

Chapter Report 4: Risk Treatment

City of Stirling Coastal Hazard Risk Management and Adaption Plan

CW1195500



Prepared for
City of Stirling

23 June 2023



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Table of Contents

1	Introduction	1
	1.1 Overview	1
	1.2 Background	1
	1.3 Overview of the CHRMAP Process	2
	1.4 Success Criteria	2
	1.5 Purpose of this Report	3
2	Adaptation Planning Framework	6
	2.1 Context	6
	2.2 Statutory Planning Context	7
	2.3 Planning Instruments	8
3	Adaptation Planning Process	9
	3.1 Adaptation Options	9
	3.2 Adaptation Options Assessment Process	12
4	Options	21
	4.1 Avoid Option	21
	4.2 Managed Retreat Options	23
	4.3 Accommodate Options	27
	4.4 Soft Protection Options	28
	4.5 Hard Protection Options	31
5	Cost Benefit Analysis	37
	5.1 Options	37
	5.2 Benefits and Costs	38
	5.3 Results	38
6	Adaption Pathways	42
	6.1 Management Triggers	42
	6.2 Pathways	45
7	Key Recommendations	57
	7.1 Coastal Adaption Measures	57
	7.2 Planning Measures	57
8	Discussion	58
	8.1 General Coastal Planning Principles	58
	8.2 Uncertainty and Adaptive Management	59
	8.3 Next Steps	59
9	References	61

Appendices

- Appendix A** Planning
- Appendix B** Asset Valuation
- Appendix C** Managed Retreat Costs
- Appendix D** Concept Design Maps
- Appendix E** CBA Methodology

Tables

Table 2-1	Key planning documents relevant to the project	7
Table 3-1	Adaptation and management options (adapted from WAPC, 2019).	11
Table 3-2	Multi-Criteria Assessment criteria	14
Table 3-3	MU1 Watermans Bay	15
Table 3-4	MU2 – North Beach	16
Table 3-5	MU3 – Mettams Pool	17
Table 3-6	MU4 – Trigg Beach North	18
Table 3-7	MU5 – Trigg Beach South	19
Table 3-8	MU6 – Scarborough Beach	20
Table 4-1	Watermans Bay Managed Retreat Asset Value	25
Table 4-2	North Beach Managed Retreat Asset Value	25
Table 4-3	Mettams Pool Managed Retreat Asset Value	25
Table 4-4	Trigg Beach North Managed Retreat Asset Value	26
Table 4-5	Trigg Beach South Managed Retreat Asset Value	26
Table 4-6	Scarborough Beach Managed Retreat Asset Value	26
Table 4-7	Indicative nourishment volumes for renourishment concept option	30
Table 4-9	Indicative costs for groyne / headland enhancement protection concept for each management unit	35
Table 4-10	Indicative costs for two stage nearshore breakwater protection concept for Sector 2A	36
Table 4-11	Indicative costs for seawall protection concept for applicable management units	36
Table 5-1	Adaption options	37
Table 5-2	Benefits and costs	38
Table 6-1	Management Triggers	43
Table 6-2	Adaptation pathway for MU1 – Watermans Bay Beach	51
Table 6-3	Adaptation pathway for MU2 – North Beach	52
Table 6-4	Adaptation pathway for MU3 – Mettams Pool	53
Table 6-5	Adaptation pathway for MU4 – Trigg Beach North	54
Table 6-6	Adaptation pathway for MU5 – Trigg Beach South	55
Table 6-7	Adaptation pathway for MU6 – Scarborough Beach	56

Figures

Figure 1-1	Sea level rise for planning purposes in Western Australia (adapted from DoT, 2010 & IPCC, 2021).	1
Figure 1-2	Study area	4
Figure 1-3	Risk management steps forming the CHRMAP process (WAPC, 2019)	5
Figure 2-1	Western Australian planning hierarchy (WAPC, 2020)	7
Figure 3-1	Adaptation and management options (WAPC, 2019)	9
Figure 4-1	Coastal foreshore reserve – sandy coast example (WAPC, 2020b).	21
Figure 4-2	Beach renourishment occurring to protect assets at C Y O'Connor Beach, North Coogee	29
Figure 4-3	Groynes at Marmion Beach, City of Joondalup. (source: Metromap, 2021)	32
Figure 4-4	Offshore breakwater at Kwinana Beach, WA	33
Figure 4-5	GSC seawall at Watermans Bay Beach	33
Figure 5-1	Net benefits of tested options at Watermans Bay	39
Figure 5-2	Net benefits of tested options at Mettams Pool	39
Figure 5-3	Net benefits of tested options at Trigg Beach North	40
Figure 5-4	Net benefits of tested options at Trigg Beach South	40
Figure 5-5	Net benefits of tested options at Scarborough Beach	41

1 Introduction

1.1 Overview

The City of Stirling (herein referred to as ‘the City’) is located approximately 6 km north-west of Perth’s Central Business District (**Figure 1-2**). The City contains approximately 7 km of Indian Ocean coastline, including iconic beaches, such as Scarborough, Trigg and Mettams Pool. The adjacent foreshore reserves support a variety of recreation, conservation and commercial land uses, including substantial built infrastructure situated in close proximity to the shoreline.

The City is undertaking a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to provide strategic guidance for coordinated, integrated and sustainable land use planning and management along its coastline. The CHRMAP will inform the City’s future decision-making with respect to areas and assets identified as being at risk from coastal hazards.

1.2 Background

Globally, mean sea level (MSL) has risen since the nineteenth century and is predicted to continue to rise, at an increasing rate, through the twenty first century (Intergovernmental Panel on Climate Change [IPCC], 2021), bringing changes to the Western Australian (WA) coastline over the coming decades. To prepare for sea level rise (SLR) induced coastal hazards, such as coastal erosion and inundation, all levels of government are putting processes in place to ensure that communities understand the risks to values and assets on the coast, and to plan to adapt over time.

Changes to MSL over the past century have been observed for the coastline adjacent to the Perth Metropolitan Area (CSIRO, BoM, 2015). *Sea Level Change in Western Australia – Application to Coastal Planning* (Department of Transport [DoT], 2010) reviewed information relating to SLR at a local scale and recommended an allowance for SLR be adopted for planning purposes. Recommendations were based on the upper bound of the global average SLR projections from *IPCC’s Fourth Assessment Report [AR4]* (IPCC, 2007). In the intervening years, following release of the DoT document, advances in climate change science have been reflected in revisions to SLR projections, such as those documented in *IPCC’s Sixth Assessment Report [AR6]* (IPCC, 2021). Current guidance on global SLR projections is derived from Shared Socioeconomic Pathways (SSP), characterising the trajectory of global society, demographics and economics over the coming century. Analogous to that used in DoT’s recommendation is SSP5, which forecasts an average SLR of 0.94m between 2020 and 2120 (**Figure 1-1**).

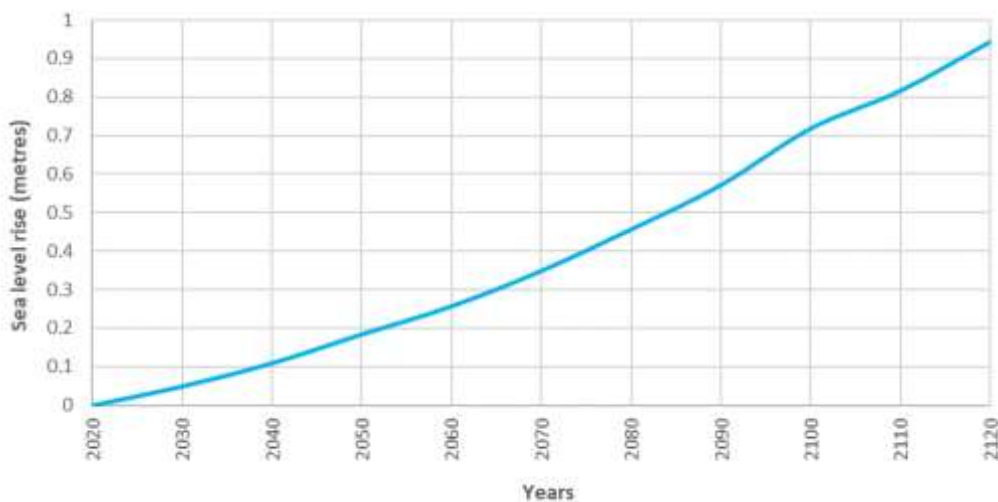


Figure 1-1 Sea level rise for planning purposes in Western Australia (adapted from DoT, 2010 & IPCC, 2021).

The City's coastline to the south of Trigg Island is sandy, featuring coastal dunes, nearshore reefs and seagrass meadows. For sandy coastlines, increases in local MSL generally result in shoreline recession, with a "rule of thumb" often applied, that a 1 cm rise in MSL will result in 1 m of landward recession of the shoreline. It should be noted that this is based on the "Bruun Rule" which is generally considered a conservative (and simplified) approach (Rosati et al, 2013; Cooper & Pilkey, 2004).

North of Trigg Island, the coastline features pocket perched beaches, with nearshore reef platforms, visible rocky cliffs and subsurface rock formations. In these areas' special consideration of the height and integrity of the rock formations is required to ascertain the level of erosion protection that the rocky features will afford adjacent areas.

1.3 Overview of the CHRMAP Process

The key policy governing coastal planning in WA is the *State Planning Policy No. 2.6: State Coastal Planning Policy* (Western Australian Planning Commission [WAPC], 2013) (SPP2.6). SPP2.6 recommends that management authorities develop a CHRMAP, using a risk mitigation approach to planning, that identifies the hazards associated with existing and future development in the coastal zone. SPP2.6 and the *State Coastal Planning Policy Guidelines* (WAPC, 2020) contain prescriptive details, for example in relation to scales of assessment, storm event types and SLR allowances.

The WAPC (2019) has also developed the *Coastal hazard risk management and adaptation planning guidelines* (CHRMAP Guidelines) which are less prescriptive in terms of technical assessment of coastal processes, but are aimed to ensure that planning is carried out using a risk-based approach. This includes paying due regard to stakeholder engagement, community consultation and education, and requires that a full range of applicable adaptation options are considered. An overview of the typical CHRMAP process is shown in **Figure 1-3**.

Coastal planning in accordance with SPP2.6 also needs to take into consideration the requirements of other planning policies, including *Statement of Planning Policy No. 2: Environment and Natural Resources Policy* (WAPC, 2003) (SPP2), *State Planning Policy No. 2.8: Bushland policy for the Perth Metropolitan Region* (WAPC, 2010) (SPP2.8), *Statement of Planning Policy No. 3: Urban Growth and Settlement* (WAPC, 2006a) (SPP3.0) and *State Planning Policy No. 3.4: Natural Hazards and Disasters* (WAPC, 2006b) (SPP3.4).

1.4 Success Criteria

Success criteria have been defined for the project, based on the outcomes of the Coastal Values Survey, and are used to guide consequence ratings in the vulnerability analysis. These are:

- > SC1: Preserve the function and opportunity for recreation activities along the coastline (such as walking/running, swimming and surfing).
- > SC2: Preserve the existing hospitality venues along the coastline and access to them.
- > SC3: Ensure the natural environment is protected and sustained in its current condition or an improved condition (concerning the dunes and flora and fauna).
- > SC4: Develop solutions to coastal processes that are sustainable (financially, socially and built form) and locally responsive.
- > SC5: Revisit regularly with community and key stakeholders their values in relation to development adjacent the coastline.
- > SC6: Maintain services that maximise community benefit for all.
- > SC7: Ensure the coastline is safe and accessible to all.
- > SC8: Achieve a balance between access needs and environmental sensitivities.

1.5 Purpose of this Report

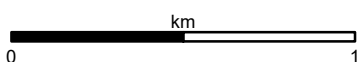
The City's CHRMAP has been developed by a staged approach, with the various stages documented in dedicated chapter reports. The chapter reports have been summarised and used to underpin the overall CHRMAP document. The purpose of the chapter reporting is to capture key technical detail, while the overall CHRMAP presents a more accessible and community-friendly document. The chapter reports prepared as part of the City's CHRMAP include:

- > Chapter 1 – Establish the Context (Stage 1) (Cardno, 2023a);
- > Chapter 2 – Risk Identification (Stage 2) (Cardno, 2023b);
- > Chapter 3 – Vulnerability Assessment and Risk Evaluation (Stages 3 and 4) (Cardno, 2023c);
- > **Chapter 4 – Risk Treatment (Stage 5);** and
- > Chapter 5 – Implementation (Stage 6) (Cardno, 2023d).

This document presents the *Chapter 4: Risk Treatment* report, identifying potential adaptation pathways for the areas and assets at risk from coastal hazards, developed during the *Vulnerability Analysis* and *Risk Evaluation* stages (Cardno, 2023c).



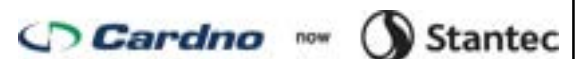
1:22,000 Scale at A3



Study Area

CITY OF STIRLING CHRMAP

FIGURE 1-2



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-08-03
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_001_StudyLocality_ManagementUnits.mxd 02
 Aerial imagery supplied by Esri et al.

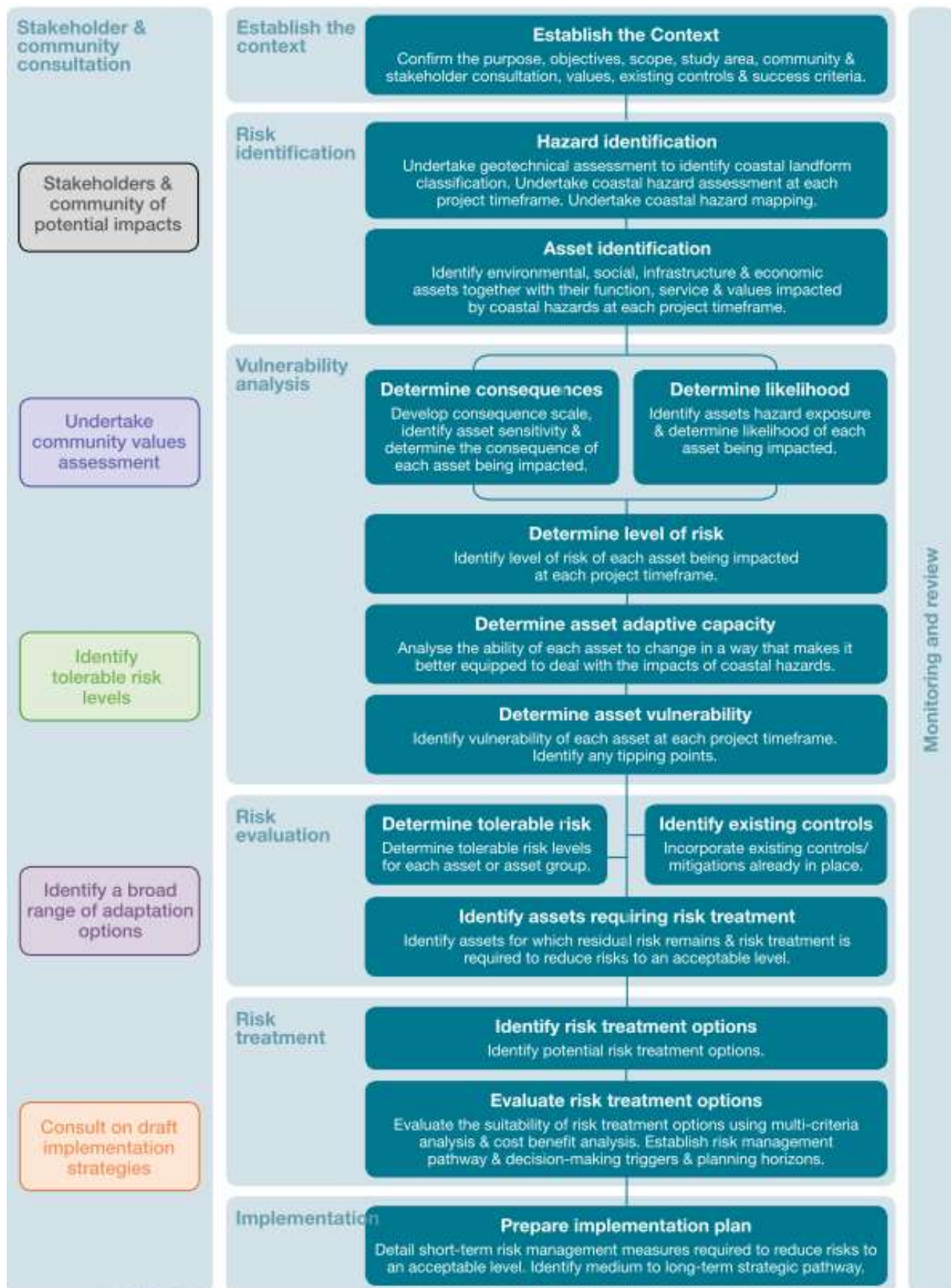


Figure 1-3 Risk management steps forming the CHRMAP process (WAPC, 2019)

2 Adaptation Planning Framework

2.1 Context

There exists a complex set of historical documents, rules and decision making that has led to the present level of development along the coast within WA. Originally, it was assumed that cadastral boundaries enclosed reasonably permanent areas suitable for developing residential and commercial assets *ad infinitum*. The notion that the land and assets within these boundaries is now vulnerable (or becoming vulnerable) to coastal hazards, and will potentially become unusable, led to the development of SPP2.6 and the need for careful planning to determine future development directions in coastal areas.

A key aim of SPP2.6 is to ensure recognition that SLR and associated coastal hazards are threatening currently fixed, coastal zone assets and will do so at an increasing rate into the future. SPP2.6 and the CHRMAP Guidelines also seek to commence the process of adjusting community expectations about life in the future, given a diminishing coastal zone. SPP2.6 aims to implement responsible long-term planning strategies to develop affordable solutions that satisfy a range of key drivers, including intergenerational equity.

As stipulated in SPP2.6 and the CHRMAP guidelines, the long-term priority is to adopt a strategy hierarchy of:

- > Avoid
- > Managed Retreat
- > Accommodate; and, once the options above have been fully investigated
- > Protect (to be funded under the beneficiary pays principle)

Ultimately, the aim is to Manage Retreat from vulnerable areas before assets are threatened. This will require a shift in the strategy from, for example, initial protection to eventual managed retreat. The Protect strategy proposes that the beneficiaries fund protection, while the transition from a Protect to Retreat strategy may trigger funding for removal or relocation under the *Land Administration Act 1997* (DoPLH, 2017d). A number of questions arise out of these strategies, for example:

- > Who are the beneficiaries?
- > What is a reasonable method for apportioning costs to the beneficiaries?
- > Who is disadvantaged by the strategies, how will they be compensated and by who? and
- > Who is responsible for funding managed retreat?

It is recommended that a comprehensive investigation of the community and visitors be undertaken to identify beneficiaries of any current or proposed protection areas. Further to this, an economic assessment of mechanisms for recouping costs from beneficiaries (e.g. parking fees, visitor entry fee, increased council rates or levy and other options) is required to inform the future review of the strategy options outlined in this Report.

It is noted that legally there is no obligation of the State or Local Governments to either protect public and private assets within the coastal hazard zone, nor to compensate for any losses incurred due to coastal hazards. While it is usually a community aspiration to maintain foreshore amenity 'as is', it must be recognised that built assets located in present and future hazardous areas may not be able to attract state or local government funding for protection works.

2.2 Statutory Planning Context

Western Australia’s planning framework includes strategic and statutory planning functions set out in the Planning and Development Act 2005 (PD Act). The planning system is hierarchical, requiring increasing levels of detail as a proposal progresses through regional, district and local planning, to subdivision and development of individual sites (**Figure 2-1**). The *Stage 1 Chapter Report: Establish the Context* (Cardno, 2023a) reviewed the planning documents within this Framework that are relevant to coastal hazard planning in the project area. **Table 2-1** summarises these documents.



Figure 2-1 Western Australian planning hierarchy (WAPC, 2020)

Table 2-1 Key planning documents relevant to the project

Document	Purpose
Corporate Governance Framework	
<i>City of Stirling Strategic Community Plan 2018 – 2028</i> (City of Stirling, 2018)	Overarching strategy to achieve the vision for the development of the City over the next 10 years and beyond.
<i>City of Stirling Corporate Business Plan 2021 – 2025</i> (City of Stirling, 2021)	Outlines the projects and services that will be delivered over the next four years, directly influenced by the City’s Long-Term Financial, Asset Management and Workforce Plans. The Corporate Business Plan guides the development of the annual budget, service plans and annual project plans, in alignment with the City’s Strategic Community Plan.
Relevant Legislation	
<i>Planning and Development (Local Planning Schemes) Regulations 2015</i> (Western Australian Government, 2020)	Regulations introduced by the state government to ensure a consistent structure, format and approach to local planning schemes
State Planning Framework	
<i>State Planning Strategy 2050</i> (WAPC, 2014a)	Provides strategic context and basis for the integration and coordination of land-use planning and development.
<i>Perth and Peel @ 3.5 Million</i> (WAPC, 2018)	Provides overarching framework to deliver four sub-regional strategies to guide future growth and development across Perth and Peel
<i>Metropolitan Region Scheme</i> (WAPC, 2014b)	The Metropolitan Region Scheme (MRS) is the principal region scheme which applies to the study area and zones and reserves land.
<i>State Planning Policy No. 2.6: State Coastal Planning Policy</i> (WAPC, 2013)	– Primary statutory document that governs development in WA’s coastal areas.

	<ul style="list-style-type: none"> – Recommends the preparation of CHRMAP's to properly inform management and adaptation.
<i>State Coastal Planning Policy Guidelines</i> (WAPC, 2020)	Supplements the State Coastal Planning Policy with further specific detail on its application.
<i>WA Coastal Zone Strategy</i> (WAPC, 2017)	High-level, overarching strategy for the use of WA's coastal zone.
<i>Coastal Hazard Risk Management and Adaptation Planning Guidelines</i> (WAPC, 2019)	Guideline outlining the process and expected outcomes for a CHRMAP.
<i>Statement of Planning Policy No. 2: Environment and Natural Resources Policy</i> (WAPC, 2003)	Aims to integrate environment and natural resource management with broader land use planning and decision-making.
<i>State Planning Policy No. 2.8 – Bushland policy for the Perth Metropolitan Region</i> (2010)	Provides a policy and implementation framework that will ensure bushland protection and management issues in the Perth Metropolitan Region are appropriately addressed and integrated with broader land use planning and decision-making.
<i>Statement of Planning Policy No. 3: Urban Growth and Settlement</i> (WAPC, 2006a)	Promotes a sustainable and well planned pattern of settlement across the State, with sufficient and suitable land to provide for a wide variety of housing, employment, recreation facilities and open space.
<i>State Planning Policy 3.4: Natural Hazards and Disasters</i> (WAPC, 2006b)	Ensures that land use planning appropriately considers the risk of natural hazards and disasters
DevelopmentWA Planning Framework	
<i>Scarborough Master Plan</i> (MRA, 2015)	Overarching Master Plan for the Scarborough Redevelopment Area.
<i>Scarborough Redevelopment Strategy</i> (MRA)	Principal strategy to achieve the vision of the Scarborough Master Plan.
<i>Scarborough Redevelopment Scheme</i> (MRA, 2016a)	The principal statutory planning document which applies land use and development controls within the Scarborough Redevelopment Area.
<i>Planning Policies and Design Guidelines</i> (MRA, 2016b)	Outlines procedures, land uses, development requirements and design guidelines for a variety of matters relevant to the Scarborough Redevelopment Area.
Local Planning Framework	
<i>City of Stirling Local Planning Strategy</i> (City of Stirling, 2019)	Establishes the vision and long-term planning directions for the City over the next decade and beyond.
<i>City of Stirling Local Planning Scheme No. 3</i> (DPLH, 2022)	The principal statutory planning document which applies land use and development controls within the City at a local level.

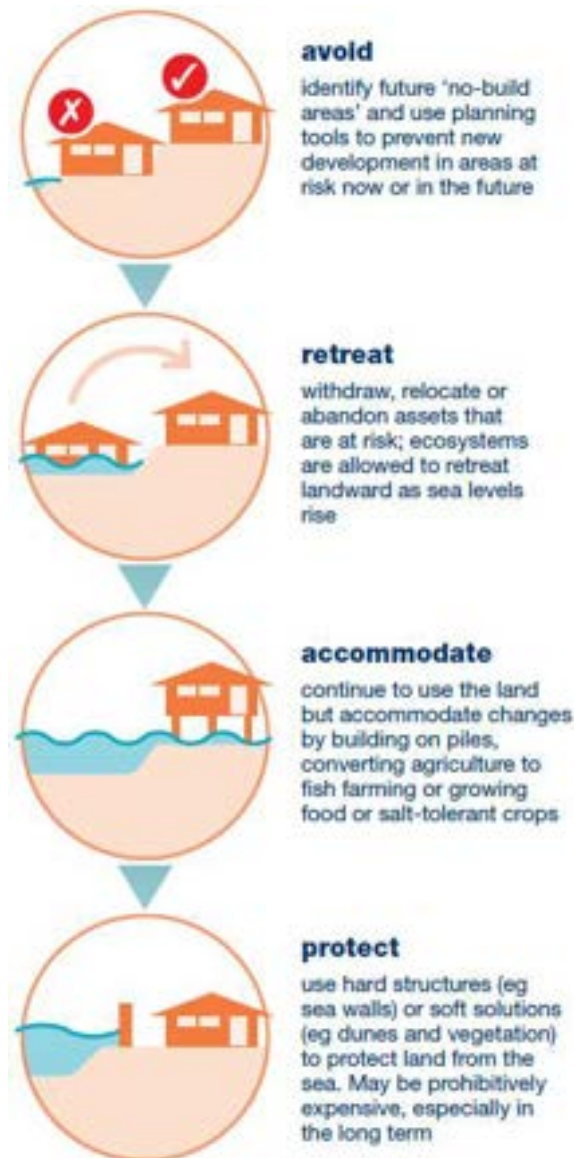
2.3 Planning Instruments

Land-use planning instruments relevant to this CHRMAP have been discussed and assessed by specialist planning consultant Element, and are provided as **Appendix A**. Erosion hazard extents for the 2122 planning timeframe, developed during Stage 2 of the CHRMAP (Cardno, 2023b), do not yet intersect private property for the City. Specific planning for such land can, therefore, be deferred to future CHRMAP iterations.

3 Adaptation Planning Process

3.1 Adaptation Options

Effective adaptation planning involves the identification and evaluation of options suitable to manage the risk of coastal hazards. In accordance with SPP2.6 and the CHRMAP guidelines, potential options have been identified under the risk management hierarchy of Avoid, Managed retreat, Accommodate and Protect. Protection being the least preferred management option. The range of adaptation and management options were based on WA’s CHRMAP guidelines and are simplified in **Figure 3-1** and presented in more detail in **Table 3-1** below.



