regime has been provided in Section 8.

3.5 Planning Context

3.5.1 Marinas

The SPP2.6 provides a number of variations to the standard case, where development may need to occur within an area identified to be potentially impacted by physical processes within the 100 year planning timeframe. Section 7.4 of the SPP2.6 identifies Industrial and Commercial development such as marinas as one such variation. That section notes the following.

Industrial and commercial development that is demonstrably dependent on a foreshore location. Such development may include, for example, marinas for tourism and recreational boating facilities, cage based aquaculture operations, and port facilities.

Therefore, the proposed Ocean Reef Marina is considered a variation to the standard assessment of the SPP2.6.

3.5.2 Coastal Protection Structures

The proposed external breakwater and seawall structures at Ocean Reef Marina are required to provide wave shelter to the internal Marina waterbody for vessel mooring and other uses. Engineered revetment and vertical wall structures will also be constructed along all of the internal shoreline of the Marina. These structures provide coastal protection to the key assets and will be designed in accordance with contemporary design methods to accommodate the 100 year ARI design event. Further details on the conceptual design of the breakwater and internal edge wall structures are contained in Appendix A.

The use of the 100 year ARI event for the design of rubble structures is in line with the Department of Transport (DoT) recommendations for the design of breakwater structures in Western Australia and is consistent with other recent marina developments in the state such as Albany Waterfront.

Rubble mound structures such as those proposed at the Marina are considered to be robust structures. This means that they can typically withstand (with some damage but not full failure) storm events greater than the design storm.

It is recommended that the breakwaters and internal revetments be monitored and maintained on a regular basis to ensure that they continue to provide an appropriate level of protection. A detailed monitoring and maintenance regime is presented in Section 8 of this report. This approach is in line with the recommendations of the SPP2.6 for coastal works and is an integral component of the CHRMAP prepared for the Marina. This monitoring and maintenance plan is to be managed by a designated Marina Waterways Manager, which is also detailed in Section 8 of this report. A combination of design robustness and maintenance has allowed old rubble mound structures such as North Head in Fremantle to continue to function today.

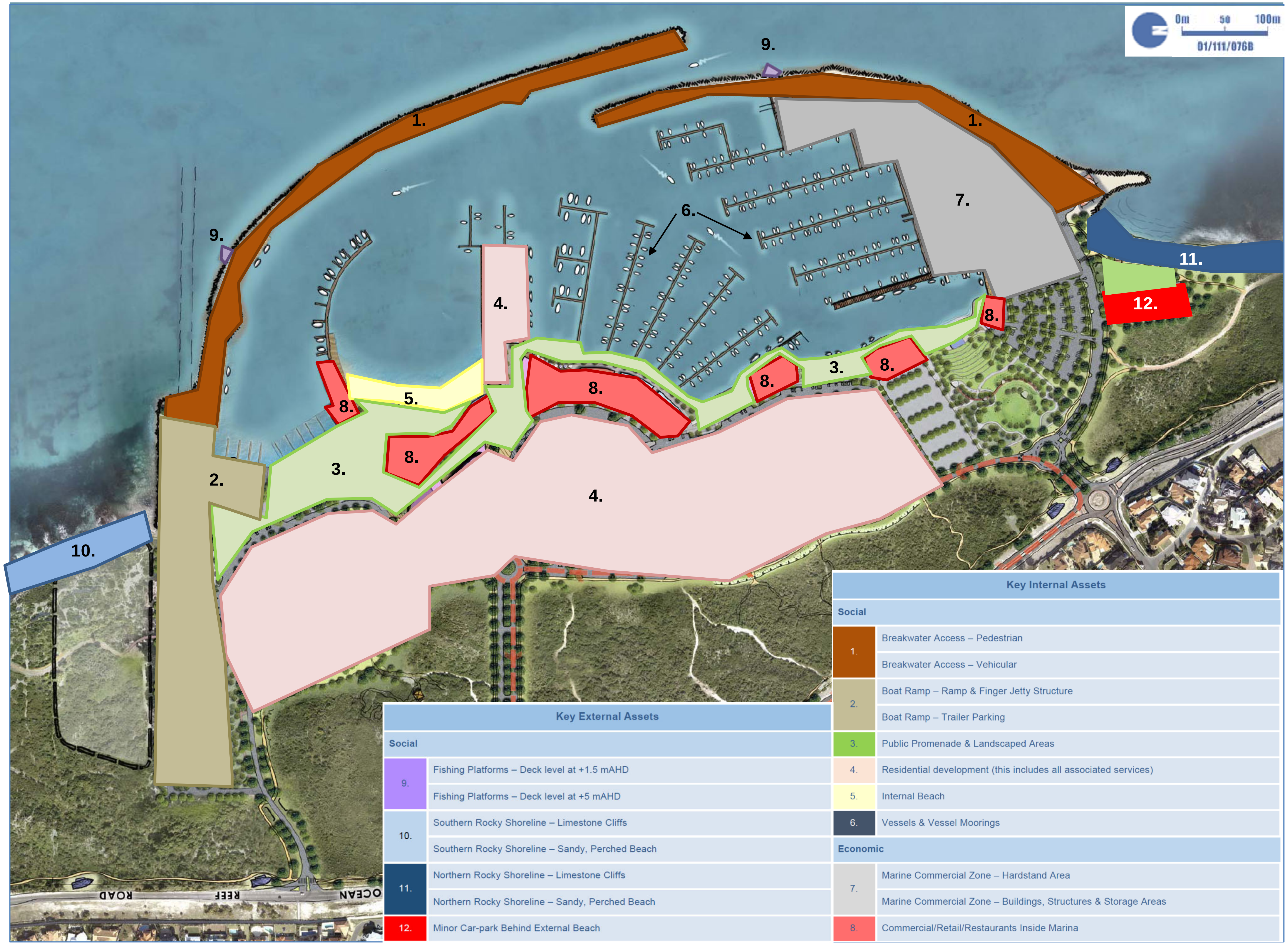
The potential to retrofit the coastal protection structures to accommodate increased sea levels beyond the 100 year planning horizon will also be incorporated into the design. For example additional rocks could be added to the crest of the external breakwaters or a wave deflector wall added to the top of the promenade revetment. This increases the Adaptive Capacity of the coastal protection structures.

3.6 Key Assets

The key Ocean Reef Marina assets have been summarised in Figure 3.2. The key assets have been separated into two types; internal assets protected by the breakwaters and external assets outside of the Marina. The Ocean Reef Marina CHRMAP will be completed for both public and private assets, as shown in Figure 3.2.

The risk assessment will focus on these assets in order to identify their vulnerability and consequently the requirement for risk management. For some of the assessment it was considered necessary to separate some assets into sub-groups for comparison of options or for functional use. For example, the Marine Commercial Zone (Asset 7) has been separated into Hardstand areas and Buildings and Structures.

Two external fishing platform deck levels have also been investigated; one with a +1.5 mAHD deck level and one with a +5 mAHD deck level. This aims to investigate the coastal risk associated with each deck level.



Key External Assets

Social	
9.	Fishing Platforms – Deck level at +1.5 mAHD
	Fishing Platforms – Deck level at +5 mAHD
10.	Southern Rocky Shoreline – Limestone Cliffs
	Southern Rocky Shoreline – Sandy, Perched Beach
11.	Northern Rocky Shoreline – Limestone Cliffs
	Northern Rocky Shoreline – Sandy, Perched Beach
12.	Minor Car-park Behind External Beach

Key Internal Assets

Social	
1.	Breakwater Access – Pedestrian
	Breakwater Access – Vehicular
2.	Boat Ramp – Ramp & Finger Jetty Structure
	Boat Ramp – Trailer Parking
3.	Public Promenade & Landscaped Areas
4.	Residential development (this includes all associated services)
5.	Internal Beach
6.	Vessels & Vessel Moorings
Economic	
7.	Marine Commercial Zone – Hardstand Area
	Marine Commercial Zone – Buildings, Structures & Storage Areas
8.	Commercial/Retail/Restaurants Inside Marina

Figure 3.2 Ocean Reef Marina Key Assets

3.7 Success Criteria

The success criteria for the CHRMAP will ultimately be as follows.

- Understand the potential coastal hazard risks associated with the construction of the Ocean Reef Marina.
- Development of acceptable risk management and adaptation strategies for the Marina.
- Development of a coastal monitoring strategy to help understand the changes in risk levels over time.

4. General Methodology

The CHRMAP process involves the following main steps.

- Hazard Identification.
- Risk Analysis.
- Risk Adaptation and Mitigation Strategies.

These steps are summarised in the following sections, providing the general methodology used in this CHRMAP. Specific assessment of the coastal hazard risks to the key assets is provided in Sections 5 to 7.

4.1 Hazard Identification

The CHRMAP is specifically designed to address potential adverse impacts from erosion and inundation hazards. These hazards are typically determined using the methodology presented in SPP2.6 Schedule 1.

For coastal erosion hazards, the standard SPP2.6 Schedule 1 methodology calculates the potential erosion on a range of shoreline classifications, including sandy, rocky and mixed shorelines. Rocky shorelines are present to the north and south of the Marina, as previously presented in Figure 2.1. The internal beach within the Marina is a sandy shoreline backed by a vertical edge wall. Further details of the erosion hazard identification are contained in Section 5.1.

For much of the proposed Ocean Reef Marina, however, this standard methodology is not directly applicable as the majority of the key assets are to be protected from erosion by the external breakwaters and seawalls or internal revetments.

Irrespective of coastal type and the presence of any coastal protection structures, the SPP2.6 requires assessment of the potential exposure of areas to coastal inundation. This is named the S4 Inundation allowance within the SPP2.6. Details of the inundation hazard identification are contained in Section 6.1.

The SPP2.6 also requires assessment of setbacks to accommodate wave overtopping, which is to be considered as part of the inundation assessment. For the purposes of this study, the wave overtopping hazards have been reviewed independently from the steady water level inundation assessment, as detailed in Section 7.1 of this report.

4.2 Risk Analysis

In accordance with WAPC (2014) a risk based approach has been used to assess the hazards and required mitigation and adaptation options for the Ocean Reef Marina. Coastal hazard risks are analysed through assessment of Likelihood and Consequence, as outlined in the following sections.

4.2.1 Likelihood

WAPC (2014) defines the Likelihood as the chance of erosion or storm tide inundation occurring, or how often they impact on existing and future assets and values over the planning horizon. This requires consideration of the frequency and probability of the event occurring over a given horizon. The probability of an event occurring is often termed the Annual Encounter Probability (AEP) or the Average Recurrence Interval (ARI).

As recommended in WAPC (2014), a scale of Likelihood has been developed. This scale follows the Australian Standard Risk Management Principles and Guidelines (AS/NZS ISO 31000:2009) and is presented in Table 4.1.

Table 4.1 Scale of Likelihood (AS/NZS ISO 31000:2009)

Rating	Description / Frequency
Almost certain	There is a high possibility the event will occur as there is a history of frequent occurrence. 90-100% probability of occurring over the timeframe.
Likely	It is likely the event will occur as there is a history of causal occurrence. 60-90% probability of occurring over the timeframe.
Possible	The event may occur. 40-60% probability of occurring over the timeframe.
Unlikely	There is a low possibility that the event will occur. 10-40% probability of occurring over the timeframe.
Rare	It is highly unlikely that the event will occur, except in extreme / exceptional circumstances. 0-10% probability of occurring over the timeframe.

The Likelihood rating will be completed separately for coastal erosion and coastal inundation, as they are different coastal hazards with different probabilities of occurrence.

4.2.2 Consequence

The second part of the risk assessment is determining the Consequence of the coastal hazards on the proposed Ocean Reef Marina development components. As recommended in WAPC (2014), a scale of Consequence has been developed which provides a range of impacts. This is presented in Table 4.2 and is based on the framework set out in Australian Greenhouse Office (AGO 2006).

Table 4.2 Scale of Consequence (AGO 2006) for Public & Private Assets

Rating	Social	Economic	Environment
Catastrophic	Loss of life and serious injury. Large long term or permanent loss of services, employment wellbeing, finances or culture (75% of community affected), international loss, no suitable alternative sites exist	Damage to property, infrastructure or local economy > $20M	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage
Major	Serious injury. Medium term disruption to services, employment wellbeing, finances or culture (<50% of community affected), national loss, limited alternative sites exist	Damage to property, infrastructure or local economy > $5M to $20M	Severe loss of environmental amenity and a danger of continuing environmental damage
Moderate	Minor injury. Major short or minor long term disruption to services, employment wellbeing, finances or culture (<25% of community affected), regional loss, many alternative sites exist	Damage to property, infrastructure or local economy > $500,000 to $5M	Isolated but significant instances of environmental damage that might be reversed with intensive efforts. Recovery may take several years.
Minor	Small to medium disruption to services, employment wellbeing, finances or culture (<10% of community affected), local loss, many alternative sites exist	Damage to property, infrastructure or local economy > $50,000 to $500,000	Minor instances of environmental damage that could be reversed. Consistent with seasonal variability, recovery may take one year.
Insignificant	Minimal short-term inconveniences to services, employment, wellbeing, finances or culture (<5% of community affected), neighbourhood loss, many alternative sites exist	Damage to property, infrastructure or local economy < $50,000	Minimal environmental damage, recovery may take less than 6 months.

Similar to the assessment of Likelihood, the Consequence rating will be completed separately for coastal erosion and coastal inundation.

4.3 Risk Evaluation

4.3.1 Risk Evaluation Matrix

The risk rating from a risk assessment is defined as “Likelihood” x “Consequence.” The City has developed a Draft Risk Management Framework (City of Joondalup 2013). MRA used the risk matrix presented in that document to define the levels of risk from combinations of Likelihood and Consequence for the coastal hazards. The risk matrix is presented in Table 4.3.

Table 4.3 Risk Matrix (City of Joondalup 2013)

RISK LEVELS		CONSEQUENCE				
		Insignificant	Minor	Moderate	Major	Catastrophic
LIKELIHOOD	Almost Certain	Low	Medium	High	Extreme	Extreme
	Likely	Low	Medium	Medium	High	Extreme
	Possible	Low	Medium	Medium	Medium	High
	Unlikely	Low	Low	Medium	Medium	Medium
	Rare	Low	Low	Low	Low	Low

A risk tolerance scale assists in determining which risks are acceptable, tolerable and unacceptable. The risk tolerance scale used for the assessment is presented in Table 4.4 and is in line with the example scale presented in WAPC (2014).

Table 4.4 Risk Tolerance Scale (WAPC 2014)

Risk Level	Action Required	Tolerance
Extreme	Immediate action required to eliminate or reduce the risk to acceptable levels	Intolerable
High	Immediate to short term action required to eliminate or reduce risk to acceptable levels	Intolerable
Medium	Reduce the risk or accept the risk provided residual risk level is understood	Tolerable
Low	Accept the risk	Acceptable

The risk tolerance scale shows that action needs to be taken to manage the extreme and high risks levels.

4.3.2 Risk Assessment

The risk assessment for the study area has been completed in accordance with the recommendations of AS5334-2013 *Climate Change Adaptation for Settlements and Infrastructure*. This requires a detailed risk analysis to include a vulnerability analysis to thoroughly examine how coastal hazards and climate change may affect the asset. This includes consideration of the Adaptive Capacity and Vulnerability of an asset.

The Adaptive Capacity reflects the ability of assets to change in a way that makes it better equipped to deal with external influences (WAPC 2014). For example, the crest of a seawall can be upgraded with additional height making it more capable of withstanding coastal hazards provided that raising the crest does not lead to another mechanism of failure. This type of seawall has a high Adaptive Capacity.

The Vulnerability of an asset is determined through comparison of potential coastal impacts with the Adaptive Capacity of the asset. An asset with a higher Adaptive Capacity will have a lower Vulnerability.

The risk assessment has been completed for the coastal erosion hazards and the coastal inundation hazards.

4.4 Risk Adaptation & Mitigation Strategies

The SPP2.6 outlines a hierarchy of risk adaptation and mitigation options, where options that allow for a wide range of future strategies are considered more favourably. These options are generally outlined below.

- Avoid – avoid new development within the area impacted by the coastal hazard.
- Retreat – the relocation or removal of assets within an area identified as likely to be subject to intolerable risk of damage from coastal hazards.
- Accommodation – measures which suitably address the identified risks.
- Protect – used to preserve the foreshore reserve, public access and public safety, property and infrastructure.

The assessment of options is generally done in a progressive manner, moving through the various options until an appropriate mitigation option is found. For example, avoiding the coastal hazard by appropriate setbacks is looked upon more favourably than building a seawall to protect the development.

This hierarchy of options is reproduced in Figure 4.1.

Figure 4.1 Risk Management & Adaptation Hierarchy

5. Coastal Erosion Hazards

The following section contains the CHRMAP assessment for coastal erosion hazards at the proposed Ocean Reef Marina site. This involves the following steps.

- Coastal Erosion Hazard Identification.
- Coastal Erosion Risk Analysis.
- Coastal Erosion Risk Adaptation and Mitigation Strategies.

These steps are detailed in the following sections.

5.1 Hazard Identification

5.1.1 External Assets

The SPP2.6 requires assessment of the potential extent of coastal erosion over a 100 year planning timeframe to determine appropriate coastal setbacks for development. The SPP2.6 provides the methodology to calculate appropriate coastal setbacks for a number of standard shoreline classifications, including sandy, rocky and mixed shorelines.

The proposed Ocean Reef Marina is to be located in a section of shoreline that is dominated by limestone cliffs and rocky embayments. 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 and during stormy periods can erode back to the underlying rock.

A coastal processes assessment was completed to determine the potential effects of the Ocean Reef Marina development on the coastal processes (MRA 2015a). Results of the sediment transport modelling contained in MRA (2015a) showed that for both a typical and atypical year, the net northerly transport of sediment around the Marina could be reduced by a few thousand cubic metres per year compared to the transport around the existing Boat Harbour. Seasonal changes in the beaches adjacent to the Marina are expected to continue.

Overall, the key finding of the coastal processes assessment is that the construction of the expanded Ocean Reef Marina is unlikely to cause any significant changes to the shoreline compared to the presence of the existing Ocean Reef Boat Harbour (MRA 2015a). Minor changes to the coastal processes and beach alignment are expected to include the following.

- Increased sand accretion adjacent to the northern and southern breakwaters due to wave shadows under certain prevailing wind and wave conditions. These accumulations may need to be managed at times.
- Increased erosion of the perched beaches due to wave reflections under certain prevailing wind and wave conditions. This erosion may need to be managed at times.

Changes that do occur are likely to be on a relatively small scale and should be able to be managed using the coastal management regime recommended in Section 8 of this report.

The approximate spatial extent of the potential changes to the coastal processes as a result of the Marina construction are presented in Figure 5.1. The proposed Ocean Reef Marina breakwater layout and observed rock extent has been overlaid on this figure.

