



Shire of Murray CHRMAP

Coastal Hazard Risk Management and Adaptation Plan

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Shire of Murray CHRMAP

Coastal Hazard Risk Management and Adaptation Plan

Prepared for:

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Executive Summary

The Shire of Murray (SoM) has developed a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to develop a greater understanding of its coastal areas and support its future coastal management and planning decisions. The study area includes the eastern shoreline of the Peel-Harvey estuary and the tidally influenced sections of the Murray River and Serpentine River.

The CHRMAP examines the processes of erosion and inundation within the study area to understand coastal hazard risk affecting the shoreline areas today and the forecast impacts over the next 100 years (to 2120) associated with projected climate change and sea level rise.

The CHRMAP project was developed in consultation with SoM, the local community and a range of stakeholders, in accordance with local and national guidelines. The project was delivered through a multi-discipline approach incorporating science, engineering, community engagement, land use planning and economic expertise. The project aim is to improve the understanding of coastal hazard risk for the community and stakeholders and to develop coastal adaptation approaches and pathways which can mitigate risk over the short to medium term (next 10-20 years) and provide management and adaptation strategies to mitigate hazard in future planning periods (next 100 years).

The seven stages in the CHRMAP are shown in Figure E.1. After each stage, the project deliverables were summarised in a Chapter Report for review by the project Steering Committee and Community Reference Group (CRG).

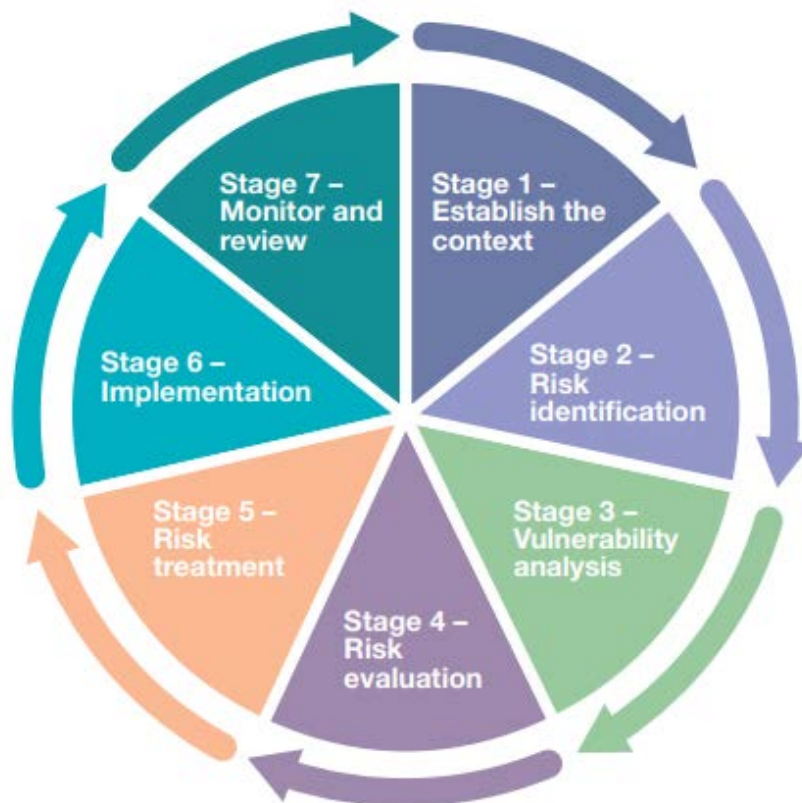


Figure E.1: CHRMAP Stages (WAPC 2019)

A range of Community Engagement activities have been undertaken to support the project which have developed the understanding of the project within the community and fostered local input to the CHRMAP process. The process with stakeholders and community is outlined in Section 3 and has sought engagement on:

- Potential risks arising from hazards in the estuarine and tidally influenced riverine zones;
- Key shoreline infrastructure and assets at risk within these zones;
- Community and cultural values within these zones; and
- Adaptation pathways and management options that the SoM and other stakeholders can pursue to address the risks from coastal hazard over time.

A summary of the coastal hazard is presented in Section 5 of this report. A range of planning timeframes are considered (present day, 2030, 2050, 2070, 2120). The study area is divided into six Shoreline Management Units (SMU) for the purpose of the CHRMAP covering the locations:

- 1. South Harvey.
- 2. Birchmont.
- 3. Point Grey to Austin Bay.
- 4. South Yunderup.
- 5. North Yunderup.
- 6. Serpentine.

There are a range of coastal assets through the SoM that will be impacted by coastal erosion and/or inundation in future planning periods. In Section 6 of this report the coastal assets are broadly described in the categories Social, Economic, Environmental and Heritage. Coastal asset types through the SoM study area and their functions, services and values were determined by the stakeholders and through community engagement activities.

The risk assessment framework is detailed in Section 7, with likelihood and consequence applied in a vulnerability assessment to determine how the effects of coastal hazards are predicted to impact assets in current and future planning periods. The assessment first considers the potential impact to coastal assets as a combination of the *likelihood* and the *consequence* of that hazard occurring. The vulnerability assessment then considers the adaptive capacity of coastal assets; that is, the ability of a coastal asset to accommodate coastal hazard impact.

The Risk Treatment in Section 10 outlines risk treatment options that are considered in this CHRMAP within general risk treatment categories 'Avoid', 'Planned or Managed Retreat', 'Accommodate' and 'Protect'. A range of adaptation tools available to mitigate coastal risk were applied in the CHRMAP under the key category definitions. Within each of the SMU there are risk treatment actions that are recommended to mitigate the risk to respective coastal assets.

A multi-criteria analysis (MCA) to contrast and compare adaptation options was completed for four key focus areas highlighted in the Risk Assessment phase (Section 13). The key focus areas that were identified for the MCA application were:

- Erosion / Inundation of Nature Reserves (Kooljerrenup)
- Inundation of low-lying properties (Murray Delta Islands, South / North Yunderup and Furnissdale)
- Erosion of riverbanks through North and South Yunderup (including Murray Delta Islands)
- Septic Tanks

Criteria were assigned a "score" based on the expected performance against three key categories - Technical, Social and Environmental. Cost was also considered but as a standalone category.

An MCA workshop was completed in November 2021, delivered by the study team in person at the Shire offices with attendees comprised of the CRG and stakeholders from the Shire. Representatives from the MDDRA attended the MCA workshop, but stated at the start of the session they would participate without endorsing the outcomes. Cost Benefit Analysis (CBA) followed on from the MCA process by examining the short-listed and highest-ranking options in detail. The CBA is detailed in Section 14 and refines the evaluation by quantifying the economic value of the various adaptation options considered to mitigate against hazards associated with coastal erosion and inundation. The key findings from the CBA in terms of supporting CHRMAP recommendations for adaptation options in the SMU's is summarised as follows:

- a) For the Murray Delta Islands, the low density of development on the islands and the large lot sizes lead to relatively high mitigation option costing relative to the benefit. While that is the case, nature-based approaches would become viable in the next 10 years (based on low cost to mid-range projections). It is recommended under the CHRMAP that natural approaches to protect the shoreline areas on the three islands commence now.
- b) For the Murray River shoreline of North Yunderup, the nature-based solutions perform well due to the density of properties in this area and their proximity to the river. However, there may be practical challenges in implementing nature-based solutions within the available space in this area. A hard engineering solution is expected to be viable within 10 years. It is recommended that a technical study is undertaken in the next five years (by 2027) to examine an engineered hard structure (river wall) along the North Yunderup section of shoreline. This process would involve representatives from the North Yunderup community and be used to confirm requirements including the design and construction method, estimate of costs and the mechanism for funding the project through residents who would directly benefit from the erosion protection provided.
- c) The shoreline along the Murray River at South Yunderup performs well with nature-based solutions indicating these options are supported for implementation today. These solutions suit the shoreline areas with generally greater land buffer in this location compared with the northern side of the Murray River.
- d) Erosion of the Kooljerrenup Nature Reserve was assessed against the adaption strategy of purchasing land on the eastern side of the reserve, to mitigate the loss of land due to erosion on the shoreline side. Loss of land area is projected to increase markedly after the 2050 period due to shoreline erosion driven by projected sea level rise. Monitoring of the shoreline areas and their response to sea level rise in the next 20 years will inform the future adaptation strategy with further consideration of the need for potential acquisition of land recommended in the 2040 to 2050 planning period.

A benefit Distribution Analysis has been completed to examine the beneficiaries of the recommended adaptation options. This has shown that the private landholders are the key beneficiaries of many of the high-cost adaptation options recommended:

- For nature-based solutions on the Murray Delta Islands there is estimated to be an 80% / 20% distribution of the benefit between the private landholders and public.
- Nature based options for the South Yunderup shorelines are estimated to deliver 50% private and 50% public benefit.

It is recommended the Shire seek funding contribution from private landholders who will directly benefit from the adaptation approaches.

A summary of the short-term implementation tasks (next 10-15 years) is as follows:

- a) Planning Recommendations: The key items for the short-term timeframe implementation program and indicative timeframe are as follows:
 - Initiate amendment to LPS4 to introduce a Special Control Area (immediately).
 - Prepare a local planning policy (immediately).
 - Update and amend Emergency Evacuation Plan (next 5-years).
 - Prepare a Foreshore Management Plan (next 5-years)

- b) Annual Monitoring Program: Projected annual cost of \$16,000 – 18,000 annually to monitor:
 - Foreshore berm on the Peel shorelines along the western facing beaches of the Murray Delta Islands. The monitoring of the berm height along the shoreline is recommended every 3-years, through spatial survey data capture (via UAV or LiDAR). Following significant events where erosion may occur on the shorelines survey should also be captured.
 - Murray Delta Island shorelines on Ballee Island, Culeenup Island and Yunderup Island should be monitored through spatial survey data capture (via UAV or LiDAR) approximately every 5 years.
 - Photo Monitoring of shoreline areas for erosion at Herron Point, North and South Yunderup and the Murray Delta Islands (photo capture 2x annually and following significant storm events)
- c) Additional Technical Studies: Projected Cost \$45,000 to investigate:
 - Assessment, planning and costing for a centralised ATU system (next 5-years)
 - Murray Delta Islands building register (next 5-years)
 - Erosion impacts from boat wakes on the river shoreline (next 5-years)
- d) Planning Based Studies and Adaptation Studies: Projected Cost \$85,000 for the following:
 - Feasibility study for protection structure along North Yunderup shoreline in front of Coolenup Rd properties (next 5-years)
 - Prepare an Emergency Evacuation Plan (next 5-years)
 - Review of CHRMAP (5-yr Review)
 - Prepare a Managed Retreat Policy (6-10 years).
- e) Adaptation Actions in Shoreline Areas.
 - Ballee Island, Coolenup Island and Yunderup Island – Nature Based solutions (now)
 - South Yunderup shoreline section Young Street to Pelicans – Nature Based Solutions (now)
 - Coopers Mill Shoreline – Nature Based solutions (now)

A summary of planning-based mechanisms recommended for implementation by the Shire to manage the impacts of erosion and inundation is presented in the CHRMAP. The key planning controls are:

- a) Introduce a Special Control Area which triggers the requirement for normally exempt development to require planning approval.
- b) Prepare a local planning policy (LPP) to establish development standards to ensure new development can address projected coastal hazard from erosion and inundation.

An annual monitoring program should be a commitment post-CHRMAP to develop the understanding of the coastal processes in the Shire at key locations for erosion and inundation risk. The monitoring outcomes will be used to assess trigger points and to inform future revisions of the CHRMAP. The monitoring and review process will ensure that the management and adaptation actions identified in the CHRMAP remain relevant.

Funding for additional technical studies and shoreline management actions would be the responsibility of the Shire. There are a number of State and National grant funding sources that could be accessed to co-fund the work that provides public benefit, with a summary of these presented in Section 19.3.

The final recommendations for long-term adaptation pathways are discussed in Section 15 and summarised in Tables E.1 to E.6 for the six respective SMU's.

Table E.1: Risk Management and Adaptation Pathways - SMU1: South end of Harvey Estuary

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 – 2120
Assets	Shire Minor Infrastructure. Herron Point Campground and Assets (Toilets, Campsites, Minor Infrastructure). Coastal Pathways / Bridle Paths			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Coastal Infrastructure. Herron Point Boat Ramp and Car Park			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Herron Point Foreshore Reserve and Beach			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			
Assets	Kooljerrenup Nature Reserve			
Pathway	Do Nothing (DN1) – Take no action and accept the risk			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			

Table E.2: Risk Management and Adaptation Pathways – SMU2: Birchmont

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage, drainage) and Coastal Pathways			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Coastal Infrastructure. Birchmont Boat Ramp and Car Park			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties at Birchmont and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1) 1. - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	Foreshore Reserve adjacent the Boat Ramp and carpark			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			
Assets	Nature Reserves			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Do Nothing (DN1) – Take no action and accept the risk			

Table E.3: Risk Management and Adaptation Pathways – SMU3: Point Grey to Austin Bay

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Carabunga Road			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1) - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	Foreshore Areas and Nature Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Do Nothing (DN1) – Take no action and accept the risk			

Table E.4: Risk Management and Adaptation Pathways – SMU4: South Yunderup

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways, Drainage Features			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Boat Ramps, Jetties, Carports, Toilets			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1) - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	River Shorelines and Foreshore Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9). Assets Forecast to become highly or very highly vulnerable in next planning timeframe or next 10 years (T6)			
Assets	Foreshore Areas and Nature Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Do Nothing (DN1) – Take no action and accept the risk			

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Protection Structures and Seawalls - Batavia Quays, South Yunderup Bund, Canals			
Pathway	Conduct a protection structure audit (NR.2)			
Pathway	Continue to maintain the existing seawalls to provide erosion and inundation protection for areas landward (Pr.4)			
Trigger	Assets predicted to become highly or very highly vulnerable within next 10 years (T6)			
Assets	Key Access Roads			
Pathway	Develop Emergency evacuation plan for key routes such as South Yunderup Road (NR.4)			

Table E.5: Risk Management and Adaptation Pathways – SMU5: North Yunderup and Murray Delta Islands

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways, Drainage Features			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Boat Ramps, Jetties, Carparks, Toilets			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Berm along the western shoreline of the Murray Delta Islands in Peel Inlet			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore (T9)			
Assets	Existing Residential Properties and Undeveloped Land – North Yunderup Culeenup Rd			
Pathway	Avoid Development in Erosion Hazard (Av.1) Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of future planning period erosion and/or inundation extent (T4, T10)			
Assets	River Shoreline section of Culeenup Road Properties with River Frontage			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.	Engineering edge treatments to protect against erosion and inundation (PR.4)		
Trigger	Residential or commercial property lies seaward of the most up to date 100-year coastal	Assets predicted to become highly or very highly vulnerable within next planning timeframe or within 10-years (T6)		

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
	erosion hazard line or coastal inundation hazard extent (T4)			
Assets	River Shorelines, Peel Inlet Shorelines and Foreshore Reserve			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			
Assets	Murray Delta Islands – Residential Properties			
Pathway	Avoid Development in Erosion Hazard (Av.1) - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion of inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.		Removal or relocation of Asset (MR2)	
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)		HSD is within the S1 distance, asset becomes highly vulnerable or damaged due to erosion (T1, T5, T6).	
Assets	Murray Delta Islands – Shorelines Ballee Island, Yunderup Island, Culeenup Island Adjacent Residential Properties			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and river shorelines (T9)			
Assets	Coopers Mill			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events and inundation events.			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Trigger	Impacts to beach and river shorelines (T9)			
Pathway	Do Nothing (DN1) – For inundation : Take no action and accept the risk			
Assets	General River Shorelines and Nature Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Do Nothing (DN1)			
Assets	Key Access Roads			
Pathway	Develop Emergency evacuation plan for key routes such as North Yunderup Road (NR.4)	Design Assets to withstand Coastal Hazard Impacts (AC2, AC3, AC4)		
		Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.		
Trigger	Assets predicted to become highly or very highly vulnerable within next 10 years (T6)	Asset is damaged or unsafe (T5)		

Table E.6: Risk Management and Adaptation Pathways – SMU6: Serpentine

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways, Drainage Features			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Boat Ramps, Jetties, Carports, Toilets			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1) - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	River Shorelines and Foreshore Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			

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Appendices

Appendix A Stakeholder and Community Engagement Plan

Appendix B Engagement Outcomes Summary

Appendix C Coastal Hazard

Appendix D Vulnerability Assessment by Shoreline Management Unit

Appendix E Planning Instruments Review

Appendix F Asset Mapping and Coastal Hazard Area

Appendix G Adaptations Option Workshop Summary

Appendix H Hazard Impact Regions

Appendix I Economic Report (Rhelm)

Table of Abbreviations

Abbreviation	Full Wording
BCR	Benefit Cost Ratio
CHRMAP	Coastal Hazard Risk Management and Adaptation Plan
CBA	Cost Benefit Analysis
CRG	Community Reference Group
DoT	Department of Transport
DPLH	Department of Planning, Lands and Heritage
DWER	Department of Water and Environmental Resources
HSD	Horizontal Shoreline Datum
LPP	Local Planning Policy
MCA	Multi-Criteria Analysis
MDRRA	Murray Delta Residents and Ratepayers Association
NBS	Nature Based Solutions
NPV	Net Present Value
SoM	Shire of Murray
SCA	Special Control Area
SMU	Shoreline Management Unit
SPP2.6	State Coastal Planning Policy. State Planning Policy 2.6
TAG	Technical Advisory Group
WAPC	Western Australian Planning Commission

1. Introduction

1.1 Introduction

The Shire of Murray (SoM) is facing the adverse impacts of coastal erosion and inundation along its estuarine shorelines, with vulnerability to these impacts within the estuarine and tidally influenced riverine zones expected to increase for land use and development in the future. The shoreline areas in the SoM are currently impacted by erosion and inundation processes, with impacts seen through loss of fringing vegetation in some areas of the Peel Harvey Estuary, the Murray and Serpentine River entrances, and through observation of the Murray delta islands being periodically affected by high water levels and erosive conditions.

The Western Australian Government has accepted that climate change and sea level rise are issues that will affect the State in the coming century and an allowance for sea level rise of 0.9m over the next 100 years has been adopted for coastal planning purposes, consistent with other Australian States. The projected sea level rise in the coming century is expected to increase the vulnerability of assets in the Peel-Harvey Estuary to coastal hazards such as inundation and erosion. In response, the Shire have initiated specialist studies to understand coastal hazard risk over a range of future planning periods which will be used to inform planning and management of its estuarine and tidally influenced riverine areas.

In accordance with Western Australia's State Planning Policy 2.6 – State Coastal Planning Policy (SPP2.6), coastal areas (including estuarine and tidally influenced riverine areas) identified as being at risk of coastal hazard require a coastal hazard risk management and adaptation plan (CHRMAP). The CHRMAP process is a risk-based approach to ensure that the coastal hazard is factored into decision-making for future planning requirements and has been established in Western Australia for the past decade, with guidelines published by the Department of Planning, Lands and Heritage (DPLH, WAPC 2019).

1.2 Project Delivery

The CHRMAP project for Murray region has been developed in consultation with SoM, the local community and a range of stakeholders, delivered in accordance with local and national guidelines and standards (WAPC 2019, AS5334-2013).

The CHRMAP project examined the processes of erosion and inundation within the study area to understand coastal hazard risk presently affecting the estuarine areas and tidally influenced riverine zones, and the impacts forecast over the next 100 years (to 2120) under projected sea level rise.

A coastal hazard study to determine coastal erosion and coastal inundation hazard informs the CHRMAP and was completed in accordance with SPP2.6 requirements (Seashore 2021). A range of planning timeframes are considered over future planning periods (present day, 2030, 2050, 2070, 2120).

A range of Community Engagement activities have been undertaken to support the project delivery which have developed the understanding of the project within the community and fostered local input to the CHRMAP process. The process with stakeholders and community has sought engagement on:

- Potential risks arising from hazards in the estuarine and tidally influenced riverine zones;
- Key shoreline infrastructure and assets at risk within these zones;
- Community and cultural values within these zones; and
- Adaptation pathways and management options that the SoM and other stakeholders can pursue to address the risks from coastal hazard over time.

The CHRMAP was developed in a manner consistent with the views of the stakeholders and community. Identification of adaptation pathways and management options were guided by a rigorous economic assessment of alternatives, with the options presented to the community reference group (CRG) and key stakeholders for approval.

The CHRMAP will provide a basis for decision making by the Shire in terms of the location and maintenance of its coastal infrastructure and provide guidance for the development of statutory planning controls.

1.3 Project Team

The SoM is the key Client, with a project team of Shire officers appointed to work with the multi-disciplinary consultant team composed of:

- Baird Australia (Coastal Hazard Risk and Adaptation Planning, Lead Consultant);
- Seashore Engineering (Coastal Hazard Assessment);
- Element (Statutory and Strategic Planning, Stakeholder and Community Engagement); and
- Rhelm (Economic Analysis).

A Technical Advisory Group (TAG) was appointed as a 'Steering Group' to review project milestones and deliverables and includes representatives from:

- Department of Planning, Lands & Heritage;
- Department of Transport;
- Department of Water and Environmental Regulation;
- Peel Harvey Catchment Council;
- Department of Biodiversity, Conservation and Attractions;
- Peron Naturaliste Partnership; and
- City of Mandurah

A Community Reference Group (CRG) was appointed following an Expressions of Interest (EoI) that was advertised in September and October 2020.

Meetings with the TAG and the CRG were scheduled as part of the project delivery at key stages.

1.4 Coastal Management Framework in Western Australia

There are two key documents that guide coastal hazard assessment and coastal planning in Western Australia:

- c) State Planning Policy No. 2.6, State Coastal Planning Policy (SPP2.6, WAPC 2020)
- d) Coastal Hazard Risk Management and Adaptation Guidelines (CHRMAP guidelines, WAPC 2019)

The purpose of these documents and their application in this project is discussed briefly in this section.

1.4.1 State Coastal Planning Policy (SPP2.6)

SPP2.6 draws on and is supported by several WAPC state planning policies, development control policies and guidelines relevant to the coastal zone. For coastal matters, SPP2.6 is the prevailing policy.

The stated purpose of SPP2.6 is to provide guidance for decision-making within the coastal zone including managing development and land use change, establishment of foreshore reserves, and to protect, conserve and enhance coastal values. This policy recognises and responds to regional diversity in coastal types, requires that coastal hazard risk management and adaptation is appropriately planned for, and

encourages innovative approaches to managing coastal hazard risk and provides public ownership of coastal foreshore reserves.

Schedule one of SPP2.6 provides guidance for calculating the component of the coastal foreshore reserve required to allow for coastal processes. The component of the coastal foreshore reserve to allow for coastal processes should be sufficient to mitigate the impacts of coastal hazards (including erosion and inundation). An appropriate coastal foreshore reserve will include a component to allow for coastal processes and be of an appropriate width to ensure a coastal foreshore reserve continues to provide the values, functions and uses prescribed to it should the adverse impact of coastal processes be realised over the planning timeframe.

It is recognised that development may need to occur within an area identified to be potentially impacted by physical coastal processes within the planning time frame. Such development should always be considered within a coastal hazard risk management and adaptation planning process (CHRMAP).

1.4.2 Coastal Hazard Risk Management and Adaptation Planning Guidelines

Coastal areas identified as at risk of being affected by coastal hazards require a CHRMAP to address this coastal hazard. A CHRMAP provides a risk management approach to decision making in the coastal zone, which assesses the risk to assets in the coastal zone for current and future planning periods, through consideration of the likelihood and consequence of coastal hazard impact.

The CHRMAP process is developed in consultation with community members and a range of stakeholders and in accordance with SPP2.6 requirements, WAPC guidelines and relevant Australian Standards (AS5334-2013). It is not a one-off linear process, but a continual cyclical process. Ongoing review is essential to ensure that the management plan remains relevant. Factors that may affect the likelihood and consequences of an outcome may change, as may the factors that affect the suitability or cost of the treatment options. It is therefore necessary to repeat the risk management cycle regularly.

1.5 Scope – Project Stages

The seven stages that made up the CHRMAP project are shown in Figure 1.1 and the tasks within each of the stages outlined in Table 1.1. After each stage, the project deliverables were summarised in a Chapter Report for review by the steering committee and CRG.

Table 1.1: Project Stages and Tasks

Stage	Tasks	Section in Current Report
Stage 1 – Establish the Context	- Task 1 – Establish the Context Report Chapter - Task 2 – Develop Stakeholder and Community Engagement Plan - Task 3 – Undertake Coastal Values Assessment	Section 2 – Section 4
Stage 2 – Risk Identification	- Task 4 – Coastal Hazard Assessment - Task 5 – Asset Identification	Section 5 – Section 6

Stage	Tasks	Section in Current Report
Stage 3 – Vulnerability Analysis	- Task 6 – Develop Likelihood and Consequence Scales - Task 7 – Develop Level of Risk Matrix and Risk Tolerance Scale - Task 8 – Adaptive Capacity and Asset Vulnerability	Section 7 – Section 9
Stage 4 – Risk Evaluation	- Task 9 – Existing Controls - Task 10 – Priorities for Risk Treatment	Section 10 – Section 11
Stage 5 – Risk Treatment	- Task 11 – Identify Risk Treatment Options - Task 12 – Multi-Criteria Analysis - Task 13 – Cost Benefit Analysis - Task 14 – Benefit Distribution Analysis - Task 15 – Identification of Long-Term Adaptation Pathways	Section 12 – Section 15
Stage 6 – Implementation Plan	- Task 16 – Short Term Implementation Plan - Task 17 – Medium and Long-term Implementation Plan - Task 18 – Land Use Planning, Local Laws and other relevant Instruments - Task 19 – Funding	Section 16 – Section 19
Stage 7 – Monitoring Reporting and Review	Task 20 – Monitoring and Reporting Plan	Section 20
Final CHRMAP	- Task 21 – Draft CHRMAP - Task 22 – Review of draft CHRMAP - Task 23 – Preparation of Final Draft CHRMAP and Public Comment - Task 24 – Finalisation of CHRMAP	

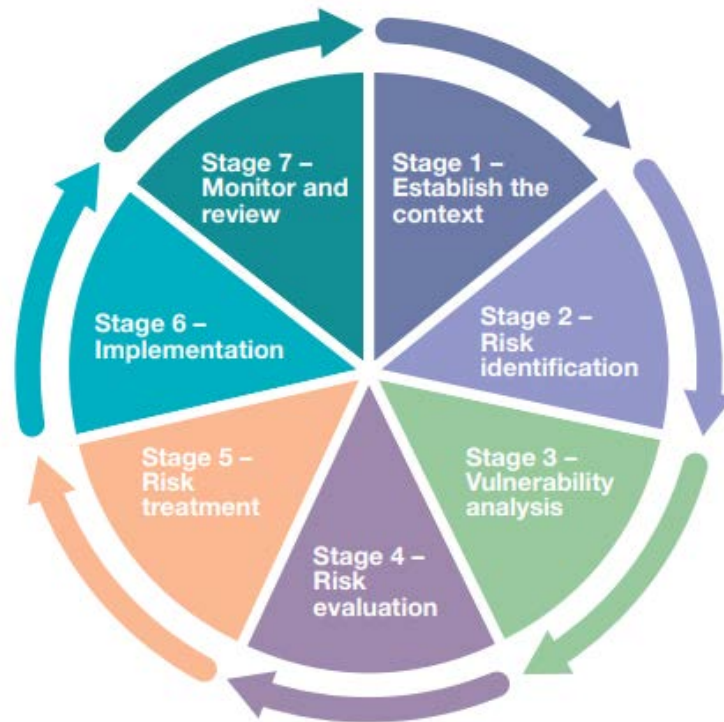


Figure 1.1: CHRMAP Stages (WAPC 2019)

2. Establish the Context

2.1 Background

The Shire of Murray is a community of approximately 17,000 residents situated 80km south of Perth. The region incorporates the Peel-Harvey Estuary and the Murray and Serpentine Rivers which provide a unique natural setting for the local community as well as the estimated 400,000 domestic and international visitors each year. The estuarine and riverine shores are an intrinsic part of life in the Murray region, which support a range of residential and commercial development and a variety of recreational activities. The Peel-Harvey Estuary was listed under the Ramsar Convention in 1990 as a wetland and ecosystem of international significance and is home to tens of thousands of water birds. The management of the estuarine and riverine areas and foreshore reserves throughout the region, and the mitigation of the coastal hazard risk posed to the community is integral to the Shire's ongoing and future success.

2.2 Purpose

The purpose of the CHRMAP is to identify coastal hazards in the Shire of Murray and to provide a framework for adaptation that can guide decision making in the short to medium term (next 10-20 years) and provide management and adaptation strategies to mitigate hazard in future planning periods (next 100 years).

2.3 Objectives

The Shire of Murray has undertaken this CHRMAP to provide strategic guidance on coordinated, integrated and sustainable management of estuarine and riverine areas identified as being at risk of coastal hazard from erosion and/or storm surge inundation.

The specific objectives of the project are to:

- Improve understanding of the Peel-Harvey estuarine coastal and Murray and Serpentine riverine features, processes, and erosion and inundation hazards in the study area.
- Gain an understanding of asset vulnerability in the Peel-Harvey estuarine coastal and Murray and Serpentine riverine zones that includes the areas of water and land that are predominately influenced by coastal processes.
- Identify significant asset vulnerability trigger points and respective timeframes to mark the need for implementation of immediate or medium-term risk management action.
- Identify assets (natural and man-made) and the services and functions they provide situated in the Peel – Harvey estuarine coastal and Murray and Serpentine riverine zones.
- Identify the value at risk of the assets that are vulnerable to adverse impacts from erosion and inundation hazards.
- Determine the likelihood and consequence of the adverse impacts of erosion and inundation hazards on the assets and assign a level of risk.
- Identify risk management measures and actions and how these shall be incorporated into short- and longer-term decision-making.
- Engage stakeholders and the community in the planning and decision-making process.

The project objectives are consistent with the State Coastal Planning Policy No. 2.6 (SPP 2.6) and Western Australian Planning Commission (WAPC) Coastal Hazard Risk Management and Adaptation Planning Guideline (WAPC 2019).

2.4 Study Area

The CHRMAP for the SoM has been developed for the region encompassing the low-lying estuarine reaches of the Peel Harvey, and the tidally influenced reaches of the Murray and Serpentine Rivers, focusing on natural assets along the length of the estuarine and relevant riverine foreshores, as well as built assets indicated in Figure 2.1.

The Shire of Murray incorporates the eastern shoreline of the Peel-Harvey Estuary which extends through approximately 50km of largely natural shoreline. A range of residential and commercial development is sited in the north including the localities of Furnissdale, North Yunderup, South Yunderup, the Murray Delta Islands and the locality of Austin Cove currently under development. South of Point Grey, the rural localities of Birchmont and Point Herron are adjacent the Harvey Estuary.