Avoid is seen as the preferred strategy but is generally only applicable to undeveloped coastal land and areas of the coast where intensification of development in hazardous areas might be proposed. This option is underpinned by the implementation of planning controls, which should prevent inappropriate use of land in areas identified as potentially at risk from coastal hazards.

Managed retreat is a preferred long-term strategy for areas of existing development at risk. This option aims to remove assets from the risk of coastal hazards and is generally the economically responsible approach over the long-term, although it may involve significant expenditure during implementation. Some of the planning mechanisms around implementing Avoid and Managed retreat options have already been discussed in **Section 2.3**.

Accommodate options aim to re-design existing infrastructure to mitigate potential impacts as they occur, and allow for land use of a low risk (for example temporary) nature. This option is rarely applicable to areas at risk of coastal erosion but is suitable to some areas prone to coastal inundation, where assets can be elevated above flooding to maintain land use in an otherwise hazardous area. The ability for substantial, built assets to be redesigned to accommodate coastal erosion hazards is generally limited.

Protect options range from temporary 'soft' protection, such as sand nourishment, to medium-term 'hard' protection options, such as groynes and seawalls. It should be noted that no protection option is considered permanent (hence their description as 'interim' protection), and all have associated expense to implement, maintain and remove.

Figure 3-1 Adaptation and management options (WAPC, 2019)

The expense, and the inability of protection options to permanently mitigate the risks associated with coastal hazards, are the primary reasons why these options are considered the least favourable in the preferential planning hierarchy. Hard protection options also have the potential to divert coastal erosion hazards elsewhere, increasing risk for adjacent areas or assets and potentially creating liability for those responsible for the structures.

SPP2.6 Clause (5.5 (iii)) states that the employment of protection options should be sought only where:

“sufficient justification can be provided for not avoiding the use or development of land that is at risk from coastal hazards and accommodation measures alone cannot adequately address the risks from coastal hazards, then coastal Protection works may be proposed for areas where there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable.”

Although protection measures are the least favoured option, particularly as a long-term mitigation measure, they remain a commonly employed coastal risk mitigation strategy globally. There are several effective protection techniques that can be employed to manage the risks of coastal erosion in the short- to medium-term (e.g. over 5 to 50 years) as listed in **Table 3-1**.

Table 3-1 Adaptation and management options (adapted from WAPC, 2019).

Option Category	Option Name	Option Code	Description
Avoid	Avoid development	AV	Avoidance of inappropriate (e.g. significant/permanent) development within coastal hazard areas.
Planned / Managed Retreat	Leave unprotected / repair	PMR1	Assets are left unprotected and loss or damage is accepted following hazard event. Assets are then repaired or removed.
	Remove / relocate	PMR2	Assets located in the hazard zone are permanently removed or relocated prior to impact.
	Planning controls to prepare for managed retreat	PMR3	Use of planning controls to allow continued use of the current infrastructure until such time that impacts arise, but restrict the development of further infrastructure (densification) as the area/asset is known to be vulnerable.
Accommodate	Planning controls to accommodate/identify risk	AC1	Indicates to current and future landholders/stakeholders that an asset is at risk from coastal hazards over the planning timeframe. Helps stakeholders to make informed decisions about the level of risk they are/may be willing to accept, and that risk management and adaptation is likely to be required at some stage.
	Emergency plans and procedures	AC2	Implement plans for assets/areas that are at risk of coastal hazards. Have procedures in place for before, during and after the events for safety. E.g. signage/barriers to prevent access.
	Redesign to withstand impact	AC3	Maintain asset in existing location but redesign and upgrade to be resilient to coastal hazard impacts.
Protect	Dune care / sand management	PR1	Development of an ongoing program for revegetation and rehabilitation of the dune system. Sand fencing to manage wind-blown erosion also falls under this category.
	Beach nourishment	PR2	Addition of sand to the beach, dune and/or nearshore area to replace lost material and/or create additional buffer. This option is often a temporary measure and can be more effective in association with hard protection options, such as groynes. The sand may be from an external source or from a nearby part of that coastal area (though outside of the local sediment cell. Use of sediment within the cell is considered sand management – PR1).
	Groynes / Headland Enhancement	PR3	Construct groynes / headland enhancement along the beach to restrict longshore sediment movement and stabilise sections of shoreline. This option is often accompanied by beach nourishment. Hard protection generally diverts/creates erosion issues elsewhere, such as to the down drift side of a structure.
	Nearshore reefs / breakwaters	PR4	Construct offshore reef(s) / breakwater(s) or raise existing natural nearshore reef structure to increase protection from wave energy as sea level rises, lowering cross-shore sediment transport. Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of the nearshore structures.
	Revetments / Seawalls	PR5	Construct seawall in front of assets or along length of coastline to protect them from coastal hazards. Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of, and directly in front of, a seawall.
Do nothing	Do nothing	DN	Take no action. No limitations on development or implementation of adaptation planning. Accept risk.

3.2 Adaptation Options Assessment Process

3.2.1 Management Units

Adaptation options have been evaluated, and pathways established, for six Management Units (MU) along the City's coastline. These MUs were selected based on the focused concentration of coastal hazard risk, as identified in the *Vulnerability Assessment and Risk Evaluation* Chapter Report (Cardno, 2023c), as well as consideration for similar coastal features and shared sediment compartments. All adaptation options were assessed for each MU, through the Multi-Criteria Analysis (MCA) process, with multiple options identified as potentially suitable for implementation within each MU. A Cost Benefit Analysis (CBA) was then undertaken to assess the costs of potential adaptation options (**Section 5**), for comparison with the value of assets at stake and the potential cost to remove them. Suitable options that have been deemed to be cost-effective are included in adaption pathways for each MU. The MUs are described in the sub-sections below.

3.2.1.1 MU1 - Watermans Bay

MU1 extends from the City's northern boundary (aligned with Beach Road) to the southern end of Watermans Dog Beach (aligned with Hale Street). Within the 2122 erosion hazard extent, MU1 contains the following key natural assets:

- > Watermans Bay Beach;
- > Watermans Bay Dog Beach; and
- > Vegetated dunes.

And the key built assets:

- > West Coast Drive, associated services and adjacent footpath;
- > Various parking and access infrastructure; and
- > The Marine Lab.

3.2.1.2 MU2 - North Beach

MU2 extends from the northern end of North Beach Dog Beach (aligned with Hale Street) to the southern end of Hamersley Pool (aligned with Hamersley Street). Within the 2122 erosion hazard extent, MU2 contains the following key natural assets:

- > North Beach Dog Beach;
- > North Beach (North);
- > North Beach (South);
- > Hamersley Pool; and
- > Vegetated dunes.

And the key built assets:

- > West Coast Drive, associated services and adjacent footpath; and
- > Various parking, access and recreational infrastructure.

3.2.1.3 MU3 - Mettams Pool

MU3 extends from the northern (aligned with Hamersley Street) to the southern (aligned with Bailey Street) end of Mettams Pool. Within the 2122 erosion hazard extent, MU3 contains the following key natural assets:

- > Mettams Pool Beach; and
- > Vegetated dunes.

And the key built assets:

- > West Coast Drive, associated services and adjacent footpath; and

- > Various parking, access and recreational infrastructure.

3.2.1.4 MU4 - Trigg Beach North

MU4 extends from the northern end of Bennion Beach (aligned with Bailey Street) to Trigg Point/Island. Within the 2122 erosion hazard extent, MU4 contains the following key natural assets:

- > Bennion Beach;
- > Trigg Beach Dog Beach;
- > Trigg Beach North; and
- > Vegetated dunes (Bush Forever Site 308).

And the key built assets:

- > West Coast Drive, associated services and adjacent footpath; and
- > Various parking, access and recreational infrastructure.

3.2.1.5 MU5 - Trigg Beach South

MU5 extends from Trigg Point/Island to the southern end of Trigg Beach. Within the 2122 erosion hazard extent, MU5 contains the following key natural assets:

- > Trigg Beach;
- > Trigg Beach South; and
- > Vegetated dunes (Bush Forever Site 308).

And the key built assets:

- > Extensive parking areas;
- > Trigg Beach Café;
- > Trigg Beach Surf Lifesaving Club buildings and facilities; and
- > Various access and recreational infrastructure/areas.

3.2.1.6 MU6 - Scarborough Beach

MU6 extends from the northern end of Scarborough Beach to the southern extent of the City's boundary at Peasholm Dog Beach. Within the 2122 erosion hazard extent, MU6 contains the following key natural assets:

- > Scarborough Beach North;
- > Scarborough Beach;
- > Brighton Beach;
- > Peasholm Dog Beach; and
- > Vegetated dunes (Bush Forever Sites 308 and 310).

And the key built assets:

- > Extensive parking areas;
- > Scarborough Amphitheatre;
- > Scarborough Surf Lifesaving Club buildings and facilities;
- > Scarborough Beach Pool and Restaurant; and
- > Various access and recreational infrastructure/areas.

3.2.2 Multi-Criteria Assessment Process

As recommended in the CHRMAP Guidelines, the MCA has been used as a preliminary tool to identify potentially suitable adaptation options for the assets within each MU, as well as to discard unviable options. The analysis uses a broad range of criteria and a simple 'traffic light' rating system to evaluate the acceptability of each option. The 'traffic light' ratings are described as follows:

- > Red light: Options will not be recommended - i.e. it is likely to be fatally flawed for that criteria;
- > Amber light: Requires further assessment or is neutral for the criteria; and
- > Green light: Likely to be positive for the respective criteria.

The assessment considers the effectiveness of options at reducing risk and performing their function in relation to governance, environmental, social and economic aspects. Information gained through the stakeholder and community engagement process has been used to reflect acceptability of options to the community in the assessment. Options have also been assessed in terms of their restriction on future planning and risk management opportunities, with options that allow for a wide range of future strategies generally considered more favourably. The MCA is informed by three overarching criteria (preliminary feasibility, preliminary acceptability and preliminary financial implications), each of which incorporates various sub-criteria, as detailed in **Table 3-2**.

Table 3-2 Multi-Criteria Assessment criteria

Preliminary feasibility	Preliminary acceptability	Preliminary financial implication
Effectiveness	Environmental and social impact	Financial gain / avoidance of cost
Governance, legal implications and approval risk	Community acceptability	Capital cost
Reversibility / adaptability	-	Ongoing cost

The options available for assessment may not be applicable to all asset types, so the applicable assets or areas assessed for each option have been specified in the MCA tables. For managed retreat of built assets, these assets have been separated and grouped as:

- > Minor public infrastructure;
- > Major public infrastructure; and
- > Residential and commercial property.

This is due to differences in the potential adaptation options that can be applied for the asset groups. Where certain assets don't exist in a particular MU, not applicable ('N/A') is assigned in the table.

3.2.3 Stakeholder Engagement

Stakeholder feedback regarding potential adaptation options and approaches has been incorporated in the MCA analysis, predominantly reflected in the two categories falling under 'Preliminary Acceptability'. A workshop was held online with stakeholders and members of the public invited to attend. The workshop presented those in attendance with erosion hazard lines, individual risk ratings for assets along the City's coastline, and potential adaptation strategies. Attendees were then asked for their preferred adaption option. Protection (beach nourishment, groynes and offshore breakwaters) was favoured amongst attendees, followed by managed retreat. There was general support for options which maintain the City's natural assets, such as beaches and dune systems.

3.2.4 Outcomes

Each of the adaptation options presented in **Table 3-1** have been considered for each MU of the City's coastline (**Table 3-3** to **Table 3-8**).

Table 3-3 MU1 Watermans Bay

Option Category	Option Code	Option Name	Applicable Assets / Areas	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
				Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development	Presently undeveloped land within the coastal foreshore reserve.									Recommend
Planned / Managed Retreat	PMR1	Leave unprotected / repair	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.									Do not recommend
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	PMR2	Remove / relocate	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.									Further assessment
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMR3	Planning controls for managed retreat	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Accommodate	AC1	Planning controls to identify/accommodate risk	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AC2	Emergency plans and controls	All areas.									Recommend
	AC3	Re-design to withstand impact	Built assets.									Do not recommend
Protect	PR1	Dune care / sand management	Beach and dunes - protective buffer to landward assets.									Recommend
	PR2	Beach Nourishment	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR3	Groyne(s) / Headland enhancement	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR4	Nearshore Reef(s) / Breakwater(s)	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR5	Revetment(s) / Seawall(s)	Protective buffer to landward assets.									Further assessment
Do Nothing	DN	Do Nothing	All areas.									Do not recommend

Table 3-4 MU2 – North Beach

Option Category	Option Code	Option Name	Applicable Assets / Areas	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
				Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development	Presently undeveloped land within the coastal foreshore reserve.									Recommend
Planned / Managed Retreat	PMR1	Leave unprotected / repair	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	PMR2	Remove / relocate	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMR3	Planning controls for managed retreat	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Accommodate	AC1	Planning controls to identify/accommodate risk	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AC2	Emergency plans and controls	All areas.									Recommend
	AC3	Re-design to withstand impact	Built assets.									Do not recommend
Protect	PR1	Dune care / sand management	Beach and dunes - protective buffer to landward assets.									Recommend
	PR2	Beach Nourishment	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR3	Groyne(s) / Headland enhancement	Beach and dunes - protective buffer to landward assets.									Do not recommend
	PR4	Nearshore Reef(s) / Breakwater(s)	Beach and dunes - protective buffer to landward assets.									Do not recommend
	PR5	Revetment(s) / Seawall(s)	Protective buffer to landward assets.									Do not recommend
Do Nothing	DN	Do Nothing	All areas.									Do not recommend

Table 3-5 MU3 – Mettams Pool

Option Category	Option Code	Option Name	Applicable Assets / Areas	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
				Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development	Presently undeveloped land within the coastal foreshore reserve.									Recommend
Planned / Managed Retreat	PMR1	Leave unprotected / repair	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.									Do not recommend
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	PMR2	Remove / relocate	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.									Further assessment
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMR3	Planning controls for managed retreat	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Accommodate	AC1	Planning controls to identify/accommodate risk	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AC2	Emergency plans and controls	All areas.									Recommend
	AC3	Re-design to withstand impact	Built assets.									Do not recommend
Protect	PR1	Dune care / sand management	Beach and dunes - protective buffer to landward assets.									Recommend
	PR2	Beach Nourishment	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR3	Groyne(s) / Headland enhancement	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR4	Nearshore Reef(s) / Breakwater(s)	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR5	Revetment(s) / Seawall(s)	Protective buffer to landward assets.									Further assessment
Do Nothing	DN	Do Nothing	All areas.									Do not recommend

Table 3-6 MU4 – Trigg Beach North

Option Category	Option Code	Option Name	Applicable Assets / Areas	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
				Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development	Presently undeveloped land within the coastal foreshore reserve.									Recommend
Planned / Managed Retreat	PMR1	Leave unprotected / repair	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.									Do not recommend
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	PMR2	Remove / relocate	Minor public infrastructure - e.g. benches, paths, amenities.									Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.									Further assessment
			Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PMR3	Planning controls for managed retreat	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Accommodate	AC1	Planning controls to identify/accommodate risk	Residential and commercial property.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	AC2	Emergency plans and controls	All areas.									Recommend
	AC3	Re-design to withstand impact	Built assets.									Do not recommend
Protect	PR1	Dune care / sand management	Beach and dunes - protective buffer to landward assets.									Recommend
	PR2	Beach Nourishment	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR3	Groyne(s) / Headland enhancement	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR4	Nearshore Reef(s) / Breakwater(s)	Beach and dunes - protective buffer to landward assets.									Further assessment
	PR5	Revetment(s) / Seawall(s)	Protective buffer to landward assets.									Further assessment
Do Nothing	DN	Do Nothing	All areas.									Do not recommend

Table 3-7 MU5 – Trigg Beach South

Option Category	Option Code	Option Name	Applicable Assets / Areas	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
				Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development	Presently undeveloped land within the coastal foreshore reserve.	Green	Yellow	Green	Green	Green	Yellow	Green	Green	Recommend
Planned / Managed Retreat	PMR1	Leave unprotected / repair	Minor public infrastructure - e.g. benches, paths, amenities.	Yellow	Green	Green	Green	Green	Yellow	Green	Yellow	Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.	Red	Red	Yellow	Red	Red	Red	Green	Yellow	Do not recommend
			Residential and commercial property.	Red	Yellow	Yellow	Red	Red	Red	Green	Red	Do not recommend
	PMR2	Remove / relocate	Minor public infrastructure - e.g. benches, paths, amenities.	Green	Yellow	Green	Yellow	Green	Yellow	Yellow	Green	Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Do not recommend
			Residential and commercial property.	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Further assessment
PMR3	Planning controls for managed retreat	Residential and commercial property.	Green	Yellow	Green	Yellow	Green	Yellow	Green	Green	Recommend	
Accommodate	AC1	Planning controls to identify/accommodate risk	Residential and commercial property.	Green	Green	Green	Green	Green	Yellow	Green	Green	Recommend
	AC2	Emergency plans and controls	All areas.	Green	Green	Green	Green	Green	Yellow	Green	Green	Recommend
	AC3	Re-design to withstand impact	Built assets.	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Yellow	Do not recommend
Protect	PR1	Dune care / sand management	Beach and dunes - protective buffer to landward assets.	Yellow	Green	Green	Green	Green	Yellow	Green	Yellow	Recommend
	PR2	Beach Nourishment	Beach and dunes - protective buffer to landward assets.	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
	PR3	Groyne(s) / Headland enhancement	Beach and dunes - protective buffer to landward assets.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
	PR4	Nearshore Reef(s) / Breakwater(s)	Beach and dunes - protective buffer to landward assets.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
	PR5	Revetment(s) / Seawall(s)	Protective buffer to landward assets.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
Do Nothing	DN	Do Nothing	All areas.	Red	Yellow	Yellow	Yellow	Red	Red	Green	Red	Do not recommend

Table 3-8 MU6 – Scarborough Beach

Option Category	Option Code	Option Name	Applicable Assets / Areas	Preliminary Feasibility			Preliminary Acceptability		Preliminary Financial Implication			Recommendation
				Effectiveness	Legal / Approval Risk	Reversibility / Adaptability	Environmental / Social Impact	Community Acceptability	Economic gain / Avoidance of Cost	Capital Cost	Ongoing Cost	
Avoid	AV	Avoid development	Presently undeveloped land within the coastal foreshore reserve.	Green	Yellow	Green	Green	Green	Yellow	Green	Green	Recommend
Planned / Managed Retreat	PMR1	Leave unprotected / repair	Minor public infrastructure - e.g. benches, paths, amenities.	Yellow	Green	Green	Green	Green	Yellow	Green	Yellow	Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.	Red	Red	Yellow	Red	Red	Red	Green	Yellow	Do not recommend
			Residential and commercial property.	Red	Yellow	Yellow	Red	Red	Red	Green	Red	Do not recommend
	PMR2	Remove / relocate	Minor public infrastructure - e.g. benches, paths, amenities.	Green	Yellow	Green	Yellow	Green	Yellow	Yellow	Green	Recommend
			Major public infrastructure - e.g. buildings, roads, carparks.	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Do not recommend
			Residential and commercial property.	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Further assessment
PMR3	Planning controls for managed retreat	Residential and commercial property.	Green	Yellow	Green	Yellow	Green	Yellow	Green	Green	Recommend	
Accommodate	AC1	Planning controls to identify/accommodate risk	Residential and commercial property.	Green	Green	Green	Green	Green	Yellow	Green	Green	Recommend
	AC2	Emergency plans and controls	All areas.	Green	Green	Green	Green	Green	Yellow	Green	Green	Recommend
	AC3	Re-design to withstand impact	Built assets.	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Yellow	Do not recommend
Protect	PR1	Dune care / sand management	Beach and dunes - protective buffer to landward assets.	Yellow	Green	Green	Green	Green	Yellow	Green	Yellow	Recommend
	PR2	Beach Nourishment	Beach and dunes - protective buffer to landward assets.	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
	PR3	Groyne(s) / Headland enhancement	Beach and dunes - protective buffer to landward assets.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
	PR4	Nearshore Reef(s) / Breakwater(s)	Beach and dunes - protective buffer to landward assets.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
	PR5	Revetment(s) / Seawall(s)	Protective buffer to landward assets.	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Further assessment
Do Nothing	DN	Do Nothing	All areas.	Red	Yellow	Yellow	Yellow	Red	Red	Green	Red	Do not recommend

4 Options

4.1 Avoid Option

The default recommendation is that the *avoid* option be applied to all presently undeveloped land lying within areas that will potentially be exposed to coastal hazards over the next 100 years. These areas should be defined by coastal erosion and inundation hazard extents at the 2122 planning timeframe. This is considered a default position because long-term management pathways for coastal hazard areas have not yet been defined.

Once long-term pathways have been defined, and responsibilities and funding arrangements for these pathways put in place, it may be acceptable for the City to permit certain types of development in these areas. For example, if an interim protect strategy (under the beneficiary pays principle) is to be in place for a section of coast, funding for this strategy could be aided by allowing additional, time-limited, development on its landward side. Developers and affected landholders would need to be fully cognisant of their responsibilities in contributing to funding the protection and the requirement for eventual managed retreat from the area, once a specified trigger is reached or protection is no longer feasible.

The City should thoroughly investigate and refine long-term pathways to guide the control of development in coastal hazard zones, ensuring responsible management and avoidance of liability. Recommendations for application of the *avoid* option, and components to its application, are detailed in the following paragraphs.

Coastal Foreshore Reservation: The coastal foreshore provides for storm erosion buffer, beach access, recreation and conservation, tourist attraction and habitat for native flora and fauna. Importantly, it also provides a buffer to mitigate risks to high value-built assets such as buildings and infrastructure.

The foreshore reserve should include allowance for physical processes and be established from the current coastline (as defined by the active limit of the shoreline or present-day horizontal shoreline datum (HSD)). It should be based on the 2122 coastal erosion hazard line, determined in accordance with SPP2.6. In addition to the allowance for physical processes such as coastal erosion, the foreshore reserve must include land allocation for maintaining the values, functions and equitable use of the coast over a 100-year planning horizon (WAPC, 2020) (**Figure 4-1**). It should be noted that the 2122 coastal erosion hazard line DOES NOT define the extent of the coastal foreshore reserve. This line defines the potential extent of coastal erosion hazards over the 100-year planning timeframe. The foreshore reserve boundary should always be landward of the 2122 hazard line.

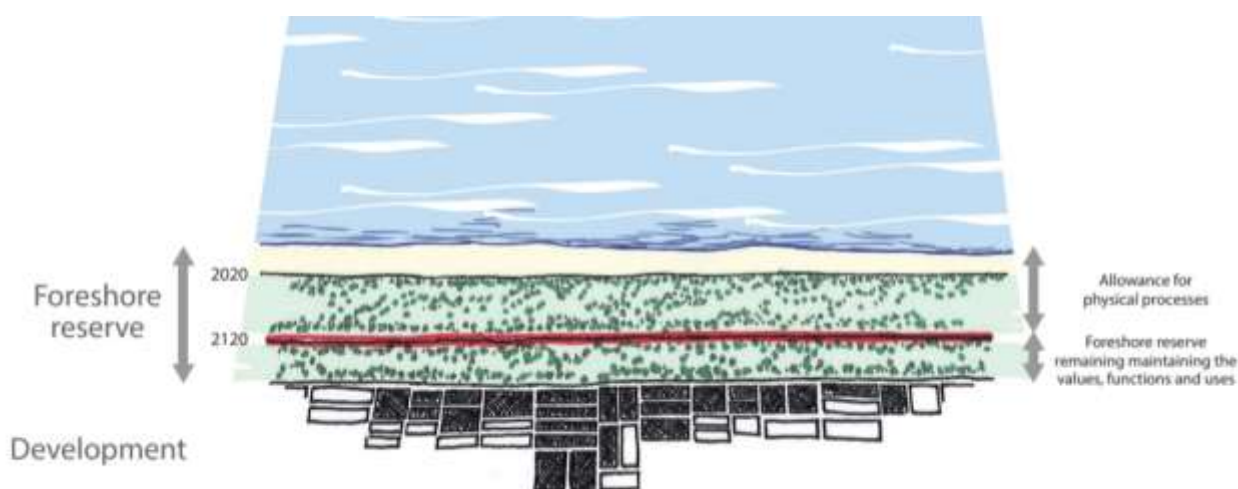


Figure 4-1 Coastal foreshore reserve – sandy coast example (WAPC, 2020b).

Permanent and easy public access to the beach and foreshore reserve is a fundamental coastal planning objective. The coast and coastal recreation reserves are a public asset which should not, now or in the future, become the de facto exclusive domain of private landowners by virtue of the erosion of coastal reserves or due to other coastal processes. Coastal reserves should be wide enough that they can still perform recreation and/or conservation functions (according to the reasons for their initial designation) even if they are affected by coastal erosion or diminution due to SLR. Coastal reserves also need to consider aspects such as the preservation of significant natural features, heritage and landscape values.

In general, permanent development should only be considered landward of the foreshore reserve boundary, however section 7 of Schedule 1 of SPP2.6 provides a number of variations to this, such as public recreation facilities with a finite lifespan and temporary and relocatable developments that are dependent on a coastal location (for example surf lifesaving clubs, tourism related facilities and businesses).

For undeveloped land lying seaward of the 2122 coastal erosion hazard line, plus an additional allowance for coastal foreshore reserve: The 2122 coastal erosion hazard line (allowance for physical process) should be used as the starting point for defining a coastal foreshore reserve (**Figure 4-1**), in which no major residential or commercial development should take place without further investigation and planning for the economic, social and environmental impacts of proposed development. This recommendation is also consistent with Section 5.2(i) of SPP2.6, which encourages urban development around existing settlements and discourages continuous linear urban development along the coast. It must be reiterated that the 2122 hazard line does not define the extent of the coastal foreshore reserve.

Any proposal for development adjacent to the 2122 coastal erosion hazard line should undertake the necessary investigations to develop a coastal foreshore reserve, between the hazard line and the development (**Figure 4-1**), to ensure the function of the coastal foreshore is maintained should the potential coastal hazards be realised over the appropriate planning timeframe (i.e. given the lifespan of the development).

Presently, much of the undeveloped land lying seaward of the 2122 hazard line is contained within the Parks & Recreation Zone under the Metropolitan Region Scheme Reserves. Where possible, it is recommended that this zone be expanded, or added to at a local scale, to contain all undeveloped land lying seaward of the 2122 hazard line. Zones allocated for development landward of, and adjacent to, the 2122 hazard line should have planning controls to ensure an appropriate coastal foreshore reserve is incorporated (determined on a case-by-case basis) and foreshore management planning is implemented.

For already developed land lying seaward of the 2122 hazard line for coastal erosion: Any zoning or rezoning of land already lying seaward of the 2122 hazard line needs to be carefully considered due to the potential to trigger a claim for injurious affection. In these instances, a Special Control Area should be applied, as described in **Appendix A**. The *State Coastal Planning Policy Guidelines* (Section 5) provide that infill development can be considered where the parcel of land lies in between existing development and does not extend seaward past the line of existing development. In considering development proposals for such land or subdivision of land seaward of the 2122 hazard line, the City should consider the adaptation and management pathway to be adopted for the area. If the recommended pathway is one of *Managed Retreat*, this land should be controlled to prevent further development or subdivision. If a *Protect* approach has been adopted, and appropriately planned and allowed for, the City may allow such land to be developed or subdivided under the provision that the responsibility for management of the coastal hazard risk is shared with the developer. This responsibility could be shared by way of a Specified Area Rate, which collects additional funds to contribute to the cost of coastal management in the area.

