City of Rockingham

North Rockingham Coastal Adaptation Plan

Prepared as part of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project

COCKBURN SOUND COASTAL ALLIANCE

city of Rockingham
where the coast comes to life

Executive Summary

Sections of the Rockingham coast are exposed, and vulnerable to coastal processes, including erosion and inundation. Over time, the coast will become increasingly vulnerable to the impacts of sea level rise, storm surges and changes in sediment regimes.

The City of Rockingham, together with the Cities of Fremantle, Cockburn and Kwinana, forms part of the Cockburn Sound Coastal Alliance, which is delivering the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project. The stages of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project are:

Stage 1 – Coastal Vulnerability Assessment (completed in February 2013):

Stage 2 – Values and Risk Assessment (Completed in November 2014)

Stage 3 – Coastal Adaptation Plan

Stage 4 – Implementation and Monitoring

Stage 3 of the project aims to ensure that coastal communities and local governments along the Owen Anchorage and Cockburn Sound coast are informed of the risks and are prepared to respond to the threats posed by current and future coastal hazards.

This plan has been prepared to adapt to the changing coast south of the Swan River, and provides recommended timeframes and trigger points for decision-making and planning for the Rockingham coast. The plan has been prepared as the first iteration of an evolving, long-term planning and decision-making process for the City of Rockingham, the community, and key stakeholders to adapt our settlements and infrastructure to coastal processes – including risks of coastal erosion and inundation.

The adaptation plan includes an implementation stage that recommends specific coastal adaptation activities to be delivered in the immediate (15-year) planning horizon. Supporting this, the plan provides a road map for incorporation of adaptation planning into the City of Rockingham's strategic plans, land use planning framework, long-term financial plan, and decision-making processes. The plan also identifies key regional strategic planning activities to be delivered by the state government to facilitate adaptation planning at the local scale.

Irrespective of the lead for preparing adaptation plans, there are a number of stakeholders and decision makers involved in adaptation planning. Successful adaptation planning over time requires cooperation from all levels of government, the community, together with asset owners and managers. Funding will be a key issue for the implementation of adaptation planning.

The adaptation plan has been prepared based on a number of principles that underpin the adaptation planning process.

- Principle 1 Adaptation planning in the current planning horizon does not impede the ability of future generations to respond to increasing risk beyond current planning horizons.
- Principle 2 Adaptation requires a decision-making framework that enables the right decision to be made at the right time, in line with the values and circumstances of the time.
- Principle 3 Adaptation planning reflects the public's interest in the social, environmental and economic value of the coast.
- Principle 4 Alternative adaptation measures should consider the full range of land uses and values.
- Principle 5 The full life-cycle benefits, costs and impacts of coastal protection works should be evaluated in considering adaptation options.

These principles are the basis of a flexible adaptation pathway for the City of Rockingham.

Flexible Adaptation: we prepare our governance and planning frameworks to maintain flexibility in available adaptation options, so that the right decisions can be made at the right time.

As risk to coastal assets increase from tolerable to intolerable over time, decisions will need to be made about how we adapt to that risk. These points in time, when decisions are required, are trigger points for adaptation planning.

Adaptation planning is cyclical. The flexible adaptation pathway combines decision-making on specific adaptation options (avoid, retreat, accommodate, interim protection) at the time of trigger points with an ongoing strategic planning process that plans for, and therefore maintains, the same range of adaptation options for future decisions in the longer term. In this way, by choosing to accommodate or protect in the short-term, we are not binding future communities to the long-term cost of that decision beyond the design life of the infrastructure or asset.

The adaptation plan includes two planning horizons for decision-making:

- Immediate (15-year) planning horizon: test values and act on any immediate trigger points.
- Long-term (100-year) planning horizon: monitor, set up planning and governance frameworks.

The flexible adaptation pathway is about enabling the community and decision makers to be ready for these triggers when they occur in the long-term planning horizon and beyond. For the majority of the Rockingham coast, trigger points requiring a decision are outside the immediate planning horizon. The coastal area of Palm Beach, however, will experience intolerable risk in the immediate planning horizon, requiring a decision and adaptation works in the short term.

The following table identifies the key focus areas for implementation to establish the flexible adaptation pathway for the long term planning horizon, and specific adaptation measures to manage coastal risks in the immediate planning horizon within the City of Rockingham.

Key focus areas for implementation

Focus for implementation	Responsible Agency
Prepare a management plan for Palm Beach to provide an implementation framework for adaptation, and include immediate term adaptation measures such as: - Groyne or offshore breakwaters at Palm Beach - Dune management and revegetation	City of Rockingham
Fill information gaps that affect decision-making, including modelling of stormwater contributions to inundation in extreme events and depth of inundation.	City of Rockingham
Engage with the community on coastal risks and impacts, values, and the adaptation plan.	City of Rockingham
Incorporate flexible adaptation pathway into strategic planning and governance frameworks	City of Rockingham
Review regional planning documents to facilitate decisions and implementation regarding long-term managed retreat.	Department of Planning and Western Australian Planning Commission
Commence dialogue with infrastructure and land owners and managers regarding the adaptation plan and coastal risk.	Department of Planning City of Rockingham
Review local planning strategy and scheme, to include investigation of special control area and necessary development controls for the coastal vulnerable areas.	City of Rockingham
Monitor risk levels to land and infrastructure	City of Rockingham

The adaptation plan should be reviewed regularly, alongside the ten-yearly reviews of the City of Rockingham Strategic Plan.

Review processes should include targeted community and industry consultation to update values and views about coastal development and assets that will be at risk both within a 15-year planning horizon and beyond. Revised values and new learnings should be used to test recommendations of this adaptation plan, and determine whether adaptation strategies for the 15-year planning horizon require modification as a result of changing values.

It will be necessary to update the hazard mapping from time to time to reflect actual sea level rise, updated projections of future sea level rise and the response of the coast to changing conditions. These updates should occur as new information becomes available.

Rockingham Beach

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1. Introduction

1.1 Project background

The City of Fremantle, along with the Cities of Cockburn, Kwinana and Rockingham, is part of the Cockburn Sound Coastal Alliance, which is delivering the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project. The stages of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project are:

Stage 1 – Coastal Vulnerability Assessment (completed in February 2013):

- Improve the understanding of the coastal features, processes and hazards of the study area (coastal landforms, geological features, sediment supplies, sediment distribution and meteo-ocean processes);
- Identify the degree of exposure and sensitivity of the various sections of coastline to the potential impacts of future weather events and sea level rise associated with both natural variability and climate change.
- Develop an understanding of the vulnerability of the coast within each coastal compartment based on an understanding of current and future physical changes (output from Stage 1);
- Identify significant vulnerability trigger points and respective timeframes for each sediment cell to mark the need for immediate or medium-term adaptation action;

Stage 2 – Values and Risk Assessment (Completed in November 2014)

- Facilitate the understanding of climate science, coastal hazards and risk management amongst key stakeholders (including community);
- Identify what assets are situated along the coast and what services and functions those assets provide;
- Identify the 'value at risk' of coastal assets potentially affected by coastal processes and climate change under different timeframes and climate change scenarios
- Identify and evaluate potential adaptation options for vulnerable areas;
- Quantify the risks in terms of consequence and likelihood of those hazards identified.

Stage 3 – Coastal Adaptation Plan

- In consultation with the key stakeholder groups and community, verify the intrinsic current and anticipated economic, socio-economic and ecologic values of assets at risk;
- In consultation with the key stakeholder groups and community, assess and verify the most effective and feasible adaptation options which can include coastal protections, planning instruments and market interventions;
- Share best practices and lessons learnt; and
- Identify critical data gaps.

Stage 3 of the project aims to ensure that coastal communities and local governments in Cockburn Sound are informed of the risks and are prepared to respond to the threats posed by current and future coastal hazards.

1.2 Purpose of this plan

This coastal adaptation plan provides a decision-making framework and recommended adaptation actions to assist the City of Rockingham adapt to coastal risks in the immediate and long-term.

This coastal adaptation plan is the beginning of the conversation and journey with the community and stakeholders to understand and respond to our changing coast. The plan has a very long-term planning horizon – considering the decisions that will need to be made from now, until 2110.

The plan sets out coastal adaptation pathways and strategies for the Rockingham coast, and forms part of the wider City of Rockingham's strategic framework for its built environment and community.

The plan has been prepared as the first iteration of an evolving, long-term planning and decision-making process for the City of Rockingham, the community, and key stakeholders to adapt our settlements and infrastructure to coastal processes – including risks of coastal erosion and inundation. As the City, stakeholders and the community learn more and understand more about how our coast will change in future, this plan and recommended adaptation responses will evolve to reflect and respond to the values, aspirations, and learnings of our community and stakeholders.

This plan has been prepared to adapt to the changing coast, and provides recommended timeframes and trigger points for decision-making and planning for the Rockingham coast from East Rockingham to Point Peron.

1.3 Previous reports

This plan is based on important work undertaken by the Cockburn Sound Coastal Alliance to understand the vulnerability of the Rockingham Coast and the values and risks of coastal assets in the vulnerable area.

Stage 1 of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project delivered the Cockburn Sound Coastal Alliance – Coastal Vulnerability Study – Erosion and inundation hazard assessment report. The report provides a coastal vulnerability assessment for Cockburn Sound, Owen Anchorage and the east coast of Garden Island. The assessment focussed on potential impacts to the coast from coastal processes, influenced by climate change and associated sea level rise. The investigation identified inundation (flooding) and erosion hazards for the study area for present day, 2070 and 2110.

Stage 2 of the project delivered the Cockburn Sound Vulnerability Values and Risk Assessment Study to understand in more detail the potential impact of the coastal hazards on assets along the coast. The study used a risk-based approach to determine the likelihood of impacts to coastal assets, assessed the value of the assets at risk, and determined the potential consequence of the impacts to understand the cost of the risk. The study also undertook a first pass of potential adaptation options for the coast.

Previous stages of the Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project

1.4 Strategic context

This plan provides a blueprint for decision-making over time, along with an implementation plan for shorter term adaptation actions. It provides a framework for incorporation of adaptation planning into the City of Rockingham's strategic plans, land use planning framework, and long-term financial plan.

As indicated by Figure 1, this plan is not an individual action plan for delivery. It is a blueprint to assist future iterations of the City's and state government strategic plans integrate and deliver coastal adaptation, in consultation with the community. In this way, coastal adaptation planning will be delivered in the City of Rockingham through existing strategic and capital planning processes at the state and local level.

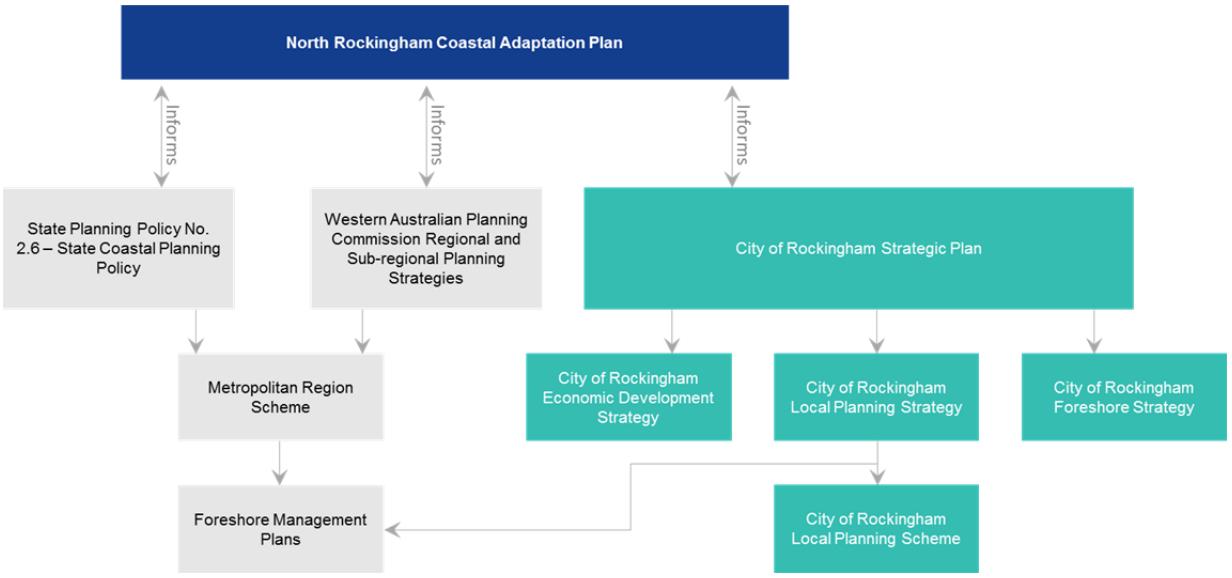


Figure 1 Strategic Context – City of Rockingham Coastal Adaptation Plan

2. The Rockingham Coast

2.1 Value of our coast

The City of Rockingham has a significant history with the coast and has maintained a strong connection with the beach. Rockingham was one of the earliest ports in Western Australia and was established initially as a seaside tourist destination for day-trippers from Perth and later emerged as a residential community alongside the growth of the Rockingham industrial area. The north facing beaches of Mangles Bay are popular amongst residents and visitors due to its protection from afternoon winds. Several beaches along the coast provide recreation and economic opportunities for the city, particularly in the coastal suburbs of Rockingham, Safety Bay and Warnbro where the coast is home to aquatic activities including snorkelling, surfing, windsurfing, recreational fishing and dolphin, sea lion and penguin interaction. Cape Peron, a headland at the southern end of Cockburn Sound, forms part of the Shoalwater Marine Park and is a popular place for diving and swimming.

Rockingham is identified as a strategic metropolitan centre by State Planning Policy 4.2 Activity Centres for Perth and Peel. Rockingham Beach is the home to an existing café strip and future proposed development has been earmarked for the waterfront, including Port Rockingham Marina, providing an extension of the pier and commercial space, and multiple dwellings and short accommodation in a waterfront village. Additionally, the LandCorp-led Mangles Bay Marina project, located east of the Garden Island Causeway, aims to transform Mangles Bay into a lively entertainment and tourist precinct with a new marina, additional recreation areas, and commercial/mixed use and residential development.

2.2 Coastal management units

The Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project has considered the coastal strip between Point Peron and the northern border of the City of Rockingham. Only this portion of the Rockingham Coast has been included in this adaptation plan. To plan for Rockingham's changing coast, the coastal the area included in the study has been broken into a series of coastal management units. The coastal management units were defined in Stage 1 and Stage 2 of the Cockburn Sound Coastal Alliance Coastal Vulnerability & Flexible Adaptation Pathways Project. The study area for the North Rockingham coast includes six coastal management units:

- Management Unit 13 – East Rockingham;
- Management Unit 14 – Rockingham Beach;
- Management Unit 15 – Palm Beach;
- Management Unit 16 – Mangles Bay;
- Management Unit 17 – Peron Foreshore; and
- Management Unit 18 – Point Peron.

Management Unit 13 – East Rockingham

Management Unit 13 (East Rockingham) extends from the coastline boundary of the City of Rockingham and City of Kwinana to Wanliss Street. This unit's coastline contains a large stretch of sandy beach, coastal reserve, the Rockingham Foreshore and other parks. Behind the coast is predominately residential land (south of grain terminal), with an existing standalone grain terminal and private jetty.

The unit has been further divided into three sub-areas, each responding to specific land uses. The nature of the individual land uses may give rise to these areas being treated individually in future iterations of the adaptation plan

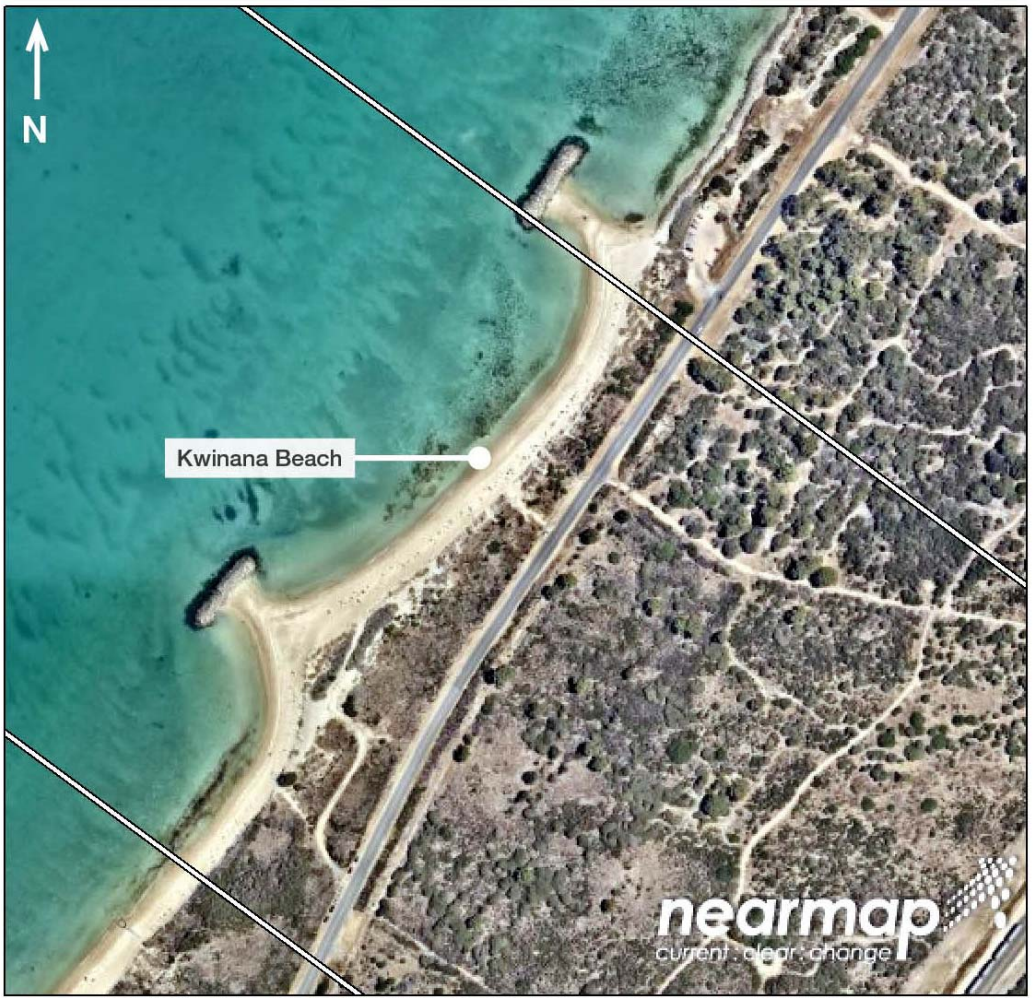


Figure 2 Management Unit 13a – East Rockingham – reserve area

Figure 3 Management Unit 13b – East Rockingham – grain terminal

Figure 4 Management Unit 13c – East Rockingham – foreshore

Management Unit 14 – Rockingham Beach

Management Unit 14 spans from Wanliss Street to Railway Terrace, as indicated in Figure 5. The coastline is primarily sandy beach, with a pedestrian promenade wedged between the coast and the popular Churchill Park.

This management unit has traditionally formed the town centre of Rockingham, with a mix of commercial and retail land uses dominating the properties to the south.

Figure 5 Management Unit 14 – Rockingham Beach

Management Unit 15 – Palm Beach

Management Unit 15 extends between Railway Terrace and Hymus Street, as shown in Figure 6. This unit's coastline consists of a valued public beach within a largely residential land use area.

Figure 6 Management Unit 15 – Palm Beach

Management Unit 16 – Mangles Bay

Management Unit 16 extends from Hymus Street to Causeway, as shown in Figure 7. This unit's coastline is a stretch of sandy beach that is used as a popular recreation area, and is reserved as Port Installations. This unit is also the proposed location of the Mangles Bay Marina development.

Figure 7 Management Unit 16 – Mangles Bay

Management Unit 17 – Peron Foreshore

Management Unit 17 spans from Causeway to the western boundary of Point Peron Recreational Camp, as shown in Figure 8. The coastline of this unit consists of sandy beach under a parks and recreation reservation, with an existing groyne to the west towards Causeway. Point Peron Recreational Camp is located in close proximity to the south of the coast.

Figure 8 Management Unit 17 – Peron Foreshore

Management Unit 18 – Point Peron

Management Unit 18 extends from the western boundary of Point Peron Recreational Camp to the westerly tip of Cockburn Sound, as shown in Figure 9. The coast is largely untouched and remains a parks and recreation reserve and forms part of the Shoalwater Islands Marine Park.

Figure 9 Management Unit 18 – Point Peron

2.3 An evolving coastline

Sections of the Rockingham coast are exposed, and vulnerable to coastal processes, including erosion and inundation. Over time, the coast will become increasingly vulnerable to the impacts of sea level rise, storm surges and changes in sediment regimes. The Coastal Vulnerability and Flexible Adaptation Pathways Project was initiated in 2011 to identify the vulnerability of the coast into the future. In Stage 1 of the project, a coastal vulnerability study was undertaken to understand the future influence of coastal processes. Stage 2 of the project undertook a values and risk assessment, to understand the implications of future coastal processes on coastal land and assets.

The learnings of Stage 1 and Stage 2 vulnerability and risk mapping show that over time, risks to coastal land and assets will increase from tolerable to intolerable. This will require government and the community to make decisions about how the coast will be used in the future.

The risk mapping undertaken in Stage 2 for the Rockingham coast is provided in Appendix A.

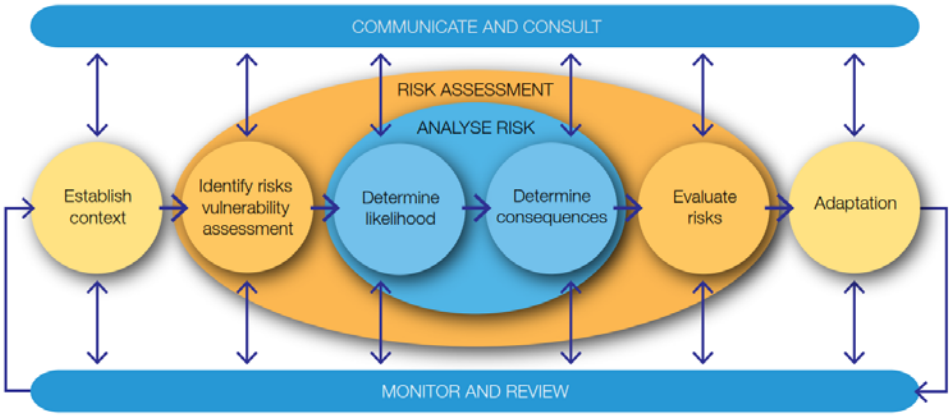
One of the public beaches of Point Peron

2.4 Adaptation planning

What is adaptation planning?

The coast has always been a dynamic, changing environment. As we have settled on the coast, continued changing of the coast line presents risk and impacts to our coastal assets – including social, environmental, and economic assets and values. Adaptation planning is about being ready to manage the risks and impacts of changes to our coast line, by planning for the most appropriate decisions and options to implement over time.

A risk management approach is being used increasingly, nationally and internationally, to deal with potential adverse impacts of coastal hazards. A risk management and adaptation planning approach is a systematic way to identify and understand coastal hazard risks, and implementing controls and measures to manage those risks in consultation with the community and stakeholders.



Risk management and adaptation process from Coastal hazard risk management and adaptation guidelines (WAPC, 2014)

Who is responsible?

In July 2013, the amended State Coastal Planning Policy No 2.6 (SPP2.6) was gazetted by the state government. The amended policy included a requirement for 'responsible management authorities' to prepare coastal hazard risk management and adaptation plans, where existing or proposed development is located in an area at risk of being affected by coastal hazards over a 100-year planning horizon. For many areas of the coast, local government is the land manager. Therefore, local government in Western Australia has been leading the development of coastal adaptation plans.

Irrespective of the lead agency for preparing adaptation plans, there are a number of stakeholders and decision makers involved in adaptation planning. Successful adaptation planning over time requires cooperation from all levels of government, the community, along with asset owners and managers. Key stakeholders and responsibilities for adaptation planning are shown in Table 1.

Table 1 Adaptation Planning – Roles and Responsibilities

Role	Responsibility	Key Stakeholders
Planners and decision makers	Prepare adaptation plan for coastal land within their management. Inform coastal asset owners and users about risk and decision-making. Make adaptation decisions on land and assets within their management.	Western Australian Planning Commission Department of Planning Department of Transport City of Rockingham
Asset owners	Manage assets in the context of coastal risk. Undertake accommodation measures, where consistent with government decisions. Decommission and relocate assets where required by government decisions to retreat.	Private landowners City of Rockingham Infrastructure agencies Department of Parks and Wildlife
Other coastal users	Engage with decision makers regarding the values of the coast to inform decision-making.	Community

Funding will be a key issue for the implementation of adaptation planning. The responsibility for paying for coastal adaptation lies with the beneficiaries of those actions. This includes land and asset owners that benefit from protection strategies, and coastal users that benefit from coastal management approaches. This is particularly relevant in coastal areas managed by the City of Rockingham, where coastal management and protection works provide a direct protection benefit to adjacent asset owners. Where public funds are used for coastal adaptation works, there should be a direct public benefit as a result of that investment.

Ongoing cooperation between local and state government and key asset owners will be required to consider and address these funding issues and responsibilities.

3. Adaptation principles and pathways

3.1 Adaptation principles

In developing a pathway to adapt to Rockingham's changing coastal processes, and guide decisions that are appropriate for the community, the following principles underpin the adaptation planning process.

Principle 1 Adaptation planning in the current planning horizon does not impede the ability of future generations to respond to increasing risk beyond current planning horizons.

Possible scenarios for sea level rise to 2110 informed the preparation of erosion and inundation mapping which underpins this plan. The projections for longer term sea level rise are dependent on the global action taken to mitigate climate change through greenhouse gas emission reductions, and are therefore uncertain. However all scenarios considered by the Intergovernmental Panel on Climate Change (IPCC) give rise to predictions that "sea level rise will continue for many centuries beyond 2100"(IPCC 2014). Accordingly the development of adaptation plans must take account of these predictions.