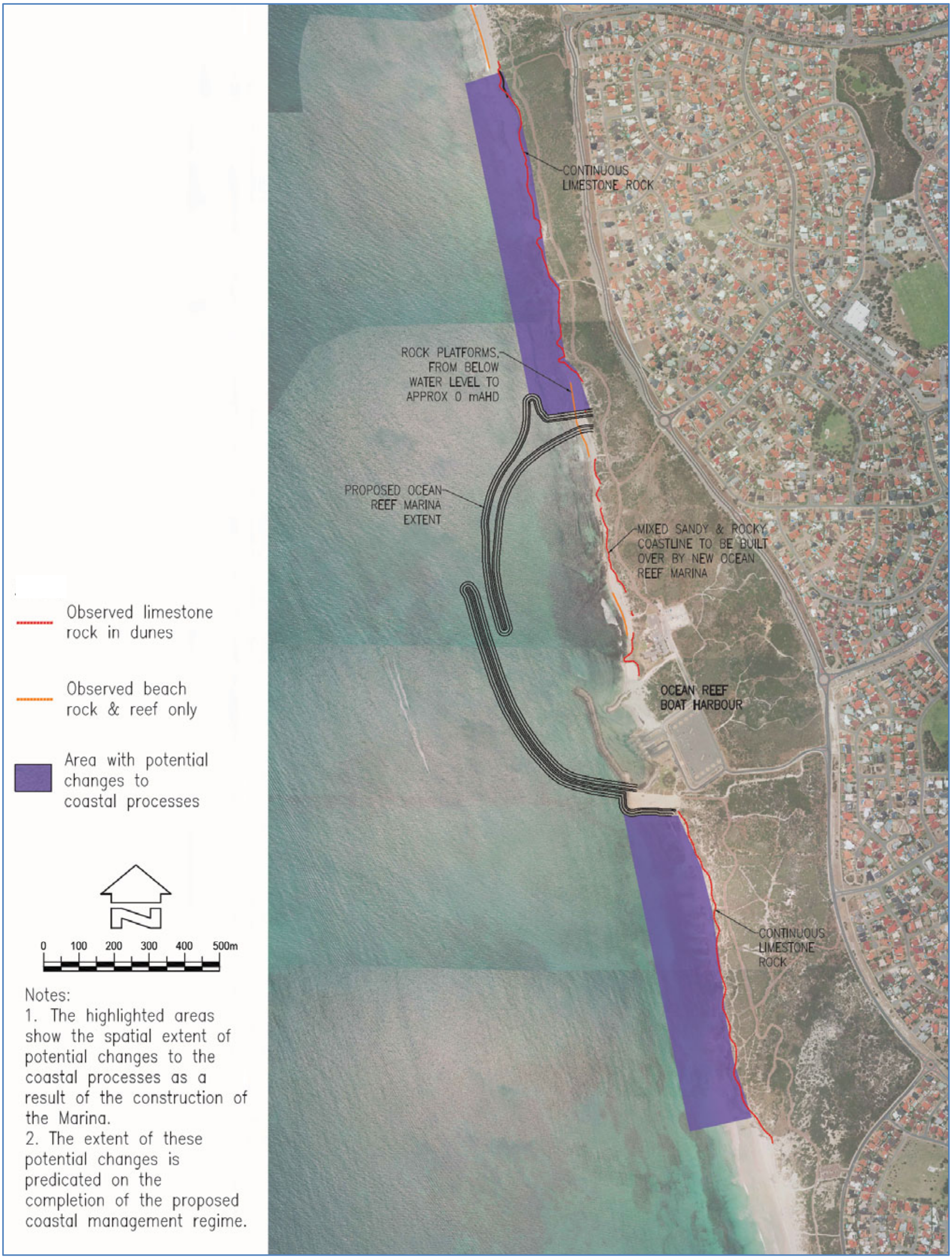


Figure 5.1 Potential Extent of Coastal Processes Changes

Figure 5.1 shows that the majority of the shoreline that may be influenced by the Marina construction is backed by limestone cliffs. A small, mixed sandy and rocky beach is located to the north of the proposed Marina breakwater. Further detail on the rocky shorelines are contained in the following sections.

Rocky Shoreline – Southern Side

To the south of the proposed Marina, the limestone rock typically extends from approximately 0 mAHD to approximately +10 mAHD. This rocky shoreline is shown in the oblique aerial photograph in Figure 5.2.

Figure 5.2 Rocky Shoreline South of the Ocean Reef Marina (WACoast)

The limestone cliffs are highest on the southern side of the existing boat harbour, with the cliff levels slowly reducing as you continue southwards. The cliffs immediately south of the existing boat harbour are shown in Figure 5.3.

Figure 5.3 Limestone Cliffs Looking South from Ocean Reef Boat Harbour (18/1/12)

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.

Figure 5.4 shows a photograph of a typical embayed beach for this section of shoreline.

Figure 5.4 Typical Embayed Beach South of the Marina (18/1/12)

These perched sandy beaches are seasonal and often form in summer and erode in winter. Limited access to these beaches is available to the public on the southern rocky shoreline.

The area behind the limestone cliffs to the south of the boat harbour is relatively undeveloped. Infrastructure is limited to a Dual Use Pathway (DUP) that is approximately 50 m back from the cliff edge. Given this level of coastal erosion protection, no assets are anticipated to be threatened by coastal erosion over the coming century in this rocky shoreline area.

Rocky Shoreline – Northern Side

The rocky shoreline continues on the northern side of the proposed Ocean Reef Marina, as shown in Figure 5.5.

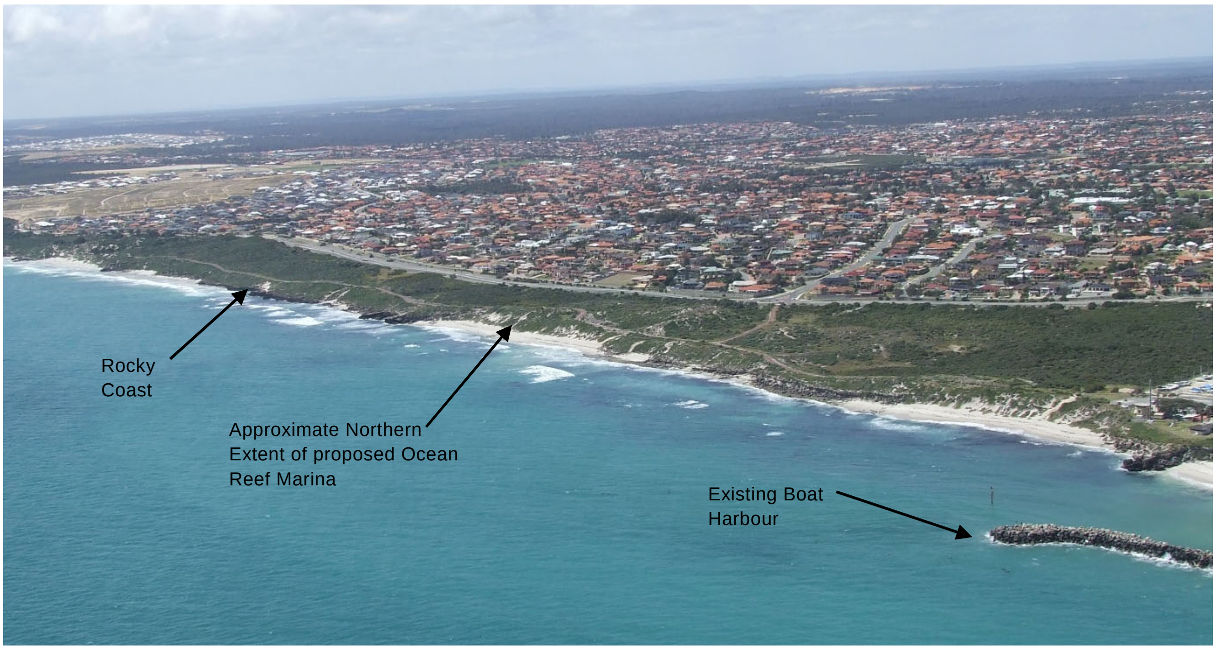


Figure 5.5 Rocky Shoreline North of the Ocean Reef Marina (WACoast)

The area behind the limestone cliffs to the north of the boat harbour is also relatively undeveloped, with a DUP approximately 30 to 50 m back from the cliff edge being the main asset.

A relatively short, perched beach is located immediately to the north of the proposed northern Marina breakwater, as shown in Figures 5.1 and 5.5. This beach is natural and will not be widened nor built seaward as is presented in the original concept in Figure 1.1. This beach may be subjected to periods of accretion from wave shadow effects from the spur groyne and northern breakwater. Increased erosion from wave reflections off the northern breakwater may also influence this beach during periods of north-westerly wave conditions.

MRA completed a site investigation on the 20 October 2015 to determine the extent and levels of rock on the northern beach and in the dunes. Figures 5.6 and 5.7 show rock outcropping at the rear of the beach. This rock outcropping extends to a level between approximately +8 mAHD and +9 mAHD.

Figure 5.6 Southern Rock Outcropping

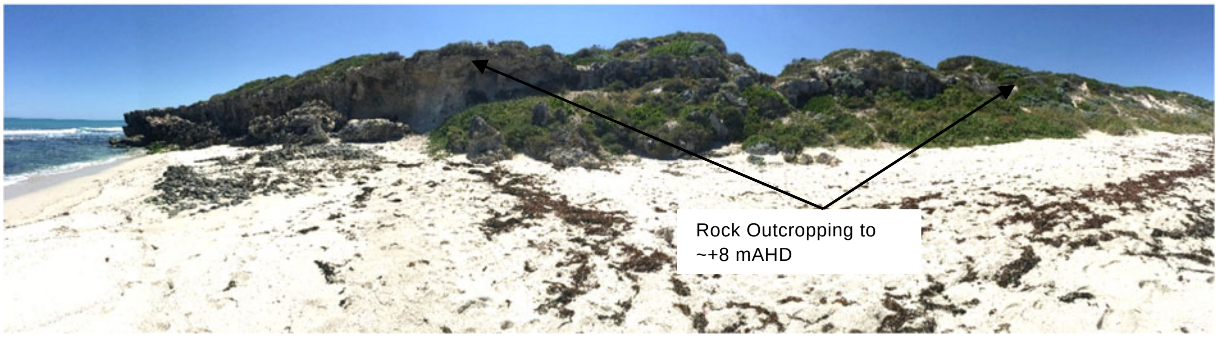


Figure 5.7 Northern Rock Outcropping

The dunes in the center of the beach rise to approximately +16 mAHD. Assuming a relatively horizontal rock profile, the rock is likely to be buried under the dune profile in this area. MRA completed two hand auger boreholes to determine the height and extent of the limestone rock underneath the dunes. The location of these boreholes and the observed rock outcropping is shown in Figure 5.8.

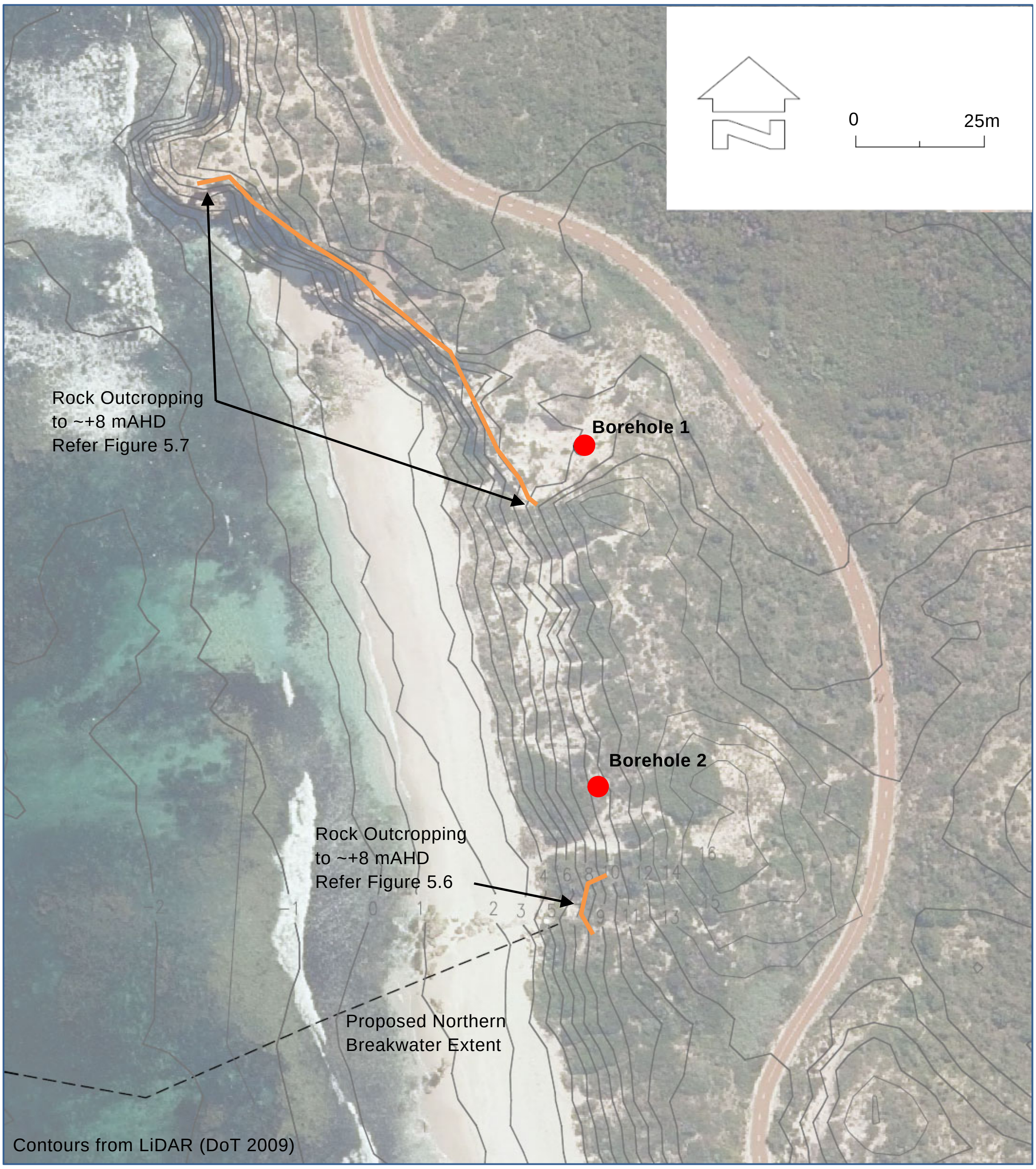


Figure 5.8 Rock Outcropping & Borehole Locations

Rock was encountered at Borehole 1, at a level of approximately +8.5 mAHD, which was 1.5 m below the natural dune surface. This suggests a relatively flat rock profile extending landward from the coastal cliffs, which have a level of between +8 and +9 mAHD.

Borehole 2 was augured to a depth of 2.2 m below the natural dune surface. No rock was encountered at Borehole 2, which had a maximum augured depth of around +9 mAHD. Given the height of the dunes in the area, further geotechnical investigation with a method allowing greater penetration would be required to refine the position of the rock under the dunes in the center of the beach.

The rock observed on site is Tamala limestone, which can offer significant protection from the processes of the ocean. As detailed previously, surveys of similar rock cliffs in south-west Western Australia indicate less than 5 m movement of the cliffs over 100 years of records. This shows that competent limestone can provide protection and withstand the erosive effects of the ocean.

The beach to the north of the Ocean Reef Marina, being particularly rocky with a thin perched sand beach, is not expected to experience significant shoreline recession over the coming century.

Minor Public Car-park

A minor public car-park is proposed to the north of the Marina behind the northern, perched beach. This car-park would have a service life of around 25 years. The SPP2.6 provides a number of variations to the standard freehold case. One such variation is public recreation facilities with finite lifespan. The SPP2.6 notes the following for this type of variation.

Development with an expected useful lifespan of less than 30 years for public recreation purposes on the proviso that the development is to be removed or modified should it be threatened by erosion or creates an erosion threat to other land. Such development may include for example minor car parks for coastal recreational users.

The proposed minor car-park at Ocean Reef Marina is therefore a variation to the standard case and may be located in an area that may be threatened by coastal erosion in the coming 100 years.

It is proposed to locate this car-park behind competent rock, which is likely to be present in the area. Given the presence of rock observed on site, it is likely that competent rock with a minimum level of +4 mAHD extends underneath the dunes along this stretch of coastline. Figure 5.9 shows the inferred +4 mAHD rock contour based on the available geotechnical information. The car-park should be set back a suitable distance behind this competent rock line to account for wave overtopping and potential erosion of the rock cliffs. Given the relatively short service life of 25 years, a setback of 10 m behind the inferred +4 mAHD rock contour is considered appropriate. This setback line is shown in Figure 5.9.

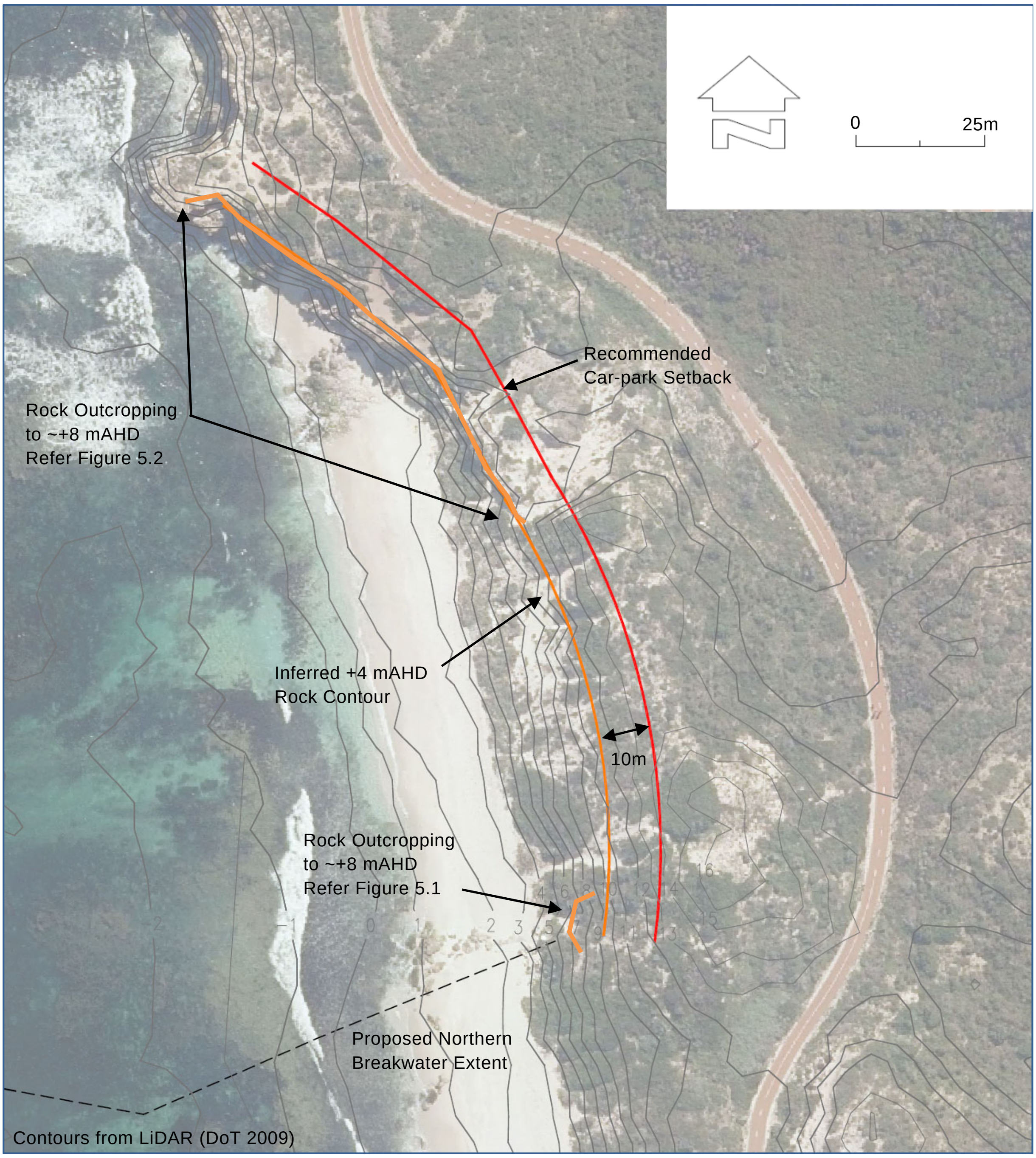


Figure 5.9 Recommended Car-park Setback

Further geotechnical investigation will be required to confirm the final car-park site. The coastal hazard risk analysis and evaluation of the car-park is contained in Sections 5.2 to 5.4.