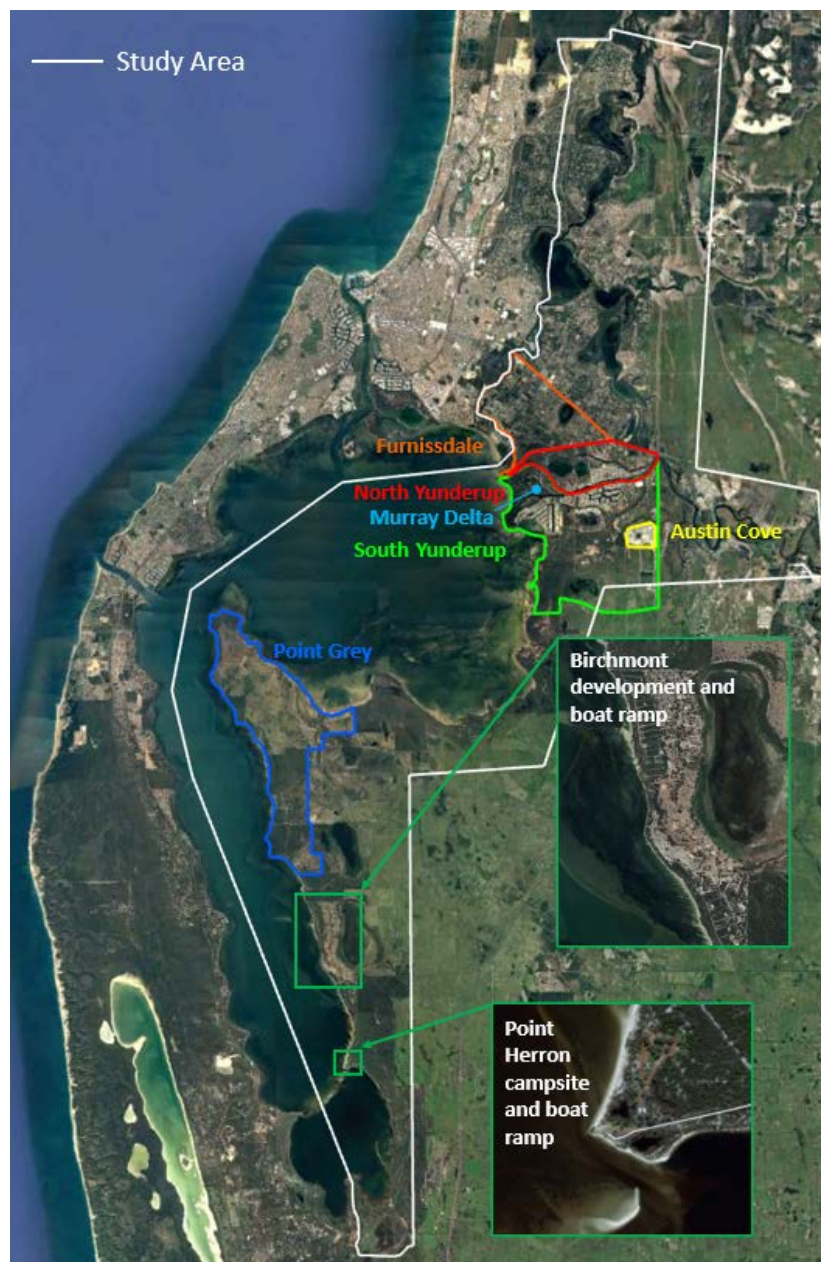


Figure 2.1: Study area, highlighting regions of focused urban, rural, and recreational development.

The study area has been divided up into six shoreline management units (SMU) for the purpose of the CHRMAP as shown in Figure 2.2.

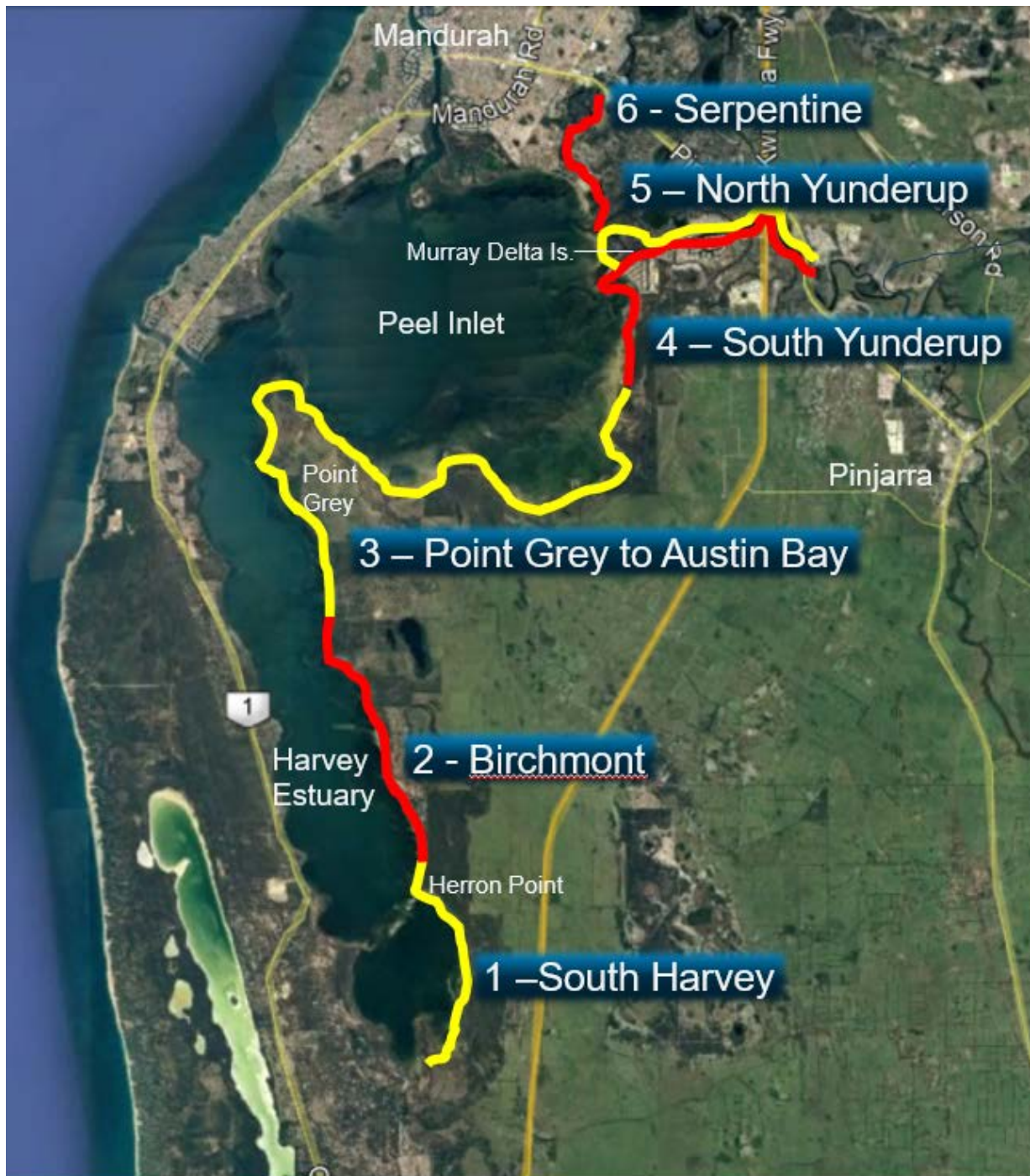


Figure 2.2: Shoreline Management Units for the Study Area adopted in the CHRMAP.

3. Community and Stakeholder Engagement

A Stakeholder and Community Engagement Strategy (SCEP) was prepared to guide the engagement process and ensure that the community and stakeholders were effectively and actively involved in the CHRMAP preparation process. The SCEP is attached in Appendix A.1.

3.1 Level of Engagement

The SCEP outlines how the community and stakeholder participation, and engagement process aligns within the inform, consult, involve and collaborate levels of IAP2 Public Participation Spectrum. The goals of each level of engagement are described in the table below.

Table 3.1: Levels of Engagement for the Project (based on IAP2 Public Participation Spectrum)

Level	Inform	Consult	Involve	Collaborate
Goal	To provide balanced and objective information in a timely manner.	To obtain feedback on analysis, issues, alternatives, and decisions.	To work with the public to make sure that concerns and aspirations are considered and understood.	To partner with the public in each aspect of the decision, including the development of alternatives and the identification of the preferred solution.
Promise	"We will keep you informed."	"We will listen to and acknowledge your concerns."	"We will work with you to ensure your concerns and aspirations are directly reflected in the decisions made."	"We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the decisions to the maximum extent."

The engagement objectives and the engagement tools are summarised in the sections that follow based on the information in the SCEP (Appendix A.1)).

3.2 Engagement objectives

The SCEP details the key stages of the project and guides stakeholders and the wider community on the CHRMAP process and their involvement in the determination of the final outcomes. The engagement objectives are to:

- Promote local knowledge sharing through citizen science – the practice of public participation and collaboration in scientific research and data collection to increase scientific knowledge.
- Create a shared sense of ownership for the estuarine environment.
- Mitigate possible risks related to community expectations.
- Clearly communicate project information and scope to community and stakeholders to acquire meaningful feedback.
- Inform, consult, and involve the community in identifying suitable adaptation options.
- Collect and collate the community and stakeholders' coastal values and aspirations for the long term.
- Understand the level of tolerance of specific risks within the community for specific assets, or groups of assets.

3.3 Engagement Tools

The key tools used during the engagement process are outlined in this section, based on the SCEP (Appendix A.1) and the Engagement Outcomes Summary Report (element) which is included in Appendix B.1.

3.3.1 Online engagement tool – Project Webpage

Through the Shire's *YourSay* portal, a CHRMAP project webpage was created, hosting information about the CHRMAP process and project, an up-to-date timeline of project milestones, and an online mapping tool via Social Pinpoint.

The online mapping tool was used to collect 'citizen science' using a GIS based platform to collect initial coastal values from participants through a series of questions which asked them to define key locations in the Shires shoreline areas describing in their own words:

- An area and how you use it
- A place and how you value it
- An environmental observation

There were 28 contributors to the online map tool who made a total of 114 contributions in the form of comments about a place they value, how they use it / value it and environmental observations.

3.3.2 Technical Advisory Group (TAG)

A Technical Advisory Group (TAG) was formed to involve key stakeholders throughout the CHRMAP process. The role of the TAG is that of a 'Steering Group'. Over the course of the project the TAG met to review project milestones and deliverables.

The TAG representatives come from:

- Department of Planning, Lands & Heritage;
- Department of Transport;
- Department of Water and Environmental Regulation;
- Peel Harvey Catchment Council;
- Department of Biodiversity, Conservation and Attractions;
- Peron Naturaliste Partnership; and
- City of Mandurah.

3.3.3 Community Reference Group

The engagement on the CHRMAP has been overseen by the Community Reference Group (CRG) for the duration of the engagement activities, to be carried through to delivery of the draft CHRMAP. By engaging the local knowledge and insights of a CRG, the project is providing a greater level of transparency, collaboration, and willingness to take on board concerns, values and ideas of the community, via selected representatives.

The CRG has met at key milestones in the project to provide feedback on the engagement approach prior to implementation, as well as provide an additional point of review of each chapter report. The CRG helped to generate community buy-in and good will and with the dissemination of key information through their networks.

3.3.4 Traditional owner engagement

Representatives of the project team met with the South-West Aboriginal Land and Sea Council (SWALSC) on 18 November 2020 to provide information on the CHRMAP project and request input to the process. Further engagement with SWALSC to provide support to the project through interviews and discussion with local elders was undertaken in November 2021.

Based on consultation with representatives from Pinjarra, Mandurah and Dwellingup traditional owner groups a number of key learnings emerged summarised as follows:

- The discussions with the group indicated the importance of being able to continue to use the shoreline areas in the way they have always been, namely for traditional hunting and gathering including collecting food, fishing and crabbing. Access to the coast and use of the estuary for these traditional purposes is highly valued and safeguarding the significant sites around the Estuary where people go crabbing and fishing is very important.
- The group would like to see signs placed at important locations around the Peel-Harvey Estuary to explain the significance of the site and the way the traditional owners used the location through the six seasons. Sharing stories and passing knowledge from Elders to the younger generations is important. A strong theme from the sessions was the idea that if you respect country, country will respect you. Educating the public in the stories and culture of the traditional owners and the importance of the Estuary is seen as highly valuable.
- There is one key site in the Estuary where the Shire should try to prevent access by the public. This is at Herron Point where the sand bar / land bridge to Egg Island is located (southwest of Herron Point). Signage should be placed to educate the general public of the importance of the location for traditional owners and convey the message that the area should not be visited.
- The Elders have seen dramatic changes in the shoreline areas since the opening of the Dawesville Cut with salt intrusion into the Estuary killing important trees and plants that traditionally provided food through the six seasons. The group strongly support the use of nature-based approaches (eg revegetation) to increase the resilience of the shorelines where needed. It was understood that plant species more salt tolerant are now required in the estuary. The Shire should look at opportunities to include representatives from the traditional owner groups in the revegetation and monitoring activities through the estuary.

3.3.5 Information event – November 2020

In November 2020, the consultant team facilitated a public information event, which was used to inform interested stakeholders and the community about the CHRMAP process. Community members were invited to attend one of two informal information events on Wednesday 25th November and Saturday 28th November 2020 (Figure 3.1).



Figure 3.1: Photos taken during Information Sessions in November 2020

The sessions were attended by the project team and Shire staff and held at the Pinjarra Court House and the local Pinjarra Shopping Centre with approximately 50 local attendees over both events.

- Over 2,000 letters were sent to residents in the community to inform them of the information sessions, with advertising online via the Shire's webpage and social media platforms in the lead up to the events.
- The delivery process was structured to provide project information to the public through interactive display boards. The consultant team was available for stakeholder and community questions and feedback with project leads from the team present to advise on coastal hazard and adaptation, planning and engagement.
- During the information event the consultant team displayed the outcomes of hazard mapping (developed in Stage 2) to the participants to promote community understanding of coastal hazard now and into the future (over the next 100 years with projected sea level rise). Planning considerations, which are influenced by coastal hazard were described in broad outlines (e.g., setting design floor levels for inundation).
- All materials on display at the information event were made available for download from the project webpage for those who could not attend. Questions taken on notice were featured on the project webpage update.
- The information event assisted the community and stakeholders in understanding coastal hazard issues affecting their coastal areas, recognising the role the CHRMAP process plays in developing future coastal planning activities and gauging the main concerns of the community.

3.3.6 Community Workshops May 2021

Workshop sessions with the community were delivered in late May 2021, undertaken to support the Risk Assessment and Evaluation stages of the CHRMAP (Stage 2 and Stage 3). The workshops were held at the Yunderup Sports and Recreation Club, the first workshop on Tuesday 25 May 2021 and the second workshop on Saturday 29 May (Figure 3.2).

The workshop agenda was as follows:

- Introductions and Welcome
- Project introduction
- Project Background
- Task One: Coastal Assets Identification
- Consequence Scale Overview
- Task Two: Consequence Scale
- Task Three: Asset Priorities Preliminary Adaptation Options Presentation
- Task Four: Adaptation Strategy Wrap up and Next Steps

Across the two workshops a total of 23 people attended (Figure 3.2).



Figure 3.2: Photos taken during Information Sessions in (Upper) November 2020 and (Lower) Community Workshops in May 2021

3.3.7 Coastal values Survey

A short coastal values survey was made available via the YourSay webpage for 5 weeks between 16 April and 18 June 2021. A series of questions were structured around the way people interact with and value the coastal and estuarine areas of the SoM.

The survey was completed online and in hard copy format, with a total of 186 responses received from individuals. The analysis of the survey outcomes was used to inform and develop the coastal values assessment outlined in the next Section.

3.3.8 Engagement methods

The CHRMAP activities were promoted through:

- Posters displayed at various venues across the Shire.
- Shire Facebook posts and targeted social media advertising campaigns.
- Targeted social media advertising and media releases.
- Shire website banner and CHRMAP Your Say page.
- Face-to-face invitations extended by staff members in Shire buildings (i.e., flyer distribution).
- Distributing letters of invitation either mailed, emailed or hand delivered to key project stakeholders.
- Flyers posted to residents/homeowners residing on and adjacent to affected coastal land.

4. Coastal Values Assessment

4.1 Coastal Values and Assets Overview

The engagement activities have been used to determine the coastal values assessment for the SoM community and stakeholders. The consequence and tolerability of risks arising from coastal hazards and the acceptability of risk treatment options to manage the values of assets was incorporated in the CHRMAP workshop activities for application in future stages of the CHRMAP.

The stakeholder engagement process has informed the coastal values assessment through:

- a) The coastal values survey;
- b) The *YourSay* interactive mapping tool on the Shire's website;
- c) Discussions with community during Information Sessions in November 2020; and
- d) Discussions with community during Workshops in May 2021

The coastal values are considered in the CHRMAP in four key areas; Social, Environmental, Infrastructure and Economic as summarised in Table 4.1.

Table 4.1: Coastal Asset Categories (WAPC 2019)

Coastal Values	General Description
Social	Values are generally those that support quality of life, health and wellbeing of a community. These values include social benefits and services provided by environmental or infrastructure assets or land. Examples include beaches and foreshore reserves (environmental), car parking, and formal access paths (public infrastructure).
Environmental	Values are generally those that support coastal habitats for their geological, geomorphological, biodiversity and ecosystem integrity, landscape, seascape, and visual landscape. Examples include ecosystem services provided by dune habitats for local flora and fauna, trapping of and storing sand, and providing a source of sand to replenish beaches following erosion events.
Infrastructure	Values of the assets that support economic, social, and environmental values. Infrastructure generally includes physical assets for transport, services, and the community. Examples include buildings, road and rail (transport), water and sewer and electricity (services), and Surf Life Saving Clubs and foreshore infrastructure including footpaths, dune fencing and ablution facilities community).
Economic	Values are those that support industry, tourism, employment, or relate to matters that have an economic implication

4.2 Coastal Values Survey

4.2.1 Survey Responses

For the coastal values survey there were 186 responses, with 65% of the responses coming from people who live in the Shire. The overall results are presented for each of the survey questions in the following section.

Q1. What age bracket do you fall under?

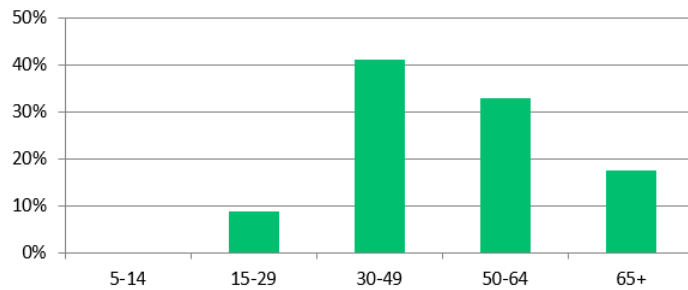


Figure 4.1: Survey Results – Demographic (Question 1)

Q2. Please select the location you live.

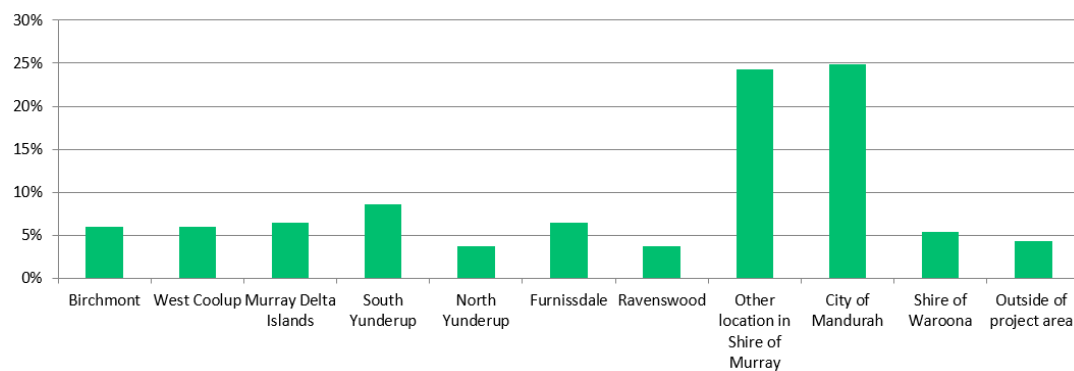


Figure 4.2: Survey Results – Location of Respondent (Question 2)

Q.3 How familiar are you with the CHRMAP project currently being undertaken by the Shire of Murray?

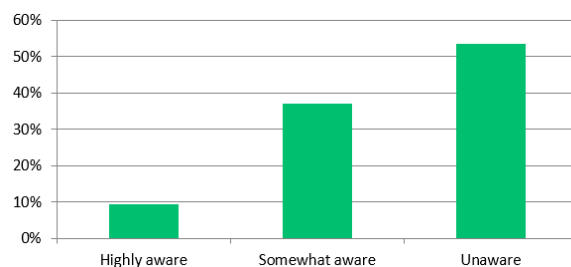


Figure 4.3: Survey Results – Awareness of Project (Question 3)

Q.4 Do you think there should be additional information available on the project YourSay page

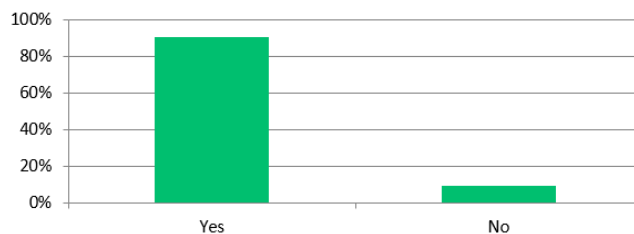


Figure 4.4: Survey Results – Additional Project Info (Question 4)

Q.5 How do you interact with the estuary? Select your 3 most common interaction options.

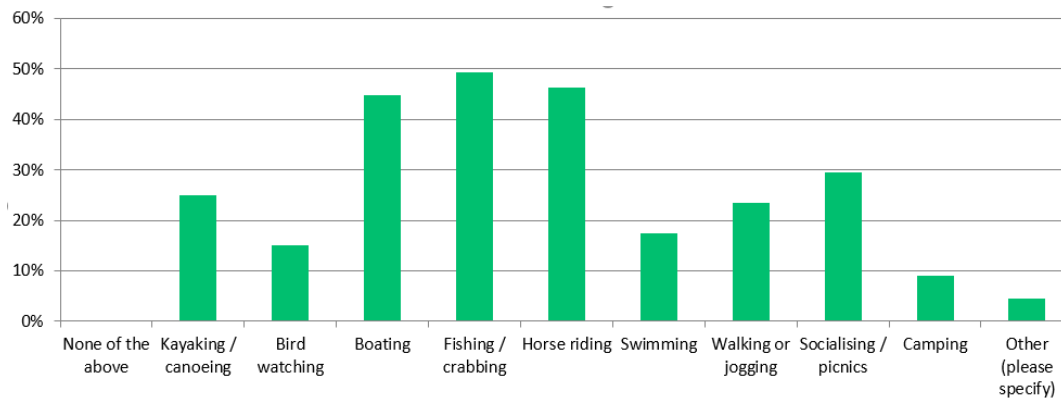


Figure 4.5: Survey Results – Interactions with the Estuary (Question 5)

Q.6 Where do you most frequently participate in the following activities?

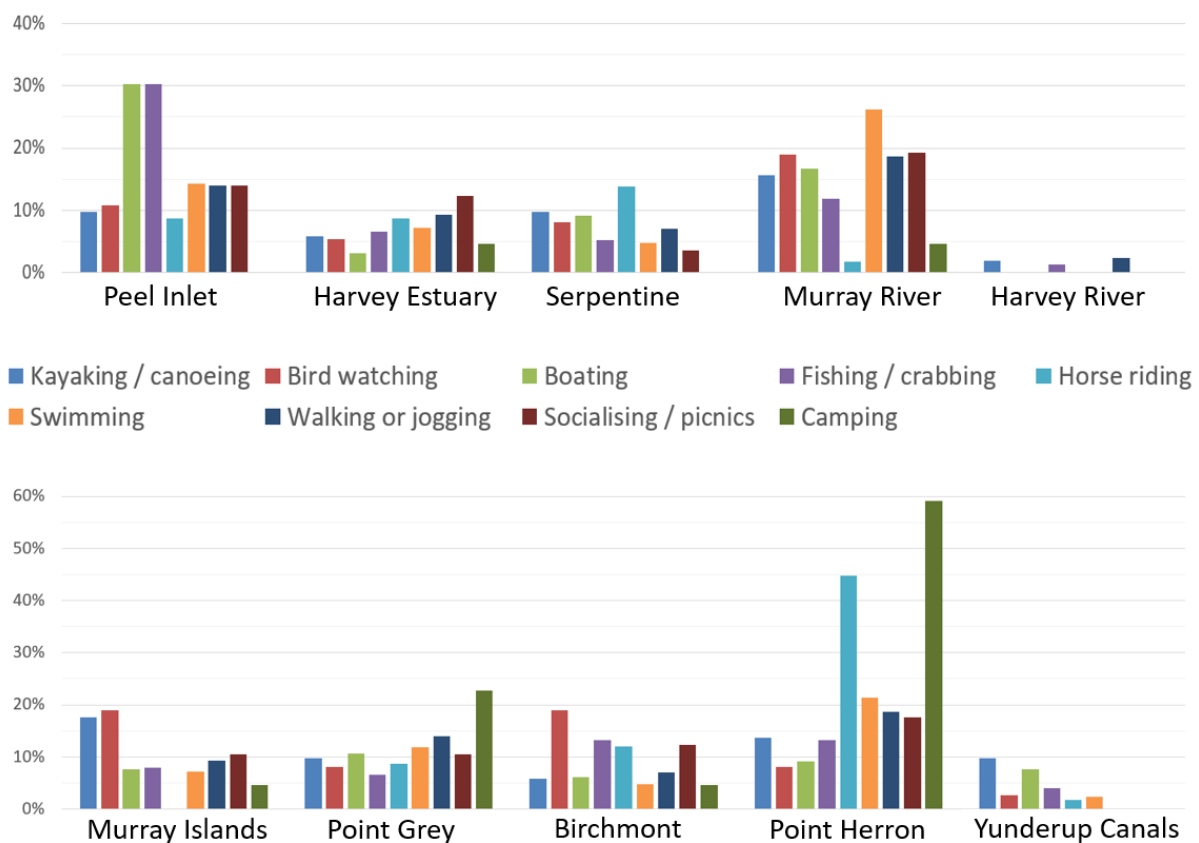


Figure 4.6: Survey Results – Areas in Estuary Frequented (Question 6)

Q.7 How often do you participate in the activity?

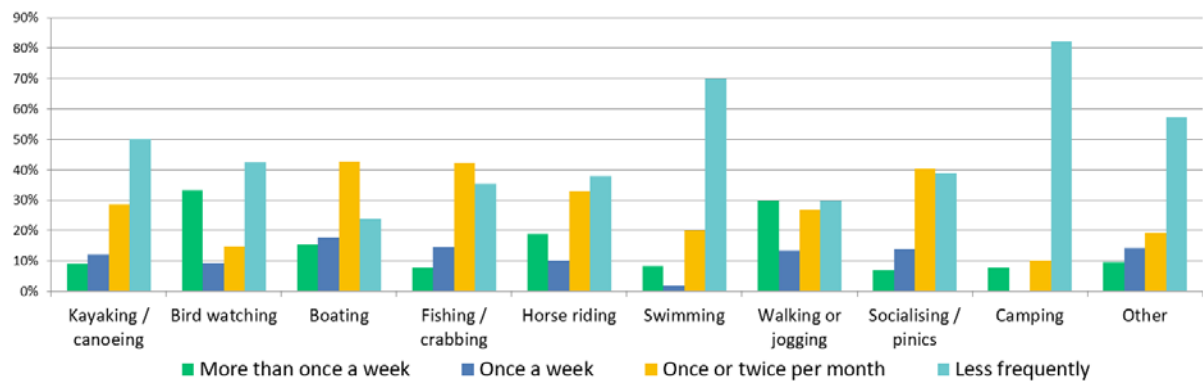


Figure 4.7: Survey Results – Participation Rates (Question 7)

Q.8 Why do you choose these locations as opposed to other areas?

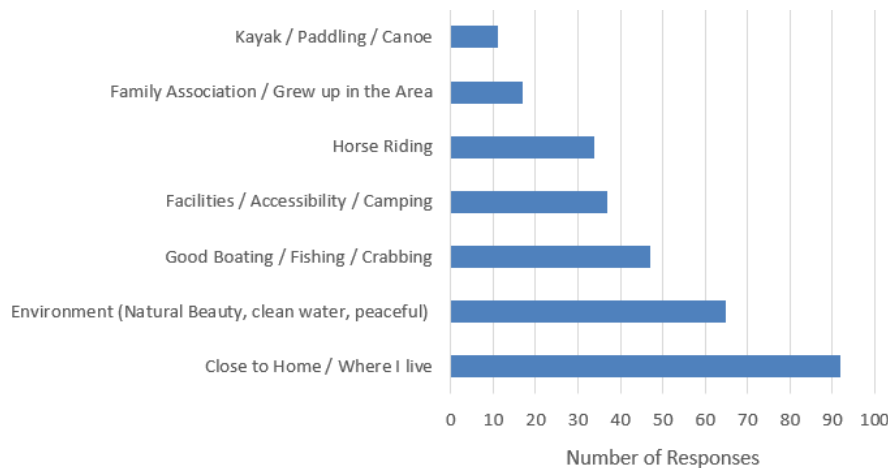


Figure 4.8: Survey Results – Location Specific (Question 8)

Q.9 What do you most value in your coastline and estuarine area?

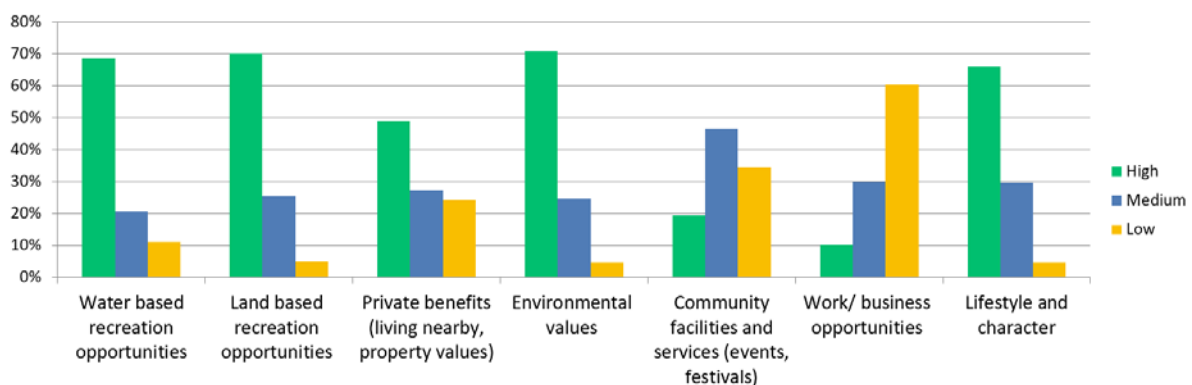


Figure 4.9: Survey Results – What is most valued in the Coastal and Estuary Area (Question 9)

4.2.2 Discussion of Survey Results

Of the 186 survey responses received, these came mostly from people residing in the SoM (65%), then City of Mandurah (25%), Shire of Waroona (6%) and a small number of people outside the Shire (4%). This is considered a reasonable cross section of the community and those outside the SoM who are actively involved with the area. The survey responses showed there was a good distribution of responses across the demographic classes with age brackets 15-29 (9%), 30-49 (41%), 50-64 (32%) and 65+ category (18%). There were no responses from people aged 14 or below (Figure 4.1).

Approximately half the respondents were aware of the CHRMAP project (Figure 4.3). The survey was successful at reaching people outside of those already aware of the project, noting there was a strong response (90%) supporting that additional information be made available on the project *YourSay* page (Figure 4.4).

Boating, fishing and horse riding were noted as the key activities along the shorelines of the SoM (Figure 4.5) followed closely by socialising / picnics, walking / jogging and kayaking. The focus for the activities varied by location, with the Peel Inlet, Murray and Serpentine Rivers very strongly linked with boating whilst the key focus areas for horse riding included Point Herron and Birchmont (Figure 4.6). Activities such as fishing / crabbing and walking / jogging were cited in all locations.

The estuary and rivers were noted as being used for a wide range of activities (Figure 4.7), with respondents indicating they would typically participate in activities such as walking and jogging frequently (more than once a week). Activities such as boating, fishing and socialising were typically done once or twice a month. The reason for choosing to use the areas for recreation (Figure 4.8) included their proximity (i.e., close to home), the natural beauty of the area, and the great fishing, crabbing and boating opportunities provide by the region. The amenities available in the Shire for the respective activity were also cited as key drivers for people's participation, particularly for horse riding and boat launch facilities. Horse riding was cited with highest frequency in the Birchmont, Point Grey and Point Herron locations with comments highlighting the trails and good facilities for parking available. In all areas of the SoM the comments reflected a strong connection to nature and the beauty of the surroundings (e.g. *'Great spot. No one around'*. *'Close to home & beautiful'*. *'Lovely pristine river system'*. *'Glorious spot'*. *'Beautiful place to swim and use the boat'*. *'Peaceful'*.)