Existing erosion and inundation risk mapping identifies the coastal hazard zone likely to be affected to 2110, but inevitably beyond that timeframe the risk in this zone will steadily increase, and the zone itself will extend landwards beyond 2110. As no protection measures can be devised that remain effective for hundreds of years, any coastal protection works that are undertaken within the presently identified zone cannot be considered permanent. Continual review of coastal protection works will be required and ultimately, retreat may be the most cost effective option in the very long-term if appropriately planned for. As a result, combating long-term sea level requires different adaptation options alongside an underlying retreat approach that should be strategically identified in the initial stages. This does not necessarily mean that retreat will be the most appropriate option in the current planning horizon; however mechanisms should be in place to allow for this adaptation option to be implemented should future risk be heightened.

Principle 2 Adaptation requires a decision-making framework that enables the right decision to be made at the right time, in line with the values and circumstances of the time.

The dynamic nature of community needs and values requires a flexible approach when considering adaptation options. The effects of climate change on the coast have only recently been identified as a potential concern for some in the community. This was apparent in the minimal interest shown by the community during the consultation undertaken during the preparation of this adaptation plan. The interest and values of the community will change over time as more information becomes available, and impacts of climate change become more apparent. Our approach to coastal adaptation will likely

change with new technology and information, opening up new approaches to manage risk. The ways in which the community uses and values the coast and its assets are likely to continue to evolve over time.

Making decisions based on community values that are likely to change can be considered short-sighted and potentially prevent the best possible outcome when considering short, medium and long-term measures to adapt to changing coastal processes. Adaptation planning should provide opportunity ongoing community consultation and for future action to reflect new technologies and community values at the time of the decision.

Principle 3 Adaptation planning reflects the public's interest in the social, environmental, and economic value of the coast.

Western Australia is renowned for its flowing coastline and beaches. Social and recreation use of such spaces along the coastline form an integral part of Western Australian culture. Public access to the coast and beaches is an iconic part of Western Australia's lifestyle, contributing to the high quality public spaces enjoyed by the community. Our economy and quality of life is supported by coastally dependant infrastructure and industries with potential for future coastal projects critical to the development of the Western Australian economy. The coast also provides important environmental values, with a unique ecology that includes marine, intertidal, and dune habitats.

Adaptation planning should respect the inherent value of the coast that is ingrained in the state's social, environmental and economic interests.

Principle 4 Alternative adaptation measures should consider the full range of land uses and values.

The objectives of State Planning Policy (SPP) 2.6 include the retention of coastal uses for a range of public and private uses including economic uses, coastal foreshore access and social and environmental uses and values, including:

- housing, tourism, recreation, ocean access, maritime industry, commercial and other activities;
- public coastal foreshore reserves and access to them on the coast; and
- landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.

Principle 5 The full life-cycle benefits, costs and impacts of coastal protection works should be evaluated in considering adaptation options.

Coastal engineering works have the potential to provide protection to nearshore coastal assets over their design life, dependent on the rate of future sea level rise. There are two broad categories of protection that have potential for use on the Rockingham coast, and these are set out in the Adaptation Options Compendium (which is a companion to this document):

Engineering (hard) measures: - seawalls, revetments, levees, groynes/breakwaters

Regenerative (soft) measures - beach nourishment and dune restoration

Seawalls and revetments, if implemented without ongoing beach nourishment, will eventually lead to a loss of beach and coastal habitat seaward of the structures, as sea levels rise. Beach nourishment measures require ongoing replenishment in response to storm-related erosion events and sea level rise. Coastal protection measures taken in a specific location may influence the adjacent coastal cells.

Interim protection measures also bring cost impacts. Engineering works can have a high capital cost, and require ongoing investment in maintenance. The cost impact of coastal engineering works should also consider decommissioning costs. Engineering options are designed to mitigate against a particular level of risk, and have a discrete design life. However, the presence of protection works can give a sense of expectation to asset owners, and can potentially limit future decision-making flexibility.

SPP 2.6 includes a presumption against coastal protection measures unless “all other options … have been fully explored”.

Adaptation principles recognise that the most appropriate adaptation decision may differ based on the values to be protected. For example, land protection measures (sea walls) can exacerbate erosion and severely affect beach amenity compared to retreat or natural recession.

3.2 Adaptation pathways

In line with adaptation principles, the most appropriate adaptation pathway is one that enables decision-making on adaptation measures to be made at the right time, in line with the values of that time.

So as to not pre-empt the values of our current and future community, the most appropriate adaptation pathway in Rockingham is:

Flexible Adaptation: we prepare our governance and planning frameworks to maintain flexibility in available adaptation options, so that the right decisions can be made at the right time.

As risk to assets increases from tolerable to intolerable, decisions must be made. These points in time when decisions are required become trigger points for adaptation planning.

The Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC, 2014) set out coastal adaptation options available when making decisions about managing coastal risk (Figure 10). The options shown in Figure 10 and Table 2 should be considered in decision-making as a hierarchy – the further down the hierarchy, the less flexibility there is to consider alternative adaptation measures. Effectively, these options become decisions for government and the community to make when deciding on the future of coastal assets and land.

The adaption options set out in SPP 2.6 are shown in Figure 10 and Table 2.

Figure 10 Hierarchy of risk management and adaptation options (WAPC, 2014)

Table 2 Levels of risk mitigation

Planned or Managed Retreat:	In the face of intolerable risk;	Existing development
Accommodation:	Design and / or management measures that address the risk	
Protection:	Where there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable.	
Avoid	Avoiding development in areas at risk	New development

In the absence of coastal protection works (or other obstacles), as sea levels rise, the shore line, beaches and dune systems will gradually move landwards. Accordingly, the risk to nearshore coastal assets will increase, initially leading to loss of land through erosion (on sandy areas) and leading to occasional and then eventually permanent inundation.

As this sequence of events unfolds, the options available in any specific location depend on the likelihood and consequence of the risk at that time. The decision made will be informed by values of the coast, coastal assets and community. Values will change over time – as they have in Rockingham over the last 100-years – therefore it is important that decisions are made at the time of the trigger point.

A successful adaptation pathway is achieved when decisions made now, in 20 years or in 50 years do not prevent other courses of action being chosen later, therefore retaining ongoing flexibility in decision-making in line with the hierarchy of options. For example, at the end of the life-cycle of interim protection structures, the hierarchy of adaptation options should be reassessed and the adaptation most appropriate for the point in time progressed. There may be a point when the viability of less flexible measures (such as protection) is compromised due to social or economic costs. This requires ongoing strategic planning to retain the full flexibility of adaptation options for future decisions, even when other options are employed in the shorter term.

The recommended flexible adaptation pathway combines decision-making at trigger points on specific adaptation measures (avoid, retreat, accommodate, interim protection) with an ongoing strategic planning process that plans for, and therefore maintains, all adaptation options for subsequent trigger points over time. In this way, by choosing to accommodate or protect in early horizons, we are not binding future communities to the long-term cost of that decision beyond the design life of the infrastructure or asset. The pathway and decision points are illustrated in Figure 11. More detailed description of the trigger points is provided later in this section.

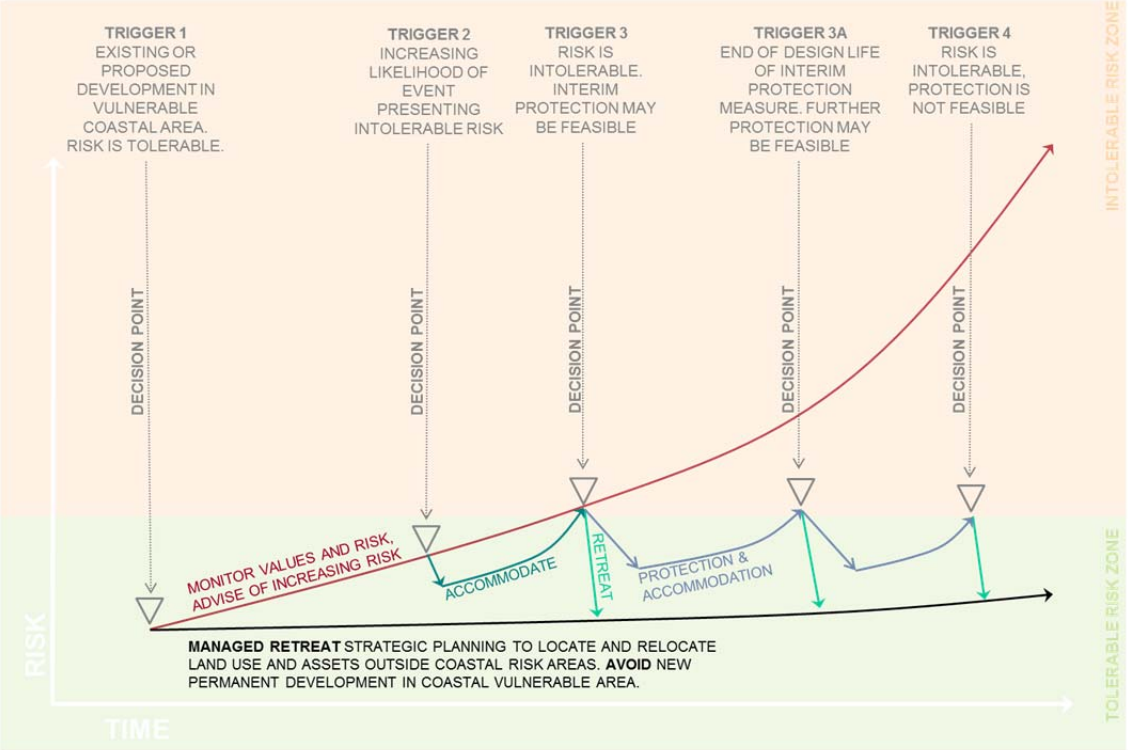


Figure 11 Flexible adaptation pathway

Underpinning the flexible pathway is the need to undertake strategic planning to avoid putting new development at risk, and facilitate changed settlement patterns over time to maintain viability (manage the cost and impacts) of a subsequent retreat decision as other adaptation measures become less feasible and more restrictive over time. This includes information sharing and awareness raising of coastal vulnerability and adaptation, and its impact on economic and social values of the area to manage community expectations for coastal use and development in future. The flexible pathway provides a roadmap to enable retreat from the most vulnerable coastal land in the long-term, while facilitating responsible interim adaptation measures that continue land uses where those measures are justified on social, economic and environmental grounds.

For assets on vulnerable land, a decision to accommodate and/or protect or retreat is dependent on a wide range of factors, including:

- the consequences of taking no action;
- the feasibility and social/environmental/economic costs associated with accommodation/protection compared to the residual value and life of the asset;
- the disruption and costs involved with relocation.

It is not reasonable for government to make judgements or decisions about these factors for individual private assets. Government decisions should reflect a consideration of these factors (and others) in respect of assets collectively in a particular coastal unit. This approach will enable private asset owners to establish their own pathway and make decisions in the light of government action and advice.

There are parallel pathways for government and private asset owners. Whether government decides to facilitate interim protection measures on certain sections of coast, or allow the coast to recede, private asset owners retain their ability to determine the pathway that reflects their own circumstances (where it is not incompatible with or less flexible than a government decision). In order for this approach to be workable and provide certainty to asset owners, it is recommended that the following principles apply to government decisions about coastal protection works:

- Decisions about the appropriateness of coastal protection works are made and implemented/facilitated by government alone, and occur on coastal reserves, notwithstanding whether or not private landowners contribute to costs;
- Any such measures are designed for a finite life, after which the presumption is that the coast will be allowed to naturally recede; and
- Advice is provided to private asset owners about government decisions to protect or otherwise, and the likely residual risk associated with those decisions.

Accommodation measures need to be considered at all times for land identified as being within the vulnerable coastal area, (i.e. at all times after trigger 1 is reached). The nature and extent of accommodation measures will change over time as risks increase, but are still required even in circumstances where protection measures are put in place. All protection options are designed for a certain set of circumstances (e.g. 100 year ARI storm event), and there is a residual risk that either these circumstances will be exceeded or that the protection measure does not perform to expectations. Accordingly accommodate measures also part of protect options, although the nature of the measures may differ.

Planning horizons

The adaptation plan includes two planning horizons for decision-making:

Long-term (100-year) planning horizon: monitor, set up planning and governance frameworks.

Immediate (15-year) planning horizon: test values and act on any immediate trigger points.

For the long-term (100 year) planning horizon, strategic planning should focus on maintaining the ability of community and stakeholders to choose from the most appropriate adaptation measures at future decision points. This includes provision in planning tools for avoid and retreat measures, even if these measures are not put into action in the immediate term.

In the immediate (15-year) planning horizon, any decision points that will arise from increasing risk in that timeframe should be identified. Community values should be confirmed to understand the social, environmental, and economic influences on the decision. Using the values of the time, the decision on the most appropriate adaptation measure (avoid, retreat, accommodate, or interim protection) should be made, and acted upon. This delivers a no-regrets adaptation decision, reserving the right to review investment and protection strategies over time. 15 years is sufficient to implement necessary planning controls in local planning schemes if retreat is required, and to commence budgeting for required adaptation measures.

This adaptation plan presents strategic planning measures to incorporate a flexible pathway into immediate (15-year) and long-term (100-year) planning horizons in the City of Rockingham. The plan recommends adaptation measures for the immediate (to 2030) planning horizon, and identifies possible measures for decision points that would occur beyond that. Provisional adaptation measures for planning horizons beyond 2030 should be subject to ongoing review and testing with the community, in line with the recommended long-term strategic planning approach.

Decision triggers

In order to make appropriate decisions it is important to identify the trigger points that separate the options available to decision makers. As noted above it is the decisions of government in relation to the interim protection or retreat of coastal units that are most important. It is recommended that the following trigger points become the basis of those decisions, using the combination of factors giving rise to inundation likelihood developed in the 2014 Cockburn Sound Coastal Vulnerability Values and Risk Assessment Study (Table 8.1, pp.). The triggers occur when, within the immediate planning horizon (e.g. 15-years), the most seaward asset (i.e. parks, road / rail reserve or urban / industrial land) meets the criteria in Table 3, and Figure 12.

Table 3 Decision triggers and adaptation pathways

Trigger	Risk Level	Location of most seaward asset:	Government options	Landowner / asset manager options
Trigger 1	Tolerable	Landward of the 500 year ARI inundation event/acute erosion line*	Advise of increasing risk	Do nothing or Retreat
Trigger 2	Increasing likelihood of intolerable risk	Landward of the 100 year ARI inundation event/acute erosion line* but seaward of 500 year ARI inundation line.	Accommodate	Accommodate or Retreat
Trigger 3	Intolerable. Interim protection may be viable	Landward of the 50 year ARI inundation event/acute erosion line* but seaward of 100 year ARI inundation line.	Protect + accommodate or Retreat	Accommodate or Retreat
Trigger 4	Risk is intolerable. Protection is not viable	Seaward of the 50 year ARI inundation event/acute erosion line*	Retreat	Retreat

* reflects the S1 erosion allowance in SPP 2.6, which is the allowance of land required to absorb the current risk of storm erosion.

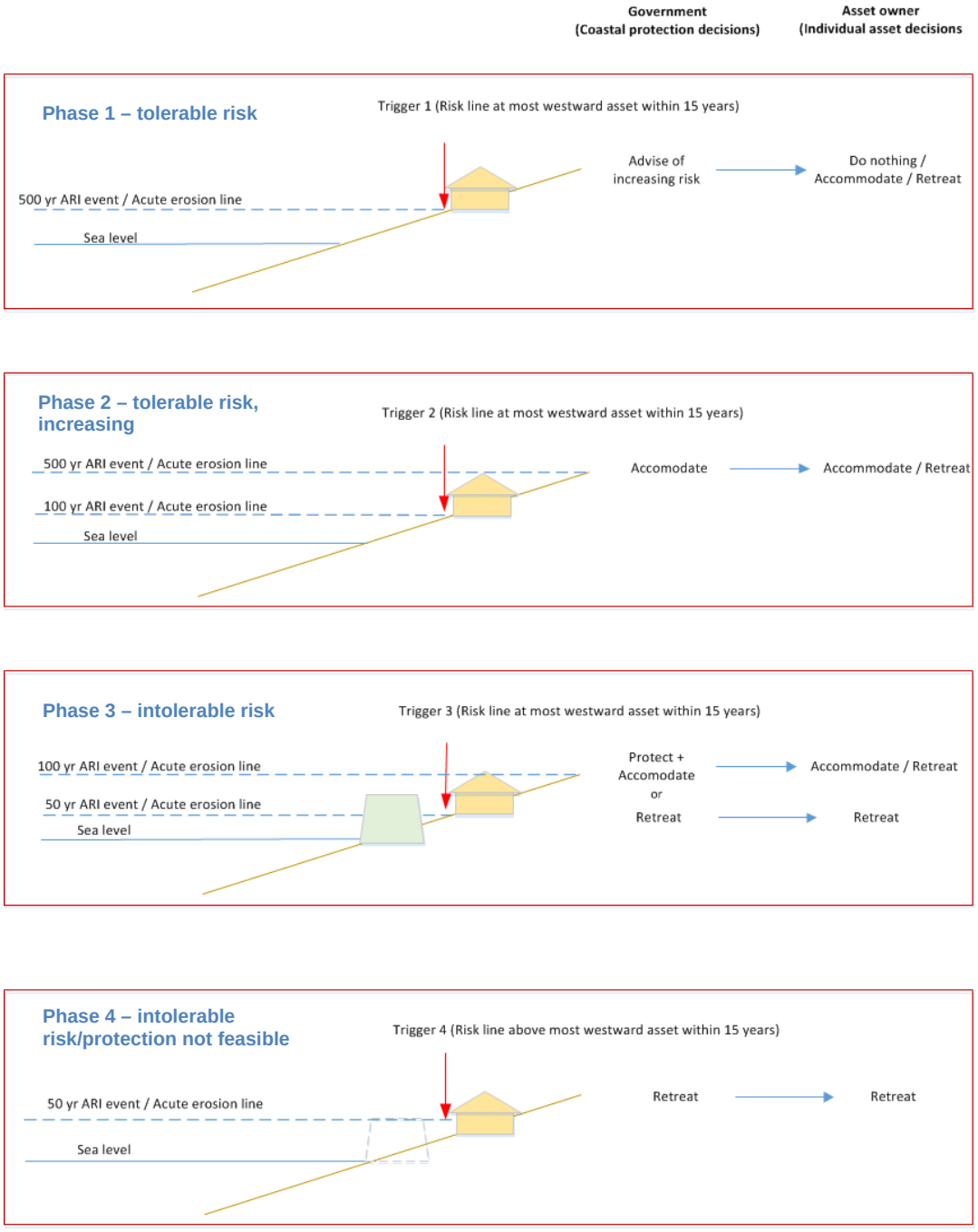


Figure 12 Decision triggers

4. Strategic planning framework

4.1 Development and planning control in the coastal zone

Developing a strategic planning framework that will adequately respond to coastal vulnerability over time needs to consider how planning and development decisions are made in relation to the coast, and who makes them. This depends on what land the development is on, as shown in Figure 13.

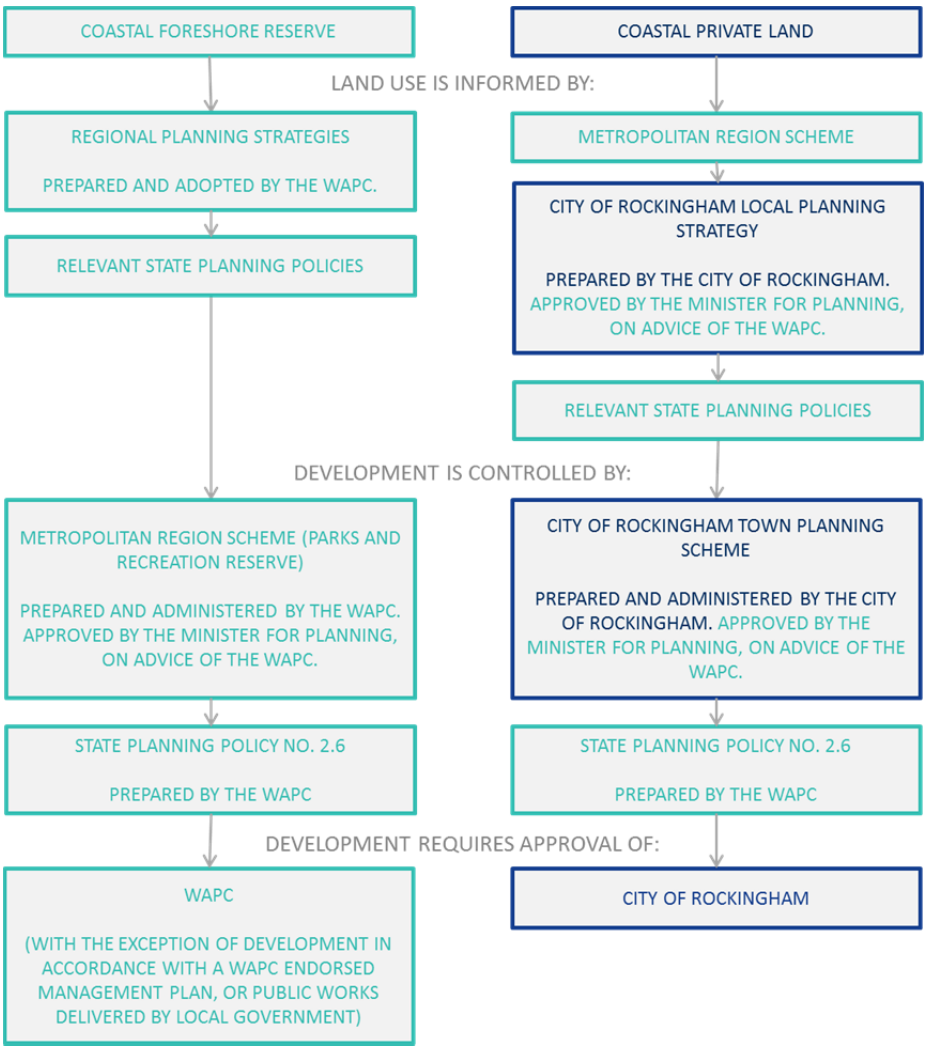


Figure 13 Overview of the statutory planning framework that applies to coastal development

As shown in Figure 13, much of the planning authority in Western Australia is centralised at the state government level. Whilst the City of Rockingham is responsible for preparing its local planning scheme and strategy, these documents must be consistent with higher level state planning documents, and must be approved by the state government. Therefore, strategic decisions regarding land use change and coastal reserves are ultimately confirmed by the state government, and not the City of Rockingham.

The Western Australian Planning Commission (WAPC) is responsible for much of the relevant planning, development control and decision-making on coastal land. In addition to being responsible for the coastal foreshore reserve (which is classified as Parks and Recreation Reserve in the Metropolitan Region Scheme), the WAPC makes recommendations to the Minister for Planning on the acceptability of land use change proposed by the City of Rockingham outside that coastal reserve.

The City of Rockingham has responsibility for development on zoned land and therefore can use their planning system to influence development on private land near the coast. The City of Rockingham can also actively engage with the WAPC to encourage the state and regional planning framework to respond to long-term coastal vulnerability.

Several projects are necessary to develop the strategic planning framework for implementation of the measures set out in this document and to maintain flexibility in adaptation over time. Strategic planning projects are necessary to generate a policy framework that facilitates future, longer term avoidance and retreat strategies beyond the design life of interim protection in the City of Rockingham.

4.2 Regional planning strategies and Metropolitan Region Scheme

Recommended strategic adaptation measure

The WAPC should review the RMS and other regional planning documents including strategic land use and infrastructure plans to provide the necessary land use framework to support the flexible adaptation pathway. This includes identifying:

- Necessary expansions to the Parks and Recreation Reserve (foreshore reserve); and
- New locations and reservations for infrastructure currently located in the vulnerable coastal area, to enable retreat as relevant triggers are reached.

The City of Rockingham, together with the Cockburn Sound Coastal Alliance, should request state government to review the MRS and regional planning documents.

Considerations in strategic adaptation measure

Regional plans and strategies – including the most recent Perth and Peel at 3.5 million – identify future urban and industrial development areas, strategic infill areas, and regional infrastructure

locations. These plans form the strategic basis for the Metropolitan Region Scheme (MRS), which zones and reserves land for development and public purposes. The MRS is the statutory planning scheme which applies the Parks and Recreation Reserve, which is the formal reserve applied to the foreshore reserve in the City of Rockingham.

Future iterations of regional plans and strategies should consider infrastructure, reservations and zoned land that that may be at risk within the immediate (15-year) planning horizon, or infrastructure in longer-term risk areas that is nearing the end of their its design life and requiring renewal. Where the interim protection of infrastructure or land is not supported by community values of the time, regional plans and strategies should include strategic planning projects to identify new locations and reservations for infrastructure outside areas of coastal risk, and plan for the appropriate expansion of the Parks and Recreation reserve. Key infrastructure located within the City of Rockingham to be considered includes:

- Causeway from Point Peron to Garden Island;
- Point Peron Wastewater Treatment Plant;
- Rockingham Foreshore Reserve; and
- Proposed Mangles Bay Development.

The Metropolitan Region Scheme will require amendment to be consistent with future iterations of regional plans and strategies. This will include incorporating appropriate reservations for:

- Parks and recreation (coastal foreshore)
- Public purposes (as required by servicing agencies)
- Road and rail reservations (as required by transport agencies)

Amendments to the MRS should be progressed where land will be required or impacted within the immediate (15-year) planning horizon.

4.3 Review of State Planning Policy No. 2.6 State Coastal Planning Policy

Recommended strategic adaptation measure

The WAPC should review SPP2.6 to provide greater policy guidance for coastal dependant development, in particular to manage the longer-term decommissioning or protection costs of such development as risk levels become intolerable.

The City of Rockingham, together with the Cockburn Sound Coastal Alliance, should request the state government to review SPP2.6.