Coastal roads: SPP2.6 states that generally, coastal roads should not be developed within the coastal foreshore reserve. Therefore, alignment of any new roads should be landward of the 2122 hazard line and also make an appropriate allowance for a coastal foreshore reserve, determined on a case-by-case

basis. Design of new subdivisions should be robust enough to allow for alternative routes to be taken in the event that a key access route is impacted by coastal processes.

Coastal car parks: SPP2.6 states that coastal carparks should be located landwards of the likely impacts of coastal processes. The design life of the carpark and most up to date coastal hazard line (relevant to that timeframe) should be considered in planning such facilities, along with the availability of suitable land to relocate them in the future, if necessary.

Commercial and Tourist Related Infrastructure: Zoning need not necessarily preclude the development of commercial and tourist related infrastructure within the coastal foreshore reserve. It should however, require that development plans for such infrastructure properly allow for the risks of coastal hazards (as determined in the CHRMAP) over the full lifespan of the proposed development. This should also include an appropriate assessment of social, economic and environmental impacts of the proposed development, and allocation of financial responsibilities, prior to approval.

Public recreation facilities: SPP2.6 is not intended to prevent the development of public recreation facilities such as minor carparks, amenities, pedestrian access, recreational equipment and infrastructure for public safety. Zoning does not need to be adjusted to exclude the development of such infrastructure, however, their full lifespan (generally less than 30 years) should be considered with respect to the appropriate hazard extents.

Temporary development: In some instances, it may be deemed acceptable for development of a temporary nature to be permitted. The City should be indemnified against any future damage to assets in such cases, and a trigger for the removal of the assets should be identified and included as a condition of any approval (with possible memorial on the title to make this known to landowners for as long as necessary).

Scheme provisions and/or a local planning policy relating to temporary private assets should be considered.

Land Records System: It is recommended that the City introduce an easily recognisable alert into its land records system. This will ensure that staff accessing information on any affected land (including road reserves and other Council controlled land within the City), for any reason, can be made aware of the presence of the coastal hazard or any other factor requiring special attention or liaison with another part of the organisation or external agency. This will reduce the risk of works being undertaken by the City that are contrary to any adopted strategy for the land under consideration.

Information on relevant coastal hazards and the implications for property, now and into the future, should also be made available to potential buyers upon making a land purchase enquiry.

4.1.2 Equity Implications for the Avoid Option

The *Avoid* option is generally considered the most equitable, hence its prioritisation on the State's adaptation planning hierarchy. It supports intergenerational equity, by preventing unnecessary costs from being passed to future generations. It also ensures that beach and coastal foreshore access and amenity is provided to the whole community, now and in the future.

The option could be seen to benefit those who already own property in coastal areas (particularly coastal hazard areas) by lowering the supply of such property (e.g. property with coastal views) and therefore increasing its value. This notion should be considered against the potential for these existing landholders to lose their property or pay a premium for ongoing coastal protection. Similarly, future generations will have less access to premium coastal property due to a lack of supply, and could be seen to lose out in this regard.

Developers and the City may lose out from implementing this option, if coastal land previously earmarked or purchased for development is no longer developable.

4.2 Managed Retreat Options

Managed retreat is the preferred adaptation pathway for already developed areas under the State's Coastal Planning Policy. Removing assets from hazardous areas eliminates the need to fund expensive

ongoing protection, making it the economically responsible approach over the long term. Appendix 4 of the CHRMAP Guidelines – *Planned or Managed Retreat – Existing Planning Framework and Instruments* outlines actions to be undertaken to enact a managed retreat policy, which includes mechanisms to compensate landholders for the acquisition of private property when risk is no longer tolerable. While there is no obligation at any level of Government to compensate landholders for the impacts of coastal hazards and SLR, there is a responsibility to act in the best interests of the community. As such, cost estimates for managed retreat include the value of the affected assets, to account for replacement cost or compensation for acquisition.

Managed retreat can occur by leaving assets unprotected and repairing or removing them when they are impacted (PMR1). This is generally recommended for low-value, public assets that can be quickly removed and will not pose a risk to the community if they are damaged. This also avoids potential expense in removing the assets before it is necessary.

Removing or relocating assets before they are impacted (PMR2) is the recommended approach for larger assets and infrastructure, including commercial/private property and roads. It is not considered appropriate to allow such infrastructure to be damaged by coastal hazards, as this would cause considerable risk and concern to the community and likely increase removal costs. To assist the pre-emptive removal of vulnerable assets, it is recommended that planning controls be put in place to facilitate the management pathway (PMR3). Key to this is the application of a Special Control Area (SCA) over vulnerable areas, to control development and identify that retreat from the area is likely to occur at some point in the future. Details around the SCA and other planning controls are outlined in **Appendix A**.

The potential cost of fully adopting the managed retreat option has been estimated based on asset value (**Appendix B**) and removal cost. The assets to be removed have been identified with respect to coastal erosion hazard lines up to the 2122 planning timeframe, within the six MUs. As the hazard lines may be considered conservative (based on current available data), these costs may be inflated above what will realistically be required. The costs are, however, comparable with costings for other adaptation options, which have also been based on hazard line extents. There are several other cost implications that could be associated with managed retreat, and these should be identified through a detailed analysis of the option. It must also be noted that there is considerable uncertainty around the estimated costs, particularly in progressing to future planning timeframes. The upfront cost of implementing managed retreat will be significant and sufficient funding, from any level of government, is highly unlikely to be available in the short term. While managed retreat from vulnerable areas should be the eventual aim throughout the City, realistically, some interim protection will be required while funding for retreat is arranged.

As the average shoreline position is expected to gradually retreat, with intermittent erosion and accretion due to seasonal and storm-based impacts, managed retreat would also take place in a staged approach. The staging of managed retreat would be trigger based, with several key triggers outlined in the CHRMAP Guidelines (Appendix 4). These and other appropriate triggers for implementing managed retreat (and other adaptation options) for the City will be discussed in detail in the implementation plan for this CHRMAP. Where appropriate, the City should look to adopt a managed retreat approach for public assets and minor infrastructure to demonstrate responsible management of the risks associated with coastal hazards. Managed retreat of assets at the foreshore should avoid coastal erosion impacts and allow the shoreline to recede naturally, maintaining beach amenity and a suitable coastal foreshore reserve.

4.2.1 MU1 – Watermans Bay

Adopting a managed retreat approach for Watermans Bay would require the removal and relocation of public infrastructure, such as West Coast Drive, carparks, the lookout and toilets. Potential cost implications are estimated for assets affected up to each planning timeframe in **Figure 4-1** below. The assets accounted for are those that are intersected by the coastal hazard extent for each timeframe, as mapped in Cardno (2023b). The costs are not cumulative, meaning that once an asset is accounted for in a timeframe it is not included in any future timeframes. A full costing breakdown for assets across the timeframes is provided in **Appendix C**.

Table 4-1 Watermans Bay Managed Retreat Asset Value

	2030	2045	2070	2122
Asset Value	\$27,900	\$60,840	\$538,280	\$468,830
Removal Cost	\$2,790	\$6,030	\$81,070	\$264,250
Total	\$30,690	\$66,870	\$619,350	\$733,080

4.2.2 MU2 – North Beach

Adopting a managed retreat approach for North Beach would require the removal of sections of West Coast Drive and beach access assets. Potential cost implications are estimated for assets affected up to each planning timeframe in **Table 4-2** below. The assets accounted for are those that are intersected by the coastal hazard extent for each timeframe, as mapped in Cardno (2023b). The costs are not cumulative, meaning that once an asset is accounted for in a timeframe it is not included in any future timeframes. A full costing breakdown for assets across the timeframes is provided in **Appendix C**.

Table 4-2 North Beach Managed Retreat Asset Value

	2030	2045	2070	2122
Asset Value	\$42,400	\$97,820	\$344,820	\$1,042,870
Removal Cost	\$4,240	\$9,264	\$25,820	\$69,530
Total	\$46,640	\$107,080	\$370,640	\$1,112,400

4.2.3 MU3 – Mettams Pool

Adopting a managed retreat approach for Mettams Pool would require the removal of public infrastructure, such as West Coast Drive and carparks, beach access ramps and stairs as well as public toilets. Potential cost implications are estimated for assets affected up to each planning timeframe in **Table 4-3** below. The assets accounted for are those that are intersected by the coastal hazard extent for each timeframe, as mapped in Cardno (2023b). The costs are not cumulative, meaning that once an asset is accounted for in a timeframe it is not included in any future timeframes. A full costing breakdown for assets across the timeframes is provided in **Appendix C**.

Table 4-3 Mettams Pool Managed Retreat Asset Value

	2030	2045	2070	2122
Asset Value	\$13,510	\$582,050	\$263,690	\$837,120
Removal Cost	\$360	\$16,610	\$17,680	\$53,970
Total	\$13,870	\$598,660	\$281,370	\$891,090

4.2.4 MU4 – Trigg Beach North

Adopting a managed retreat approach for Trigg Beach North would require the removal of public infrastructure, such as West Coast Drive and carparks, as well as grassed areas and toilets. Potential cost implications are estimated for assets affected up to each planning timeframe in **Table 4-5** below. The assets accounted for are those that are intersected by the coastal hazard extent for each timeframe, as mapped in Cardno (2023b). The costs are not cumulative, meaning that once an asset is accounted for in a timeframe it is not included in any future timeframes. A full costing breakdown for assets across the timeframes is provided in **Appendix C**.

Table 4-4 Trigg Beach North Managed Retreat Asset Value

	2030	2045	2070	2122
Asset Value	\$29,700	\$59,400	\$89,100	\$278,100
Removal Cost	\$2,970	\$5,940	\$8,910	\$25,880
Total	\$32,670	\$65,340	\$98,010	\$303,980

4.2.5 MU5 – Trigg Beach South

Adopting a managed retreat approach for Trigg Beach South would require the removal of carparks, the public amenities at Trigg South such as grassed areas and toilets, Trigg Beach Cafe, Trigg Surf Lookout, as well as the Trigg Surf Lifesaving Club. Potential cost implications are estimated for assets affected up to each planning timeframe in **Table 4-5** below. The assets accounted for are those that are intersected by the coastal hazard extent for each timeframe, as mapped in Cardno (2023b). The costs are not cumulative, meaning that once an asset is accounted for in a timeframe it is not included in any future timeframes. A full costing breakdown for assets across the timeframes is provided in **Appendix C**.

Table 4-5 Trigg Beach South Managed Retreat Asset Value

	2030	2045	2070	2122
Asset Value	\$29,700	\$1,051,860	\$7,431,940	\$10,353,950
Removal Cost	\$2,970	\$28,150	\$17,390	\$452,650
Total	\$32,670	\$1,080,010	\$7,449,330	\$10,806,600

4.2.6 MU6 – Scarborough Beach

Adopting a managed retreat approach for Scarborough Beach would require the removal of public infrastructure, such as roads and carparks, the public amenities such as grassed and paved areas, Scarborough Amphitheatre, playgrounds, skate park and toilets, Scarborough Pool and Restaurant, as well as the Scarboro Surf Lifesaving Club. Potential cost implications are estimated for assets affected up to each planning timeframe in **Table 4-6** below. The assets accounted for are those that are intersected by the coastal hazard extent for each timeframe, as mapped in Cardno (2023b). The costs are not cumulative, meaning that once an asset is accounted for in a timeframe it is not included in any future timeframes. A full costing breakdown for assets across the timeframes is provided in **Appendix C**.

Table 4-6 Scarborough Beach Managed Retreat Asset Value

	2030	2045	2070	2122
Asset Value	\$458,200	\$4,694,420	\$4,814,280	\$41,384,720
Removal Cost	\$45,820	\$469,440	\$248,320	\$3,783,540
Total	\$504,020	\$5,163,860	\$5,062,590	\$45,168,260

4.2.7 Planning Implications for Managed Retreat

Managed retreat of assets within the existing Coastal Foreshore Reserve would be best managed by Foreshore Management Planning, prepared and implemented by the City. Any development/redevelopment plans for coastal areas should pay due regard to the recommendations of this CHRMAP. Public assets, such as roads, are the responsibility of the State Government (Main Roads) and planning for modification of these would require collaboration with the State.

Private property within the City is not anticipated to be impacted by coastal hazards or begin to impinge of the Coastal Foreshore Reserve until late in the century. The CHRMAP Guidelines includes guidance on the Planned and Managed Retreat approach for private properties that are subject to erosion within the planning timeline. The CHRMAP Guidelines provide a framework for triggering the acquisition of

private land affected by erosion where the public foreshore can no longer provide a natural buffer to coastal processes.

The Planned and Managed Retreat approach will require the City to acquire properties at risk over time which will enable expansion of the foreshore reserve. The acquisition processes recommended in the CHRMAP Guidelines supports compensation paid to property owners, in accordance with the *Land Administration Act 1997*. However, there is no obligation to adopt a policy that effectively forces the City to compensate property owners. In addition, there is no legal responsibility for the City, or the State Government, to provide protection of a private property from natural hazards, nor compensate property owners where the land is lost to erosion. The City has the ability to intervene and enforce eviction if a private property becomes uninhabitable or if the property presents a public risk.

There is risk to community if sufficient investment is not allocated by the City to deliver a strategic and proactive response to erosion. In accordance with the CHRMAP Guidelines, the property acquisition options include:

- > Purchase of the land if the owner is willing to sell it by ordinary sale pursuant to Section 190 of the *Planning and Development Act 2005*; or
- > Compulsory taking of the land by the responsible authority without agreement pursuant to Section 191 of the *Planning and Development Act 2005*. The compulsory taking is to be carried out in accordance with the *Land Administration Act 1997*.

4.2.8 Equity Implications for Managed Retreat

The *managed retreat* option leads to considerable equity implications. The option is considered fair to the broader community, whose ability to access and use the beach and foreshore is maintained. Those owning residential properties that will be removed will be seen to lose out through the strategy, significantly so if mechanisms for adequate compensation are not put in place.

From an intergenerational equity perspective, the significant short-term costs associated with the option in many areas could be seen to disadvantage current and future generations. These generations would effectively be paying to rectify land mismanagement and inappropriate development, attributable to previous generations. The question of who should be responsible for funding a *managed retreat* approach, at all levels of government, is not properly resolved.

4.3 Accommodate Options

4.3.1 Planning Controls (AC1)

Planning controls may be used to allow the temporary use of land falling within hazard extents until such time as hazards materialise, or their risk is no longer tolerable. Implementing time-limited planning consent conditions, will give the City the ability to utilise land in the hazard zone. This will ensure the continuation of construction of minor structures such as benches, paths, playgrounds, BBQs etc. to keep up with the increasing patronage of the foreshore areas along the City's coastline. Temporary use of land for more significant infrastructure (toilet blocks, cafes etc.) may also be considered if the design life of the proposed asset is shorter than the predicted time at which risk from coastal hazards will become intolerable. **Appendix A.**

4.3.2 Emergency Plans and Controls (AC2)

Emergency plans and controls are not generally used to accommodate the risk of coastal erosion. Once an asset is impacted by coastal erosion it is deemed to be non-recoverable and evacuation is assumed to have occurred before this point, limiting the effectiveness of emergency plans and controls. **Appendix A.**

4.4 Soft Protection Options

Soft protection options do not involve the use of hard infrastructure and provide only temporary or minor protection. Large scale beach renourishment, for example, can provide additional protection for 18 months to 5 years, before the shoreline recedes to its original position. The options can be used as interim measures or on an ongoing basis but should not be viewed as permanent solutions to deal with rising MSL.

4.4.1 Dune Care / Sand Management (PR1)

Sand dunes are naturally formed and maintained by wind-blown sand transport and provide for complex ecosystems, located at the boundary between the marine and terrestrial environment. They are critical for shoreline stabilisation and protection through two primary mechanisms:

- > Providing a natural barrier against wave impact and storm surge inundation; and
- > Providing an erodible sand supply for the beaches fronting them.

Dunes have been diminished in many areas throughout the State, due to receding shorelines and development directly inland. The methods available for dune management and rehabilitation include the following:

- > Dune revegetation and vegetation enhancement;
- > Sand/wind fencing; and
- > Beach entry/access management.

Dune vegetation and revegetation is frequently undertaken along the Perth Metropolitan coastline through dune care programs, usually undertaken by volunteer groups (primarily working under Coastcare). It should be noted that dune vegetation itself provides minimal protection against coastal erosion, due to the shallow rooted nature of coastal flora. It does however help to capture and retain wind-blown sand, stabilising the dune and helping to maintain it as a natural barrier. Maintenance and installation of coastal dune vegetation is generally recommended, under the assumption that government funding and volunteer input can assist its implementation. If dune vegetation is to be fully funded by the City, it should carefully consider the allocation of resources to the protection method.

Sand fencing is commonly employed to retain wind-blown sand in certain areas of a beach and also to prevent sand from being deposited where it is not wanted, such as on coastal carparks, parks, paths and roads. Sand fencing is relatively inexpensive to install and maintain (although frequent maintenance can be required) and can be highly effective in lowering wind driven erosion. Such fencing could also double as access prevention.

Heavy beach use can rapidly degrade coastal dune vegetation and diminish sand dunes. The provision of designated beach access ways is already in place throughout the City. As discussed above, dunes are critical natural barriers against coastal impact and are under increasing pressure. Protecting important dune systems with fencing, barriers and signage should be continued and improved wherever possible within the City.

4.4.2 Beach Nourishment (PR2)

Beach nourishment (or renourishment) involves the placement of sand on the upper beach profile to increase the sand buffer in front of the dunes and any assets or infrastructure behind (**Figure 4-2**). The City has already undertaken nourishment at Mettams Pool, sourcing the sand from an accretion area immediately south of Trigg Island, as well as donated sand from accumulation at Sorrento Beach within the City of Joondalup. This source may be sufficient for smaller nourishment programs, however, if the City expands its nourishment campaigns it may need to consider sources outside the City's jurisdiction, such as from Sorrento Beach (accretion point adjacent to Hillary's Boat Harbour), sand quarries, inland dunes and/or offshore dredging.

Once suitable beach nourishment sand has been placed on the beach, it should be naturally redistributed by coastal processes until the beach has reached an equilibrium profile. Subsequent storm events and calm periods will result in the natural cycle of storm bite and recovery, but the nourished beach buffer can generally be expected to reduce over time and is likely to require eventual renourishment.

Beach renourishment is considered a 'soft' *protection* option and does not guarantee protection of the dunes or assets/infrastructure located landward. During severe storm events or if multiple storm events occur in close succession, the renourished volume can be quickly eroded. For this reason, it is important to monitor areas where beach nourishment has been applied to assess ongoing risk to sensitive or important assets.

As beach nourishment generally enhances the natural beach, it maintains or improves beach amenity, which usually results in strong support from stakeholders and the community who value this. However, beach nourishment can become prohibitively expensive if very large volumes of sand are required or if it is required repetitively over a long period of time. The fact that nourishment sand is naturally redistributed by coastal processes and is eroded during storm events can lead to a perception among stakeholders and the community that beach nourishment is ineffective and a waste of money. It can also disrupt beach users and annoy the community if its application is required frequently. Poor community perception is also known to occur when the aesthetic quality of the nourishment sand does not meet their expectations or if they believe it is washing away too easily (waste of money).

There can be environmental risk associated with beach nourishment if contaminated or inappropriate grain size material is applied. Excessive fines can lead to plumes in the nearshore environment which can block sunlight and directly smother benthic habitats. Contaminated material may present a hazard to human health or sensitive environmental receptors.

There is risk associated with assessing (and committing to) nourishment options into the future, given uncertainty around availability of suitable source material. Further investigations are required to identify potential sources, the suitability and volume of material they hold and the cost of sourcing sand from them. This is discussed in further detail in Section 3.2.2 of the next chapter report – *Implementation* (Cardno, 2023d).



Figure 4-2 Beach renourishment occurring to protect assets at C Y O'Connor Beach, North Coogee

An estimated volume and cost (assuming cost of \$60/m³) of nourishment sand that would be required to maintain the present shoreline position, along each of the MUs, has been determined. The nourishment volumes over three timeframes, up to 2070 have been considered. The costs are in present day dollars and factor in a conservative estimate for the annual increase in the price of sand, due to its growing scarcity, of 2%. The costs of sourcing sand, transporting and placing it, as well as the locations that will require sand nourishment, will change from year to year.

The nourishment volumes are based on beach profile slopes and the future long-term shoreline recession rates (S2 – Historical erosion trend combined with S3 – Future erosion due to sea level rise) calculated as part of the coastal hazard assessment for this project (Cardno, 2023b). Effectively, the change in volume is calculated for the beach area of interest by multiplying the width of beach by its length. The vertical change over this area is incorporated by considering the landward beach shift, with respect to its slope/profile. This is acknowledged as a simplified method of calculating net sediment deficit, for the purpose of preliminary estimate and costing of nourishment requirements. Furthermore, as the hazard lines may be considered conservative (based on current available data), these volumes and calculated costs may be inflated above what will realistically be required. The costs are, however, comparable with costings for other adaptation options, which have also been based on hazard line extents.

Nourishment estimates for each of the MUs are provided in **Table 4-7** and **Table 4-8** respectively. It has been assumed that groynes or offshore breakwaters are expected to trap 80% of sand placed in their compartments, reducing the nourishment required if used in parallel with these hard protection options. Sand is a valuable commodity and sourcing high quality material that meets the technical specification, in the required quantity, is a potential challenge over the long term. The large volumes (and thus cost) of sand nourishment required to protect a large area over the medium to long term may be a significant constraint to the adoption of this *protection* option over a significant period of time.

Table 4-7 Indicative nourishment volumes for renourishment concept option

Management Unit	Present - 2030 (m ³)	2030 - 2045 (m ³)	2045 - 2070 (m ³)
MU1	660	1310	2630
MU2	1760	3520	7040
MU3	1140	2280	4560
MU4	880	1760	3530
MU5	4290	8580	17150
MU6	7200	14390	28780

Table 4-8 Indicative nourishment costs* for renourishment concept option

Management Unit	Present - 2030 (\$)	2030 - 2045 (\$)	2045 - 2070 (\$)
MU1	43,000	108,000	329,000
MU2	115,000	290,000	879,000
MU3	74,000	188,000	568,000
MU4	57,000	145,000	441,000
MU5	279,000	707,000	2,142,000
MU6	469,000	1,187,000	3,595,000

* Figures include cost escalation for the price of sand

4.4.3 Equity Implications for Soft Protection Options

The results of 'soft' *protection* options are generally seen as equitable, as they maintain or enhance beach amenity, while also providing temporary (and in some cases minor) protection to landward assets. The temporary nature of the options means that significant funds can be exhausted by their application. This has implications for equity (predominantly with beach nourishment), where significant

funds are being directed to the protection approach and diverted away from benefiting other areas of the City's community, without long-term benefit. Landholders located in current or future hazard areas are direct benefactors of any protection approach and should contribute to funding such measures accordingly.

Funding ongoing *protection* options, rather than *avoiding* or *retreating* from the hazards in these areas, could be seen as passing the problem on to future generations, given that these hazards are currently predicted to increase indefinitely. The approach may, however, assist in distributing the substantial 'up front' cost of options such as *managed retreat* over a longer time period.

4.5 Hard Protection Options

Hard protection options work to control and/or reconfigure the shoreline by placing significant hard infrastructure on the beach or in the nearshore zone. The options are considered to be interim protection measures as they will eventually require removal, replacement or refurbishment. Hard rock structures (granite or limestone) generally have a maximum design life of 50 years, which may be shortened depending on the extent of SLR in the area. Using hard protection to control long stretches of shoreline will be expensive and the cost to maintain the protection will become increasingly expensive with rising MSL into the future. As such, the options should be carefully considered for interim use, with the intent to eventually manage the retreat of protected assets and avoid the need to control the shoreline over the long term.

The level of hard protection has been based on recession rates associated with calculated hazard lines. As the hazard lines may be considered conservative (based on current available data), these costs may be inflated above what will realistically be required. The costs are, however, comparable with costings for other adaptation options, which have also been based on hazard line extents.

4.5.1 Overview of Structures

4.5.1.1 Groynes / Headland Enhancement (PR3)

Groynes are structures that extend from the rear of the beach and into the surf zone. They work by blocking the sediment that moves along the beach. This results in an increased beach width on the updrift side of the groyne with a similar amount of erosion on the downdrift side. Headland enhancement relies upon the same sediment trapping principals as groynes, however, the structure extends from a rock headland instead of the rear of the beach.

To counteract the downdrift erosion, multiple groynes (known as a groyne field) are often used. In a groyne field the sand between the groynes is stabilised, and the field is terminated in an area that either has a hard bottom or is allowed to erode. Beach nourishment is also typically undertaken at the time of construction to "fill" the beaches between the groynes.

At present the City does not have any groynes along its coastline, an example of a groyne field is shown below in **Figure 4-3**, which shows an aerial view of two groynes at Marmion Beach (approximately 1.5 km north of the City). Due to the presence of a persistent sea breeze cycle, the net longshore transport of sand along the City's coastline is northward. This would result in an increased beach width on the southern side of a groyne or headland enhancement, similar to that shown in **Figure 4-3**. It should be noted that longshore transport patterns along the City's coastline are seasonal, with occasional southward movement of sand during winter, and infrequently during summer attributed to the passage of ex-tropical cyclones.

The effectiveness of groynes is dependent on a number of factors including but not limited to local sediment dynamics, nearshore bathymetry, local wave climate and the geometry of the structure.

Depending on the local conditions, groynes can be constructed out of concrete, rock, timber or Geotextile Sand Containers (GSCs). Due to the City's relatively exposed nearshore wave climate, it is likely that rock groynes would be recommended.



Figure 4-3 Groynes at Marmion Beach, City of Joondalup. (source: Metromap, 2021)

4.5.1.2 Nearshore Reefs / Breakwaters (PR4)

Nearshore reefs or breakwaters are structures built offshore of the shoreline to disrupt and dissipate the incoming waves. Waves diffract behind the structure, which results in local realignments of the shoreline and alters the longshore and cross shore sediment transport patterns.

The result of the nearshore reefs or breakwaters is often the formation of either a tombolo (which is where the shoreline reorients and connects to the breakwater) or a salient (which is similar, but does not connect to the breakwater).

Figure 4-4 shows a visual example of an offshore breakwater at Kwinana Beach and changes to the alignment of the shoreline. In this example, a tombolo has formed, connecting the breakwater to the shore.

Similar to groynes, breakwaters can be constructed out of concrete, rock or GSCs, depending on the local conditions. Due to the City’s relatively exposed nearshore wave climate, it is likely that rock groynes would be recommended.