The final question, relating to the most highly valued attributes identified by the community (Figure 4.9) identified the following attributes:

- Environmental Values
- Water based recreation opportunities
- Land based recreation opportunities
- Lifestyle and Character
- Private benefits (living nearby, property values)

This outcome is very consistent with the high value cited for assets in the coastal zone that were identified through the May 2021 workshop sessions. Participants were tasked with identifying key assets through the region and how they value them. In the May 2021 workshops, the most frequently cited categories identified were Houses and property, Businesses, Boat ramps and Jetties, Coopers Mill and Environmental locations such as the estuary, rivers and shorelines.

4.3 Coastal Values Summary

In summary, through the coastal values survey and discussions with community during workshop and info sessions there is a strong connection of the community to the Shire's waterways, its shorelines and coastal / estuarine zone. The community place a high value on the natural beauty of the location and the range of water based and land-based activities that are on offer as part of living within the community. The region is

a drawcard to visitors from the local areas adjacent the SoM (e.g., Waroona, Mandurah) and from further afield, who come to enjoy the natural environment, water and land-based activities and who cite the amenities / facilities available to them as visitors.

In terms of the four key categories the coastal values are outlined in Table 4.2.

Table 4.2: Coastal Values

Category	Asset Types	Values
Social	• Paths for walking, jogging, dog walking • Fishing areas • Crabbing areas • Bridle trails • Kayaking, canoeing locations • Cooper's mill • Herron Point • Access for horse activities • Foreshore areas	The Murray and Serpentine rivers and Peel-Harvey estuary are highly utilised for a range of water and shore-based activities, as well as for social gatherings. Access to the coast and river areas is important for local community and the lifestyle of the residents. There is a strong connection to nature for the residents who enjoy close proximity to the natural surroundings and shoreline areas with safe access to water / land-based activities. Opportunity to enjoy uncrowded access to nature and recreational activities.
Environmental	• Natural shoreline areas through the Peel-Harvey • River system of the Murray and Serpentine Rivers (shorelines, natural setting) • Murray Delta Islands • Flora and Fauna present throughout the region	The environment is very highly valued by the local community. The scenery, beauty, natural character and tranquillity of the estuary and river areas are all recognised as being of key importance. The area is highly utilised for fishing and crabbing and is a Ramsar site of recognised importance for birds.
Infrastructure	• Houses (private property) • Boat ramp access • Parking access • Foreshore facilities and amenities - playgrounds, toilets, BBQ, shelter • Jetties and Small boat Facilities	Private property is very highly valued by community, with people in close proximity to the estuary and river system. The amenities and infrastructure around the Shire's foreshore areas are key to allowing safe and accessible options to enjoy the social and environmental values associated with water based and land-based activities and for the Islander community's direct connection to the mainland.
Economic	• Pelican's café in South Yunderup • Pubs accessible by the river • Fishing, Crabbing and Boating opportunities • Horse riding facilities • Camping ground at Point Herron	Activities including fishing, crabbing, boating, kayaking, camping and horse riding provide economic support to SoM businesses through spending by visitors and locals who come to the area (e.g. cafes and tourist accommodation).

4.4 Success Criteria

Success criteria determine if the objectives of the CHRMAP are achievable and sustainable. The success of the CHRMAP will be determined by the asset(s) identified through the CHRMAP process continuing to provide their present function, service and values or some adapted level still acceptable to the community and stakeholders, at an acceptable cost, socially, economically, and environmentally (WAPC 2019).

Based on the coastal values discussed in the previous section and summarised in Table 4.2, the following success criteria have been defined:

- a) Conserve, enhance and maintain the natural environmental and character of the river regions and Peel-Harvey estuary areas.
- b) Protect and restore estuary / river shorelines and their wetlands and manage coastal processes.
- c) Manage impacts to the existing residential areas from erosion and inundation.
- d) Maintain critical infrastructure supporting the community (roads, utilities).
- e) Manage and maintain coastal infrastructure that provides access to the water and supports the lifestyle enjoyed by people in the region
- f) Maintain the health of the river and estuary systems that are vital to supporting the local ecosystem and (e.g., birds, fishing and crabbing).
- g) Preserve the key Heritage sites of significance (e.g., Coopers Mill).
- h) Facilitate and promote public usage and enjoyment of the estuary and river by the community – swimming, kayaks / canoeing, horse riding, bird watching, camping, fishing, crabbing.

5. Coastal Hazard Assessment

5.1 Identification of Coastal Hazard for Shire of Murray

A coastal hazard assessment was completed for the Shire of Murray (SoM) Study area to inform the hazard identification stage of the CHRMAP (Seashore 2021). This assessment was completed under the guidelines of the State Coastal Planning Policy (SPP2.6, WAPC 2020) and examines projected coastal erosion and inundation processes over the next century, with planning periods in 2020, 2030, 2050, 2070 and 2120.

The Coastal Hazard Assessment is a technical document and provided in full in Appendix C1. The key findings from the report and a summary of how the erosion and inundation assessment for future planning periods will be applied in the CHRMAP process is provided in this Section. The current and future extent of land exposed to coastal hazard over a range of planning periods is shown in mapping in Appendix C.2 and C.3 for Erosion and Appendix C.4 for Inundation.

5.2 Water Level

5.2.1 Tidal Planes

The general tides in the Peel-Harvey are 'micro-tidal' with a tide range of approximately 0.3m from high to low water with one high tide and one low tide a day. There are several tide gauges through the Mandurah region with two inside the Peel-Harvey (Figure 5.1). Tides are continuously measured at these gauges, with the tidal planes shown for the Mandurah, Peel and Harvey tide gauges in Table 5.1, measured to the local Chart Datum (CD).

The water level inside the Peel-Harvey is driven by the connection of the estuary basin with the open ocean via the Mandurah Channel and Dawesville Channel. A reduction in tidal range from the open coast (Mandurah) to the Peel-Harvey estuary basin is a feature of the tides in the region (Seashore 2021).

The opening of the Dawesville Cut in 1994 changed the character of water levels inside the Peel-Harvey basin with the enhanced connection to the open ocean allowing greater flushing rates for the system, whilst also leading to an increased tide range within the estuary.

Table 5.1: Tidal Planes from Mandurah, Peel and Harvey Tide Gauges

Tidal Plane		Mandurah	Peel	Harvey
Highest Astronomical Tide	HAT	1.14m CD	1.02m CD	1.07m CD
Mean Higher High Water	MHHW	0.78m CD	0.70m CD	0.73m CD
Mean Lower Low Water	MLLW	0.71m CD	0.68m CD	0.70m CD
Mean Sea Level	MSL	0.55m CD	0.55m CD	0.55m CD
Australian Height Datum	AHD	0.54m CD	0.54m CD	0.54m CD
Mean Higher Low Water	MHLW	0.39m CD	0.42m CD	0.40m CD
Mean Lower Low Water	MLLW	0.32m CD	0.39m CD	0.37m CD
Lowest Astronomical Tide	LAT	-0.04m CD	0.08m CD	0.03m CD

5.2.2 Water Level Influences and Residual Tide Effects

The tide range shown in Table 5.1 is based on predicted tides, however the water level inside the Peel-Harvey is affected by a range of short term and longer-term influences that result in the actual water level being generally above the predicted range. Because the general tide level is so small (micro-tidal) in the Peel-Harvey, residual tide or surge effects can result in significantly higher water levels above highest astronomical tide (HAT).

The key influences that cause the variation in water level in the Peel-Harvey from the predicted tide level are summarised from Seashore (2021) as:

- Surges associated with low barometric pressure and storm events with westerly winds.
- Minor, occasional surges associated with the passage of continental shelf waves.
- Inter-annual mean sea level variability, correlated with the El Niño-Southern Oscillation (ENSO) phenomenon, also correlated with variability of Leeuwin Current structure and intensity
- An 18.6-year cycle of daily tide range, with the annual tidal range varying by approximately 20% (~0.2m). The lunar nodal cycle last peaked around 2006, with the next peak due in 2025 (Eliot 2010).
- Local wind set-up associated with strong winds across basins. The influence of wind set up was evident during the passage of TC Alby in April 1978 when strong north-northwest winds across the Harvey Estuary resulted in an increase in water levels from north to south of almost 0.6m (Damara WA 2009).

Although storm events may occur at any time during the year, extreme water levels are generally restricted to the period between May to July, when seasonal peaks for mean sea level, surge and tide are in phase. The likelihood of high-water level events increases during periods of elevated mean sea levels (La Niña) and highs in the lunar nodal tidal cycle, and particularly when these two phenomena are in phase (Seashore 2021).

There are a range of different storm types which can generate high water levels in the Peel-Harvey Estuary. The passage of winter storms will result in water levels in the Peel-Harvey that exceed the HAT level several times each winter due to storm surge associated with low pressure coupled with strong winds. In general for the southwest of Western Australia, the highest water levels are typically associated with rare south tracking tropical cyclones, with the most significant water level event on record caused by Tropical Cyclone Alby in April 1978, which caused extensive flooding from Mandurah through to Busselton (MacPherson et al. 2011).

An example of the influence of residual tide at the DoT's Harvey tide gauge (DoT 2021) is shown for the period 26 to 30th July 2021 in Figure 5.1. Through this period a series of winter storms passed across the state, creating residual tide effects due to low pressure and strong westerly winds.

In Figure 5.1 the Harvey tide gauge water level residual (green line) varies over the 5-day period, with a peak of +0.7m on the 29th July. This residual is the additional water level above the predicted tide level (grey line). At 1pm on the 29th of July the predicted high tide level was 0.65m CD, while the measured water level (blue line) was 1.3m CD, sitting above the HAT level (1.07mCD).

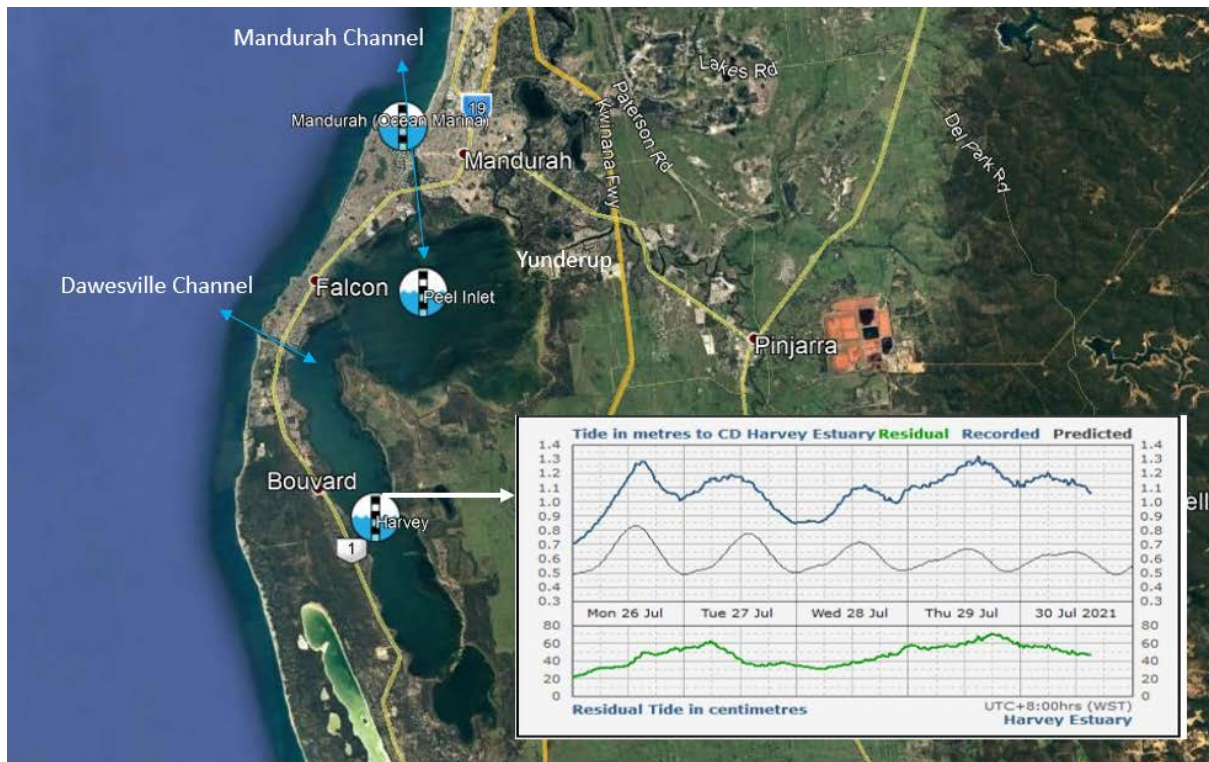


Figure 5.1: Location of DoT tide gauges in the Peel-Harvey area. Measured water level reported from the Harvey Estuary tide gauge over the period 26 – 30 July 2021 showing the residual tide levels of up to 0.7m associated with the passage of winter storms [inset].

5.2.3 Peel Tide Gauge

There has been a tide gauge in the Peel inlet just offshore of Yunderup providing measured water level at hourly intervals since 1984 (Figure 5.1). The measured water level record post 1994 is used in the Coastal Hazard report for analysis and projection of return period water levels in the SoM, recognising the change to water level associated with the opening of the Dawesville Cut in 1994. The highest levels in the measured record from the Peel tide gauge are:

- 16 May 2003: 1.03m AHD (1.58m CD). Associated with the passage of a large winter storm
- 25 May 2020: 0.95m AHD (1.50m CD). Associated with the passage of the TC Mangga storm.

5.2.4 Sea Level Rise Allowances

The sea level rise recommendations for Western Australia applicable at a planning level are outlined in *Sea Level Change in Western Australia, Application to Coastal Planning* (DoT 2010). Sea level rise must be factored into future coastal planning as follows:

- an allowance for vertical sea level rise of +0.4m over the next 50 years (2070) and +0.9m over the next 100 years (2120).

The sea level rise values adopted in the hazard assessment over the planning timeframes of the CHRMAP are summarised in Table 5.2.

Table 5.2: Sea level rise allowances over the planning timeframe of the CHRMAP study.

Planning Year	2020	2030	2050	2070	2120
Sea Level Rise	0m	+0.1m	+0.2m	+0.4m	+0.9m

The sea level rise recommendations have been determined in DoT 2010 based on the findings of the Fourth Intergovernmental Panel on Climate Change (IPCC AR4) 2007 report. The IPCC reports examine a range of sea level rise projections over the next century linked to future global emissions. The sea level rise projections used here are based on the IPCC AR4 report using 'the 95th percentile of the SRES scenario A1FI', which assumes carbon dioxide emissions associated with a fossil fuel intensive pathway with allowance for scaled up ice-sheet discharge (DoT 2010).

It is noted that whilst the sea level rise recommendations in DoT 2010 have not been reviewed following subsequent revision of the IPCC report (IPCC AR5 2014 and IPCC AR6 2021), this is not considered to be material to the CHRMAP process. The sea level allowances for future planning years that are adopted in this CHRMAP will be used to provide a range of potential future scenarios over the planning timeframe. Whilst there is uncertainty regarding the rate at which future sea level rise will *actually* occur, this is recognised in the CHRMAP process.

The CHRMAP will examine multiple planning timeframes, with each timeframe considering sea level rise scenarios in terms of the likelihood of their occurrence (e.g., almost certain, likely, unlikely, rare). In later stages of the CHRMAP (Stage 5), adaptation pathways will be developed with associated triggers related to inundation / flooding based on an observed measure of sea level rise. This means that the sea level rise assumptions prescribed by the DoT (Table 5.2) do not define the adaptation pathway. Rather, an adaptation pathway is linked to a trigger defined by a sea level rise value that is directly measured in the Peel-Harvey in the coming years.

As discussed in the previous section there are a range of processes that affect mean sea level in the Peel-Harvey in any given year, with the chief sources of variability cited in Seashore (2021) as:

- Up to 0.3m of variability in the mean sea level signal between high and low years, largely corresponding to ENSO phenomenon; and
- Up to 0.15m of variability in the oceanic tidal signal between high and low years attributed to the 18.6-year lunar nodical cycle. A smaller influence occurs within the estuary. The latest peak in the cycle occurred in 2006 with the next due in 2025.

The decision-making framework for the CHRMAP will use water level triggers to set future adaptation responses; these triggers will need to recognise and consider the natural variability in water level that occurs through inter-annual and decadal cycles.

5.3 Coastal Erosion

Coastal erosion allowance has been assessed for three different shoreline types:

- Peel-Harvey shorelines
- Lower Murray and Serpentine Rivers
- Canal Estates

A summary of each of these is presented in the sections to follow.

5.3.1 Coastal Erosion Allowance – Peel-Harvey Shorelines

The coastal processes allowance for erosion is a horizontal distance measured landward from the present-day shoreline. The coastal processes allowance lines for the SoM study area have been defined for the years 2020, 2030, 2050, 2070 and 2120 under the guidelines of SPP2.6 in the Coastal Hazard Report (Appendix C.2).

- The lines are measured landward of the horizontal shoreline datum (HSD), which is a reference point defined in the current study by the 0.6m AHD level. The adoption of 0.6m AHD is based on the HAT level (Table 5.1) and is a departure from the traditional approach in SPP2.6 which applies the HSD generally based on the still water level under the 100yr ARI storm. As this case within the SoM study area is for an estuarine setting with a small tide range (as opposed to the open coast setting that it is usually applied to), this altered approach is considered appropriate.
- It is noted that the coastal erosion allowance lines are not a prediction of the shoreline position in future years, rather the region marks the possible area over which a range of coastal erosion processes may impact the shoreline in future years.

The coastal erosion allowance line around the Peel-Harvey shoreline is calculated from the sum of four components in accordance with SPP2.6:

- S1: The loss of beach width resulting from the impact of a storm with a 1 in 100 chance of occurring (in any given year);
- S2: The historical rate of change along the shore (i.e., accreting or eroding coast);
- S3: Response to sea level rise allowance; and
- Additional allowance for uncertainty (+ 0.2 m annually)

The erosion allowance changes along a section of coast as the relative contributions from S1, S2 and S3 vary due to local characteristics. A summary of the outcomes for the calculation of these respective components from Seashore (2021) is as follows:

- The S1 component was calculated using the SBEACH model to evaluate the erosion associated with a 100yr-ARI storm on a series of representative shoreline profiles within the study area. The calculated erosion allowances varied along the Peel-Harvey shoreline with a larger response occurring on lower-lying foreshore areas (e.g., the eastern shorelines of the Peel at the mouth of the Serpentine and Murray Rivers). The S1 erosion ranged between 8m to 22m through the study area.
- The S2 component was calculated through analysis of historical aerial imagery between 1994 and 2017, assessing shoreline changes in the period following the opening of the Dawesville Channel in 1994. The shoreline analysis uses the position of the vegetation line at the edge of the shore as a proxy for shoreline position. It was noted from this analysis that the shorelines through the study area are largely stable, with the most notable changes to shoreline position around the Peel shoreline of the Murray Delta Islands, where erosion of up to 1.6m annually has occurred.
- The S3 component, examining future changes to the shoreline associated with projected sea level rise, was assessed applying the Davidson-Arnott model, recognising the unique nature of the Peel-Harvey estuarine setting. The Coastal Hazard study noted the potential response of the shoreline to future sea level rise is strongly linked to the height and stability of the shoreline sand berms. For the Harvey Estuary shoreline, the erosion response is small due to the relatively high foreshore area (i.e., high berms). Meanwhile, the shorelines along the Murray Islands and the Yunderup region experience a large erosion response due to the low-lying topography of the foreshore berm.

In summary the erosion allowances are largest for the eastern shorelines of the Peel, along South Yunderup and the Murray Islands and through the low-lying sections of coast to the south in the Austin Bay nature reserve.

5.3.2 Coastal Erosion Allowance – Lower Murray and Serpentine Rivers

Erosion hazard along the channel margins of the lower Murray and Serpentine Rivers has been treated separately, based upon observation of different active processes, including ‘switching’ of channels experiencing flow between the Islands, and local influences of foreshore vegetation.

The calculation of coastal erosion allowance for the Murray Delta Islands and along the Murray and Serpentine riverbanks was developed following discussions with the DoT and DPLH and is based upon the likelihood of different erosion mechanisms being active, distinguished for three sections:

- Channels within the Islands area have been defined with an erosion hazard of 50m by 2120, accounting for higher tidal flows and potential for channel switching.
- An erosion hazard allowance of 30m by 2120 has been defined where there is a single main channel for the Murray River (adjacent to Yunderup) and within the Serpentine River.
- Within the secondary channels and small lakes adjacent to the Murray River, an erosion hazard of 15m by 2120 has been defined. These waterbodies typically receive only a small quantity of flow, usually under extreme water level or flood overflow conditions.

This approach to determine coastal erosion allowance differs from standard SPP2.6 approaches used on Peel-Harvey shorelines using S1, S2 and S3 components and allowance for uncertainty (refer Section 5.3.1), recognising the unique setting of the islands and lower river region.



Figure 5.2: Oblique view looking west over the lower Murray and Serpentine Rivers over the Murray Delta Islands to the Peel Inlet (DWER).

5.3.3 Coastal Erosion Allowance - Canal Estates

Existing foreshore protection structures within Yunderup provide land retention, including canal estate walling and a bund around the man-made lake south of Yunderup. These features have been assumed to be maintained to provide the existing standard of protection across the planning periods used in the CHRMAP. For canal walling, additional upkeep is likely required with higher water levels, but existing wall heights are sufficient for walling to provide protection against erosion. This requirement to maintain canal walling will be noted under the existing controls section (Stage 4, Risk evaluation).

5.4 Coastal inundation hazard

For the CHRMAP study, development in the coastal zone must consider the risk to low lying coastal areas at risk of coastal inundation hazard under extreme coastal flooding events. Design water levels have been determined in the coastal hazard study for a range of average recurrence intervals (ARI) increasing in magnitude from 2-year, 10-year, 100-year, and 500yr-ARI levels. Flooding of coastal areas will be examined in the CHRMAP to determine the risk to coastal assets situated along the shoreline, with consideration of events that occur every few years (e.g., 2-year, 10-year ARI) as well as rare and unlikely events (e.g., 100-year and 500yr-ARI). The addition of sea level rise is considered in future planning periods as summarised in Table 5.2.

Under SPP2.6 guidelines, the inundation from a 500-year ARI event needs to be considered during coastal planning and is referred to as the S4 component for coastal hazard assessment. This is an event with a 1 in 500 probability of being equalled or exceeded in any given year over the planning timeframe. Whilst this is a very low probability event, over a 100-year planning period there is an approximately 20% chance that this event could occur.

The estimation of design water levels for the Peel-Harvey in the Coastal Hazard report applied the following analysis:

- The levels of 2-year ARI up to the 100yr-ARI level were estimated using standard extreme value distribution analysis of the Peel Inlet tide gauge data over the period 1994 to 2020.
- simulation of a design storm based upon TC Alby (1978) was completed using a hydrodynamic model and a flood level of +1.44m AHD determined as representative of the 500yr-ARI storm event for the S4 component.

The extreme value distribution for the measured water level from the Peel tide gauge is shown in Figure 5.3 from Seashore (2021).

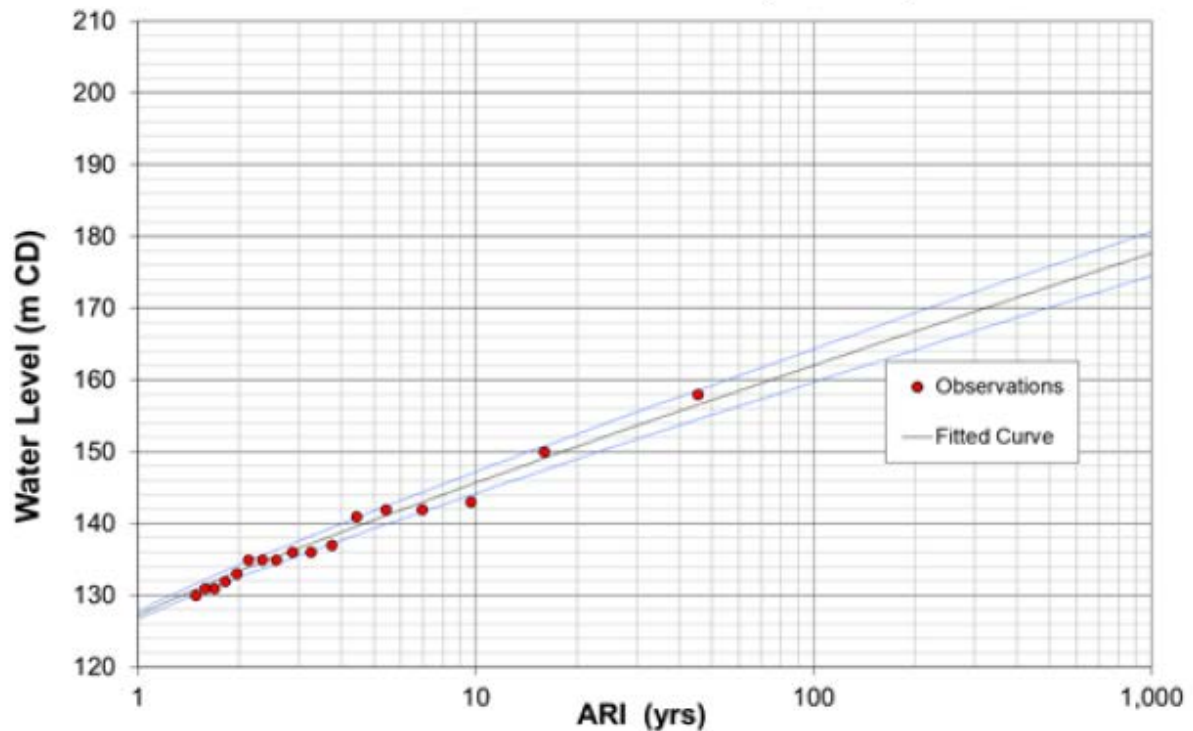


Figure 5.3: Extreme value analysis of measured water levels from the Peel tide gauge of the period 1994 to 2020 (Seashore 2021). Water level return periods up to the 100-year return period were defined from the analysis.

The design water levels for the present day (2020) are summarised in Table 5.3. These represent peak water level associated with extreme storm events.

Table 5.3: Design Water Level

Return Period	Water Level (mCD)	Water Level (mAHD)
2yr ARI	1.3m CD	0.8m AHD
10yr ARI	1.4m CD	0.9m AHD
100yr ARI	1.6m CD	1.1m AHD
500yr ARI	1.9m CD	1.4m AHD

The final design water levels are summarised in Table 5.4 across all planning periods for the CHRMAP. The coastal inundation hazard does not consider stormwater runoff, riverine flooding (joint occurrence) or groundwater impacts.

Table 5.4: Design Water Levels for Shire of Murray adopted in CHRMAP (vertical datum mAHD)

Planning Year	2020	2030	2050	2070	2120
Sea Level Rise¹	0m	+0.1m	+0.2m	+0.4m	+0.9m
2yr ARI	0.8m	0.9m	1.0m	1.2m	1.7m
10yr ARI	0.9m	1.0m	1.1m	1.3m	1.8m
100yr ARI	1.1m	1.2m	1.3m	1.5m	2.0m
500yr ARI	1.4m	1.5m	1.6m	1.8m	2.3m

Notes

1. Sea level rise values for the relevant planning period are included in the calculated coastal inundation levels and are based on current coastal planning recommendations for Western Australia (DoT 2010)

It is noted that the design flood level for the Peel Inlet and Murray River in the Shire's town planning scheme is 2.1m AHD based on the 1 in 100-year flood event which includes sea level rise allowance over the 100-year planning period (+0.9m). This is based on recommendations and advice from the Department of Water and Environmental Resources (DWER) and studies completed for the region (GHD, 2010). New development must also provide a freeboard allowance above the design flood level of between 0.15m and 0.5m depending on the location.

5.5 Coastal Hazard Mapping

The inundation and erosion extents calculated in the Coastal Hazard study (Seashore 2021) were applied in coastal hazard mapping that will be used for the CHRMAP. An overview of the mapping process follows.

5.5.1 Coastal Processes Allowance – Erosion Allowance for Peel-Harvey Estuary

The mapping of the erosion hazard from Seashore 2021 for the Peel-Harvey shoreline is presented in **Appendix C.3** showing the erosion allowance for all planning periods (2020, 2030, 2050, 2070, 2120). An example of the format of the mapping is presented in Figure 5.4.

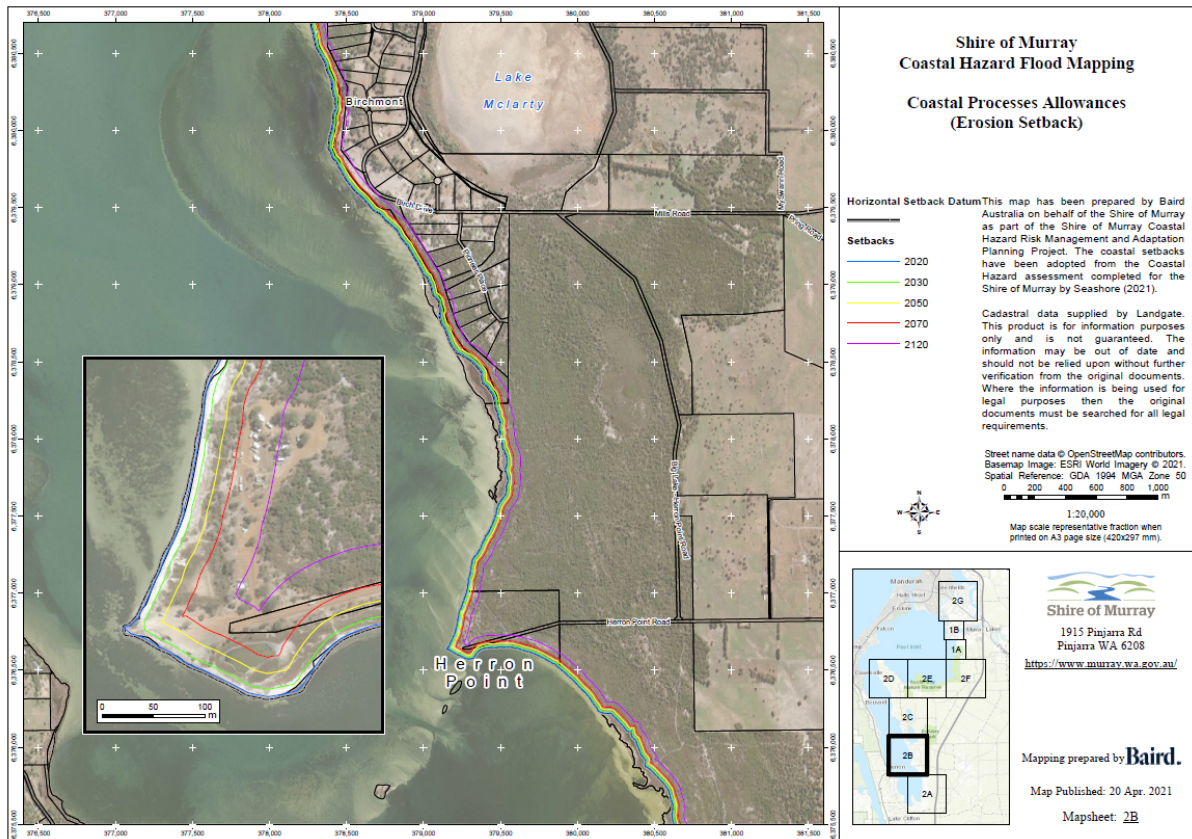


Figure 5.4: Coastal processes allowances in Peel-Harvey Estuary shorelines – Example map showing the Herron Point section of the Harvey Estuary.

5.5.2 Coastal Processes Allowance – Channel Margins

Erosion hazard along channel margins for the lower Murray and Serpentine Rivers is presented in **Appendix C.4**. The mapping shows the coastal erosion allowance for all planning periods (2020, 2030, 2050, 2070, 2120). An example of the format of the mapping is presented in Figure 5.5.