Considerations in strategic adaptation measure

SPP2.6 lists a number of development types that are variations to the policy, and that might be considered appropriate within areas identified as being potentially impacted by physical coastal processes. These include:

- Public recreation facilities with finite lifespan;
- Coastally dependent and easily relocatable development;
- Department of Defence operational installations;
- Industrial and commercial development (including marinas);
- Coastal nodes; and
- Surf life saving clubs

Coastal nodes and commercial development – in particular marinas – provide important community access and enjoyment of the coast. However they also create community and landowner expectations of ongoing protection and retention of such facilities and land beyond the design life of these coastal assets. This presents potential for significant decommissioning or protection costs in the long-term to retain those facilities and protect any land sold in the area.

A review of the SPP to provide greater policy guidance for these types of development is necessary, where the policy supports their location in areas of risk. Additional policy measures to manage potential costs of protection or decommissioning following the design life or current long-term (100-year) planning horizon include:

- Consideration of impermanent land tenure (such as release of leasehold land) for coastal development to avoid future need for acquisition or compensation of private land;
- Incorporation of notifications on title to identify that the land is located in a vulnerable coastal area, and there is no long-term expectation of protection; and
- Consideration of the need for development contributions to support decommissioning or longer-term interim protection costs.

Such policy measures will help future communities – beyond the current long-term planning horizon – retain flexibility in the adaptation pathways available for coastal settlements, and do not bear unreasonable costs of protection, land acquisition or decommissioning.

Foreshore management plans (discussed later in this section) are a suitable tool to require public recreation facilities, relocatable development and surf lifesaving clubs to be planned and managed according to coastal risk.

4.4 City of Rockingham Strategic Plan

Recommended strategic adaptation measure

Future iterations of the City of Rockingham strategic plan should test values and act on any triggers that are predicted to occur in the immediate planning horizon of the plan.

Considerations in strategic adaptation measure

The current City of Rockingham strategic plan has recently been released, providing guidance to 2025. The plan identifies climate change and foreshore development as key concerns of the community. Incorporation of coastal adaptation planning into the strategic plan will be necessary to provide a local governance framework for integrated decision-making in relation to strategic land use and infrastructure and capital works planning. In particular, the plan should reflect the adaptation pathway set out in section 3 of this plan.

Five-yearly reviews of the strategic plan should operate as a trigger to undertake targeted community and industry consultation to test and update values and views about coastal development and assets that will be at risk both within a 15-year planning horizon and beyond. Revised values and any new information available (for example any reviews of risk and vulnerability mapping) should be used to determine whether adaptation strategies for the 15-year planning horizon require modification as a result of changing values.

Based on the strategic plan, the costs to the City of any interim protection works or associated measures required to be delivered within the 15-year planning horizon should be incorporated into the City of Rockingham long-term financial plan.

4.5 City of Rockingham Local Planning Strategy and Scheme

Recommended strategic adaptation measure

The City of Rockingham local planning strategy and scheme should be reviewed to incorporate a special control area for the vulnerable coastal area.

The local planning strategy and scheme should provide a policy framework to apply SPP 2.6 to infill development to manage location of increased densities. Future land use change should avoid intensifying density and development opportunity within the vulnerable coastal area.

Considerations in strategic adaptation measure

The City of Rockingham is currently preparing its Local Planning Strategy. The City of Rockingham Town Planning Scheme No. 2 was gazetted in 2004. These planning documents are scheduled for review. The review of these documents should incorporate the requisite planning framework to adapt to coastal risks in the immediate (15-year) and longer (100-year) term.

The purpose of local planning strategies is to set out the local government's objectives for future planning and development and includes a broad framework by which to pursue those objectives. The strategy is therefore the appropriate document to clearly enunciate the longer-term nature of the challenges arising from sea level rise and its associated effects on the coastline, and the City of Rockingham's response to those challenges. Inclusion of planning measures in the strategy will be the precursor to the introduction over time of statutory measures in the local planning scheme, which provides the statutory framework for land use on private land adjacent to the coast.

Special control area for vulnerable coastal area

The local planning strategy review should incorporate a clear local coastal planning strategy in accordance with SPP 2.6. A key planning mechanism to deliver the local coastal planning strategy could be a special control area applied to the vulnerable coastal area, which provides additional planning controls for a specific area. In developing a special control area for the vulnerable coastal area, the following elements should be considered in the local planning strategy review:

- Determination of an appropriate special control area that encompasses land that would be impacted by a) physical processes plus b) an appropriate foreshore reserve for a 100-year planning horizon:
  - Determination of the physical processes setback for a 100-year planning horizon in accordance with SPP 2.6 using best available information – this would include the coastal vulnerability mapping undertaken by the Cockburn Sound Coastal Alliance – Coastal Vulnerability Study. Erosion and Inundation Hazard Assessment Report (2013) supplemented by any further or more detailed investigations undertaken subsequent to the project;
  - Determination of the future foreshore reserve width for a 100-year planning horizon in accordance with Section 8 of the State Coastal Planning Policy Guidelines;
- A presumption that the special control area will expand landwards over time as sea levels rise;
- Investigation of necessary development controls for the special control area, and the timing or trigger points for inclusion of those controls in the scheme. This would include consideration of:
  - Notifications on title for properties within the special control area which are reviewed and updated over time;
  - Policy provisions requiring coastal processes setback for all new development and redevelopment within the special control area, which would facilitate incremental relocation of private development to meet coastal setback requirements.

The local planning strategy should clearly identify at what point the scheme should incorporate controls on development or redevelopment in vulnerable areas.

The local planning scheme, informed by the strategy, should incorporate the special control area to advise land owners and planners that the area is in a vulnerable coastal area for the long-term (100-year) planning horizon. The extent of development controls included should reflect whether or not intolerable risk will be experienced in the immediate (15-year) planning horizon. If risks are tolerable in the immediate planning horizon, development controls may not be necessary. If risks are considered intolerable in the immediate planning horizon, then controls should be introduced.

The local planning strategy will be a key consultation and communication tool that will engage the community in decision-making and communicate triggers and timeframes for additional controls of coastal land use to manage coastal risks.

Coastal settlement planning

Whilst SPP 2.6 requires that infill development consider the adaptation planning hierarchy, such infill development may not be subject to the same requirement for setbacks and ceding of foreshore reserves as new development and settlements, particularly where it is not contiguous with the current foreshore reserve. The local planning strategy review should consider the long-term implications of this, and investigate policy measures to provide a consistent approach to new and infill development.

In particular, the local planning strategy review should investigate:

- Density recommendations to locate future increases of density outside the coastal vulnerable area;
- Infrastructure locations and strategies that avoid placing future infrastructure within the physical processes setback and adjacent long-term foreshore reserve, and avoid placing linear servicing infrastructure (including roads) that run parallel to the coast, therefore potentially becoming a threatened asset in longer-term planning horizons.

The settlement recommendations, which would effectively apply SPP 2.6 to revitalisation of existing developed areas, identified in the local planning strategy review should be incorporated into the local planning scheme at the appropriate time.

4.6 Foreshore management plans

Recommended strategic adaptation measure

The City of Rockingham should prepare a foreshore management plan for the coastal reserve north of the grain terminal, adjacent to the City of Rockingham. The City of Rockingham should translate the existing Rockingham Beach Foreshore Master Plan, and associated coastal risk management and adaptation report, into a formal management plan.

The Department of Parks and Wildlife should prepare a foreshore management plan for Point Peron.

Considerations in strategic adaptation measure

Management plans are formal planning documents prepared for areas of Parks and Recreation Reserve under the MRS. These plans provide additional land use controls regarding appropriate development within the reserve, and also provide a tool to prioritise management activities.

Plans should be prepared by the reserve manager and adopted by the WAPC as management plans under the MRS. The plans will then form the statutory planning framework for all development within the foreshore reserve.

The foreshore management plans will be a key tool for communication and engagement with the community as they include detailed planning for community places and facilities. Therefore, they reflect a key opportunity to encourage awareness of the dynamic nature of the coast, the impermanent nature of coastal development, and how that will influence the future form of these areas.

Key elements to be considered in the foreshore management plans are:

- Identification, prioritisation, and funding of natural coastal and dune management techniques to enhance the ability of the natural system to buffer coastal processes;
- Consideration of sea level rise and coastal risk, defining any relevant trigger points for the reserve and whether there is a need for the relocation or decommissioning of existing assets as required;
- Identification of appropriate, impermanent community facilities to meet demand for coastal infrastructure in the immediate (15-year) planning horizon;
- Policy requirements for temporary development, including:
    - Design life for assets to reflect risk timeframes;
    - Architectural and construction requirements for development to portray a temporary aesthetic – communicating to the community the impermanent nature of facilities;
    - Incorporation of community education, including interpretive signage – to educate the community about the dynamic nature of the coastal zone.

- Coastal interim protection works required in the immediate (15-year) planning horizon, including estimated costs, maintenance responsibility, and impacts on the reserve.
- Provisional coastal interim protection works that may be required in the long-term (up to 100-year) planning horizon, including costs and impacts on the reserve, to engage the community in future strategic planning cycles to test values and confirm adaptation options for these locations over time.

The level of information to be included in foreshore management plans – in particular related to detailed erosion and inundation modelling – will be dependent on the level of risk, and the timeframe to anticipated trigger points. Foreshore management plans should be reviewed on a five year cycle and updated to reflect changing values and adaptation options in line with future iterations of the City of Rockingham strategic plan.

Churchill Park in Rockingham

5. Adaptation measures

The following trigger points and decisions were analysed for the immediate and long-term planning horizons:

- Trigger 1 (risk tolerable): decision to avoid future development in vulnerable coastal area
- Trigger 2 (increasing likelihood of intolerable risk): decision to avoid and accommodate
- Trigger 3 (risk is intolerable, interim protection may be viable): decision required between interim protection and retreat
- Trigger 4 (risk is intolerable, protection is not viable): decision to retreat

5.1 Developing adaptation measures

Avoid

Avoid measures that involve the location of new development in an area of coastal vulnerability. This does not preclude the use and enjoyment of the coast; however it avoids locating future development in an area that would experience intolerable risk, at some stage during the life of that development. Strategies associated with avoid measures are delivered through planning policies and frameworks, and are set out in Section 4.

Managed retreat

Managed retreat means relocating assets outside the area of risk, to allow land at risk to naturally experience erosion and/or inundation. Retreat can be on a small scale, for example relocating a car park within a large foreshore reserve to an area outside immediate risk. In the long-term, retreat strategies can occur on a significant scale, for example the expansion and remediation of the foreshore reserve, which requires the relocation of infrastructure (such as road, rail, and sewer) and inclusion of private land within the expanding foreshore reserve. Large-scale strategic retreat will require coordination and partnership across state and local government. A potential model to deliver these outcomes is provided in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016).

Accommodation measures

Accommodation measures are asset specific activities that enable an asset to continue to operate whist being affected by coastal impacts. In the face of erosion, this includes measures to accommodate increased risk, such as dune revegetation to reduce the immediate impact of wave erosion. In relation to inundation, this includes measures to enable an asset to manage occasional flooding, such as flood gates on buildings and emergency management plans.

Key accommodation options are presented in section 5.7.

Interim protection measures

The role of coastal protection is to reduce the risks associated with the coastal hazards of erosion and inundation to land and assets. Interim protection measures can involve either soft or hard and passive or active engineering approaches. Descriptions and examples of these approaches are defined in Table 4.

Table 4 Interim protection measures

Approach	Description	Examples
Soft – Passive	Foreshore protection works that offer benefits to erosion and inundation but do not involve construction of structures and do not directly affect coastal processes.	Sand nourishment and dune stabilisation
Hard – Passive	Foreshore protection works that involve the construction of structures which alter the coastal processes that act on the land/beach/nearshore environments with the intention to maintain or improve beach amenity through retention of sand.	Groynes and offshore breakwaters
Hard – Active	Works that involve the construction of structures which offer a source of protection to landside assets in proximity to the foreshore. The construction of hard active engineering options can alter the way coastal processes act on the land/beach interface. These changes to the shape of the land (e.g. erosion of a beach in front of a seawall) can have implications on land use (e.g. loss of beach amenity).	Seawalls and Levees

* Refer to the Adaptation Options Compendium for the definition of foreshore protection examples

Interim protection measures are only considered for implementation when coastal hazards (erosion or inundation) present intolerable risk to assets and values (i.e. at trigger point 3) within the immediate (15-year) planning horizon.

Offshore breakwaters and groynes are examples of hard passive interim protection measures. This groyne example is made from geotextiles. Groynes can also be constructed from rocks to extend their design life. Offshore breakwaters can interrupt open views of the ocean, and groynes can create a barrier along the beach.

Sea walls are an example of hard active interim protection measures. Designed well, they can integrate well into the development of beach amenities, although they can exacerbate erosion (beach loss) in front of the wall over time if ongoing sand nourishment is not undertaken.

5.2 Assessing the available adaptation options

A full description of the option evaluation process is set out in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016) which accompanies this adaptation plan. The following sections provide a summary to inform the recommendations presented in this adaptation plan.

Triggers 1 and 2

Where trigger points 1(risk tolerable) or 2 (increasing likelihood of intolerable risk) are anticipated to occur in the immediate or long-term planning horizons, avoid and accommodation measures are considered appropriate for implementation.

Soft – passive protection measures, including reactive beach nourishment to major storm events, in the short-to-medium-term (subject to the availability of materials) are also considered as management tools available to replenish beaches, and slow down the loss of land from erosion processes.

East Rockingham Foreshore showing the grain jetty

Trigger 3

The option analysis (including but not limited to financial costs) for trigger point 3 compared the following options:

- Retreat when risk becomes unacceptable; and
- Interim protection incorporating a range of short to long-term options for protection measures that delay retreat for the life of the structure (until the next trigger point is reached, be it another trigger point 3 or trigger point 4).

Accordingly, the purpose of the option evaluation process is to compare the costs and benefits of retreat to one or more interim protection measures for each coastal management unit.

The technique known as multi-criteria decision analysis (MCDA) was used to make these comparisons. The results of the MCDA, including the sensitivity analysis, are set out in Appendix B.

For those areas where trigger 3 has been reached in the immediate planning horizon, two levels of analysis were undertaken to inform decision-making:

- MCDA analysis to decide between interim protection measures and retreat; and
- If interim protection is preferred, more detailed assessment of the preferred protection strategy (passive vs active) to recommend an appropriate option for detailed planning.

5.3 Decisions in the immediate planning horizon (to 2030)

Coastal Management Unit 13 – East Rockingham, 14 – Rockingham Beach, 16 – Mangles Bay and 17 – Peron Foreshore

The Cockburn Sound Hazard Assessment Report (2013) identified areas which are currently vulnerable to inundation and erosion. However an intolerable risk level (representing a trigger point 3 or 4) is not expected to be reached in the immediate planning horizon (15-years) within these areas. Therefore no immediate decision between retreat and interim protection is required in the current planning horizon.

Adaptation in the immediate planning horizon relates to trigger points 1 and 2, and the following should be implemented:

Trigger point 1 (development in vulnerable coastal area; risk is tolerable)

- Monitor values and risk
- Advise land and asset owners of increasing risk over time
- Deliver the strategic planning framework discussed in section 4.

Trigger point 2 (increasing likelihood of an event presenting intolerable risk)

- Responsive beach nourishment to erosion events
- Dune management and revegetation
- Other accommodation options listed in section 5.7.

Coastal Management Unit 15 – Palm Beach

Risk profile

The Cockburn Sound Hazard Assessment Report (2013) indicated that Coastal Management Unit (CMU) 15 – Palm Beach is an area that is becoming increasingly vulnerable to inundation, erosion and a loss of beach area from coastal actions and sea level rise. The vulnerability mapping showed that the risk associated with inundation and erosion is currently intolerable for some assets and is expected to significantly increase in the future, refer Appendix A.

This will require a decision between retreat and appropriate interim protection in the immediate planning horizon.

Protection options

Several protection measures and material options could be suitable to protect against the potential coastal hazards in this area. Two preliminary protection measures were considered for assessment and comparison in the MCDA process. These options represent indicative hard-passive and hard-active coastal protection approaches to defend the coastline and assets.

Option 1:	Initial stage (Present) – Build a seawall to protect the Rotary Beach and Esplanade foreshore Later stage (2070) – Build a levee with a road on top along the foreshore
Option 2:	Initial stage (Present) – Install groynes or offshore breakwaters (nom. four) along the coastline – Undertake beach nourishment to establish artificial beach Later stage (2070) – Elevate the dune system – Install one way valves (Flap or Duck) on ocean storm water outfall pipes

Cost of options

A summary of the capital, maintenance and decommissioning costs are provided in Table 5. The basis for costing the protection options is described fully in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016).

Table 5 Cost Estimate of Preliminary Concept options

	Option 1			Option 2		
	Capital ($k)	Annual ($k)	Decom ($k)	Capital ($k)	Annual ($k)	Decom ($k)
Present	4,472	45		13,468	442	
2070	4,914	25		4,511	45	
2110	-	-	4,286	-	-	2,257

Recommended adaptation decision

MCDA results suggest that interim protection is an appropriate decision over retreat, based on assumed values (criteria weightings) in the immediate planning horizon.

Of the interim protection measures, the hard-passive approach of Option 2 that would attempt to maintain beach amenity was identified as the preferred option over the hard-active approach of Option 1. This preference was found to be sensitive to the costs of the works and the value placed on beach amenity.

The recommended option involves implementing soft and hard passive interim protection measures that will maintain beach areas and defend the current shoreline position against erosion in the short to medium-term. The nature and extent of works will be guided by the cost and availability of funding. A sketch of a potential arrangement is included in Appendix C, which includes the following items.

– Beach Nourishment and Dune Redevelopment:

  Proactive coastal management (including dune management and revegetation) will be important so that natural erosion processes are not accelerated by poor quality environments. In addition, beach nourishment, in the short to medium-term (subject to the availability of materials) is a management tool available to replenish beaches, and slow the loss of land from erosion processes. Increasing the height of dune system in the medium-term would assist in reducing inundation risk which is expected in increase in this area due to sea level rise.

– Interim Hard-Passive Protection Structures:

  Groynes and breakwaters are structures that offer protection to the coastline while maintaining beach amenity and therefore present a viable solution for use in CMU15. The position, size/length and spacing of groynes and breakwaters will determine their effectiveness and the

implications to coastal processes and sediment transport experienced at other locations both upstream and downstream of the groynes and breakwaters.

- Drainage Works

  The hazard mapping identified potential inundation in the medium-term, highlighting the need for the City to consider how stormwater drainage and groundwater levels can be effectively managed in the low-lying area of Rockingham. Installation of one-way valves (Flap or Duck valves) on ocean storm water outfall pipes is recommended as a preliminary minimum requirement, with further studies needed beyond the scope of this project.

Further assessment of interim protection for CMU 15

An additional evaluation was undertaken to compare the benefits of the two interim protection measures identified in the MCDA.

Table 6 CMU 15 – Additional foreshore protection options

Option 2a: Offshore Breakwaters	– Install four to six 100 metre long offshore breakwaters in stages, to protect the vulnerable coastline in the medium-term as risks increases. – Undertake post construction and ongoing reactive beach nourishment practices – Undertake ongoing dune redevelopment to increase height in the medium-term as inundation risks increases – Investigate and improve storm water drainage in the medium-term as inundation risks increases
Option 2b: Groynes	– Install three to five groynes in stages, to protect the vulnerable coastline in the medium-term as risks increases. – Undertake post construction and ongoing reactive beach nourishment practices – Undertake ongoing dune redevelopment to increase height in the medium-term as inundation risks increases – Investigate and improve storm water drainage in the medium-term as inundation risks increases

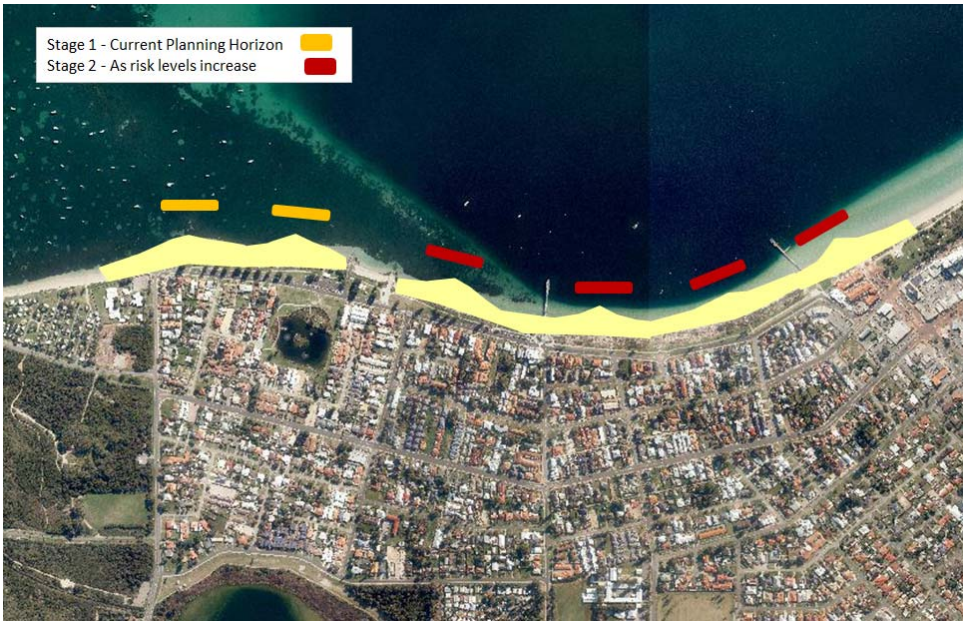


Figure 14 Additional foreshore protection option 2a

Figure 15 Additional foreshore protection option 2b

The results of the additional assessment for CMU 15 – Palm Beach (Appendix D) determined that the installation of breakwaters may provide better performance then groynes, although they would entail higher initial costs. Concept design development and modelling should be undertaken to confirm these findings and determine the most suitable arrangement based on performance and feasibility.

In relation to beach amenity impacts, community consultation is recommended to assess the two concepts and define a preference on the basis of social impacts. Offshore breakwaters can be perceived to present an impact to views from the beach, whilst groynes can bisect the beach environment. Engagement with the community, an essential step in preparing a detailed foreshore management plan for this location, will explore these impacts and assist in determining a preferred outcome from the perspective of amenity.

Irrespective of the decisions made, proactive coastal management (including dune management and revegetation) will be important so that natural erosion processes are not accelerated by poor quality environments. In addition, beach nourishment, in the short to medium-term (subject to the availability of materials) is a management tool available to replenish beaches, and slow the loss of land from erosion.

The implementation measures described should be accompanied by accommodation strategies as described in in Section 5.7.

Coastal Management Unit 18 – Point Peron

Risk profile

The Cockburn Sound Hazard Study (2013) indicated that CMU 18 – Point Peron is an area that is becoming increasingly vulnerable to inundation, erosion and a loss of beach area from coastal actions and sea level rise requiring a decision between retreat and appropriate interim protection in the immediate planning horizon.

Protection options

Point Peron is susceptible to coastal actions from both sides. The parkland and recreational assets located in this unit have short setbacks and are currently susceptible to coastal events. As such, there are limited interim protection options available for this area. When the effects of sea level rise begin to take effect the coastline will be more regularly overtopped and eroded.

The most suitable interim protection measure for the length of coastline is a seawall. The construction of a seawall was compared with the option of retreat in the MCDA.

Cost of options

A summary of the capital, maintenance and decommissioning costs are provided in Table 7. The basis for costing the protection options is described fully in the Cockburn Sound Coastal Adaptation Plan (GHD, 2016).

Table 7 Cost Estimate of Preliminary Concept options

	Seawall		
	Capital ($k)	Annual ($k)	Decom ($k)
Present	-	-	
2070	1,144	11	
2110	-	-	484

Recommended adaptation decision

MCDA results suggest that retreat may be an appropriate decision over interim protection, based on assumed values (criteria weightings) for the current planning horizon. The recommended adaptation decision is therefore accommodate and retreat.

Adaptation measures to deliver the accommodate and retreat decision include:

- Accommodate impacts where possible

  Dune management and revegetation

- Retreat from short-term risks

  Prepare foreshore management plan to guide relocation and decommissioning of assets at immediate risk

- Plan for strategic, long-term retreat

  A whole of government approach to retreat private and public assets from risk is provided in Cockburn Sound Coastal Vulnerability & Flexible Adaptation Pathways Project – Stage 3 Report Coastal Adaptation Plan (GHD, 2016)

With retreat proposed, stakeholders should be aware that there is the potential for a loss of land. As the coastline erodes and risk levels increase it is noted that particular assets may need to be temporally protected and/or relocated. Interim protection works could involve seawall construction for specific assets; however these works should be undertaken with an understanding that long-term retreat is intended and any new or relocated assets should have sufficient setback according to SPP2.6. This should be planned for in a foreshore management plan.

5.4 Long-term planning horizon (post-2030)

Risk mapping suggests that the risk of erosion or inundation becoming intolerable (trigger point 3) for CMUs 13 – East Rockingham, 14 – Rockingham Beach, 16 – Mangles Bay, and 17 – Peron Foreshore will not occur until well into the future.

To gain a sense of what the future might look like at the time of trigger point 3, the MCDA provides a provisional recommendation of what decision might be made. This information should only be considered as provisional, and a future, decision will depend on:

- an ongoing risk assessment
- the cost and technical feasibility of these and other options that might be identified in future
- future developments proposed in the area
- any changing attitudes to appropriate measures to address sea level rise in general and in these location specifically.

Coastal Management Unit 13 – East Rockingham

Risk profile

As CMU 13 – East Rockingham is not subject to a trigger 3 decision in the immediate planning horizon, the provisional assessment has considered the CMU as a whole, rather than as the sub-areas. In future planning horizons, as risk becomes intolerable, assessment and adaptation planning should consider the sub-areas as values and weighting of criteria in the MCDA may vary based on the land use of the area.

The Cockburn Sound Hazard Study (2013) indicated that CMU 13 – East Rockingham was not significantly vulnerable to purely inundation events. However, CMU 13 – East Rockingham is identified as becoming increasingly vulnerable to erosion and a loss of beach area from coastal actions and sea level rise. The storm event and sea level rise vulnerability mapping showed that the risk associated with erosion and inundation is likely to become intolerable for some assets before 2070,(refer Appendix A). This will require a decision between retreat and appropriate interim protection options in the planning period leading up to 2070, or as risk becomes intolerable.