Figure 4-4 Offshore breakwater at Kwinana Beach, WA

4.5.1.3 Seawalls (PR5)

Seawalls are hard structures built on the beach, and act as a last line of defence against coastal erosion. Seawalls are very effective in limiting the extent of coastal erosion, however a drawback is that their presence often leads to accelerated loss of the beach in front of them (or additional nourishment required to maintain the beach).

The City has a GSC seawall running along Watermans Bay Beach, shown below in **Figure 4-5**. The seawall was built to defend infrastructure such as the public amenities and West Coast Drive. In 2020, the seawall was damaged in a winter storm requiring repairs later than year.



Figure 4-5 GSC seawall at Watermans Bay Beach

Seawalls have been considered in timeframes where there is high or very high vulnerability to coastal erosion. Their potential to degrade beach amenity is likely to lower their acceptability to the broader community. Any potential seawalls have been placed such that they would be considered a last line of defence, to minimise impacts to beach amenity at present. These could be designed as buried seawalls to minimise their impact on visual amenity. As MSL rises, these seawalls will have the increasing potential to exacerbate erosion of the beach in front of them and seawalls that are initially buried can easily become exposed.

4.5.2 Equity Implications for Hard Protection Options

'Hard' *protection* options have significant associated equity implications. Landholders located in current or future hazard areas are direct beneficiaries of any protection approach, and should contribute to funding such measures accordingly. Where hard protection works are the preferred option, a Benefit Distribution Analysis (BDA) is required to help apportion the capital and ongoing associated costs among beneficiaries. Groynes/headland enhancement and nearshore reefs/breakwaters are seen to generally maintain beach amenity for the broader community, although this may be degraded – visually and due to changes in shoreline shape. Seawalls protect landward assets but often lead to a loss of beach amenity, meaning the broader community who use the beach lose out.

Because protection structures interrupt and alter the local sediment transport regime, they have the potential to impact the shoreline in areas beyond their desired area of treatment. For example, groynes and marinas often lead to net accretion on one side ('upstream') and net erosion on the other side ('downstream'). These effects can continue for years and even decades after construction. It would not be seen as equitable if the protection of one area leads to negative impacts to another section of coastline that provides value to stakeholders. The potential for such impacts should be assessed if a protection option is to be selected. It would be reasonable to expect that the beneficiaries of the protection measure should be held responsible for any loss of coastal values elsewhere, directly attributable to the protection measure. This may require them to compensate for or remedy any negative impacts.

Funding interim *protection* options, rather than *avoiding* or *retreating* from the hazards in these areas, could be seen as passing the problem on to future generations, given that these hazards are predicted to increase indefinitely. This should be carefully considered because although the cost of protection may be less than that for managed retreat in the short-term, eventual *managed retreat* is likely to be required at some point in the future. Cost implications could be considerably greater at this point and significant funding will have been 'used up' in maintaining the interim protection measures.

4.5.3 Hard Protection Options for the City of Stirling

The MCA found that groynes / headland enhancement, nearshore reefs / breakwaters and seawalls all warrant further assessment for all MUs, excluding North Beach. Installation of hard protection options at North Beach is unlikely, due to the low value of assets it is not expected this section of the City's coastline will be the focus for funding. The key vulnerable assets to consider when assessing the effects of hard protection include:

- > Beaches including Watermans Bay, Mettams Pool, Bennion, Trigg and Scarborough;
- > West Coast Drive and associated shared use path;
- > Coastal dunes and their vegetation;
- > Beach access paths;
- > Carparks;
- > Surf Lifesaving Clubs;
- > The development at Scarborough Beach;

- > Commercial properties; and
- > Public Amenities.

4.5.3.1 Groynes / Headland Enhancement (PR3)

Appendix D includes a high-level concept map of how groynes and headland enhancement could be used to provide protection to assets along the City’s coastline. It should be noted that these structures almost always require coincident nourishment to “fill” the beach compartments they create. The concept map shows an indicative future shoreline which has been based on anticipated shoreline response, also assuming a coincident nourishment program.

An indicative cost for the groynes and headland enhancement as shown in the concept map is presented in **Table 4-9** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs). The costs have been separated into each MU and include an indicative estimate of the cost of nourishment (assumed \$60/m³ total cost) required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-9 Indicative costs for groyne / headland enhancement protection concept for each management unit

Section	Length of Groyne / Headland	Groyne / Headland Cost (total)	Maintenance Cost to 2070	Associated Renourishment Cost to 2070	Allowance for Design Work	Total MU Cost
MU1	92 m	\$4.6 m	\$1.1 m	\$124k	\$150k	\$6 m
MU3	113 m	\$5.7 m	\$1.4 m	\$214k	\$150k	\$7.4 m
MU4	95 m	\$4.8 m	\$1.1 m	\$166k	\$150k	\$6.2 m
MU5	160 m	\$4.8 m	\$1.2 m	\$808k	\$200k	\$7.0 m
MU6	315 m	\$9.5 m	\$2.3 m	\$1.4 m	\$400k	\$13.6 m

The optimum number of groynes, groyne lengths, groyne spacing, construction staging and coincident renourishment requirements for any groyne protection option along the City’s coastline will require a detailed engineering study, which should be undertaken if this option is favoured.

4.5.3.2 Nearshore Reef(s)/Breakwater(s) (PR4)

Appendix D includes a concept map of how nearshore reefs and breakwaters could be used to provide protection along the City’s coastline. It should be noted that both nearshore reefs and breakwaters usually require coincident renourishment to maintain shoreline position. The nearshore reefs / breakwaters shown in the concept map may be constructed independently, based on defined triggers being reached within each MU. The concept map shows an indicative future shoreline which has been based on anticipated shoreline response, also assuming a coincident nourishment program.

An indicative cost for the reefs / breakwaters as shown in the concept map is presented in **Table 4-10** below. Maintenance and nourishment costs to 2070 have been calculated assuming breakwaters are constructed in the present day. The costs are in present day dollars (they do not factor in inflation or escalation of costs). The costs have been separated into each MU and include an indicative estimate of the cost of nourishment (assumed \$60/m³ total cost) for each stage, required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-10 Indicative costs for two stage nearshore breakwater protection concept for Sector 2A

Section	Length of Reef / Breakwater	Reef / Breakwater Cost (total)	Maintenance Cost to 2070	Associated Renourishment Cost to 2070	Allowance for Design Work Required	Total MU Cost
MU1	264 m	\$1.3 m	\$317k	\$124k	\$200k	\$2 m
MU3	530 m	\$2.7 m	\$636k	\$214k	\$400k	\$3.9 m
MU4	335 m	\$1.7 m	\$402k	\$166k	\$250k	\$2.5 m
MU5	180 m	\$10.8 m	\$2.6 m	\$808k	\$150k	\$14.4 m
MU6	510 m	\$30.6 m	\$7.3 m	\$1.4 m	\$400k	\$39.7 m

The optimum nearshore reef/breakwater size, spacing and coincident nourishment requirements for any breakwater protection option require a detailed coastal processes and engineering study, which should be undertaken if this option is favoured for further assessment. Nearshore reef(s)/breakwaters do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

4.5.3.3 Seawall(s) (PR5)

Appendix D includes a concept map of how seawalls could be used to provide protection along the City’s coastline. It was assumed that all seawalls would be constructed as a ‘last line of defence’, where they remain buried most of the time except during extreme events and, therefore, no nourishment is considered. The seawalls shown in the concept map would likely be constructed in separate sections, independent of each other, based on defined triggers being reached. The staging of seawall construction should generally reflect the timing with which assets and areas arrive at intolerable risk levels. At Scarborough Beach for example, the southern half of the seawall protecting the amphitheatre, Scarboro SLC and Scarborough Pool, would likely be constructed first, and at a later timeframe, the northern portion of the seawall protecting the skatepark, playground and carparking would be constructed as the area moves to a higher risk level.

An indicative cost in present day dollars for the seawalls for each MU, as shown in the concept map, is presented in **Table 4-11** below. Maintenance costs to 2070 have been calculated assuming the seawalls have been constructed in the present day.

Table 4-11 Indicative costs for seawall protection concept for applicable management units

Management Unit	Total Length of Seawall	Seawall Cost	Maintenance Cost to 2070	Allowance for Design Work Required	Total MU Cost
MU1	196 m	\$735 k	\$176k	\$100k	\$1 m
MU3	606 m	\$2.3 m	\$545k	\$200k	\$3 m
MU4	170 m	\$638 k	\$153k	\$100k	\$891k
MU5	279 m	\$1.4 m	\$335k	\$150k	\$1.9 m
MU6	870 m	\$4.4 m	\$1 m	\$250k	\$5.7 m

The optimum seawall layout, cross-section and construction staging for any seawall protection option requires a detailed engineering study, which should be undertaken if this option is favoured. It must be noted that seawalls are effective in providing a physical barrier to continuing shoreline recession, however the presence of such structures interferes with local sediment transport processes, by separating the active beach from sediment reserves stored in the dune system. As a result of the deficit of sediment supply, turbulence at the toe of these structures during storm events typically leads to a gradual lowering of the beach. Wave reflection from such structures built within the active beach has also been reported to contribute to scouring. This makes it more expensive or unfeasible to maintain a useable beach in the area.

5 Cost Benefit Analysis

5.1 Options

A CBA was undertaken to inform selection of preferred risk treatment options for each management option that was recommended by the MCA as warranting further assessment. The costs and benefits of risk treatments have been forecast over their expected lifetimes. Costs were subtracted from benefits to determine the Net Present Economic Value (NPEV) of each option. NPEV is a measure which allows a simple comparison of the net benefit to society of risk treatment options. It is important to note that this refers to economic benefit only, and this does not always reflect societal acceptance of options.

For a detailed description of CBA inputs, methodology and sensitivity testing see **Appendix D**.

Table 5-1 lists the five options modelled in the CBA analysis, which includes Option 0, a base case used to determine the NPEV of Options 1-4. The base case assumes a managed retreat strategy, in response to SLR, as detailed in **Section 4.2**.

Table 5-1 Adaption options

Adaption option	Description	Assumed impact
Option 0: Managed retreat	<ul style="list-style-type: none"> Assets currently in or soon to be in the hazard zone are to be relocated 	<ul style="list-style-type: none"> Foreshore reserve maintained Built assets relocated
Option 1: Protection – Beach Nourishment	<ul style="list-style-type: none"> Beach nourishment to maintain the present location of the shoreline, effectively negating the erosive effects of SLR (S2 & S3) 	<ul style="list-style-type: none"> No loss of built and natural coastal assets at applicable MUs
Option 2: Protection – Groynes / headland enhancement and Nourishment	<ul style="list-style-type: none"> Construction of groynes / headland enhancements in applicable MUs as shown in concept maps (Appendix D) Maintenance of structures maintained throughout Beach nourishment to maintain the present location of the shoreline (nourishment volumes reduced due to groynes / headland enhancement, see Section 4.4.2) 	<ul style="list-style-type: none"> No loss of built and natural coastal assets within applicable MUs
Option 3: Protection – Nearshore reef / Breakwater and Nourishment	<ul style="list-style-type: none"> Construction of nearshore reefs / breakwaters in applicable MUs as shown in concept maps (Appendix D) Beach nourishment to maintain the present location of the shoreline (nourishment volumes reduced due to offshore breakwaters, see Section 4.4.2) 	<ul style="list-style-type: none"> No loss of built and natural coastal assets within applicable MUs
Option 4: Protection – Seawall	<ul style="list-style-type: none"> Construction of seawalls in applicable MUs as shown in concept maps (Appendix D) 	<ul style="list-style-type: none"> No loss of built assets landside of seawall Loss of natural assets seaside of seawall (e.g. sandy beach) Loss of environmental and social values Potential erosion impacts either side of seawall.

5.2 Benefits and Costs

Table 5-2 lists the benefits and costs of each option. Benefits include positive benefits, which are avoided losses and include ‘negative benefits’ which are the current values that are lost over time. Costs reflect the financial cost to the City of implementing the option.

Table 5-2 Benefits and costs

Adaption option	Benefits / Negative benefits	Costs
Option 0: Managed retreat	<ul style="list-style-type: none"> • No loss of beach as the coastline retreats • Loss of dune systems • No loss of facilities value • No loss of asset value (taken as replacement value) 	<ul style="list-style-type: none"> • Demolishing infrastructure • Replacing infrastructure • Reinstatement of natural environment (e.g. revegetation)
Option 1 - 3: Protection (Groynes / Headland Enhancement, Nearshore Reefs / Breakwaters & Nourishment)	<ul style="list-style-type: none"> • No loss of beach as the coastline retreats • No loss of dune systems • No loss of facilities value • No loss asset value (taken as replacement value) 	<ul style="list-style-type: none"> • Structure construction / maintenance • Beach nourishment
Option 4: Protection – Seawall	<ul style="list-style-type: none"> • Loss of beach in front of seawall and either side • No loss of dune systems • No loss of facilities value • No loss asset value (taken as replacement value) 	<ul style="list-style-type: none"> • Seawall construction / maintenance

5.3 Results

The CBA was undertaken for all options listed in **Table 5-1**, which output the net benefits to society for each option shown in **Figure 5-1** to **Figure 5-5**. Beach nourishment provides the greatest net benefit due to maintaining all values, both natural and built, along the City’s coastline with minimal upfront capital costs. This option is expected to become less economically viable over time as the rate of SLR increases, in the short term however, it is a highly cost-effective solution. The economic viability of beach nourishment is also dependent on the nourishment’s efficacy and longevity, which is likely to be greatest along sections of coastline where nourished material is contained between natural headlands or coastal controls. Consideration should also be given to the presence of nearshore reef platforms, which could restrict sediment from being transported back onshore following a storm event. Thus, impeding the recovery of the beach from natural on-shore sediment transport processes. Note for MU2 (North Beach) beach nourishment was the only option tested, returning a NPEV of \$15,730,00.

In the short to medium term, the CBA shows protective options also to be economically viable. North of Trigg Point (MUs 1,3 and 4), nearshore reefs are shown to provide positive economic benefit. At Trigg Beach North, implementation of a seawall provides similar benefit to a reef option. This is due to the small surface area of sandy beach in the MU and subsequent lower economic valuation of natural assets that will be lost with the implementation of a seawall. It is again reiterated that economic value is not always fully representative of societal acceptance.

South of Trigg Point, groynes are shown to give the greatest economic benefit of the protective management options, achieving an NPEV closer to that of beach nourishment. This is due to the high upfront construction cost of the groynes being offset by lower continuing nourishment volumes. This

option is set to become increasingly viable in the future as the rate of SLR and cost of sand both increase.

Managed retreat of the City’s coastline provides a negative economic benefit. Whilst currently not the most cost-effective option, in the long term, as the cost of protecting the City’s coastline becomes prohibitively high, managed retreat will likely become the most economically viable option.

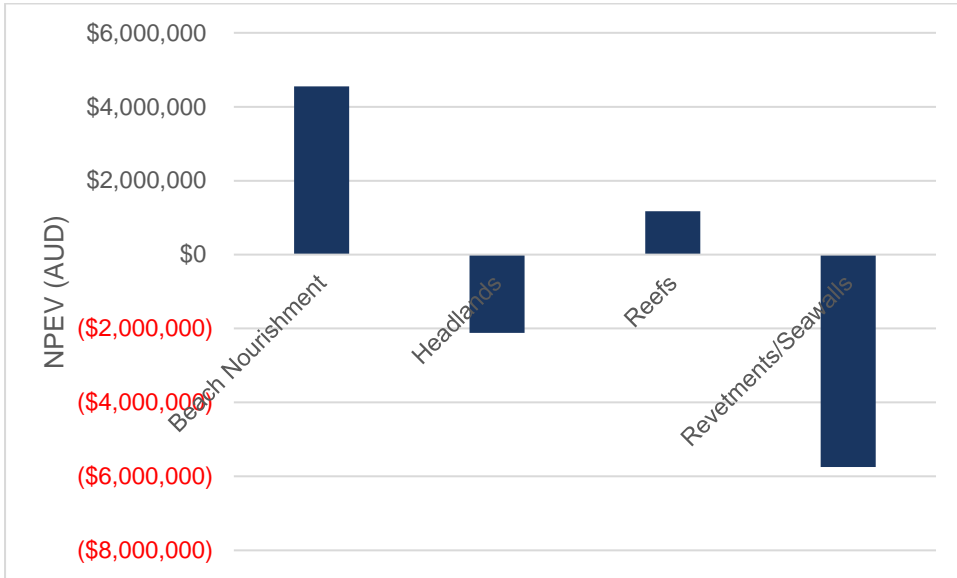


Figure 5-1 Net benefits of tested options at Watermans Bay

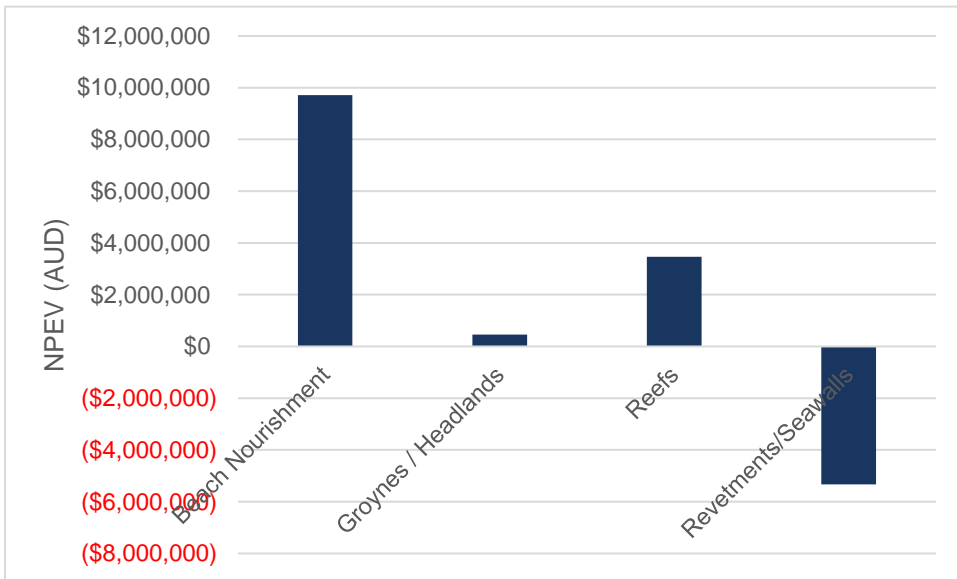


Figure 5-2 Net benefits of tested options at Mettams Pool

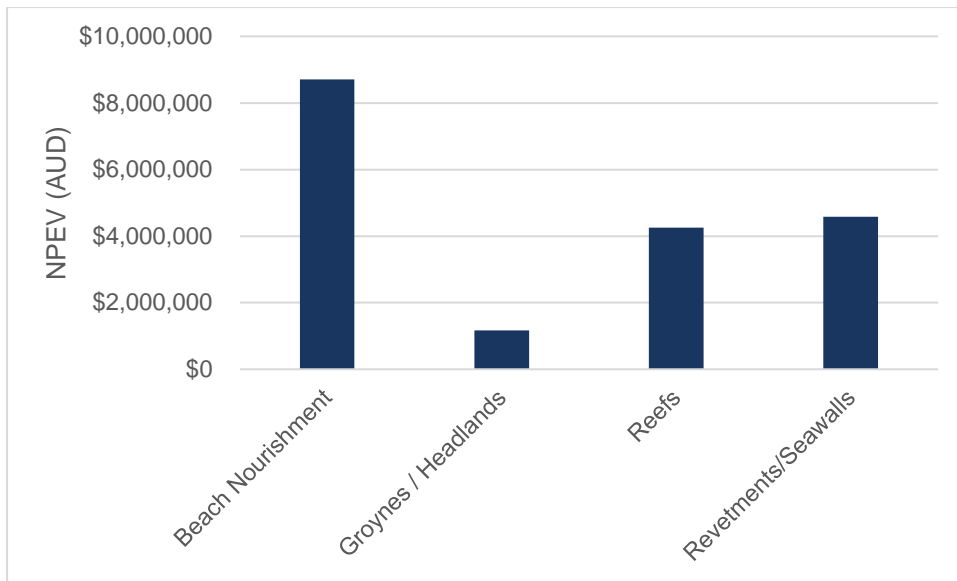


Figure 5-3 Net benefits of tested options at Trigg Beach North

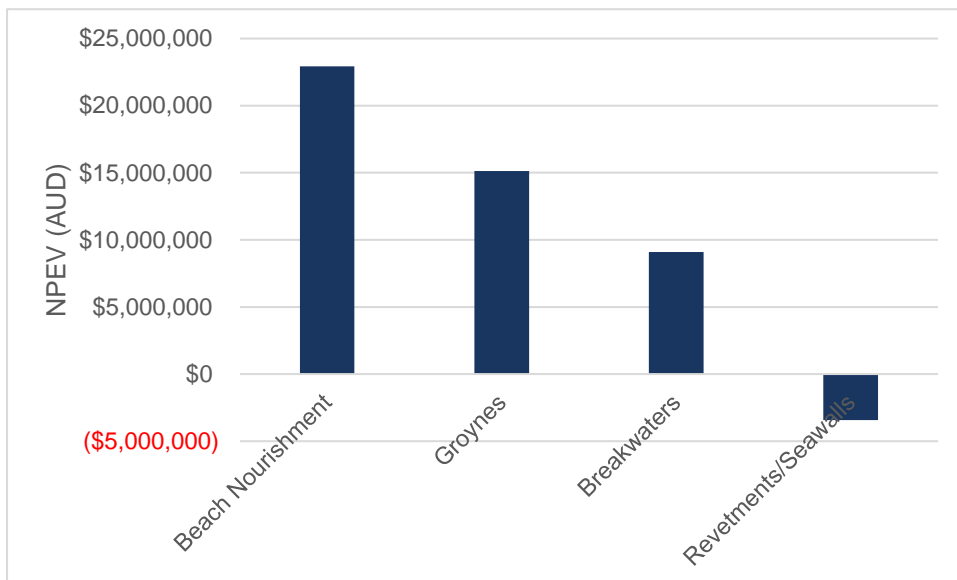


Figure 5-4 Net benefits of tested options at Trigg Beach South

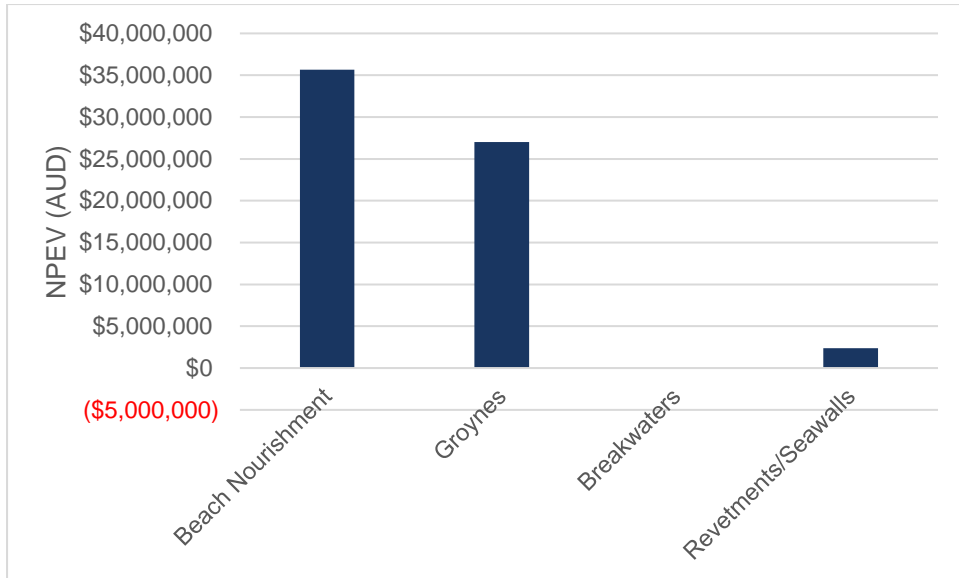


Figure 5-5 Net benefits of tested options at Scarborough Beach

6 Adaption Pathways

6.1 Management Triggers

Management triggers have been developed so that management and adaptation actions respond to actual future climate change conditions and ongoing risk levels, rather than forecasts that may not be realised (i.e. unnecessary expenditure). Triggers are in place to initiate both management action and preparation for such action. Triggers are generally associated with the measurement of risk. Specifically, when intolerable risk is encountered. **Table 6-1** tabulates the following:

- > Triggers applicable to the City's assets;
- > Methods of assessment available to determine when a trigger threshold has been met; and
- > Potential responses. As the majority of triggers are several years away from being met, potential responses are high level and require further refinement at the time of implementation.

Table 6-1 Management Triggers

Trigger ID	Description	Method(s) of assessment	Example response(s)
T1	The HSD is within the S1 distance of an asset's most seaward extent.	<ul style="list-style-type: none"> – Ongoing shoreline monitoring (survey profiles) to determine location of HSD. – S1 defined by modelling, with data collected during shoreline and storm monitoring used to validate/refine the S1 value. 	<ul style="list-style-type: none"> – Remove major infrastructure (roads, carparks), residential and commercial buildings, and transfer land to the public realm. – Provide interim protection for major infrastructure (roads, carparks), residential and commercial buildings. – Prepare response plans for minor infrastructure that could be impacted.
T2	A public road is no longer available or able to provide legal access to a property.	<ul style="list-style-type: none"> – Liaison with/notification by relevant State Government departments. 	<ul style="list-style-type: none"> – Remove residential and commercial buildings and transfer land to public realm.
T3	Water, sewerage or electricity to a lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.	<ul style="list-style-type: none"> – Engagement with service providers including education of CHRMAP outcomes. 	<ul style="list-style-type: none"> – Remove asset and relocate to less hazardous area if possible/appropriate.
T4	Residential, commercial or public property lies within the extent of the most up to date 100-year coastal erosion hazard extent.	<ul style="list-style-type: none"> – Definition of hazard extents through this CHRMAP. – CHRMAP and hazard extent updates due to the availability of more relevant/recent information (such as updated SLR predictions) and changes in environmental conditions (such as changes to MSL). 	<ul style="list-style-type: none"> – Include all affected land zoned 'Urban' in a SCA and ensure the hazard information is incorporated in structure planning. – Provide notification of potential hazards on certificates of title where possible and by direct contact with affected landholders.
T5	An asset is damaged, destroyed or becomes unsafe due to coastal erosion.	<ul style="list-style-type: none"> – Inspection of coastal assets following storm events or during times of increased longshore erosion (e.g. by works staff, Rangers). – Remote coastal monitoring cameras. – Notification by the public. 	<ul style="list-style-type: none"> – Remove asset and relocate to less hazardous area if possible/appropriate.
T6	Assets are predicted to move to high or extreme risk within the next planning timeframe.	<ul style="list-style-type: none"> – Definition of hazard extents through the CHRMAP. 	<ul style="list-style-type: none"> – Undertake detailed cost-benefit analysis and assessment of community acceptance of interim protection vs managed retreat of the affected assets.