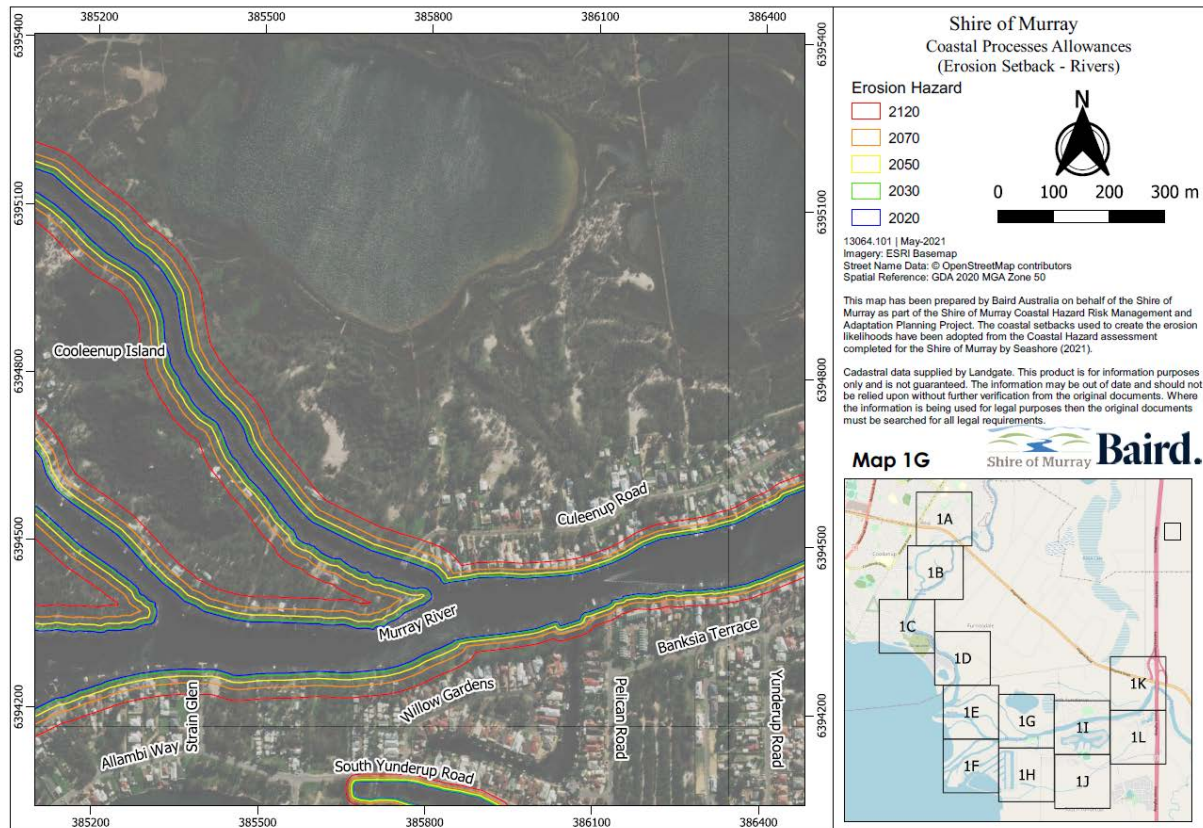


Figure 5.5: Erosion hazard allowances in the lower Murray and Serpentine Rivers – Example map.

5.5.3 Mapping Process - Inundation

The mapping of inundation areas in Appendix C.4 shows flood depth. The depth has been determined applying the design flooding levels from Table 5.4 to the land surface, defined by LiDAR data flown in 2008 and 2016. An example of the LiDAR is shown in Figure 5.6.

To improve the spatial mapping from a simple ‘bathtub’ flooding approach, all inundated areas have been defined using a ‘hydro-connectivity’ algorithm. Hydro-connectivity ensures that the flooded areas inland connect to the offshore ocean region. The hydro-connected surface overcomes the limitation of the bathtub method where isolated inland pockets of inundation will occur, and this provided a more robust product when presenting results to the community and later developing adaptation approaches for the inland areas which would incorrectly show as flooded under the bathtub approach. It is noted that finished floor levels of properties in the coastal areas is not considered in the inundation mapping. This will be considered later in the CHRMAP process as part of the existing controls (Section 10.2) to determine how this may affect the risk management actions.

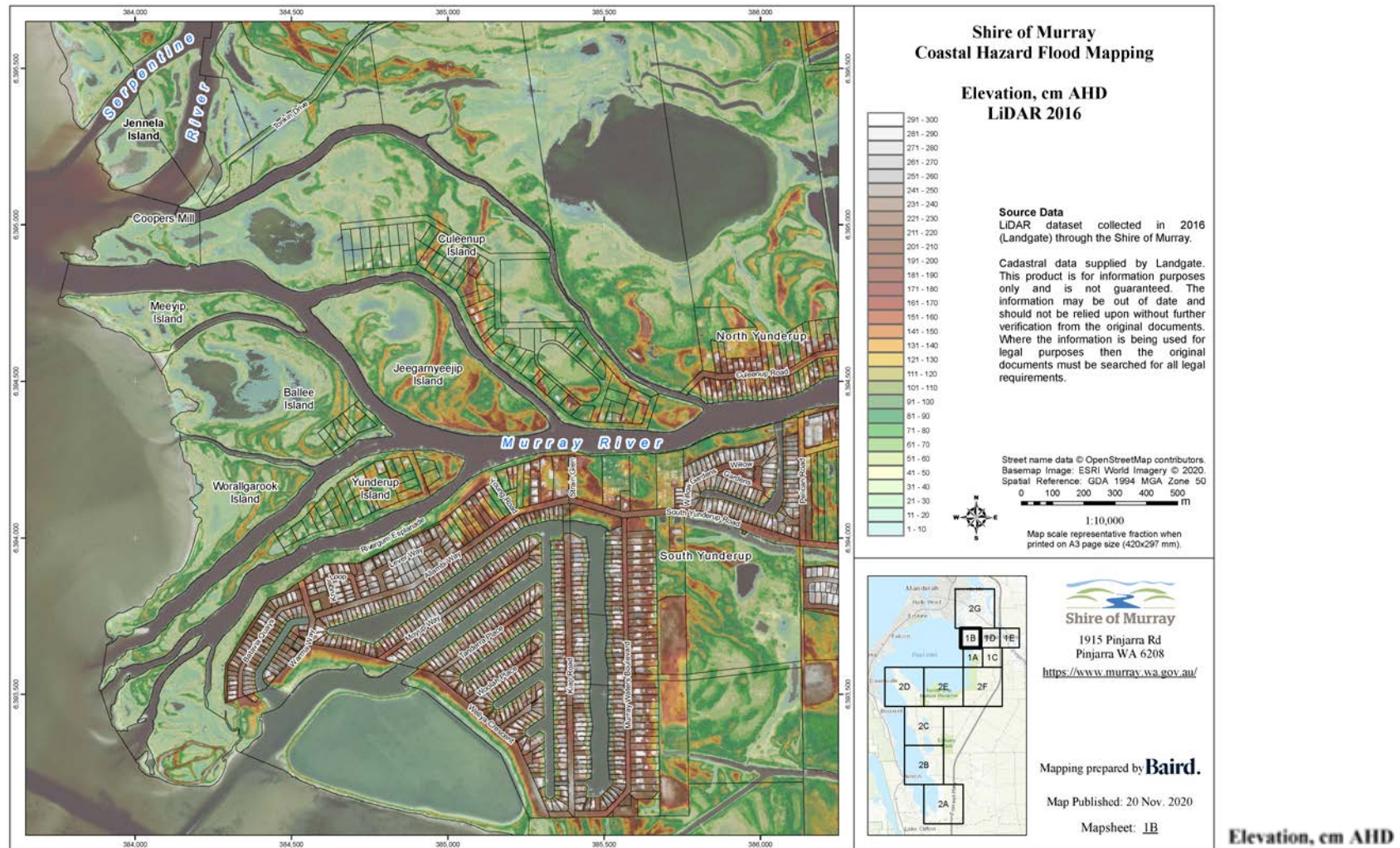


Figure 5.6: Example of elevation map showing land level for South Yunderup, North Yunderup and Murray Islands (datum cm AHD)

5.5.4 Flood Mapping Scenarios - Extreme Events

Flood Inundation scenarios (10yr ARI, 100yr ARI and 500yr ARI) are considered over a full range of planning periods for the CHRMAP. The coastal hazard mapping is presented in **Appendix C** for selected inundation scenarios:

- The inundation depth for the 100-yr ARI event in the current (2020) planning period is presented in Appendix C.4.1.
- The inundation depth for the 100-yr ARI event in the 2070 planning period is presented in Appendix C.4.2 (includes +0.4m sea level rise).
- The inundation depth for the 500-yr ARI event in the current (2020) planning period is presented in Appendix C.4.3.
- The inundation depth for the 500-yr ARI event in the 2120 planning period (includes +0.9m sea level rise) has been presented in Appendix C.4.4 This is the highest level of inundation hazard that must be considered in CHRMAP.

An example of the inundation mapping is shown in Figure 5.7.

5.5.5 Flood Risk for Low Lying areas under General Tides

For the low-lying Murray Delta Islands and shorelines around South Yunderup there are only limited areas which are low enough to be inundated presently under the general tide regime. The general tide level reaches approximately 0.3m above MSL (Table 5.1), though this can be increased due to residual tide effects in the Peel-Harvey (refer Section 5.2.2). The larger tide levels typically associated with winter storms will reach a level of 0.6m to 0.8m above MSL a few times a year.

Under a scenario where sea level rise of +0.9m was realised, this would result in many sections of the low-lying Murray Delta Islands and shorelines through Yunderup being inundated under general tides i.e. the land areas would be regularly submerged even outside of extreme events. Referring to island regions shown in Figure 5.6:

- The island regions that are at a level of 1.2m or lower would be susceptible to flooding during general tides under a scenario of +0.9m sea level rise.
- regions at a level of 1.7m AHD or lower would be at risk of flooding several times a year under large winter storm conditions.

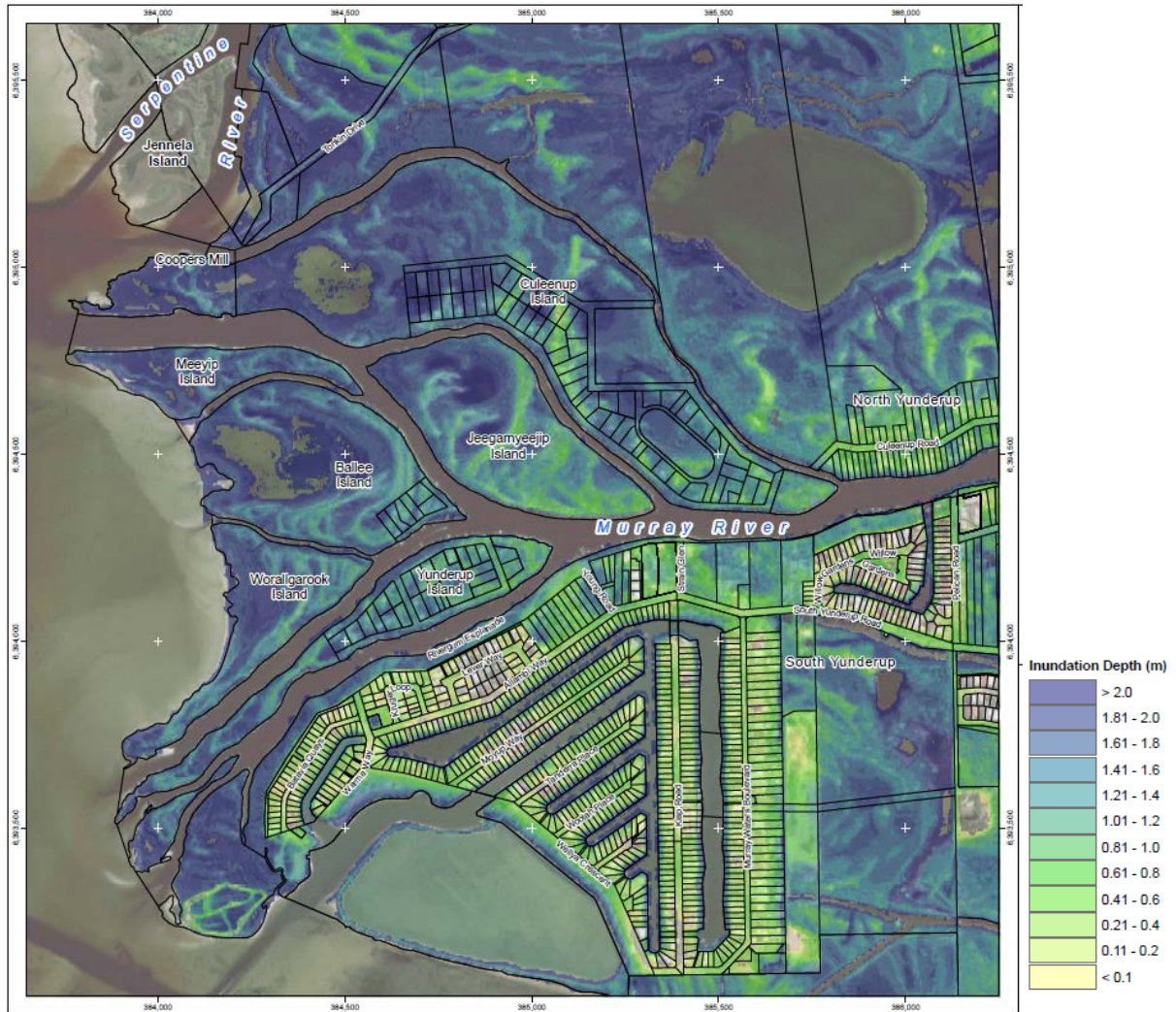


Figure 5.7: Inundation depth for the 500yr-ARI event in the year 2120 (includes 0.9m sea level rise). Example map shown for Murray Delta Islands and North and South Yunderup.

5.6 Assumptions and Limitations

The assumptions and limitations of the hazard mapping are summarised in Table 5.5.

Table 5.5: Hazard Mapping Assumptions and Limitations

Data Source / Feature	Assumptions and Limitations
LiDAR capture date and accuracy	The LiDAR data that describes the land surface through the majority of the study area was acquired in 2016. This is supplemented by data captured in 2008 (DoW) to describe areas further inland. The levels through the Austin lakes development were assigned based on design drawings from the Shire. Modification to ground levels as a result of development post 2016 are not described.
Geotechnical Conditions	Detailed geotechnical data is not available for the coastal areas.
Bathtub Flood Mapping	The 'bathtub' approach does not account for frictional losses for overland flow during flood events (e.g. roughness, structures / obstacles). The method is contingent on the accuracy of the LiDAR data. Stormwater connectivity is not considered in this type of assessment, whereby stormwater could be directed through the drainage network.
Flood Velocity	Velocity of flood waters in extreme events has not been determined
Catchment Flooding and River Flood levels	The flooding impact from rainfall runoff and the possibility of joint occurrence with elevated ocean levels in an extreme event has not been considered. For the Murray River and Serpentine River there are flood levels determined in studies completed by the DWER set at 2.1m AHD.
Finished Floor Levels	The finished floor levels of built structures are not considered in the flood mapping, with flood depth based on ground level data as defined in the LiDAR. Additional consideration of finished floor level for risk management will be presented in Stage 4 as part of the existing controls.
Groundwater	Groundwater is not considered in the study.

6. Asset Identification

6.1 Coastal Assets

6.1.1 Asset Types

There are a range of coastal assets through the SoM that will be impacted by coastal erosion and/or inundation in future planning periods. Coastal assets are broadly described in the following categories:

- Social - examples include community use of coast, recreation along the coast;
- Economic – examples include facilities, services, jobs, industry, private property including infrastructure;
- Environmental – examples include environmental values, coastal flora and fauna, ecosystem, dunes; and
- Heritage – significant sites and places of historical or cultural importance.

6.1.2 Coastal Asset Functions, Services and Value

Coastal asset types through the SoM study area and their functions, services and values are presented in Table 6.1, adapted from WAPC (2019) and informed by the stakeholder views captured through the community engagement activities.

Table 6.1: Overview of Coastal Asset functions, services, value based on WAPC (2019)

Asset	Function, Service, Value
Environment	
Foreshore Reserve, Nature Reserves and Beaches	Coastal access, recreation, and conservation. Tourist drawcard. Habitat for flora and fauna (conservation value for rare and threatened species). Recognised importance with RAMSAR. Supports biodiversity and ecosystem integrity. Geo-morphological features of locality. Buffer to other 'higher value' assets. Protects endangered species, peace, retreat, recreation. Ecosystem benefit
Social	
Camping Ground and Caravan Parks	Provides local employment. Tourist drawcard. Seasonal population. Contributes to local economy.
Foreshore reserve amenity – dual use paths, toilet/picnic facilities, bridle pathways	Ongoing access, community services, recreation and health benefits. Lifestyle, social/family recreation
Residential (existing/future) development	Provides housing for resident population and future population
Economic	
Private Property	Housing / shelter. Financial investment
Jetties and Boat Ramps	Provides recreation facilities. Provides local employment. Contributes to local economy. Island access, community use for boating/fishing, adds value to properties.

Asset	Function, Service, Value
Foreshore reserve infrastructure – dual use paths, toilet/picnic facilities	Provides recreation facilities
Utilities (stormwater, power etc)	Provides essential services for Community
Roads	Access. Facilitates transport
Commercial / Industrial Development and Infrastructure	Provides employment and contributes to economy. Provides jobs, serves community, recreation for holidays
Heritage	
Significant Sites e.g., Coopers Mill	Significant site and place of historical importance. Historical value, tourist attraction, culture.

6.1.3 Asset Identification

The coastal assets in the study area were defined through a range of sources including:

- Community engagement - information sessions, workshop and coastal values survey;
- SoM asset database provided to the study in GIS format;
- A search of service providers registered in the Dial Before You Dig network to determine the utilities (e.g., Telstra, Water Corporation etc)

6.2 Coastal Asset Register

6.2.1 Compilation of Asset Data

There are six shoreline management units (SMU) for the CHRMAP as summarised in Table 6.2 and Figure 2.2.

Table 6.2: Shoreline Management Units (SMU)

No.	Shoreline Management Unit
1	South end of Harvey Estuary (Includes Herron Point).
2	Birchmont
3	Point Grey to Austin Bay
4	South Yunderup (including the Canals)
5	North Yunderup including Murray Delta Islands
6	Serpentine River and Furnissdale

The coastal assets that are within the coastal hazard extent defined by erosion and inundation at the year 2120 were identified and assigned a data type category as either Environment, Social, Economic or Heritage. The summary of asset types is presented in Table 6.3 to Table 6.8. Maps showing the overview of each SMU and key assets are presented in Figure 6.1 to Figure 6.12.

Table 6.3: Coastal Asset Identification. SMU1 – South Harvey Estuary and Herron Point

Asset Type	Asset
Environmental	Beach areas
	Foreshore Nature Reserve
	Harvey Drain
	Kooljerrenup Nature Reserve
Social	Herron Point Camping Ground
	Herron Point Foreshore
	Coastal Pathways / Bridle Paths
Economic – Privately held	Agricultural Properties
Economic	Carpark at Herron Boat Ramp
	Herron Point Boat Ramp
	Herron Point Reserve Camping Ground Toilet / Showers
	Infrastructure (Signage, shelters, fencing)
	Herron Point Road, Roads in Campground
	Carpark at Herron Boat Ramp



Figure 2.1: SMU1 - Examples of coastal assets from Herron Point. Clockwise from top left, coastal pathways through foreshore reserve, foreshore and beach, Herron Point Reserve camping ground toilet and gravel road, Herron Point boat ramp and carpark behind.

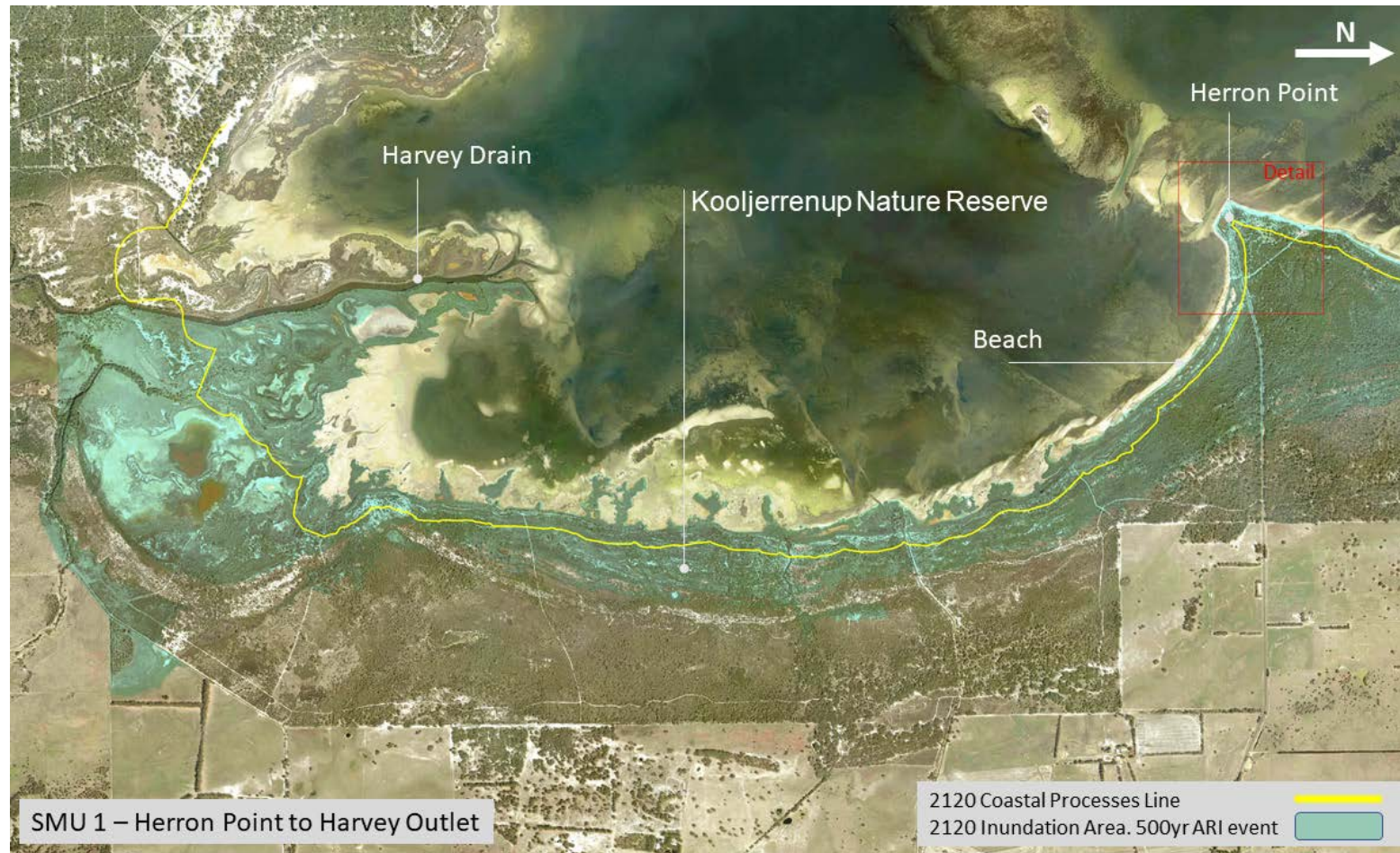


Figure 6.1: SMU1 - Coastal Assets within 2120 Coastal Hazard Extents. Harvey Drain to Herron Point



Figure 6.2: SMU1 - Coastal Assets within 2120 Coastal Hazard Extents. Herron Point

Table 6.4: Coastal Asset Identification. SMU2 – Birchmont

Asset Type	Asset
Environmental	Beach area
	Foreshore Nature Reserve
	Lake McLarty and McLarty Nature Reserve
	Lake Mealup and Mealup Point Nature Reserve
Social	Foreshore Reserve at Birchmont Boat Ramp
	Coastal Pathways / Bridle Paths
Economic – Privately held	Residential Properties
	Carpark at Birchmont Boat Ramp
Economic	Birchmont Boat Ramp
	Infrastructure (signage, fencing, bus shelter)
	Drainage features
	Roads (Birch Drive, Mills Rd, Pioneer Place, Numbat Place, Kangaroo Loop)

**Figure 6.3: SMU2 - Examples of coastal assets from Birchmont. Clockwise from top left, Birchmont boat ramp, Birchmont boat ramp carpark and foreshore reserve, Lake McLarty Nature Reserve**

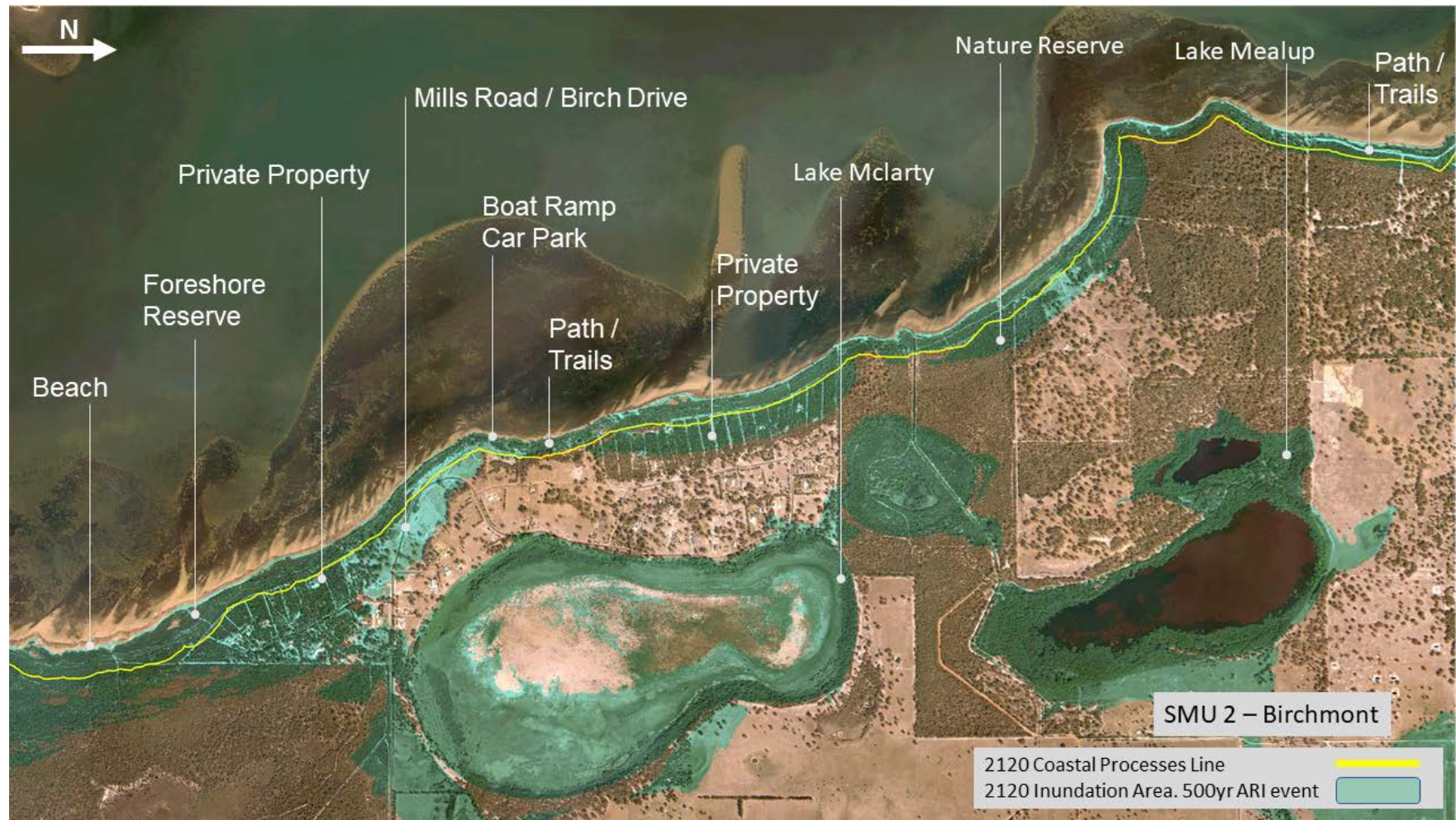


Figure 6.4: SMU2 - Coastal Assets within 2120 Coastal Hazard Extents. Birchmont

Table 6.5: Coastal Asset Identification. SMU3 – Point Grey to Austin Bay

Asset Type	Asset
Environmental	Beach area
	Foreshore Reserve
	Austin Bay Nature Reserve
	Robert Bay Swamp
Social	Foreshore Reserve at Birchmont Boat Ramp
	Coastal Pathways / Bridle Paths
Economic – Privately held	Residential Properties
	Agricultural Property
Economic	Drainage features
	Carrabungup Road
	Minor Infrastructure (Signage, fencing)

**Figure 6.5: SMU3 - Examples of coastal assets from Point Grey. Clockwise from top left - Carrabungup Road, signage, natural foreshore areas of Roberts Bay**

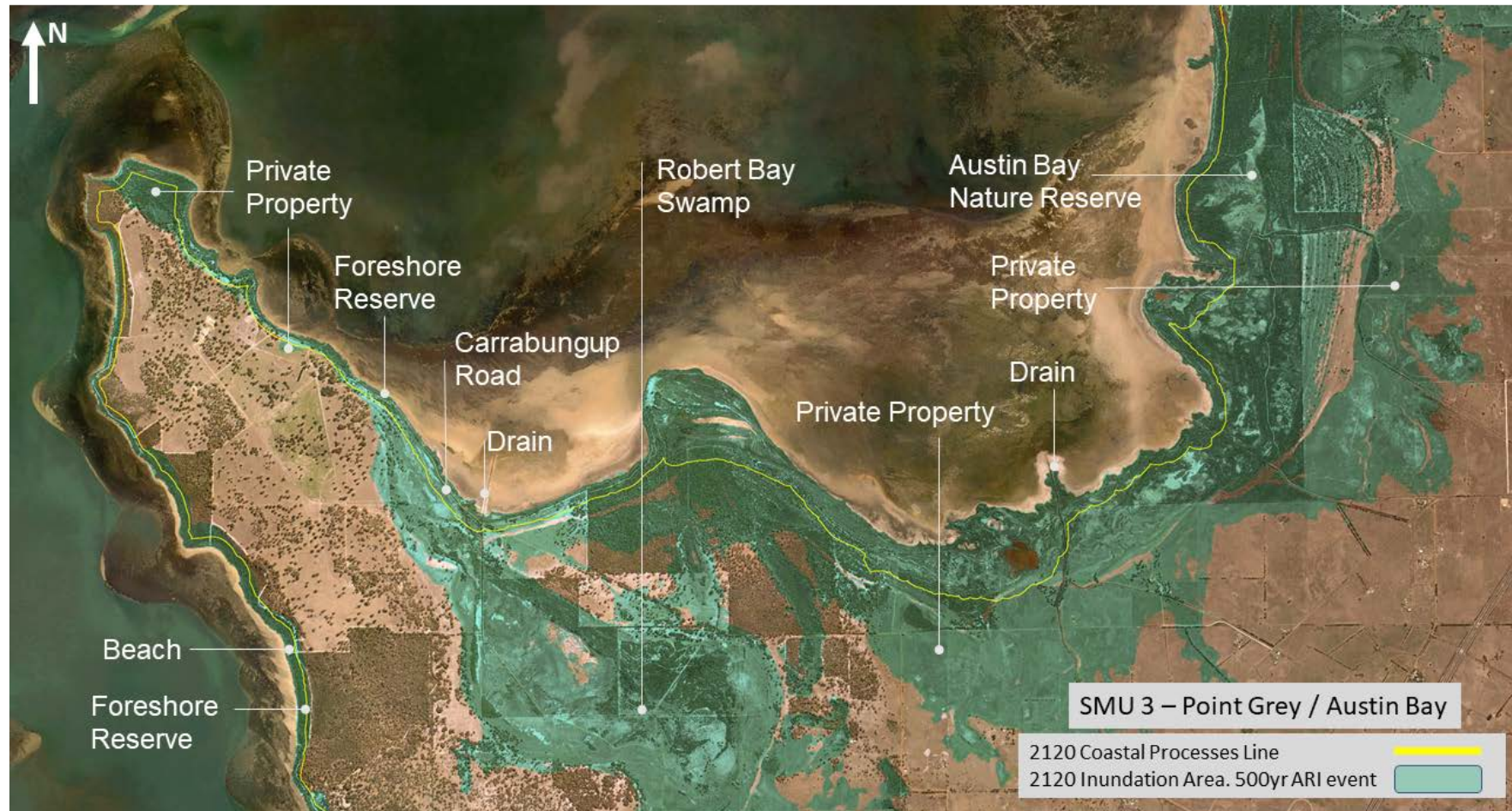


Figure 6.6: SMU3 - Coastal Assets within 2120 Coastal Hazard Extents. Point Grey to Austin Bay