5.1.2 Internal Assets

For much of the proposed Ocean Reef Marina, the standard SPP2.6 methodology for identification of coastal erosion hazards is not directly applicable, as the majority of the key assets are to be protected from erosion by the external breakwaters and seawalls or internal revetments. This means they are not exposed to coastal erosion hazards. The internal beach may experience erosion during severe storm events as detailed in the following section.

Internal Beach

An internal beach is proposed in the southern portion of the Ocean Reef Marina. The Concept Design Report (Appendix A) provides details on this beach, including a concept cross-section. The beach is to be held at either end by impermeable rock structures.

The internal beach is protected from large offshore wave conditions by the breakwaters. This beach may be subjected to wave erosion forces but these forces are likely to be small given the small waves that may be present within the protected Marina waterbody. Boat wake will also affect this beach. This beach will be backed by a vertical wall or revetment, so erosion behind the defined area for the internal beach is unlikely.

Erosion modelling contained in Appendix A suggests that this beach will experience minor erosion of up to 2 m of beach width during the 100 year ARI storm event. Further details on the storm event and the modelling results are contained in Appendix A.

5.2 Likelihood

The following section details the Likelihood of the key assets being impacted by coastal erosion hazards. Where appropriate, a range of return period events and their Consequences have been investigated as part of this assessment so that the peak risk level for each asset is assessed.

An assessment of the relative Likelihood of each of the identified key assets being impacted by coastal erosion hazards has been completed. This is summarised in Table 5.1 and the following dot points.

- The internal beach is the only internal asset that may be impacted by the erosion of a sandy shoreline. Table 5.1 presents the Likelihood of the 100 year ARI storm event occurring over the 100 year exposure period. Details of the 100 year ARI storm event are contained in Appendix A.

- The northern and southern shorelines adjacent to the Marina are rocky. The Likelihood that the Marina will cause more than 10 m of shoreline recession of these rocky shorelines is *Rare*.

- The perched, sandy beaches fronting the rocky shoreline are *Likely* to experience some erosion and accretion due to the presence of the Marina. This erosion and accretion currently occurs in these areas due to the prevailing weather conditions.

- It is proposed to site the minor car-park behind competent rock that is likely to be at a suitable level to provide protection from coastal erosion. Assuming likely protection provided by the existing natural rock, it is *Unlikely* that the car-park will be exposed to coastal erosion over the 100 year planning timeframe. Should additional geotechnical investigation find no rock exists, then the proposed carpark may need to be relocated to a suitable location.

Table 5.1 Assessment of Likelihood of Erosion Impact (Using Table 4.1)

Key Assets	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Social					
5. Internal Beach	Rare	Unlikely	Unlikely	Possible	Likely
10. Recession of Northern Rocky Shoreline	Rare	Rare	Rare	Rare	Rare
10. Loss of perched sand veneer on Northern Rocky Shoreline	Likely	Likely	Likely	Likely	Likely
11. Recession of Southern Rocky Shoreline	Rare	Rare	Rare	Rare	Rare
11. Loss of perched sand veneer on Southern Rocky Shoreline	Likely	Likely	Likely	Likely	Likely
12. Minor Car-park Behind External Beach	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely

5.3 Consequence

The following section details the Consequence of the key assets being impacted by coastal erosion hazards. As with the Likelihood assessment, a range of return period events and their Consequences have been investigated as part of this assessment so that the peak risk level for each asset is assessed. It was found that the Consequence scales for the erosion hazards do not change over time.

Using Table 4.2, the Consequences of coastal erosion on the identified key assets were assessed. This Consequence assessment is outlined in Table 5.2 and summarised below.

- During the 100 year ARI storm event the Consequence of erosion of the internal beach is likely to be *Minor* given less than 2 m of erosion predicted for this storm. The beach may need to be renourished following a major storm but the erosion would not be expected to extend landward of the edge wall backing the beach. These renourishment works may lead to a small to medium disruption in use of the beach.

- The Consequence of up to 10 m of erosion of the rocky shoreline is *Insignificant*. No assets are located within this erosion zone.

- The Consequence of erosion of the perched sandy beach to the north of the Marina would be *Minor*. This beach is accessible to the public. Many alternative beach sites exist within close proximity to the Marina and seasonal erosion of the sandy veneer is already known to occur. Erosion of the perched, sandy beach would result in an assessed small to medium disruption to the public.

- The Consequence of erosion of the perched sandy beaches to the south of the Marina would be *Insignificant*. These beaches are seasonal and are not readily accessible to the public.
- The Consequence of the minor car-park being exposed to erosion would be *Minor.* Closure of the car-park would result in a small to medium disruption to the use of the beach, of which there are many alternatives in the area. The minor car-park is a small asset of value less than $500,000.

Table 5.2 Assessment of Consequence of Coastal Erosion Impact (Using Table 4.2)

Key Assets	Consequence Scale
Social	
5. Internal Beach	Minor
10. Recession of Northern Rocky Shoreline	Insignificant
10. Loss of perched sand veneer on Northern Rocky Shoreline	Minor
11. Recession of Southern Rocky Shoreline	Insignificant
11. Loss of perched sand veneer on Southern Rocky Shoreline	Insignificant
12. Minor Car-park Behind External Beach	Minor

5.4 Risk Evaluation

Based on the matrices presented in Table 4.3 in conjunction with the results of the risk analysis completed previously, Table 5.3 presents the coastal erosion risk levels for each of the identified key assets.

The order of the assessed risks in the table has been completed to show the priority risk areas for each planning timeframe at the start of the table, with decreasing risk down the table.

Table 5.3 Preliminary Assessment of Coastal Erosion Risk Levels (Using Table 4.3)

Key Asset	Coastal Hazard Description	Assessed Risk Level				
		Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
10. Loss of perched sand veneer on Northern Rocky Shoreline	Erosion	Medium	Medium	Medium	Medium	Medium
5. Internal Beach	Erosion	Low	Low	Low	Medium	Medium
10. Recession of Northern Rocky Shoreline	Erosion	Low	Low	Low	Low	Low
11. Recession of Southern Rocky Shoreline	Erosion	Low	Low	Low	Low	Low
11. Loss of perched sand veneer on Southern Rocky Shoreline	Erosion	Low	Low	Low	Low	Low
12. Minor Car-park Behind External Beach	Erosion	Low	Low	Low	Low	Low

Table 5.3 highlights that the key assets have a low to medium level of risk of coastal erosion over the 100 year planning timeframe.

The Vulnerability of an asset is calculated through evaluation of the risk level and the Adaptive Capacity of the asset. The Adaptive Capacity reflects the ability of assets to change in a way that makes it better equipped to deal with coastal hazards, in this case erosion. For simplicity, the Vulnerability of the key assets will be taken as the risk levels presented in Table 5.3. This provides a conservative (ie safer) estimate of the Vulnerability of these assets coastal erosion.

5.5 Risk Adaptation & Mitigation

Table 5.3 highlighted that the key assets vulnerable to coastal erosion were assessed as having acceptable or tolerable risk levels over the 100 year exposure period. The sandy beach to the north of the Marina has an assessed Medium coastal erosion risk, as sand is expected to erode and accrete depending on the prevailing met-ocean conditions. The management requirements for this beach and the other assets should ultimately be informed by a coastal monitoring regime, as outlined in Section 8.

6. Coastal Inundation

The following section contains the CHRMAP assessment for coastal inundation hazards at the proposed Ocean Reef Marina. This involves the following steps.

- Coastal Inundation Hazard Identification.
- Coastal Inundation Risk Analysis.
- Coastal Inundation Risk Adaptation and Mitigation Strategies.

Irrespective of coastal type and the presence of any coastal protection structures, the SPP2.6 requires assessment of the potential exposure of areas to coastal inundation. This is named the S4 Inundation allowance within the SPP2.6.

Figure 6.1 presents the coastal inundation mechanism on an open ocean shoreline. It should be noted that storm tide is not necessarily associated with the highest tide and that Figure 6.1 is a depiction of the main components that can make up a storm tide.

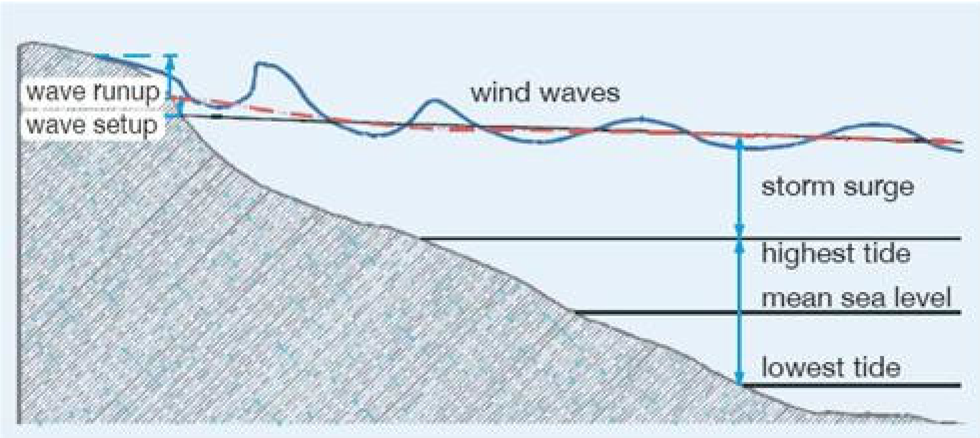


Figure 6.1 Coastal Inundation Mechanism

Assets behind low permeability or impermeable structures such as breakwaters and revetments may also be subjected to wave overtopping. The SPP2.6 recommends that the S4 Inundation Allowance include a setback to accommodate wave overtopping effects, which is the approach that has been used in this assessment. The inundation hazard assessment can therefore be considered as two separate assessments.

- Steady water level (including wave run-up) hazards resulting in a vertical development level.
- Wave overtopping hazards resulting in a horizontal setback distance for buildings and vessels or wave overtopping hazards to public access and safety.

The inundation hazard assessment has been separated accordingly. Section 6 of this report outlines the coastal hazard risk assessment due to steady water level inundation, hereafter referred to as coastal inundation. Section 7 of this report outlines the wave overtopping hazard risk assessment.

6.1 Hazard Identification

The following section outlines the coastal inundation hazard identification. Wave overtopping hazard identification is contained in Section 7.1.

For freehold residential and commercial development, the coastal inundation assessment is to be completed with reference to an event with a 0.2% chance of exceedance per year, which is akin to the 500 year average recurrence interval (ARI) event.

The S4 Inundation allowance is calculated by combining three water level components.

- 500 year ARI steady water level.
- Sea level rise over the coming century.
- Local wind and wave setup.

Although the breakwaters provide protection from typical coastal erosion hazards, outlined in Section 5.1 of this report, increased water levels due to storm surge will still be present within the protected waters of the breakwaters. This is because the water inside the breakwaters is hydraulically connected to the open ocean.

The coastal inundation levels along the shoreline to the north and south of the Marina breakwaters are likely to be higher than inside due to the increased wave activity and associated wave setup in the shallower areas, which is depicted in Figure 6.1. The Marina entrance is situated in deeper waters beyond the zone of this nearshore setup, so the water levels inside the Marina are slightly lower than the adjacent shoreline. Therefore, it is necessary to assess these two cases separately, as their different exposure to the open ocean will result in different inundation levels. These inundation assessments are summarised in the following sections.

6.1.1 Coastal Inundation Inside Marina

The coastal inundation assessment inside the Marina is contained in the following section.

As detailed earlier, the SPP2.6 requires the S4 Inundation allowance to be calculated for a 500 year ARI water level event. The Concept Design Report summarises the extreme water levels at the proposed Ocean Reef Marina, with a 500 year ARI steady water level of +1.44 mAHD in 5 m of water. Further details on the extreme water levels, internal wave climate and potential sea level rise are contained within the Concept Design Report (Appendix A).

The 500 year ARI steady water level is combined with the projected sea level rise for the range of planning timeframes, as presented in Table 6.1.

Table 6.1 Projected Sea Level Rise & Steady Water Level

Planning Timeframe	Sea Level Rise (m) (DoT 2010)	500 year ARI Steady Water Level in 5 m of Water (mAHD)
Present Day	0.00	+1.44
25 years	0.12	+1.56
50 years	0.34	+1.78
75 years	0.61	+2.05
100 years	0.90	+2.34

Even with the protection of the breakwaters there is the potential for local wind and wave setup within the Marina and for wave run-up on the sloped internal revetments.

The wave conditions within the Marina were hindcast using the methods outlined in CIRIA (2007). This results in a wave height of around 0.5 m at the edge wall in the 500 year ARI event. Winds for this assessment were taken from Australian New Zealand Standard (AS/NZS) 1170.2-2011. Further details on the concept design waves and water levels are contained in Appendix A. The 500 year ARI winds and waves inside the Marina were modelled using the SBEACH model in conjunction with a steady water level of +2.34 mAHD.

Results suggest a local wind and wave setup, including wave run-up, of around 0.3 m. The 0.3 m allowance was combined with the values in Table 6.1 to give the potential steady water levels at the Marina shoreline, as presented in Table 6.2.

Some of this type of local setup is likely to already be included in the Fremantle water level record. Consequently, this is likely to be a slightly conservative (ie safe) estimate. The wave run-up was calculated from the SBEACH model output for run-up on a sloped, impermeable revetment.

Table 6.2 500 year ARI Steady Water Level Inside Marina

Planning Timeframe	500 year ARI Steady Water Level in 5 m of Water (mAHD)	Local Wind & Wave Setup & Run-up Inside Marina (m)	500 year ARI Steady Water Level at Marina Shoreline (mAHD)
Present Day	+1.44	0.3	+1.74
25 years	+1.56	0.3	+1.86
50 years	+1.78	0.3	+2.08
75 years	+2.05	0.3	+2.35
100 years	+2.34	0.3	+2.64

Table 6.2 shows that inside of the Marina a development level (total Allowance for Storm Surge Inundation) of **+2.7 mAHD** is appropriate for the 100 year planning timeframe.

Freehold Assets – Residential & Associated Commercial

Based on the findings in Table 6.2, a development level of **+2.7 mAHD** is recommended for freehold residential and associated commercial development within the areas protected by the breakwaters. Siting this type of development above the S4 Inundation level limits the risk of coastal inundation hazards for these assets. Finished floor levels will be higher than the development level of +2.7 mAHD.

Leasehold Assets – Recreational, Commercial & Industrial

The SPP2.6 provides a number of variations to the standard case, where development may need to occur within an area identified to be potentially impacted by physical processes within the 100 year planning timeframe. Section 7.4 of the SPP2.6 identifies Industrial and Commercial development such as a marina as a variation within the SPP2.6.

Therefore, a lower development level may be appropriate for recreational, commercial and industrial development within the Marina, depending on the nature of the development. For example, an industrial hard stand area for boats, which has a requirement to be close to the water's edge and at a functionally lower level, may have a reduced development level. These areas may be inundated during extreme water level events but would be designed to accommodate this short term inundation. This requires consideration of the probability of inundation over the range of planning horizons for different development levels.

The development levels for the following assets are dictated by their need to be close to the water.

- Internal beach.
- Boat ramp and parking.
- Public promenade.
- Marine commercial zone.

Breakwater access is generally set significantly above the steady water level as the structures needs to be high enough to limit wave overtopping into the internal marina.

The vessel moorings within the Marina are proposed to be floating pontoons designed to accommodate extreme water levels with a suitable pile height. Hence, the vessels and their moorings will not be affected by inundation.

Based on the above, the proposed development levels for the key internal assets are provided in Table 6.3. The values presented in Table 6.3 are development or reclamation levels. Residential and Commercial Finished Floor Levels will be higher than the development levels presented in Table 6.3.

Table 6.3 Proposed Development Levels – Internal Assets

Asset		Suggested Development Level
Social		
1.	Breakwater Access (Pedestrian & Vehicular)	+5 mAHD
2.	Boat Ramp – Ramp & Finger Jetty Structure	+1.1 mAHD
	Boat Ramp – Trailer Parking	+2.1 mAHD
3.	Public Promenade & Landscaped Areas	+1.5 mAHD
4.	Residential Development	**+2.7 mAHD (S4 SPP2.6)**
5.	Internal Beach	+1.5 mAHD
Economic		
7.	Marine Commercial Zone – Hardstand Area	+1.5 mAHD
	Marine Commercial Zone – Buildings, Structures & Storage Areas	+2.3 mAHD
8.	Commercial/Retail/Restaurants	**+2.7 mAHD (S4 SPP2.6)**

Buildings within the following areas that may be inundated or subject to wave overtopping should have electrical sockets and equipment set above the S4 Inundation allowance level of +2.7 mAHD.

- Marine commercial buildings.
- Marine commercial hardstand.
- Boat ramp trailer parking area.
- Public promenade.

The Likelihood and Consequence assessment are carried out in Sections 6.2 and 6.3.

6.1.2 Coastal Inundation Outside Marina

Two infrastructure assets proposed to be built as part of the Ocean Reef Marina outside of the Marina breakwaters are listed below.

- External fishing platforms.
- Minor Public car-park to the north of the Marina.

External Fishing Platforms

Two external fishing platforms are proposed to be built on the outside of the Marina breakwaters. Public consultation requested these be on the outside of the breakwaters. Although generally found to be hazardous, two different platform levels, +1.5 mAHD and +5 mAHD, have been assessed to determine if an external fishing platform could be suitable.

External Beaches & Minor Public Car-park

The coastal inundation levels outside of the Marina will be different from those inside. The minor car-park to the north of the Marina is located outside of the protection of the Marina breakwaters behind a beach. In order to determine the extent of nearshore setup that would occur on the external beach SBEACH simulations were completed with the results presented in Figure 6.2. The following conditions were input into SBEACH.

- 500 year ARI Water Level in 5 m of water = +1.44 mAHD.
- 100 year ARI Hs in 10 m of water = 3.6 m.