Protection options

Since this stretch of coastline has a significant vegetated dune buffer zone and relatively low levels of risk in the medium-term, the only interim protection option assessed was a soft-passive approach to stabilise the existing dune system with planting and geotextiles.

Cost of options

A summary of the capital, maintenance and decommissioning costs are provided in Table 8. The basis for costing the protection options is described fully in Cockburn Sound Coastal Adaptation Plan (GHD, 2016).

Table 8 Cost Estimate of Preliminary Concept options

	Option 1		
	Capital ($k)	Annual ($k)	Decom ($k)
Present	-	-	
2070	3,770	75	

Provisional adaptation decision

MCDA results suggest that interim protection – at the time of the trigger point – may be an appropriate decision over retreat, based on assumed values (criteria weightings). The MCDA should be repeated prior to the trigger point to confirm if this decision is viable at the time of the trigger. The preferred protection measure is a passive engineering option which proposes the implementation of dune stabilisation.

The beach and dune areas of CMU 13 – East Rockingham are identified as currently being almost certainly vulnerable to coastal risk however the coastal reserve, park areas and urban assets have a sufficient setback that more significant actions are not imminently required. Significant dune stabilisation works are not immediately required however proactive coastal management (including dune management and revegetation) will be important so that natural erosion processes are not accelerated by poor quality environments. In addition, reactive beach nourishment after extreme storm events (subject to the availability of materials) is a management tool available to replenish beaches, and slow down the loss of land from erosion processes. It is also recommended that the dunes are monitored and areas that shown signs of erosion addressed as necessary.

Coastal Management Unit 14 – Rockingham Beach

Risk profile

The Cockburn Sound Hazard Study (2013) indicated that CMU 14 – Rockingham Beach is not currently significantly vulnerable to purely inundation events. However, CMU 14 – Rockingham Beach has been identified as becoming increasingly vulnerable to erosion and a loss of beach area from coastal actions and sea level rise. The storm event and sea level rise vulnerability mapping showed that the risk associated with erosion and inundation is likely to become intolerable for some assets before 2070 (refer Appendix A).

This will require a decision between retreat and appropriate interim protection options in the planning horizon leading up to 2070, or as risk becomes intolerable.

Protection options

There are several protection options and materials which could be suitable to protect against the potential coastal hazards in this area. Two preliminary protection measures were considered for assessment and comparison to retreat in the MCDA process, which are listed below. These options represent indicative hard-passive and hard-active measures to protect the coastline and assets.

Option 1:	Initial stage (2070) – Install a seawall along the shoreline
Option 2:	Initial stage (2070) – Install two offshore breakwaters or groynes – Undertake beach nourishment to establish artificial beach

Cost of options

A summary of the capital, maintenance and decommissioning costs are provided in Table 9. The basis for costing the protection options is described fully in Cockburn Sound Coastal Adaptation Plan (GHD, 2016).

Table 9 Cost Estimate of Preliminary Concept options

	Option1			Option2		
	Capital ($k)	Annual ($k)	Decom ($k)	Capital ($k)	Annual ($k)	Decom ($k)
Present	-	-		-	-	
2070	7,800	78		6,474	208	
2110	-	-	3,300	-	-	1,122

Provisional Adaptation Decision

MCDA results suggest that interim protection – at the time of the trigger point – may be an appropriate decision over retreat, based on assumed values (criteria weightings) for the current planning horizon.

The MCDA highlighted the value placed by the community on maintaining the amenity of coastal assets along the Rockingham foreshore. Groynes or breakwaters (hard-passive engineering approach) were preferred to retreat or a seawall (hard-active engineering approach). The MCDA clearly indicated that capital spending on interim protection measures that can maintain the recreational beach and reserve area while offering some protection to urban assets is warranted.

A sketch of a potential arrangement is included in Appendix C. The exact nature and extent of works will be guided by public preference, the cost of works and the availability of funding.

Neither groynes nor breakwaters will be effective for protection against storm tide inundation and should be combined with beach nourishment to mitigate the adverse effects on coastal processes.

The implementation measures described should be accompanied by accommodation strategies as described in in Section 5.7.

In the current planning horizon, ongoing reactive beach nourishment practices should be maintained as should maintenance of any existing coastal structures and beach monitoring.

Coastal Management Unit 16 – Mangles Bay

Risk profile

The Cockburn Sound Hazard Study (2013) indicated that CMU 16 – Mangles Bay is an area which is becoming increasingly vulnerable to inundation, erosion and a loss of beach area from coastal actions and sea level rise. The vulnerability mapping showed that the risk associated with inundation and erosion will become intolerable for some assets before 2070 (refer Appendix A).

This will require a decision between retreat and appropriate interim protection options in the long-term planning horizon leading up to 2070, or as risk becomes intolerable.

Protection options

There are several protection methods and material options which could be suitable to protect against the potential coastal hazards in this area. Two preliminary protection measures were considered for assessment and comparison in the MCDA process against retreat, which are listed below. These options represent indicative hard-passive and hard-active coastal protection approaches to defend the coastline and assets.

Option 1:	Initial stage (2070) – Build seawall along the shore
Option 2:	Initial stage (2070) – Upgrade, extend and build new groyne structures – Place sand and build beach

Cost of options

A summary of the capital, maintenance and decommissioning costs are provided in Table 10. The basis for costing the protection options is described fully in the Cockburn Sound Coastal Adaptation Plan report (GHD, 2016).

Table 10 Cost Estimate of Preliminary Concept options

	Option1			Option2		
	Capital ($k)	Annual ($k)	Decom ($k)	Capital ($k)	Annual ($k)	Decom ($k)
Present	-	-		-	-	
2070	12,792	128		8,970	333	
2110	-	-	5,412	-	-	1,122

Provisional adaptation decision

MCDA results suggest that interim protection – at the time of the trigger point – may be an appropriate decision over retreat, based on assumed values (criteria weightings) for the current planning horizon.

Of the interim protection measures, the hard-passive approach of upgrading and extending and building groynes that would attempt to maintain beach amenity was identified as the preferred option. The MCDA clearly indicated that capital spending on interim protection measures that could help maintain the recreational beach and reserve area, while offering some protection to urban assets, may be warranted.

This preference was found to be sensitive to the potential costs of the works and the value placed on beach amenity.

A sketch of a potential arrangement is included in Appendix C. The groynes, combined with an artificial beach, will retain sand moving along the coast, and generate a new shorefront aligned to the wave direction and reflecting sand transport directions. In this manner, the groynes will help defend

the current shoreline position against erosion by reducing longshore transport to maintain beach width but will remain susceptible to cross shore erosion.

The construction of groynes should be accompanied by accommodation strategies as described in in Section 5.7. It should also be noted that the works proposed would be subject to the outcomes of the proposed Mangles Bay Marina situated in this area. This area of coastline could also be impacted by the performance of the sand trap location in the adjacent CMU 17 – Peron Foreshore. If the system changes then a greater volume of sand may bypass and impact on the boat launching facility and this section of coastline.

Coastal Management Unit 17 – Peron Foreshore

Risk profile

The Cockburn Sound Hazard Report (2013) indicated that CMU 17 – Peron Foreshore is an area which is becoming increasingly vulnerable to inundation, erosion and a loss of beach area from coastal actions and sea level rise. This location was previously noted as a sediment trap, with sand collected and used for sand nourishment at locations experiencing erosion in the City of Rockingham. However, more recently, parts of the area experienced erosion resulting in the construction of an additional geotextile sand container groyne. The sand trap is continuing to accumulate sand, and early monitoring suggests the groyne has been successful in reducing significant erosion of the beach to the west. Performance of the groyne is being monitored. The vulnerability mapping indicates that the risk associated with inundation and erosion will reach an intolerable point for some assets before 2070 (refer Appendix A). This will require a decision between retreat and appropriate interim protection options in the planning horizon leading up to 2070, or as risk becomes intolerable.

Protection options

Two preliminary protection measures were considered for assessment and comparison in the MCDA process, which are listed below. These options represent indicative hard passive or hard active measures to protect the coastline and assets.

Option 1:	Initial stage (2070) – Build seawall along the shore
Option 2:	Initial stage (2070) – Upgrade, extend and build new groyne structures – Place sand and build beach

Cost of options

A summary of the capital, maintenance and decommissioning costs are provided in Table 11. The basis for costing the protection options is described fully in the Cockburn Sound Coastal Adaptation Plan (GHD, 2016).

Table 11 Cost Estimate of Preliminary Concept options

	Option1			Option2		
	Capital ($k)	Annual ($k)	Decom ($k)	Capital ($k)	Annual ($k)	Decom ($k)
Present	-	-		-	-	
2070	6,240	62		4,407	162	
2110	-	-	2,640	-	-	561

Provisional adaptation decision

MCDA results suggest that interim protection – at the time of the trigger point – may be an appropriate decision over retreat, based on assumed values (criteria weightings) for the current planning horizon.

Of the interim protection measures, the hard-passive approach of upgrading, extending and building groynes which would maintain beach amenity was identified as the preferred option a seawall which could result in beach loss. This highlights the value placed on the coastal assets in this area, with the MCDA indicating that capital spending on interim protection measures that could help maintain the recreational beach and reserve area while offering some protection to urban assets may be warranted.

CMU 17 – Peron Foreshore has existing coastal protection groynes which have historically trapped the sediment and increased the beach width. Option 2 proposes the upgrade of these structures or the construction of new groynes along the coastline which will assist the existing structures to defend the current shoreline position against erosion. A sketch of a potential arrangement is included in Appendix C. Initial beach nourishment will be required to establish a wider beach front to prevent inundation. The extent and nature of works will be guided by the local community's values for beach and foreshore amenity, the cost of works and the availability of funding. Therefore, adequate planning and budget allocations will be needed moving forward to ensure approvals are met and funding is available.

The implementation measures described should be accompanied by accommodation strategies as described in in Section 5.7. This coastal area may also be susceptible to inundation and erosion from the southern side of Point Peron, which should be considered in future planning.

5.5 Implementation of interim protection

Prior to the construction of coastal engineering protection structures, there are several steps that should be undertaken to develop the basis of design and confirm that the proposed interim protection methods are the most suitable approach from a performance and financial viability perspective. The following steps (as a minimum) are proposed:

1. Develop a data register and acquire long-term information on the Cockburn Sound and near shore site specific locations including: erosion and accretion patterns, wave climate, water levels, sediment processes, bathymetric data and shoreline area surface levels.
2. Review the data register to identify gaps in information required to inform design works.
3. Undertake the required investigations to fill any gaps in the data. This may require installation of data recording devices, survey work and modelling.
4. Develop a basis of design with available information.
5. Develop several concept designs based on the preferred approach to be optimised to confirm the most suitable design.
6. Obtain environmental approvals for the preferred design.
7. Once a final design option has been selected, detailed design and documentation can then be prepared.

The earlier that steps 1 to 3 can be undertaken in advance of any construction works the better informed the design work will be.

Coastal development along the Rockingham foreshore

5.6 Outstanding issues to resolve prior to decision-making

Stormwater and groundwater contributions to inundation

Future decisions to protect against inundation in Rockingham should take into account other risks to land and assets in this area from stormwater and groundwater. The vulnerability assessments undertaken in the Stage 1 and 2 Assessments investigated inundation from coastal processes and excluded the effects of the management of land side stormwater which is likely to add to the inundation risks during an extreme event. It is also expected that as sea level rises, there will be an increase in groundwater levels in coastal areas.

If decisions to protect coastal land and assets are made, then the decision needs to consider how stormwater drainage and groundwater levels can be effectively managed. Additional technical investigations are required to fully understand the likely impacts of stormwater and groundwater in the area, and use this to inform future decision-making.

Materials availability and cost

The increase in construction and infrastructure development to support the expected population growth of Perth and Peel will increase the demand for basic raw materials including those commonly used in coastal works such as sand, limestone, and hard rock (EPA, 2015). This may lead to a limit in the supply of suitable materials required for protection options.

Additionally, beach nourishment is proposed for a number of the CMUs in the Owen Anchorage and Cockburn Sound in order to maintain public beach amenity which will place a long-term demand on a limited supply. Sand may be sourced at localised accretion locations and from offshore dredging. However the availability of suitable sources is likely to become increasingly limited in the future.

There are many variables to consider when predicting the potential future availability and cost of coastal protection materials that may be required for a long-term planning horizon. Developing a long-term material resource plan requires a detailed feasibility assessment and was outside the scope of this project.

It is recommended that the City of Rockingham, together with the Cockburn Sound Coastal Alliance undertakes a study of the current and potential sources of materials suitable for coastal protection works and any potential environmental impacts of their sourcing in order to adequately plan for the options identified over the long-term planning horizon. If it is determined that obtaining the required volumes of materials is unlikely, then alternative techniques or pathways may be required.

Environmental impact

The environmental impact of the proposed works on both the shoreline and benthic habitat would need to be established in further studies of the options. This should also include consideration of the impacts of adaptation decisions on neighbouring coastal management units. Potential issues to be resolved would include consultation with affected local government areas - especially if proposed

measures were to accelerate a problem elsewhere, how impacts will be measured and monitored, and the reassessment of adaptation options under changed conditions.

Vulnerability from south

The assessment of the vulnerability to coastal events from the southern side of the peninsula was limited in the Stage 1 and 2 Assessments and therefore the proposed options primarily focussed on protection of the northern coastline. The decisions to protect against inundation in Rockingham should take into account the vulnerability from the southern side of the peninsula which may require additional technical investigations.

Strategic proposals

In planning for adaptation, interim protection and retreat scenarios, it is necessary to consider the future major infrastructure projects that could impact coastal vulnerability and sediment transport. GHD is currently aware of the following potential major plans which would influence the proposed works within the City of Rockingham area:

- Modifications to the Garden Island Causeway
- Construction of a marina in Mangles Bay

From a WA state investment point of view, it is also important to consider the costs of protection of long stretches of the shoreline which could be offset by the costs of developments which could provide economic or public value.

5.7 Accommodation measures

Local planning policy – inundation mitigation

Local planning policy is an effective tool for the City of Rockingham to provide more detailed guidance for coastal development than is currently provided by state planning policy. If future iterations of the City of Rockingham strategic plan identify that the values of the community do not support interim protection to manage inundation of residential areas, local planning policy can be explored to determine opportunities to accommodate inundation risks through building design and retrofitting. Informed by greater detail of the likely extent of inundation, design guidelines implemented through local planning policy may enable the continued use and enjoyment of buildings where they are impacted by occasional inundation that is manageable through flood control measures and other building modifications. The policy needs to clearly articulate that inundation risks will increase over time.

Whether the responses of private owners should remain voluntary or be required by regulation (if possible) needs to be considered.

Building retrofitting

Private land and building owners, who wish to accommodate the risk of inundation rather than retreat, should consider the options available to retrofit their premises to better mitigate the risk of inundation during these extreme events. A number of flood proofing measures are outlined in the Building Code of Australia. When considering the potential accommodation measures available it is important to not only address the potential effects of flooding on the building fabric but also on services, particularly electrical equipment and their cables. Depending on the scale of retrofitting, there may be a need to consider impacts to surrounding neighbours.

Public infrastructure

Increased risk of inundation also needs to be accommodated by infrastructure owners including roads (local government), electricity, gas, water, wastewater and drainage. It is recommended that state and local government engage with infrastructure providers with assets in the proposed Special Control area to develop plans for accommodation or protection and eventual removal of their assets over time.

Emergency planning

Where the risk assessment determined that the adaptation options of Do Nothing and Accommodate were considered appropriate, the implications of these options were not considered in the MCDA process as they will not result in any changes in land use or values to the area and will not incur any significant costs. For these areas it is recommended that emergency safety management plans and suitable forward planning is maintained to address the risk of rare events and adequately plan for sea level rise.

Point Peron beach, with the Garden Island causeway in the background

5.8 Ocean and shoreline monitoring

As indicated in the 2014 Cockburn Sound Coastal Vulnerability Values and Risk Assessment Study, management of the coast would benefit from ongoing monitoring and interpretation. A list of monitoring and data acquisition/analysis that would be beneficial for coastal management in the City is listed below.

- The Department of Transport and other state agencies currently undertake monitoring and data collection within the Cockburn Sound. Long-term historic wave and water levels are publically available, as well as coastal surveys, vegetation line mapping, and ongoing scientific studies. Regular review of these data by the City is recommended to allow for trends that may be affecting their coastline to be identified and to ensure that the information required for the design of coastal structures is readily available.
- Installation of nearshore hydrodynamic instrumentation to collect wave and water level conditions at locations where interim protection is expected to be implemented will enable better calibration and validation of any modelling required.
- Photo monitoring should be undertaken biannually (winter/summer) and during/post significant storm events, in accordance with the methodology recommended by Department of Transport (DaSilva 2012). Visual comparison of site photos provides context for interpretation of the measured profile, vegetation line and bathymetric changes.
- Continued annual or twice yearly monitoring and annual reporting of the transect profiles established through the Metropolitan Redevelopment Authority along the City of Cockburn coastline.
- LIDAR survey and aerial photography of the coastline should be repeated on a regular basis (~5 to 10 years). When undertaken, it should be compared with previous datasets to identity coastal trends and interpret coastal management pressures.
- Local tidal stations should be established to record storm water level extremes and monthly mean sea level, to help interpret coastal management pressures, along with annual means (and exceedance levels). A local and global understanding of recorded sea level rise and future projections should also be maintained to inform future studies.

Working with and sharing relevant coastal data with the other members of the Cockburn Sound Coastal Alliance would allow for resources to be pooled and trends across local government boundaries to be identified.

6. Implementation plan

Key adaptation measures recommended by this adaptation plan are summarised in Table 12 and Figures 16 through to 23. In line with the preferred adaptation responses, a range of specific implementation actions will be required over time alongside key strategic planning activities to deliver the trigger based, flexible adaptation approach. Table 13 provides a consolidated list of all recommendations and required actions from across this adaptation plan, for delivery by relevant stakeholders in the immediate planning horizon.

The adaptation plan identifies focus areas/actions for implementation by state government, particularly in relation to policy, expansion of the foreshore reserve (where necessary in the longer term), and major infrastructure. This plan does not bind state government or other stakeholders to the actions, however recognises that long term adaptation requires the support of these key stakeholders. The City of Rockingham, alongside the Cockburn Sound Coastal Alliance, will work closely with the state government and other key stakeholders to deliver the actions necessary to achieve adaptation principles.

Private residences along the coast in Rockingham

Table 12 Summary of coastal vulnerability and preferred adaptation responses

Coastal Management Unit	Coastal Vulnerabilities	Immediate Planning Horizon (to 2030)	Long-term Planning Horizon (to 2110)
CMU 13 – East Rockingham	Erosion, with intolerable risk presented to assets and a loss of beach area leading up to 2070.	Avoid Accommodate	Interim protection through dune stabilisation works may be feasible
CMU 14 – Rockingham Beach	Erosion, with intolerable risk presented to assets and a loss of beach area leading up to 2070.	Avoid Accommodate	Interim protection, through hard passive engineering structures (groynes or offshore breakwaters) and beach nourishment may be feasible
CMU 15 – Palm Beach	Currently intolerable inundation and erosion risks to assets	Interim protection, through hard passive engineering structures (groynes or offshore breakwaters) and beach nourishment	Continued interim protection, through hard passive engineering structures (groynes or offshore breakwaters) and beach nourishment may be feasible
CMU 16 – Mangles Bay	Erosion, with intolerable risk presented to assets and a loss of beach area leading up to 2070.	Avoid Accommodate	Interim protection, through hard passive engineering structures (groynes or offshore breakwaters) and beach nourishment may be feasible
CMU 17 – Peron Foreshore	Erosion, with intolerable risk presented to assets and a loss of beach area leading up to 2070.	Avoid Accommodate	Interim protection, through hard passive engineering structures (groynes or offshore breakwaters) and beach nourishment may be feasible
CMU 18 – Point Peron	Currently intolerable inundation and erosion risk.	Retreat	Retreat

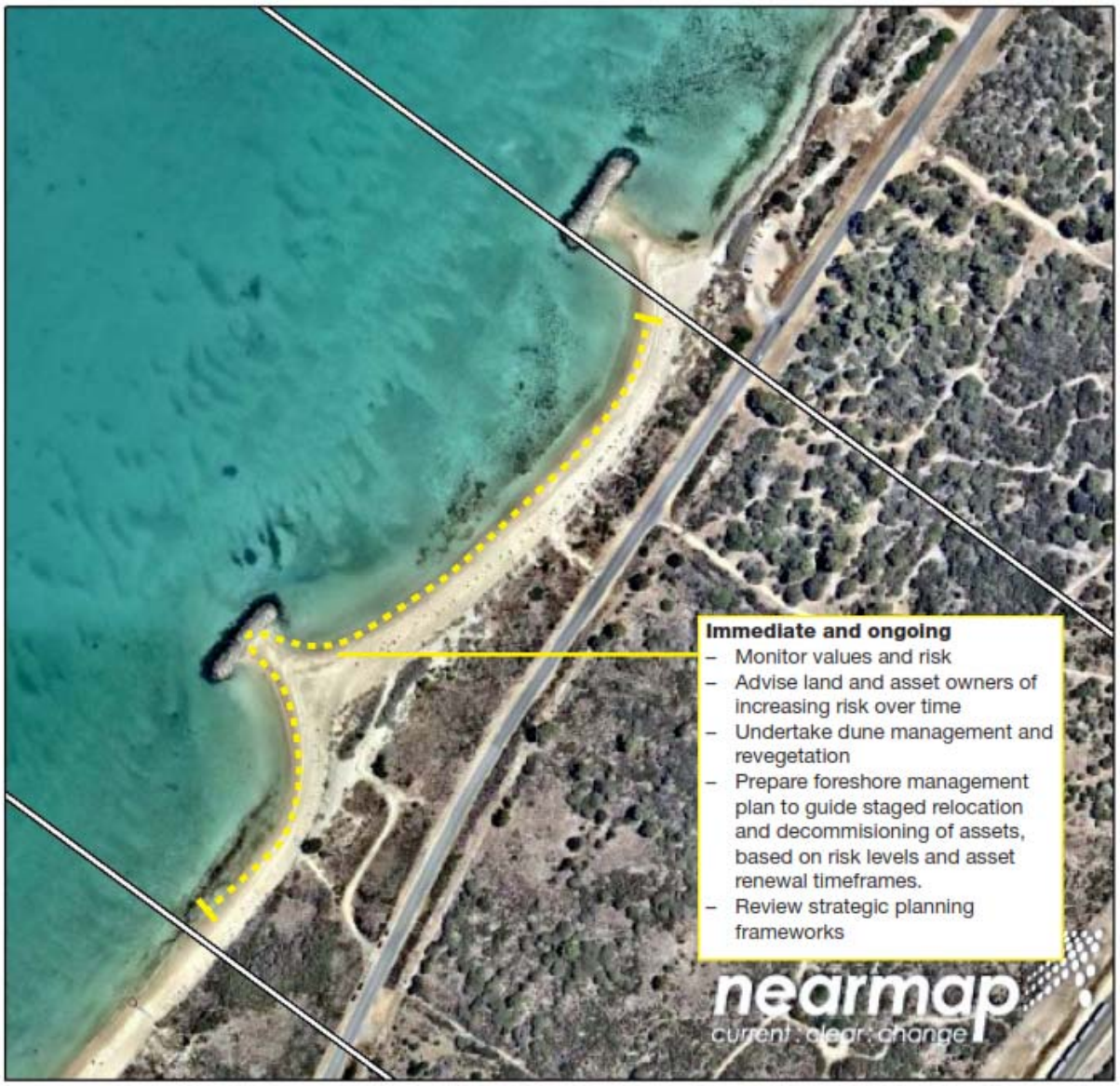


Figure 16 East Rockingham (CMU 13a) – reserve - recommended adaptation measures

Figure 17 East Rockingham (CMU 13b) – Grain Terminal - recommended adaptation measures

Figure 18 East Rockingham (CMU 13c) – Foreshore - recommended adaptation measures