Table 6.6: Coastal Asset Identification. SMU4 – South Yunderup

Asset Type	Asset
Environmental	Beach area
	Foreshore Reserve
	Austin Bay Nature Reserve
	Batavia Quays Wetland
	Revetment / Bund protecting shoreline at Batavia Quays
	Bund in front of South Yunderup canals
Social	Foreshore Reserve along Murray
	Coastal Pathways
	River access (jetties, boat ramps)
Economic – Privately held	Residential Properties
	Jetties and Moorings along River
Economic	Road network
	Canal Network
	Shire Jetties - Tatham Rd, Pelican Rd, Centenary Park
	Boat Launch - Rivergum Esplanade Foreshore, Batavia Quays Launch Facility
	Car Park - Rivergum Esplanade Foreshore, Centenary Park, Pelican Road, Willow Gardens, Fire Station
	South Yunderup Fire Station
	Batavia Quays Club Shed
	Toilets - Centenary Park, Batavia Quays, Pelican Road
	Playground Equipment - Centenary Park, Wellya Crescent Park, Pelican Rd Park
	Gazebos, shelters, picnic tables, BBQs - Centenary Park, Lucie Hunter Park, Wellya Crescent Park. Foreshore areas
	Footpaths / pathways
	Minor Infrastructure (Signage, fencing, lighting, bus shelter)
	Drainage features (pits, pipes, culverts)
	Utilities (WaterCorp infrastructure)



Figure 6.7: SMU4 - Examples of coastal assets from South Yunderup. Clockwise from top left – Foreshore Reserve Pelican St, Wharf Cove decking, crabbing on the Peel, Peel shoreline Batavia Quays, Wetland area Batavia Quays, Pelican St Park, Pelican St Jetty

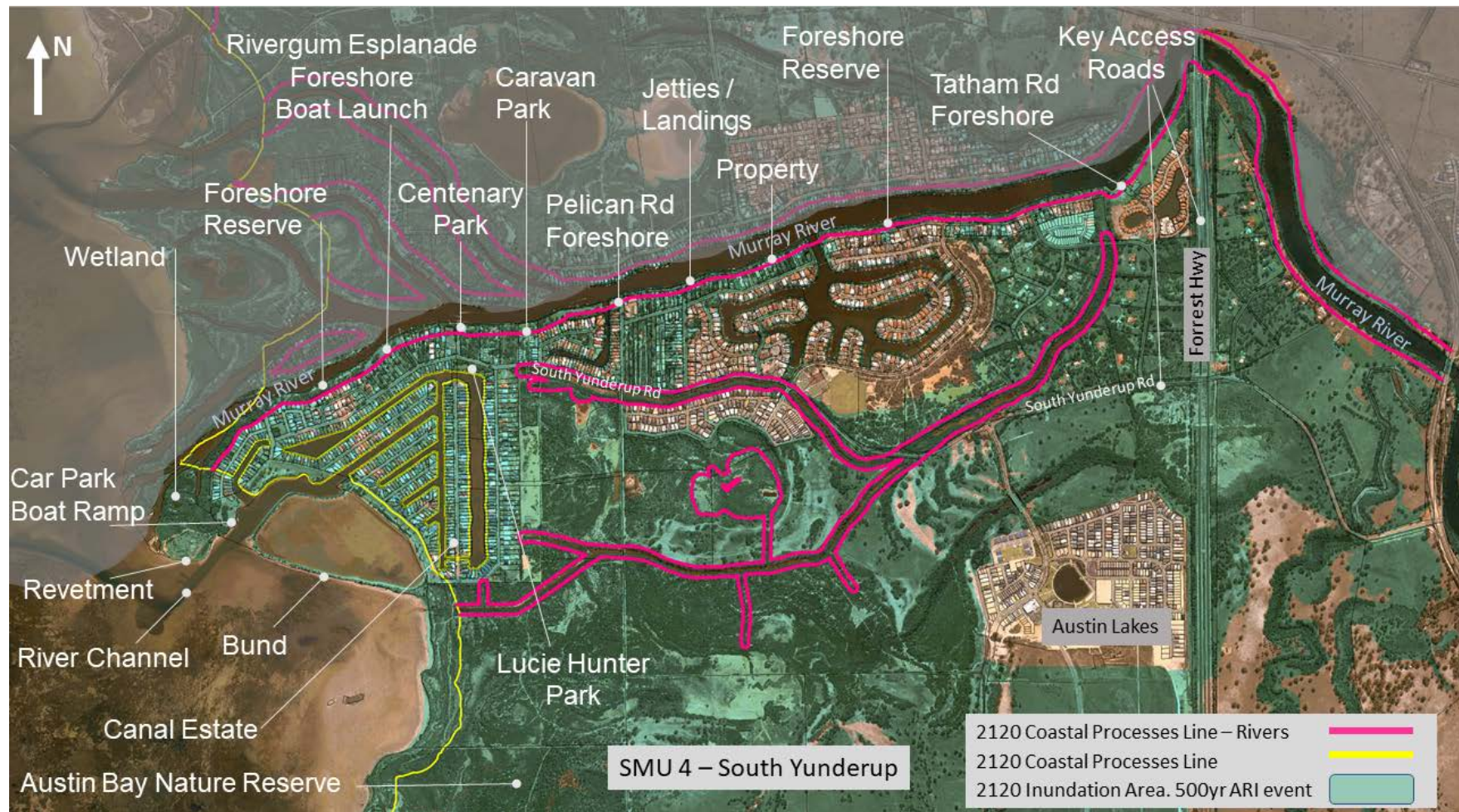


Figure 6.8: SMU4 - Coastal Assets within 2120 Coastal Hazard Extents. South Yunderup

Table 6.7: Coastal Asset Identification. SMU5 – North Yunderup and Murray Islands

Asset Type	Asset
Environmental	Beach area
	Foreshore Reserve
	Batavia Quays Wetland
Social	Foreshore Reserve along Murray
	Coastal Pathways
	River access facilities (channel, jetties, boat ramps, swimming pontoon)
Economic – Privately held	Residential Properties
	Jetties and Moorings along River
Economic	Road network
	Coopers Mill and Coppers Mill Cottage
	Shire managed Jetties – Culeenup Rd, Coopers Mill Precinct, North Yunderup Launch Facility. Swimming pontoon at swim beach
	Boat Launch - North Yunderup Launch Facility
	Car Park - North Yunderup Launch Facility
	Kingfisher Park BMX Track, Exercise Equipment, Sports Court
	Toilets - Kingfisher Park, North Yunderup Launch Facility, Coopers Mill Precinct
	Playground Equipment - Kingfisher Park, Coopers Mill Precinct
	Gazebos, shelters, picnic tables, BBQs, memorial structure - Kingfisher Park, North Yunderup Launch Facility, Foreshore areas, Coopers Mill Precinct
	Footpaths / pathways
	Minor Infrastructure (Signage, fencing, lighting, bus shelter)
	Drainage features (pits, pipes, culverts)
	Utilities (WaterCorp infrastructure)



Figure 6.9: SMU5 - Examples of coastal assets in North Yunderup and Murray Islands. Clockwise from top right – Example of Island house, jetty at Coopers Mill Precinct, Coopers Mill

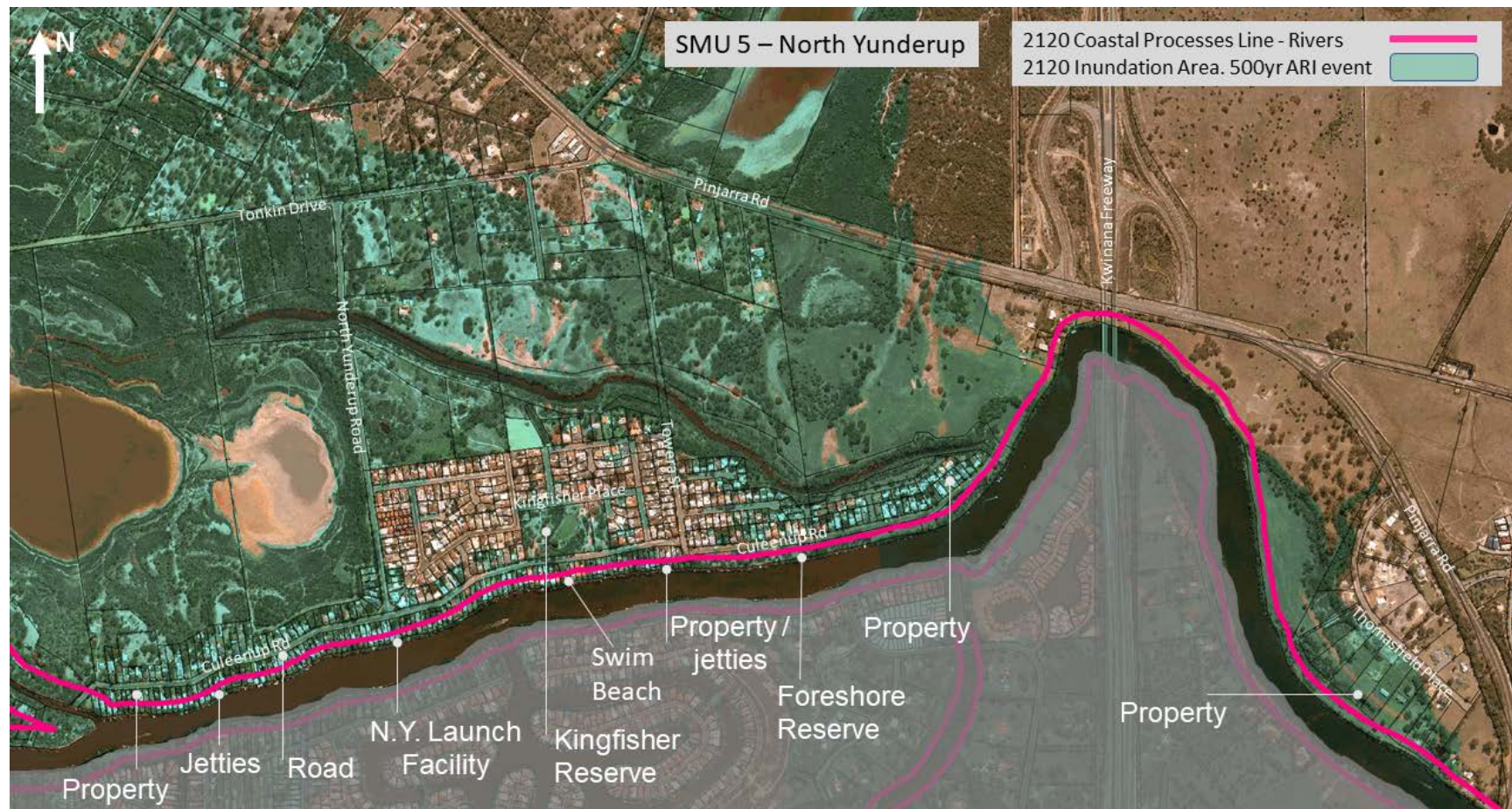


Figure 6.10: SMU5 - Coastal Assets within 2120 Coastal Hazard Extents. North Yunderup



Figure 6.11: SMU5 - Coastal Assets within 2120 Coastal Hazard Extents. North Yunderup – Murray Delta Islands

Table 6.8: Coastal Asset Identification. SMU6 – Serpentine River and Furnissdale

Asset Type	Asset
Environmental	Beach area Furnissdale Foreshore
	Foreshore Reserve
	Batavia Quays Wetland
Social	Foreshore Reserve
	Coastal Pathways
	River access and facilities (channel, jetties, boat ramps)
Economic – Privately held	Residential Properties
	Jetties and Moorings along River
	Road network
Economic	Caravan Park
	Boat Launch Furnissdale Launch Facility
	Car Parks - Furnissdale Launch Facility, Riverside Drive, Furnissdale Bridge Foreshore
	Toilets - Furnissdale Launch Facility, York Road
	Playground Equipment - Furnissdale Foreshore, York Road
	York Road Clubrooms and Sports Courts
	Gazebos, shelters, picnic tables, BBQs - Furnissdale Foreshore, York Road
	Footpaths / pathways
	Minor Infrastructure (Signage, fencing, lighting, bus shelter)
	Drainage features (pits, pipes, culverts)
	Utilities (WaterCorp infrastructure)

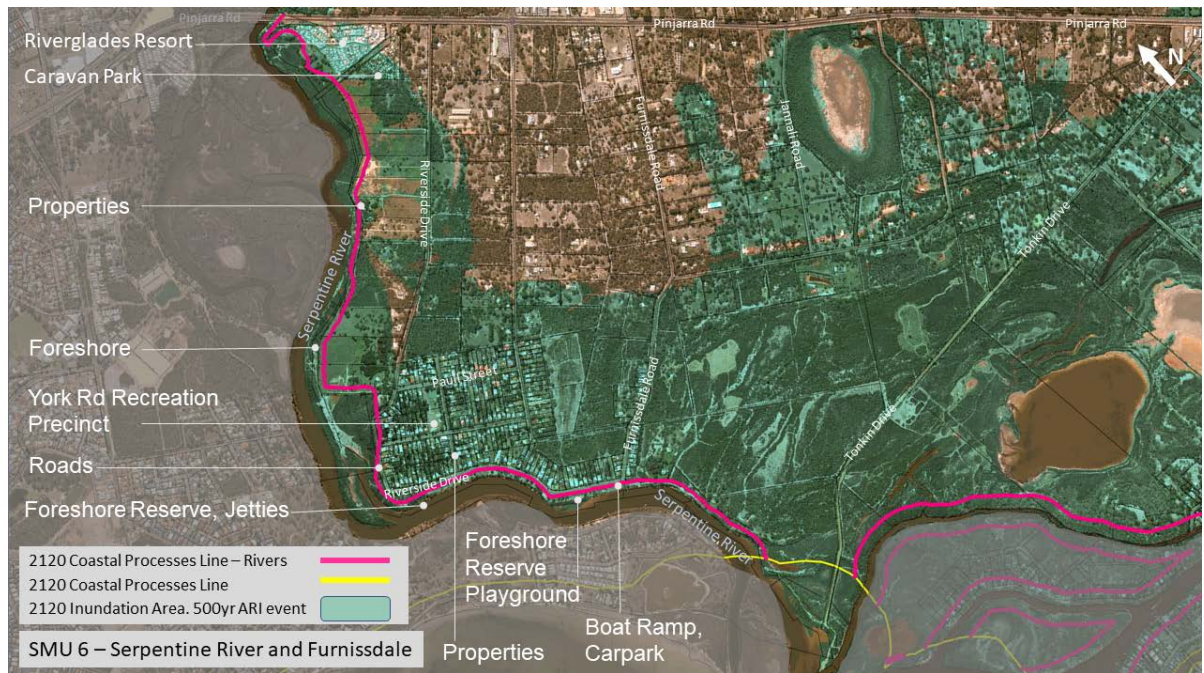


Figure 6.12: SMU6 - Coastal Assets within 2120 Coastal Hazard Extents. Serpentine River and Furnissdale

7. Risk Assessment Framework

7.1 Vulnerability Assessment

To determine the coastal assets that are most vulnerable to coastal hazard requires consideration of the asset's exposure to coastal hazard, the sensitivity of the asset to the impacts from exposure and its adaptive capacity.

For the coastal asset register identified in each of the SMU's, a vulnerability assessment is undertaken to determine how the effects of coastal hazards are predicted to impact assets in current and future planning periods.

The CHRMAP vulnerability assessment first considers the potential impact to coastal assets as a combination of the *likelihood* and the *consequence* of that hazard occurring. The vulnerability assessment then considers the adaptive capacity of coastal assets; that is, the ability of a coastal asset to accommodate coastal hazard impact.

The vulnerability assessment process is presented in Figure 7.1 (WAPC 2019).

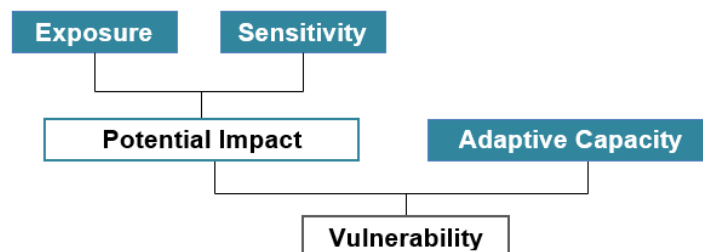


Figure 7.1: Vulnerability Assessment Flowchart

The key components in the vulnerability assessment are:

- Exposure = *Likelihood* of coastal hazard occurring
- Sensitivity = *Consequence* of coastal asset being impacted
- Potential impact = *Risk* to coastal assets as a product of likelihood and consequence
- Adaptive Capacity = The ability for an asset to accommodate the coastal hazard impact and recover
- Vulnerability = Final risk rating which incorporates the adaptive capacity of the asset

The application of the key components in the vulnerability assessment is explained in the sections to follow.

7.2 Likelihood

7.2.1 Likelihood Definitions

In risk management terms, 'likelihood' is the chance of something happening, and is similar to the concept of probability. The likelihood scale that has been developed for the CHRMAP follows the guidance presented in WAPC (2019). The definitions for the likelihood scale are shown on Table 7.1 with each category associated in terms of a generalised description and approximate Annual Exceedence Probability (AEP).

Table 7.1: Likelihood Scale Definitions (WAPC 2019, AS5334-2013)

Rating	Description	Indicative Annual Exceedance Probability (AEP)
Almost Certain	The event is expected to occur in most circumstances	Has a greater than 95% chance of occurring in the identified time period if the risk is not mitigated
Likely	The event will probably occur in most circumstances	Has a 63-95% chance of occurring in the identified time period if the risk is not mitigated
Possible	The event should occur at some time	Has a 20-63% chance of occurring in the identified time period if the risk is not mitigated
Unlikely	The event could occur at some time	Has a 5-20% chance of occurring in the identified time period if the risk is not mitigated
Rare	The event may only occur in exceptional circumstances	May occur in exceptional circumstances, i.e. less than 5% chance of occurring in the identified time period if the risk is not mitigated

7.2.2 Likelihood Scale – Coastal Erosion

The erosion hazard for the SoM shoreline areas has been defined as coastal process allowances through the planning timeframes 2020, 2030, 2050, 2070 and 2120. The CHRMAP erosion likelihood scale is developed based on the following:

- coastal process allowances are considered as the 'Possible' category in each respective planning year
- It is assumed that a level of erosion risk that is 'Possible' today becomes more likely in future time periods (i.e. 'Likely' or 'Almost Certain').
- Lower categories of likelihood ('Unlikely', 'Rare') can be defined by the scenarios defined at a future time frame.

Through this approach the likelihood scale has been developed. An example is given for the planning year 2050:

- Almost Certain Coastal Processes Allowance line 2020
- Likely Coastal Processes Allowance line 2030
- Possible Coastal Processes Allowance line 2050
- Unlikely Coastal Processes Allowance line 2070
- Rare Coastal Processes Allowance line 2120

The application of this process through all planning periods is presented in Table 7.2.

Table 7.2: Murray CHRMAP Likelihood Scale for Coastal Erosion

Likelihood Category	2020 Planning Period	2030 Planning Period	2050 Planning Period	2070 Planning Period	2120 Planning Period
Almost Certain	-	-	2020 Erosion	2030 Erosion	2050 Erosion
Likely	-	2020 Erosion	2030 Erosion	2050 Erosion	2070 Erosion
Possible	2020 Erosion	2030 Erosion	2050 Erosion	2070 Erosion	2120 Erosion
Unlikely	2030 Erosion	2050 Erosion	2070 Erosion	2120 Erosion	-
Rare	2050 Erosion	2070 Erosion	2120 Erosion	-	-

7.2.3 Coastal Inundation Likelihood Scale

The inundation likelihood scale is developed using the coastal hazard inundation levels calculated for the study area (2 yr, 10yr, 100 yr and 500 yr ARI) and assigning each of the design inundation scenarios a category based on the probability of occurrence (refer Table 7.1). In future planning periods sea level rise (SLR) is included in the likelihood scale. The SLR recommendations for Western Australia applicable at a planning level are outlined in *Sea Level Change in Western Australia, Application to Coastal Planning* (DoT 2010) as summarised in Table 5.2.

Table 7.3: Sea level rise allowances over the planning timeframe of the CHRMAP study.

Planning Year	2020	2030	2050	2070	2120
Sea Level Rise	0m	+0.1m	+0.2m	+0.4m	+0.9m

The coastal inundation likelihood scale categories are shown in Table 7.4 and the corresponding level is shown in Table 7.5:

- The ARI categories selected to represent the likelihood categories 'Likely', 'Possible', 'Unlikely' and 'Rare' are based on the 2 yr, 10yr, 100 yr and 500 yr ARI respectively and include the SLR corresponding to the planning year.
- The Almost Certain category has been established based on the highest astronomical tide level (HAT).

Table 7.4: Inundation Likelihood Categories

Rating	2020	2030 +0.1m SLR	2050 +0.2m SLR	2070 +0.4m SLR	2120 +0.9m SLR
Almost Certain	2020 HAT	2030 HAT	2050 HAT	2070 HAT	2120 HAT
Likely	2020 2yr ARI	2030 2yr ARI	2050 2yr ARI	2070 2yr ARI	2120 2yr ARI
Possible	2020 10yr ARI	2030 10yr ARI	2050 10yr ARI	2070 10yr ARI	2120 10yr ARI
Unlikely	2020 100yr ARI	2030 100yr ARI	2050 100yr ARI	2070 100yr ARI	2120 100yr ARI
Rare	2020 500yr ARI	2030 500yr ARI	2050 500yr ARI	2070 500yr ARI	2120 500yr ARI

Table 7.5: Inundation Likelihood for Shire of Murray - Water Level (Vertical Datum m AHD)

Rating	2020 Water Level (m AHD)	2030 Water Level (m AHD)	2050 Water Level (m AHD)	2070 Water Level (m AHD)	2120 Water Level (m AHD)
Almost Certain	0.6m	0.7m	0.9m	1.1m	1.6m
Likely	0.8m	0.9m	1.0m	1.2m	1.7m
Possible	0.9m	1.0m	1.1m	1.3m	1.8m
Unlikely	1.1m	1.2m	1.3m	1.5m	2.0m
Rare	1.4m	1.5m	1.6m	1.8m	2.3m

7.3 Consequence

7.3.1 Consequence Scale

Consequence is used to describe the impact to assets when coastal hazard is realised. The consequence of coastal hazard is considered across a range of categories representing severity: 'Insignificant, Minor, Moderate, Major, Catastrophic'.

The consequence scale considers impact in terms of Physical, Environmental and Social impact as shown in Table 7.6. In the community engagement workshops (May 2021), stakeholders and community worked with the consequence scale on Table 7.6 to rate the impact of erosion and inundation on assets identified within each of the SMUs. Through a series of tasks, the format of the consequence scale presented in Table 7.6 was found to work appropriately for this process.

Table 7.6: Consequence Scale

Rating	Economic Impact	Environmental Impact	Social / Cultural Impact	Infrastructure
Catastrophic	Permanent loss or damage > \$5 million	Permanent loss of flora and fauna – will not recover	Long-term or permanent loss of function >75% of community affected	Damage to majority of infrastructure (>75%)
Major	Permanent loss or damage \$2 - \$5 million	Long term loss of flora and fauna, limited chance of recovery	Medium-term disruption to function <50% of community affected	Damage to significant proportion of infrastructure (50% to 75%)
Moderate	Permanent loss or damage \$200k - \$2mil	Medium term loss of flora and fauna. Recovery likely	Minor long Term or major Short-Term loss of function <25% of community affected	Damage to up to half the infrastructure (25% to 50%)
Minor	Permanent loss or damage \$20k - \$200k	Short term loss of flora and fauna. Strong Recovery	Small to medium disruption to function <10% of community affected	Minor damage (10 to 25%)
Insignificant	Permanent loss or damage < \$ 20k	Negligible to no loss of flora and fauna	Minimal short-term inconvenience <5% of community affected	Little or no damage (<10%)

7.3.2 Safety and Structural Considerations

Inundation depth in extreme events and the safety and stability limits for people and structures in floodwaters generally requires consideration of flood depth and velocity. Safety limits for people and infrastructure based on velocity and depth is presented in Figure 7.2 (from Smith et al 2014). A limitation of the flooding results available to the CHRMAP study is that velocity is not available for the extreme events. In the absence of velocity information, a flood level of 1m over the finished floor level has been adopted as representing a threshold where structures would fail, unless specifically constructed to withstand flooding (category H5 in Figure 7.2). At a depth of 1m, there is also a risk posed to the safety of people. This is recognised in the consequence rating for inundation of houses, whereby a depth of flooding greater than 1.0m above the finished floor level is categorised as major consequence.

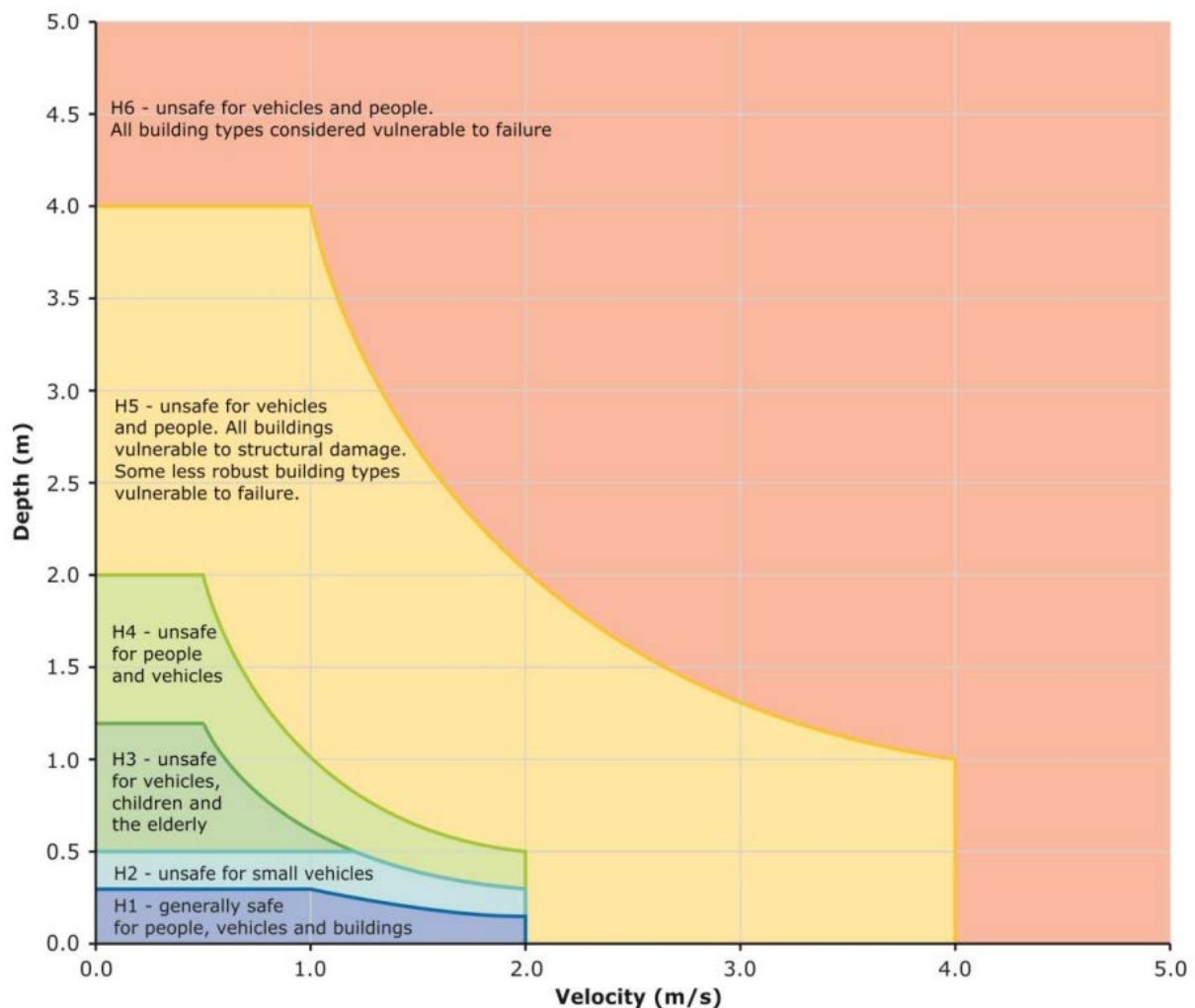


Figure 7.2: Flood Hazard Curve – Vulnerability thresholds as a Product of Inundation Depth and Velocity (from Smith et al 2014)

7.3.3 Consequence Rating – Coastal Asset Register

The consequence of coastal hazard impact is different for each respective coastal asset and severity of impact is dependent on the hazard type – as an example the consequence of erosion for a shoreline is much more severe than that of inundation.

The consequence rating is shown for erosion and for inundation for a range of asset types in Table 7.7. It is noted that the consequence rating in Table 7.7 is the 'worst' rating across the categories Economic, Environmental, Social/Cultural and Infrastructure for each respective asset.

Table 7.7: Consequence Rating for Coastal assets – Erosion and Inundation

Asset Type	Erosion	Inundation
	Consequence	Consequence
Houses	Major	Moderate ¹
Vacant Land	Moderate	Minor
Local Roads	Moderate	Moderate
Agricultural Land	Minor	Minor
Major Roads (Forrest Highway)	Major	Major
Carparks	Moderate	Minor
Beaches	Major	Insignificant
Riverbanks	Major	Insignificant
Foreshore Reserve	Moderate	Minor
Lake McLarty, Lake Mealup, Kooljerrenup Nature Reserve ²	Major	Major
Jetties and Boat Ramps	Moderate	Minor
Park Furniture (Benches, Gazebo, BBQ, Play equipment)	Minor	Minor
Minor Infrastructure (signage, shelters, fencing)	Insignificant	Insignificant
Camp and Caravan Parks	Moderate	Minor
Coastal Pathway / cycle paths	Moderate	Minor
WaterCorp Utilities (pipes / pits)	Moderate	Moderate
Stormwater pipes / outlets, culverts	Moderate	Minor
Toilets	Minor	Minor
Footpaths	Minor	Minor

Notes

1. For houses with depth of flooding >1.0m over the Finished Floor level the consequence is rated as major. Below this level the rating is moderate.
2. Consequence rating reflects importance under Ramsar Site 482

8. Level of Risk

8.1 Potential Impact

The assessment of potential impact to coastal assets uses the likelihood and consequence to determine a level of risk.

Risk ratings are designated in four categories based on WAPC (2019):

- Extreme - risks are intolerable, requiring immediate implementation of risk management measures.
- High - risks are the most severe that can be tolerated and need monitoring in the short term as risk management measures are likely to be needed in the short-term.
- Medium - risk can be tolerated and need monitoring in the short to medium term.
- Low - risk can be accepted, no risk management measures will be required in the short to medium term other than monitoring.

The risk level matrix is presented in Table 8.1.