Trigger ID	Description	Method(s) of assessment	Example response(s)
		<ul style="list-style-type: none"> - CHRMAP and hazard extent updates due to the availability of more relevant/recent information (such as updated SLR predictions) and changes in environmental conditions (such as changes to MSL). 	<ul style="list-style-type: none"> - Identify sources and begin to allocate funding for management.
T7	The overall community and stakeholders are no longer supportive of a specific coastal management technique or approach.	<ul style="list-style-type: none"> - Ongoing community engagement. 	<ul style="list-style-type: none"> - Investigate, identify and implement a change in the adaption pathway.
T8	A specific coastal management technique is forecast to no longer be economically or physically feasible within 10 years.	<ul style="list-style-type: none"> - Ongoing shoreline and coastal asset monitoring. - Budget expenditure and forecasts. 	<ul style="list-style-type: none"> - Investigate, identify and implement a change in the adaption pathway
T9	The beach and coastal foreshore reserve is significantly diminished with respect to its original state and function.	<ul style="list-style-type: none"> - Long-term coastal monitoring program. - Assessment of aerial imagery. - Feedback through ongoing community consultation. 	<ul style="list-style-type: none"> - Investigate, identify and implement a change in the adaption pathway.
T10	Localised erosion of beach and dune systems.	<ul style="list-style-type: none"> - Ongoing shoreline monitoring program. - Community engagement. - Aerial imagery. 	<ul style="list-style-type: none"> - Soft protection measures such as wind/sand fencing and revegetation of dunes.
T11	Community support for current shoreline position to be maintained.	<ul style="list-style-type: none"> - Ongoing community engagement. 	<ul style="list-style-type: none"> - Implementation of new, or strengthening of existing, coastal controls.
T12	Undeveloped land is identified as lying within the hazard extents.	<ul style="list-style-type: none"> - Definition of hazard extents through this CHRMAP. - CHRMAP and hazard extent updates due to the availability of more relevant/recent information (such as updated SLR predictions) and changes in environmental conditions (such as changes to MSL). 	<ul style="list-style-type: none"> - Implement planning controls to avoid inappropriate development of the land.

6.2 Pathways

Adaptation pathways have been established to guide the City's management activities/approach, so that tolerable risk levels for assets are maintained across planning timeframes. It is important to reiterate that several assumptions have been used to approximate risk levels at each timeframe. The levels of (intolerable) risk may be arrived at sooner or later than predicted. Because of this, adaptation should be in response to the associated trigger(s) being reached, rather than the timeframe-based predictions. This approach prevents unnecessary expense on adaptation prior to risk being present, as well as triggering a response if risk levels become intolerable sooner than anticipated.

Separate pathways are provided for each MU. Pathways include preferred management/adaptation options, triggers for management action and indications of timeframes where they are likely to be required. Further discussion of pathways for each asset category is provided in the sub-sections below.

6.2.1 MU1 – Watermans Bay

The general approaches recommended to adapt to the risk of coastal erosion at Watermans Bay include:

- > Avoiding further permanent development on land which has been identified as prone to erosion over the next 100 years;
- > Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure, until such time that risk levels require transition to a managed retreat pathway;
- > Protecting infrastructure at Watermans Bay in the short term, through beach nourishment and potentially through the construction of coastal engineering protection in the short to medium term (subject to more detailed assessment); and
- > Planning for the eventual managed retreat of existing assets in the foreshore reserve as risk becomes intolerable.

Identified as a coastal erosion hotspot, Watermans Bay has a number of built assets which move to a 'high' risk of being impacted by coastal erosion by 2070. Community engagement surveys and drop-in sessions have shown stakeholders to be in favour of protecting assets, particularly natural assets, at Watermans Bay in the short term.

Beach nourishment, headland enhancement, nearshore reef enhancement and seawalls were recommended by the MCA analysis as protective physical controls warranting further assessment. The CBA found beach nourishment to be the most cost-effective protective control in early planning timeframes due to minimal upfront capital costs and maintaining all existing infrastructure value. It is recommended that nourishment be undertaken in the short term to maintain the position of the present-day shoreline at Watermans Bay and protect built assets.

In the medium term, nourishment volumes required to maintain the position of the shoreline will increase with the rate of SLR and the cost of suitable nourishment sand is expected to increase due to pressure on its supply, particularly within the Perth Metropolitan Area. This will lower the comparative cost of options like nearshore reef enhancement, which should lower nourishment volumes to maintain the shoreline, dampening the economic effect of increasing cost and volumes of sand. Prolonged beach nourishment may also start to fall out of favour with the public due to the perception that money is being 'washed away', increasing public desire for a more permanent solution. When nourishment is no longer economically or socially viable, it is recommended that coastal protection structures, such as nearshore reef enhancement, be investigated in detail and, if suitable, implemented in combination with a reduced nourishment program to protect assets at Watermans Bay and maintain the existing beach and shoreline.

In the long term, as risk levels increase, assets age and/or as economic or public support for the protection of assets is withdrawn, managed retreat of the City's assets at Watermans Bay is recommended. Assets are removed and relocated behind erosion extents. This adaption pathway is in keeping with the State Coastal Planning Policy's preferred pathway (managed retreat) for developed land. Implementation of planning

instruments to ready the City for this transition should begin in the short term, discussed in further detail in **Section 7.2**.

Implementation of planning controls will allow infrastructure to be maintained seaside of 2122 hazard lines, effectively accommodating current risk. This is recommended only for assets with community demand, built to withstand coastal hazards or with design lives less than or equal to the timeframe they are impacted by coastal hazard lines.

Recommended adaption pathways for Watermans Bay are displayed in **Table 6-2**. Trigger descriptions have been simplified for clarity, for full descriptions please refer back to **Table 6-1**.

6.2.2 MU2 – North Beach

The general approaches recommended to adapt to the risk of coastal erosion at North Beach include:

- > Avoiding further permanent development on land which has been identified as prone to erosion over the next 100 years;
- > Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure until such time that risk levels require transition to a managed retreat pathway;
- > Protecting infrastructure at North Beach in the short term, through beach nourishment; and
- > Planning for the eventual managed retreat of assets at North Beach.

Sections of West Coast Drive and North Beach Jetty move to a ‘high’ risk of being impacted by coastal erosion by 2070. Community engagement surveys and drop-in sessions have shown stakeholders to be in favour of protecting assets, particularly natural, at North Beach in the short term.

The CBA found beach nourishment to be a cost-effective protective control in the short to medium term. At present, the City does not nourish within this MU, however this may become increasingly necessary to maintain the present-day shoreline position as SLR increases.

In the medium to long term, as risk levels increase, assets age, and/or as economic or public support for the protection of assets is withdrawn, managed retreat of North Beach is recommended. Under a managed retreat pathway assets are removed and relocated behind erosion extents. This adaption pathway is in keeping with the State Coastal Planning Policy’s preferred pathway (managed retreat) for developed land. Implementation of planning instruments to ready the City for this transition should begin in the short term, discussed in further detail in **Section 7.2**.

Implementation of planning controls will allow infrastructure to be maintained seaside of 2122 hazard lines, effectively accommodating current risk. This is recommended only for assets with community demand, built to withstand coastal hazards or with design lives less than or equal to the timeframe they are impacted by coastal hazard lines.

Recommended adaption pathways for North Beach are displayed in **Table 6-3**. Trigger descriptions have been simplified for clarity, for full descriptions please refer back to **Table 6-1**.

6.2.3 MU3 – Mettams Pool

The general approaches recommended to adapt to the risk of coastal erosion at Mettams Pool include:

- > Avoiding further permanent development on land which has been identified as prone to erosion over the next 100 years;
- > Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure, until such time that risk levels require transition to a managed retreat pathway;
- > Protecting infrastructure at Mettams Pool in the short term, through beach nourishment in the short term and potentially through the construction of coastal engineering protection in the short to medium term (subject to more detailed assessment); and
- > Planning for the eventual managed retreat of existing assets in the foreshore reserve as risk becomes intolerable.

Identified as a coastal erosion hotspot, Mettams Pool Beach itself is already at ‘high’ risk of being impacted by coastal erosion with parking areas (2030) and public toilets (2045) also moving to a ‘high’ risk level in the short to medium term. Community engagement surveys and drop-in sessions have shown stakeholders to be in favour of protecting assets at Mettams Pool in the short term, with particular focus on protecting natural assets and change room facilities.

Beach nourishment, headland enhancement, nearshore reef enhancement and seawalls were recommended by the MCA analysis as protective physical controls warranting further assessment. The CBA found beach nourishment to be the most cost-effective protective control in early planning timeframes due to minimal upfront capital costs and maintaining all existing infrastructure value. Beach nourishment has already been undertaken at Mettams Pool and it is recommended that this be continued in the short term to maintain the position of the present-day shoreline at Mettams Pool and protect built assets.

In the medium term, nourishment volumes required to maintain the position of the shoreline will increase with the rate of SLR and the cost of suitable nourishment sand is expected to increase due to pressure on its supply, particularly within the Perth Metropolitan Area. This will lower the comparative cost of coastal engineering protection, which should lower nourishment volumes required to maintain the shoreline, dampening the economic effect of increasing cost and volumes of sand. Prolonged beach nourishment may also start to fall out of favour with the public due to the perception that money is being ‘washed away’, increasing public desire for a more permanent solution. When nourishment is no longer economically or socially viable, it is recommended that coastal protection options, such as nearshore reef enhancement, be investigated and, if appropriate, implemented in combination with a reduced nourishment program to protect assets at Mettams Pool and maintain the existing beach and shoreline.

In the long term, as risk levels increase, assets age and/or as economic or public support for the protection of assets is withdrawn, managed retreat of the City’s assets at Mettams Pool is recommended. Assets are removed and relocated behind erosion extents. This adaption pathway is in keeping with the State Coastal Planning Policy’s preferred pathway for developed land (managed retreat). Implementation of planning instruments to ready the City for this transition should begin in the short term, discussed in further detail in **Section 7.2**.

Implementation of planning controls will allow infrastructure to be maintained seaside of 2122 hazard lines, effectively accommodating current risk. This is recommended only for assets with community demand, built to withstand coastal hazards or with design lives less than or equal to the timeframe they are impacted by coastal hazard lines.

Recommended adaption pathways for Mettams Pool are displayed in **Table 6-4**. Trigger descriptions have been simplified for clarity, for full descriptions please refer back to **Table 6-1**.

6.2.4 MU4 – Trigg Beach North

The general approaches recommended to adapt to the risk of coastal erosion at Trigg Beach North include:

- > Avoiding further permanent development on land which has been identified as prone to erosion over the next 100 years;
- > Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure, until such time that risk levels require transition to a managed retreat pathway;
- > Protecting infrastructure at Trigg Beach North in the short term, through beach nourishment and potentially through the construction of coastal engineering protection in the short to medium term (subject to more detailed assessment); and
- > Planning for the eventual managed retreat of existing assets in the foreshore reserve as risk becomes intolerable.

Benion Beach and Trigg Beach North move to a ‘high’ risk of being impacted by coastal erosion by 2030 and built assets such as West Coast Drive and carparks move to ‘high’ risk by 2070. Community engagement surveys and drop-in sessions have shown stakeholders want to retain assets such as the surf club, parking

and shared use path at Trigg Beach North, but are also understanding of a managed retreat strategy in the medium to long term.

Beach nourishment, headland enhancement, nearshore reef enhancement and seawalls were recommended by the MCA analysis as protective physical controls warranting further assessment. The CBA found beach nourishment to be the most cost-effective protective control in early planning timeframes due to minimal upfront capital costs and maintaining all existing infrastructure value. It is recommended that nourishment be undertaken in the short term to maintain the position of the present-day shoreline at Trigg Beach North and protect built assets.

In the medium term, nourishment volumes required to maintain the position of the shoreline will increase with the rate of SLR and the cost of suitable nourishment sand is expected to increase due to pressure on its supply, particularly within the Perth Metropolitan Area. This will lower the comparative cost of coastal protection structures, which should lower required nourishment volumes to maintain the shoreline, dampening the economic effect of increasing cost and volumes of sand. Prolonged beach nourishment may also start to fall out of favour with the public due to the perception that money is being ‘washed away’, increasing public desire for a more permanent solution. When nourishment is no longer economically or socially viable, it is recommended that coastal protection options, such as nearshore reef enhancement, be implemented in combination with a reduced nourishment program to protect assets at Trigg Beach North and maintain the present-day shoreline.

In the long term, as risk levels increase, assets age, and/or as economic or public support for the protection of assets is withdrawn, managed retreat of the City’s assets at Trigg Beach North is recommended. Assets are removed and relocated behind erosion extents. This adaption pathway is in keeping with the State Coastal Planning Policy’s preferred pathway (managed retreat) for developed land. Implementation of planning instruments to ready the City for this transition should begin in the short term, discussed in further detail in **Section 7.2**.

Implementation of planning controls will allow infrastructure to be maintained seaside of 2122 hazard lines, effectively accommodating current risk. This is recommended only for assets with community demand, built to withstand coastal hazards or with design lives less than or equal to the timeframe they are impacted by coastal hazard lines.

Recommended adaption pathways for Trigg Beach North are displayed in **Table 6-5**. Trigger descriptions have been simplified for clarity, for full descriptions please refer back to **Table 6-1**.

6.2.5 MU5 – Trigg Beach South

The general approaches recommended to adapt to the risk of coastal erosion at Trigg Beach South include:

- > Avoiding further permanent development on land which has been identified as prone to erosion over the next 100 years;
- > Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure, until such time that risk levels require transition to a managed retreat pathway;
- > Protecting infrastructure at Trigg Beach South in the short term, if necessary, through beach nourishment and potentially through the construction of coastal engineering protection in the short to medium term (subject to more detailed assessment); and
- > Planning for the eventual managed retreat of existing assets in the foreshore reserve as risk becomes intolerable.

Trigg Beach and Trigg Beach South move to a ‘high’ risk of being impacted by coastal erosion by 2030 and extreme by 2070. Assets just south of Trigg Point such as the carpark, surf lookout and beach café move to a ‘high’ risk by 2070. Natural dune systems provide a buffer for much of the southern portion of the MU with built assets in this area only moving to a ‘high’ rating in the 2022 timeframe. Community engagement surveys and drop-in sessions have shown stakeholders want to protect natural assets and retain built assets such as parking, but are also understanding of a managed retreat strategy in the medium to long term.

Beach nourishment, headland enhancement, nearshore reef enhancement and seawalls were recommended by the MCA analysis as protective physical controls warranting further assessment. The CBA found beach nourishment to be the most cost-effective protective control in early planning timeframes due to minimal upfront capital costs and maintaining all existing infrastructure value. It should also be noted, the CBA assumes an 'overflow' factor to account for the proportion of nourishment that is not retained by the beach. The sandy, exposed environment in the south of the MU is not conducive for trapping placed sand, and the true 'overflow' factor is extremely difficult to estimate. Therefore, it is only recommended that nourishment be undertaken as an interim solution to maintain the position of the present-day shoreline at Trigg South and protect built assets.

In the short to medium term, as the shoreline retreats and/or nourishment volumes required to maintain the position of the shoreline are proven to be substantially higher than predicted, it is expected that coastal protection structures, which require much lower nourishment volumes to maintain the shoreline, will become comparatively cheaper than nourishment alone. It is recommended that coastal protection structures, such as groynes or nearshore reefs/breakwaters, be investigated further and, if appropriate, implemented in combination with a reduced nourishment program to protect assets at Trigg South and maintain the existing beach and shoreline.

In the long term, as risk levels increase, or as economic or public support for the protection of assets is withdrawn, managed retreat of the City's assets at Trigg South is recommended. Assets are removed and relocated behind erosion extents. This adaption pathway is in keeping with the State Coastal Planning Policy's preferred pathway for developed land (managed retreat). Implementation of planning instruments to ready the City for this transition should begin in the short term, discussed in further detail in **Section 7.2**.

Implementation of planning controls will allow infrastructure to be maintained seaside of 2122 hazard lines, effectively accommodating current risk. This is recommended only for assets with community demand, built to withstand coastal hazards or with design lives less than or equal to the timeframe they are impacted by coastal hazard lines.

Recommended adaption pathways for Trigg Beach South are displayed in **Table 6-6**. Trigger descriptions have been simplified for clarity, for full descriptions please refer back to **Table 6-1**.

6.2.6 MU6 – Scarborough Beach

The general approaches recommended to adapt to the risk of coastal erosion at Scarborough Beach include:

- > Avoiding further permanent development on land which has been identified as prone to erosion over the next 100 years;
- > Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure, until such time that risk levels require transition to a managed retreat pathway;
- > Protecting infrastructure at Scarborough Beach in the short term, if necessary, through beach nourishment and potentially through the construction of coastal engineering protection in the short to medium term (subject to more detailed assessment); and
- > Planning for the eventual managed retreat of existing assets in the foreshore reserve as risk becomes intolerable.

Scarborough, Brighton and Peasholm Beach move to a 'high' risk of being impacted by coastal erosion by 2030 and extreme by 2070. Built assets such as Scarboro SLC and Scarborough Amphitheatre are at medium risk at present, with most built assets in the MU moving to 'high' risk by 2070. Community engagement surveys and drop-in sessions have shown stakeholders to be in favour of protecting assets at Scarborough Beach in the short term. Feedback also showed understanding that assets such as the surf lifesaving club will eventually need to retreat.

Beach nourishment, headland enhancement, nearshore reef enhancement and seawalls were recommended by the MCA analysis as protective physical controls warranting further assessment. The CBA found beach nourishment to be the most cost-effective protective control in early planning timeframes due to minimal upfront capital costs and maintaining all existing infrastructure value. It should also be noted, the CBA assumes an 'overflow' factor to account for the proportion of nourishment that is not retained by the beach. The sandy,

exposed environment at Scarborough Beach is not conducive for trapping placed sand, and the true 'overfill' factor is extremely difficult to estimate. Therefore, it is only recommended that nourishment be undertaken as an interim solution to maintain the position of the present-day shoreline at Scarborough Beach and protect built assets.

In the short to medium term, as the shoreline retreats and/or nourishment volumes required to maintain the position of the shoreline are proven to be substantially higher than predicted, it is expected that groynes, which require much lower nourishment volumes to maintain the shoreline, will become comparatively cheaper than nourishment. At this stage it is recommended that coastal protection options be investigated and, if appropriate, be implemented in combination with a reduced nourishment program to protect assets at Scarborough Beach and maintain the existing beach and shoreline.

In the long term, as risk levels increase, or as economic or public support for the protection of assets is withdrawn, managed retreat of the City's assets at Scarborough is recommended. Assets are removed and relocated behind erosion extents, for commercial property this may require voluntary or compulsory acquisition of land. This adaption pathway is in keeping with the State Coastal Planning Policy's preferred pathway for developed land (managed retreat). Implementation of planning instruments to ready the City for this transition should begin in the short term, discussed in further detail in **Section 7.2**.

Implementation of planning controls will allow infrastructure to be maintained seaside of 2122 hazard lines, effectively accommodating current risk. This is recommended only for assets with community demand, built to withstand coastal hazards or with design lives less than or equal to the timeframe they are impacted by coastal hazard lines.

Recommended adaption pathways for Scarborough Beach are displayed in **Table 6-7**. Trigger descriptions have been simplified for clarity, for full descriptions please refer back to **Table 6-1**.

Table 6-2 Adaptation pathway for MU1 – Watermans Bay Beach

Planning Timeframe	2025 -2030	2030 -2045	2045 - 2070	2070 - future
Assets	Undeveloped land			
Pathway	<i>Avoid (AV)</i>			
Trigger(s)	T12: Undeveloped land lying within the hazard extent.			
Assets	Developed land			
Pathway	<i>Planned / Managed Retreat (PMR3)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Accommodate (AC1)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Soft Protect (PR2)</i>	<i>Protect (TBC) and (PR2)</i>		<i>Planned / Managed Retreat (PMR2)</i>
Trigger(s)	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe.	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible.		T2: Access to property lost. T3: Services to asset decommissioned. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible. T9: The beach / coastal foreshore reserve is significantly diminished.
Assets	Beach and Dunes			
Pathway	<i>Soft Protect (PR1)</i>			
Trigger(s)	T10: Localised erosion of beach and dune systems.			

Table 6-3 Adaptation pathway for MU2 – North Beach

Planning Timeframe	2025 -2030	2030 -2045	2045 - 2070	2070 - future
Assets	Undeveloped land			
Pathway	<i>Avoid (AV)</i>			
Trigger(s)	T12: Undeveloped land lying within the hazard extent.			
Assets	Developed land			
Pathway	<i>Planned / Managed Retreat (PMR3)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Accommodate (AC1)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Soft Protect (PR2)</i>		<i>Planned / Managed Retreat (PMR2)</i>	
Trigger(s)	T11: Community support for current shoreline position to be maintained.		T2: Access to property lost. T3: Services to asset decommissioned. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible. T9: The beach / coastal foreshore reserve is significantly diminished.	
Assets	Beach and Dunes			
Pathway	<i>Soft Protect (PR1)</i>			
Trigger(s)	T10: Localised erosion of beach and dune systems.			

Table 6-4 Adaptation pathway for MU3 – Mettams Pool

Planning Timeframe	2025 -2030	2030 -2045	2045 - 2070	2070 - future
Assets	Undeveloped land			
Pathway	<i>Avoid (AV)</i>			
Trigger(s)	T12: Undeveloped land lying within the hazard extent.			
Assets	Developed land			
Pathway	<i>Planned / Managed Retreat (PMR3)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Accommodate (AC1)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Soft Protect (PR2)</i>	<i>Protect (TBC) and (PR2)</i>		<i>Planned / Managed Retreat (PMR2)</i>
Trigger(s)	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe.	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible.		T2: Access to property lost. T3: Services to asset decommissioned. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible. T9: The beach / coastal foreshore reserve is significantly diminished.
Assets	Beach and Dunes			
Pathway	<i>Soft Protect (PR1)</i>			
Trigger(s)	T10: Localised erosion of beach and dune systems.			

Table 6-5 Adaptation pathway for MU4 – Trigg Beach North

Planning Timeframe	2025 -2030	2030 -2045	2045 - 2070	2070 - future
Assets	Undeveloped land			
Pathway	<i>Avoid (AV)</i>			
Trigger(s)	T12: Undeveloped land lying within the hazard extent.			
Assets	Developed land			
Pathway	<i>Planned / Managed Retreat (PMR3)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Accommodate (AC1)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Soft Protect (PR2)</i>	<i>Protect (TBC) and (PR2)</i>		<i>Planned / Managed Retreat (PMR2)</i>
Trigger(s)	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe.	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible.		T2: Access to property lost. T3: Services to asset decommissioned. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible. T9: The beach / coastal foreshore reserve is significantly diminished.
Assets	Beach and Dunes			
Pathway	<i>Soft Protect (PR1)</i>			
Trigger(s)	T10: Localised erosion of beach and dune systems.			

Table 6-6 Adaptation pathway for MU5 – Trigg Beach South

Planning Timeframe	2025 -2030	2030 -2045	2045 - 2070	2070 - future
Assets	Undeveloped land			
Pathway	<i>Avoid (AV)</i>			
Trigger(s)	T12: Undeveloped land lying within the hazard extent.			
Assets	Developed land			
Pathway	<i>Planned / Managed Retreat (PMR3)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Accommodate (AC1)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Soft Protect (PR2)</i>	<i>Protect (TBC) and (PR2)</i>		<i>Planned / Managed Retreat (PMR2)</i>
Trigger(s)	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe.	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible.		T2: Access to property lost. T3: Services to asset decommissioned. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible. T9: The beach / coastal foreshore reserve is significantly diminished.
Assets	Beach and Dunes			
Pathway	<i>Soft Protect (PR1) when necessary</i>			
Trigger(s)	T10: Localised erosion of beach and dune systems.			

Table 6-7 Adaptation pathway for MU6 – Scarborough Beach

Planning Timeframe	2025 -2030	2030 -2045	2045 - 2070	2070 - future
Assets	Undeveloped land			
Pathway	<i>Avoid (AV)</i>			
Trigger(s)	T12: Undeveloped land lying within the hazard extent.			
Assets	Developed land			
Pathway	<i>Planned / Managed Retreat (PMR3)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Accommodate (AC1)</i>			
Trigger(s)	T4: Asset lying within 100-year coastal hazard extent.			
Pathway	<i>Soft Protect (PR2)</i>	<i>Protect (TBC) and (PR2)</i>		<i>Planned / Managed Retreat (PMR2)</i>
Trigger(s)	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe.	T1: HSD is with S1 distance of an asset. T5: Asset damaged, destroyed or unsafe. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible.		T2: Access to property lost. T3: Services to asset decommissioned. T6: Asset to move to high or extreme risk in next planning timeframe. T7: Stakeholders no longer supportive. T8: Technique no longer economically or physically feasible. T9: The beach / coastal foreshore reserve is significantly diminished.
Assets	Beach and Dunes			
Pathway	<i>Soft Protect (PR1) when necessary</i>			
Trigger(s)	T10: Localised erosion of beach and dune systems.			

7 Key Recommendations

7.1 Coastal Adaption Measures

The general approaches recommended to adapt to the risk of coastal erosion follow guidance set out in the State Coastal Planning Policy and include:

- > Avoiding development on land which has been identified as prone to erosion over the next 100 years;
- > Accommodating coastal hazard risk through implementation of planning controls to allow for the continued use of current infrastructure until such time the risk levels require a managed retreat pathway;
- > Protecting infrastructure in the short term through beach nourishment and potentially through the construction of further coastal protection (subject to further detailed investigation);
- > Continuing low cost, soft protection measures, such as dune fencing and revegetation programs, to strengthen dune systems under the assumption that government funding and volunteer input can assist implementation; and
- > Planning for the eventual managed retreat of assets along the City's coastline.

For more detailed coastal adaption measures, see **Section 6.2**.

7.2 Planning Measures

Recommended planning measures have been outlined in detail in **Appendix A** and are generally consistent with those outlined in the *Draft Planned or Managed Retreat Guidelines* (DoPLH, 2017c). The City should look to incorporate these instruments into their planning framework, and these can be refined as clarity around long-term pathways, financial implications of options and funding arrangements evolve.

8 Discussion

Through the MCA, various options have been either recommended, not recommended or identified as requiring further investigation. Implementation of *Avoid, Managed Retreat, Accommodate and Protect* options have been discussed with respect to the six identified MUs along the City's coastline. In general, the proposed adaptation options provide technical mitigation approaches for adapting to the effects of landward migration of the shoreline, due to future SLR and associated coastal erosion. A summary of the range of planning instruments available to effect changes in the character and use of the coastal zone has been provided in **Section 2**.

In general, options recommend that:

- > Where there is currently no existing development seaward of the predicted 2122 coastal erosion hazard line, planning controls and coastal zone boundaries be adjusted to preclude inappropriate development within the zone;
- > Where high value natural and social assets exist seaward of the 2122 coastal erosion hazard line, adaptation options and pathways which maintain the present values of these assets should be favoured;
- > Where public built assets exist seaward of the 2122 coastal erosion hazard line, managed retreat options should be considered; and/or
- > Where private land and dwellings are located seaward of the 2122 coastal erosion hazard line (which is not the case for the City at this stage), long term planning for retreat should be considered.