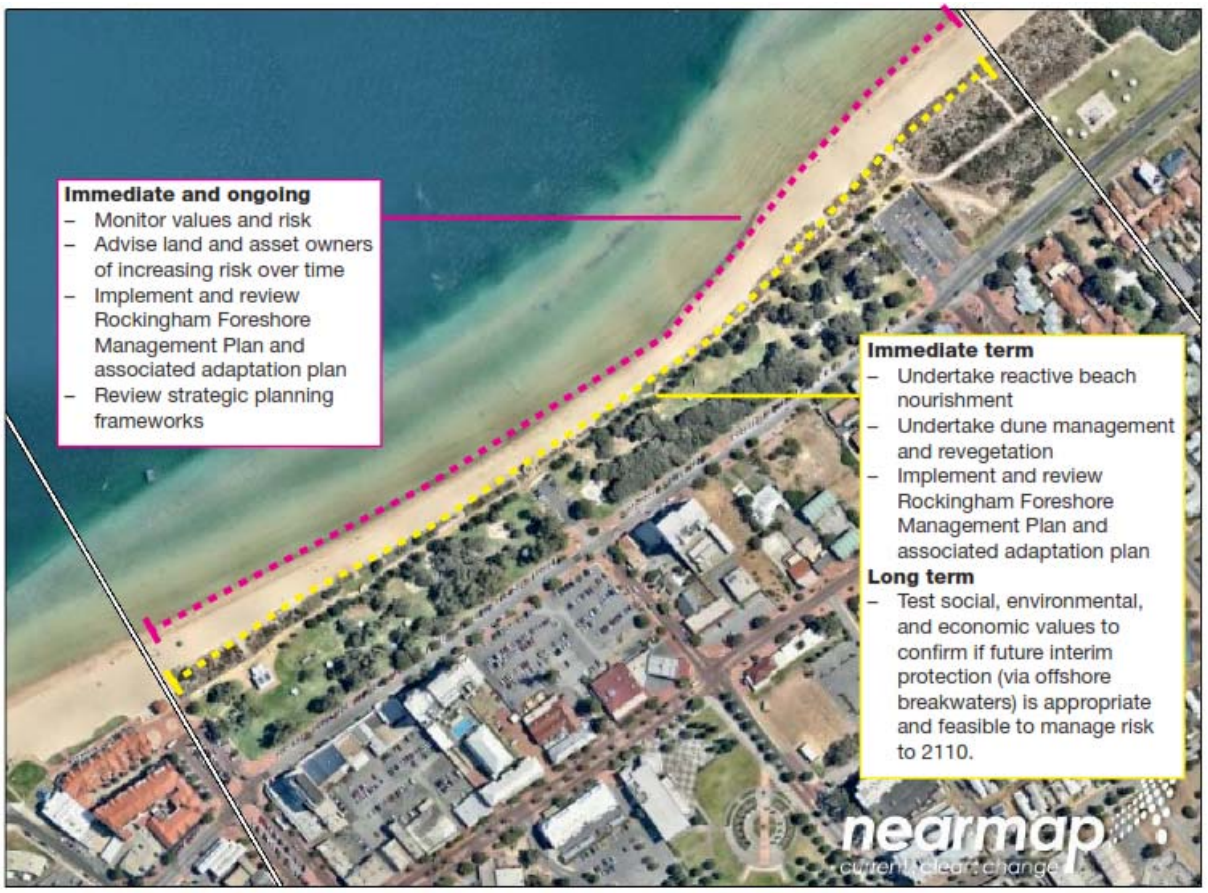


Figure 19 Rockingham Beach - recommended adaptation measures

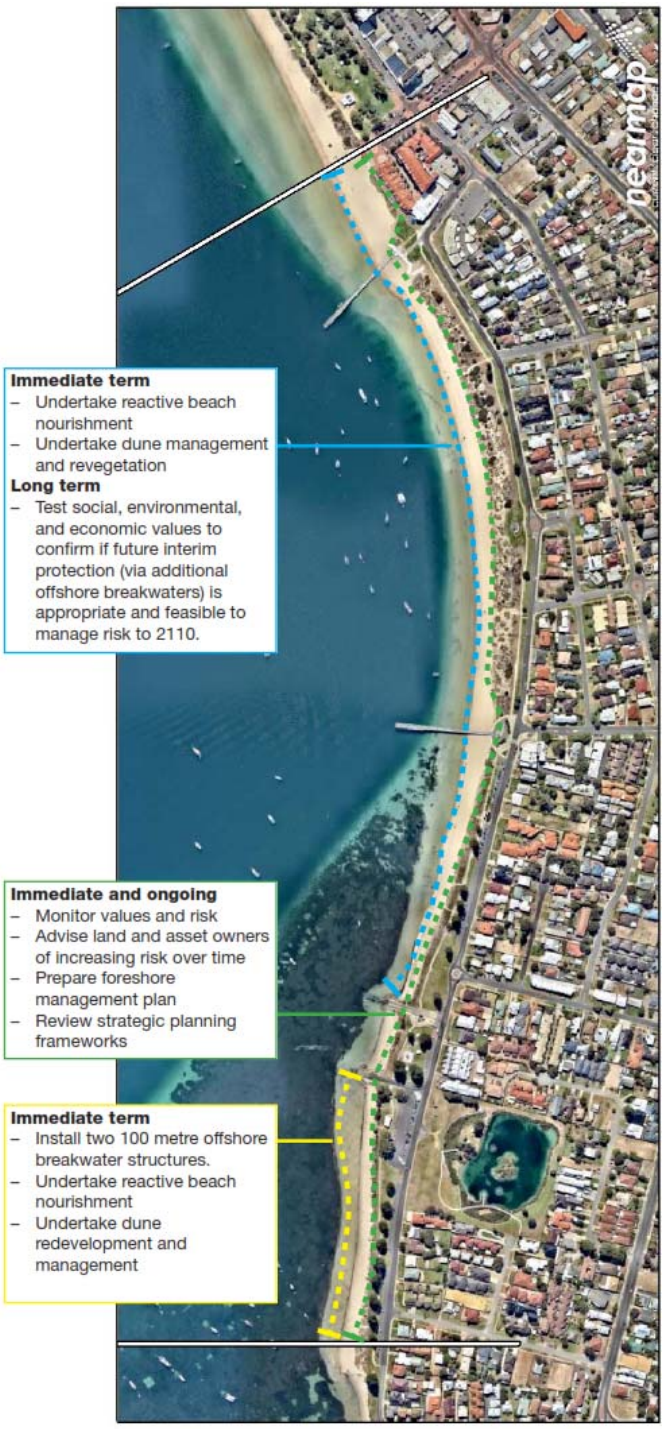


Figure 20 Palm Beach - recommended adaptation measures

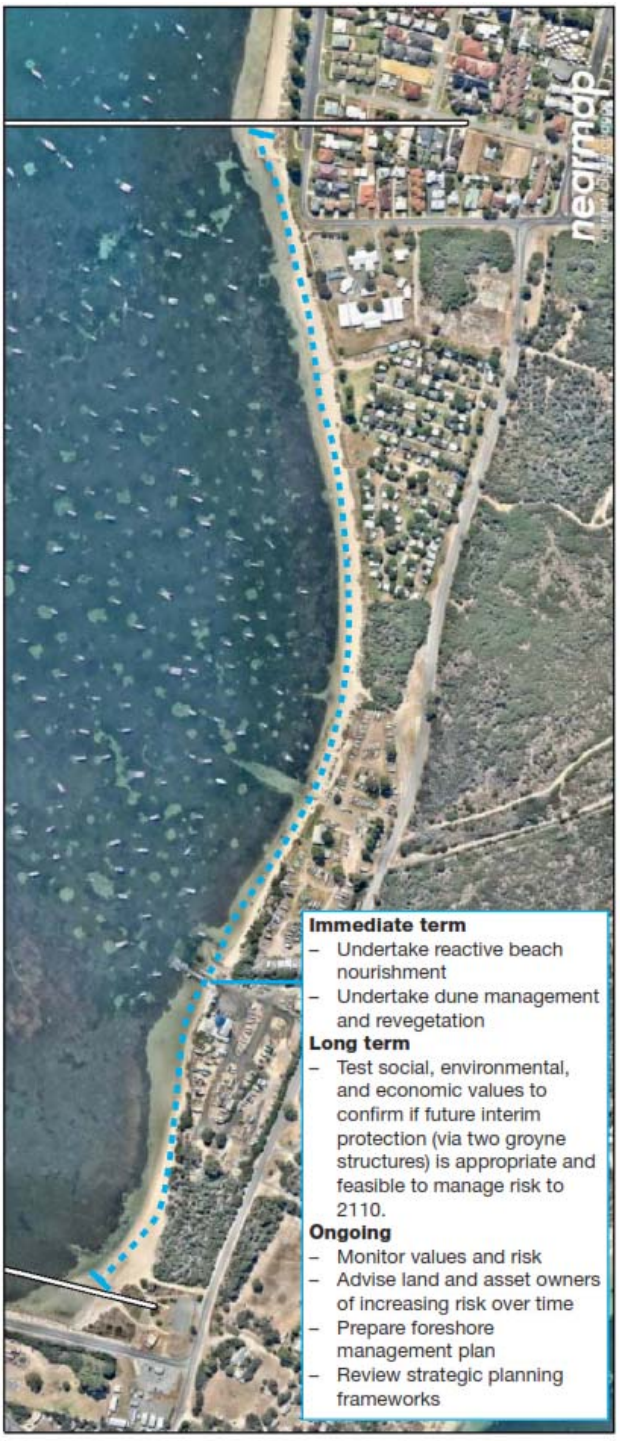


Figure 21 Mangles Bay - recommended adaptation measures

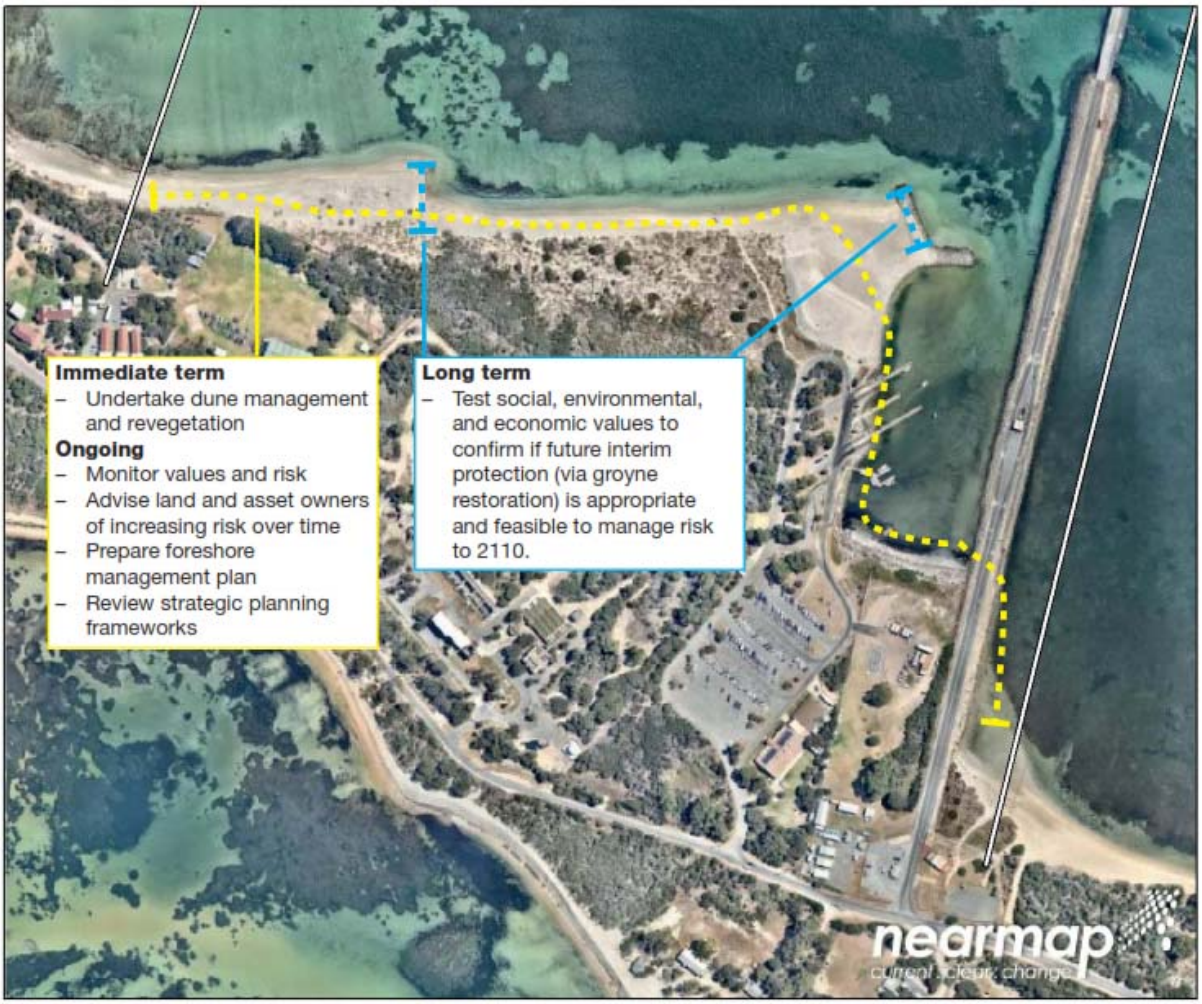


Figure 22 Peron Foreshore - recommended adaptation measures

Figure 23 Point Peron - recommended adaptation measures

Table 13 Immediate planning horizon – implementation plan

Action	Lead Stakeholder	Supporting Stakeholders
Strategic Actions		
Investigate funding responsibilities and opportunities for implementation of coastal adaptation across Western Australian.	Department of Planning	Department of Transport Infrastructure agencies Local government
Review State Planning Policy 2.6 to incorporate additional policy measures for coastal dependant development that is considered a variation to setback requirements.	Western Australian Planning Commission	Department of Planning City of Rockingham Department of Transport (Facilities Management)
Develop and deliver a community awareness campaign regarding coastal risks and impacts, and the adaptation plan.	City of Rockingham	Department of Planning Department of Transport
Review strategic plan, including significant community awareness and engagement regarding coastal adaptation and values.	City of Rockingham	Rockingham community.
Review local planning strategy, to include investigation of special control area and necessary development controls for the coastal vulnerable area.	City of Rockingham	Department of Planning Western Australian Planning Commission Land owners and managers
Review local planning scheme to incorporate special control area and development controls as recommended by the local planning strategy review.	City of Rockingham	Department of Planning Western Australian Planning Commission Land owners and managers
Prepare foreshore management plans	City of Rockingham	Department of Planning Western Australian Planning Commission

Action	Lead Stakeholder	Supporting Stakeholders
Prepare management plan for Point Peron reserve	Department of Parks and Wildlife	Department of Planning Western Australian Planning Commission
Prepare local planning policy for inundation mitigation	City of Rockingham	
Commence dialogue with infrastructure owners and managers regarding adaptation plan and coastal risk.	Department of Planning	City of Rockingham
Prepare emergency safety management plan for extreme events.	City of Rockingham	
Monitor risk levels to land and infrastructure	City of Rockingham	
Provide information to land owners in vulnerable area regarding increasing coastal risk	City of Rockingham	
Specific Adaptation Measures		
Undertake community consultation, concept design and detailed scoping study for establishment of groynes/offshore breakwaters to manage immediate risk at Palm Beach	City of Rockingham	Department of Transport
Undertake responsive beach nourishment and dune management for all coastal reserves	City of Rockingham	

Action	Lead Stakeholder	Supporting Stakeholders
Additional investigations		
Undertake modelling of stormwater contributions to inundation in extreme events and investigate groundwater levels.	City of Rockingham	Water Corporation Department of Water
Investigate materials availability and cost for all potential long-term coastal protection options across Owen Anchorage and Cockburn Sound.	Cockburn Sound Coastal Alliance	Department of Planning Department of Transport
Undertake strategic environmental impact review of cumulative impact of all potential long-term coastal protection options across Owen Anchorage and Cockburn Sound.	Cockburn Sound Coastal Alliance	Department of Planning Department of Transport
Develop and implement coordinated coastal risk monitoring program.	Cockburn Sound Coastal Alliance	Department of Planning Department of Transport

7. Review framework

7.1 Adaptation plan review

This adaptation plan should be reviewed regularly, alongside the review of the City of Rockingham Strategic Plan, and at least every ten years.

Review processes should include targeted community and industry consultation to update values and views about coastal development and assets that will be at risk both within a 15-year planning horizon and beyond. Revised values and new learnings should be used to test recommendations of this adaptation plan, and determine whether adaptation strategies for the 15-year planning horizon require modification as a result of changing values.

The regular testing of values and adaptation measures will involve the following actions incorporated into the review of future strategic plans, for land and assets identified as being at risk within 15-years of the strategic plan review:

- Identification of any new or alternative adaptation options based on greater information and new technology;
- Review of criteria used in the multi-criteria assessment;
- Community, stakeholder and industry consultation on the weighting of criteria;
- Review of the weighted scoring of adaptation options;
- Confirmation of adaptation options for a 15-year planning horizon.

7.2 Future hazard assessment

It will be necessary to update the hazard mapping from time to time to reflect actual sea level rise, updated projections of future sea level rise and the response of the coast to changing conditions. These updates should occur as new information becomes available.

It is recommended that the erosion and inundation hazard assessment is updated following the release of the next Intergovernmental Panel for Climate Change (IPCC) assessment report which is expected in 2020/21.

8. References

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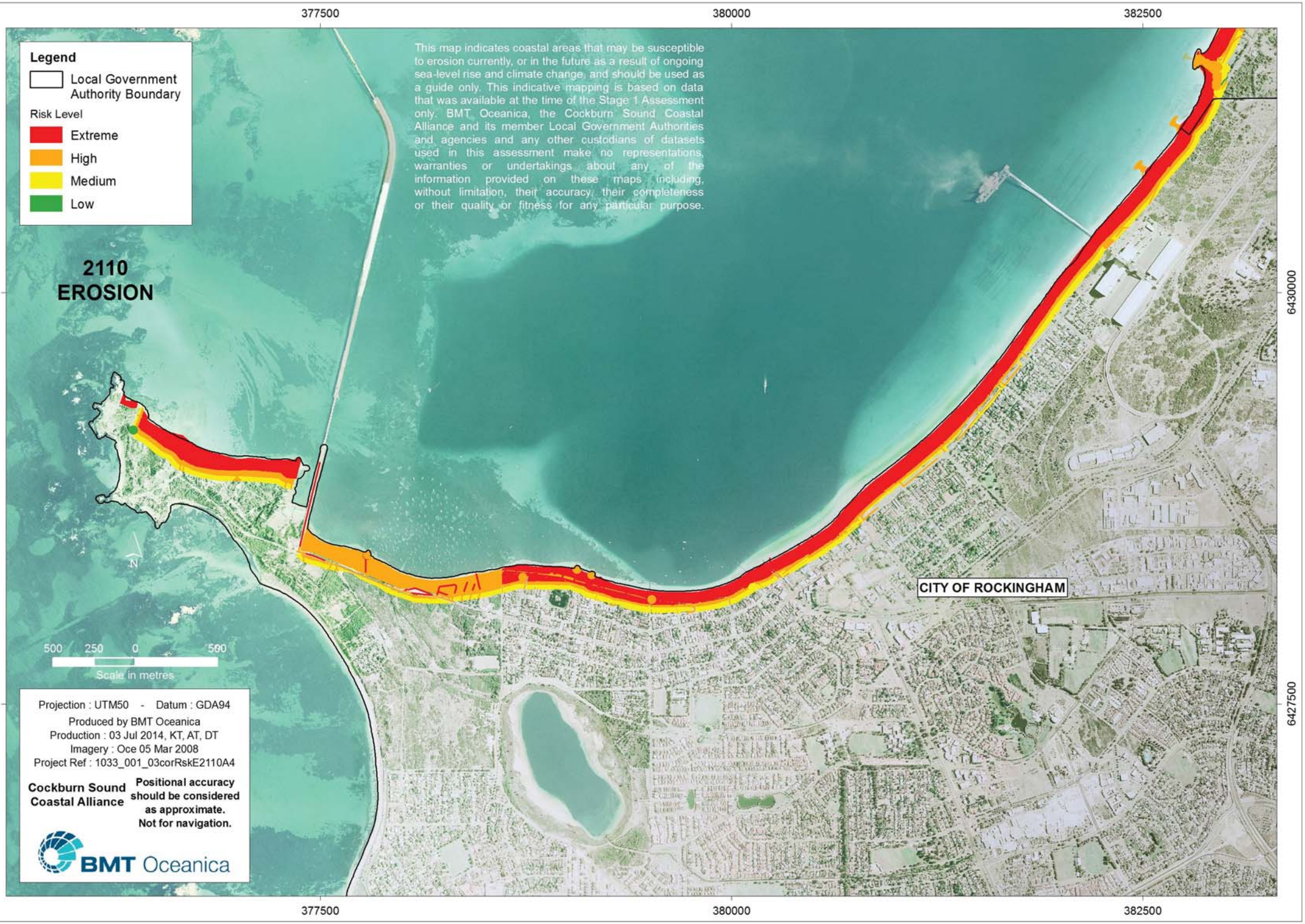
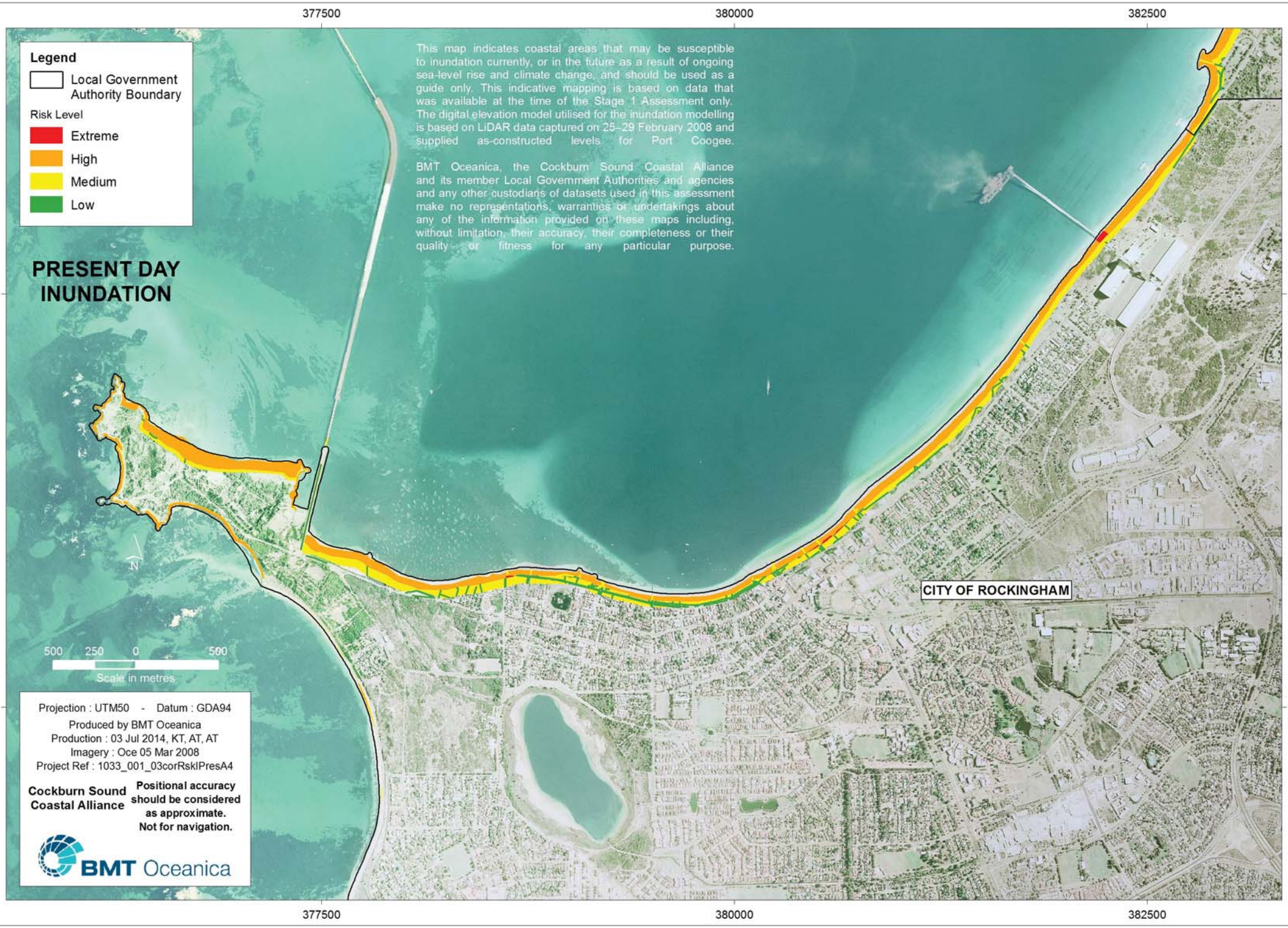
Appendix A

Coastal Risk Mapping – present, 2070 and 2110

Prepared by BMT Oceanica for the Cockburn Sound Vulnerability Values and Risk Assessment Study





Appendix B

MCDA Results and Sensitivity Analysis

MCA results and sensitivity analysis

The results of the MCDA and associated sensitivity analysis plots are set out below.

The tables indicate the unweighted and weighted scores for each option.

The sensitivity analysis was carried out using HiView's inbuilt analysis plots.

Sensitivity down plots

The sensitivity down window calculates which criteria weights are sensitive. The criteria are listed down the middle of the screen. Where a change to the cumulative weight of a criterion can result in a new most preferred option, a bar is drawn on the graph. The bars are colour coded. A red bar is very sensitive, a yellow bar is less sensitive and a green bar would require a large weight change to change the most preferred option. The thresholds for colour coding are as follows:

Red - cumulative weight would have to change by 5 points or less in order to change the most preferred option.

Yellow - cumulative weight would have to change by between > 5 to 15 points in order to change the most preferred option.

Green - cumulative weight would have to change by more than 15 points in order to change the most preferred option.

The bars drawn to the left of the criteria list represent a decrease in cumulative weight, whilst the bars drawn to the right represent an increase. For each instance of a bar being drawn, the new most preferred option is displayed at the end of the bar. Where there is no bar, no amount of weight change will change the most preferred option. The sensitivity down window is used to direct further analysis of the model. Where criteria have a red bar, further analysis is a high priority.

Sensitivity up plots

The sensitivity up graph displays the sensitivity of the selected tree item with regard to the most preferred option at the top of the tree.

This graph demonstrates how the most preferred option at the top of the tree varies with the cumulative weight on node selected. The x-axis represents the cumulative weight on the criterion. The y-axis shows the total weighted values, at the root node, of each of the options. The vertical red line shows the current cumulative weight of the selected node. Reading the y-values for each option, these are the same as the total weighted scores in the node data window for the root node. The line for each option shows how this total weighted score will change as the cumulative weight on the criterion changes. The most preferred option at any cumulative weight has the highest y-value. At the vertical red line, whichever line has the highest y-value is currently the most preferred option.