Table 8.1: Potential Impact Scale - Likelihood / Consequences matrix to assess level of risk

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

For the assets in the asset register the risk rating has been determined in each planning timeframe for each of the SMU's. The summary is presented in Appendix D.1 for erosion and Appendix D.2 for inundation.

8.2 Risk Acceptance and Tolerance

The risk tolerance scale provides the basis for decision making to inform which risk, locations and assets require risk management measures as a priority. For the level of risk defined for the coastal assets, the corresponding tolerance scale is shown on Table 8.2. The tolerance scale has been developed from engagement with the community and based on the approach in WAPC (2019).

For a risk at the 'High' and 'Extreme' level, action to mitigate the risk is required. At lower level of risk, the risk is acceptable and no action is required.

Table 8.2: Risk Tolerance Scale

Risk Level	Action Required	Acceptance / Tolerance
Extreme	Immediate action required to eliminate or reduce the risk to acceptable levels	Unacceptable / Intolerable
High	Immediate to short term action required to eliminate or reduce the risk to acceptable levels	Tolerable
Medium	Short to medium term action to reduce the risk to acceptable levels, or accept risk	Tolerable / Acceptable
Low	Accept Risk	Acceptable

8.3 Adaptive Capacity

The concept of adaptive capacity recognises that some assets will cope with coastal hazard risk better than others. The coastal assets are rated with a consideration of how well they can recover from coastal inundation or erosion hazard, i.e. their potential to adjust to address risk arising from coastal hazards with minimal disruption and cost.

The adaptive capacity scale of the assets adopts a rating in one of three categories from worst performing ('Poor') to best performing ('Good') as shown in Table 8.3 developed from WAPC (2019).

Table 8.3: Adaptive Capacity Rating for Coastal Assets (based on WAPC 2019)

Rating	Adaptive Capacity
Poor	Little or no adaptive capacity. Potential impact would destroy all functionality. Redesign required
Average	Small amount of adaptive capacity. Difficult but possible to restore functionality through repair and redesign
Good	- Good adaptive capacity. Functionality restored easily. - Adaptive systems restored at a relatively low cost or naturally over time.

The potential for an asset to recover from the impact of either erosion or inundation is generally different and has been rated separately. A summary of the adaptive capacity ratings is provided in Table 8.4.

Table 8.4: Adaptive Capacity Ratings of Coastal Assets – Erosion and Inundation

Asset Type	Adaptive Capacity Rating	
	Erosion	Inundation
Houses	Poor	Average / Poor ¹
Vacant Land	Average	Good
Local Roads	Poor	Average
Major Roads (Forrest Highway)	Poor	Average
Carparks	Poor	Good
Beaches	Average	Good
Riverbanks	Average	Good
Foreshore Reserve	Average	Good
Jetties and Boat Ramps	Average	Good
Lake Mealup, Lake McLarty, Roberts Bay Swamp	-	Poor ²
Kooljerrenup Nature Reserve	Average	Average
Parks & Playgrounds (Benches, Gazebo, BBQ, Play equipment)	Average	Average
Minor Infrastructure (signage, shelters, fencing)	Good	Good
Camp and Caravan Parks	Average	Good
Coastal Pathway / cycle paths	Average	Good
WaterCorp Utilities (pipes / pits)	Poor	Average
Stormwater pipes / outlets, culverts	Poor	Average
Toilets	Poor	Average

Notes

1. For houses and commercial business with depth of flooding >1.0m over the Finished Floor level the adaptive capacity is rated as poor.
2. This rating accounts for system ability to manage saltwater intrusion from the Estuary
3. The GIS information from WaterCorp received through Dial before you dig did not specify the location of pumping stations. Only pipes and pits have been evaluated in this assessment.

8.4 Vulnerability Scales

Using the risk level calculated in the potential impact stage (Table 8.1), the adaptive capacity of the respective assets was then considered to determine the final vulnerability rating for each of the assets.

Table 8.5: Asset Vulnerability Matrix

Potential Impact	Adaptive Capacity Rating		
	Poor	Average	Good
Extreme	Very High	Very High	High
High	Very High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

The final vulnerability rating of the assets in all CMU's is summarised in **Appendix D.1** for erosion risk and **Appendix D.2** for inundation risk.

A vulnerability tolerance scale determines the level at which vulnerability is deemed acceptable, tolerable or intolerable. The vulnerability tolerance scale is shown in Table 8.6 developed from WAPC (2019) and used to identify which risk, locations, assets and values require risk management measures as a priority.

Table 8.6: Vulnerability Tolerance Scale

Risk Level	Action Required	Acceptance / Tolerance
Very High	Asset has minimal ability to cope with the impacts of coastal hazards without additional support. Adaptation will need to be considered as a priority.	Unacceptable / Intolerable
High	Asset has limited ability to cope with the impacts of coastal hazards. Immediate to short-term adaptation is likely to be required to reduce risk to acceptable levels.	Tolerable
Medium	Asset has some ability to cope with the impacts of coastal hazards. However short to medium term actions are likely to be required to reduce risk to acceptable levels	Tolerable / Acceptable
Low	Asset has high resilience; it is able to cope with the impacts of coastal hazards without additional support. No immediate action required	Acceptable

9. Risk Assessment Outcomes

The outcomes of the risk assessment are discussed here for the six SMU's based on the full results of the risk assessment presented in **Appendix D.1** for erosion risk and **Appendix D.2** for inundation risk.

9.1 SMU1 - South end of Harvey Estuary (Includes Herron Point).

SMU1 extends along the shoreline of the Kooljerrenup Nature Reserve, across approximately 8km of the lower Harvey Estuary. Due to the natural state of the foreshore areas, it is considered the majority of the SMU provides adequate area landward of the present-day shoreline for coastal processes in future planning periods. The shoreline areas are low lying and inundation extents associated with extreme events and sea level rise scenarios show the hazard region extending up to 400m inland through the Kooljerrenup Nature Reserve in the region south of Herron Point.

A summary of the key findings for SMU1 are:

- The vulnerability rating for the Kooljerrenup Nature Reserve is high in 2030 and 2050 rising to very high in 2070 and beyond. For inundation the vulnerability rating is moderate in 2030, high in 2050 and 2070, rising to very high in 2120
- The consequence rating for inundation and erosion risk is major for the Kooljerrenup Nature Reserve as it is one of the components of Ramsar Site 482 primarily because of the habitat (food, shelter and refuge) it provides for water birds, including migratory shorebirds, some of which are threatened species. The estuary foreshore also supports patches of samphire, a threatened ecological community (EPBC Act 1999) - coastal saltmarsh occurs along most of the foreshore from the Harvey Drain through Kooljerrenup Nature Reserve to the north of Herron Point (pers comm S.Fisher-J.Churchill).

For Herron Point, there are a range of assets that are at risk of erosion and inundation including the Herron Point access road, Herron Point boat ramp, campground and car park.

- For inundation the vulnerability is rated low to moderate for most assets, with the roads in the campground and the Herron Point access road rated highly vulnerable from the 2070 period onward.
- For erosion, the beach around Herron Point, the carpark and boat ramp are all rated highly vulnerable by 2030 with increasing vulnerability (increasing to very high rating) in future planning periods. In planning timeframes from 2050 onward, assets that reach high vulnerability ratings include the foreshore reserve, coastal pathways and roads and toilets of the camping ground.

9.2 SMU2 – Birchmont

SMU2 extends along approximately 7km of the Harvey estuary and includes the Birchmont section of coast through to Mealup Point. The shoreline is largely undeveloped with foreshore reserve in front of the Birchmont developed lots and the Mealup Point nature reserve providing a buffer between the Harvey Estuary and areas landward. The Birchmont boat ramp and carpark are sited in close proximity to the estuary within the coastal hazard region for inundation and erosion. Development north and south of the boat ramp in the form of large rural lots is generally behind the coastal hazard areas with some encroachment of the hazard on the lower western edge of the lots in future planning periods. There is natural elevation in the shoreline areas inland which means there is a narrower section of the coast susceptible to flooding during extreme design flooding scenarios compared with SMU1.

A summary of the key findings for SMU2 are:

- The erosion vulnerability is rated high for beaches in the timeframe from 2030 onwards, whilst there are several assets that reach a high rating by the year 2050 including nature reserve, coastal pathways, the boat ramp and car park. By planning year 2070, the residential lots (western edge) as well as the access road to the boat ramp and Birch Drive are rated highly vulnerable.

- For inundation
 - the vulnerability is moderate to low for most coastal assets. For residential properties the rating is moderate at 2030 and 2050 and then high in the planning year 2070 onwards reflecting the influence of projected sea level rise.
 - For Lake McLarty and Lake Mealup the vulnerability is moderate in 2030, high in 2050 and 2070 and extreme in 2120 reflecting the sensitivity of the Lake systems should salt-water intrusion from the Estuary in large events under sea level rise projections become commonplace. It is noted the flood control weir at Lake Mealup is not considered in this assessment – this is discussed further in Chapter Report 4 controls.

9.3 SMU3 – Point Grey to Austin Bay

SMU3 extends along approximately 25km of shoreline which includes the northern section of the Harvey estuary around Point Grey and into the Peel Estuary through the shorelines of Roberts Bay and Austin Bay.

The shoreline through this SMU is undeveloped with foreshore reserve and nature reserve providing a buffer between the Peel-Harvey shorelines and areas landward. Around Point Grey, the natural topography rises sharply directly inland of the shoreline, reducing the inundation hazard extent to a minimum. The shoreline areas are much flatter through the Peel sections of Roberts Bay and Austin Bay and inundation hazard reaches further inland compared with Point Grey. In future planning periods extreme flooding scenarios impact agricultural land on the edge of the nature reserve of Austin Bay.

A summary of the key findings for SMU3 are:

- The vulnerability to erosion of Carabunga Road is rated high in 2030 and very high 2050 onwards. For the beach areas and drainage features these are also rated highly vulnerable to erosion from 2030 onwards. Foreshore reserve, coastal pathways and agricultural land are rated moderate in 2030 and highly vulnerable by planning year 2050. For residential lots on Point Grey, small sections of the land area adjacent the Peel-Harvey estuary are rated highly vulnerable from planning year 2070.
- The inundation vulnerability is rated low to moderate for most of the coastal assets, with the exception of:
 - Carabunga Rd which is rated highly vulnerable through all planning periods. The Carabunga Rd section along Roberts Bay approaching Point grey is low lying and close to the Peel Estuary shoreline.
 - Roberts Bay swamp which is rated highly vulnerable at 2030 and very highly vulnerable in future under projected sea level rise based on the understanding that increasing salt water intrusion is a major threat to the ecological character of Robert Bay swamp (pers comm S.Fisher-J.Churchill).

9.4 SMU4 - South Yunderup (including the Canals)

SMU4 describes South Yunderup, including the 4km section of the Peel Estuary shoreline south of the Murray River entrance as well as the southern side of the Murray River from the entrance to Pinjarra Road (~7.5km). The South Yunderup canals and the Austin Cove development are included in the SMU.

The erosion vulnerability assessment showed:

- Beaches of the Peel and the riverbank areas were rated highly vulnerable in the 2030 period increasing to very high later in the planning timeframe.
- At Batavia Quay the revetment on the Peel shoreline has been established to protect the area inland, which was the site of the dredge spoil for the original canals of South Yunderup. Acid Sulphate Soils are located on the site which if disturbed and released into the Murray River would cause environmental damage. Under the vulnerability assessment the very high rating is determined under

an assumption the revetment is not maintained by the Shire (ie allowed to fail affecting land protection behind it). This assumption will be reviewed in the next Chapter report as part of the existing controls.

- Residential properties located in the section of shoreline between Young Rd to Strain Glen and from Pelican Road to Banksia Terrace are rated highly vulnerable in 2030 and very high from 2050 onwards. The properties directly adjacent the Batavia Quays car park are rated very highly vulnerable in all planning periods, an outcome which is directly affected by the decision on whether to maintain the revetment structure on the headland. This will be further explored in Chapter Report 4.
- The bund in front of the South Yunderup canals is rated high to very highly vulnerable in the 2070 to 2120 planning periods.
- Coastal pathways, car parks and toilets adjacent the River Murray are all rated highly vulnerable over the planning timeframe. Jetties, boat launch areas and foreshore reserve are rated highly vulnerable.
- Drainage features (culverts/ pipework etc) and Watercorp infrastructure is rated high to very highly vulnerable through the planning periods due to its close proximity to the coastal erosion hazard area.

The findings of the inundation assessment were:

- The lower Peel shoreline and the Austin Bay nature reserve are very low lying and susceptible to flooding. Inland development is minimal through this section of the coast with agricultural land around Beacham Rd experiencing coastal inundation hazard in extreme events in future planning periods. The planning levels for the recently established Austin Cove development are safely above the coastal inundation hazard over the 100-year planning timeframe.
- For the south Yunderup canal developments, the floor level of properties is set high enough that vulnerability inundation is rated low until the year 2120 at which point it is rated moderate.
- The recent canal developments and landside areas around the Sandy Cove Tavern and South Yunderup sports club are all sited above the inundation hazard.
- The bund feature that is constructed on the Peel shoreline in front of the canal development to control water quality is rated as highly vulnerable to inundation in 2030 and 2050 and then very highly vulnerable in future planning years. This will be further explored in Chapter Report 4 as part of existing controls.
- The revetment on the Peel shoreline at the Murray entrance adjacent Batavia Quay protects the site of the dredge spoil sediments (Acid Sulphate Soils) which if released into the Murray River would be harmful. The level of the revetment is expected to protect the region from inundation in all coastal inundation scenarios. It is imperative this revetment be maintained in its current form or higher in future planning periods (discussed further in Chapter Report 4).
- For residential areas along the Murray there are two key areas which are rated highly vulnerable to inundation by planning year 2120. These are for properties located in the section between Young Rd to Strain Glen and from Pelican Road to Banksia Terrace. The finished floor level of the properties was determined by assessing the ground level of the LiDAR with the addition of 0.3m assumed for freeboard (eg pad height of developed properties).
- Other assets that are rated highly vulnerable in the 2030 period include drainage features and WaterCorp infrastructure due to being located close to the shoreline areas.

9.5 SMU5 - North Yunderup including Murray Delta Islands

SMU5 describes the areas on the northern bank of the Murray River at North Yunderup, and also includes the Murray Delta Islands. The projected erosion along the banks of the Murray River is the driver for vulnerability of residential areas in SMU5. The Murray Delta islands are generally low lying. Whilst they are generally set above the present-day extreme water levels, they are susceptible to flooding in extreme events in future planning periods under adopted sea level rise.

The erosion assessment outcomes are as follows:

- The developed areas on Yunderup Island, Ballee Island and Cooleenup are all rated very highly vulnerable by planning year 2070. For the residential properties on Culeenup Road along the river, these are rated very highly vulnerable from 2030.
- The site of Coopers Mill and the caretakers house are rated highly vulnerable in planning year 2030 and beyond.
- The beaches on the Peel estuary and the riverbank areas of the Murray and delta islands are all rated high to very highly vulnerable through the planning timeframe.
- The car park at the boat launch and the toilets adjacent the Coopers Mill are both rated highly to very highly vulnerable over the planning timeframe.
- Jetties, boat launch areas, coastal pathways and foreshore reserve are rated highly vulnerable.
- Drainage features (culverts/ pipework etc) and Watercorp infrastructure is rated high to very highly vulnerable through the planning periods due to its close proximity to the coastal erosion hazard area.

The findings of the inundation assessment were:

- The vulnerability rating for residential properties on the Murray Delta Islands increased through future planning periods and was rated high in 2050 and 2070 and very high in 2120, due to the increased exposure risk to flooding as a result of projected sea level rise. The floor level of the properties was determined by assessing the ground level of the LiDAR around established structures with an addition of +0.3m assumed for freeboard (eg pad height of developed properties). It is noted that the land area around the house is generally at a lower elevation. The risk analysis and vulnerability rating is based on the finished floor level of the lowest established property on each respective island ie there are other developed properties that are at a higher elevation. Undeveloped lots have not been considered in the results.
- It is assumed all island properties are on septic systems. These are rated as highly vulnerable from 2030 onward on all islands. The level of the septic system is considered to be just above the highest astronomical tide (0.6m to 0.7m AHD). The risk of flooding is rated extreme, with the septic system considered to have good adaptive capacity. The resulting vulnerability rating is high for all planning periods.
- Coopers Mill is rated highly vulnerable in all planning periods. The site is low lying and close to the rivers edge and there is evidence of previous flooding from recent large storms events.
- Drainage features (culverts/ pipework etc) and Watercorp infrastructure is rated highly vulnerable through the planning periods due to its close proximity to the coastal erosion hazard area.

9.6 SMU6 - Serpentine River and Furnissdale

SMU6 describes the approximate 5km section of the Serpentine River from the entrance to Pinjarra Road and includes the suburb of Furnissdale. The SMU is a mix of residential and large rural blocks. The inland area in the region bounded by Tonkin Rd, Goodooga Rd and Furnissdale Rd is low-lying and largely undeveloped and is susceptible to flooding. The developed areas along the river at Riverside Drive are susceptible to inundation risk in future planning periods.

The erosion assessment outcomes showed:

- The riverbank areas are high to very highly vulnerable to erosion over the planning periods.
- The foreshore reserve at Furnissdale, the jetties and boat ramp are all rated highly vulnerable.
- Car parks are rated high to very highly vulnerable over the planning period
- Residential properties along Riverside Drive near Smith Street and in the larger properties north of Paull Street were rated high to very highly vulnerable over the planning timeframe. Several residential properties on the banks of the Serpentine River in the section between Furnissdale Road and the Serpentine entrance were rated high to very highly vulnerable.

- A small section of Riverside Drive near Smith Street which is in close proximity to the foreshore is rated as high to very highly vulnerable.
- Drainage features (culverts/ pipework etc) and Watercorp infrastructure is rated high to very highly vulnerable through the planning periods due to its close proximity to the coastal erosion hazard area.

The findings of the inundation assessment were:

- The foreshore reserve, jetties and carparks are rated at low to moderate vulnerability over the planning period.
- The residential properties along Riverside Drive are rated highly vulnerable in the planning year 2120
- Sections of Riverside drive, Ronlyn Rd and Furnissdale Rd are rated highly vulnerable by 2070 under adopted sea level rise.
- Drainage features (culverts/ pipework etc) and Watercorp infrastructure is rated highly vulnerable through the planning periods due to its close proximity to the coastal erosion hazard area.

10. Risk Evaluation

10.1 Overview

The Risk Evaluation phase of the CHRMAP is used to prioritise risk management measures for the study area. The results from the risk assessment detailed in the previous Section are examined in greater detail for assets with vulnerability risk rated high and very high. The risk evaluation considers if there are already risk management measures in place or existing controls that can be taken into consideration to reduce the risk rating determined through the vulnerability assessment.

This approach is designed to prioritise the treatment of the assets at risk and help direct resources to key locations that are in greatest need of attention, recognising that it is not possible to treat every asset at risk in the study area. Upon completion of this stage, the residual risk rating for assets through the study area will be determined and the most vulnerable assets requiring risk management measures as a priority will be identified.

10.2 Existing Controls

Existing controls and risk management measures already in place in the Shire of Murray study area have the potential to reduce the consequences and/or likelihood of coastal hazard. Controls can be in the form of

- Physical controls (e.g. shoreline protection structures or seawalls);
- Natural controls (e.g. shoreline topography features); or
- Planning Controls (e.g. controls on building development like finished floor levels).

The existing controls were not considered in the initial risk assessment and vulnerability assessment. The influence of the existing controls on mitigating risk for assets is completed in this Section to determine a final rating of residual risk for assets in each SMU.

10.3 Existing Controls by SMU

Within the SoM shoreline areas there are a range of planning controls, physical controls, and natural controls. For each of the SMU's these controls and their influence are summarised in Table 10.1. The influence of the controls on asset vulnerability is summarised in Table 11.2 to Table 11.7 in the Section 3.

Table 10.1: Summary of Existing Controls in the Coastal Management Units

SMU	Control	Comment
1 South end of Harvey Estuary (Includes Herron Point).	1. Natural shoreline areas	Provide buffer against erosion for landward areas. No development in the shoreline.
	2. Harvey River Outlet	Localised impacts - control of alongshore flow of sediment
	3. Herron Point Boat Ramp	Shoreline control of alongshore flow of sediment. The boat ramp is flanked by rocks and low rock revetments along the foreshore either side of the structure. In current form, this is not considered to be adequate erosion protection for the car park in future planning periods.

SMU	Control	Comment
2. Birchmont	1. Natural shoreline areas	Provide buffer against erosion for landward areas.
	2. Birchmont Boat Ramp – control structures either side on foreshore	Localised impacts - control of alongshore flow of sediment. The boat ramp is flanked by low rock groynes either side of the structure.
	3. Development controls	Development is setback from the coast to allow for coastal processes in the future. Some areas of land are at risk of erosion and/ or inundation hazard.
	4. Lake Mealup flood control structure	There is a flood control structure in place at Lake Mealup which prevents ingress of salt water from the estuary during extreme events. It is assumed this will be maintained and upgraded to meet any future sea level rise.
3. Point Grey to Austin Bay	1. Natural shoreline areas	Provide buffer against erosion for landward areas. No development in the shoreline.
	2. Development controls	Development is setback from the coast to allow for coastal processes in the future.
4. South Yunderup (including the Canals)	1. Bund / revetment structure around the foreshore at Batavia Quays protecting old dredge spoil site	Assumed this is maintained in future planning periods to provide erosion control measure to prevent the breach of the site and potential exposure of acid sulphate soils in the river system.
	2. Bund around the shoreline in front of South Yunderup Canals	Assumed this is maintained in future planning periods to prevent erosion and inundation in large events and continue to serve as a water quality safeguard for the canal network.
	3. Canal Walls - Yunderup Canals - Murray Waters - Murray Lakes	Assumed that the integrity of canal walls is maintained in future planning periods to safeguard landward areas against erosion. The Shire has a specific Policy that provides requirements for the replacement and modification of canal walls in Yunderup Canals Stage 1 that were originally constructed of asbestos in the 1970's. The objectives and requirements of the Policy will ensure new canal walls are constructed to a suitable standard and height, are of a consistent design and are structurally sound within their marine environment.
	4. Development Controls	Local Planning Scheme 4 (LPS4) Part XII establishes requirements for land located within river flood plains. Amongst these requirements are the following:

SMU	Control	Comment
		a) A plan of subdivision shall not be approved for land within a flood fringe in the Residential or Canal Development zones unless that part of the land behind the minimum setbacks from street and rear boundaries is not less than 300mm above the flood level. b) A plan of subdivision shall not be approved for land within a flood fringe in the Special Rural zone unless part of the land in each lot has an area of not less than 2,000sqm at or above the flood level and is suitable for the erection of a dwelling in accordance with the provisions of this Scheme. c) Building levels within flood fringe land shall be a minimum of 150mm above the 1 in 100 year flood level for all existing subdivisions and for new subdivisions 500mm above the 1 in 100 year flood level.
	5. Shoreline Structures a. Tatham Rd Foreshore River wall b. Lucie Hunter Park Canal wall c. Pelican Road Park River wall and Canal wall d. Batavia Quays Launch Canal Wall and Revetment	Assumed these are Maintained by the Shire in future planning years. Provide protection to areas landward from erosion.
5. North Yunderup including Murray Delta Islands	1. Development Controls	Local Planning Scheme 4 (LPS4) Part XII establishes requirements for land located within river flood plains. Amongst these requirements are the following: a) A plan of subdivision shall not be approved for land within a flood fringe in the Residential or Canal Development zones unless that part of the land behind the minimum setbacks from street and rear boundaries is not less than 300mm above the flood level. b) A plan of subdivision shall not be approved for land within a flood fringe in the Special Rural zone unless part of the land in each lot has an area of not less than 2,000sqm at or above the flood level and is suitable for the erection of a dwelling in accordance with the provisions of this Scheme. c) Building levels within flood fringe land shall be a minimum of 150mm above the 1 in 100 year flood level for all existing subdivisions and for

SMU	Control	Comment
6. Serpentine River and Furnissdale		new subdivisions 500mm above the 1 in 100 year flood level.
	2. Natural Shorelines of the Murray Islands on the Peel Inlet (Meeyip Island, Ballee Island, Worallgarook Island, Yunderup Island)	Provide buffer against erosion for landward areas. Noted in Coastal Hazard assessment that maintaining the foreshore berm is critical to prevent significant erosion and inundation in large events in future.
	3. Shoreline Structures	
	a. Coopers Mill Precinct River Wall	Assumed these are Maintained by the Shire in future planning years. Provide protection to areas landward from erosion.
	b. N.Y River wall at western end Culeenup Rd	
	1. Development Controls	Local Planning Scheme 4 (LPS4) Part XII establishes requirements for land located within river flood plains. Amongst these requirements are the following: a) A plan of subdivision shall not be approved for land within a flood fringe in the Residential or Canal Development zones unless that part of the land behind the minimum setbacks from street and rear boundaries is not less than 300mm above the flood level. b) A plan of subdivision shall not be approved for land within a flood fringe in the Special Rural zone unless part of the land in each lot has an area of not less than 2,000sqm at or above the flood level and is suitable for the erection of a dwelling in accordance with the provisions of this Scheme. c) Building levels within flood fringe land shall be a minimum of 150mm above the 1 in 100 year flood level for all existing subdivisions and for new subdivisions 500mm above the 1 in 100 year flood level.
	2. Serpentine River Entrance and shorelines	Provide buffer against erosion for landward areas.
	3. Shoreline Structures	
	a. River Wall, Furnissdale Bridge Foreshore	Assumed these are Maintained by the Shire in future planning years. Provide protection to areas landward from erosion.

10.4 Planning Controls

10.4.1 Existing Planning Controls

The existing planning controls applicable to land use and development within the Shire have been reviewed with a complete summary in Appendix E.1. The review has a particular focus on coastal planning and management aspects relating to the preparation of this CHRMAP.

The following documents are included in the review:

- Corporation Strategic Planning
 - Murray 2030 Strategic Community Plan
 - Corporate Business Plan 2020 - 2024
 - Emergency Risk Management Report 2013
- Relevant Legislation
 - Planning and Development (Local Planning Schemes) Regulations 2015
- State Planning Framework
 - Perth and Peel @ 3.5 Million
 - Peel Region Scheme
 - State Planning 2.1: Peel-Harvey coastal plain catchment
 - State Planning Policy 2.6: State Coastal Planning
 - State Planning Policy 2.6: State Coastal Planning Policy Guidelines
 - State Planning Policy 3.4: Natural Hazards and Disasters
 - Development Control Policy 1.8: Canal Estates and Artificial Waterway Development
- Local Planning Framework
 - Shire of Murray Local Planning Scheme No. 4
 - Boating Facilities and Moorings Local Planning Policy
 - General Development Requirements for Properties Abutting an Artificial Canal Waterway
 - Canal Walls – Yunderup State One Canals, Local Planning Policy
- Structure Plans
 - Lot 803 North Yunderup Road Structure Plan Map
 - Lots 1, 2 and 49 Banksia Terrace, South Yunderup
- Masterplans
 - Murray River Foreshore Masterplan

10.4.2 Summary of Statutory Planning Mechanisms

Based on a review of the existing planning controls, the statutory planning mechanisms that may be available to address coastal hazards within the Shire of Murray as part of the Stage 5 Risk Treatment are considered in the following table which outlines the advantages and disadvantages of each option. Based on the review, a Special Control Area (SCA) in conjunction with the Local Planning Policy is considered the most appropriate mechanism.

Table 10.2: Summary of Existing Planning Controls

Statutory Measure	Advantages	Disadvantages
Structure Plan / Activity Centre Plan	Can address location specific issues i.e. identification of coastal physical setbacks and areas affected by storm surge.	Does not have the force and effect of the Scheme. Decision makers to have due regard only. Structure Plan cannot specify / enforce built form requirements. Location specific only and therefore cannot address coastal hazard issues on a broad scale. Generally, requires the land to be appropriately zoned to require the preparation of a structure plan.
Local Development Plan	Can specify built form requirements to address location specific coastal hazard issues i.e. increased setbacks, minimum habitable floor levels etc. Has statutory weight of the local planning scheme. Can vary 'deemed-to-comply' development requirements.	Location specific only and therefore cannot address coastal hazard issues on a broad scale.
Local Planning Policy	Can address coastal hazard and risk issues at a district (broad) level and/or at a location specific level. Can include mapping of coastal hazard issues with flexibility to update mapping as and when amendments are required to be undertaken. Can vary 'deemed-to-comply' development requirements. Can be amended relatively quickly (compared to local planning scheme amendment as new coastal studies are completed).	
Special Control Area	SCAs may establish specific provisions to address a specific issue such as storm surge and or coastal processes. SCAs can broadly address unique issues that extend across multiple zones and/ or reserves.	A scheme amendment would potentially need to be progressed every time mapping of the coastal issue is amended and/or updated. This may be avoided if the Special Control Area refers to a separate Local Planning Policy which may

Statutory Measure	Advantages	Disadvantages
	SCAs can be used to require development approval for otherwise normally 'exempted' development. In this regard, SCAs are the preferred mechanism to identify where and what type of development requires development approval to allow for appropriate consideration of the risk of coastal processes.	contain reference to mapping of coastal hazards.
General Development Provisions (Part 4; Clause 32 of the model scheme provisions)	Can establish provisions which broadly address coastal hazards. Can introduce provisions which relate to a local planning policy addressing coastal hazards and which may contain coastal hazard mapping.	Given the specific nature of coastal issues, including the varied locational extent to which it may affect land within a district, specific development requirements would more appropriately be established within a Special Control Area as opposed to general provisions within the scheme.
Supplemental Provisions to Schedule 1 and 2 of the Regulations	May be used to supplement the standard scheme provisions set out in Schedule 1 and 2 of the Regulations to address specific coastal process issues.	Given the specific nature of coastal issues, including the varied locational extent to which it may affect land within a district, specific development requirements would more appropriately be established within a Special Control Area as opposed to the supplemental provisions of a scheme.

11. Residual Risk and Priority for Treatment

The vulnerability rating for assets is presented in this section, which incorporates consideration of existing controls through each SMU. The existing controls, found in Table 10.1, relevant to certain assets will be denoted with a superscript number referencing the existing control number from this table.

The final asset vulnerability rating is presented in a traffic light system as shown in Table 11.1.

Table 11.1: Vulnerability Rating Summary

Rating	Description of Asset Vulnerability and Action Required
● Low	Asset has high resilience; it is able to cope with the impacts of coastal hazards without additional support. No immediate action required
● Medium	Asset has some ability to cope with the impacts of coastal hazards. However short to medium term actions are likely to be required to reduce risk to acceptable levels
● High	Asset has limited ability to cope with the impacts of coastal hazards. Immediate to short-term adaptation is likely to be required to reduce risk to acceptable levels.
● Very High	Asset has minimal ability to cope with the impacts of coastal hazards without additional support. Adaptation will need to be considered as a priority.

For each of the SMU's the assets and the coastal hazards are presented in mapping in Appendix F. The format of the mapping in Appendix F presents the 2120 planning year coastal processes allowance (erosion) and the inundation hazard for the 500yr ARI event in the planning year 2120 (shown as depth). The hazard areas depicted in the Appendix F maps are presented as potential inundation and coastal processes areas of impact based on SPP2.6. They are used to inform areas requiring further consideration for planning, management and monitoring in this CHRMAP (example from SMU4 is shown in Figure 11.1).