General coastal planning principles (**Section 8.1**) and acknowledgement of the uncertainty in the hazard lines (**Section 8.2**) will need to be conveyed during the next opportunity to engage with the community, where the aim should be to elicit community consensus on the priorities and content of the City's CHRMAP.

8.1 General Coastal Planning Principles

With a view to achieving the planning objective of ensuring permanent and easy public access to the beach and coastal recreation (foreshore) reserves, some guiding principles are proposed. These could form the basis for drafting scheme and/or policy provisions relating to the definition of coastal foreshore reserves.

- > The coast and coastal foreshore reserves are a public asset that should not, now or in the future, become the de facto exclusive domain of private landowners by virtue of the erosion of coastal reserves or other coastal processes;
- > Foreshore reserves should be wide enough that they can still perform recreation and/or conservation functions (according to the reasons for their initial designation) even if they are affected by coastal erosion or diminution due to SLR;
- > Privatisation of coastal land at risk of coastal erosion, now or in the future, through freehold or long-term leasehold subdivision should be avoided;
- > Permanent structures, including buildings, should not be permitted on land at risk of coastal erosion or significant inundation; and
- > Redevelopment of land at risk of coastal erosion or inundation with permanent structures (e.g. houses) should not be permitted within the at-risk parts of a site.

8.2 Uncertainty and Adaptive Management

The coastal hazard lines derived during the coastal hazard assessment are subject to a number of assumptions that introduce uncertainty into the predicted location of each hazard line, at each planning time frame. The CHRMAP process recognises this and utilises adaptive management techniques to continually monitor, assess and revise plans as new information comes to light in the future. The confounding aspects of hazard line predictions for variable SLR and climate change scenarios, and the complex coastal planning instruments will require a careful, balanced consideration when prioritising implementation of proposed adaptation options. The general principles discussed above and acceptance of the uncertainty in the hazard lines are intended to provide a reasonable overview to inform the community, that will be important to guide the development of long-term management pathways.

As the shoreline is dynamic and new information is constantly being collected, there may be opportunity to revise hazard line extents prior to the next formal review of the CHRMAP. A review of hazard lines may be appropriate if significant new information becomes available, such as a change to State endorsed SLR predictions or the addition of collected shoreline movement or metocean datasets that contradict existing information/predictions. It is important that any hazard line revisions are made for an entire sediment cell (at least the Secondary Sediment Cell as defined by Stul et al, 2015) containing the area of interest, as stipulated in Section 4 of SPP2.6.

With regard to sediment cells, CHRMAPs have often been produced in the past for specific development sites or areas of interest, which are not compliant with the requirements of SPP2.6 (due to not considering entire sediment cells) or consistent with the intent of the CHRMAP process. The City should avoid condoning the preparation of individual CHRMAPs (which are also unlikely to be acceptable to the WAPC), but rather require the recalculation of hazard line extents for its consideration and incorporation into its overall CHRMAP and risk management database. The calculation of hazard lines should be accompanied by an explanation of the reason for the proposed revision and a full description of calculations undertaken to achieve hazard extents, in line with the methodology stipulated in SPP2.6. The City may then choose to adopt the new hazard lines and incorporate them by amending mapping in their local planning scheme. A reassessment of risk and vulnerability levels for that area, using the assessment spreadsheets provided as part of this CHRMAP, may also then be appropriate.

Rather than using site-specific CHRMAPs, foreshore/coastal management plans and structure plans should be used to increase the level of detail for management of specific sites and ensure the outcomes of the City's CHRMAP are incorporated into planned development. A key purpose of the CHRMAP process is to empower and guide local government agencies to control coastal development and ensure it is carried out in a responsible manner. It is reiterated that hazard line extents contain conservative assumptions, which are necessary given future uncertainty and the need to avoid inappropriate, permanent development. Such development has been identified to already exist within the City and will require expensive management over the next 100 years. The City should be wary of proponents wishing to revise hazard extents based on different interpretations of prescriptive methods in SPP2.6, with the aim of maximising the development potential for their area of interest.

Alongside the recommended adaptation pathways that will underpin implementation over the short term, recommendations will be made for further investigation and specific monitoring programs. This will help refine and guide the adaptation pathways into the future. A key aim will be to make recommendations that will help reduce the uncertainty in the coastal process hazards, prior to subsequent future updates of the City's CHRMAP.

8.3 Next Steps

The next steps for the project is Stage 6; *Implementation*. This involves development of a specific CHRMAP Implementation Plan, with actions and further investigation to be completed over the next ~25 years (to 2045). Longer-term implementation requirements are also incorporated, noting the level

of uncertainty at such future timeframes. A program for monitoring and reviewing of the City's coastal hazard risk exposure will also be established. This has been documented in the fifth and final chapter report (Cardno, 2023d).

9 References

- Cardno (2023a) *City of Stirling Coastal Hazard Risk Management and Adaptation Plan – Chapter 1: Establish the Context*. Prepared for City of Stirling on 23/06/2023.
- Cardno (2023b) *City of Stirling Coastal Hazard Risk Management and Adaptation Plan – Chapter 2: Risk Identification*. Prepared for City of Stirling on 23/06/2023.
- Cardno (2023c) *City of Stirling Coastal Hazard Risk Management and Adaptation Plan – Chapter 3: Vulnerability Assessment and Risk Evaluation*. Prepared for City of Stirling on 23/06/2023.
- Cardno (2023d) *City of Stirling Coastal Hazard Risk Management and Adaptation Plan – Chapter 5: Implementation*. Prepared for City of Stirling on 23/06/2023.
- City of Stirling (2020) *City of Stirling Risk Management Framework*. Published November 2020.
- Cooper, J. A. G & Pilkey, O. H (2004) *Sea-level rise and shoreline retreat: time to abandon the Bruun Rule*. *Global and Planetary Change* 43 (2004) 157 – 171
- DoT (2010) *Sea Level Change in Western Australia Application to Coastal Planning*. Department of Transport, Perth, Western Australia.
- IPCC (2007) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- IPCC (2021) *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.
- Rosati, J. D., Dean, R. G. & Walton, T. L. (2013) *The modified Bruun Rule extended for landward transport*. *Marine Geology* 340 (2013) 71-81.
- Standards Australia (2013) *Climate change adaption for settlements and infrastructure – A risk based approach* (AS 5334-2013)
- Stul T, Gozzard JR, Eliot IG and Eliot MJ (2015) *Coastal Sediment Cells for the Vlamingh Region between Cape Naturaliste and Moore River, Western Australia*. Report prepared by Seashore Engineering Pty Ltd and Geological Survey of Western Australia for the Western Australian Department of Transport, Fremantle.
- WAPC (2003) *Statement of Planning Policy No. 2: Environment and Natural Resources Policy*. Published by the Western Australian Planning Commission, Perth, Western Australia.
- WAPC (2006a) *Statement of Planning Policy No. 3: Urban Growth and Settlement*. Published by the Western Australian Planning Commission, Perth, Western Australia.
- WAPC (2006b) *State Planning Policy No. 3.4 – Natural Hazards and Disasters*. Published by the Western Australian Planning Commission, Perth, Western Australia.
- WAPC (2010) *State Planning Policy No. 2.8 – Bushland policy for the Perth Metropolitan Region*. Published by the Western Australian Planning Commission, Perth, Western Australia.
- WAPC (2013) *State Planning Policy No. 2.6: State Coastal Planning Policy*. Published by the Western Australian Planning Commission, Perth, Western Australia.
- WAPC (2019) *Coastal Hazard Risk Management and Adaptation Planning Guidelines*. Published by the Western Australian Planning Commission, Perth, WA.

WAPC (2020) *State Coastal Planning Policy Guidelines*. November 2020. Prepared by the Department of Planning, Lands and Heritage on behalf of the Western Australian Planning Commission. Published version February 2021.

APPENDIX

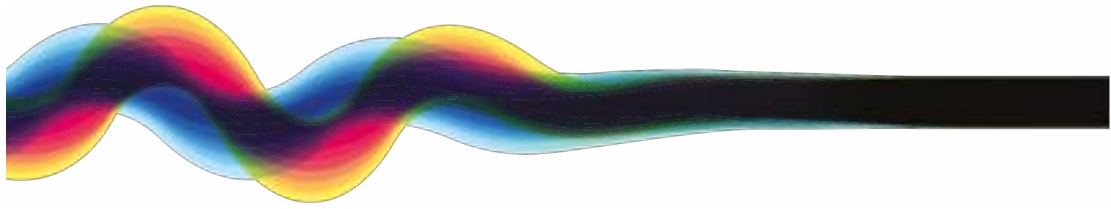
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STATUTORY PLANNING
RECOMMENDATIONS



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element.

City of Stirling CHRMAP

Risk Treatment & Implementation

30 May 2023

Document ID: 21-338

Issue	Date	Status	Prepared by	Approved by
			Name	Name
1	14 June 2022	Draft 1	Dylan Wray	Matt Raymond
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4	30 May 2023	FINAL 2	Dylan Wray	Matt Raymond

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Contents

Risk Treatment	1
Statutory Planning Controls.....	1
Current Recommended Planning Controls.....	1
Possible Future Planning Controls	1
Local Planning Strategy	1
Structure Planning	1
Local Planning Scheme Amendment	2
Special Control Area	2
Coastal Local Planning Policy	3
Management Requirements	5
Model Conditions List	5
Planned or Managed Retreat Policy	5
Foreshore Management Plans	6
Publicly Available Information	6
Emergency Response and Evacuation	6
Implementation	7
Short Term Planning Controls.....	7
Medium to Long Term Planning Controls	7
Further Investigations	7
Foreshore Management Plan	7
CHRMAP Revisions	8

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Risk Treatment

Statutory Planning Controls

Chapter 1: Establish the Context reviewed the existing planning framework relevant to the study area, including the identification of planning controls that can be implemented by the City to respond to coastal erosion and inundation.

The current hazard modelling indicates that only one zoned property under LPS 3 may be impacted by erosion or inundation within the 2120 planning timeframe. As such, there is no immediate need for the City to implement the recommendations outlined below. However, the recommendations provide a foundation for future revisions of the CHRMAP, including implementation triggers once there is more certainty around the impacts of coastal erosion and inundation through updated hazard estimates.

Current Recommended Planning Controls

There is no immediate need for the City to implement additional planning controls given the 2120 modelled hazard lines only impact a small area of one zoned property. While no immediate planning controls are required, the City must be proactive and commence long term planning for coastal hazards which will become more prevalent through future iterations of this CHRMAP.

Possible Future Planning Controls

The following recommendations provide the foundation for sustainable coastal planning in the City, in accordance with SPP 2.6. These recommendations shall be implemented once the impacts of erosion and/or inundation are more certain, as identified through future revisions of the CHRMAP.

Although these planning controls are recommended to be implemented, they are based on possible future scenarios. As such, development within impacted areas will be assessed on a case-by-case basis and may in fact not be permitted.

Local Planning Strategy

The CHRMAP will inform the City's Local Planning Strategy to guide land use planning and development in areas prone to erosion or inundation. Areas of risk identified through revisions of the CHRMAP should not be identified for further development, intensification or rezoning.

Subsequent revisions of the Local Planning Strategy shall include a provision for all SPP 2.6 requirements to be met at the earliest stage possible, including the requirements for the ongoing provision of a coastal foreshore reserve.

The Local Planning Strategy must assess the hazard risks identified in this CHRMAP alongside other relevant planning matters including environmental, economic and social considerations to holistically inform and shape future expansion, as a precursor to future amendments to the City's Local Planning Scheme.

Structure Planning

Structure planning is considered the most effective mechanism where some degree of comprehensive redevelopment of land remains an option. While a structure plan is unlikely to be prepared by the City, it must be considered given the interim arrangements for the normalisation of the Scarborough Redevelopment Area.

The agreed approach to transfer the planning framework back to the City is to rezone the Scarborough Redevelopment Area from 'No Zone' to 'Development' zone under LPS3. The City does not intend to prepare a structure plan for this area. However, the 'Development' zone does enable the private sector to prepare and submit a structure plan to the City for consideration.

In the event a structure plan is prepared for land subject to erosion or inundation as identified through future revisions of the CHRMAP, the City shall require the proponent to accommodate coastal risks by including provisions for all SPP 2.6 requirements to be met at the earliest stage of subdivision and development.

Local Planning Scheme Amendment

The City will be required to initiate an amendment to the Local Planning Scheme when future revisions of the CHRMAP, which incorporate additional geotechnical information and planned coastal controls, identify the coastal hazard extents as intersecting private properties. The scheme amendments shall include:

- Insert CHRMAP Special Control Area (SCA) under Part 6; and
- Update Scheme Maps to include CHRMAP SCA over all zoned land impacted by erosion or inundation.

The City shall determine the most appropriate time to amend the Local Planning Scheme following updates to the hazard estimates through revisions of the CHRMAP.

Special Control Area

The introduction of an SCA over zoned land affected by erosion or inundation in the 100-year planning timeframe will provide the most effective response to coastal hazards. The SCA will stipulate provisions to respond to the risks identified in the CHRMAP, including the trigger for normally exempt development to require development approval.

It is noted that some forms of development cannot be controlled by the SCA, such as works carried out by the State Government under the *Public Works Act 1902*. The City should liaise with the State regarding such development to ensure it is not incompatible with the long-term pathway set out for the area.

The following SCA shall be introduced into the Local Planning Scheme when future revisions of the CHRMAP, which incorporate additional geotechnical information and planned coastal controls, identify the coastal hazard extents as intersecting private properties.

Table 1: CHRMAP Special Control Area

CHRMAP Special Control Area
<p><u>Objectives:</u></p> <ul style="list-style-type: none"> a) To ensure land in the coastal zone is continuously available for coastal foreshore management, public access, recreation and conservation. b) To ensure public safety and reduce risk associated with erosion and inundation. c) To avoid inappropriate land use and development of land at risk of erosion and inundation. d) To ensure land use and development does not accelerate erosion or inundation risk; or have a detrimental impact on the functions of public reserves. e) To protect new development from the impacts of erosion and inundation. f) To provide for implementation of the City of Stirling Coastal Hazard and Risk Management Adaptation Plan.
<p><u>Special Control Area</u></p> <ul style="list-style-type: none"> a) The CHRMAP Special Control Area is shown on the Scheme Maps and delineated as such.
<p><u>Approval</u></p> <ul style="list-style-type: none"> a) Notwithstanding any other provision of the Scheme, all proposed development within the CHRMAP Special Control Area requires the approval of the local government, inclusive of any development which may otherwise be exempt under the Planning and Development (Local Planning Schemes) Regulations 2015.

<p><u>Structure Plans</u></p> <p>a) Structure Plans shall be consistent with –</p> <ol style="list-style-type: none"> I. The City of Stirling Coastal Hazard and Risk Management Adaptation Plan. II. The provisions of State Planning Policy 2.6 – State Coastal Planning Policy. III. Coastal Local Planning Policy. IV. Relevant local planning policies.
<p><u>Subdivision and Development</u></p> <p>a) The subdivision and development of land within the CHRMAP Special Control Area shall have due regard to –</p> <ol style="list-style-type: none"> I. The City of Stirling Coastal Hazard and Risk Management Adaptation Plan. II. The provisions of State Planning Policy 2.6 – State Coastal Planning Policy. III. Coastal Local Planning Policy. IV. Relevant local planning policies.
<p><u>Notifications</u></p> <p>a) Where subdivision applications are received within the CHRMAP SCA, a notification pursuant to Section 165A of the Planning and Development Act 2005 is to be placed on the Certificate(s) of Title of the subject land, at the cost of the landowner advising that the lot is located in an area likely to be subject to erosion and/or inundation over the next 100 years.</p> <p>b) Where development applications are received within the CHRMAP SCA, the local government shall require a notification pursuant to section 70A of the Transfer of Land Act 1983 to be placed on the Certificate(s) of Title of the subject land, at the cost of the landowner, advising that the lot is located in an area likely to be subject to erosion and/or inundation over the next 100 years.</p>
<p><u>Referrals</u></p> <p>a) In certain instances, there may be a requirement to refer the application to the Department of Transport, the Western Australian Planning Commission and any other relevant authority for advice and comment on the risk of erosion and inundation.</p>

Coastal Local Planning Policy

Development on properties located within the SCA will be required to give due regard to additional development provisions to better accommodate and respond to the risk of erosion and inundation.

Following the introduction of the SCA into the Local Planning Scheme, the City shall prepare and adopt a Coastal Local Planning Policy in accordance with Schedule 2 of the *Planning and Development (Local Planning Schemes) Regulations 2015*. It is recommended that the Coastal Local Planning Policy includes the following provisions, as deemed appropriate by the City.

Application for Development Approval:

- All development within the CHRMAP SCA requires development approval prior to the commencement of construction, unless specifically exempted by this Policy.
- Applicants will need to clearly demonstrate that their proposal meets the objectives and requirements of this policy and the City of Stirling CHRMAP.

Application for Subdivision Approval:

- As previously stated, there is a general presumption against further intensification of properties within the CHRMAP SCA. However, the City may consider subdivision if it can be demonstrated that adequate protection measures are provided, at the cost of the landowner and to the satisfaction of the City.
- Subdivision of land within the CHRMAP SCA will only be supported by the City where the applicant can demonstrate a reduction in the identified hazard risks through site specific studies, in accordance with State Planning Policy 2.6 Coastal Planning Policy and the CHRMAP Guidelines.
- A notification pursuant to Section 165A of the *Planning and Development Act 2005* is to be placed on the Certificate(s) of Title of the subject land, at the cost of the landowner. The notification shall be required as a condition of subdivision approval, advising that the lots are located in an area likely to be subject to erosion and/or inundation over the next 100 years.

Erosion Requirements:

- No permanent development is to be located seaward of the 100-year erosion hazard line, as defined in the CHRMAP, unless expressly exempt under this policy.
- Development that is not permanent can be located seaward of the erosion hazard lines provided the applicant demonstrates that the design life is suitable for its location with regard to the coastal hazard lines contained within the CHRMAP.
- Development proposed seaward of the 100-year erosion hazard line shall only be considered where the applicant demonstrates that the development can be relocated or removed. The below conditions and advice notes shall be applied to development approvals pertaining to properties at risk of erosion, to the discretion of the City.
- Properties without access to reticulated sewerage shall provide an aerobic treatment unit system, to the satisfaction of the City's Environmental Health Officer.
- Exemptions for minor development on properties seaward of the 100-year erosion hazard line may be considered where they do not substantially alter the development footprint. Exemptions could include additions and alterations, incidental land uses, or development and land uses that are not considered an intensification of development.

Inundation Requirements:

- Habitable rooms for residential buildings and net lettable areas for commercial, retail or community buildings require minimum finished floor level of at least 0.5m above the modelled inundation level.
- Where the filling of land is proposed to achieve minimum finished floor levels, the design and location of retaining walls shall not create an adverse impact of inundation levels on adjoining properties.
- All essential services, including electricity, water, sewerage and communications infrastructure shall be elevated and / or designed to be protected from the impact of inundation. The City may require information to demonstrate how this will be achieved or apply conditions to this effect.
- Buildings designed to withstand structural loads associated with inundation, including water resistant building materials and construction methods. The City may require information to demonstrate how this will be achieved or apply conditions to this effect.
- Effluent disposal systems shall be designed to withstand inundation events. Properties without access to reticulated sewerage shall provide an aerobic treatment unit system, to the satisfaction of the City's Environmental Health Officer.
- Lower levels of buildings at risk of inundation may be used for non-habitable rooms or spaces. These rooms and uses are to be clearly labelled on the plans submitted for development approval.
- Exemptions for minor development which could include additions and alterations that do not increase the development footprint by more than 50m² in habitable or net lettable area, or is not considered an intensification of development or land use.
- Development applications for vulnerable land uses shall be accompanied by a site-specific emergency evacuation plan. Vulnerable land uses include the occupation of people who are less physically or mentally able to respond in an emergency and include the elderly, children under 18 years of age and the sick or injured.

Management Requirements

Model Conditions List

The following list of conditions and advice notes shall be applied to development approvals within the CHRMAP SCA, at the discretion of the City.

Conditions:

1. The development approval shall cease to have effect and the development removed when:
 - a. The most landward part of the Horizontal Shoreline Datum is within the S1 distance of the most seaward part of the habitable buildings; or
 - b. A public road is no longer available or able to provide legal access to the property; or
 - c. Water, sewerage or electricity to the lot is no longer available due to coastal hazards.
2. Any development approval granted in respect to Condition 1 shall require the land to be rehabilitated to its pre-development condition, once the development has been removed. The land shall be rehabilitated to the specifications and satisfaction of the Local Government, at the landowners cost.
3. A notification, pursuant to Section 70A of the Transfer of Land Act 1893 is to be placed on the Certificate of Title of the proposed development lot advising of the existence of a hazard. The notification is to state as follows:

'Vulnerable coastal area - This lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years and is subject to conditions of development approval which requires removal and/or rehabilitation of development to pre-development conditions if the time limit specified on the development approval is reached or any one of the following events occurs:

- a) *the most landward part of the Horizontal Shoreline Datum being within (insert number) meters of the most seaward part of the habitable building;*
- b) *a public road no longer being available or able to provide legal access to the property;*
- c) *when water, sewerage or electricity to the lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards.'*

Advice Notes:

1. The applicant is advised that the Horizontal Shoreline Datum means the active limit of the shoreline under storm activity, as defined in State Planning Policy 2.6 – State Coastal Planning Policy (2013).
2. The applicant is advised that the distance between the Horizontal Shoreline Datum and the most seaward part of the habitable building is the S1 value, as defined for each coastal management zone in the CHRMAP.

The City shall also recommend conditions and advice notes to a similar effect to the WAPC for any development proposed within the foreshore reserve.

Planned or Managed Retreat Policy

There is no immediate need for the City to prepare a Planned or Managed Retreat Policy given the erosion hazard lines are not expected to impact assets on private properties within the 100-year planning timeframe. The City should however acknowledge that a Planned or Managed Retreat Policy may need to be prepared when there is more certainty around the risk of erosion on private properties.

In view of this, a recommendation for a Managed Retreat Policy is not included in this version of the CHRMAP. The City should review the need and timing for such policy in conjunction with future revisions of the CHRMAP which may include further guidance on the content and direction of a Managed Retreat Policy.

The City should also work with the State Government to determine an appropriate response to the managed retreat of at risk assets within the existing foreshore reserve. These assets would be best managed by a Foreshore Management Plan, prepared and implemented by the City.

Any development within the foreshore reserve should give due regard to the recommendations of the CHRMAP. The City shall collaborate with the State Government to determine the most appropriate response for the ongoing use of existing and proposed public assets.

Foreshore Management Plans

Foreshore management plans can provide a strategy to deliver the recommendations of the CHRMAP for particular foreshore reserves throughout the City. Foreshore management plans can be a key tool for communication and engagement with the community as they include detailed planning for community places and facilities.

The City should prepare a foreshore management plan for its coastlines to provide guidance for the ongoing management of foreshore reserves, monitoring of assets and the triggers for the managed retreat of assets and infrastructure at risk of erosion.

Publicly Available Information

It is recommended that the City introduces the erosion and inundation hazard data into the publicly available mapping system. This will ensure staff and the community have access to information on any affected land and can be made aware of the presence of the coastal hazards.

Information on relevant coastal hazards and the implications for property, now and into the future, should also be made available to potential buyers upon making a land purchase enquiry.

Emergency Response and Evacuation

In accordance with the *Emergency Management Act 2005*, the City is responsible for assisting the community in preparing, preventing, responding and recovering from various emergencies. The City's Local Emergency Management Committee (LEMC) has prepared a Local Emergency Management Arrangements (LEMA) which includes useful information in relation to emergency preparation and response.

The LEMA should be reviewed in conjunction with this CHRMAP to ensure areas identified as being at risk of inundation events have arrangements in place to assist with emergency response and recovery.

Implementation

Short Term Planning Controls

The following planning and management controls presented in Chapter 5: Risk Treatment should be implemented by the City over the next 25 years in response to the coastal hazards identified in the CHRMAP. There is no immediate need to update the City’s planning framework based on the current hazard modelling. However, the controls in Table 2 should be implemented once there is greater certainty around the impact of coastal processes on zoned land. This will be established through periodic reviews of the CHRMAP which will require revised hazard modelling.

Table 2 – Short Term Implementation (next 25 years)

Planning Controls	Description	Implementation Triggers
Structure Plans	Require proponents to include coastal adaptation and management provisions into structure plans.	The submission of a structure plan containing lots being affected by coastal hazards.
Scheme Amendment	Introduce SCA into the City's local planning scheme.	When future revisions of the CHRMAP identify the coastal hazard extends as intersecting private properties.
Coastal Local Planning Policy	Adoption of a local planning policy to guide future development within the SCA.	Following the introduction of the SCA into the City's local planning scheme.
Model Conditions List	Update model conditions list to include conditions relating to notifications on title and managed retreat.	Following the introduction of the SCA into the City's local planning scheme.
Publicly Available Information	Update IntraMaps to include coastal hazard data.	Upon completion of the CHRMAP.

Medium to Long Term Planning Controls

The following planning and management controls presented in Chapter 5: Risk Treatment should be implemented by the City at a time when the risk of coastal process is more certain through periodic reviews of the CHRMAP.

Table 3 – Medium to Long Term Implementation (25 - 100 years)

Planning Controls	Description	Implementation Triggers
Planned or Managed Retreat Policy	Adoption of a policy for the retreat of assets and acquisition of at-risk land.	Once it has been determined that the land can no longer be used for its intended purpose.
MRS Amendment	Rezone acquired land to 'Parks and Recreation' reserve under the MRS.	Once land has been acquired in accordance with the adopted Planned or Managed Retreat Policy.
Emergency Response and Evacuation	Review LEMA alongside the inundation mapping identified in the CHRMAP.	Once it has been determined that habitable buildings will be subject to inundation events.

Further Investigations

Foreshore Management Plan

The City shall undertake the development of Foreshore Management Plan(s) to guide future management of the City’s coastal areas and assets. The City shall determine the most appropriate time to prepare a Foreshore Management Plan however should prioritise high use areas with at-risk public assets, including Scarborough Beach, Trigg, Watermans Bay and Mettams Pool.

CHRMAP Revisions

As noted in the CHRMAP Guidelines, the CHRMAP should be a living document and undergo regular revisions alongside periodic reviews of the City's Local Planning Strategy and Local Planning Scheme.

The key considerations for future revisions of the CHRMAP should include any changes to community values and expectations, revised hazard mapping based on current data, changes to the use of foreshore reserves and changes to relevant legislation.