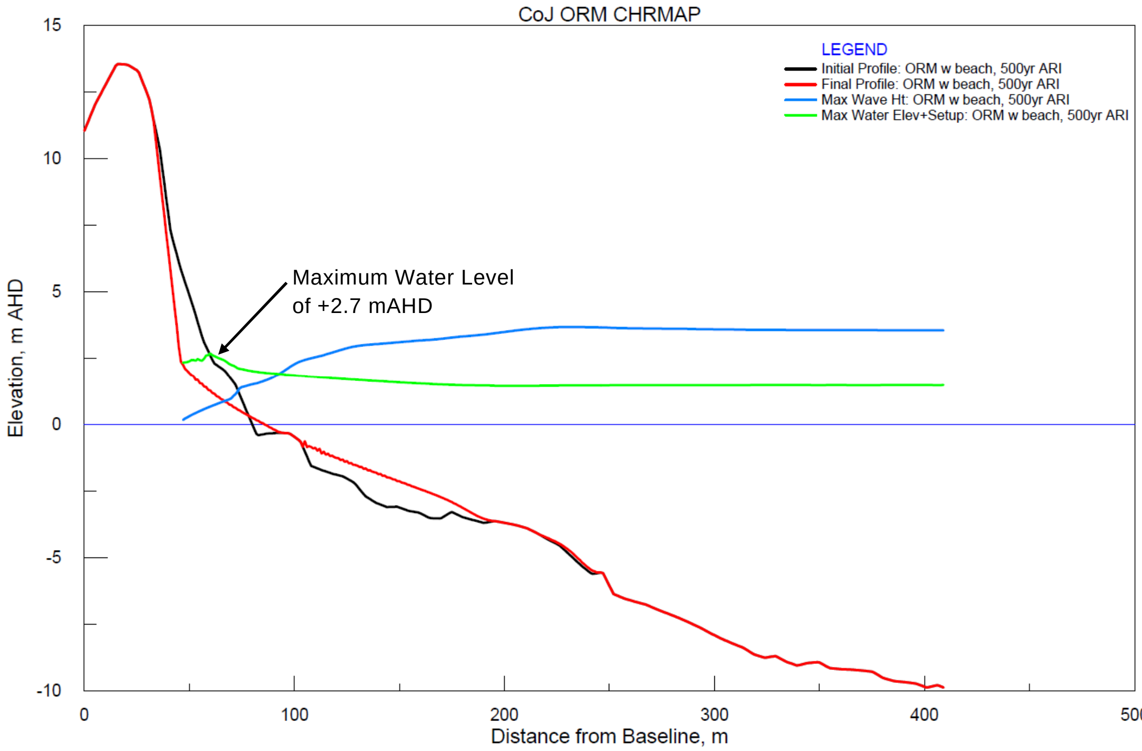


Figure 6.2 SBEACH Simulation to Determine Extent of Nearshore Setup

The SBEACH simulation was calibrated to the design water levels and wave heights in the appropriate water depth.

On the shoreline adjacent to the Marina, a peak steady water level of +2.7 mAHD was calculated, corresponding to an approximate +1.3 m nearshore setup. The S4 Inundation allowance is combined with the +0.9 m sea level rise, giving a Total Allowance for Storm Surge Inundation of +3.6 mAHD on the beaches adjacent to the Marina. It is recommended to set the minor car-park level at around **+5 mAHD**, above the Allowance for Storm Surge Inundation to accommodate coastal inundation. Given the presence of the high dune systems at the rear of the beach (> 8 mAHD) in the proposed location of the car-park this should be relatively straightforward to achieve. In addition it is expected that rock will be found in the area which would further reduce any erosion risk.

Further refinement of the levels and setback for the car-park is required when further geotechnical assessment is completed to site the car-park.

6.2 Likelihood

The following sections detail the Likelihood of the key assets being exposed to coastal inundation hazards.

6.2.1 Internal Assets

The potential for coastal inundation will change in the future as the sea level rises. This means that an area that would only be inundated during a very severe event in the present day could potentially be inundated by a much less severe event in the future. Assessment of the probability of an area being inundated or exceeded within a given planning timeframe therefore needs to consider the changing probability of event occurrence throughout that planning timeframe.

As an example, an area with an elevation of +1.7 mAHD would just be inundated by the 500 year ARI event in 2015. However, it would be inundated by approximately the 200 year ARI event in 25 years, approximately the 16 year ARI event in 50 years and approximately the 1 year ARI event in 100 years. Combining all of these probabilities of exceedance on an annual basis would mean that the actual chance of an area with an elevation of +1.7 mAHD being inundated over a planning horizon to 2115 would be over 99%.

Similar probabilities of exceedance for different elevations and planning horizons are presented in Table 6.4. These probabilities provide a basis for setting the development levels of the various assets proposed within the Marina.

Table 6.4 Cumulative Probability of Exceedance for Different Inundation Elevations over each Planning Timeframe

		Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Inundation Elevation (mAHD)	1.1	50%	>99%	>99%	>99%	>99%
	1.3	9%	98%	>99%	>99%	>99%
	1.5	1%	49%	98%	>99%	>99%
	1.7	<1%	8%	38%	>99%	>99%
	1.9	<1%	3%	10%	47%	>99%
	2.1	<1%	2%	4%	14%	67%
	2.3	<1%	1%	3%	6%	21%
	2.5	<1%	1%	2%	4%	8%
	2.7	<1%	1%	2%	3%	5%

Using the proposed development levels in Table 6.3 and the inundation values in Table 6.4, the Likelihood of coastal inundation for each of the key internal assets was calculated and is presented in Table 6.5.

Table 6.5 Assessment of Likelihood of Coastal Inundation for Internal Assets (Using Tables 4.1, 6.3 & 6.4)

Key Assets	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Social					
1. Breakwater Access (Pedestrian & Vehicular)	Rare	Rare	Rare	Rare	Rare
2. Boat Ramp – Ramp & Finger Jetty Structure	Possible	Almost Certain	Almost Certain	Almost Certain	Almost Certain
2. Boat Ramp – Trailer Parking	Rare	Rare	Rare	Rare	Unlikely
3. Public Promenade & Landscaped Areas	Rare	Possible	Almost Certain	Almost Certain	Almost Certain
4. Residential Development	Rare	Rare	Rare	Rare	Rare
5. Internal Beach	Rare	Possible	Almost Certain	Almost Certain	Almost Certain
Economic					
7. Marine Commercial Zone – Hardstand Area	Rare	Possible	Almost Certain	Almost Certain	Almost Certain
7. Marine Commercial Zone – Buildings, Structures & Storage Areas	Rare	Rare	Rare	Rare	Unlikely
8. Commercial/Retail/ Restaurants	Rare	Rare	Rare	Rare	Rare

Notes: 1. Asset 6, Vessels and moorings are floating and are therefore not exposed to inundation hazards.

6.2.2 External Assets

The key points to note regarding the assessment of Likelihood for coastal inundation of the key external assets are summarised below. These are summarised in Table 6.6.

- The external fishing platform at +1.5 mAHD has a *Rare* Likelihood of being inundated by still water levels at present. The Likelihood of inundation at the end of the 100 year exposure period is *Almost Certain*. The critical risk for the fishing platform is wave overtopping which is assessed in Section 7 of this report.
- The external fishing platform at +5 mAHD has a *Rare* Likelihood of being inundated over the coming century.

- The limestone cliffs to the north and south of the Marina are typically above +5 mAHD. These rocky shorelines have a *Rare* Likelihood of being inundated over the coming century.

- The sandy beaches fronting the rocky shoreline vary in level depending on the season and prevailing weather conditions. Figures 5.3 and 5.4 show the different beach levels of the shoreline adjacent to the Marina. These beaches are expected to be completely inundated in a 1 year ARI storm event, resulting in an *Almost Certain* Likelihood of coastal inundation at present. The frequency of this inundation will increase over the 100 year exposure period.

- Given the presence of the high dune system at the rear of the beach (> 8 mAHD) the proposed minor car-park can easily be founded at +5 mAHD above the Allowance for Inundation of +3.6 mAHD. This level corresponds to a 500 year ARI water level in 2115. Therefore, it has a *Rare* Likelihood of being inundated over the coming century.

Table 6.6 Assessment of Likelihood of Coastal Inundation for External Assets (Using Table 4.1)

Key Assets	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Social					
9. External Fishing Platform @ +1.5 mAHD	Rare	Possible	Almost Certain	Almost Certain	Almost Certain
9. External Fishing Platform @ +5 mAHD	Rare	Rare	Rare	Rare	Rare
10. Inundation of Northern Rocky Shoreline	Rare	Rare	Rare	Rare	Rare
10. Inundation of sandy beach on Northern Rocky Shoreline	Almost Certain	Almost Certain	Almost Certain	Almost Certain	Almost Certain
11. Inundation of Southern Rocky Shoreline	Rare	Rare	Rare	Rare	Rare
11. Inundation of sandy beach on Southern Rocky Shoreline	Almost Certain	Almost Certain	Almost Certain	Almost Certain	Almost Certain
12. Minor Car-park Behind External Beach	Rare	Rare	Rare	Rare	Rare

6.3 Consequence

The following sections detail the Consequence of the key assets being exposed to coastal inundation hazards.

6.3.1 Internal Assets

Using Table 4.2, the Consequence of coastal inundation on the internal assets were assessed for each of the planning timeframes as presented in Table 6.7. The Consequence scale can change over time given sea level rise, which is reflected in Table 6.7.

For Table 6.7, the key points to note regarding the assessment of Consequence are summarised below.

- Beaches are naturally inundated by storm events with little Consequence on the beach itself. However, public use of the internal beach may be impacted by high water levels, making the beach unusable. The social Consequence was assessed as being *Insignificant* over a 75 year exposure period with minimal, short-term inconvenience to the use of the beach in storm events. The social Consequence was assessed to be *Minor* over the 100 year exposure period with a 0.9 m sea level rise, as the beach would nearly be covered and unusable during some high tides. The area would still be available to utilise as a protected swimming area, however some of the amenity would be lost.

- The breakwater access will be set too high to be inundated by steady water levels in the 500 year ARI inundation event. The Consequence was assessed as being *Insignificant,* as it is in excess of the SPP2.6 requirements. The critical risk for the breakwater access is wave overtopping as outlined in Section 7.

- The boat ramp would be designed to accommodate inundation and as such would not be damaged in an inundation event. However, the use of the boat ramp would be affected for the time that the ramp was inundated. The amount of time the ramp is inundated will increase with increasing sea levels, as the tides rise with the mean sea level. The impact of the inundation was assessed as having *Insignificant* Consequence over the 50 year exposure period, with a *Minor* Consequence for the 75 and 100 year exposure periods.

- The trailer parking would be designed to accommodate inundation, which would typically be associated with a storm tide. This is likely to be for a short period of time, resulting in an *Insignificant* Consequence.

- The public promenade would be designed to accommodate inundation. The impact of the inundation was assessed as having an *Insignificant* social Consequence over the 75 year exposure period, with a *Minor* Consequence for the 100 year exposure period. The critical risk for the promenade access is wave overtopping as outlined in Section 7.

- Inundation of the residential buildings was assessed as having a *Major* Consequence, given the likely damage and disruption caused by inundation.

- Inundation of the non-marine commercial buildings was assessed as having a *Major* Consequence, given the likely damage and disruption caused by inundation.

- The marine commercial zone hardstand area would be designed to accommodate inundation. The impact of short term storm inundation on the hardstand area was assessed as having *Insignificant* Consequence over the 75 year exposure period, with a *Minor* Consequence for the 100 year exposure period.

- Inundation of the buildings, structures and storage areas within the marine commercial zone was assessed as having a *Moderate* Consequence, as they would be designed to accommodate limited inundation. Details on the cost of assets in the proposed Marine

Commercial Zone are limited, so the damage from inundation was estimated at up to $5 million during an inundation event.

Table 6.7 Assessment of Consequence of Coastal Inundation for Internal Assets (Using Table 4.2)

Key Assets	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Social					
1. Breakwater Access (Pedestrian & Vehicular)	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
2. Boat Ramp – Ramp & Finger Jetty Structure	Insignificant	Insignificant	Insignificant	Minor	Minor
2. Boat Ramp – Trailer Parking	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
3. Public Promenade & Landscaped Areas	Insignificant	Insignificant	Insignificant	Insignificant	Minor
4. Residential Development	Major	Major	Major	Major	Major
5. Internal Beach	Insignificant	Insignificant	Insignificant	Insignificant	Minor
Economic					
7. Marine Commercial Zone – Hardstand Area	Insignificant	Insignificant	Insignificant	Insignificant	Minor
8. Marine Commercial Zone – Buildings, Structures & Storage Areas	Moderate	Moderate	Moderate	Moderate	Moderate
8. Commercial/Retail/ Restaurants	Major	Major	Major	Major	Major

Notes: 1. Asset 6, Vessels and moorings are floating and are therefore not exposed to inundation hazards given the restraint system is designed to accommodate these extreme water levels.

6.3.2 External Assets

Using Table 4.2, the Consequence of coastal inundation on the external assets were assessed for each of the planning timeframes as presented in Table 6.8. It was found that the Consequence scales for the inundation hazards do not change over time for these assets.

For Table 6.8, the key points to note regarding the assessment of Consequence are summarised below.

- Inundation of the external fishing platform at +1.5 mAHD could lead to short term closure in storm events today. As the sea level rises, the platform would be inundated by high tides at the end of the century. The Consequence of inundation is *Minor* at present and over the coming century. The critical risk for the fishing platforms is wave overtopping on public access as outlined in Section 7.

- The external fishing platform at +5 mAHD will be set too high to be inundated by steady water levels in the 500 year ARI inundation event. The Consequence of inundation was assessed as being *Insignificant,* as it is in excess of the SPP2.6 requirements. The critical risk for the fishing platforms is wave overtopping on public access as outlined in Section 7.

- The northern and southern rocky shorelines are typically above + 5mAHD, which is too high to be inundated by steady water levels in the 500 year ARI inundation event. The Consequence of inundation was assessed as being *Insignificant,* as it is in excess of the SPP2.6 requirements.

- As noted previously, beaches are naturally inundated by storm events with little Consequence on the beach itself. The main consequence from coastal inundation is therefore related to use of the sandy perched beaches. The Consequence of inundation is *Insignificant* at present and over the coming century, as the disruption would be short lived during the passage of an extreme storm event. When the beaches are inundated by high tides late in the 100 year planning horizon, many alternative beach sites at higher levels exist that beach users can visit.

- The minor public car-park will be set above + 5mAHD, which is too high to be inundated by steady water levels in the 500 year ARI inundation event. The Consequence of inundation was assessed as being *Insignificant,* as it is in excess of the SPP2.6 requirements.

Table 6.8 Assessment of Consequence of Coastal Inundation for External Assets (Using Table 4.2)

Key Assets	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Social					
9. External Fishing Platform @ +1.5 mAHD	Minor				
9. External Fishing Platform @ +5 mAHD	Insignificant				
10. Inundation of Northern Rocky Shoreline	Insignificant				
10. Inundation of sandy beach on Northern Rocky Shoreline	Insignificant				
11. Inundation of Southern Rocky Shoreline	Insignificant				
11. Inundation of sandy beach on Southern Rocky Shoreline	Insignificant				
12. Minor Car-park Behind External Beach	Insignificant				

6.4 Risk Evaluation

Based on the matrices presented in Tables 4.3 and 4.4 in conjunction with the results of the risk analysis completed previously, Table 6.9 presents the coastal inundation risk levels for each of the identified key assets.

The order of the assessed risks in the table has been completed to show the priority risk areas for each planning timeframe at the start of the table, with decreasing risk down the table.

Table 6.9 Preliminary Assessment of Coastal Inundation Risk Levels

Key Asset	Assessed Risk Level				
	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
9. External Fishing Platform @ +1.5 mAHD	Low	Medium	Medium	Medium	Medium
2. Boat Ramp – Ramp & Finger Jetty Structure	Low	Low	Low	Medium	Medium
3. Public Promenade & Landscaped Areas	Low	Low	Low	Low	Medium
5. Internal Beach	Low	Low	Low	Low	Medium
7. Marine Commercial Zone – Hardstand Area	Low	Low	Low	Low	Medium
7. Marine Commercial Zone – Buildings & Structures	Low	Low	Low	Low	Medium
1. Breakwater Access (Pedestrian & Vehicular)	Low	Low	Low	Low	Low
2. Boat Ramp – Trailer Parking	Low	Low	Low	Low	Low
4. Residential Development	**Low**	**Low**	**Low**	**Low**	**Low**
8. Commercial/ Retail/ Restaurants	**Low**	**Low**	**Low**	**Low**	**Low**
9. External Fishing Platform @ +5 mAHD	Low	Low	Low	Low	Low
10. Inundation of Northern Rocky Shoreline	Low	Low	Low	Low	Low
10. Inundation of sandy beach on Northern Rocky Shoreline	Low	Low	Low	Low	Low
11. Inundation of Southern Rocky Shoreline	Low	Low	Low	Low	Low
11. Inundation of sandy beach on Southern Rocky Shoreline	Low	Low	Low	Low	Low
12. Minor Car-park Behind External Beach	Low	Low	Low	Low	Low

Notes: 1. Asset 6, Vessels and moorings are floating and are therefore not exposed to inundation hazards.

Table 6.9 highlights that all of the assets have low or medium levels of risk to inundation at the assessed development levels over the 100 year exposure period. As per Table 4.4 from WAPC (2014) these levels of risk are acceptable and tolerable.

The Vulnerability of an asset is calculated through evaluation of the risk level and the Adaptive Capacity of the asset. The Adaptive Capacity reflects the ability of assets to change in a way that makes it better equipped to deal with coastal hazards, in this case inundation.

The potential to retrofit the coastal protection structures to accommodate increased sea levels will be incorporated into the detailed design as part of the risk mitigation for the project. Many of the assets such as the boat ramp, Marine Commercial Zone hardstand and the internal beach could also be raised when they are replaced over time. These assets typically have a service life of the order of 25 years, therefore would be expected to be replaced at least two times during the 100 year planning horizon. Consequently, these structures and assets have a high degree of Adaptive Capacity and as such their overall Vulnerability to coastal inundation would be lower than the risk levels presented in Table 6.9.

For simplicity, the Vulnerability of the key assets will be taken as the risk levels presented in Table 6.9 without further accounting for Adaptive Capacity. This provides a conservative (ie safer) estimate of the Vulnerability of these assets to coastal inundation.

6.5 Risk Adaptation & Mitigation

Table 6.9 highlights that all of the key assets are assessed as having acceptable and tolerable risk levels to coastal inundation over the 100 year exposure period. Asset 9, the fishing platform at +1.5 mAHD was assessed as having a medium level of coastal inundation risk at the end of the 25 year exposure period. The critical coastal hazard for this asset is wave overtopping. Therefore, the risk adaptation and mitigation of this risk is covered in the overtopping assessment (Section 7.5), as wave overtopping represents a more critical coastal hazard.

For the remainder of the assets risk adaptation and mitigation measures are not required. Nevertheless, the management requirements for these assets should ultimately be informed by a coastal monitoring regime, as outlined in Section 8.

7. Wave Overtopping

As outlined previously, assets behind low permeability or impermeable structures such as breakwaters and revetments may also be subjected to wave overtopping. The SPP2.6 recommends that the S4 Inundation Allowance include a setback to accommodate wave overtopping effects, which is the approach that has been used in this assessment.

The following section contains the CHRMAP assessment for wave overtopping hazards at the proposed Ocean Reef Marina. This involves the following steps.

- Wave Overtopping Hazard Identification.
- Wave Overtopping Risk Analysis.
- Wave Overtopping Risk Adaptation and Mitigation Strategies.

7.1 Hazard Identification

Wave overtopping occurs when a wave hits an impermeable structure or natural feature and results in water rushing over the top of the structure. Proper coastal engineering design includes assessment of wave overtopping impacts. The breakwaters, seawalls and revetments are to be designed to accommodate wave overtopping during the 100 year ARI design event. Further details on the wave overtopping and the concept design of these structures are contained in Appendix A.