Coastal Management Unit 12

Northern boundary:	South boundary of Kwinana Bulk Jetty
Southern boundary	Kwinana / Rockingham local govt boundary
Key assets	Wells Park, The Wreck

Interim protection options

Option 1: Initial stage (2070)

- Seawall along northern boundary

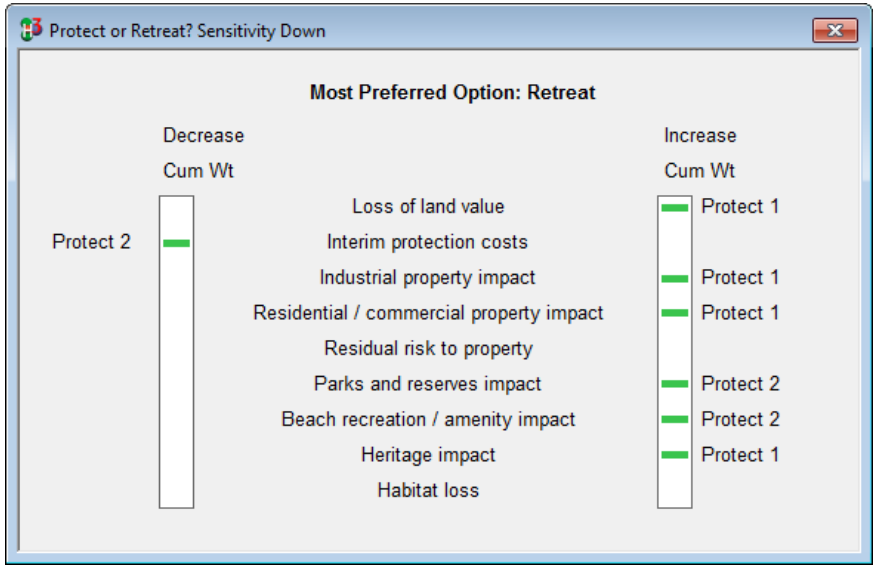
Option 2 Initial stage (2070)

- Offshore breakwaters
- Beach nourishment

		Raw data						Normalised score					Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3		Nominal	Adjusted
Loss of land value	Discounted cost ($m)	0	0	0		#DIV/0!	R/A	0	0	0			0.11	0.00
Interim protection costs	Discounted cost ($m)	0	1.9	2.3		164%	R/A	100	17	0			0.11	0.50
Industrial property impact	No. potential lots affected		0.00			0%	Ttl lots	0	0	0			0.19	0.00
Residential & commercial property impact	No. potential lots affected		0			0%	Ttl lots	0	100	100			0.11	0.00
Residual risk to property	Scale of 1-5	1	2	3				100	50	0			0.07	0.00
Parks and reserves impact	Area (ha)		10.69			2.38%	Ttl area	0	100	100			0.11	0.10
Beach recreation / amenity impact	m of beach		400			2%	Ttl beach	100	0	100			0.15	0.20
Heritage impact	No. of heritage properties affected		0			0%	Ttl props	0	100	100			0.04	0.00
Habitat loss	Area (ha)		4.4			2%	Ttl area	100	0	50			0.11	0.20
								400	367	450			1.00	1.00
					Weighted score			90	19	40				
					Rank			1	3	2				

Notes:

1. Weighting for Parks and reserves assumes that the equivalent area cannot be retained in the Retreat option.



Coastal Management Unit 13

Northern boundary:	Kwinana / Rockingham local govt boundary
Southern boundary	Wanliss Street
Key assets	Rockingham Beach, CBH Grain Terminal

Interim protection options

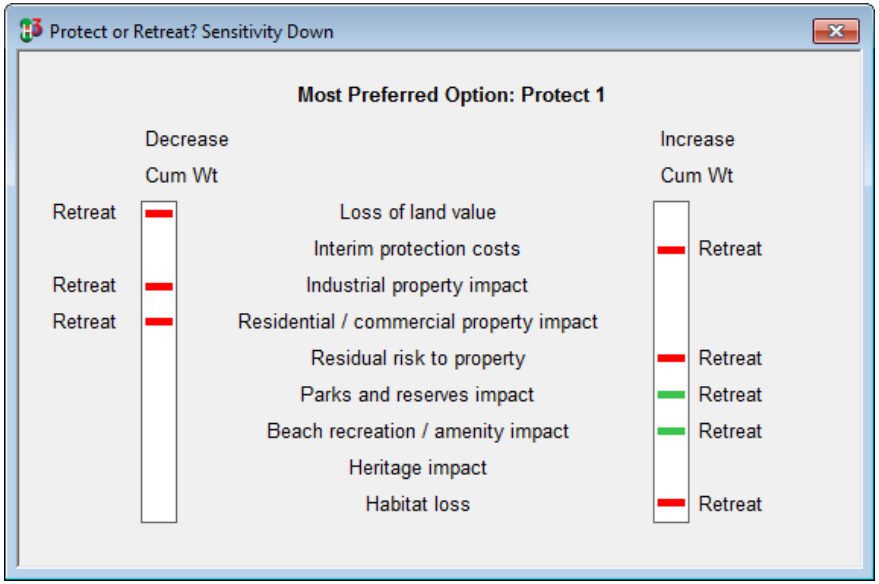
Option 1: Initial stage (2070)

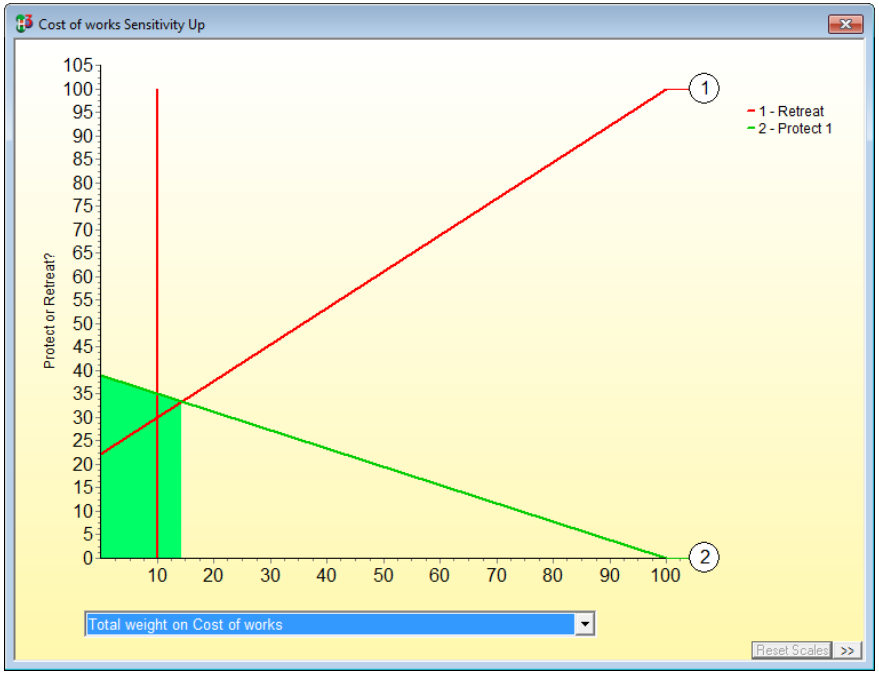
- Dune stabilisation

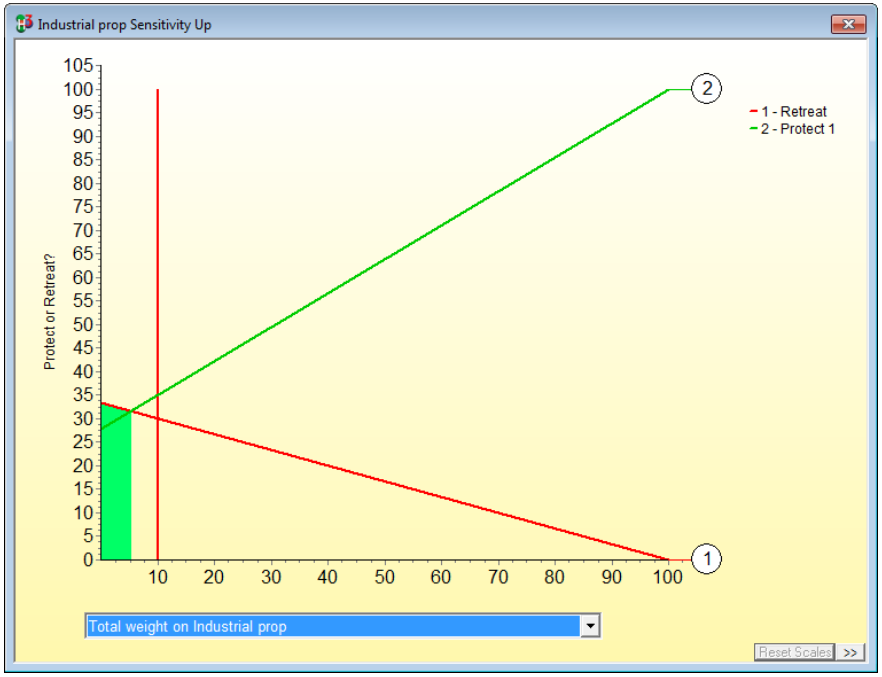
		Raw data						Normalised score				Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3	Nominal	Adjusted
Loss of land value	Discounted cost ($m)	118	65			58%	R/A	0	100			0.11	0.10
Interim protection costs	Discounted cost ($m)	0	6			200%	R/A	100	0			0.11	0.10
Industrial property impact	No. potential lots affected		11.00			10%	Ttl lots	0	100			0.19	0.10
Residential & commercial property impact	No. potential lots affected		105			4%	Ttl lots	0	100			0.11	0.15
Residual risk to property	Scale of 1-5	1	5					100	0			0.07	0.05
Parks and reserves impact	Area (ha)		38.50			8.59%	Ttl area	0	0			0.11	0.15
Beach recreation / amenity impact	m of beach		2760			12%	Ttl beach	0	0			0.15	0.20
Heritage impact	No. of heritage properties affected		0			0%	Ttl props	0	100			0.04	0.00
Habitat loss	Area (ha)		30.4			15%	Ttl area	100	0			0.11	0.15
								300	400			1.00	1.00
					Weighted score			30	35				
					Rank			2	1				

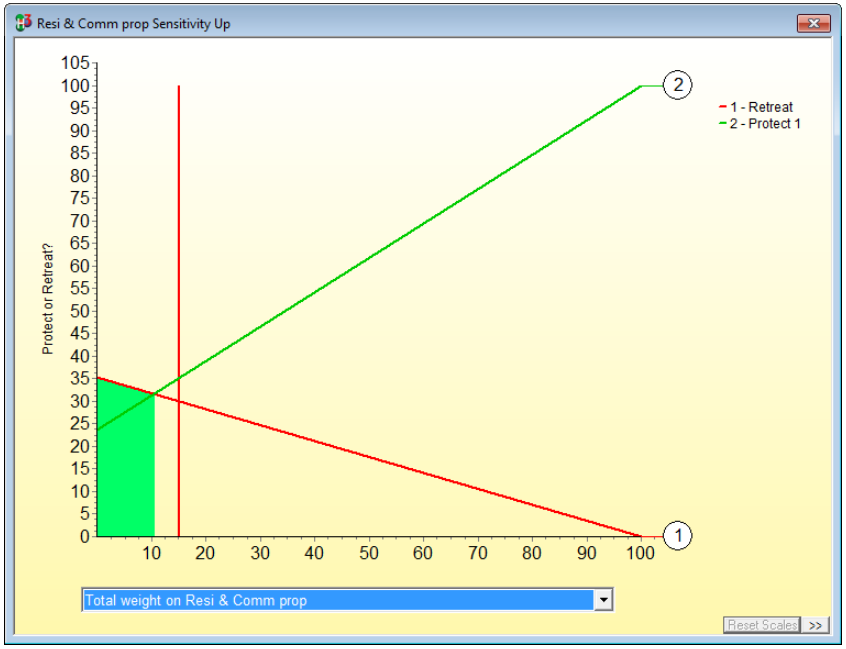
Notes:

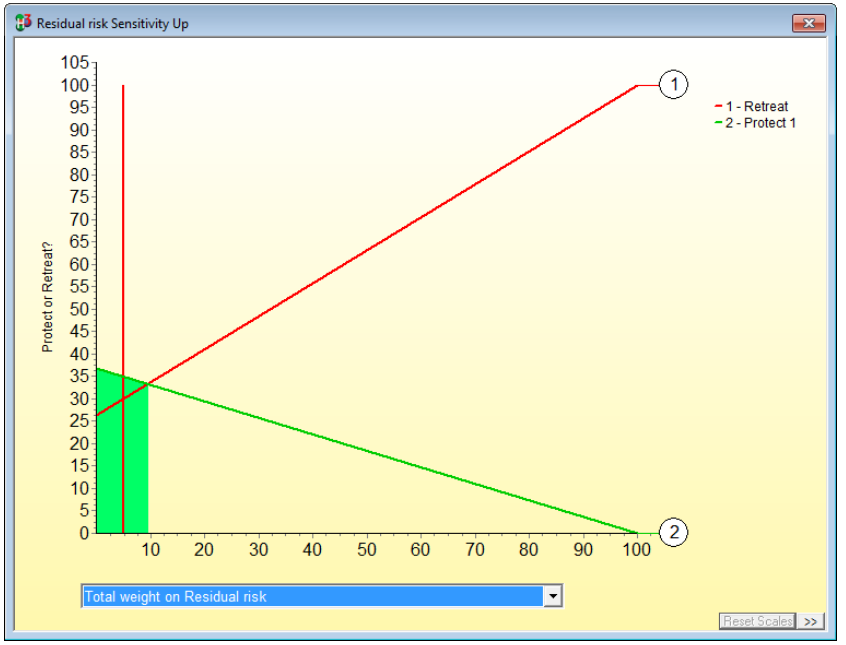
1. Weighting for Parks and reserves assumes that the equivalent area can be retained in the Retreat option.

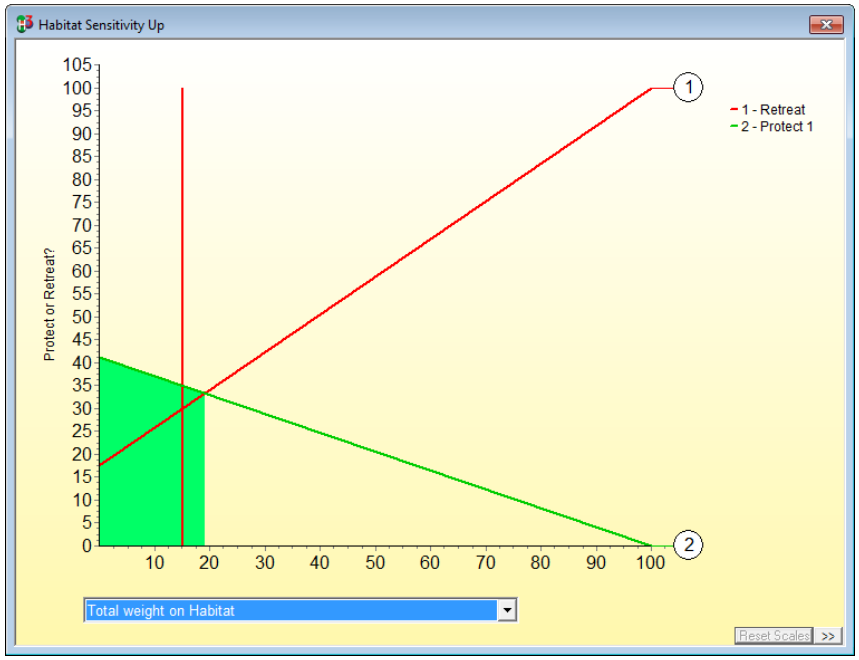












Coastal Management Unit 14

Northern boundary:	Wanliss Street
Southern boundary	Railway Terrace
Key assets	Bell and Churchill Park

Interim protection options

Option 1: Initial stage (2070)

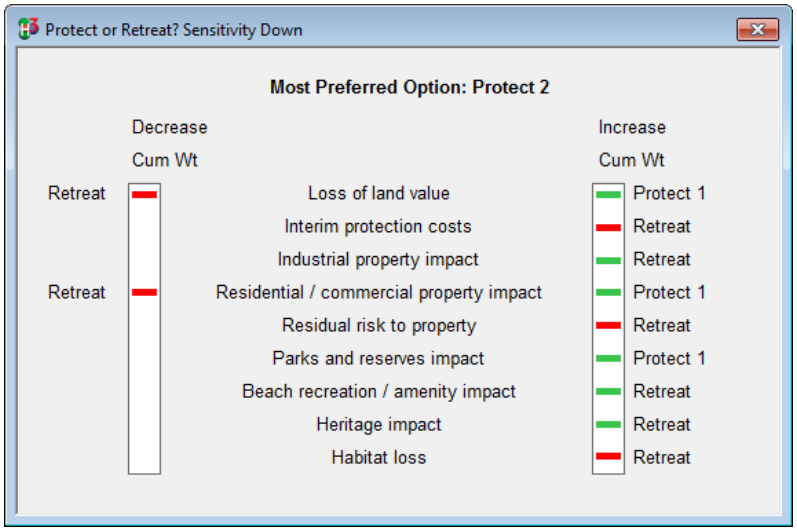
- Build seawall along the shore

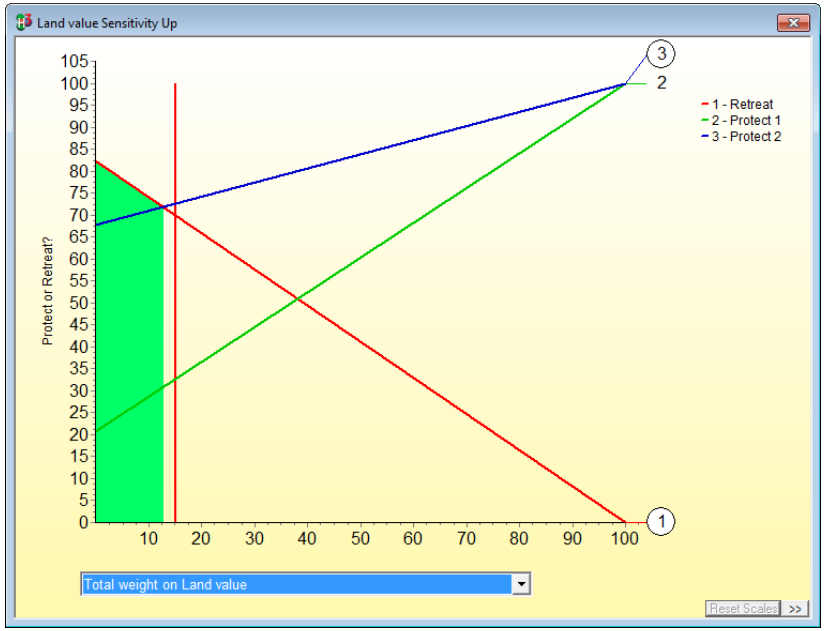
Option 2 Initial stage (2070)

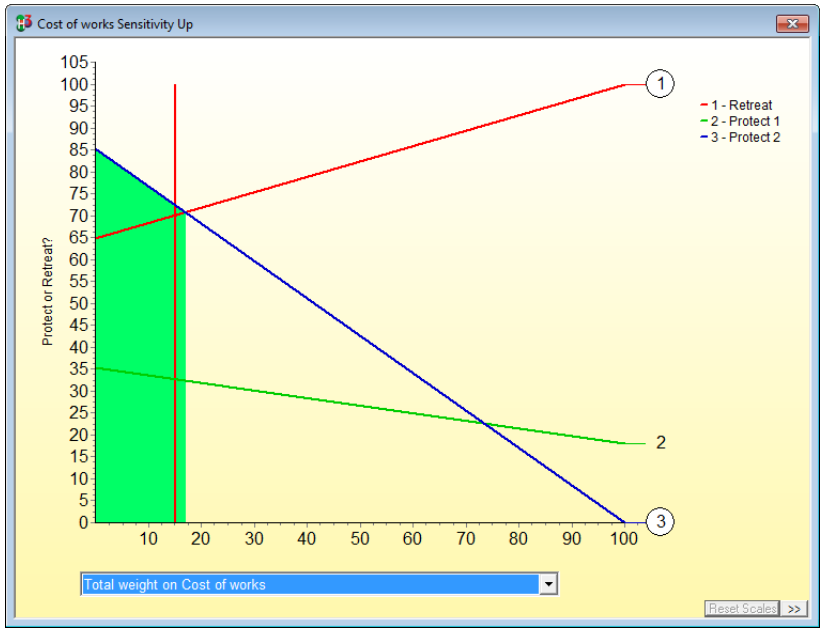
- Upgrade, extend and build new groyne structures
- Place sand and build beach

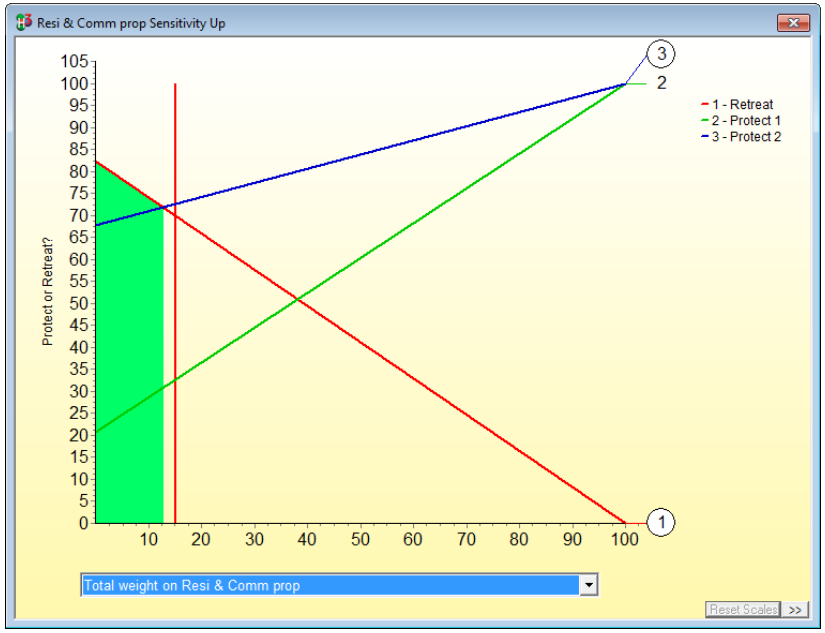
		Raw data						Normalised score					Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3		Nominal	Adjusted
Loss of land value	Discounted cost ($m)	67	37	37		64%	R/A	0	100	100			0.11	0.15
Interim protection costs	Discounted cost ($m)	0	11	13.4		162%	R/A	100	15	0			0.11	0.15
Industrial property impact	No. potential lots affected		0.00			0%	Ttl lots	0	0	0			0.19	0.00
Residential & commercial property impact	No. potential lots affected		47			2%	Ttl lots	0	100	100			0.11	0.15
Residual risk to property	Scale of 1-5	1	3	2				100	0	50			0.07	0.15
Parks and reserves impact	Area (ha)		5.35			1.19%	Ttl area	0	100	100			0.11	0.00
Beach recreation / amenity impact	m of beach		720			3%	Ttl beach	100	0	100			0.15	0.30
Heritage impact	No. of heritage properties affected		0			0%	Ttl props	0	0	0			0.04	0.00
Habitat loss	Area (ha)		2.4			1%	Ttl area	100	0	50			0.11	0.10
								400	315	500			1.00	1.00
					Weighted score			70	32	73				
					Rank			2	3	1				

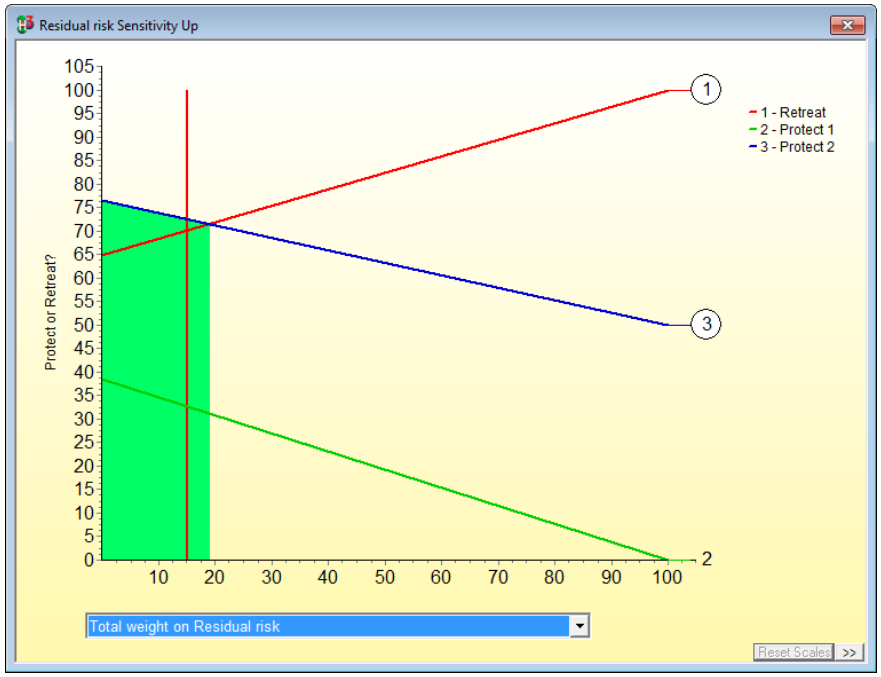
1. Weighting of zero for Parks and reserves assumes that the equivalent area can be retained in the Retreat option.