APPENDIX

B

ASSET VALUATION



now



Classification	Asset ID	Assets	Quantity	Units	Cost / unit	Reference	Total Value
Natural	MU1-01	Watermans Bay Beach	5607	sqm	\$3,116	UWA	\$17,471,000
Natural	MU1-02	Watermans Bay Dog Beach	2592	sqm	\$3,116	UWA	\$8,077,000
Natural	MU1-03	Watermans vegetated dunes	6593	sqm	\$132.00	UWA	\$870,000
Built	MU1-04	Watermans GSC revetment	160	m	\$5,250.00	Internal database	\$840,000
Built	MU1-05	West Coast Drive, footpath and services (Beach Rd to Mary St)	821	sqm	\$186.00	Rawlinsons	\$153,000
Built	MU1-06	Lookout and amenities, Watermans Bay	130	sqm	\$2,780.00	Rawlinsons	\$361,000
Built	MU1-07	Car park and lookout, Margaret St	815	sqm	\$126.00	Rawlinsons	\$103,000
Built	MU1-08	Watermans access, amenity and minor infrastructure		%	1%	Internal database	\$279,000
Natural	MU2-01	North Beach Dog Beach	1761	sqm	\$3,116	UWA	\$5,487,000
Natural	MU2-02	North Beach (North)	5260	sqm	\$3,116	UWA	\$16,390,000
Natural	MU2-03	North Beach (South)	5770	sqm	\$3,116	UWA	\$17,979,000
Built	MU2-04	North Beach access, amenity and minor infrastructure		%	1%	Internal database	\$424,000
Natural	MU2-05	North Beach Vegetated Dunes	7042	sqm	\$132.00	UWA	\$930,000
Built	MU2-06	West Coast Drive, footpath and services (Malcolm St to James St)	1472	sqm	\$186.00	Rawlinsons	\$274,000
Built	MU2-07	North Beach Revetment and Jetty	22	m	\$22,000.00	Internal database	\$484,000
Built	MU2-08	West Coast Drive, footpath and services (Sorrento St to Hamersley St)	4414	sqm	\$186.00	Rawlinsons	\$821,000
Natural	MU3-01	Mettams Pool Beach	15077	sqm	\$3,116	UWA	\$46,980,000
Built	MU3-02	Parking Area, Saunders St	2149	sqm	\$126.00	Rawlinsons	\$271,000
Built	MU3-03	Mettams Pool public toilets	152	sqm	\$3,150.00	Rawlinsons	\$479,000
Built	MU3-04	West Coast Drive, footpath and services (Sholl Ave to Bailey St)	5726	sqm	\$186.00	Rawlinsons	\$1,065,000
Natural	MU3-05	Mettams vegetated dunes	88	sqm	\$58.00	Rawlinsons	\$5,000
Built	MU3-06	Mettams access, amenity and minor infrastructure		%	1%	Internal database	\$488,000
Natural	MU4-01	Bennion Beach	4150	sqm	\$3,116	UWA	\$12,931,000
Natural	MU4-02	Trigg Beach Dog Beach	2255	sqm	\$3,116	UWA	\$7,027,000
Natural	MU4-03	Trigg Beach North	2847	sqm	\$3,116	UWA	\$8,871,000
Natural	MU4-04	Trigg North Vegetated Dunes	3794	sqm	\$132.00	UWA	\$501,000
Built	MU4-05	West Coast Drive, footpath and services (near Kathleen St)	464	sqm	\$186.00	Rawlinsons	\$86,000
Built	MU4-06	Car park between Bennion and Bailey Streets	1200	sqm	\$126.00	Rawlinsons	\$151,000
Built	MU4-07	Parking area, Trigg Place	1054	sqm	\$126.00	Rawlinsons	\$133,000
Built	MU4-08	Trigg North access, amenity and minor infrastructure		%	1%	Internal database	\$297,000
Natural	MU5-01	Trigg Beach	37260	sqm	\$3,116	UWA	\$116,102,000
Natural	MU5-02	Trigg Beach South	38684	sqm	\$3,116	UWA	\$120,539,000
Natural	MU5-03	Trigg South Vegetated Dunes	16671	sqm	\$132.00	UWA	\$2,201,000
Built	MU5-04	Trigg Surf Lookout	357	sqm	\$2,780.00	Rawlinsons	\$992,000
Built	MU5-05	Parking area, Trigg Beach north	2379	sqm	\$126.00	Rawlinsons	\$300,000
Built	MU5-06	Trigg Beach SLSC building 1	1153	sqm	\$2,780.00	Rawlinsons	\$3,205,000
Built	MU5-07	Trigg Beach SLSC building 2	296	sqm	\$2,780.00	Rawlinsons	\$823,000
Built	MU5-08	Trigg Beach Café	2607	sqm	\$2,780.00	Rawlinsons	\$7,247,000
Built	MU5-09	Parking area, Trigg Beach central	10397	sqm	\$126.00	Rawlinsons	\$1,310,000
Built	MU5-10	Trigg South access, amenity and minor infrastructure		%	1%	Internal database	\$2,575,000
Built	MU5-11	Surfing WA Headquarters	1360	sqm	\$2,780.00	Rawlinsons	\$3,781,000
Built	MU5-12	Trigg Beach Carpark	8000	sqm	\$126.00	Rawlinsons	\$1,008,000
Natural	MU6-01	Scarborough Beach North	27345	sqm	\$3,116	UWA	\$85,207,000
Natural	MU6-02	Scarborough Beach	41089	sqm	\$3,116	UWA	\$128,033,000
Natural	MU6-03	Brighton Beach	26878	sqm	\$3,116	UWA	\$83,752,000
Natural	MU6-04	Peasholm Beach	34055	sqm	\$3,116	UWA	\$106,115,000
Natural	MU6-05	Scarborough Vegetated Dunes	57810	sqm	\$132.00	UWA	\$7,631,000
Built	MU6-06	Scarborough Beach Carpark	11300	sqm	\$126.00	Rawlinsons	\$1,424,000
Built	MU6-07	Scarborough Amphitheatre	1359	sqm	\$2,780.00	Rawlinsons	\$3,778,000
Built	MU6-08	Scarboro SLSC	1069	sqm	\$2,780.00	Rawlinsons	\$2,972,000
Built	MU6-09	Scarborough Beach Pool	1	unit	\$28,600,000.00	CoS	\$28,600,000
Built	MU6-10	Scarborough Beach Restaurant	3087	sqm	\$2,780.00	Rawlinsons	\$8,582,000
Built	MU6-11	Scarborough Playground and Skate Park	2052	sqm	\$228.00	Rawlinsons	\$468,000
Built	MU6-12	Scarborough Beach carpark south	7900	sqm	\$126.00	Rawlinsons	\$995,000
Built	MU6-13	Brighton Beach carpark	4850	sqm	\$126.00	Rawlinsons	\$611,000
Built	MU6-14	Scarborough access, amenity and minor infrastructure		%	1%	Internal database	\$4,582,000

APPENDIX

C

MANAGED RETREAT COSTS



now



Classification	Asset ID	Assets	Units	Dam 2030	Replace 2030 (\$)	Demo 2022 (\$)	Damage 2045	Replace 2045 (\$)	Demo 2045 (\$)	Damage 2070	Replace 2070 (\$)	Demo 2070 (\$)	Damage 2122	Replace 2122 (\$)	Demo 2122 (\$)
Natural	MU1-01	Watermans Bay Beach	sqm												
Natural	MU1-02	Watermans Bay Dog Beach	sqm												
Natural	MU1-03	Watermans vegetated dunes	sqm												
Built	MU1-04	Watermans GSC revetment	m												
Built	MU1-05	West Coast Drive, footpath and services	sqm	\$0	\$0	\$0	0	\$0	\$0	230	\$42,780	\$32,085	\$1,800	\$334,800	\$251,100
Built	MU1-06	Lookout and amenities, Watermans Bay	sqm	\$0	\$0	\$0	0	\$0	\$0	130	\$361,400	\$36,140	\$0	\$0	\$0
Built	MU1-07	Car park and lookout, Margaret St	sqm	\$0	\$0	\$0	40	\$5,040	\$448	400	\$50,400	\$4,478	\$178	\$22,428	\$1,993
Built	MU1-08	Watermans access, amenity and minor	%	\$0	\$27,900	\$2,790	0	\$55,800	\$5,580	\$0.0	\$83,700	\$8,370	\$0	\$111,600	\$11,160
Natural	MU2-01	North Beach Dog Beach	sqm												
Natural	MU2-02	North Beach (North)	sqm												
Natural	MU2-03	North Beach (South)	sqm												
Built	MU2-04	North Beach access, amenity and minor	%	\$0	\$42,400	\$4,240	0	\$84,800	\$8,480	0	\$127,200	\$12,720	\$0	\$169,600	\$16,960
Natural	MU2-05	North Beach Vegetated Dunes	sqm												
Built	MU2-06	West Coast Drive, footpath and services	sqm	\$0	\$0	\$0	45	\$8,370	\$504	420	\$78,120	\$4,702	\$1,340	\$249,240	\$15,003
Built	MU2-07	North Beach Revetment and Jetty	m	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$0	\$0	\$0
Built	MU2-08	West Coast Drive, footpath and services	sqm	\$0	\$0	\$0	25	\$4,650	\$280	750	\$139,500	\$8,397	\$3,355	\$624,030	\$37,563
Natural	MU3-01	Mettams Pool Beach	sqm												
Built	MU3-02	Parking Area, Saunders St	sqm	60	\$7,560	\$0	260	\$32,760	\$2,911	500	\$63,000	\$5,598	\$990	\$124,740	\$11,084
Built	MU3-03	Mettams Pool public toilets	sqm	\$0	\$0	\$0	152	\$478,800	\$9,454	0	\$0	\$0	\$0	\$0	\$0
Built	MU3-04	West Coast Drive, footpath and services (Sholl	sqm	32	\$5,952	\$358	379	\$70,494	\$4,243	1079	\$200,694	\$12,081	\$3,830	\$712,380	\$42,881
Natural	MU3-05	Mettams vegetated dunes	sqm												
Built	MU3-06	Mettams access, amenity and minor	%	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$0	\$0	\$0
Natural	MU4-01	Bennion Beach	sqm												
Natural	MU4-02	Trigg Beach Dog Beach	sqm												
Natural	MU4-03	Trigg Beach North	sqm												
Natural	MU4-04	Trigg North Vegetated Dunes	sqm												
Built	MU4-05	West Coast Drive, footpath and services (near	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$30	\$5,580	\$336
Built	MU4-06	Car park between Bennion and Bailey Streets	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$470	\$59,220	\$5,262
Built	MU4-07	Parking area, Trigg Place	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$750	\$94,500	\$8,397
Built	MU4-08	Trigg North access, amenity and minor	%	\$0	\$29,700	\$2,970	0	\$59,400	\$5,940	\$594.0	\$89,100	\$8,910	\$891	\$118,800	\$11,880
Natural	MU5-01	Trigg Beach	sqm												
Natural	MU5-02	Trigg Beach South	sqm												
Natural	MU5-03	Trigg South Vegetated Dunes	sqm												
Built	MU5-04	Trigg Surf Lookout	sqm	\$0	\$0	\$0	357	\$992,460	\$22,205	0	\$0	\$0	\$0	\$0	\$0
Built	MU5-05	Parking area, Trigg Beach north	sqm	\$0	\$0	\$0	0	\$0	\$0	757	\$95,382	\$8,475	\$858	\$108,108	\$9,606
Built	MU5-06	Trigg Beach SLSC building 1	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$1,153	\$3,205,340	\$75,302
Built	MU5-07	Trigg Beach SLSC building 2	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$296	\$822,880	\$26,791
Built	MU5-08	Trigg Beach Café	sqm	\$0	\$0	\$0	0	\$0	\$0	2607	\$7,247,460	\$0	\$0	\$0	\$0
Built	MU5-09	Parking area, Trigg Beach central	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$10,397	\$1,310,022	\$116,406
Built	MU5-10	Trigg South access, amenity and minor	%	\$0	\$29,700	\$2,970	0	\$59,400	\$5,940	0	\$89,100	\$8,910	\$0	\$118,800	\$11,880
Built	MU5-11	Surfing WA Headquarters	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$1,360	\$3,780,800	\$123,094
Built	MU5-12	Trigg Beach Carpark	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$8,000	\$1,008,000	\$89,569
Natural	MU6-01	Scarborough Beach North	sqm												
Natural	MU6-02	Scarborough Beach	sqm												
Natural	MU6-03	Brighton Beach	sqm												
Natural	MU6-04	Peasholm Beach	sqm												
Natural	MU6-05	Scarborough Vegetated Dunes	sqm												
Built	MU6-06	Scarborough Beach Carpark	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$11,300	\$1,423,800	\$126,516
Built	MU6-07	Scarborough Amphitheatre	sqm	\$0	\$0	\$0	1359	\$3,778,020	\$377,802	0	\$0	\$0	\$0	\$0	\$0
Built	MU6-08	Scarboro SLSC	sqm	\$0	\$0	\$0	0	\$0	\$0	1069	\$2,971,820	\$69,816	\$0	\$0	\$0
Built	MU6-09	Scarborough Beach Pool	unit	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$1	\$28,600,000	\$2,860,000
Built	MU6-10	Scarborough Beach Restaurant	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$3,087	\$8,581,860	\$201,612
Built	MU6-11	Scarborough Playground and Skate Park	sqm	\$0	\$0	\$0	0	\$0	\$0	2052	\$467,856	\$41,040	\$0	\$0	\$0
Built	MU6-12	Scarborough Beach carpark south	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$1,650	\$207,900	\$18,474
Built	MU6-13	Brighton Beach carpark	sqm	\$0	\$0	\$0	0	\$0	\$0	0	\$0	\$0	\$5,860	\$738,360	\$393,657
Built	MU6-14	Scarborough access, amenity and minor	%	\$0	\$458,200	\$45,820	0	\$916,400	\$91,640	0	\$1,374,600	\$137,460	\$0	\$1,832,800	\$183,280

APPENDIX

D

CONCEPT DESIGN MAPS



now



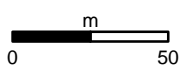


Legend

- Indicative Existing Shoreline
- Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- Managed Retreat Zone



1:2,430 Scale at A3

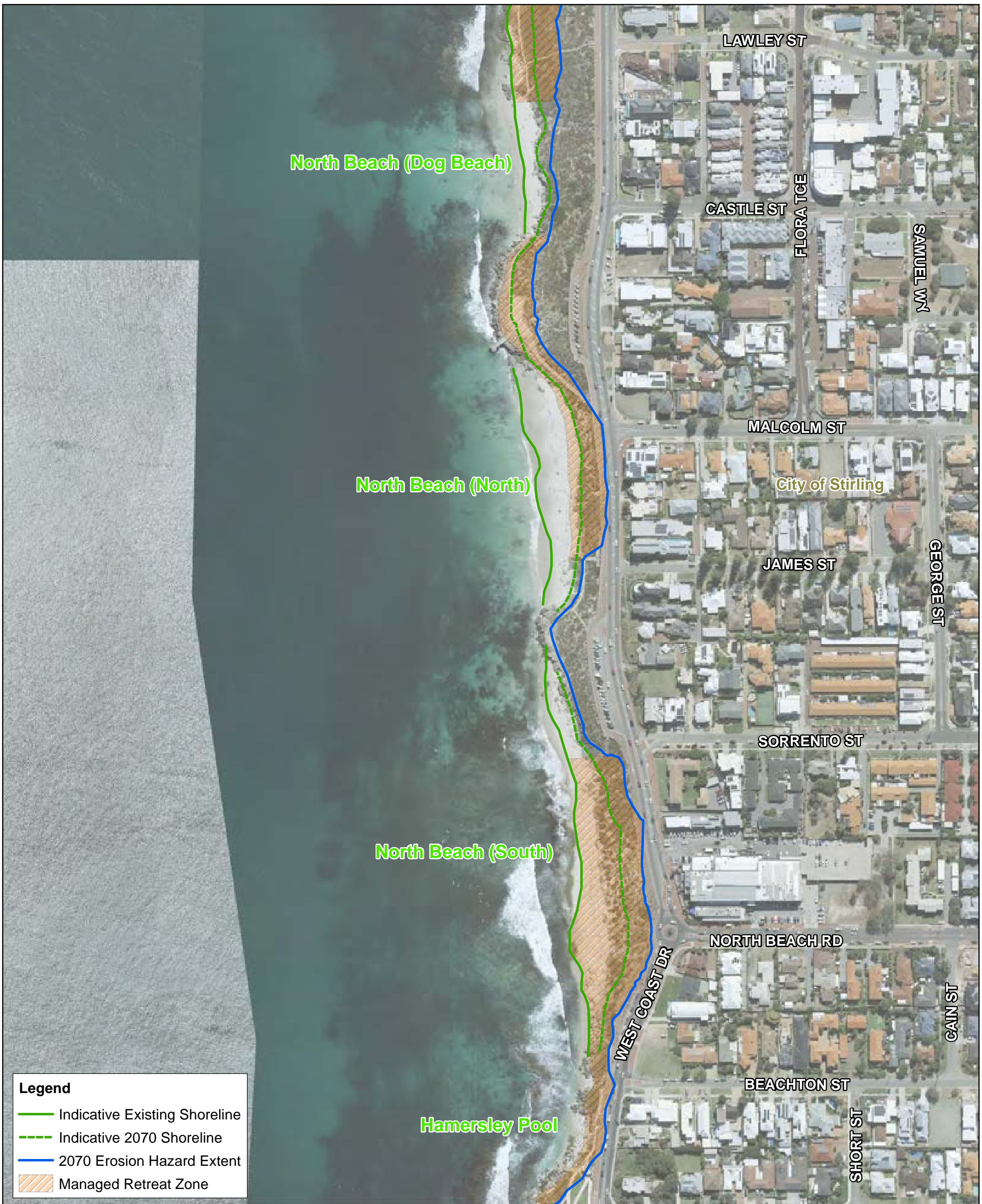


Adaptation Options Managed Retreat (MR1) MU1 - Watermans Bay

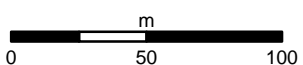
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_ManagedRetreat.mxd 01
 Aerial imagery supplied by Metromap (2022)



1:2,790 Scale at A3



Adaptation Options Managed Retreat (MR1) MU2 - North Beach

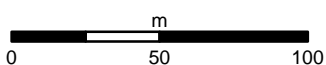
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-20
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_ManagedRetreat.mxd 01
 Aerial imagery supplied by Metromap (2022)



1:2,550 Scale at A3



Adaptation Options Managed Retreat (MR1) MU3 - Mettams Pool

CITY OF STIRLING CHRMAP



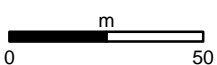
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 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_ManagedRetreat.mxd 01
 Aerial imagery supplied by Metromap (2022)



- Legend**
- Indicative Existing Shoreline
 - - - Indicative 2070 Shoreline
 - 2070 Erosion Hazard Extent
 - Managed Retreat Zone



1:1,950 Scale at A3

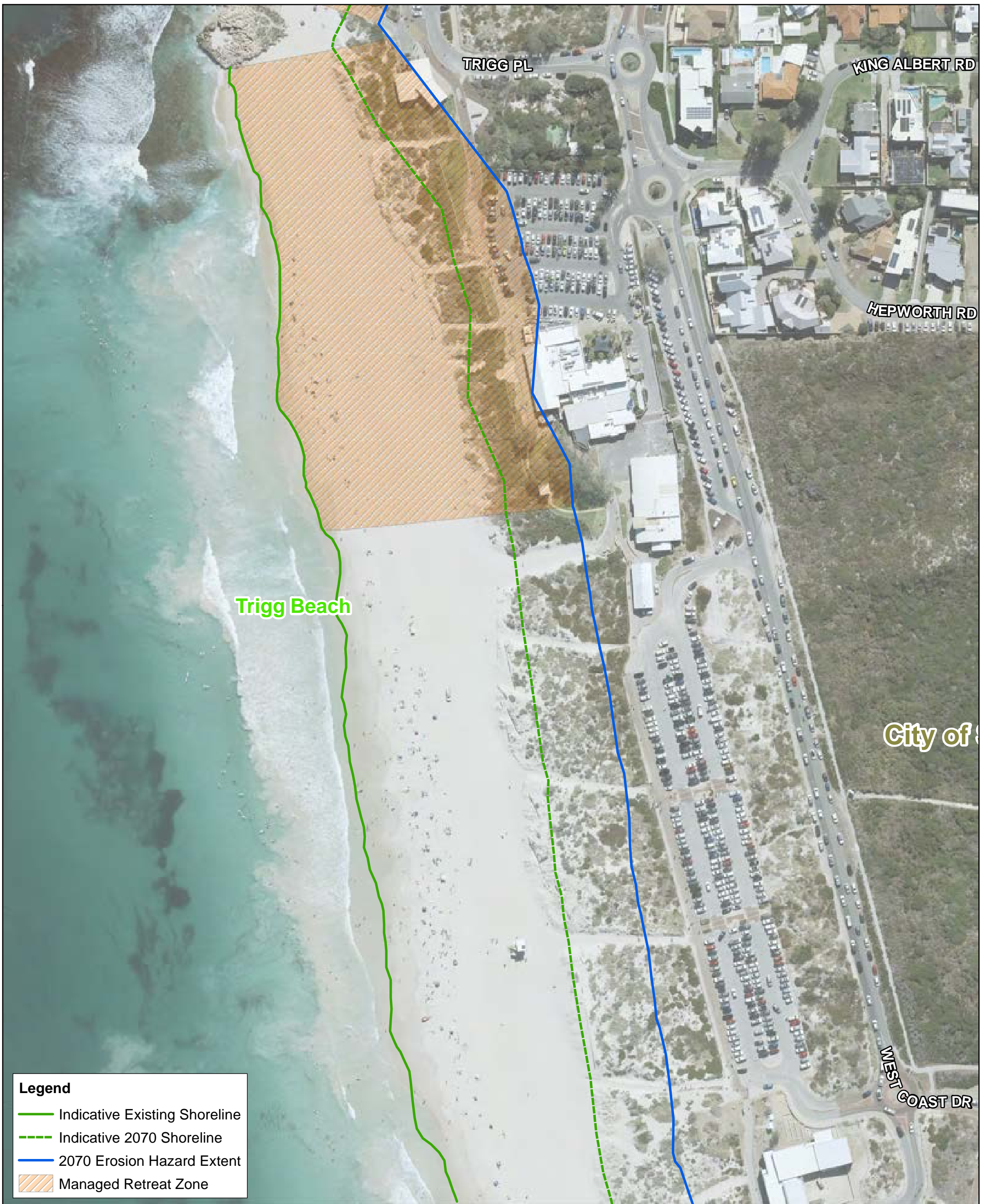


Adaptation Options Managed Retreat (MR1) MU4 - Trigg Beach North

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-13
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_ManagedRetreat.mxd 01
 Aerial imagery supplied by Metromap (2022)



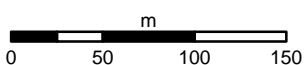


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- Managed Retreat Zone



1:4,120 Scale at A3



Adaptation Options Managed Retreat (MR1) MU6 - Scarborough Beach

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-13
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_ManagedRetreat.mxd 01
 Aerial imagery supplied by Metromap (2022)



1:2,430 Scale at A3

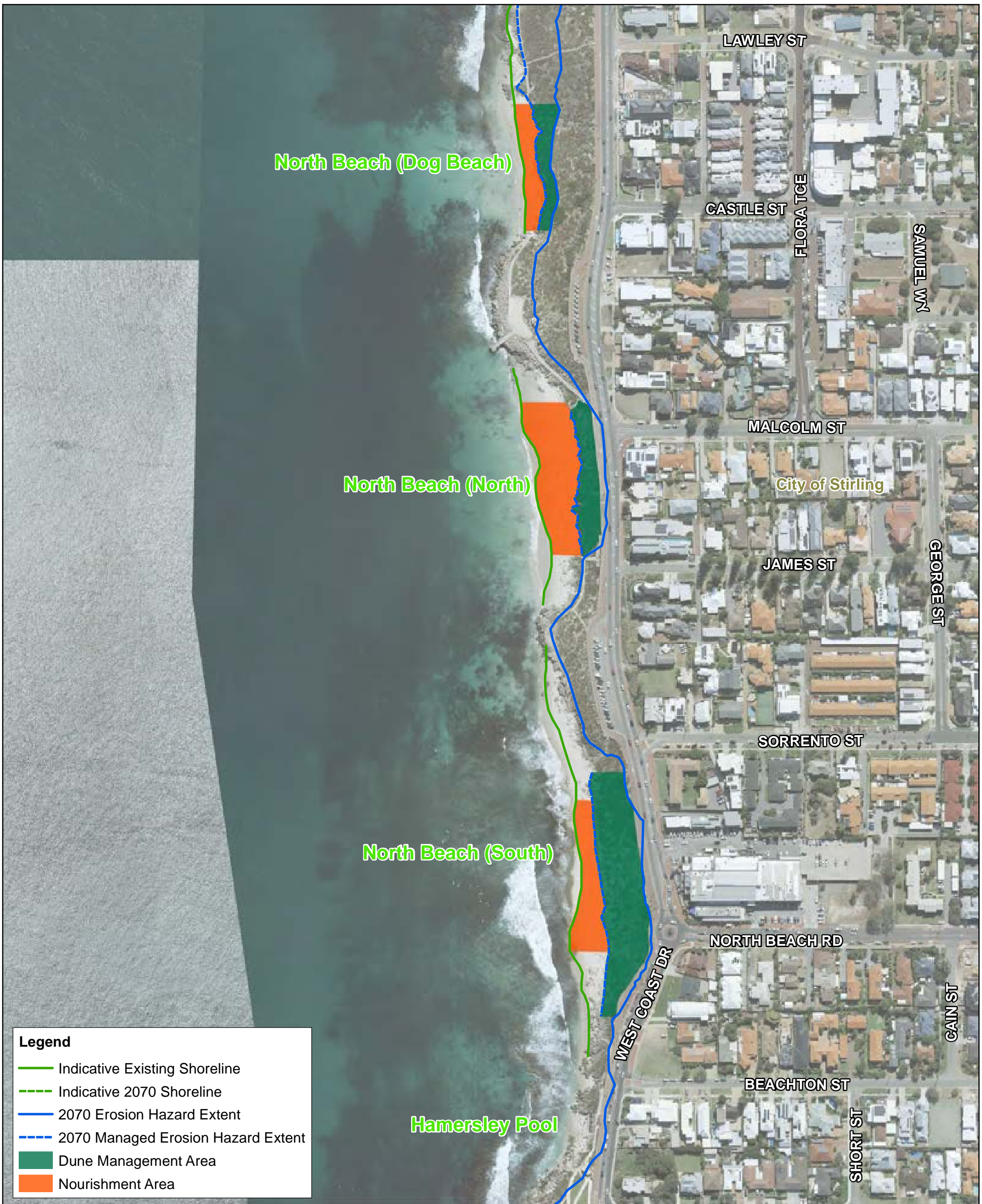


Adaptation Options Soft Protection (PR1 and PR2) MU1 - Watermans Bay

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-18
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_010_MU_ZONES_SoftProtection.mxd 01
Aerial imagery supplied by Metromap (2022)