Development must also be set back an appropriate distance behind the rear crest of coastal structures to accommodate wave overtopping. The setback distance will depend on a number of factors as follows.

- The wave exposure of the protection structure.
- The crest level of the protection structure.
- The type of protection structure.
- The type of development being protected such as industrial, residential, commercial or vessels.

For example wave overtopping forces immediately behind the external breakwaters may be higher than wave overtopping forces behind the internal revetments. This difference in exposure needs to be considered within the coastal hazard risk assessment.

Public access and safety may also be affected by wave overtopping during extreme events. The assets have been summarised in Table 7.1 as either a public access overtopping hazard or a setback distance for overtopping. Where both public access and structural damage may occur due to overtopping, public access has been chosen as the key element as it is a stricter criteria.

Table 7.1 Wave Overtopping Hazard Summary

Asset		Wave Overtopping Hazard
Social		
1.	Breakwater Access (Pedestrian & Vehicular)	Public Access
2.	Boat Ramp & Trailer Parking	Public Access
3.	Public Promenade & Landscaped Areas	Public Access
4.	Residential Development	Building Setback for Structural Damage
6.	Vessels & Vessel Moorings	Vessel Setback for Sinking & Damage
9.	Fishing Platforms	Public Access
10.	Southern Rocky Shoreline	Public Access
11.	Northern Rocky Shoreline	Public Access
12.	Minor Car-park Behind External Beach	Public Access
Economic		
7.	Marine Commercial Zone (Hardstand & Buildings/Structures)	Building Setback for Structural Damage
8.	Commercial/Retail/Restaurants	Building Setback for Structural Damage

The coastal inundation risk on the internal (Asset 5) and external sandy beaches (Asset 10 and 11) has previously been completed in Section 6 of this report. These sandy beaches are highly permeable and not subjected to wave overtopping and therefore have not been assessed for wave overtopping hazards.

The Likelihood and Consequence of these wave overtopping hazards are contained in the following sections.

7.2 Likelihood

The following section details the Likelihood of the key assets being exposed to wave overtopping hazards. The potential for wave overtopping will change in the future as the sea level rises. This means that an area that would be exposed to wave overtopping during a very severe event in the present day could potentially be affected by a much less severe event in the future.

For ease of analysis, the assets have been separated into those related to setbacks for structural damage and those related to public access and safety. These are presented in Tables 7.2 and 7.3 respectively and used the Likelihood ratings contained in Table 4.1.

For Table 7.2, the key points to note regarding the assessment of Likelihood for overtopping setbacks are summarised below.

- Overtopping calculations in Appendix A suggest that residential and commercial buildings set back approximately 5 m behind the internal promenade will avoid structural damage in the 500 year ARI event at the end of the 100 year planning timeframe. The Likelihood of this event occurring is *Rare* at present and *Unlikely* over the 100 year exposure period.

- Overtopping calculations in Appendix A suggest that commercial buildings set back approximately 5 m behind the internal promenade will avoid structural damage in the 500 year ARI event at the end of the 100 year planning timeframe. The Likelihood of this event occurring is *Rare* at present and *Unlikely* over the 100 year exposure period.

- Overtopping calculations in Appendix A suggest that small and large vessels 30 m or further from the rear crest of the breakwaters are safe from overtopping in the 100 year ARI event at the end of the 100 year planning timeframe. The Likelihood of this event occurring is *Rare* at present and *Likely* over the 100 year exposure period.

- Overtopping calculations in Appendix A suggest that buildings in the Marine Commercial zone require a setback of 25 m behind the rear crest of the external seawall to avoid structural damage in the 100 year ARI event at the end of the 100 year planning timeframe. The Likelihood of this event occurring and thus wave overtopping impacting the marine commercial zone is *Rare* at present and *Likely* over the 100 year exposure period.

Table 7.2 Assessment of Likelihood of Overtopping – Building & Vessel Setbacks (Using Table 4.1)

Key Assets	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Social					
4. Residential Development	Rare	Rare	Rare	Rare	Unlikely
6. Vessels & Vessel Moorings	Rare	Unlikely	Unlikely	Possible	Likely
Economic					
7. Marine Commercial Zone (Hardstand & Buildings/Structures)	Rare	Unlikely	Unlikely	Possible	Likely
8. Commercial/Retail/ Restaurants	Rare	Rare	Rare	Rare	Unlikely

For Table 7.3, the key points to note regarding the assessment of overtopping Likelihood for public access and safety are summarised below.

- As previously noted, wind speeds are expected to be unsafe for breakwater access above the 5 year ARI event. Pedestrian access on the breakwaters has been limited to the 5 year ARI event. Beyond the 5 year ARI event, pedestrian access on the breakwaters becomes unsafe. Therefore, the Likelihood of wave overtopping impacting pedestrian access is *Unlikely* at present and *Almost Certain* over a 100 year exposure period.

- Overtopping calculations in Appendix A suggest that low speed vehicular access along the breakwater is expected to be safe during the 100 year ARI event at the end of the 100 year planning timeframe. Therefore, the Likelihood of the 100 year ARI event occurring is *Rare* at present and *Likely* over the 100 year exposure period. This has been set so that if breakwater access is required during a storm, experienced technical staff can access the breakwater via a vehicle to inspect it.

- Overtopping calculations in Appendix A suggest that pedestrian access on the internal marina public promenade is expected to be safe during the 100 year ARI event at present. With sea level rise over the coming 100 years, the 100 year ARI storm event would become dangerous to aware pedestrians on the promenade with a clear view of the sea. The Likelihood of the 100 year ARI event occurring is *Rare* at present and *Likely* over the 100 year exposure period.

- Overtopping calculations in Appendix A suggest that pedestrian access on the boat ramp is expected to be safe during the 100 year ARI event at the end of the 100 year planning timeframe. Therefore, the Likelihood of the 100 year ARI event occurring is *Rare* at present and *Likely* over the 100 year exposure period.

- An external fishing platform with a height of +1.5 mAHD will be overtopped by storm waves less than the 1 year ARI event and therefore has an *Almost Certain* Likelihood of being overtopped at present.

- An external fishing platform with a height of +5 mAHD will be overtopped in a 2 year ARI storm and therefore the Likelihood of occurrence is *Possible* at present and *Almost Certain* over the 100 year exposure period.

- Given the large setback distance (~30 to 50 m) between the rock cliffs and the DUP, pedestrian access is expected to be safe during the 500 year ARI event (shown in Figure 6.2) at present and at the end of the 100 year exposure period. This corresponds to a *Rare* Likelihood at present and *Unlikely* over the 100 year exposure period.

- Given a 10 m setback distance between the rock cliffs and the minor car-park and a car-park level of at least +5 mAHD, pedestrian access is expected to be safe during the 500 year ARI event (shown in Figure 6.2) at present and at the end of the 100 year exposure period. This corresponds to a *Rare* Likelihood at present and *Unlikely* over the 100 year exposure period.

Table 7.3 Assessment of Likelihood of Overtopping – Public Access (Using Table 4.1)

Key Assets	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
Social					
1. Breakwater Access - Pedestrian	Unlikely	Almost Certain	Almost Certain	Almost Certain	Almost Certain
1. Breakwater Access - Vehicular	Rare	Unlikely	Unlikely	Possible	Likely
2. Boat Ramp (Ramp Structure & Trailer Parking)	Rare	Unlikely	Unlikely	Possible	Likely
3. Public Promenade & Landscaped Areas	Rare	Unlikely	Unlikely	Possible	Likely
9. External Fishing Platform @ +1.5 mAHD	Almost Certain	Almost Certain	Almost Certain	Almost Certain	Almost Certain
9. External Fishing Platform @ +5 mAHD	Possible	Almost Certain	Almost Certain	Almost Certain	Almost Certain
10. Southern Rocky Shoreline	Rare	Rare	Rare	Rare	Unlikely
11. Southern Rocky Shoreline	Rare	Rare	Rare	Rare	Unlikely
12. Minor Car-park Behind External Beach	Rare	Rare	Rare	Rare	Unlikely

7.3 Consequence

The following section details the Consequence of the key assets being exposed to wave overtopping hazards.

For ease of analysis, the assets have been separated into those related to building setbacks for structural damage and those related to public access and safety. These are presented in Tables 7.4 and 7.5 respectively and used the Consequence ratings contained in Table 4.2.

For Table 7.4, the key points to note regarding the assessment of Consequence for building and vessel setbacks are summarised below.

- Given overtopping levels expected in the 500 year ARI event (outlined in Appendix A), the Residential zone would need to be setback around 5 m behind the internal promenade to have a *Minor* economic Consequence.

- Given overtopping levels expected in the 500 year ARI event (outlined in Appendix A), the non-marine Commercial zone would need to be setback around 5 m behind the internal promenade to have a *Minor* economic Consequence.

- Given overtopping levels expected in the 100 year ARI event (outlined in Appendix A), small and large vessels would need to be setback around 30 m behind the rear crest of the external breakwater to have an *Insignificant* economic Consequence.

- Given overtopping levels expected in the 100 year ARI design event (outlined in Appendix A), the Marine Commercial Zone would need to be setback 25 m behind the rear crest of the external breakwater to have a *Minor* economic Consequence, less than $500,000 damage expected.

Table 7.4 Assessment of Consequence of Overtopping – Building & Vessel Setbacks (Using Table 4.2)

Key Assets	Consequence Scale
Social	
4. Residential Development	Minor
6. Vessels & Vessel Moorings	Insignificant
Economic	
7. Marine Commercial Zone (Hardstand & Buildings/Structures)	Minor
8. Commercial/Retail/ Restaurants	Minor

For Table 7.5, the key points to note regarding the assessment of overtopping Consequences for public access are summarised below.

- Overtopping rates on the breakwaters during a 5 year ARI storm (outlined in Appendix A) would be unsafe for well trained staff who are well shod and protected. Therefore, pedestrian access on the breakwaters during severe storm events could result in loss of life, which corresponds to a *Catastrophic* Consequence.

- Vehicles travelling at low speed are safe on the breakwaters during the 100 year ARI event (outlined in Appendix A) as long as people do not leave their vehicle. This has been set so that if breakwater access is required during a storm, experienced technical staff can access the breakwater via a vehicle to inspect it. This corresponds to a *Minor* Consequence as there may be a small to medium disruption in use of the facilities during and following this significant event.

- The Consequence of wave overtopping on the public promenade is likely to be *Minor* during the 100 year ARI event at present (outlined in Appendix A). This may lead to a small to medium disruption in use of the area during and following this significant event. At the end of the 100 year planning timeframe, wave overtopping during the 100 year ARI event is likely to be dangerous to aware pedestrians with a clear view of the water. Therefore, the wave overtopping could result in injuries or loss of life, which corresponds to a *Catastrophic* Consequence. It should be noted that the wind speeds in the 100 year ARI event are likely to be too strong for most people to stand up in.

- The Consequence of wave overtopping on the boat ramp are likely to be *Minor* during the 100 year ARI event (outlined in Appendix A). This may lead to a small to medium disruption in use of the facilities during and following this significant event.

- External fishing platforms with deck levels at +1.5 mAHD and +5 mAHD would be extremely dangerous during typical winter storms and large swell events, with the potential for waves to inundate the platforms. This could result in loss of life, corresponding to a *Catastrophic* Consequence.

- The Consequence of wave overtopping on public access on the DUP behind the rocky shorelines is *Insignificant* during the 500 year ARI event.

- The Consequence of wave overtopping on public access in the minor car-park behind the rocky shorelines is *Insignificant* during the 500 year ARI event.

Table 7.5 Assessment of Consequence of Overtopping – Public Access (Using Table 4.2)

Key Assets	Consequence Scale				
Social					
1. Breakwater Access - Pedestrian	Catastrophic	Catastrophic	Catastrophic	Catastrophic	Catastrophic
1. Breakwater Access - Vehicular	Minor	Minor	Minor	Minor	Minor
2. Boat Ramp & Trailer Parking	Minor	Minor	Minor	Minor	Minor
3. Public Promenade & Landscaped Areas	Minor	Minor	Minor	Minor	Catastrophic
9. External Fishing Platform @ +1.5 mAHD	Catastrophic	Catastrophic	Catastrophic	Catastrophic	Catastrophic
9. External Fishing Platform @ +5 mAHD	Catastrophic	Catastrophic	Catastrophic	Catastrophic	Catastrophic
10. Southern Rocky Shoreline	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
11. Southern Rocky Shoreline	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
12. Minor Car-park Behind External Beach	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant

7.4 Risk Evaluation

Based on the matrices presented in Tables 4.3 and 4.4 in conjunction with the results of the risk analysis completed previously, Table 7.6 presents the wave overtopping risk levels for each of the identified key assets.

The order of the assessed risks in the table has been completed to show the priority risk areas for each planning timeframe at the start of the table, with decreasing risk down the table.

Table 7.6 Preliminary Assessment of Wave Overtopping Risk Levels

Key Asset	Assessed Risk Level				
	Present Day	25 Year Exposure Period	50 Year Exposure Period	75 Year Exposure Period	100 Year Exposure Period
9. External Fishing Platform @ +1.5 mAHD	Extreme	Extreme	Extreme	Extreme	Extreme
9. External Fishing Platform @ +5 mAHD	High	Extreme	Extreme	Extreme	Extreme
1. Breakwater Access - Pedestrian	Medium	Extreme	Extreme	Extreme	Extreme
3. Public Promenade & Landscaped Areas	Low	Low	Low	Medium	Extreme
1. Breakwater Access - Vehicular	Low	Low	Low	Medium	Medium
7. Marine Commercial Zone (Hardstand & Buildings/Structures)	Low	Low	Low	Medium	Medium
2. Boat Ramp & Trailer Parking	Low	Low	Low	Medium	Medium
4. Residential Development	**Low**	**Low**	**Low**	**Low**	**Low**
6. Vessels & Vessel Moorings	Low	Low	Low	Low	Low
8. Commercial/ Retail/ Restaurants	**Low**	**Low**	**Low**	**Low**	**Low**
10. Southern Rocky Shoreline	Low	Low	Low	Low	Low
11. Southern Rocky Shoreline	Low	Low	Low	Low	Low
12. Minor Car-park Behind External Beach	Low	Low	Low	Low	Low

Notes: 1. Asset 5, the Internal Beach is a permeable, sandy beach and therefore not subjected to wave overtopping hazards.

The potential to retrofit the coastal protection structures to accommodate increased sea levels within the coming 100 years will be incorporated into the detailed design of the structures. This would reduce the future overtopping rates and thus the risk posed by increased wave overtopping due to increases in mean sea level. Many of the assets such as the boat ramp and the Marine Commercial Zone hardstand could also be raised when they are replaced, as the majority of the structures only have a 25 year design life. Consequently, these structures and assets have a high degree of Adaptive Capacity and as such their overall Vulnerability to overtopping hazards in the latter periods of the planning timeframes would be lower than the risk levels presented in Table 7.6.

7.5 Risk Adaptation & Mitigation

Table 7.6 highlighted only three key assets with intolerable wave overtopping risk levels over the assessed exposure periods. Possible risk mitigation strategies for these assets are presented in Table 7.7.

Table 7.7 Wave Overtopping Risk Mitigation Strategies

Key Asset	Coastal Hazard Description	Risk Management Approach
9. External Fishing Platforms @+1.5 & +5 mAHD	**Wave Overtopping**	**Avoid.** Move the fishing platforms to an appropriate and safe location inside of the Marina breakwaters where they are offered protection from wave overtopping.
1. Breakwater Access	**Wave Overtopping**	**Accommodate.** Manage pedestrian and vehicular access during storm events. This could be through signage and a gate that is closed during periods of storm events. During a storm event it would be safe for well-trained technical staff to inspect the breakwater from a vehicle travelling at low speeds.
3. Public Promenade & Landscaped Areas	**Wave Overtopping**	**Accommodate.** Overtopping rates are expected to be safe to aware pedestrians on the promenade to the end of the 75 year planning timeframe for storm events less than the 100 year ARI event. After this time, the level of the promenade pathway and crown wall could be raised by around 0.5 to 1 m to reduce the overtopping rates in extreme events.

The remainder of the assets were assessed as having acceptable or tolerable risk levels over the 100 year exposure period. The management requirements for these assets should ultimately be informed by a coastal monitoring regime, as outlined in Section 8. Additionally, one of the key risk management options is for the current structures to consider future crest level increases in the design, which would reduce the overtopping risk if implemented.

8. Ocean Reef Marina Management & Coastal Monitoring

The management and monitoring of the Ocean Reef Marina forms an integral part of the CHRMAP process. The integrity of the breakwaters, seawalls and internal revetments needs to be monitored, as these structures form an integral component of the risk mitigation strategy. Changes in the extreme events due to sea level rise that could alter the risk exposure of the Marina to coastal hazards also needs to be monitored in the future. This could be achieved through review of the Marina CHRMAP every decade or so.

A number of reports have previously been prepared that are relevant to the coastal management of the Ocean Reef Marina and the adjacent shoreline. These reports are listed below.

- Ocean Reef Marina – Coastal Processes Assessment (MRA 2015a)
- Ocean Reef Marina – Beach Wrack Management (MRA 2015b)
- Joondalup Coastal Monitoring Brief (MRA 2015c)

These reports contain details on recommended monitoring programmes and potential management activities and timing. This report collates and summarises these recommendations.

8.1 Responsibility

The existing Ocean Reef Boat Harbour and adjacent shoreline is currently managed by the City, under an agreement with the DoT. DoT are responsible for the dredging of the boat harbour, which has historically involved removal of an average 4,200 m^3 of material per year between 1998 and 2013 (MRA 2015a). There is currently no monitoring or management programme for wrack accumulation within the harbour (MRA 2015b).

With construction of the new Ocean Reef Marina, overall management of the facility should be taken over by the City or by an entity approved by the relevant government authorities. This ensures one entity is responsible for the monitoring and management of the Marina and associated infrastructure. Should multiple parties be involved it is suggested that a Memorandum of Understanding is established to clearly define management and monitoring responsibilities. Coastal aspects that need to be monitored and will likely need to be managed include the following.

- Coastal processes, including erosion and accretion of adjacent beaches and siltation of navigable waters.
- Seagrass wrack accumulation inside and outside of the Marina.
- Coastal structures such as breakwaters and seawalls.

Details of the recommended monitoring and management regime are contained in the following sections.

The City may want to employ a Marina Manager to assist with the daily operation of the Marina should they become the facility manager. This position may be responsible for some of the visual monitoring aspects detailed in the following sections and provides a point of contact for general management issues should they arise.

A number of monitoring activities recommended in the next section will require input from specialist consultants such as coastal engineers and licensed surveyors. These consultants would be commissioned by the City or by the approved entity who is ultimately responsible for monitoring and management of the proposed Ocean Reef Marina.

8.2 Coastal Structures Monitoring & Management

The completed Ocean Reef Marina will consist of a number of coastal structures. The structures are likely to be constructed of rock armour and are listed below.

- External breakwaters.
- External seawall
- Internal revetment.

The coastal structures should be monitored on a regular basis, with maintenance completed as required to ensure they continue to provide an appropriate level of protection. This is in line with the requirements set out in the SPP2.6 for coastal works. This is also an integral part of the CHRMAP process, as the coastal erosion hazards are managed using the Protect risk mitigation strategy. This strategy is also cost effective as routine maintenance reduces the risk of a major, costly failure occurring.

Rock protection structures are somewhat flexible and robust, being able to accommodate some damage without failure. Damage may include movement of rocks, settlement, toe scour, scour from overtopping and fracturing or erosion of rocks.