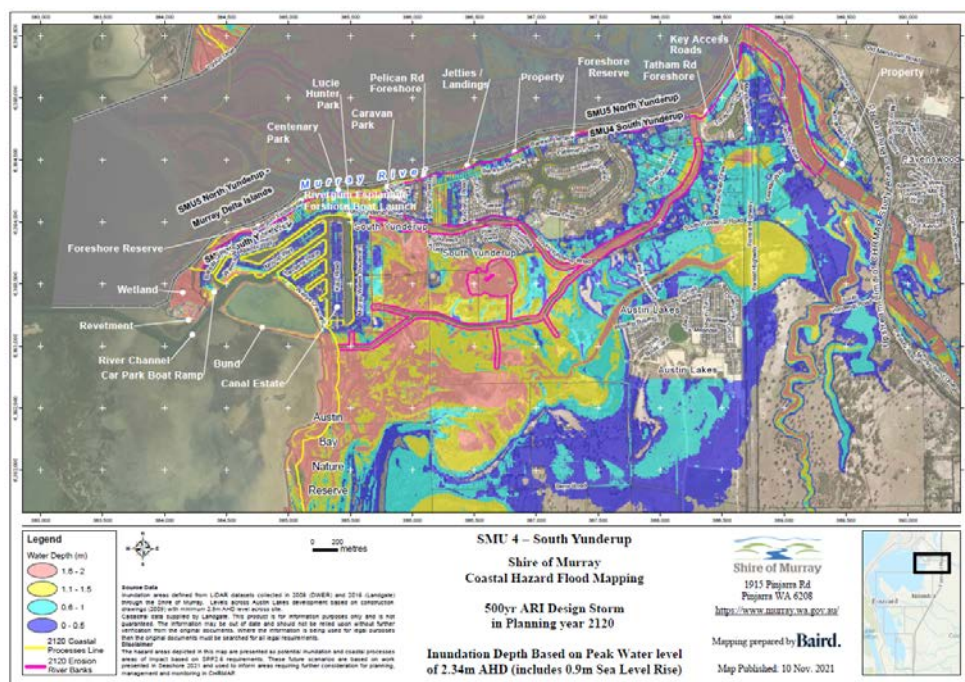


Figure 11.1: Example of SMU4 Assets with Coastal Hazard Mapping (plots available in Appendix F)

11.1 SMU1 - South end of Harvey Estuary

The vulnerability rating for assets in SMU1 are presented in Table 11.2 for erosion and inundation. The priority assets that require risk management are the beach, car park, boat ramp, roads and Kooljerrenup Nature Reserve.

Table 11.2: Vulnerability Rating – SMU 1: South end of Harvey Estuary

Assets	Consideration of Existing Controls	2030	2050	2070	2120
Erosion					
1	Beach areas				
2	Foreshore Nature Reserve				
3	Harvey Drain				
4	Kooljerrenup Nature Reserve				
5	Herron Point Camping Ground				
6	Herron Point Foreshore				
7	Coastal Pathways / Bridle Paths				
8	Carpark at Herron Boat Ramp				
9	Herron Point Boat Ramp				
10	Campground Toilet / Showers				
11	Heron Point Minor Infrastructure (signs)				
12	Heron Point Road, Campground Rd				
Inundation					
1	Beach areas				
2	Foreshore Nature Reserve				
3	Harvey Drain				
4	Kooljerrenup Nature Reserve				
5	Herron Point Camping Ground				
6	Herron Point Foreshore				
7	Coastal Pathways / Bridle Paths				
8/9	Carpark / Boat Ramp				
10	Campground Toilet / Showers				
11	Heron Point Minor Infrastructure (signs)				
12	Heron Point Road, Campground Rd				

Vulnerability Rating:  Low  Medium  High  Very High

11.2 SMU2 - Birchmont

The vulnerability rating for assets in SMU2 are presented in Table 11.3 for erosion and inundation. The priority assets that require risk management are the beach areas, car park, properties and Lake McLarty.

Table 11.3: Vulnerability Rating – SMU 2: Birchmont

Erosion						
	Assets	Consideration of Existing Controls	2030	2050	2070	2120
1	Beach areas					
2	Foreshore Nature Reserve					
3	McLarty Nature Reserve					
4	Mealup Point Nature Reserve					
5	Foreshore Reserve at Birchmont Boat Ramp					
6	Coastal Pathways / Bridle Paths					
7	Residential Properties					
8	Carpark at Birchmont Boat Ramp					
9	Birchmont Boat Ramp					
10	Minor Infrastructure (signage, fencing)					
11	Roads					
Inundation						
	Assets		2030	2050	2070	2120
1	Beach areas					
2	Foreshore Nature Reserve					
3	Lake McLarty					
4	Lake Mealup ⁴					
5	Foreshore Reserve at Birchmont Boat Ramp					
6	Coastal Pathways / Bridle Paths					
7	Residential Properties					
8	Carpark at Birchmont Boat Ramp					
9	Birchmont Boat Ramp					
10	Infrastructure (signage, fencing, bus shelter)					
11	Drainage features					
12	Roads					

Vulnerability Rating: Low Medium High Very High

11.3 SMU3 – Point Grey to Austin Bay

The vulnerability rating for assets in SMU3 are presented in Table 11.4 for erosion and inundation. The priority assets that require risk management are the beach areas, properties, drainage features, roads and Roberts Bay Swamp.

Table 11.4: Vulnerability Rating – SMU 3: Point Grey to Austin Bay

Erosion						
	Assets	Consideration of Existing Controls	2030	2050	2070	2120
1	Beach area					
2	Foreshore Reserve					
3	Austin Bay Nature Reserve					
4	Foreshore Reserve					
5	Coastal Pathways / Bridle Paths					
6	Residential Properties					
7	Agricultural Properties					
8	Minor Infrastructure (signage, fencing)					
9	Drainage features					
10	Roads (Carabunga Road).					
Inundation						
	Assets		2030	2050	2070	2120
1	Beach area					
2	Foreshore Reserve					
3	Austin Bay Nature Reserve					
4	Robert Bay Swamp					
5	Coastal Pathways / Bridle Paths					
6	Agricultural Properties					
7	Agricultural Land					
8	Minor Infrastructure (signage, fencing)					
9	Drainage features					
10	Roads (Carabunga Road).					

Vulnerability Rating:  Low  Medium  High  Very High

11.4 SMU4 – South Yunderup

The vulnerability rating for assets in SMU4 are presented in Table 11.5 for erosion and inundation. The priority assets that require risk management are the beach areas, riverbanks, residential properties, car parks, drainage features and roads.

Table 11.5: Vulnerability Rating – SMU 4: South Yunderup

Erosion					
Assets	Consideration of Existing Controls	2030	2050	2070	2120
1	Beach area - Peel Inlet facing beach Batavia				
2	Riverbanks - Murray River				
3	Austin Bay Nature Reserve				
4	Batavia Quays Wetland				
5	Batavia Quays Dredge Spoil Site ^{4.1}				
6	S.Y. Canal Bund - Water Quality ^{4.2}				
7	Coastal Pathway – Bund, S.Y. canals ^{4.2}				
8	Coastal Pathway - Wellya Crescent Park ^{4.2}				
9	Foreshore Reserve (Tatham Rd, Rivergum Esplanade, Centenary Park)				
10	Coastal Pathways Murray River (Tatham Rd ^{4.5a} , Rivergum Esplanade)				
11	Coastal Pathway, Batavia Q Headland ^{4.1}				
12	Res. Properties S.Y Canal Estate ^{4.1 4.3}				
13	Res. Properties Placid Bend, Chipper Way, Countess Circuit				
14	Res. Properties Batavia Quay ^{4.1 4.3}				
15	Res. Properties Warma Wy to Young Rd				
16	Res. Properties Young Rd to Strain Glen				
17	Res. Properties Pelican Rd, Banksia Terrace				
18	Tathams, Murray River Caravan Park				
19	Jetties and Moorings Privately Held				
20	Minor Roads (Rivergum Esplanade, Young Rd, Strain Glen, Pelican Rd, Banksia Tce)				
21	Shire Jetties - Tatham Rd, Pelican Rd,				
22	Boat Launch - Rivergum Esplanade				
23	Boat Launch - Batavia Quays Launch Facility				

Erosion				
24	Batavia Quays Club Shed			
25	Toilets - Batavia Quays			
26	Toilets - Pelican Road ^{4.5c}			
27	Car Park - Batavia Quays			
28	Car Park - Rivergum Esplanade Foreshore			
29	Car Park - Centenary Park			
30	Car Park - Pelican Road ^{4.5c}			
31	Park Furniture - Centenary Park			
32	Playground Equipment - Centenary Park			
33	Park Furniture- Wellya Crescent Park ^{4.2}			
34	Playground Equipment - Wellya Crescent ^{4.2}			
35	Park Furniture - Pelican Rd Park ^{4.5c}			
36	Playground Equipment - Pelican Rd Park ^{4.5c}			
37	Park Furniture - South Yunderup Foreshore			
38	Footpaths			
39	Minor Infrastructure (Signage, fencing etc)			
40	Drainage features (pits, pipes, culverts)			
41	Water Corp Infrastructure			
Inundation				
Assets	2030	2050	2070	2120
1 Beach area - Peel Inlet facing beach Batavia				
2 Riverbank - Murray River				
3 Austin Bay Nature Reserve				
4 Batavia Quays Wetland				
5 Batavia Quays Dredge Spoil Site ^{4.1}				
6 S.Y. Canal Bund - Water Quality ^{4.2}				
7 Coastal Pathway – Bund, S.Y. canals				
8 Coastal Pathway - Wellya Crescent Park				
9 Foreshore Reserve (Tatham Rd, Rivergum Esplanade, Centenary Park)				

Inundation				
10	Coastal Pathways Murray River (Tatham Rd, Rivergum Esplanade)	●	●	●
11	Coastal Pathway Batavia Quay Headland ^{4.1}	●	●	●
12	Res. Properties South Yunderup Canal	●	●	●
13	Res. Properties Placid Bend, Chipper Way, Countess Circuit	●	●	●
14	Res. Properties Batavia Quay	●	●	●
15	Res. Properties Warma Wy to Young Rd	●	●	●
16	Res. Properties Young Rd to Strain Glen	●	●	●
17	Res. Properties Pelican Rd, Banksia Terrace	●	●	●
18	Tathams, Murray River Caravan Park	●	●	●
19	Jetties and Moorings Privately Held	●	●	●
20	Minor Roads (Rivergum Esplanade, Young	●	●	●
21	Shire Jetties - Tatham Rd, Pelican Rd, Centenary Park	●	●	●
22	Boat Launch - Rivergum Esplanade	●	●	●
23	Boat Launch - Batavia Quays Launch Facility	●	●	●
24	Batavia Quays Club Shed	●	●	●
25	Toilets - Batavia Quays	●	●	●
26	Toilets - Pelican Road	●	●	●
27	Car Park - Batavia Quays	●	●	●
28	Car Park - Rivergum Esplanade Foreshore	●	●	●
29	Car Park - Centenary Park	●	●	●
30	Car Park - Pelican Road	●	●	●
31	Park Furniture - Centenary Park	●	●	●
32	Playground Equipment - Centenary Park	●	●	●
33	Park Furniture- Wellya Crescent Park	●	●	●
34	Playground Equipment - Wellya Crescent	●	●	●
35	Park Furniture - Pelican Rd Park	●	●	●
36	Playground Equipment - Pelican Rd Park	●	●	●
37	Park Furniture - South Yunderup Foreshore	●	●	●

Inundation				
38	Footpaths	●	●	●
39	Minor Infrastructure (Signage, fencing etc)	●	●	●
40	Drainage features (pits, pipes, culverts)	●	●	●
41	WaterCorp Infrastructure	●	●	●
42	Residential Properties Murray River Drive, Leander Way, Pericho Close ^{4.4}	●	●	●
43	Agricultural / Vacant Land - Beacham Rd to Austin Cove ^{4.4}	●	●	●
44	Major Roads (South Yunderup Road, Forrest Highway)	●	●	●
45	South Yunderup Fire Station	●	●	●
46	Toilets - Centenary Park	●	●	●
47	Car Park - Willow Gardens	●	●	●
48	Car Park - Fire Station	●	●	●
49	Park Furniture – Lucie Hunter Park	●	●	●

Vulnerability Rating: ● Low ● Medium ● High ● Very High

11.5 SMU5 – North Yunderup and the Murray Delta Islands

The vulnerability rating for assets in SMU5 are presented in Table 11.6 for erosion and inundation. The priority assets that require risk management are the beach areas, riverbanks, residential properties, car parks, Coopers Mill, WaterCorp infrastructure and drainage features

Table 11.6: Vulnerability Rating – SMU 5: North Yunderup and the Murray Delta Islands

		Erosion			
	Assets Consideration of Existing Controls	2030	2050	2070	2120
1	Beaches, Peel Inlet Murray Delta Islands				
2	Riverbank - Delta Islands and Murray River				
3	Nature Reserve, West end Yunderup Island				
4	Ballee Island Wetland				
5	Pathway - Culeenup Rd east of Towerup St				
6	Foreshore Reserve - Culeenup Rd				
7	Foreshore Reserve - Yunderup Island, Ballee Island, Cooleenup Island				
8	Residential Properties North Yunderup, Culeenup Rd				
9	Residential Properties Thomasfield Pl, Ravenswood				
10	Residential Properties Yunderup Island				
11	Residential Properties Ballee Island				
12	Residential Properties Cooleenup Island				
13	Jetties and Moorings - Privately Held				
14	Minor Roads Culeenup Rd West ^{5.3b}				
15	Shire Jetties - Culeenup Rd, Coopers Mill Precinct, North Yunderup Launch Facility.				
16	Boat Launch - North Yunderup Launch				
17	Toilets - Coopers Mill Precinct				
18	Car Park - North Yunderup Launch Facility				
19	Park Furniture - North Yunderup Foreshore				
20	Park Furniture- North Yunderup Launch				
21	Park Furniture - Coopers Mill Precinct				
22	Playground Equipment - Coopers Mill				
23	Footpaths				
24	Minor Infrastructure (Signage, fencing etc)				
25	Drainage features (pits, pipes, culverts)				

Erosion				
26	WaterCorp Infrastructure			
27	Coopers Mill			
28	Coopers Mill Caretakers House			
Inundation				
Assets	2030	2050	2070	2120
1 Beaches, Peel Inlet Murray Delta Islands				
2 Riverbank - Delta Islands and Murray River				
3 Nature Reserve, West end Yunderup Island				
4 Ballee Island Wetland				
5 Foreshore Reserve - Culeenup Rd Towerup				
6 Foreshore Reserve - Yunderup Island, Ballee Island, Cooleenup Island				
7 Residential Properties North Yunderup, Culeenup Rd				
8 Residential Properties Thomasfield Pl, Ravenswood ^{5.1}				
9 Rural Properties Pinjarra Rd, Tonkin Drv, Walter Rd ^{5.1}				
10 Residential Properties Thomasfield Pl, Ravenswood ^{5.1}				
11 Residential Properties Yunderup Island				
12 Residential Properties Ballee Island				
13 Residential Properties Cooleenup Island				
14 Septic Sytems Yunderup Island				
15 Septic Sytems Ballee Island				
16 Septic Sytems Cooleenup Island				
17 Jetties and Moorings along River Privately				
18 Minor Roads (Culeenup Rd - Western end)				
19 Major Roads (Pinjarra Rd, Forrest Hwy)				
Inundation				
20 Shire Jetties - Culeenup Rd, Coopers Mill Precinct, North Yunderup Launch Facility.				

Inundation				
21	Boat Launch – N.Y Launch Facility	●	●	●
22	Toilets - Kingfisher Park	●	●	●
23	Toilets - Coopers Mill Precinct	●	●	●
24	Toilets - North Yunderup Launch Facility	●	●	●
25	Car Park - North Yunderup Launch Facility	●	●	●
26	Park Furniture - North Yunderup Foreshore	●	●	●
27	Park Furniture- North Yunderup Launch	●	●	●
28	Park Furniture - Coopers Mill Precinct	●	●	●
29	Playground Equipment - Coopers Mill	●	●	●
30	Park Furniture- Kingfisher Park	●	●	●
31	Playground Equipment - Kingfisher Park	●	●	●
32	Footpaths	●	●	●
33	Minor Infrastructure (Signage, fencing,	●	●	●
34	Drainage features (pits, pipes, culverts)	●	●	●
35	WaterCorp Infrastructure	●	●	●
36	Coopers Mill	●	●	●
37	Coopers Mill Caretakers House	●	●	●

Vulnerability Rating: ● Low ● Medium ● High ● Very High

11.6 SMU6 – Serpentine and Furnissdale

The vulnerability rating for assets in SMU6 are presented in Table 11.7 for erosion and inundation. The priority assets that require risk management are the riverbanks, residential properties, car parks, drainage features and Riverside Drive.

Table 11.7: Vulnerability Rating – SMU6: Serpentine and Furnissdale

Erosion					
Assets	Consideration of Existing Controls	2030	2050	2070	2120
1	Riverbank - Serpentine River				
2	Foreshore Reserve - Furnissdale Foreshore				
3	Residential Properties Riverside Drive along				
4	Residential Properties along Serpentine				
5	Residential Properties Riverside Drive Smith				
6	Residential Properties Riverside Drive NE of Paull St				
7	River Glades Resort				
8	Jetties and Moorings along River - Private				
9	Minor Roads (Riverside Drive Near Smith St)				
10	Shire Jetties - Furnissdale Launch Facility, Floating Jetty				
11	Shire Jetties - Furnissdale Launch Facility, Timber Jetty				
12	Shire Jetties - Tonkin Drive Foreshore Timber Jetty				
13	Boat Ramp - Furnissdale Launch Facility				
14	Car Park - Furnissdale Launch Facility				
15	Car Park - Riverside Drive				
17	Car Park - Tonkin Drive Foreshore				
18	Car Park - Furnissdale Bridge Foreshore ^{6.3a}				
19	Park Furniture - Furnissdale Launch Facility Foreshore Reserve				
20	Playground Equipment - Furnissdale Foreshore				
21	Footpaths				
22	Minor Infrastructure (Signage, fencing etc)				

Erosion				
23	Drainage features (pits, pipes, culverts)			
24	WaterCorp Infrastructure			
Inundation				
Assets	2030	2050	2070	2120
1 Riverbank - Serpentine River				
2 Foreshore Reserve - Furnissdale Foreshore				
3 Residential Properties Riverside Drive along Furnissdale Foreshore				
4 Residential Properties along Serpentine River, Tonkin Drive to Furnissdale Road				
5 Residential Properties Riverside Drive Smith St to Paull St				
6 Residential Properties Riverside Drive NE of Paull St ^{6.1}				
7 Rural Properties Pinjarra to Goodooga Rd ^{6.1}				
8 Caravan Park				
9 Riverglades Resort				
10 Jetties and Moorings along River - Privately				
11 Minor Roads (Riverside Drive Near Smith St)				
12 Minor Roads (Riverside Drive foreshore, Furnissdale Rd, Ronlyn Rd)				
13 Major Roads (Pinjarra Rd)				
14 Shire Jetties - Furnissdale Launch Facility, Floating Jetty				
15 Shire Jetties - Furnissdale Launch Facility, Timber Jetty				
16 Shire Jetties - Tonkin Drive Foreshore				
17 Boat Ramp - Furnissdale Launch Facility				
18 Toilets - York Road				
19 Car Park - Furnissdale Launch Facility				
20 Car Park - Riverside Drive				
21 Car Park - Tonkin Drive Foreshore				
22 Car Park - Furnissdale Bridge Foreshore				

Inundation				
23	Park Furniture - Furnissdale Launch Facility	●	●	●
24	Playground Equipment - Furnissdale	●	●	●
25	Park Furniture- York Road Park.	●	●	●
26	Playground Equipment - York Road Park.	●	●	●
27	Footpaths	●	●	●
28	Minor Infrastructure (Signage, fencing,	●	●	●
29	Drainage features (pits, pipes, culverts)	●	●	●
30	WaterCorp Infrastructure	●	●	●
31	York Road Clubrooms and Sports Courts	●	●	●

Vulnerability Rating: ● Low ● Medium ● High ● Very High

12. Risk Treatment Process

12.1 Risk Treatment Overview

The risk treatment and adaptation stage of the CHRMAP considers the approaches that can be used to address the residual risk to coastal assets. The goal of this stage is to determine appropriate risk treatment responses that can mitigate coastal hazard risk identified for the SoM shoreline areas and coastal assets over the immediate short term (next 10-15 years) and which can maintain a level of flexibility for future decision making. This will provide a basis for decision making by the Shire on what is important to focus on today, and what other locations could be affected in the future should projected sea level rise and climate change impacts be realised over the 100-year planning timeframe.

The level of coastal hazard risk for the coastal assets through the SoM region is generally low for the present day, however this risk is expected to increase under projected sea level rise in future years. Sea level rise scenarios consistent with SPP2.6 have been examined in the previous CHRMAP stages to examine how coastal assets could be affected by coastal hazard in future. This process has also considered a range of possible scenarios ranging from events that occur annually up to extreme events with a low likelihood of occurrence (50yr, 100yr and 500yr ARI). It is recognised that there is uncertainty in making long term predictions on both the timing and nature of sea level rise and climate change, and in the risk treatment process this uncertainty is taken into consideration in a number of ways.

The risk treatment process presents the SoM with a range of risk treatment pathways that can be used to manage its coastal assets now and which adjust to meet with the changing risk profile in future years. The pathways are designed to change over time to meet the increasing level of risk associated with sea level rise and climate change, linked to *Trigger points* in the future rather than a fixed time frame. Examples of triggers where a move to a new level of risk management may be required are a measured/actual change in the sea level or the erosion of the shoreline landward in close proximity to structures (eg houses).

The ability of the shorelines and riverine areas in the SoM to adapt and respond to the changing conditions in future planning periods will be the responsibility of the SoM and the community. The role of the CHRMAP is to focus attention today on the most critical areas of the shoreline requiring management for the short-term timeframe and to identify the trigger points at which a change in risk treatment may be required to meet the challenge of a higher level of risk to coastal assets in the future planning years.

In this Section:

- a) Adaptation approaches are outlined in general terms in the categories 'Avoid, Managed or Planned Retreat, Accommodate, Protect, No-Regrets and Do-Nothing'.
- b) Specific risk treatment approaches within each of the categories are introduced and discussed in detail and considered in terms of their effectiveness in treating the risk for respective assets in the SoM. Risk treatment responses can vary within SMU's and in many instances a range of complementary risk treatment responses can serve to address the coastal risk most effectively.
- c) Risk treatment pathways and Triggers are summarised within each of the SMU's to provide guidance to decision making and management of the shoreline areas and assets for the SoM.

12.2 Risk Treatment Options

The Risk Treatment options that are considered in this CHRMAP have been developed from a range of sources. The key guidance comes from the CHRMAP guidelines (WAPC 2019) which describes the general risk treatment categories in a *risk treatment and adaptation hierarchy (hierarchy)*, under the categories 'Avoid', 'Planned or Managed Retreat', 'Accommodate' and 'Protect'. The hierarchy was developed on the principal of maintaining flexibility for decision makers in the future. The management approaches at the top of the list allow greater flexibility for decision makers in future (eg Avoid), whilst

options further down the list in the hierarchy moving towards the final option of Protect limit the future decision making options available.

The categories in brief are as follows from highest to lowest:

- a) **Avoid:** this approach is to simply avoid new development in areas at risk of coastal hazard. This approach is only applicable to locations where development has not commenced; The aim of this risk treatment option is to avoid the construction of new public and private assets within areas identified to be impacted by coastal hazards. Avoidance risk treatment options are the best form of risk management (mitigation) and where possible should be the risk treatment option of choice (WAPC 2019). Avoidance is particularly applicable to all land use and development in greenfield locations
- b) **Planned or Managed Retreat:** the concept of planned or managed retreat allows existing public assets and private property to remain in place until such time as coastal hazard from erosion or inundation is untenable. Planned or managed retreat for existing development involves relocating or sacrificing infrastructure, both public assets and private property, when erosion and recession impacts reach action trigger points. Under this option the use of temporary coastal protection structures and/or restoration of natural controls such as dunes and shoreline areas is supported to maintain or create a buffer against storm erosion. As existing assets reach the end of their functional life (or if they are substantially damaged by a storm event), they would be removed, including any associated coastal protection structures.
- c) **Accommodate:** The accommodate risk treatment option aims to utilise design and management strategies which render the risks as tolerable/acceptable, allowing land to continue to be utilised until risks become intolerable. Design and management strategies may include a mix of structural or non-structural approaches. Structural approaches include minimum finished floor levels and elevated electrical circuitry, and relocatable structures which can be moved to a different location on- or off-site to manage risk arising from inundation coastal hazards. Non-structural approaches such as modifications to local planning frameworks can also enable accommodate risk treatment options; and
- d) **Protect:** Protect risk treatment options aim to protect assets from damage resulting from erosion and recession and storm surge inundation. Protect risk treatment options should be primarily proposed in the public interest and enhance or preserve beach and foreshore reserve amenity. The Protect option is only available when all other options are exhausted and should be justified in terms of the benefit it delivers to the community.
 - Common hard protection structures include seawalls; groynes; offshore breakwaters and artificial headlands; and soft protection measures such as beach nourishment.
 - Interim protection structures can be applied to delay shoreline recession over the short to medium term. This might be achieved through soft protection measures such as regular sand renourishment and revegetating coastal dunes.

In addition to the four main categories above additional management approaches considered in the CHRMAP are:

e) No Regrets

The no-regrets category is used for approaches that can improve resilience and preparedness against the impact of coastal hazards. These can be implemented where further understanding of the risk to assets is being collected or while the assessments to determine a preferred risk treatment option.

f) Do Nothing

The do-nothing risk treatment option assumes that all levels of risk is accepted and that no further action will be taken. This risk treatment option provides a basis for comparison of all other risk treatment options.

12.3 Adaptation Tools

A range of adaptation tools available to mitigate coastal risk applied in the CHRMAP under the key category definitions is summarised in Table 12.1. These have been developed from a range of sources including WAPC 2019 and the National Climate Change Adaptation Research Facility (NCCARF) Coast Adapt tools, as well as incorporating options provided through the community involvement in the CHRMAP workshops.

The coastal hazard and risk level identified for the assets within each of the coastal management units is considered with reference to the adaptation approaches in the adaptation hierarchy. Adaptation responses can vary within coastal compartments, and in many instances a range of complementary adaptation responses that mitigate the coastal risk are applied.

The range of adaptation responses to counter coastal hazard risk will vary throughout the study area. In some cases, a single adaptation response may be appropriate, but it is likely that a suite of adaptation approaches that can complement each other will be required.

12.4 Trigger Points

The concept of a trigger point is to have a pre-determined point that is set to 'trigger' the commencement of planning and/or implementation actions relating to a risk management option.

Triggers for the decision points are generally associated with the observation of key events on the ground rather than being time based. Estimated timeframes presented in the CHRMAP are based on the erosion and inundation hazard that is projected to occur in future planning periods as defined in the Risk Identification Stage (Stage 2). The trigger points are assessed as part of future monitoring, to determine when they are reached or approaching. This is an important feature in the CHRMAP risk management pathways approach that addresses the uncertainty associated with predicting the rate of future climate change.

The Trigger points, Decision Making and Measures that will be applied in the risk management pathways are summarised in Table 12.2.

The key activities that are used to monitor trigger points and inform where these are reached or close to being reached are:

- Annual Monitoring Program
 - The annual monitoring program (refer Section 16.3) will be used to examine changes in the shoreline areas and track the rate of movement of the position of the shoreline. The annual monitoring program will be used to identify the position of the Horizontal Shoreline Datum (HSD) and whether this moves either landward (as a result of erosion) or seaward (as a result of accretion).
- Asset Management and Structure condition reporting
 - The Shire currently has an inspection protocol established to examine the condition of engineering structures that includes the following:
 - Herron Point Boat Ramp and Car Park
 - Birchmont Boat Ramp
 - Boat Ramp at Young St
 - Boat Ramp at North Yunderup
 - South Yunderup Canal Walls
 - Bund in front of the South Yunderup Canals
 - Small Revetment structures in North and South Yunderup river shorelines

- Batavia Quays Revetment
- Riverside Drive Boat Ramp

The condition reports and asset management will provide the basis for understanding when structures need replacement or upgrade (and inform Trigger 5, refer Table 12.2).

- Review of CHRMAP (recommended every 5 to 10 years)
 - It is recommended that the CHRMAP be reviewed and updated every five to ten years. As part of this review the following would be included:
 - The improved knowledge of coastal hazards in the shoreline areas from the annual monitoring and additional studies should be incorporated into the review and where this may impact any of the recommendations in the CHRMAP
 - The guidance on sea level rise projections by the DoT (DoT 2010) should be reviewed for any updates. Any change to the projected sea level rise allowances would require assessment of updates to the CHRMAP.
 - Review of changes in the SPP2.6 advice (WAPC 2020) or updates to the CHRMAP guidelines (WAPC 2019) would be assessed as part of the review process.
 - Engagement with the community to provide an overview of learnings from the annual monitoring program and outline how these are captured in the CHRMAP review process. A review of the community values to determine if they are consistent with values collected in the previous version of the CHRMAP would be sought as part of the engagement activities.
 - assets that are predicted to become highly or very highly vulnerable within the next planning timeframe (or within 10 years) would be identified.

Table 12.1: Adaptation Options Toolbox (Adapted from WAPC 2019)

	Code	Adaptation Type	Applicable	Measure
Avoid	Av.1	Locating Assets in areas that are not vulnerable to coastal hazards	Can be applied to all asset types. Applicable to undeveloped residential and commercial land	1. Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion of inundation hazard over the 100-year planning period. 2. Establish planning-based controls that only allow development in the SCA that can address coastal hazard.
	MR.1	Leaving Assets Unprotected	Low cost, Temporary and easily relocatable recreation amenities	1. Amend local planning scheme to include Special Control Area. 2. Determine assets that are deemed sacrificial. 3. Monitoring (NR1) to identify when trigger is reached.
Planned / Managed Retreat	MR.2	Demolition, Removal or relocation of Assets from inside the hazard area	Assets of low value where it is impractical both technically and financially to design the asset to withstand the impact of the coastal hazards instead of relocating it.	1. Amend local planning scheme to include Special Control Area. 2. Determine assets that are deemed sacrificial or relocatable, and update Council's Asset register to reflect likely timeframe for impact to assist in prioritising asset relocation. 3. Monitoring (NR1) to identify when trigger is reached.
	MR.3	Event limited development approval / prohibit expansion of existing use rights.	Generally applicable where protection of assets is not viable. All assets where it is impractical to ultimately implement protection.	Amend local planning scheme to include Special Control Area
	MR.4	Voluntary Acquisition	All private property where it is impractical to ultimately implement protection. This risk treatment option would require the acquisition of affected properties, on a voluntary basis. Ensures land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation	1. Investigate/put in place funding for acquisition of priority properties. 2. Offer voluntary acquisitions reflecting asset value in light of hazard.

	Code	Adaptation Type	Applicable	Measure
	MR.5	Limit Further Subdivision	Limit further subdivision of existing lots identified in the hazard area.	Amend local planning scheme to include Special Control Area
Accommodate	Ac.1	Building Design Relocatable Structures	Design assets to be relocatable. Structures can be moved in future as risk increases and becomes intolerable	1. Amend local planning scheme to include Special Control Area. 2. Prepare local planning policy containing relevant inundation and wave overtopping development controls. 3. Approval of local planning policy by Council. 4. Implement local planning policy development controls to all properties within the special control area for coastal hazards within the local government area.
	Ac.2	Building Design Design assets to withstand impacts.	Where avoiding or relocating an asset is not an option, design of assets to withstand the impact of inundation.	
	Ac.3	Building Design Appropriate Finished Floor Levels	Roads, car parks, residential property, hospitals, aged care facilities, schools, childcare facilities.	
	AC.4	Filling Land		
Protect	Pr.1	Beach Management / sand management	Shorelines of the Peel Inlet where maintenance of the berm is expected to play a key role in preventing significant erosion impacts under future sea level rise scenarios	Rehabilitate the berm, investigate field approaches that can be used to reshape the upper beach profile. Investigate and secure suitable sand sources for nourishment, planning approvals and to determine funding mechanisms.
	Pr.2	Erosion Control – Nature Based Solutions	This approach refers to ‘soft engineering’ methods that are in keeping with nature. Protection of the Murray Delta Islands shoreline areas, the Murray and Serpentine River and Peel-Harvey shorelines	Shire to issue guideline on river erosion edge treatments that will provide a framework for acceptable standard of approaches by the landowner
	Pr.3	Coastal Revegetation	Revegetation of the shoreline areas with plant species that can stabilise and bind together the sediment in the shoreline and provide natural resilience.	Shire to issue guideline on coastal revegetation in its shorelines that will provide information of key plant species for Shire areas.