Coastal Management Unit 15

Northern boundary:	Railway Terrace
Southern boundary	Hymus Street
Key assets	Palm Beach

Interim protection options

Option 1: Initial stage (Present)

- Build a seawall to protect the park

Later stage (2070)

- Build a road and levee along the foreshore

Option 2 Initial stage (Present)

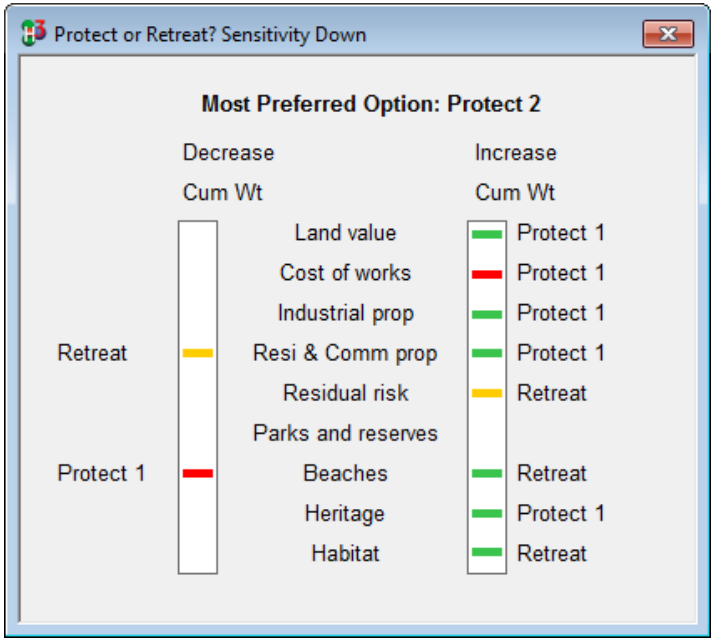
- Groynes (four @ 110 m)
- Nourishment

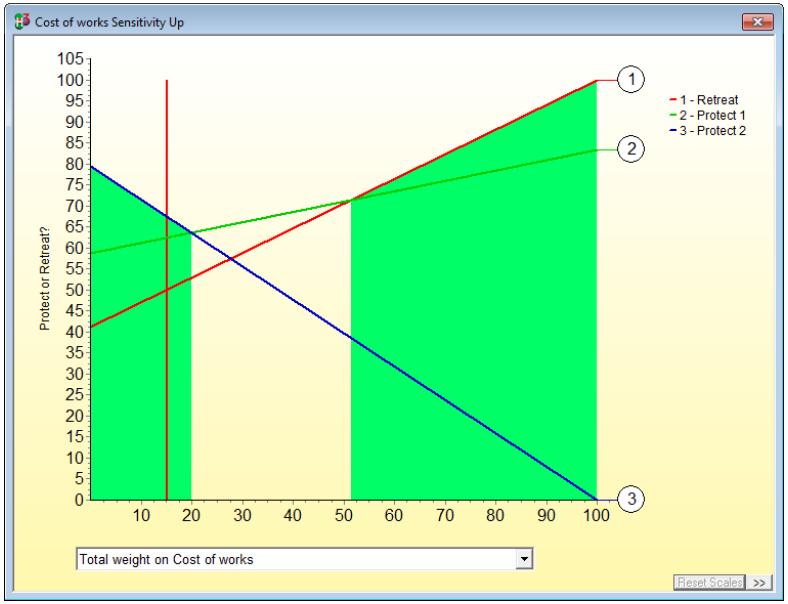
Later stage (2070)

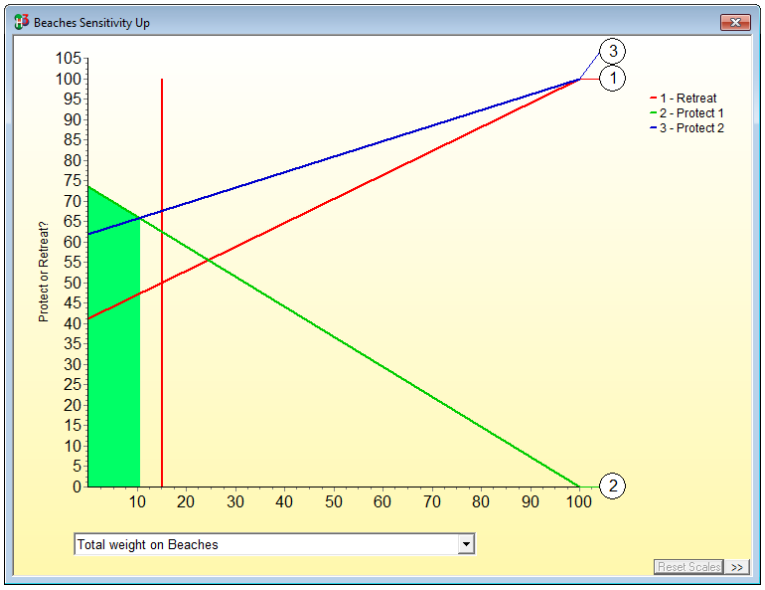
- Increase dune elevation
- Stormwater drainage one way valves

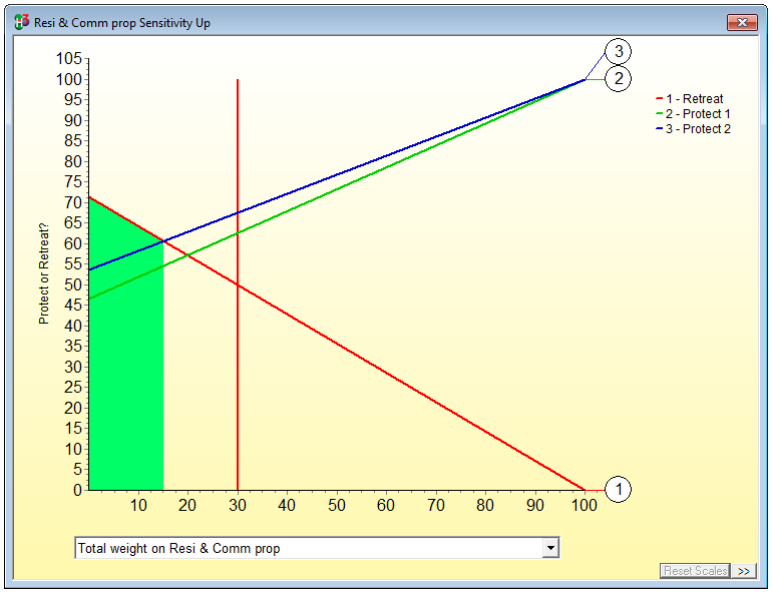
		Raw data						Normalised score				Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3	Nominal	Adjusted
Loss of land value	Discounted cost ($m)	1174	234	234		172%	R/A	0	100	100		0.11	0.15
Interim protection costs	Discounted cost ($m)	0	9	54		257%	R/A	100	83	0		0.11	0.15
Industrial property impact	No. potential lots affected	0.00				0%	Ttl lots	0	0	0		0.19	0.00
Residential & commercial property impact	No. potential lots affected	1204				45%	Ttl lots	0	100	100		0.11	0.30
Residual risk to property	Scale of 1-5	1	5	5				100	0	0		0.07	0.15
Parks and reserves impact	Area (ha)	30.45				6.79%	Ttl area	0	100	100		0.11	0.00
Beach recreation / amenity impact	m of beach	1200				5%	Ttl beach	100	0	100		0.15	0.15
Heritage impact	No. of heritage properties affected	5				10%	Ttl props	0	100	100		0.04	0.05
Habitat loss	Area (ha)	5.8				3%	Ttl area	100	0	50		0.11	0.05
								400	483	550		1.00	1.00
					Weighted score			50	63	68			
					Rank			3	2	1			

1. Weighting of zero for Parks and reserves assumes that the equivalent area can be retained in the Retreat option.









Coastal Management Unit 16

Northern boundary:	Hymus Street
Southern boundary	Garden Island causeway
Key assets	Causeway

Interim protection options

Option 1: Initial stage (2070)

- Build seawall along the shore

Option 2 Initial stage (2070)

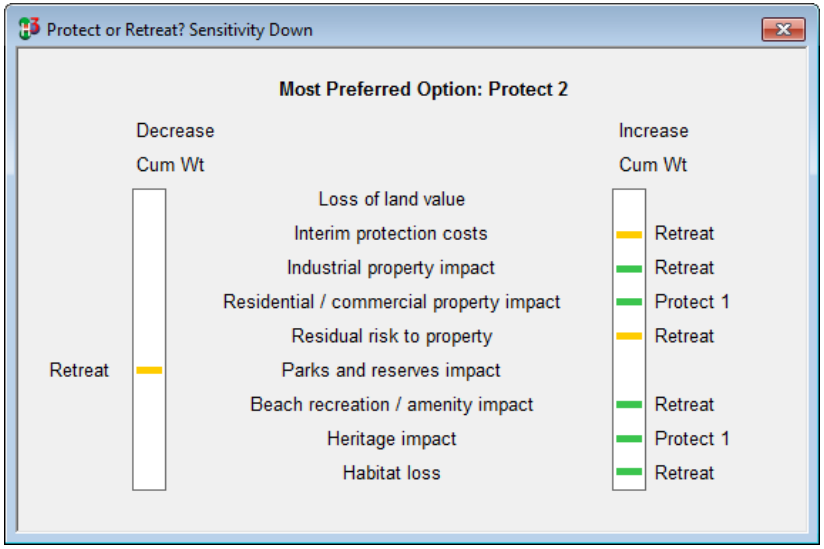
- Upgrade, extend and build new groyne structures
- Place sand and build beach

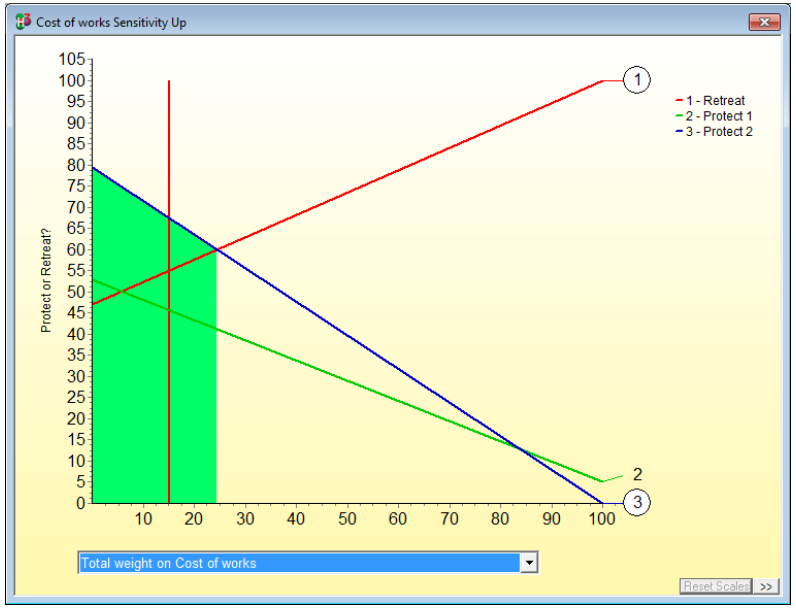
		Raw data						Normalised score					Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3		Nominal	Adjusted
Loss of land value	Discounted cost ($m)	92	51	51		64%	R/A	0	100	100			0.11	0.10
Interim protection costs	Discounted cost ($m)	0	19	20		154%	R/A	100	6	0			0.11	0.15
Industrial property impact	No. potential lots affected	0.00				0%	Ttl lots	0	0	0			0.19	0.00
Residential & commercial property impact	No. potential lots affected	93				3%	Ttl lots	0	100	100			0.11	0.05
Residual risk to property	Scale of 1-5	1	5	5				100	0	0			0.07	0.15
Parks and reserves impact	Area (ha)	49.36				11.01%	Ttl area	0	100	100			0.11	0.20
Beach recreation / amenity impact	m of beach	1230				5%	Ttl beach	100	0	100			0.15	0.20
Heritage impact	No. of heritage properties affected	6				12%	Ttl props	0	100	100			0.04	0.10
Habitat loss	Area (ha)	1.8				1%	Ttl area	100	0	50			0.11	0.05
								400	406	550			1.00	1.00
					Weighted score			55	46	68				
					Rank			2	3	1				

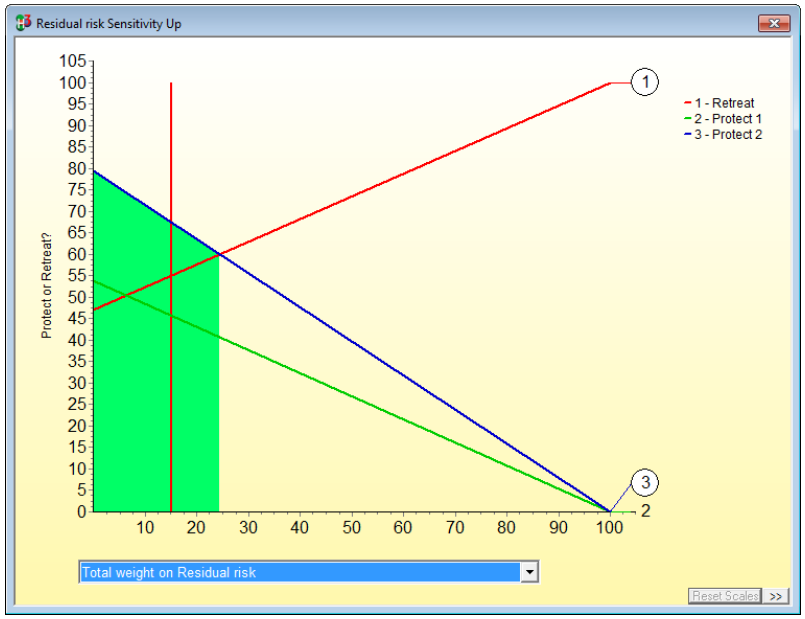
Notes:

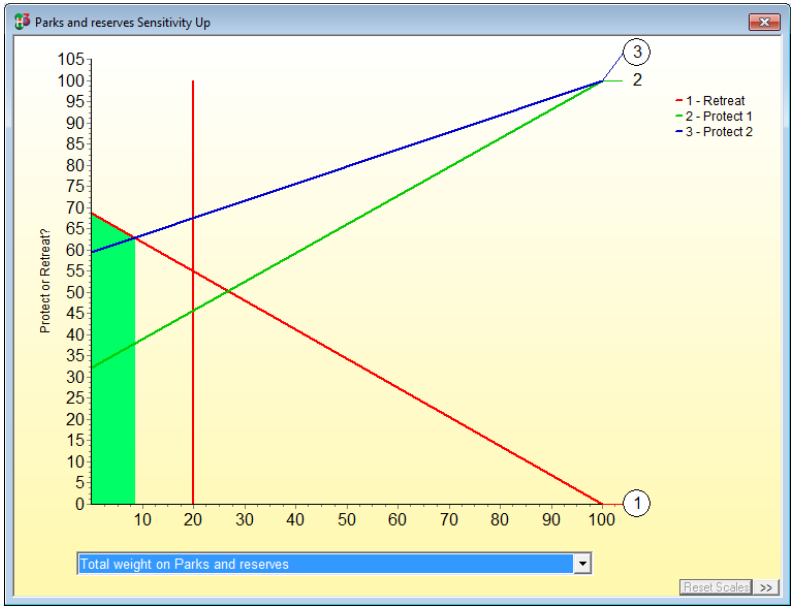
1. Ranking is provisional only as measures for this area require information about coastal risks to the south of the peninsula

2. Weighting for Parks and reserves assumes that the equivalent area cannot be retained in the Retreat option.


Protect or Retreat? Sensitivity Down
Most Preferred Option: Protect 2
Decrease
Cum Wt
Increase
Cum Wt
Loss of land value
Interim protection costs
Industrial property impact
Residential / commercial property impact
Residual risk to property
Parks and reserves impact
Beach recreation / amenity impact
Heritage impact
Habitat loss
Retreat
Retreat
Retreat
Protect 1
Retreat
Retreat
Retreat
Protect 1
Retreat


Cost of works Sensitivity Up
Protect or Retreat?
1 - Retreat
2 - Protect 1
3 - Protect 2
Total weight on Cost of works
Reset Scales
>>


Residual risk Sensitivity Up
Protect or Retreat?
1 - Retreat
2 - Protect 1
3 - Protect 2
Total weight on Residual risk
Reset Scales
>>


Parks and reserves Sensitivity Up
Protect or Retreat?
1 - Retreat
2 - Protect 1
3 - Protect 2
Total weight on Parks and reserves
Reset Scales
>>

Coastal Management Unit 17

Northern boundary:	Garden Island causeway
Southern boundary	Western boundary of Point Peron Recreational Camp
Key assets	Point Peron Recreational Camp

Interim protection options

Option 1: Initial stage (2070)

- Build seawall along the shore

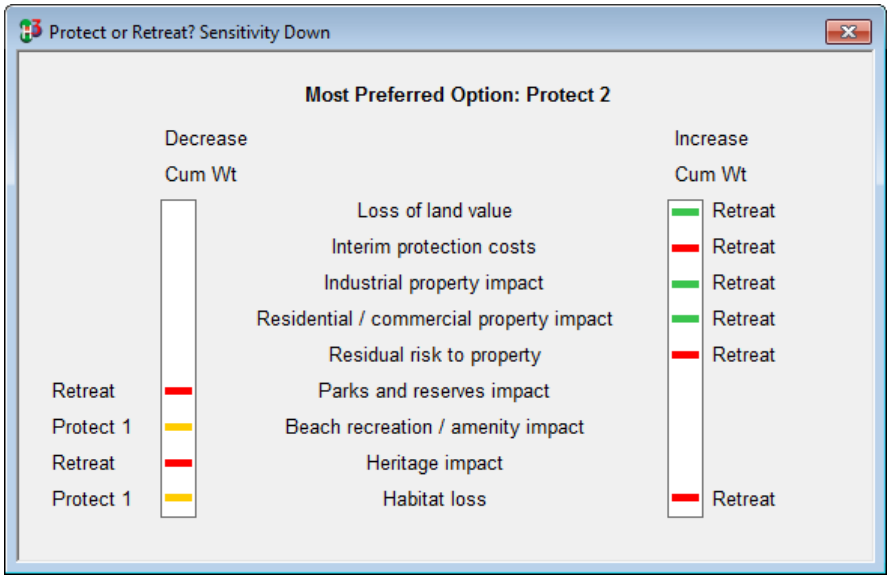
Option 2 Initial stage (2070)

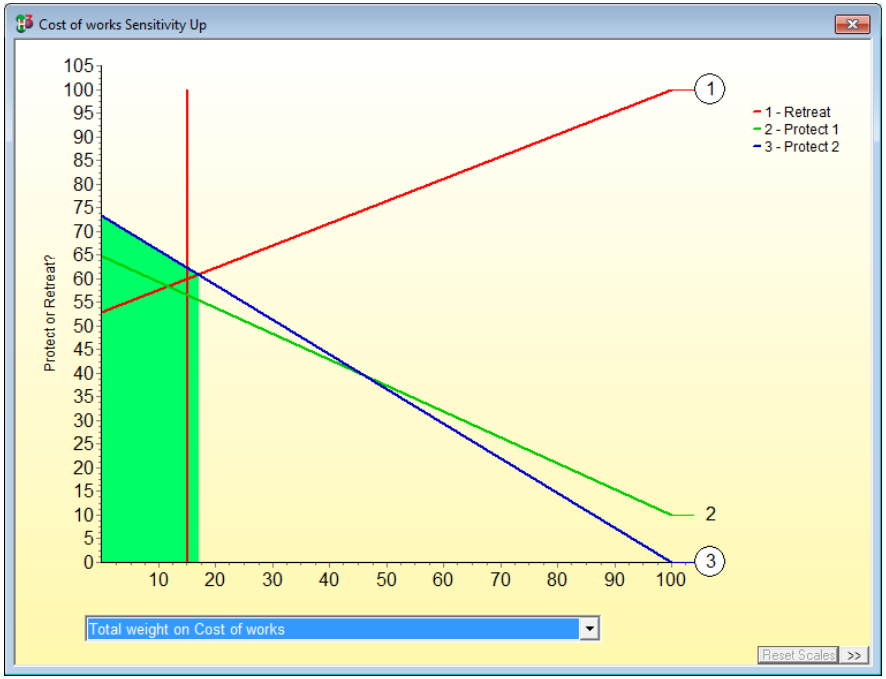
- Upgrade, extend and build new groyne structures
- Place sand and build beach

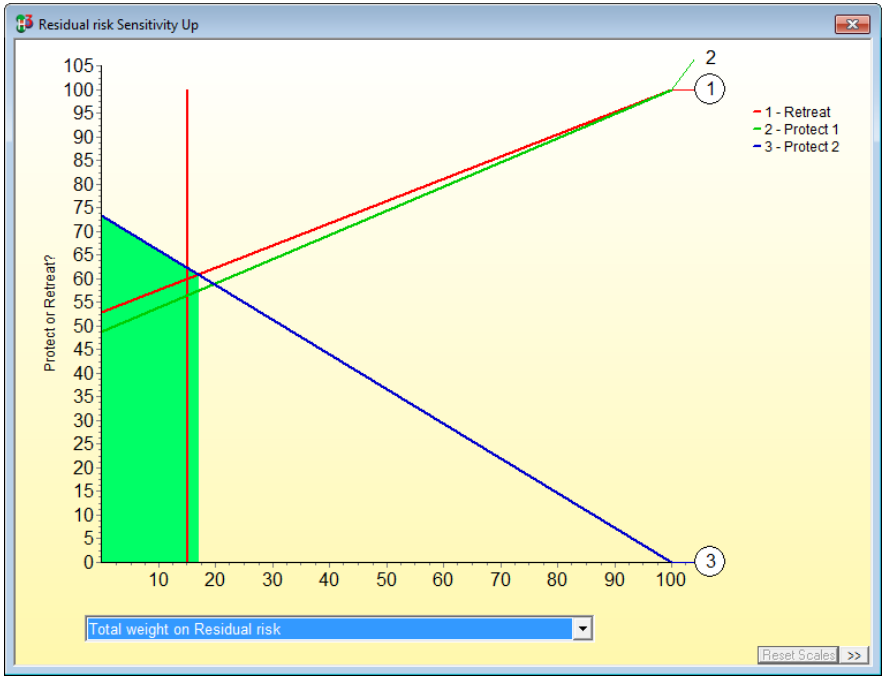
		Raw data						Normalised score				Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3	Nominal	Adjusted
Loss of land value	Discounted cost ($m)	0	0	0			R/A	0	0	0		0.11	0.00
Interim protection costs	Discounted cost ($m)	0	9	10		155%	R/A	100	6	0		0.11	0.15
Industrial property impact	No. potential lots affected		0.00			0%	Ttl lots	0	0	0		0.19	0.00
Residential & commercial property impact	No. potential lots affected		0			0%	Ttl lots	0	0	0		0.11	0.00
Residual risk to property	Scale of 1-5	1	1	5				100	100	0		0.07	0.15
Parks and reserves impact	Area (ha)		17.23			3.84%	Ttl area	0	100	100		0.11	0.35
Beach recreation / amenity impact	m of beach		600			3%	Ttl beach	100	0	100		0.15	0.15
Heritage impact	No. of heritage properties affected		1			2%	Ttl props	0	100	100		0.04	0.05
Habitat loss	Area (ha)		7.5			4%	Ttl area	100	0	50		0.11	0.15
								400	306	350		1.00	1.00
					Weighted score			60	56	63			
					Rank			2	3	1			

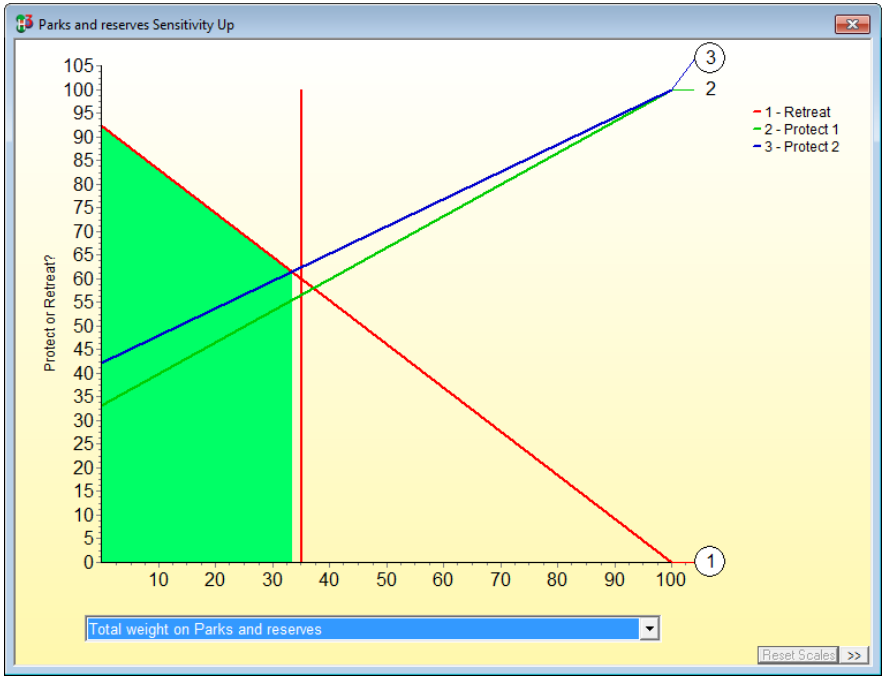
1. Ranking is provisional only as measures for this area require information about coastal risks to the south of the peninsula.

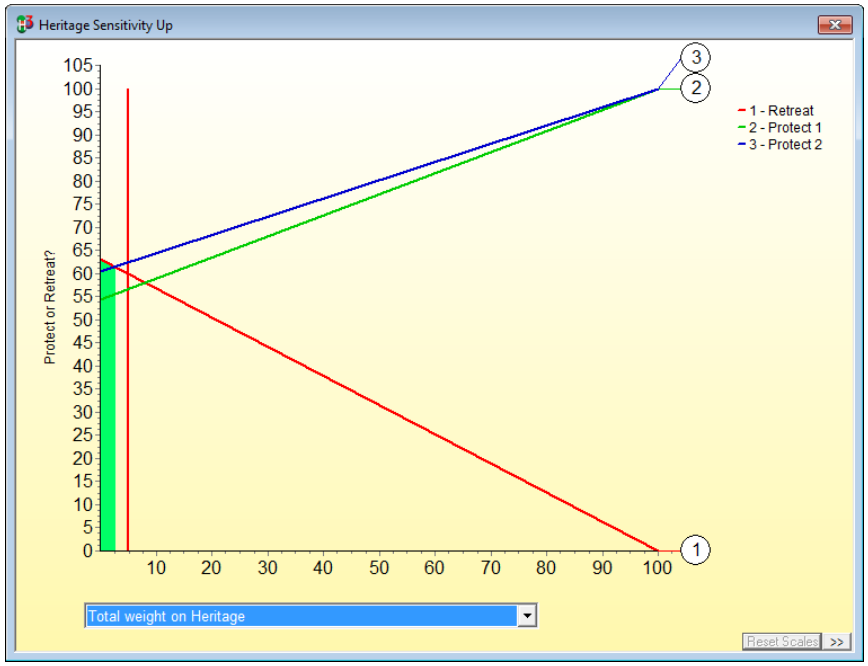
2. Weighting for Parks and reserves assumes that the equivalent area cannot be retained in the Retreat option.