8.2.1 Structures Monitoring

The following monitoring programme is recommended for the Ocean Reef Marina coastal structures. This is a similar level of monitoring to that currently completed at the Port Coogee Marina.

- Annual visual monitoring of the full length of the structures by coastal engineers. This includes photographs, notes and identification of any areas showing signs of wave overtopping damage, rock movement, crest settlement or general damage.
- Annual survey of the crest levels at fixed locations along the full length of each structure. This aims to quantify the extent and magnitude of any settlement in the seawall crest. A nail can be placed at each survey point to ensure consistent measuring points. This survey should be completed by a licensed surveyor at the same time as the visual monitoring.
- A multibeam hydrosurvey of the full underwater extent of the protection structures should be completed every 5 years. This could be completed in conjunction with the multibeam survey of the waterway (Section 8.3.1). This should be completed by licensed surveyors experienced in hydrosurvey work. A diver inspection could also be completed every 5 years.

Analysis of the visual monitoring and crest survey should be completed by coastal engineers every year, with the findings and recommendations of the analysis summarised in a brief, annual report. Analysis of the multibeam hydrosurvey should also be included in the report as the surveys become available every 5 years.

8.2.2 Structures Maintenance

The need for maintenance would be identified in the annual reporting and should be completed as recommended in the reporting. The type of maintenance required will depend on the damage identified. Rocks that have moved or rolled away may need to be repacked or possibly replaced by imported rocks. Crest settlement can be countered through repacking of existing rocks and the addition of imported rocks. Split or eroded rocks that no longer meet the original design specification can be removed and replaced with imported rocks.

The timing for maintenance will vary depending on the severity and duration of the storms experienced since the previous monitoring and maintenance programme. Minimal damage may result from a series of mild winters. However, a particularly severe storm may cause a number of rocks to move, requiring repacking. Some settlement of the armour crest may also occur in the first 10 years following construction.

For financial planning it is recommended to allow for maintenance of the coastal structures at least once every 5 years. The area immediately adjacent to the breakwater and seawall crests should be kept clear to provide access for maintenance equipment and plant during maintenance operations. If landscaping is to be placed in this area, it should be low cost and easily replaceable, as it will be damaged during maintenance works.

8.3 Coastal Processes Monitoring & Management

The coastal processes study included development of a sediment budget for the shoreline adjacent to the existing Ocean Reef Boat Harbour. Extensive wave and sediment transport modelling was also completed as part of this study to determine the potential impact of the proposed Marina expansion on the coastal processes (MRA 2015a). This study found that the sediment fluxes adjacent to the Marina are likely to be quite small.

Given these potentially small sediment fluxes, the management response to the Marina construction should be based on monitoring and subsequent management of the sediment transport to maintain the status quo. Some re-alignment of the beach to the north and south of the Marina may occur due to wave reflections and shadowing effects from the new breakwaters. These re-alignments are likely to be seasonal and should be monitored as outlined in Section 8.3.1.

The coastal processes management approach proposed here is slightly different to the case where the Marina was proposed to be constructed on an active sandy coastline with large sediment fluxes, which would typically require a more structured and pre-emptive management response.

8.3.1 Coastal Processes Monitoring

The most important aspect of the future coastal management regime will be to ensure that adequate coastal monitoring is completed. The *Joondalup Coastal Monitoring Brief* (MRA 2015c) outlines the recommended monitoring programme for the Joondalup coast, extending from the northern end of Waterman's Bay in the south to Burns Beach in the north. This monitoring scope encompasses the Ocean Reef Marina and is expected to be suitable for monitoring the potential impacts of the newly constructed Ocean Reef Marina on the coastal processes.

Full details of the proposed monitoring can be found in MRA (2015c), with a summary of the proposed monitoring activities included below.

- Photographic monitoring at 18 locations every 6 months or after significant storms. This could be completed by City officers.

- Shoreline mapping every 1 to 2 years using rectified aerial photographs. This could be completed by the City if they have appropriately experienced staff, or by experienced coastal engineers.

- Dune, beach and nearshore surveys at 21 locations every 2 years. Licensed surveyors should be used to complete the surveys.

This beach monitoring programme has recently commenced which will provide a base line data set for comparison prior to the Marina construction. The alignment of the beaches to the north and south of the Marina should be monitored so that management measures can be put in place should this be required. In the first year, particular attention should be placed on monitoring the beach alignments, as changes in alignment could occur quickly.

The other item to be considered regarding the monitoring and management requirements for the Marina would be the potential for siltation of the entrance channel. This could be due to the entrance partially capturing some of the sediment transport that may occur around the Marina. To monitor the potential siltation, a multibeam survey of the Marina navigation entrance should be completed by a licensed surveyor experienced in hydrosurvey work. This navigation survey should be completed annually for the first 5 years and then every 5 years if no major siltation issues are observed.

Analysis of the photographs, shoreline mapping and the beach and navigation entrance surveys should be completed by experienced coastal engineers every 2 years, following receipt of the surveys. This analysis would aim to identify and account for significant changes in shoreline movement and propose management options such as beach nourishment as required. Specific focus on the Ocean Reef Marina would be necessary to identify if the Marina construction has contributed to any shoreline changes. The findings and recommendations of the analysis would be summarised in a report prepared by coastal engineers every 2 years.

8.3.2 Coastal Processes Management

The requirement for coastal processes management would be identified in the reports prepared every second year. As noted previously, the sediment fluxes adjacent to the proposed Ocean Reef Marina are likely to be quite small (MRA 2015a). Some re-alignment of the beaches to the north and south of the Marina may occur due to wave reflections and shadowing from the breakwaters. These re-alignments are likely to be seasonal in nature depending on the dominant wave conditions. The management response to the Marina construction should be based on the monitoring report recommendations and subsequent management of the sediment transport to maintain the status quo.

For financial planning purposes, MRA (2015a) recommends allowing for the placement of around 15,000 m^3 of beach nourishment on the northern side of the Marina every 5 years. This sand is most likely to be sourced from a terrestrial sandpit, as access to the southern beaches for sand bypass operations is limited.

With regards to potential dredging of the Marina entrance channel, for financial planning purposes, MRA (2015a) recommends allowing for the dredging of around 10,000 to 20,000 m^3 of material every decade.

8.4 Seagrass Wrack Monitoring & Management

8.4.1 Seagrass Wrack Monitoring

A seagrass wrack monitoring programme was developed by MRA and presented in the *Ocean Reef Marina – Beach Wrack Management* report (MRA 2015b). Full details of the proposed monitoring can be found in MRA (2015b), with a summary of the proposed monitoring activities outlined below.

- Visual monitoring of seagrass accumulation inside the Marina, including the waterways, internal beach, boat ramp and other areas. This could be completed by the Marina Manager as part of their daily operations and would guide the management of any larger accumulations.

- Visual monitoring of seagrass accumulation outside the Marina every 6 months in conjunction with the coastal photo monitoring (Section 8.3.1). This could be completed by City officers.

- Navigation monitoring with an annual multibeam survey of the Marina entrance (as detailed in Section 8.3.1) and a multibeam survey of the whole Marina waterway every 5 years. This should be completed by licensed surveyors experienced in hydrosurvey work.

Analysis of the seagrass wrack monitoring should be completed by coastal engineers every second year in conjunction with the coastal monitoring analysis. The findings and recommendations of the analysis would be summarised in a report prepared every second year.

8.4.2 Seagrass Wrack Management

Small quantities of wrack which may accumulate from time to time around the Marina will be removed as part of the general rubbish removal and cleaning operations. This may accumulate among the rocks of the breakwaters and edge walls, on the beach, boat ramps and other structures. It is assumed this would be catered for under general rubbish and wrack removal operating budgets for the Marina. This is consistent with the approach of areas such as the Fremantle Harbours.

Larger accumulations which may enter the Marina could be removed in one of the following ways:

- Removal by weed barge or trap. This would likely only be required following periods of northwesterly storms.

- Removal by machine from areas such as the beach or boat ramp. This could be completed by bob-cat or small excavator for example. The wrack would likely need to be disposed of to landfill, or approved wrack disposal sites.

The method of removal as outlined above would likely be determined based on the actual accumulations and may vary from year to year. Surface wrack which is being dispersed around the waterways could be removed by the barge. Accumulations in fixed areas could be removed by machine.

Should large accumulations of wrack be identified at depth and impacting water quality or navigation, removal could be completed in one of the following ways.

- Removal by fishing trawler. This has been trialled by the DoT at Jurien Bay and Port Geographe. The trawler uses nets to collect the wrack, which can be towed to an offshore disposal site or offloaded onshore for disposal.

- Removal by dredge. Wrack has been removed by dredge in a number of locations around Western Australia, including Port Geographe. This can be time consuming and costly, as dredging operations need to be modified specifically for the wrack.

Each of these methods has been successfully utilised in marinas and harbours in Western Australia.

Accumulations present on the beaches and shorelines adjacent to the development may naturally disperse and break down, as they currently do on the shorelines of Mullaloo or Ocean Reef. However should the accumulations begin to impact the recreational values of these areas, the City may want to mechanically remove the wrack.

It is recommended machine access is provided to the beach north of the development. This would allow wrack to be excavated and removed. This may be considered comparable to beach sweeping or cleaning for recreation.

Given the dynamic nature of wrack and the natural variations in metocean conditions it is not possible to precisely estimate the quantities or timing associated with management of wrack. Possible timing for the various management measures are outlined below.

- Management of small internal wrack accumulations as required as part of the rubbish removal works.

- Management of internal wrack accumulations by weed barge or mechanical excavation as required, possibly once per year.

- Management of external wrack accumulations on the northern beach as required, possibly once per year.

- Management of external wrack accumulations on the southern beaches as required, possibly once every 5 years.

- Removal of wrack accumulations on the Marina seabed as required, possibly every 10 years.

8.5 Review of CHRMAP

The Ocean Reef Marina CHRMAP was developed using current day projections of future sea level rise. Future sea levels may not match these projections, which has the potential to alter, both positively and negatively, the results of the risk analysis.

Mean sea levels should be recorded and analysed in the future so that observed sea levels can be compared to the projections used in this CHRMAP. Advice on sea level rise projections provided by the WA Government should also be noted and compared to the projections used in this CHRMAP.

The CHRMAP for the Ocean Reef Marina should then be reviewed every decade or so to identify if the assessed risk levels are still appropriate. This will allow adaptation and mitigation strategies to be implemented as new information on climate change comes to light.

8.6 Summary

The previous sections collated and summarised the various monitoring and management recommendations from a number of coastal reports (MRA 2015a, 2015b, 2015c).

Table 8.1 presents the recommended coastal monitoring programme for the Ocean Reef Marina. All activities presented in Table 8.1 would be managed and funded by the City or approved entity but a number of these activities will require input from specialist consultants such as coastal engineers and licensed surveyors.

Table 8.1 Recommended Coastal Monitoring Programme

Item	Frequency	Completed by
Visual monitoring of internal wrack accumulation	Daily	Marina Manager
Photo monitoring of external beaches & seagrass wrack accumulation	Twice annually & after storms	City Officers
Coastal structures visual monitoring, crest survey & reporting	Annually	Coastal Engineers & Licensed Surveyors
Shoreline mapping (aerial photographs)	Every 1-2 years	City Officers or Coastal Engineers
Dune, beach and nearshore surveys	Every 2 years	Licensed Surveyors
Coastal processes & seagrass wrack monitoring report	Every 2 years	Coastal Engineers
Navigational survey for sand and seagrass wrack accumulation	Annual 0-5 years then every 5 years	Licensed Surveyors
Multibeam survey of breakwater & full internal waterway	Every 5 years	Licensed Surveyors

The recommended monitoring programme frequency is presented in Table 7.2.

Table 8.2 Recommended Coastal Monitoring Programme

Item	Years Since Breakwater Construction									
	0	1	2	3	4	5	6	7	8	9
Photo monitoring of external beaches & seagrass wrack accumulation [1]	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X
Coastal structures visual monitoring, crest survey & reporting	X	X	X	X	X	X	X	X	X	X
Shoreline mapping [2]	X		X		X		X		X	
Dune, beach and nearshore surveys [2]	X		X		X		X		X	
Coastal processes & seagrass wrack monitoring report [2]	X		X		X		X		X	
Navigational survey for sand and seagrass wrack accumulation [3]	X	X	X	X	X					X
Multibeam survey of breakwater& full internal waterway	X				X					X
Review sea level rise & CHRMAP	X									X

Note: 1. Completed at least twice annually and following severe storms.
2. Base line data on shoreline movement and beach surveys should be collected a number of years prior to the Marina construction.
3. Monitoring frequency extends to once every 5 years if no significant siltation or seagrass wrack accumulation identified in first 5 years.

Given the dynamic nature of coastal processes and the natural variations in metocean conditions it is not possible to precisely estimate the quantities or timing associated with management of the Ocean Reef Marina. Table 8.3 presents the potential timing of the coastal management regime at Ocean Reef Marina. The frequency estimates presented in Table 8.3 should be viewed as indicative.

Table 8.3 Possible Coastal Management Regime

Item	Frequency
Management of small internal wrack accumulations	As required
Management of internal wrack accumulations by weed barge or mechanical excavation	As required, ~1 year
Management of external wrack accumulations (northern beach)	As required, ~1 year
Sand nourishment of northern beach using imported fill	As required, ~5 years
Management of external wrack accumulations (southern beach)	As required, ~5 years
Maintenance of coastal structures	As required, ~5 years
Removal of wrack accumulations and sand build-up on Marina seabed	As required, ~10 years

9. Summary & Conclusions

The City of Joondalup (the City) proposes to redevelop the existing Ocean Reef Boat Harbour into a world class marina featuring recreational, boating, residential and tourist precincts. The City commissioned MRA to develop a CHRMAP for the proposed Marina. Preparation of this plan is consistent with the requirements of the amended SPP2.6 (WAPC 2013), including the assessment of hazards from coastal erosion and coastal inundation.

The SPP2.6 provides a number of variations to the standard case, where development may need to occur within an area identified to be potentially impacted by physical processes within the 100 year planning timeframe. Section 7.4 identifies Industrial and Commercial development such as marinas as a variation within the SPP2.6.

The proposed breakwater structures are required to provide wave shelter to the Marina waterbody for boats and other uses. Engineered seawall and revetment structures will also be constructed along the internal shoreline of the Marina. These structures will provide coastal protection to the internal key assets and will be designed in accordance with contemporary design methods and sound engineering design practice.

The potential to retrofit the structures to accommodate increased sea levels will be incorporated into the design. It is also recommended that the breakwaters and internal revetments be monitored and maintained as detailed in Section 8 of this report to ensure they continue to provide an appropriate level of protection. This is in line with the recommendations of the SPP2.6 for coastal works and is an integral component of the CHRMAP for the Marina.

Analysis and evaluation of the coastal erosion risk revealed that all of the key assets have acceptable or tolerable levels of risk over the 100 year planning timeframe.

Analysis and evaluation of the coastal inundation risk revealed that all of the key assets have acceptable or tolerable levels of risk over the 100 year planning timeframe.

Three key assets were shown to have an intolerable level of risk from wave overtopping. These assets are outlined below.

- The external fishing platforms are unsafe during severe storm events due to the large waves that are likely to be experienced on the outside of the breakwaters. It is recommended that the fishing platforms are constructed at an appropriate and safe location inside the breakwaters to reduce this risk to a tolerable level.

- Pedestrian access on the breakwaters during storm and large swell events would be tolerable today but would increase to intolerable over the coming 25 years. At present it would be dangerous and unsafe to allow pedestrian access to the proposed breakwaters during very severe storm events. This hazard is from both wave overtopping and winds. Management of pedestrian and vehicular access should be implemented during storm events. This could be through signage and a gate that is closed during periods of storm events. Breakwater access would still be safe for well trained staff travelling in vehicles at low speed.

- At the end of the 100 year planning timeframe, wave overtopping during the 100 year ARI event is likely to be dangerous to pedestrians on the promenade. The promenade level and crown wall could be raised after approximately 75 years to reduce the wave overtopping risk.

It is planned as part of the design of the structures to be able to accommodate some future increases in crest height. This ensures the structures have some available Adaptive Capacity to minimise any future risk changes. No further adaptation or mitigation measures are proposed to accommodate this risk at present.

A recommended coastal monitoring and management programme was also developed for the Ocean Reef Marina. Mean sea levels should be recorded and analysed in the future so that observed sea levels can be compared to the projections used in this CHRMAP. The CHRMAP for the Ocean Reef Marina should then be reviewed every decade or so to identify if the assessed risk levels are still appropriate. This will allow adaptation and mitigation strategies to be implemented as new information on climate change comes to light. The integrity of the breakwaters, seawalls and internal revetments also needs to be monitored, as these structures form an integral component of the risk mitigation strategy.

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11. Appendices

Appendix A Concept Design Report (MRA 2016)

Appendix B Consultation Summary Table

Appendix A Concept Design Report (MRA 2016)

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creating better coasts and ports

R748 Rev 0

April 2016

City of Joondalup

Ocean Reef Marina
Concept Design Report

marinas
boat harbours
canals
breakwaters
jetties
seawalls
dredging
reclamation
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1. Introduction

The City of Joondalup (City) is investigating the development of the Ocean Reef Marina (the Marina), approximately 25 km north of Perth, Western Australia. Various planning and approval studies have been completed for the Marina development.

In 2010 and 2011, specialist coastal and port engineers M P Rogers & Associates Pty Ltd (MRA) was commissioned to assist with the conceptual design and development of a business case for the Marina Concept 7.2A shown in Figure 1.1.

Figure 1.1 Ocean Reef Marina Concept Plan 7.2A (TBB dated 28 March 2014)

The conceptual sections presented in Appendix A were developed to assist with the Concept 7.2A Marina business case. This report summarises the conceptual design of the Marina with the purpose of providing additional information to the Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) prepared for the Marina (MRA 2016).

The concept design criteria and sections presented in this report are subject to change following preliminary and detailed design. Further details on the development of the conceptual Marina layout and sections are provided in the relevant report sections.

1.1 Existing Ocean Reef Boat Harbour

Currently a small boat launching facility is situated at Ocean Reef, as shown in Figure 1.2. The boat harbour consists of 8 trailer boat launching ramps and associated finger jetties. The boat harbour is protected by a limestone armour breakwater. It is proposed as part of the Marina development that the existing boat harbour breakwater and ramps are removed and incorporated into the new development.

Figure 1.2 Existing Ocean Reef Boat Harbour

2. Design Criteria

2.1 Design Event

A number of events have been investigated during the conceptual design phase for the Marina.

The rubble mound structures will be designed for the 100 year Average Recurrence Interval (ARI) event. Further details on the combination of waves and water levels used to estimate the 100 year ARI event are provided in Section 3.

The use of the 100 year ARI event for the design of rubble structures is in line with the Department of Transport (DoT) recommendations for the design of breakwater structures in Western Australia and is consistent with other recent marina developments in the state such as Albany Waterfront. Rubble mound structures such as those proposed at the Marina are considered to be robust structures. This means that they can typically withstand (with some damage but not full failure) storm events greater than the design storm.

2.2 Design Water Levels

The water level at the site fluctuates on a varying time scale based on astronomical, meteorological and hydrological effects.