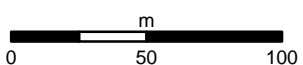


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- - - 2070 Managed Erosion Hazard Extent
- Dune Management Area
- Nourishment Area



1:2,790 Scale at A3



Adaptation Options Soft Protection (PR1 and PR2) **MU2 - North Beach**

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_SoftProtection.mxd 01
 Aerial imagery supplied by Metromap (2022)

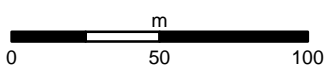


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- - - 2070 Managed Erosion Hazard Extent
- Dune Management Area
- Nourishment Area



1:2,550 Scale at A3



Adaptation Options Soft Protection (PR1 and PR2) **MU3 - Mettams Pool**

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_SoftProtection.mxd 01
 Aerial imagery supplied by Metromap (2022)

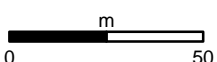


Legend

- Indicative Existing Shoreline
- 2070 Erosion Hazard Extent
- - - 2070 Managed Erosion Hazard Extent
- Dune Management Area
- Nourishment Area



1:1,950 Scale at A3

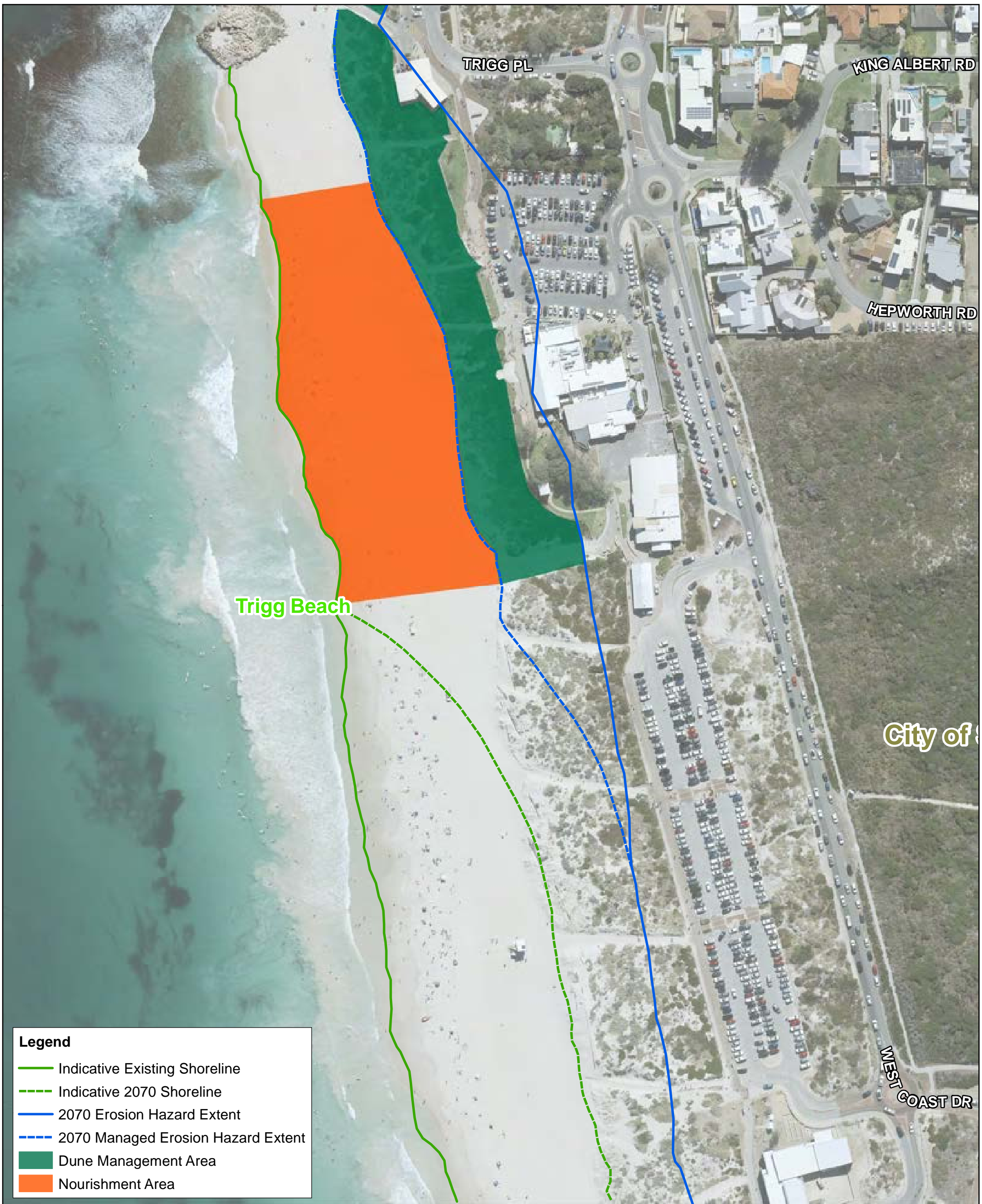


Adaptation Options Soft Protection (PR1 and PR2) MU4 - Trigg Beach North

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_SoftProtection.mxd 01
 Aerial imagery supplied by Metromap (2022)

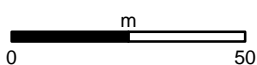


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- - - 2070 Managed Erosion Hazard Extent
- Dune Management Area
- Nourishment Area



1:1,620 Scale at A3



Adaptation Options Soft Protection (PR1 and PR2) **MU5 - Trigg Beach South**

CITY OF STIRLING CHRMAP




Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_SoftProtection.mxd 01
 Aerial imagery supplied by Metromap (2022)



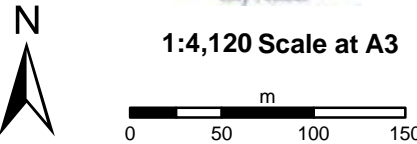
Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- - - 2070 Managed Erosion Hazard Extent
- Dune Management Area
- Nourishment Area



City of Stirling
City of Choice

1:4,120 Scale at A3



0 50 100 150
m

Adaptation Options
Soft Protection (PR1 and PR2)
MU6 - Scarborough Beach
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-18
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_010_MU_ZONES_SoftProtection.mxd 01
Aerial imagery supplied by Metromap (2022)



Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- - - Controlled 2070 Hazard Extent
- Groyne/Headland Enhancement

Adaptation Options
 Groynes / Headland Enhancement (PR3)
MU1 - Watermans Bay
 CITY OF STIRLING CHRMAP

now

Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_GroyneHeadlandEnhancement.mxd 01
 Aerial imagery supplied by Metromap (2022)

City of Stirling
 City of Choice
 1:2,430 Scale at A3

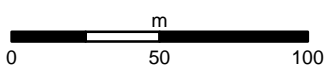


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- - - Controlled 2070 Hazard Extent
- Groyne/Headland Enhancement



1:2,550 Scale at A3



Adaptation Options
 Groynes / Headland Enhancement (PR3)
MU3 - Mettams Pool
 CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_GroyneHeadlandEnhancement.mxd 01
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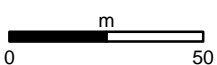


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Erosion Hazard Extent
- - - Controlled 2070 Hazard Extent
- Groyne/Headland Enhancement



1:1,950 Scale at A3



Adaptation Options Groynes / Headland Enhancement (PR3) MU4 - Trigg Beach North

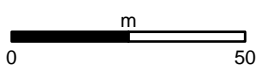
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
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 Project: CW1195500
 Map: CW1195500_MU_ZONES_GroyneHeadlandEnhancement_v2.mxd 01
 Aerial imagery supplied by Metromap (2022)



1:1,620 Scale at A3



Adaptation Options Groynes / Headland Enhancement (PR3) MU5 - Trigg Beach South

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-18
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_MU_ZONES_GroyneHeadlandEnhancement_v2.mxd 01
Aerial imagery supplied by Metromap (2022)





1:2,430 Scale at A3



Adaptation Options Nearshore Reefs / Breakwaters (PR4) MU1 - Watermans Bay

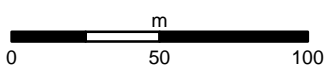
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_NearshoreReefBreakwater.mxd 01
 Aerial imagery supplied by Metromap (2022)



1:2,550 Scale at A3



Adaptation Options Nearshore Reefs / Breakwaters (PR4) **MU3 - Mettam's Pool**

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-18
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_010_MU_ZONES_NearshoreReefBreakwater.mxd 01
Aerial imagery supplied by Metromap (2022)

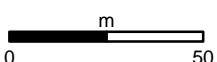


Legend

- 2070 Erosion Hazard Extent
- - - 2070 Managed Erosion Hazard Extent
- Indicative Existing Shoreline (maintained to 2070)
- Indicative Enhancement Area



1:1,950 Scale at A3



Adaptation Options Nearshore Reefs / Breakwaters (PR4) MU4 - Trigg Beach North

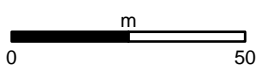
CITY OF STIRLING CHRMAP



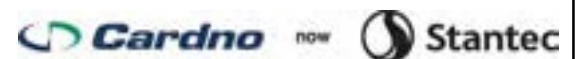
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 Date: 2022-07-13
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_NearshoreReefBreakwater.mxd 01
 Aerial imagery supplied by Metromap (2022)



1:1,620 Scale at A3



Adaptation Options
 Nearshore Reefs / Breakwaters (PR4)
MU5 - Trigg Beach South
 CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-22
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_NearshoreReefBreakwater.mxd 01
 Aerial imagery supplied by Metromap (2022)



Scarborough Beach (North)

Scarborough Beach

Brighton Beach

PEARL PDE

NAUTILUS CR

SOUTHBOURNE ST

RESERVE ST

FILBURN ST

EDGEHILL ST

MANNING ST

THE ESPLANADE

City of Stirling

SCARBOROUGH BEACH RD

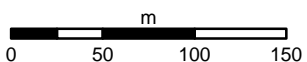
WEST COAST HWY

BRIGHTON RD

HASTINGS ST



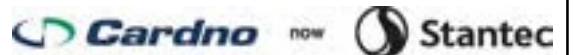
1:4,120 Scale at A3



Adaptation Options
Nearshore Reefs / Breakwaters (PR4)

MU6 - Scarborough Beach

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-22
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_010_MU_ZONES_NearshoreReefBreakwater.mxd 01
Aerial imagery supplied by Metromap (2022)



Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Hazard Extent
- - - Controlled 2070 Hazard Extent
- Revetment/Seawall



1:2,430 Scale at A3



Adaptation Options
Revetments / Seawalls (PR5)
MU1 - Watermans Bay
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-18
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_010_MU_ZONES_RevetmentSeawall.mxd 01
Aerial imagery supplied by Metromap (2022)

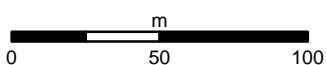


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Hazard Extent
- - - Controlled 2070 Hazard Extent
- Revetment/Seawall



1:2,550 Scale at A3



Adaptation Options Revetments / Seawalls (PR5)

MU3 - Mettams Pool

CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-18
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_RevetmentSeawall.mxd 01
 Aerial imagery supplied by Metromap (2022)

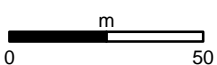


Legend

- Indicative Existing Shoreline
- - - Indicative 2070 Shoreline
- 2070 Hazard Extent
- - - Controlled 2070 Hazard Extent
- Revetment/Seawall



1:1,950 Scale at A3



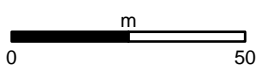
Adaptation Options
Revetments / Seawalls (PR5)
MU4 - Trigg Beach North
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-13
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_010_MU_ZONES_RevetmentSeawall.mxd 01
Aerial imagery supplied by Metromap (2022)



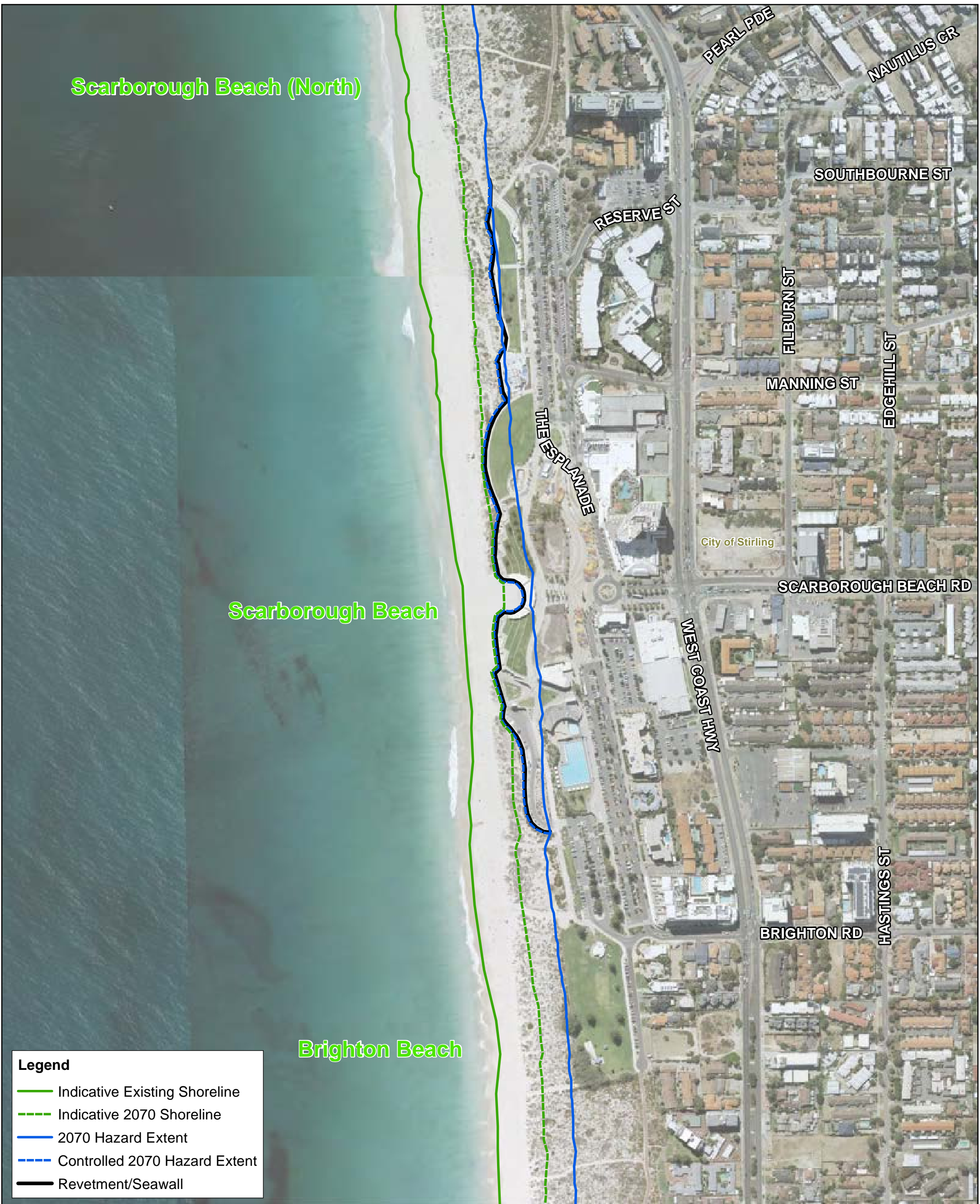
1:1,620 Scale at A3



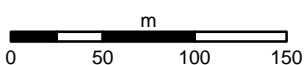
Adaptation Options
 Revetments / Seawalls (PR5)
MU5 - Trigg Beach South
 CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
 Date: 2022-07-13
 Coordinate System: GDA 1994 MGA Zone 50
 Project: CW1195500
 Map: CW1195500_GS_010_MU_ZONES_RevetmentSeawall.mxd 01
 Aerial imagery supplied by Metromap (2022)



1:4,110 Scale at A3



Adaptation Options
Revetments / Seawalls (PR5)
MU6 - Scarborough Beach
CITY OF STIRLING CHRMAP



Map Produced by Cardno (WA) Pty Ltd
Date: 2022-07-13
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_010_MU_ZONES_RevetmentSeawall.mxd 01
Aerial imagery supplied by Metromap (2022)

APPENDIX

E

CBA METHODOLOGY



now



City of Stirling CHRMAP

Benefit-cost analysis of adaptation options

Michael P Burton* and Abbie A Rogers

Centre for Environmental Economics & Policy

UWA School of Agriculture & Environment

UWA Oceans Institute

***michael.burton@uwa.edu.au**

Report prepared for Cardno and the City of Stirling



19th September, 2022

Benefit-cost analysis for coastal adaptation

This report summarises the data inputs, approach and assumptions made in the benefit-cost analysis (BCA) of coastal adaptation responses for the City of Stirling CHRMAP. The complete detail of the benefit-cost analysis can be found in the accompanying spreadsheet (Stirling EconomicAnalysisInputs_909.xlsx).

Terms used throughout:

BCA = benefit-cost analysis

MU = management unit

NPV = net present value

Structure of analysis

A separate, but consistent, BCA was conducted for each of the management units (MUs). For each MU a range of adaptation options were evaluated based on the technically feasible options determined by Cardno (Stantec).

Below are the MUs and the options evaluated for each (*italics indicating the base case for comparison*):

MU1 Watermans Bay	MU2 North Beach	MU3 Mettams Pool	MU4 Trigg Beach North	MU5 Trigg Beach South	MU6 Scarborough Beach
<i>Managed retreat</i>	<i>Managed retreat</i>	<i>Managed retreat</i>	<i>Managed retreat</i>	<i>Managed retreat</i>	<i>Managed retreat</i>
Beach nourishment	Beach nourishment	Beach nourishment	Beach nourishment	Beach nourishment	Beach nourishment
Headlands		Headlands	Headlands	Groynes	Groynes
Reefs		Reefs	Reefs	Breakwaters	Breakwaters
Revetments / seawalls		Revetments / seawalls	Revetments / seawalls	Revetments / seawalls	Revetments / seawalls

The net present value (NPV) of the potential options must be measured relative to a counterfactual or 'base case', which represents the scenario of business-as-usual. Sometimes this reflects the zero-investment, do nothing situation. However, in the context of coastal adaptation where there are built assets in place this solution is not viable, as there is a requirement to remove infrastructure as it becomes impacted or damaged, to avoid safety risks. This means that some form of managed retreat must reflect the base case.

Managed retreat can take on various forms, ranging from the removal of infrastructure as the hazard lines encroach, to the removal of infrastructure and full replacement of that infrastructure in another location.

Here, we assume that the base case of managed retreat is defined as the latter, where infrastructure are demolished and rebuilt. However, as explained in the footnotes later (page 4), the relative NPV and rankings of options would be the same using either of the potential definitions of managed retreat because of assumptions made about the value of the built assets, given data availability.

The results of the BCA are reported as the NPV of each of the potential adaptation options for a MU relative to the base case of managed retreat. That is, it reflects whether there is a benefit gained or a

cost incurred to implement an option of beach nourishment, reefs, revetments, etc, relative to the cost of managed retreat.

Below, we refer to 'financial costs' as the costs that would be borne by the City to implement an option. Among other benefits and costs, there are both 'positive benefits', meaning there is a positive value associated with implementing an option, typically due to an avoided loss of an asset due to the protection afforded by an adaptation response, and also as 'negative benefits'. Negative benefits are effectively a cost, but as they reflect the lost value of an asset that is no longer protected, they are not a financial cost.

Data inputs and assumptions

Timeframe for analysis

The BCA is conducted over a 50 year time frame, with future benefits and costs discounted to present values using a 7% discount rate.

It is assumed that, without intervention:

- Loss of natural assets (beach, dunes, foreshore reserve) will occur linearly over time.
- Built assets would require demolition at different points in time, reflecting the hazard lines (i.e. they are not likely to need immediate removal). Removal was specified to occur in either 25 years time, in 50 years time, or as a proportion at 25 and 50 years time, depending on the location of the asset relative to hazard lines and whether it would need complete or partial (staged) removal.

Assets

Built assets represented in the analysis included:

- Pavement / roads
- Minor infrastructure and amenities
- Assets at specific MUs, including
 - Lookout, GSC revetment (MU1)
 - Jetty (MU2)
 - Toilet blocks, access ramps (MU3)
 - Surf lookout, café (MU5)
 - Amphitheatre, skate park, playground (MU6)

Natural assets represented in the analysis included:

- The area of sandy beach available
- The area of vegetated dunes maintained
- The area of foreshore reserve available

Data sources

Financial cost estimates were provided by Cardno, based on current market prices.

Natural assets require non-market value estimates, which provide a measure of people's willingness to pay to maintain or avoid loss of intangible, environmental assets. These values were sourced via

benefit transfer (extrapolation) from the Rogers et al. 2019¹ non-market valuation study of Yanchep Beach.

Making appropriate adjustments to allow for differences in absolute size of the coastal locations, inflation, and the number of households in the City of Stirling, this provided the following estimates:

- \$3,116.18 aggregate value per square metre of sandy beach
- \$131.99 aggregate value per square metre of vegetated dune

The Yanchep study did not provide an estimate of willingness to pay for foreshore reserves. As the foreshore reserve supports a similar range of uses to the sandy beach as a recreational space, we adopted a conservative estimate per square metre of 50% of the sandy beach value.

The Yanchep study did provide a willingness to pay estimate of facilities being present, which was considered to represent the benefit of retaining built assets. However, the scope of assets represented across the Stirling MUs was substantially different to those considered at Yanchep for most MUs (e.g. an amphitheatre, large playground, skatepark, jetty, lookout). As such, we did not consider a benefit transfer of this value to be reliable.

Instead, we adopted the conservative approach to use the replacement cost of the built assets as a proxy² for its actual value: it can be assumed that the benefit of the asset is at least as much as it costs to re-build it.

Managed retreat base case – costs and benefits

The financial costs associated with the managed retreat option were provided by Cardno based on current market estimates, and included:

- Demolition costs of infrastructure.
- Replacement cost of infrastructure.

The benefits included:

- The re-located infrastructure, using the replacement cost as the measure of value.
- Non-market benefits (positive or negative) associated with gain or loss of natural assets.

Adaptation options – costs and benefits

The financial costs of implementing the adaptation options included the following (wherever relevant for a particular option):

- Capital costs of infrastructure
- Ongoing maintenance costs of infrastructure
- Nourishment costs

¹ Rogers, A.A., Burton, M.P. and Subroy, V. 2019, "Testing the application of non-market valuation instruments for measuring community values affected by coastal hazards: Yanchep Beach case study". Report prepared for the Western Australian Department of Planning, Lands & Heritage by The University of Western Australia, Crawley.

² Adopting the replacement cost to represent the benefit of re-building the assets effectively nets out the benefit of replacing to zero: there is the cost of replacing, and the benefit of having done that is an equivalent value. It is for this reason that there is no difference in present value costs or benefits for a managed retreat scenario that does or doesn't replace infrastructure. If the value of the asset exceeds costs then the option of not replacing the infrastructure will underestimate the costs associated with the loss.

Reflecting that sand is likely to increase in scarcity as beach nourishment activities increase in future, the cost of sand is assumed to increase at 2% per year in real terms (i.e. above any increases due to inflation).

The outcomes of the options in terms of their gain or loss of the built and natural assets are then factored in, using value estimates as per the data sources described above. Where a gain is made, the value is positive. Where there is an asset loss, the value is negative.

Results

The table below reports the NPV of the adaptation options, relative to the managed retreat base case. Positive values indicate that the option generates net benefits over the base case of managed retreat. Negative values indicate the additional costs exceed the values being protected.

NPV of management options, using managed retreat as base case				
MU1 - Watermans Bay				
	Beach Nourishment	Headlands	Reefs	Revetments/Seawalls
	\$4,555,177	-\$2,120,182	\$1,171,571	-\$5,746,076
MU2 - North Beach				
	Beach Nourishment			
	\$15,733,320			
MU3 - Mettams Pool				
	Beach Nourishment	Headlands	Reefs	Revetments/Seawalls
	\$9,707,888	\$458,190	\$3,468,940	-\$5,327,660
MU4 - Trigg Beach North				
	Beach Nourishment	Headlands	Reefs	Revetments/Seawalls
	\$8,709,200	\$1,168,709	\$4,254,727	\$4,580,552
MU5 - Trigg Beach South				
	Beach Nourishment	Groynes	Breakwaters	Revetments/Seawalls
	\$22,939,717	\$15,120,924	\$9,099,425	-\$3,436,922
MU6 - Scarborough Beach				
	Beach Nourishment	Groynes	Breakwaters	Revetments/Seawalls
	\$35,667,990	\$27,007,908	-\$78,426	\$2,357,126

Summary and additional considerations

The key outcomes are summarised as follows:

- Beach nourishment represents the preferred option in all MUs, generating the largest NPV.
- Reefs are also a viable option for MU1 and MU3 where they are the second ranked option, and MU4 where they are the third ranked option (but see the additional considerations below: the potential co-benefits of the reef option would likely place this ahead of revetments in the MU4 ranking given they generate a similar NPV in the current analysis).

- Groynes are the second ranked option for MU5 and MU6.
- Headlands are marginally beneficial for MU3 and MU4, but do not generate a net benefit for MU1.
- Breakwaters are the third ranked option for MU5, but do not generate a benefit for MU6.
- Revetments provide a net benefit similar to reefs at MU4, and a marginal benefit at MU6. They generate a net cost at MU1, MU3 and MU5.

The NPV results are based on the data inputs and assumptions outlined earlier. Different assumptions will change the NPV and could lead to different rankings. We conducted sensitivity tests to understand how robust the rankings are.

- Changing the discount rate to 3% or 10%, which is a standard sensitivity test in BCA: this does not alter the rankings.
- Changing the real increase in sand costs, in case scarcity increases more than expected: this needs to be increased from 2% to ~12% to make the beach nourishment option uncompetitive to other options. A 12% real increase implies a 10-fold increase in costs by the end of year 20.
- Changing the assumed 50% scaling of the sandy beach willingness to pay value, as applied to the foreshore reserve value: changing the % used changes the absolute NPV but does not affect ranking.

Finally, we recognise that as this BCA has been conducted as a screening analysis, rather than as a full business case that considers a wider range of (more accurate) data inputs. Some omissions from this BCA include:

- An accurate estimation of the value associated with replacing built infrastructure (i.e. a true measure of consumer and producer surplus, instead of using replacement costs).
- Loss of access to beaches. This has not been included as an additional value, over loss in beach area. If included this would increase the values being protected but have no impact on the absolute ranking of options.
- The co-benefits of the reef options. When considering the reef options, it is assumed that the benefits that accrue are limited to changes in coastal assets. However, depending on the nature/location of the reef there may be additional environmental or recreational benefits that could be considered, for example their contribution to marine habitat, or opportunity to dive/snorkel on the reef.

Given that reefs are ranked second, the difference in values between reef and beach nourishment options gives some indication of the size of the co-benefits that would be required from the reef to change the rankings. Given the temporary effect of beach nourishment (i.e. it requires ongoing implementation), there is an opportunity to pursue that option in the interim while gathering additional information to identify estimates of reef co-benefits which might provide a longer term solution.