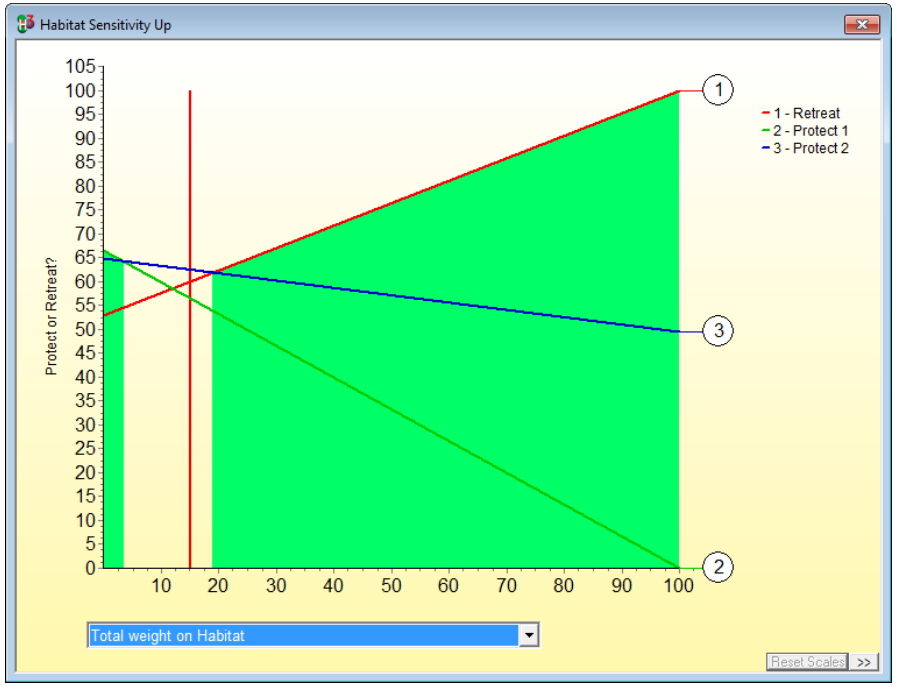












Coastal Management Unit 18

Northern boundary:	Western boundary of Point Peron Recreational Camp
Southern boundary	End of peninsula
Key assets	Point Peron – Rockingham Lakes Regional Park

Interim protection options

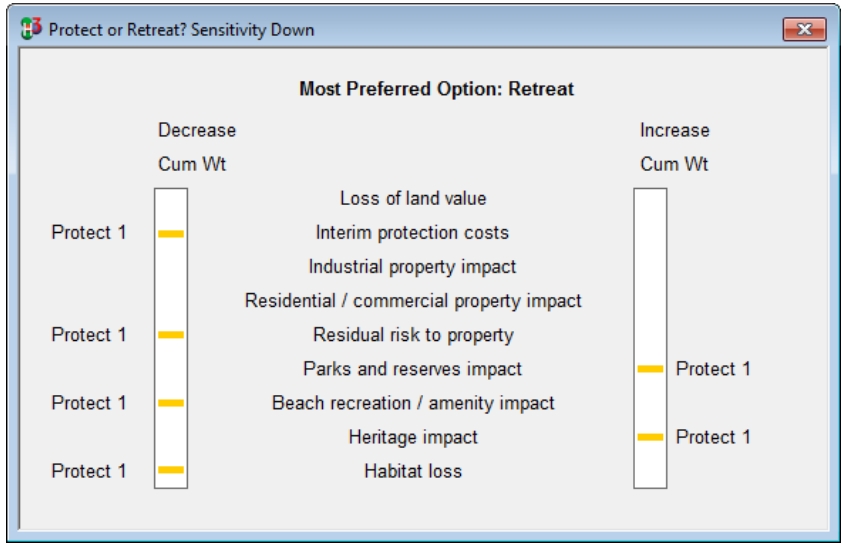
Option 1: Initial stage (2070)

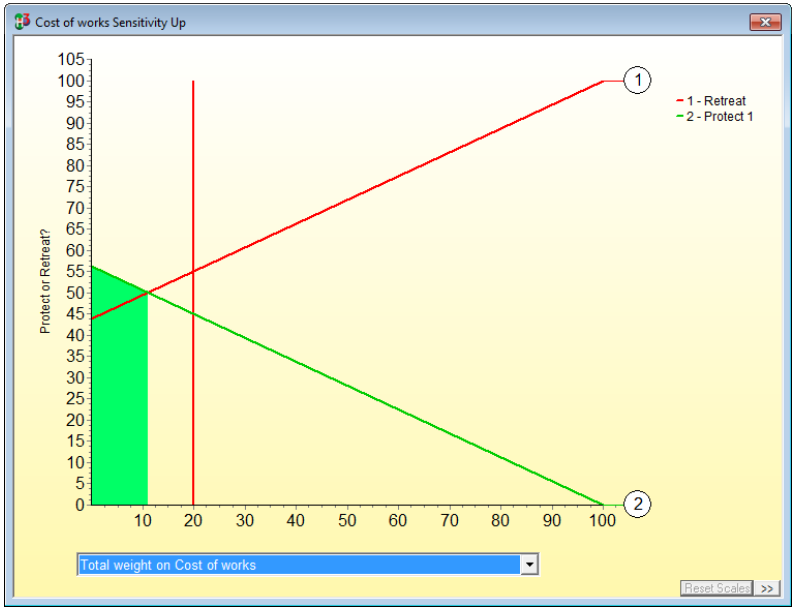
- Build seawall along the shore

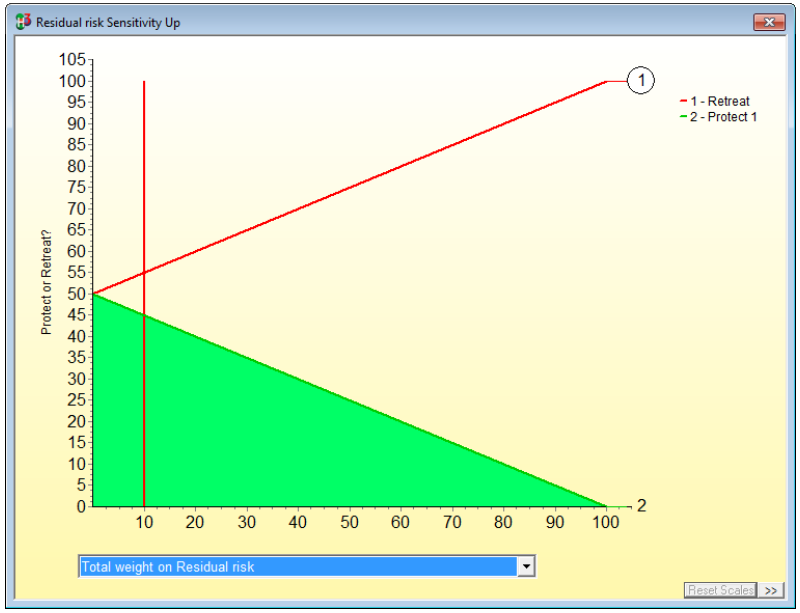
		Raw data						Normalised score					Weight	
		Retreat	Protect 1	Protect 2	Protect 3			Retreat	Protect 1	Protect 2	Protect 3		Nominal	Adjusted
Loss of land value	Discounted cost ($m)	0	0				R/A	0	0				0.11	0.00
Interim protection costs	Discounted cost ($m)	0	2			200%	R/A	100	0				0.11	0.20
Industrial property impact	No. potential lots affected	0.00				0%	Ttl lots	0	0				0.19	0.00
Residential & commercial property impact	No. potential lots affected	0				0%	Ttl lots	0	0				0.11	0.00
Residual risk to property	Scale of 1-5	1	5					100	0				0.07	0.10
Parks and reserves impact	Area (ha)	25.02				5.58%	Ttl area	0	100				0.11	0.25
Beach recreation / amenity impact	m of beach	280				1%	Ttl beach	100	0				0.15	0.10
Heritage impact	No. of heritage properties affected	5				10%	Ttl props	0	100				0.04	0.20
Habitat loss	Area (ha)	6.4				3%	Ttl area	100	0				0.11	0.15
								400	200				1.00	1.00
					Weighted score			55	45					
					Rank			1	2					

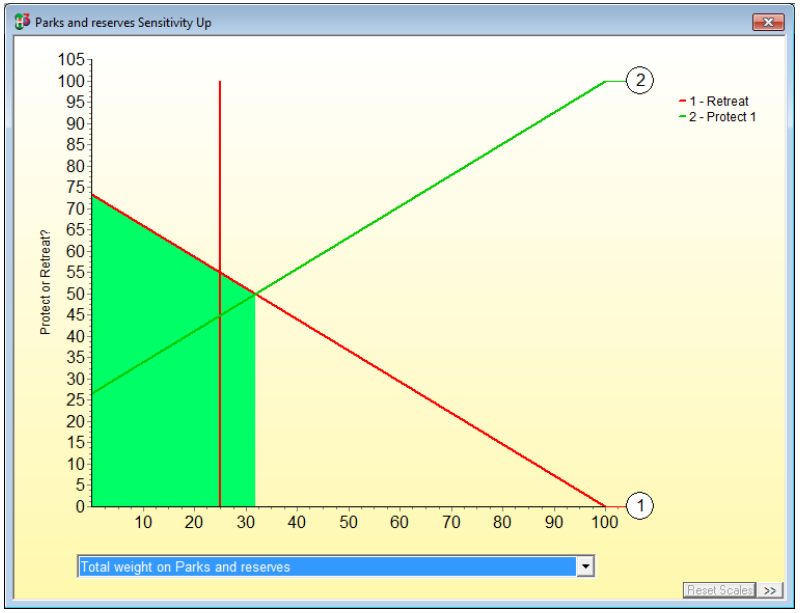
1. Ranking is provisional only as measures for this area require information about coastal risks to the south of the peninsula

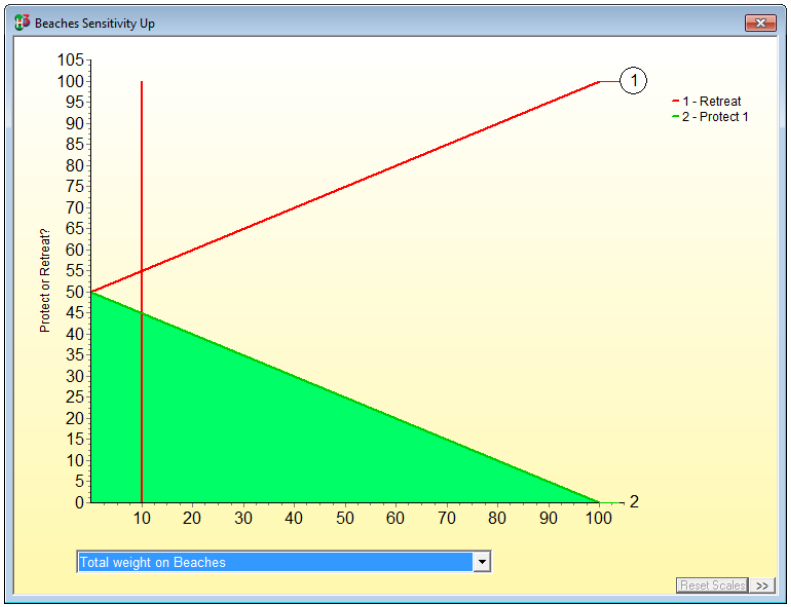
2. Weighting for Parks and reserves assumes that the equivalent area cannot be retained in the Retreat option.

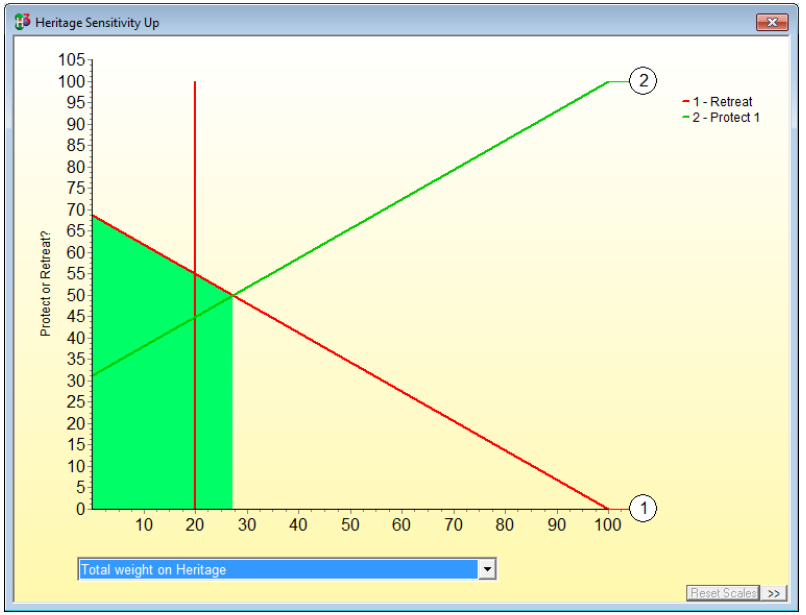


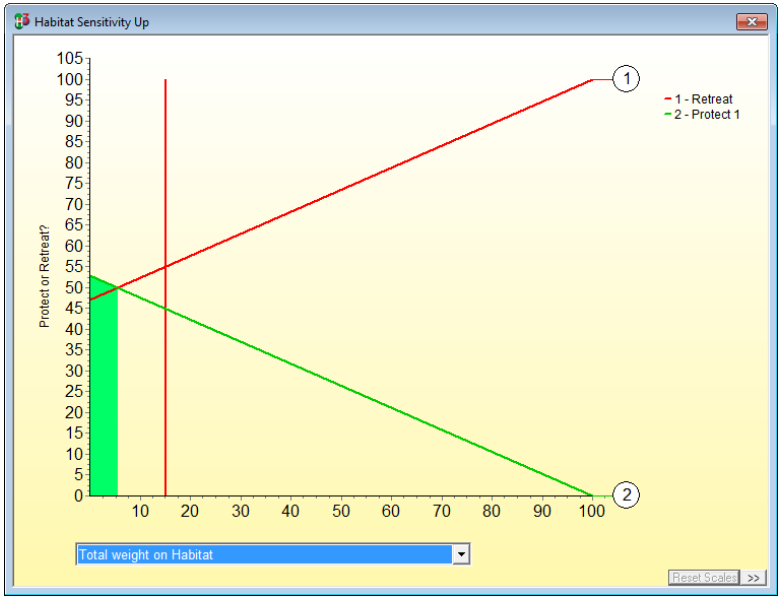







Beaches Sensitivity Up
Protect or Retreat?
1 - Retreat
2 - Protect 1
Total weight on Beaches
Reset Scales
>>


Heritage Sensitivity Up
Protect or Retreat?
1 - Retreat
2 - Protect 1
Total weight on Heritage
Reset Scales
>>


Habitat Sensitivity Up
Protect or Retreat?
1 - Retreat
2 - Protect 1
Total weight on Habitat
Reset Scales
>>

Appendix C

Provisional Adaptation Measures

LEGEND

- Indicative Management Unit Boundary

Protection Works

- Dune Stabilisation
- Breakwater or Groyne (5m high)
- Offshore Breakwater
- Revetment or Seawall (6m High)
- 1.5m Levee - 15m Wide with Road on Top
- Investigate Groyne Modifications
- Beach Nourishment
- Dune Stabilisation
- Raise Ground Levels, Reclaim Land and Upgrade Wharf Structures
- Local Government Area Boundary
- Retreat

Breakwater or Groyne (5m high)
Offshore Breakwater
Revetment or Seawall (6m High)
1.5m Levee - 15m Wide with Road on Top

Cross Section

Paper Size A3

0 62.5 125 250 375 500 625

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Cockburn Sound Coastal Alliance
Cockburn Sound Coastal Adaptation Plan

Job Number	61-32106
Revision	1
Date	05 Feb 2016

Management Unit 13

Provisional Adaptation Measures

Figure 1

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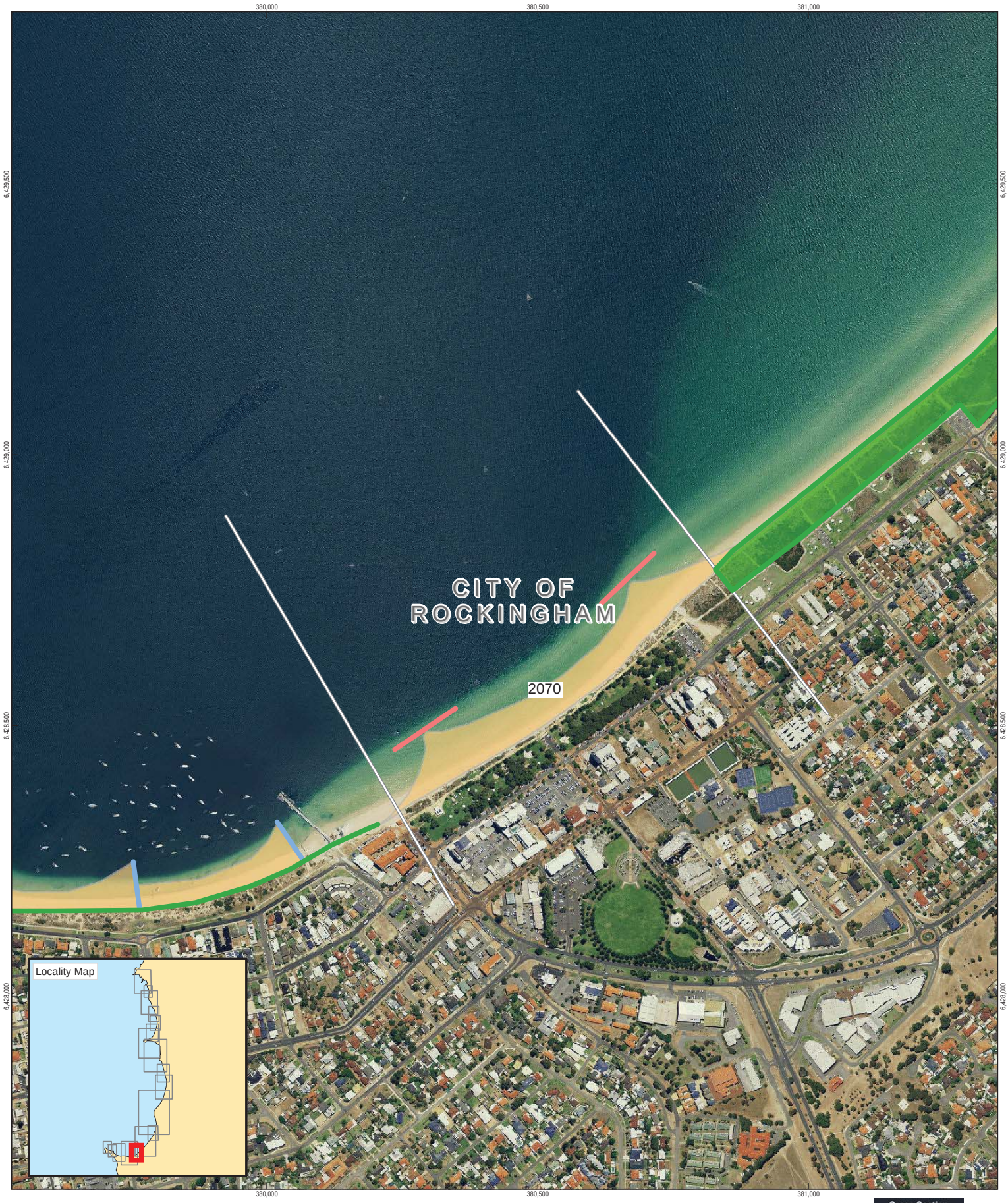
999 Hay Street Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data source: Landgate: Imagery (Metro Central Feb 2015); GHD: Indicative Management Unit Boundaries - 20160204, Protection Works - 20151027; ABS: Local government area boundary - 20150416. Created by: mczekaj



LEGEND

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Cross Section

Paper Size A3

0 30 60 120 180 240 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Cockburn Sound Coastal Adaptation Plan

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Revision	1
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Management Unit 14

Provisional Adaptation Measures

Figure 1

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LEGEND

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Breakwater or Groyne (5m high)
Offshore Breakwater
Revetment or Seawall (6m High)
1.5m Levee - 15m Wide with Road on Top

Cross Section

Paper Size A3

0 50 100 200 300 400 500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Cockburn Sound Coastal Alliance
Cockburn Sound Coastal Adaptation Plan

Job Number	61-32106
Revision	1
Date	05 Feb 2016

Management Unit 15

Provisional Adaptation Measures

Figure 1

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Data source: Landgate: Imagery (Metro Central Feb 2015); GHD: Indicative Management Unit Boundaries - 20160204, Protection Works - 20151027; ABS: Local government area boundary - 20150416. Created by: mczekaj

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LEGEND

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Breakwater or Groyne (5m high)
Offshore Breakwater
Revetment or Seawall (6m High)
1.5m Levee - 15m Wide with Road on Top

Cross Section

Paper Size A3

0 35 70 140 210 280 350

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Cockburn Sound Coastal Alliance
Cockburn Sound Coastal Adaptation Plan

Job Number	61-32106
Revision	1
Date	05 Feb 2016

Management Unit 16

Provisional Adaptation Measures

Figure 1

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LEGEND

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Cross Section

Paper Size A3

0 20 40 80 120 160 200
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Cockburn Sound Coastal Alliance
Cockburn Sound Coastal Adaptation Plan

Job Number 61-32106
Revision 1
Date 05 Feb 2016

Management Unit 17

Provisional Adaptation Measures

Figure 1

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LEGEND

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Cross Section

Paper Size A3

0 20 40 80 120 160 200
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Cockburn Sound Coastal Alliance
Cockburn Sound Coastal Adaptation Plan

Job Number 61-32106
Revision 1
Date 05 Feb 2016

Management Unit 18

Provisional Adaptation Measures

Figure 1

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Appendix D

Additional Assessment – Palm Beach

Management Unit 15 extends between Railway Terrace and Hymus Street in Rockingham. This unit's coastline consists of a valued public beach within a largely residential land use area. The unit's sandy beach is backed by a foreshore reserve consisting of park land with some parking facilities, amenities and footpaths with relatively narrow setbacks from the ocean. Running parallel to this is a road and relatively dense residential area. Boat launching facilities are also located on this stretch of coastline. The combination of these factors places this stretch of coastline as a high value asset to the City of Rockingham.

The current vulnerability assessment and risk mapping undertaken in the Stage 1 and Stage 2 Assessments indicated that there are critical assets in CMU 3 that are currently at risk and becoming increasingly vulnerable to erosion that would result in a loss of beach area and foreshore land. In the medium-term inundation risks will also likely become intolerable due to sea level rise.

The sediment feed is limited in this area, the inward transport is variable and there is cross shore erosion patterns during storm events. Therefore the design of hard-passive interim protection structures that can effectively capture and maintain beach sediment to create a buffer to erosion is critical to the success of any works and as such the predicted performance will likely be the defining criterion over cost, amenity etc.

Criterion: Performance

Based on the sediment transport regime in CMU 15, it is believed that all options could be effective at altering longshore currents and sediment transport and as a result reduce longshore erosion and increase the beach width. The following items provide a comparison between the options:

- The study area suffers from severe deficiency in sand supply. The foreshore is very narrow and accretion and erosion patterns are irregular noting suggesting by directional sediment movement in various conditions. This suggests that effectiveness of groynes to capture sand is limited and estimation of true drift direction requires further detailed assessment.
- While accretion is expected up drift of the proposed first two groynes, erosion would be expected on the down-drift. Offshore breakwaters may offer erosion protection in its immediate shadow area however there is the potential for erosion either side of the structure due to the interruption to longshore drift. Therefore placement of the breakwaters and selection of distance, spacing and length of the structures should ensure that they do not aggravate the existing erosion issues.
- Offshore breakwaters do have the capability to reduce wave energy transmission which groynes do not. Therefore the beach response (effectively S1 component of setback) behind the offshore breakwaters is likely to be less than open coasts or where groynes are placed. The direction of littoral drift is also less critical for offshore breakwaters then groynes as sand does not have to saturate an up-drift side before it can bypass the structure.

Modelling is recommended to confirm the performance of these structures however through this preliminary GHD recommends a ranking of 1 for offshore breakwaters and 2 for groynes.

Criterion: Costs

The capital costs, annual operating, and decommissioning costs for each option would ultimately depend on the final design developed for construction. Cost estimates should be developed during a concept design stage with an understanding of available funding to ensure feasibility. All options propose the inclusion of beach nourishment and dune redevelopment which will have relatively consistent requirements across all options so the defining cost differentiator between options will be the capital, maintenance and adaptation costs of the interim protection structures.

The design development and modelling of the effectiveness of groynes and breakwaters is considered comparable, as is the development of detailed design documentation. Construction requirements do vary between the two options, as the construction of groynes can be undertaken from land with standard equipment while offshore breakwaters, depending on depth can be built through use of a temporary causeway but this can add significant time and difficulty to the works.

In Western Australia groynes and breakwaters are typically constructed with a rock armour outer layer with a core of smaller rock materials, and this approach was used for this assessment. Although suitable rock sources can be found locally throughout most of the state, availability of materials will become scarcer in the future. Some alternative construction materials for these structures are precast concrete units and geotextile sand filled containers, which should be considered during design development. The volume of materials required is likely to be higher for offshore breakwaters due to the deeper water.

The availability of suitable sand nourishment sources from a financially viable source is a key consideration for ongoing maintenance requirements in the Cockburn Sound. All options are likely to require ongoing sand nourishment in response to extreme events, with the more effective structures requiring less in the long-term.

The preliminary high level costs were aggregated to provide a total discounted cost for a high level comparison of the options.

Preliminary Capital Cost Estimates

	Option 2a			Option 2b		
Timing	Capital ($)	Annual ($)	Decom ($)	Capital ($)	Annual ($)	Decom ($)
Present	$ 5,200,000	$ 119,600		$ 3,900,000	$ 113,100	
2070	$ 14,326,000	$ 278,720		$ 10,816,000	$ 261,170	
2110			$ 7,813,000			$ 4,713,000

Limitations

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Our services are based on GHD undertaking these services in accordance with the following industry standards, codes and guidelines:

– Bicknell C 2010, Sea Level Change in Western Australia: Application to Coastal Planning, prepared by the Department of Transport,

– WAPC 2013, State Coastal Planning Policy Guideline, prepared by the Western Australian Planning Commission, Perth, WA.

These standards, codes and guidelines take into account potential sea level rise impacts only to the extent indicated by these policies and guidelines.

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Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
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