2.2.1 Tidal Levels

Tidal levels at Ocean Reef Marina are expected to be consistent with those measured in around 5 m of water at Fremantle Fishing Boat Harbour (FFBH), 30 km south of the Marina. This is one of the longest tidal records in the state. The Department of Transport (DoT) measures water levels at FFBH and has prepared a submergence curve showing the key tidal levels, see Figure 2.1 on the following page. The key tidal levels are presented in Table 2.1 below.

Table 2.1 FFBH Tidal Levels

Tidal Plane	Prefix	RL (mAHD)
Highest Astronomical Tide	HAT	+0.58
Mean High High Water	MHHW	+0.20
Mean Sea Level	MSL	-0.01
Mean Low Low Water	MLLW	-0.23
Lowest Astronomical Tide	LAT	-0.56

Note: 1. Levels taken from DoT Submergence Curve (DOT 696-33-01 B, March 2004)

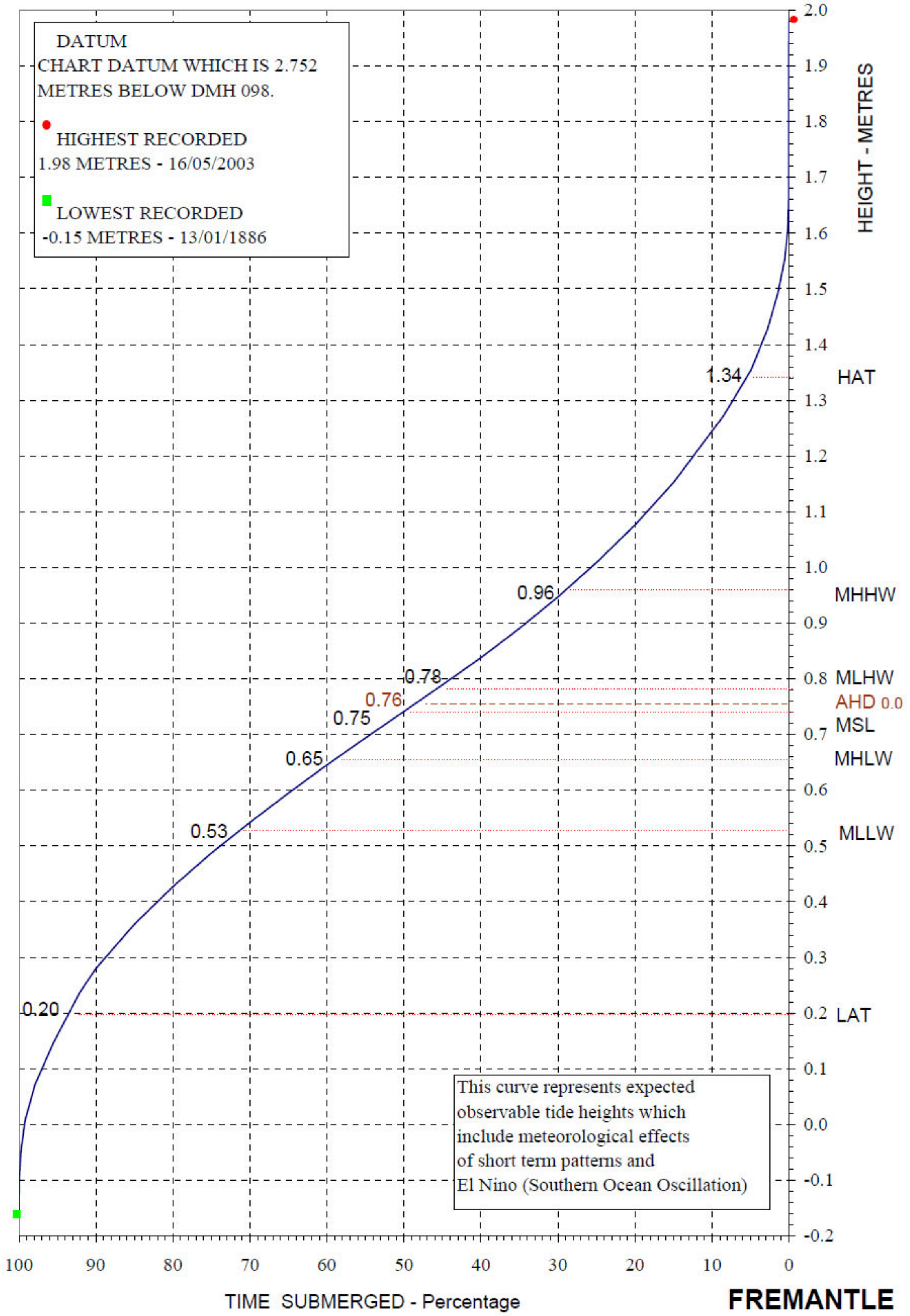

Figure 2.1 FFBH Submergence Curve (DoT 696-33-01 B)

2.2.2 Extreme Water Levels

Whilst astronomical tides can be accurately predicted there is the potential for these levels to be exceeded due to meteorological or hydrological effects.

An analysis of extreme water levels experienced at FFBH has been conducted by MRA based on 65 years of water level records at FFBH from 1950 to 2014. The highest 65 water level events (one for each year) were identified and fitted to an extreme distribution. A Weibull distribution with k=1.25 had the best fit for the data, with the resultant extreme water level values shown in Table 2.2.

Table 2.2 Extreme Water Levels – FFBH

Average Recurrence Interval	RL (mAHD)
1 year	+0.96
5 year	+1.12
10 year	+1.18
50 year	+1.29
100 year	+1.34
500 year	+1.44

2.2.3 Sea Level Rise

Sea level rise must be allowed for in the design of marine structures. The magnitude of this allowance has been determined in accordance with information published by DoT relating to the appropriate allowance for sea level rise in Western Australia (DoT 2010). A plot showing the recommended allowance is provided in the following figure.

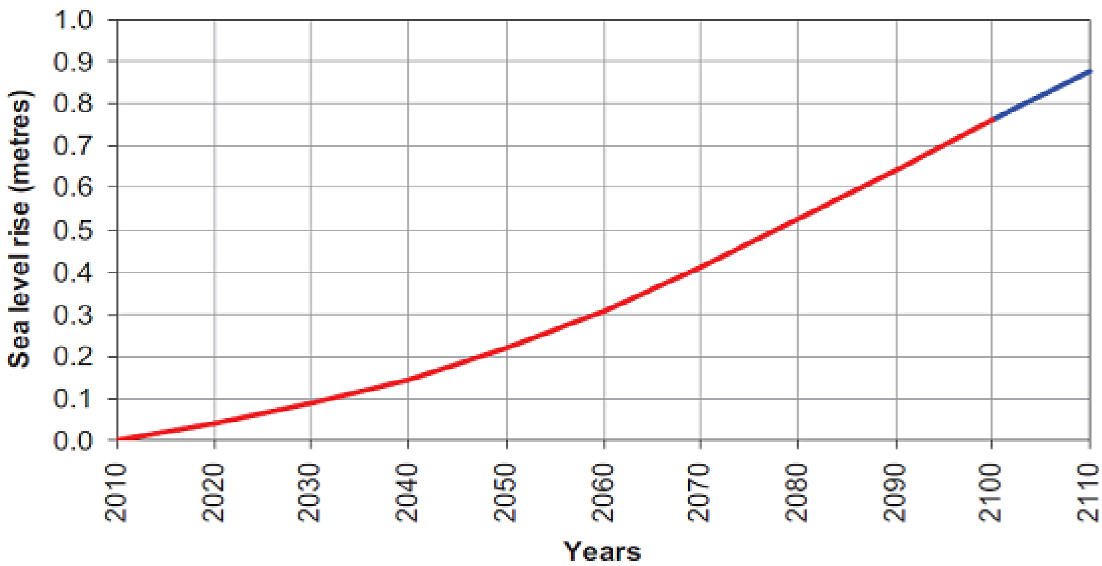

Figure 2.2 Sea level rise in Western Australia (DoT 2010)

Based on the information provided in Figure 2.2 with a base year of 2015, the sea level rise allowances for a range of timeframes were determined and presented in Table 2.3.

Table 2.3 Projected Sea Level Rise

Planning Timeframe	Sea Level Rise (m) (DoT 2010)
Present Day (2015)	0.00
25 years	0.12
50 years	0.34
75 years	0.61
100 years	0.90

Note: 1. Values taken from DoT (2010) using a base year of 2015, assuming 0.03 m of sea level rise between 2010 and 2015.

A 50 year allowance for sea level rise is typically used in the design of rubble mound structures based on DoT recommendations for the design of breakwater structures in Western Australia. Therefore, a sea level rise of 0.34 m was used in the structural design of the rubble mound structures.

The potential to retrofit the coastal protection structures to accommodate increased sea levels beyond the 50 year timeframe has been incorporated into the concept design.

2.3 Design Wave Climate

2.3.1 External Wave Climate

DoT have recorded wave conditions at South-West Rottnest (SWR) in approximately 48 m of water since 1994. MRA has completed an extreme analysis on the SWR significant wave heights (H_s). The highest 50 H_s recordings were identified and fitted to an extreme distribution. A Weibull distribution with k=2 had the best fit for the data, with the results shown in Table 2.4.

Table 2.4 Extreme Wave Heights – SWR

Average Recurrence Interval	Hs (m)
1 year	7.0
5 year	8.1
10 year	8.4
50 year	8.8
100 year	9.0
500 year	9.6

Table 2.4 presents the offshore wave conditions recorded at SWR. A reef system runs parallel to the shoreline where the Marina is proposed to be constructed, as shown in Figure 2.3. This offshore reef reduces the wave heights passing from offshore to nearshore areas.

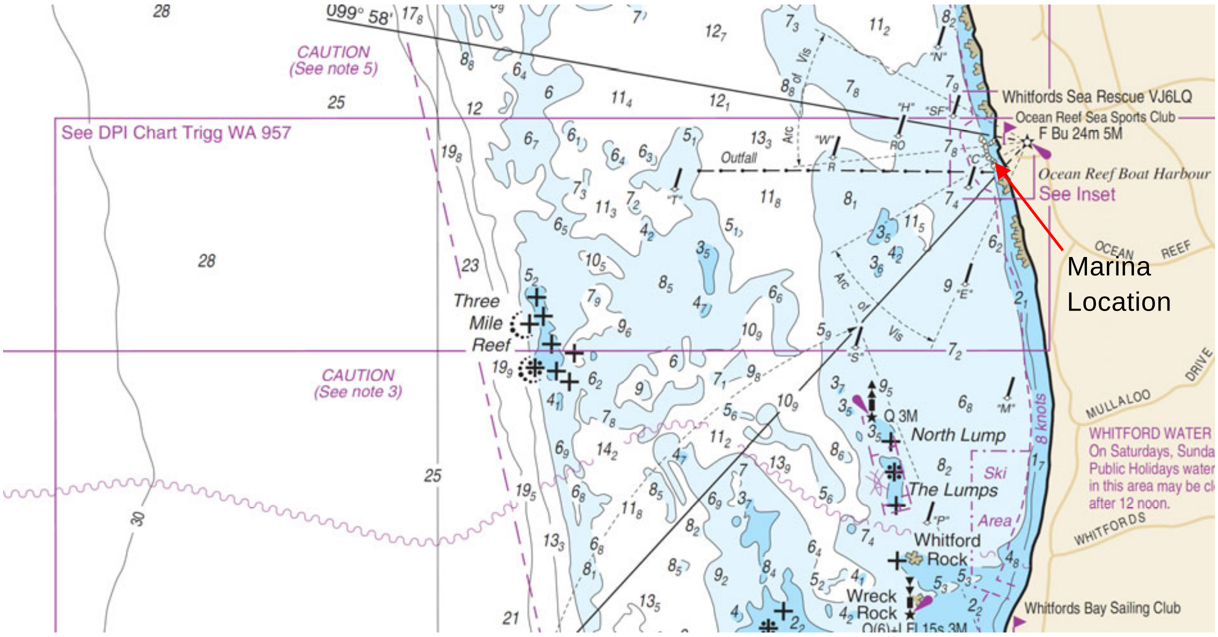

Figure 2.3 ORM Bathymetry (DPI Nautical Chart WA 001)

A number of modelling studies have shown that at the proposed Marina location, the nearshore wave heights in 10 m of water are approximately 40% of the offshore wave heights recorded at SWR. These studies include Worley Parsons (2008 & 2009), MRA (2005), Steedman Science & Engineering (1988). The extreme wave heights calculated at SWR were therefore reduced to 40% of their total to give the wave conditions in 10 m water depth at the Marina. This is presented in Table 2.5.

Table 2.5 Extreme Wave Heights – 10 m of Water @ the Marina

Average Recurrence Interval	H_s (m)
1 year	2.8
5 year	3.2
10 year	3.4
50 year	3.5
100 year	3.6
500 year	3.8

These wave conditions were used in the concept design of the external breakwater armour, crest heights and to determine levels of wave overtopping. The breakwaters are founded at a maximum seabed depth of around -9 mAHD, so the wave heights presented in Table 2.4 are likely to be conservative. Further definition of these wave conditions through detailed wave modelling is required when the project progresses to the preliminary and detailed design stage.

2.3.2 Internal Wave Climate

The external breakwaters and seawalls provide wave shelter to the internal Marina waterbody for vessel mooring and other uses. Wave conditions inside the Marina are therefore much smaller than those outside. The wave climate inside the Marina is made up by a number of wave sources, as listed below.

- Wave penetration through the Marina entrance.
- Locally generated wind waves.
- Waves transmitting through the permeable breakwater.
- Waves overtopping the external breakwater creating waves on the inside of the breakwater.

The conceptual entrance channel arrangement has been based on previous marinas such as Port Coogee. Detailed wave penetration modelling has yet to be completed on this entrance arrangement. This is to be completed as part of the detailed design of the Marina.

The initial concept for the breakwater entrance is for a northwards facing entrance with a navigable width of approximately 50 m. The entrance is proposed to have a breakwater overlap of approximately 150 m. The north facing entrance provides shelter to vessels from prevailing seabreeze conditions, however will be open to northerly swells. The majority of vessel pens are north of the breakwater entrance, therefore any swell penetrating into the Marina experiences a large degree of diffraction before interacting with the pens and vessels.

As wind blows across an expanse of water the friction between the air and water surface generates waves. The height and period of the resulting wave is dependant primarily on the fetch length, water depth, wind velocity and wind duration. Figure 2.4 shows a potential wind fetch from the south-west inside the Marina.

Figure 2.4 Wind Fetch Inside Marina

The wave conditions within the Marina were hindcast using the methods outlined in CIRIA (2007). This results in the wave conditions presented in Table 2.6 for a range of average recurrence intervals. Winds for this assessment were taken from Australian New Zealand Standard (AS/NZS)

1170.2-2011. This assessment did not include the likely dampening effect of any boats, boat pens or piles on the wave conditions and are therefore likely to be conservative.

Table 2.6 Hindcast Internal Wave Climate at Edge Wall

Average Recurrence Interval	Significant Wave Height at Edge Wall (H_s)	Wave period (T_p)
1 year	0.32	1.5
5 year	0.34	1.5
10 year	0.36	1.5
50 year	0.40	1.6
100 year	0.40	1.6
500 year	0.50	1.7

Table 2.6 contains the wave heights at the edge wall. The wave heights at the boat pens would be smaller than these values given the shorter fetch distance from the west and south-west wind fetches.

Using the findings of Briganti et al (2003), the wave heights generated from wave overtopping and transmission through the breakwater were calculated for the 50 year ARI event. This is the extreme recurrence interval used in the classification of internal wave climates. The 50 year ARI event was made up of the following components.

- 50 year ARI H_s = 3.6 m.
- 5 year ARI water level = +1.12 mAHD.
- 50 year sea level rise = 0.34 m.

The breakwater section (Section B) used in this analysis can be found in Appendix A. This gives a combined wave overtopping and transmitted wave height of around 0.25 m during the 50 year ARI storm event. This is the upper limit of the recommended criteria for a 'good' wave climate in AS3962-2001 for beams seas greater than 2 s and less than the requirements of oblique seas.

4. Structural Design

The following section presents the concept design of the following elements.

- External Breakwaters.
- External Seawall.
- Internal Revetment.
- Internal Beach.
- Internal Holding Structure.

The Marina facilities, including Marina berths and jetties have different design standards. Detailed internal wave climate modelling has yet to be completed for the Marina. Hence, only the functional design of the Marina facilities have been completed to date. The structural design will be completed when the internal wave climate modelling has been commissioned and completed.

4.1 External Seawall & Breakwaters

The concept sections for the external seawall (Section A) and breakwaters (Section B) are presented in Appendix A. These sections were developed for the Marina Concept 7.2A business case assessment.

4.1.1 Armour Sizing

The armour size was calculated for the 100 year ARI storm event. The 100 year ARI storm event consists of the following wave and water level conditions.

- 100 year ARI H_s = 3.6 m.
- T_m = 9 s.
- 10 year ARI water level = +1.18 mAHD.
- 50 year sea level rise = 0.34 m.

Two layers of 6 tonne granite armour were calculated for the external breakwater armour. This was based on the Hudson formula (CIRIA 2007) and MRA's experience with physical model flume test results for the Port Headland tug harbour design. Larger rock sizes would be used on the heads. The calculated armour size is conceptual only and is subject to further refinement through detailed wave modelling and detailed design.

4.1.2 Wave Overtopping

Wave overtopping of the external breakwaters and seawalls was calculated for a number of cases. The Owen (1982) formula with revised coefficients from HR Wallingford and the permeable crest berm reduction factor was used to calculate the wave overtopping.

The following cases were investigated.

- Structural performance – 100 year ARI.
- Pedestrian Safety – 5 year ARI.

The 5 year ARI event has been selected as a cutoff for pedestrian safety as per discussions with DoT on previous breakwater structures. This event is approximately the limit in terms of wind strength for pedestrian safety, therefore it is deemed that it will be difficult for pedestrians to stand in an exposed location.

Vehicular access was the critical case during the 100 year ARI event, previously defined in Section 4.1.1. Should it be required, a vehicle can access the breakwaters in an extreme event travelling at a slow speed. Calculations suggest an overtopping rate of around 0.017 m^3/s per m length, which is the lower end of the recommended low speed driving range in CIRIA (2007).

Overtopping results suggest that buildings should be set back approximately 25 m behind the rear seawall crest to avoid structural damage in the 100 year ARI event.

Small and large vessels 30 m or further from the rear crest of the breakwaters are safe from overtopping in the 100 year ARI event.

Overtopping rates were calculated for the 5 year ARI storm conditions. The wave and water level conditions are listed below.

- 5 year ARI H_s = 3.2 m.
- T_m = 9 s.
- 5 year ARI water level = +1.12 mAHD.
- 50 year sea level rise = 0.34 m.

Calculations suggest an overtopping rate of around 0.01 m^3/s per m length. This is around the level that becomes dangerous to all pedestrians, as specified in CIRIA (2007). Breakwater access will need to be managed during storm events to prevent public being exposed to dangerous conditions. This approach has previously been discussed and agreed to with the Western Australian DoT.

It is important to note the reasoning for the selection of this event, that the winds during a 5 year ARI storm will be so strong that pedestrians are unlikely to be able to stand in an exposed location such as a breakwater. This then becomes the design limit rather than overtopping volume.

Further investigation of the design wave conditions is required in the detailed design phase to refine these estimates of wave overtopping.

4.2 Internal Edge Walls

The concept sections for the internal revetments (Sections C, D and E), groyne (Section G) and internal beach (Section F) are presented in Appendix A. These sections were developed for the Marina Concept 7.2A business case assessment and have been further refined following additional concept design.

4.2.1 Armour Sizing

The internal armour size was calculated for the 100 year ARI storm event. The 100 year ARI storm event consists of the following internal wave and water level conditions.

- 100 year ARI H_s = 0.4 m.

- T_m = 1.6 s.
- 10 year ARI water level = +1.18 mAHD.
- 50 year sea level rise = 0.34 m.

Two layers of 1 tonne limestone armour were calculated using the Hudson formula (CIRIA 2007) for the internal protection.

4.2.2 Wave Overtopping

The revetment fronting the Marine Commercial Area (Section C) has a functional requirement to be low, as vessels are generally required to be lifted or launched into and out of the water. In addition, pedestrian access is required across the water/land interface and if the commercial area is set too high, gangway lengths become excessive. The land behind the revetment would be paved for traffic use and boat hardstand.

The revetment fronting the residential areas (Sections D and E) is also proposed to be at a low level to provide a sense of connection between the promenade and the water. The area behind the revetment is also proposed to be paved. Damage from inundation and overtopping would not be expected if the paving is constructed and maintained in good order. To reduce overtopping rates in extreme events, this internal revetment is backed by a low 0.5 m high crest wall. This is shown in Appendix A.

Estimating overtopping rates using the methods set out in Eurotop (2007) for armoured slopes with crown walls and Allsop et al (1995) for composite vertical walls with submerged mounds, pedestrian access along the promenade would be safe for any event less than the 100 year ARI event at present. With sea level rise over the coming 100 years, the 100 year ARI storm event above would become dangerous to aware pedestrians on the promenade with a clear view of the sea.

Overtopping results suggest that residential and commercial buildings will avoid structural damage in the 500 year ARI event in 2115 if they are set back 5 m from the crest of the edge wall. The 500 year ARI event is the 500 year ARI water level with 0.9 m sea level rise in conjunction with the 50 year ARI wave height. This event has been assessed as more critical for overtopping than the 50 year ARI water level with the 500 year ARI wave height.

The concept section of the lower promenade is able to accommodate future lifting of this promenade level if required. Further investigation of the internal wave climate is required in the detailed design phase to refine these estimates of wave overtopping.

4.3 Internal Beach

A beach is proposed to be constructed within the Marina, as shown in Figure 1.1 and Section F in Appendix A. This beach will be backed by a vertical edge wall, as shown in the sketch.

It is proposed that a rock berm at a level 2 meters below Chart Datum (-2.76 mAHD) will be left from the existing Ocean Reef Boat Harbour breakwater in order to help maintain the toe of this internal beach and also to reduce the volumes of imported sand required. This rock berm will extend across the entire toe of the internal beach section.

The beach would be constructed of coarse sand with a slope of approximately 1 in 25. Beach erosion during the 100 year ARI storm was modelled in the SBEACH model. 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 this time the model has been further developed, updated and verified based on field measurements (Wise et al 1996).

SBEACH has also been validated locally by MRA (Rogers et al 2005). This local validation has shown that SBEACH can provide useful and relevant predictions of the storm induced erosion provided the inputs are correctly applied. These inputs include time histories of wave height, period and water elevation, as well as pre-storm beach profile and median sediment grain size. Care should also be taken to ensure that the model is accurately reproducing the recorded wave heights and water levels.

The stability of the beach to wave attack was modelled using two storm events in SBEACH. The wave and water level conditions are presented in Table 4.1.

Table 4.1 Hindcast Internal Wave Climate

Storm Condition	Case 1 100 year ARI Offshore Hs	Case 2 3 x July 1996 Storm as per SPP2.6
H_s	0.4 m	0.32 m
T_m	1.6 s	2 s
Steady Water Level	+1.18 mAHD	Varies from -0.3 to +1 mAHD
Duration	6 hours	334 hours

SBEACH modelling suggest that the beach erodes around 2 to 3 m under both of the storm cases. Figure 4.1 shows the output from the Case 2 storm conditions, which showed the most erosion of the two modelled events.

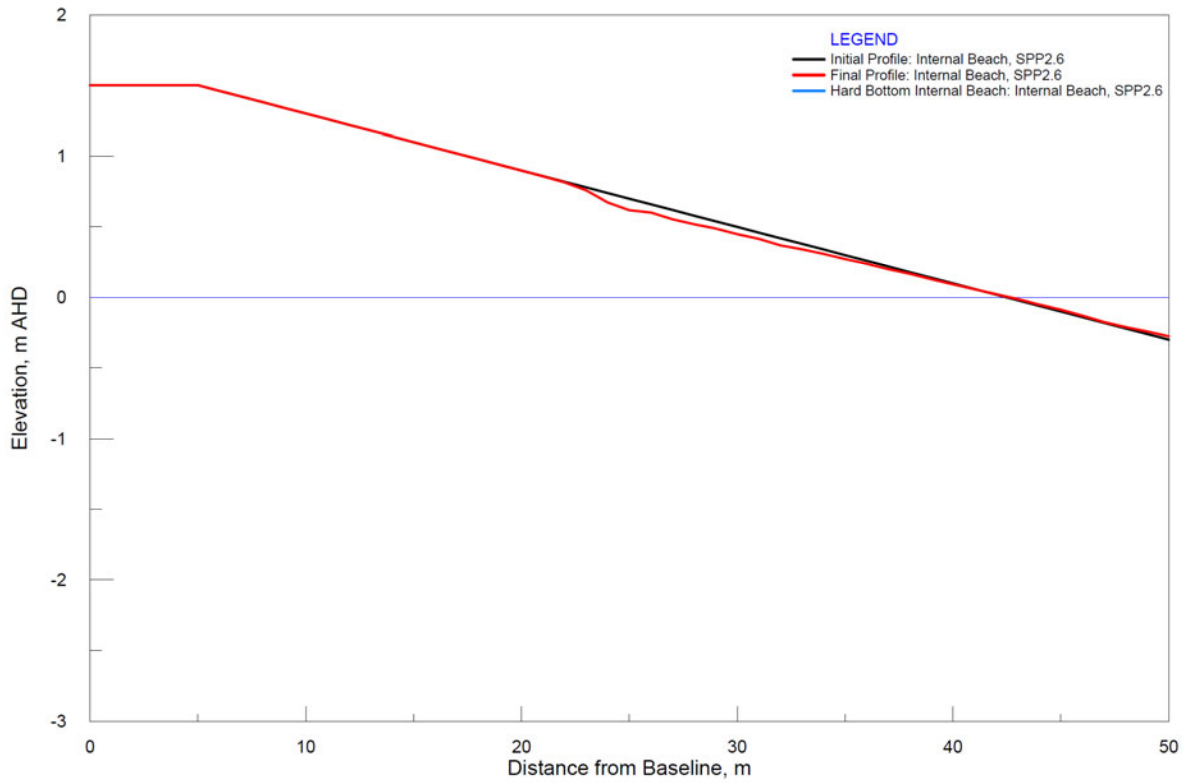

Figure 4.1 SBEACH Output for Case 2 Storm

The SBEACH modelling suggests around 0.3 m of wave setup and runup is experienced on the beach

A rock groyne is to be constructed on the southern side of the beach to prevent loss of sand through longshore transport due to the action of oblique boat wake and wind waves. The proposed groyne section is presented in Appendix A (Section G). The northern side of the beach would be held in place by the impermeable reclaimed peninsula (Section E).

4.4 External Beaches

The external beach shown on the concept plan (Figure 1.1) is no longer being considered for construction. Further details on the existing sandy and rocky beaches to the north and south of the proposed Marina are contained in the Marina CHRMAP (MRA 2016).

5. Summary

The City of Joondalup (City) is investigating the development of the Ocean Reef Marina, approximately 25 km north of Perth, Western Australia. Various planning and approval studies have been completed for the Marina development.

To date, only conceptual design of the Marina breakwaters, seawalls and internal edge treatments has been completed for cost estimation purposes. This report summarises the conceptual design of the Marina with the purpose of providing additional information to the Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the Marina (MRA 2016). The concept design criteria and sections presented in this report are therefore subject to change following preliminary and detailed design.

6. References

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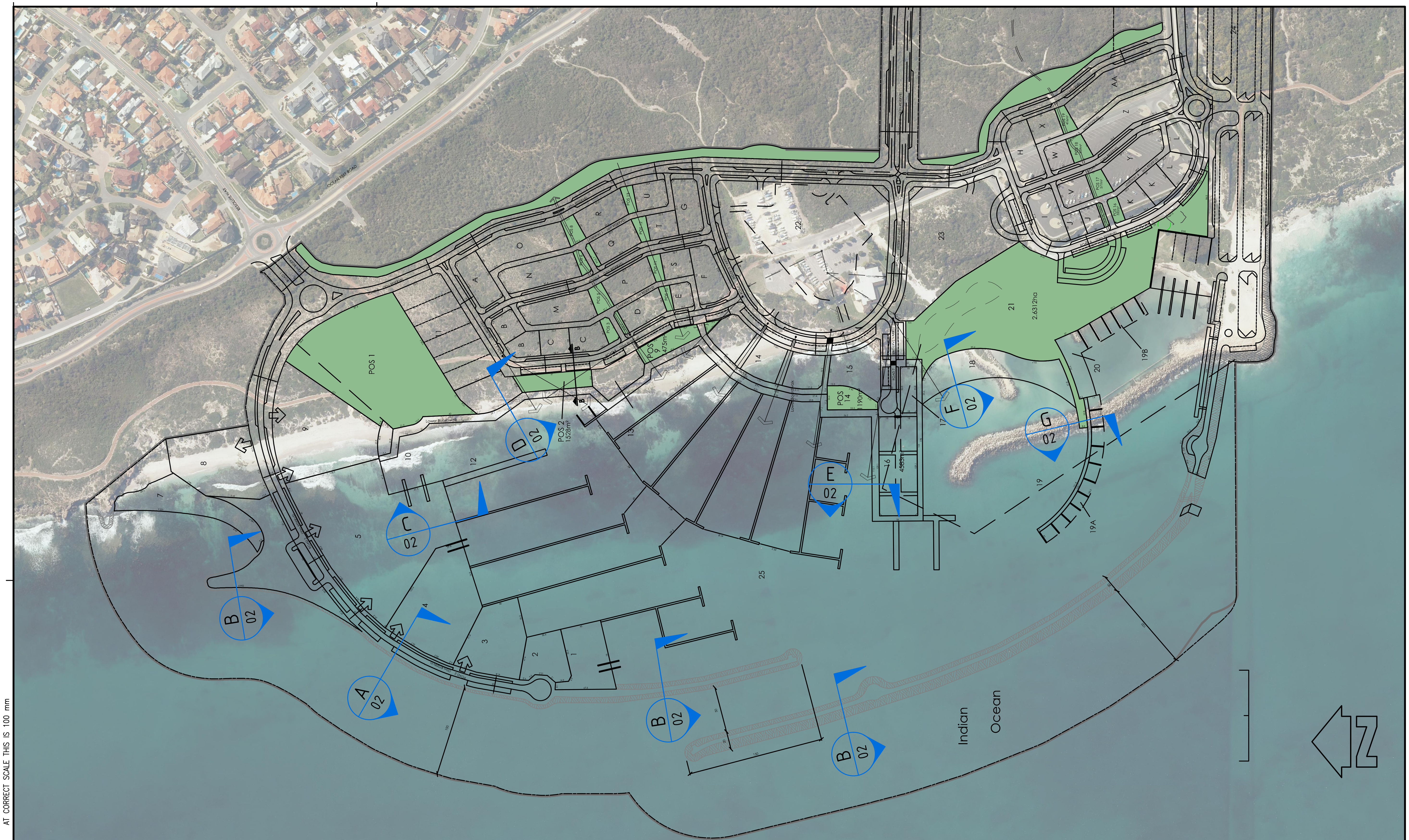
7. Appendices

Appendix A Marina Concept Sections

Appendix A Marina Concept Sections



AT CORRECT SCALE THIS IS 100 mm

NOTES:

1. LAYOUT PLAN DATED 20 NOVEMBER 2014 PROVIDED BY TBB.
2. REFER MRA SKETCH SK1217-03/03/16-2 FOR INDICATIVE SECTIONS.

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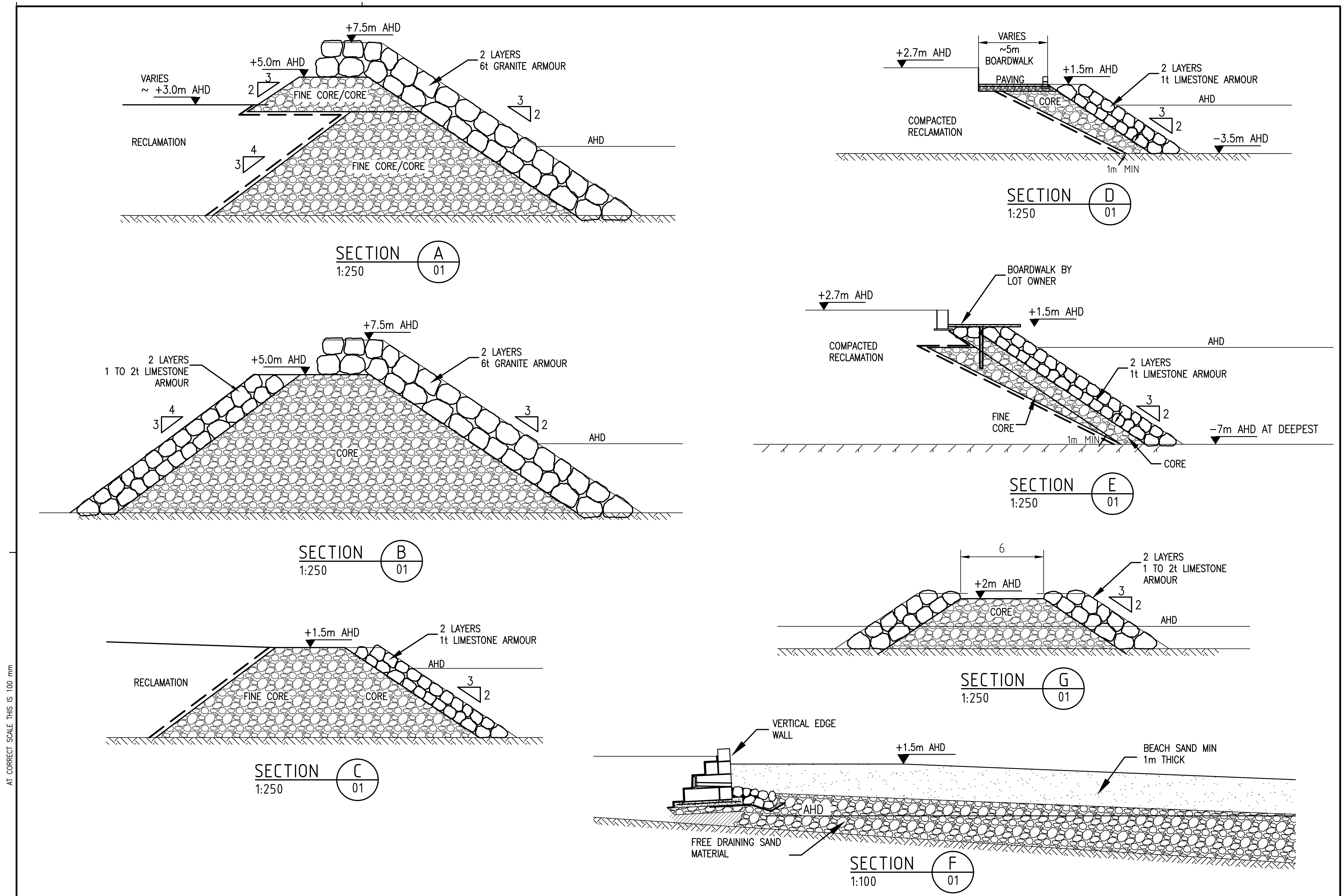
CONCEPT CROSS-SECTION LOCATIONS

OCEAN REEF MARINA

SCALE AT A3 1:4,000

MARCH 2016

SK1217-03/03/16-1A



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CONCEPT CROSS-SECTIONS

OCEAN REEF MARINA

SCALE AT A3 AS SHOWN

MARCH 2016

SK1217-3/03/16-2A

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Appendix B Consultation Summary Table

COMMUNITY/STAKEHOLDER INVOLVEMENT AND SIGNIFICANT HISTORICAL MILESTONES

1979	Part Lot 1029 acquired by the Shire of Wanneroo for the purposes of marina development.
1987	Preliminary structure plan developed.
2000	Investigations undertaken resulting in the preparation of a report *Lot 1029 Ocean Reef and Boat Launching Facility – A preliminary overview of the commercial potential of the location and facilities* (Turen Property Consulting)
2000	Minister for Planning confirms that Lot 1029 identified as "Possible Future Strategic Regional Recreation and Tourism Node" in the final Bushplan.
2001	Ocean Reef Development Committee formed by the City of Joondalup.
2002	Stakeholders workshop facilitated by Taylor Burrell Barnett. Attendees included: • Elected Members • LandCorp • Department of Planning and Infrastructure • Water Corporation • Whitford Volunteer Sea Rescue Group • Ocean Reef Yacht Club • Whitford Sea Sports Club • Ocean Reef Residents Association • Joondalup Coast Care • BBG • MP Rogers & Associates • Bowman Bishaw Gorham
2002	Community consultation undertaken – 500 City residents. Main aims of the survey were to measure awareness of ownership of the land and that it would eventually be developed; expectations about the form the development would take; support for the proposed development and the reasons for and against this. Top line results: 76.6% support or are neutral about the development.
2003	Interagency meetings held with representatives from the Office of Premier, Office of Minister for Planning and Infrastructure, Department of Planning and Infrastructure, Water Corporation, Environmental Protection Authority, LandCorp and the City.
2004	Over 400 submissions received on the development of the Ocean Reef Boat Harbour during the advertising of the City's Principal Activities Plan 2004/05 to 2008/09. All submissions supported the development.
2004	$700,000 grant received from the Minister for Planning for the development of a concept plan for the Ocean Reef Marina.
2005	Ocean Reef Boat Harbour – Risk Management Workshop held. Attended by LandCorp, Department of Planning and Infrastructure and the Project Manager.

2006	Community Participation Plan prepared.
2006	Elected Members questionnaire on what they would like to see at the Ocean Reef Marina.
2007	Public Submissions on what the public would like to see at the Ocean Reef Marina and nominations for the Ocean Reef Marina Community Reference Group. 456 submissions received.
2007	Ocean Reef Marina Committee (of Council) established Ocean Reef Marina Government Steering Committee established
2008	Ocean Reef Marina Community Reference Group established to provide input into the development of the Ocean Reef Marina concept design.
2009	Following Council endorsement to advertise Concept Plan 7 an intensive media campaign was launched including electronic and print media, web, information booths at local shopping centres, displays at the City's Libraries, Leisure Centres and Customer Services Centres.
2009	Community survey on Concept Plan 7. 11,728 submissions received. Top line results 93.5% supported the development of a marina at the Ocean Reef Boat Harbour site.
2013	Three community forums conducted attended by approximately 600 members of public.
2014	Following the decisions of the WAPC and EPA in relation to the Metropolitan Region Scheme Amendment, a media campaign (newspaper, web and social media) was undertaken to inform the community of the project status.

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