Code	Adaptation Type	Applicable	Measure
Pr.4	Seawalls	Involves construction of a seawall usually along an entire section of shoreline. The seawall could be applied to protect important built assets from erosion.	1. Undertake NR2, to investigate viability of existing seawalls on beaches. 2. Consider in accordance with Council's Asset Management Plan. 3. Undertake investigation of rock and sand sources for detailed costing's, design of seawall and nourishment, planning approvals and funding mechanisms. 4. Continued monitoring (NR1) for trigger.
Pr.5	Flood Mitigation Structure	Involves construction of a flood control which is either permanent or temporary along an entire section of shoreline. Format could be a large-scale permanent flood control structure at the Dawesville Cut or local scale small dike structure on the island shorelines	1. Undertake investigation of rock and sand sources for detailed costing's, design of flood structure and nourishment, planning approvals and developing business case for funding. 2. Continued monitoring (NR1) for trigger.
No Regrets	NR1	Monitoring	Applicable all areas. Long term baseline monitoring and event-based monitoring following storm erosion events. 1. Set up a baseline monitoring programme for long term trend and condition following major events. 2. Review results for particular asset triggers regularly. 3. Re-run risk assessment based on monitoring results and revise risk management measures if risk level changes (i.e. increase or decrease in level of risk).
	NR2	Protection Structure Audit	All existing coastal protection structures. This risk treatment option involves undertaking an audit of existing protection structures, to determine their current condition, effectiveness and future protection potential. 1. Conduct audit of existing protection structures. 2. Update hazard lines where relevant to account for existing protection structures. 3. Update CHRMAP proposed actions to account for condition (life) of existing protection structures.

Code	Adaptation Type	Applicable	Measure
			4. Protection structures added to Council's Asset Management Plan, and outcomes of audit used to determine asset replacement and maintenance schedules for the structures
NR3	Notification on title (also relevant to, planned/ managed retreat, accommodate and protect options).	All assets located within an area vulnerable to coastal hazards within the planning timeframe Indicates to current and future landowners that an asset is likely to be affected by coastal erosion and/or inundation over the planning timeframe. Helps current and future owners make informed decision about level of risk they are/may be willing to accept, and that risk management is likely to be required at some stage within the planning timeframe.	Implement in accordance with the planning framework, and as conditions of approval for subdivision and development.
NR4	Emergency evacuation plans (also relevant to accommodate options)	Roads (with regard to managing traffic flows during an event), car parks, residential property, hospitals, aged care facilities, schools, childcare facilities.	1. Development evacuation plans for locations without existing inundation mapping as a priority. 2. Update evacuation plans with latest inundation mapping available or include coastal inundation area into existing evacuation plans.
NR5	Reduce Vessel Speeds in the waterways	Review the speed limits for vessels travelling through the lower Murray River	1. Complete studies to examine erosion impacts to the riverbanks from vessel speed and provide basis for reduction in speed for vessels and or vessel activities. 2. Implement revised speed limits through the Shire's waterways (signage etc).
Do Nothing	DN1	Doing nothing and accepting the risk to the assets	Low value assets and assets that must be located in the shoreline areas for their function / purpose.
			Take no action and accept risk

Table 12.2: Trigger Points Decision Making and Measures (Adapted from WAPC 2019)

Trigger Name	Trigger	Decision	Measures	Identification Method
T1	The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent	Ongoing Monitoring to define changes to the HSD line (NR1) Refinement to the S1 value based on field data collected following extreme events / updated modelling information	Provide interim protection for major infrastructure (roads, carparks), residential and commercial buildings Remove major infrastructure (roads, carparks), residential and commercial buildings, transfer land to public realm Prepare response plans for minor infrastructure that could be impacted	Assessment of the shoreline position will be a task included in the annual monitoring program.
T2	A public road is no longer available or able to provide legal access to a property	Liaison with/notification by relevant level of government	Remove residential and commercial buildings, and transfer land to public realm	Task included in the annual monitoring program.
T3	Water, sewer or electricity to a lot is no longer available as they have been removed/decommissioned by the relevant authority due to coastal hazards	Liaison with/notification by utility providers	Remove residential and commercial buildings, and transfer land to public realm	Task included in the annual monitoring program.
T4	Residential or commercial property lies seaward of the most up to date 100-year coastal erosion hazard line or coastal inundation hazard extent	Definition of hazard extents through CHRMAP. CHRMAP and hazard extent updates due to availability of more relevant/recent information (such as updated sea level rise predictions) and changes in environmental conditions (such	Include all affected land in a SCA and ensure the hazard information is incorporated in structure planning Provide notification of potential hazards on certificates of title where reasonably practicable and by direct contact with affected landholders	This is defined in the SCA1 as an outcome of the CHRMAP.

Trigger Name	Trigger	Decision	Measures	Identification Method
		as changes to tidal planes / Mean seal level).		
T5	An asset is damaged, destroyed or becomes unsafe due to coastal erosion	Inspection of coastal assets following storm events or during times of increased longshore erosion. Shire asset management includes inspection and reporting on condition of the structures. Notification by the public	Remove assets and relocate to less hazardous area if possible/appropriate	Informed by the Asset management and Structure Condition Assessments undertaken by Shire. Also captured in Annual Monitoring program
T6	Assets are predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years	Definition of hazard extents through CHRMAP. CHRMAP and hazard extent updates due to availability of more relevant/recent information (such as updated sea level rise predictions) and changes in environmental conditions (such as changes to tidal planes / Mean seal level).	Undertake details cost-benefit analysis and assessment of community acceptance of interim protection vs. managed retreat of the affected asset; Identify sources and begin to allocate funding for risk management measures	As part of future CHRMAP review this can be reassessed periodically (every 5-10 years).
T7	The overall community and stakeholders are no longer supportive of a specific risk management technique or approach	Ongoing community engagement; Cost-benefit analysis	Investigate, identify and implement a change in the risk management pathway, if appropriate	As part of future CHRMAP review this can be reassessed periodically (every 5-10 years).

Trigger Name	Trigger	Decision	Measures	Identification Method
T8	A specific risk management technique is forecast to no longer be economically or physically feasible within 10 years	Ongoing shoreline and coastal asset monitoring Budget expenditure and forecasts Cost-benefit analysis	Investigate, identify and implement a change in the risk management pathway, if appropriate	As part of future CHRMAP review this can be reassessed periodically (every 5-10 years).
T9	The beach and coastal foreshore reserve is significantly diminished with respect to its original state and function	Long-term coastal monitoring program Assessment of aerial imagery Feedback through ongoing community consultation	Investigate, identify and implement a change in the risk management pathway, if appropriate	Assessment of the shoreline position will be a task included in the annual monitoring program.
T10	Undeveloped land is identified as lying within the hazard extents	Definition of hazard extents through CHRMAP. CHRMAP and hazard extent updates due to availability of more relevant/recent information (such as updated sea level rise predictions) and changes in environmental conditions (such as changes to tidal planes / Mean seal level).	Implement planning controls to avoid inappropriate development of the land	This is defined in the SCA1. As part of future CHRMAP review this can be reassessed periodically (every 5-10 years).

12.5 Planning Based Approaches

12.5.1 Statutory Planning Mechanisms

A review of the existing planning controls concluded that a Special Control Area (SCA) in conjunction with a Local Planning Policy (LPP) is considered the most appropriate statutory planning mechanism to address coastal hazards within the Shire of Murray. The following section provides a summary of recommendations for the Shire of Murray, to update its current planning instruments to manage coastal hazard risks identified for erosion and inundation in the CHRMAP.

12.5.2 Recommended Planning Controls

12.5.2.1 Local Planning Strategy

This CHRMAP will inform the Shire's Local Planning Strategy to guide land use planning and development in areas prone to erosion or inundation. Areas of risk should generally 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 revision should commence following the CHRMAP adoption (refer to Implementation (Section 16)).

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 Shire's Local Planning Scheme.

12.5.3 Local Planning Scheme Amendment

In accordance with CHRMAP Guidelines, the Shire shall initiate the following amendments to the Local Planning Scheme No. 4 (LPS 4):

- Insert the following sub-clause under Part 6, after Clause 6.14.1.1 (b):
 - *(c) Special Control Areas are shown on the Scheme Map as SCA with a number and included in Schedule 14.*
- Insert Schedule 14 – Special Control Areas into LPS 4 and include SCA 1 – CHRMAP Area for zoned land impacted by erosion or inundation by 2120. The recommended text for SCA 1 has been outlined in Table 12.3.

The Scheme Map will require updating to include:

- SCA 1 over all zoned land impacted by erosion or inundation by 2120.

The Shire shall amend LPS 4 to include the recommendations of this CHRMAP as part of the upcoming scheme review, following endorsement of the Local Planning Strategy. The review should commence immediately following the adoption of the CHRMAP by council. The Shire may defer implementation of certain recommendations following updates to the hazard estimates through future revisions of this CHRMAP.

12.5.3.1 Special Control Area (SCA)

The introduction of a Special Control Area (SCA) for all zoned land affected by erosion or inundation over the 100-year planning period will provide the most effective response to coastal and riverine hazards. The SCA will stipulate provisions to respond to the risks identified in this CHRMAP, including the trigger for normally exempt development to require development approval.

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

The following SCA1 shall be included into LPS4 through the scheme amendment process.

Table 12.3: Planning Controls – Special Control Area (SCA1)

Name of Area	Purpose	Objectives	Additional Provisions
SCA 1 – Coastal Hazard	To provide guidance for land use and development within areas subject to coastal erosion and inundation hazard.	(1) To identify land within the Shire of Murray at risk of erosion and inundation by coastal processes by 2120. (2) To ensure public health and safety and reduce risk associated with coastal erosion and inundation. (3) To protect new development from the impacts of coastal erosion and inundation. (4) To avoid inappropriate land use and development of land at risk of coastal erosion and inundation. (5) To ensure land in the coastal zone is continuously available for coastal foreshore management, public access, recreation and conservation purposes. (6) To ensure land use and development does not accelerate coastal erosion or inundation risk; or have a detrimental	(1) In this clause — coastal hazard notice means a notice given under subclause (7); trigger event means one or more of the following events: (a) the distance between the Horizontal Shoreline Datum and the seaward edge of a built structure is less than the acute erosion allowance specified in a Coastal Hazard Risk Management and Adaptation Plan; or (b) a public road access to a property is no longer available, where this is needed to provide physical or legal access to the property; or (c) when water, sewerage or electricity is no longer available to the property, as the service has been removed or decommissioned by the relevant authority due to coastal hazard; or (d) where a property is not serviced by a reticulated sewerage system, when the separation distance between highest known ground water level and the discharge point of the onsite sewage system as set out in the Government Sewerage Policy is not met.

		impact on the functions of public reserves. To ensure coastal process considerations are taken into account in preparing strategic planning proposals and in assessing subdivision and development applications.	(2) Notwithstanding any other provision of the Scheme, all proposed development within SCA 1 requires the development approval of the local government, unless the development is specified in the local government's Coastal Hazard Local Planning Policy as a type that does not require development approval. (3) In considering any application for development approval, or its advice in relation to a proposed structure plan, or application for subdivision of land within SCA 1, the local government is to have particular regard to: (a) The Shire of Murray Coastal Hazard Risk Management and Adaptation Plan; (b) State Planning Policy 2.6 – State Coastal Planning Policy; (c) The Shire of Murray Coastal Hazard Local Planning Policy; (d) The likely effect on public safety and the risk associated with coastal inundation and erosion; (e) The existing and likely future effect of coastal erosion or inundation on the land; (f) The vulnerability of any roads providing access to the land and any public utility infrastructure servicing the land; (g) The continued suitability of servicing the land with an onsite effluent disposal system, where reticulated sewer is not available; (h) The impact that any proposed earthworks, retaining walls or other protective measures will have on the amenity of
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			the locality and water flows; (i) The adequacy of the coastal foreshore reserve to provide for continued coastal foreshore management, public access, recreation, conservation and landscape amenity; (4) An application for development approval for development proposed within SCA 1 may be referred to any statutory, public or planning authority for advice and recommendations before being considered by the local government. (5) Where the local government decides to approve an application for development approval it may impose conditions so as to: (a) constrain the location of development; (b) control the form of construction, including foundations and associated works; (c) determine the form, location and construction of access; (d) require a minimum floor level for development; (e) limit the term of the approval; (f) require the approved development to be removed and the land restored to a condition as near as practicable to its condition immediately before development started to the satisfaction of the local government upon a trigger event occurring; and (g) require the registration of a notification under section 70A of the <i>Transfer of Land Act</i>
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			1893 on the Certificate of Title of the subject land at the cost of the landowner advising: (i) that the lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years; (ii) of any limited term of a development approval; and (iii) of any requirement to remove approved development and restore the land as near as practicable to its condition immediately before the development started to the satisfaction of the local government upon a trigger event occurring. (6) Where an application for subdivision of land within SCA 1 is referred to the local government, it may recommend that the Commission applies conditions requiring: (a) the finished surface level of the land, or the level of public roads providing access to the land are raised sufficient to reduce the risk of coastal inundation; (b) building envelope/s, where applicable, provide a specified area of land that is located above the coastal inundation level; (c) a notification under section 165 of the Act to be placed on the Certificate(s) of Title of the subject land, at the cost of the landowner advising that the lot(s) is located in an area likely to be subject to erosion and/or inundation over the
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			next 100 years. (7) If the local government forms the view that a trigger event has occurred it may give to a person who is the owner of land or any other person who undertook development on land within SCA 1, a coastal hazard notice requiring the person to: (a) remove, pull down, take up, alter or relocate the development or portion of the development specified in the notice; and (b) restore the land as nearly as practicable to its condition immediately before the development was undertaken to the satisfaction of the local government; by a specified time, being a time that is not less than 60 days after the day on which the notice is given. (8) If a person fails to comply with a coastal hazard notice, the local government may enter the land and carry out the works specified in the notice. (9) The expenses incurred by the local government in carrying out the works under clause (8) may be recovered as a debt due from the person to whom the notice was given in a court of competent jurisdiction. (10) The local government may — (a) vary a coastal hazard notice to extend the time for carrying out the specified works; or (b) revoke a coastal hazard notice. (11) A person who is given a coastal hazard notice may apply to the State Administrative Tribunal for a review, in accordance with Part 14 of the Act of a decision —
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			(a) to give the notice; or (b) to require the works specified in the notice to be carried out; or (c) to require the works specified in the notice to be carried out by the time specified in the notice.
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12.5.4 Coastal Hazard Local Planning Policy (LPP)

1.0 Application

This policy applies to all land within Special Control Area No. 1 (SCA 1), which is that land identified in the Shire of Murray Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) as being subject to erosion or inundation by 2120. The extent of SCA 1 is shown on the plans in Appendices C2, C3 and C4.3 of the CHRMAP.

The policy applies all strategic planning, subdivision and development proposals for land within SCA 1.

2.0 Background

The Shire of Murray's CHRMAP has identified that part of the Shire near the Peel Harvey Estuary and the lower reaches of the Murray and Serpentine Rivers will be subject to coastal hazard over the 100 year planning timeframe to 2120.

SCA 1 has been included in the Shire's Scheme which covers the area subject to the coastal hazards and requires development approval to be granted before commencing or carrying out any works or use of land within SCA 1, unless the development is a type specifically exempted.

The policy does not apply to existing development. Rather it provides guidance on how the Shire will consider proposals within the SCA 1 area to better accommodate and respond to the risk of coastal hazard.

3.0 Objectives

1. To identify land within the Shire of Murray at risk of coastal hazard by 2120.
2. To ensure public health and safety and reduce risk associated with coastal erosion and inundation.
3. To protect new development from the impacts of coastal erosion and inundation.
4. To avoid inappropriate land use and development of land at risk of coastal erosion and inundation.
5. To ensure sufficient land within or adjacent to the coastal zone is continuously available for coastal foreshore management, public access, recreation and conservation.
6. To ensure coastal hazard considerations are taken into account in preparing strategic planning proposals and in assessing applications for development and subdivision.

4.0 Definitions

Annual Recurrence Interval (ARI) means how likely an event is to occur. For example a 1% ARI event is an event that occurs or is exceeded on average once every 100 years.

CHRMAP means the Shire of Murray Coastal Hazard Risk Management and Adaptation Plan.

Coastal means the area of water and land that may be influenced by coastal processes.

Coastal hazard means the consequence of coastal processes that affect the environment and safety of people. Potential coastal hazards include erosion and inundation.

Coastal processes means any action of natural forces on the coastal environment.

Commission means the Western Australian Planning Commission.

Erosion Hazard Line means the mapped erosion hazard lines identified in the CHRMAP.

Habitable room has the same meaning as given in State Planning Policy 7.3 Residential Design Codes – Volume 1.

Horizontal Shoreline Datum (HSD) means the active limit of the shoreline under storm activity, as defined in SPP 2.6.

Net lettable area has the same meaning given in the *Planning and Development (Local Planning Schemes) Regulations 2015*.

Permanent development means development that is not time or event limited as determined by the Shire.

SCA 1 means Special Control Area No. 1 as defined on the Scheme maps.

SPP 2.6 means the Commission's State Planning Policy 2.6 Coastal Planning Policy.

Strategic Planning Proposals means a Local Planning Strategy, Local Planning Scheme, amendment to a Local Planning Scheme, Structure Plan or Local Development Plan.

Scheme means the Shire of Murray Local Planning Scheme No.4 or any subsequent local planning scheme approved by the Minister for Planning.

Trigger event has the same meaning given in the Scheme.

Vulnerable land use means a land use that caters for vulnerable occupants such as the elderly, children under 18 years of age, and the sick or injured. This includes schools, child care centres, hospitals, nursing homes and any other land use considered vulnerable at the discretion of the Shire.

5.0 Requirement for Development Approval

Notwithstanding any other provision of the Scheme, development approval is required before commencing or carrying out any works or use of land within SCA 1, unless specified in this Policy as a type that does not require development approval.

Where development approval is required applicants will need to clearly demonstrate that the proposed development meets the objectives and requirements of this Policy and any other relevant requirements of the Shire's planning framework.

Note: Approval to commence development may also be required from the Western Australian Planning Commission under the Peel Region Scheme.

5.1 Exempted Development

Notwithstanding the land being located within SCA 1, unless otherwise required by the Scheme, development approval is not required for:

1. Alterations and additions to a habitable room of an existing residential building or net lettable area of commercial, retail or community building which does not exceed 10m² cumulatively from the date of adoption of this Policy.
2. A change of use that does not involve works, does not intensify development or use of the land and does not involve a vulnerable land use.
3. Development located landward of the 2120 Erosion Hazard Line, which meets all the requirements of this Policy.

6.0 Policy Requirements

6.1 General

Coastal hazard must be considered in preparing strategic planning proposals and when making land use planning and development decisions in order to avoid increasing the impact of coastal processes through inappropriately located land use and development.

Notwithstanding the requirements of this Policy, the Shire may exercise discretion in its consideration of a planning proposal where a site-specific coastal hazard assessment, prepared by a suitably qualified and experienced specialist consultant and which is consistent with SPP 2.6 has adequately demonstrated the suitability of the proposal.

6.2 Strategic Planning Proposals

Strategic planning proposals for land within SCA 1 must demonstrate how it is proposed to plan for and appropriately manage coastal hazards, including risk to public utility infrastructure servicing the land and roads which provide public access to the land.

Strategic planning proposals for land on the seaward side of the 2120 Erosion Hazard Line should not provide for more intensive development or use of this land.

Strategic planning proposals for land adjacent to the coast must include provision for a coastal foreshore reserve. This reserve should be ceded free of cost to the Crown without payment of compensation. The coastal foreshore reserve width is to include a suitable allowance for coastal processes through to 2120 and in addition, sufficient land which is not vulnerable to coastal processes in order to provide for coastal foreshore management, public access, recreation, conservation and landscape amenity.

6.3 Subdivision

Subdivision applications for land on the seaward side of the 2120 Erosion Hazard Line will generally not be supported, except where the application is for:

1. a purpose which will not create the potential for additional private development within the erosion hazard area; or
2. a boundary realignment, rationalisation of landholdings or lots created for a foreshore reserve which will not create the potential for additional private development within the erosion hazard area;

and the subdivision is otherwise consistent with the Scheme and the Commission's general subdivision policies.

For subdivision applications for land on the landside of the 2120 Erosion Hazard Line, the Shire will need to be satisfied that the subdivision will not lead to development at risk of coastal hazard, and in particular:

1. for subdivision of land in an urban area, the finished surface level of new lots should allow for the development of habitable dwellings, being the combination of the lot level plus building pad, should be at or above 2.34m AHD. The surface of all roads providing access to the new lots should also be at this level, unless it can be demonstrated in a particular instance that a lower level is suitable having regard to coastal inundation risks.
2. for subdivision of land in special rural zones a building envelope is to be prepared consistent with the provisions of the Scheme which includes an area of at least 1,000m² which is which above 2.34m AHD, with the exception of lots within the current riverine 1% ARI flood mapping area, where the finished surface level is otherwise required to exceed 2.34m AHD.
3. public road access to the new lots must not be subject to inundation to the extent that would result in difficulty providing evacuation during a coastal inundation event.

The Shire will recommend to the Commission that a condition be imposed on all subdivision approvals requiring a notification under section 165 of the *Planning and Development Act 2005* to be placed on

the Certificate(s) of Title of the subject land, at the cost of the landowner, advising that the lot(s) are located in an area likely to be subject to coastal hazard within the period to 2120, except where the coastal hazard will be adequately addressed through the subdivision construction works or has otherwise been suitably addressed.

6.4 Development

For land on the seaward side of the 2120 Erosion Hazard Line:

1. Alterations and additions to a habitable room of an existing residential building or to the net lettable area of an existing commercial, retail or community building may be permitted provided this does not exceed 10m² cumulatively from the date of adoption of this policy.
2. Development which is incidental to an existing building, including outbuildings, carports, and patios may be permitted. This does not include Ancillary Dwellings.
3. Other development may only be permitted provided:
 - a. the applicant adequately demonstrates that the design life of the development is suitable for its location with regard to the Erosion Hazard Lines contained within the CHRMAP and that the development can be relocated or removed;
 - b. a condition is imposed limiting the term of the development approval and requiring the approved development to be removed and the land restored as nearly as practicable to its condition immediately before development started to the satisfaction of the Shire, upon a trigger event occurring; and
 - c. a condition is imposed requiring a notification to be placed on the certificate of title of the subject land pursuant to section 70A of the *Transfer of Land Act 1893* to alert prospective purchasers of the limited term of the approval and the requirement to remove the development and restore the land as nearly as practicable to its condition immediately before development started to the satisfaction of the Shire, upon a trigger event occurring.
4. Where ever reasonably practicable to do so any new development is to be located on the least vulnerable portion of the land.
5. Habitable rooms for residential buildings and net lettable areas for commercial, retail or community buildings require a minimum finished floor level of at least 2.34m AHD with the exception of properties within the current riverine 1% ARI flood mapping areas, where the required finished floor levels exceed 2.34m AHD. The following buildings may be constructed below this level:
 - a. minor additions and alterations to buildings which exist at the date of adoption of this policy, where this floor level is not reasonably practicable or desirable in a particular instance;
 - b. non-habitable buildings or floorspace such as outbuildings, car ports.
6. Where the filling of land is proposed to achieve minimum finished floor levels, the design and extent of the fill and any retaining walls must not create an adverse impact on inundation levels on adjacent properties or on the amenity of the locality.
7. All utility service connections including power points, light switches, communications connections, sewer vents and the like shall be elevated and / or designed to be protected from the impact of inundation. The Shire may require information to demonstrate how this will be achieved or apply conditions to this effect.
8. Buildings are to be designed to withstand structural loads associated with inundation, including water resistant building materials and construction methods. The Shire may require information from a structural engineer to demonstrate how this will be achieved or apply conditions to this effect.
9. Where reticulated sewerage is not provided to the land, the onsite effluent disposal system must be an aerobic treatment unit with nutrient retentive capacity to the satisfaction of the Shire and be designed to withstand inundation events.
10. All development approvals will include a condition requiring a notification to be placed on the

certificate of title of the subject land pursuant to section 70A of the *Transfer of Land Act 1893* to alert prospective purchasers that the land is located within an area likely to be subject to coastal hazard within the period to 2120, except where the coastal hazard will be adequately addressed through the development works or is otherwise suitably addressed.

For land on the landward side of the 2120 Erosion Hazard Line development may be approved provided:

1. Where ever reasonably practicable to do so any new development should be located on the least vulnerable portion of the land.
2. Habitable rooms for residential buildings and net lettable areas for commercial, retail or community buildings require a minimum finished floor level of at least 2.34m AHD, with the exception of properties within the current riverine 1% ARI flood mapping areas, where the required finished floor levels exceed 2.34 AHD. The following buildings may be constructed below this level:
 - a. Minor additions and alterations to buildings which exist at the date of adoption of this policy, where this floor level is not reasonably practicable or desirable in a particular instance;
 - b. non-habitable buildings or floorspace, such as outbuildings or car ports.
3. Where the filling of land is proposed to achieve minimum finished floor levels, the design and extent of the fill and any retaining walls must not create an adverse impact on inundation levels on adjacent properties or on the amenity of the area.
4. All utility service connections including power points, light switches, communications connections, sewer vents and the like shall be elevated and / or designed to be protected from the impact of inundation. The Shire may require information to demonstrate how this will be achieved or apply conditions to this effect.
5. Buildings are to be designed to withstand structural loads associated with inundation, including water resistant building materials and construction methods. The Shire may require information from a structural engineer to demonstrate how this will be achieved or apply conditions to this effect.
6. Where reticulated sewerage is not provided to the land, the onsite effluent disposal system must be an aerobic treatment unit with nutrient retentive capacity to the satisfaction of the Shire and be designed to withstand inundation events.
7. All development approvals will include a condition requiring a notification to be placed on the certificate of title of the subject land pursuant to section 70A of the *Transfer of Land Act* to alert prospective purchasers that the land is located within an area likely to be subject to coastal hazard within the period to 2120, except where the coastal hazard will be adequately addressed through the development works or is otherwise suitably addressed.

12.5.5 Planned or Managed Retreat Policy

There is no immediate need for the Shire to prepare a Planned or Managed Retreat Policy given the erosion hazard lines are not expected to impact habitable buildings until at least 2040. The Shire should however commence planning for the managed retreat of at-risk properties once habitable buildings are mapped as being impacted within the 10-year planning timeframe. Based on the current modelling, the Shire should aim to prepare and adopt a Managed Retreat Policy by 2030.

In view of this timeframe, a recommendation for a Managed Retreat Policy has been included in this CHRMAP for the 2025 to 2030 period. Whilst the policy approach would need to consider local circumstances, WAPC2019 includes guidance on the Planned and Managed Retreat approach for properties that are subject to erosion and inundation, and this would provide a basis for the policy development.

The CHRMAP Guidelines provide a framework for triggering the voluntary or compulsory acquisition of private land affected by erosion where the public foreshore can no longer provide a natural barrier to coastal and riverine processes. This will however require careful consideration and close engagement with the community to ensure an approach that meets community aspirations, provides a strategic and proactive response to the coastal risks, and is financially viable to implement.

12.5.6 Foreshore Management Plans

Foreshore management plans can provide a strategy to deliver the recommendations of this CHRMAP for particular foreshore reserves throughout the Shire. 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 Shire should prepare a foreshore management plan for each SMU 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.

12.5.7 Emergency Response and Evacuation

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

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

12.6 Economic Framework

The economic evaluation of adaptation options used to support the CHRMAP process involves:

- Determining economic value of assets at risk to coastal hazards;
- Determining the current and future annual cost of hazards to susceptible assets in the Shire's Coastal Zone;
- Determining the cost of options to mitigate coastal hazards; and
- Economic evaluation of reduction in costs of hazards to susceptible assets as a result of mitigation options.

The evaluation of the adaptation options task has two key components:

- Multi-Criteria Analysis (MCA) detailed in Section 13; and
- Cost Benefits Analysis (CBA) detailed in Section 14.

The multi-criteria analysis and cost benefit analysis is used to assist the evaluation of adaptation options and future pathways recommendations in this report.

In the Implementation Plan for the CHRMAP (Section 16) the benefit distribution analysis is considered in detail. This includes the analysis of the beneficiaries of proposed mitigation options as well as the funding mechanisms that are available to fund the capital and ongoing costs.

13. Multi Criteria Analysis

13.1 Overview of the MCA process

13.1.1 General Explanation

A multi-criteria analysis (MCA) to contrast and compare adaptation options was completed for four key focus areas highlighted in the risk assessment. An MCA is a tool to compare various alternatives or options. It provides a structured way to compare and contrast options and uses a number of criteria, and scoring of those criteria, to compare options.

The key focus areas that were identified for the MCA application are:

- Erosion / Inundation of Nature Reserves (Kooljerrenup)
- Inundation of low-lying properties (Murray Delta Islands, South / North Yunderup and Furnissdale)
- Erosion of riverbanks through North and South Yunderup (including Murray Delta Islands)
- Septic Tanks

Criteria are assigned a “score” based on the expected performance against those criteria. Three key categories adopted for Shire of Murray were:

- Technical
- Social
- Environmental

The assessment categories are outlined in Table 13.1

Table 13.1: MCA Categories and Key Criteria

Category	Criteria
Technical	Feasibility – the feasibility of designing and implementing the option (also incorporates legal considerations)
	Effectiveness – how effective the option is at achieving the outcome
	Climate Change Adaptation – how adaptable the option is to meet the likely changes due to climate change
	Construction and Maintenance – ease of construction and associated maintenance
Social	Community – impacts on the community
	Public Amenity – impacts on the recreational use of areas, access to areas etc
Environmental	Natural Environment – impacts on the natural environment
	Visual Amenity – visual impacts associated with the option

The MCA scoring was developed to provide a basis for assessment across the categories with the approach summarised in Table 13.2 and Table 13.3.

Table 13.2: MCA Scoring – Performance and Impact

Score	Technical	Social and Environmental
-2	Very Poor Performance	High negative impact
-1	Poor Performance	Medium Negative Impact
0		Low to no Impact
+1	Good Performance	Medium Positive Impact
+2	Very Good Performance	High Positive Impact

Table 13.3: MCA Scoring - Cost

Score	Technical
1	Most Expensive
2	
3	
4	
5	Least Expensive



13.1.2 MCA Workshop

An MCA workshop was completed in November 2021 which examined the range of adaptation options in areas of the Shire of Murray where a high level of risk from erosion or inundation had been identified in the earlier stages of the CHRMAP. This focussed on the Murray Delta Islands, shoreline areas of North and South Yunderup and the Peel-Harvey.

The MCA session was hosted by Rhys Thomson, an Economist at Rhelm with assistance from Jim Churchill (Baird). The session was delivered in person at the Shire offices, with attendees comprised of the CRG and stakeholders from the Shire.

It is noted that representatives from the Murray Delta Residents and Ratepayers Association (MDRRA) attended the MCA workshop, but stated at the start of the session they would participate without endorsing the outcomes.

For each of the focus locations, the range of adaptation approaches was discussed with the group to arrive at a consensus for the scoring, with outcomes agreed in the sessions presented in the following section. The presentation slides from the workshop are attached in Appendix G.1.

13.2 MCA Summary of Outcomes

13.2.1 Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve

Brief description of the issue (as shown in Figure 13.1):

- Erosion potential of the shoreline, with future coastal processes allowance of 150m - 200m inland projected based on assumed sea level rise and current understanding of the location.
- With sea level rise and extreme events, the inundation area extends ~500m inland for the 2120 design inundation hazard (500yr ARI)
- Potential impacts include:
 - Loss of Habitat for water birds / shore birds
 - Modification of coastal saltmarsh area

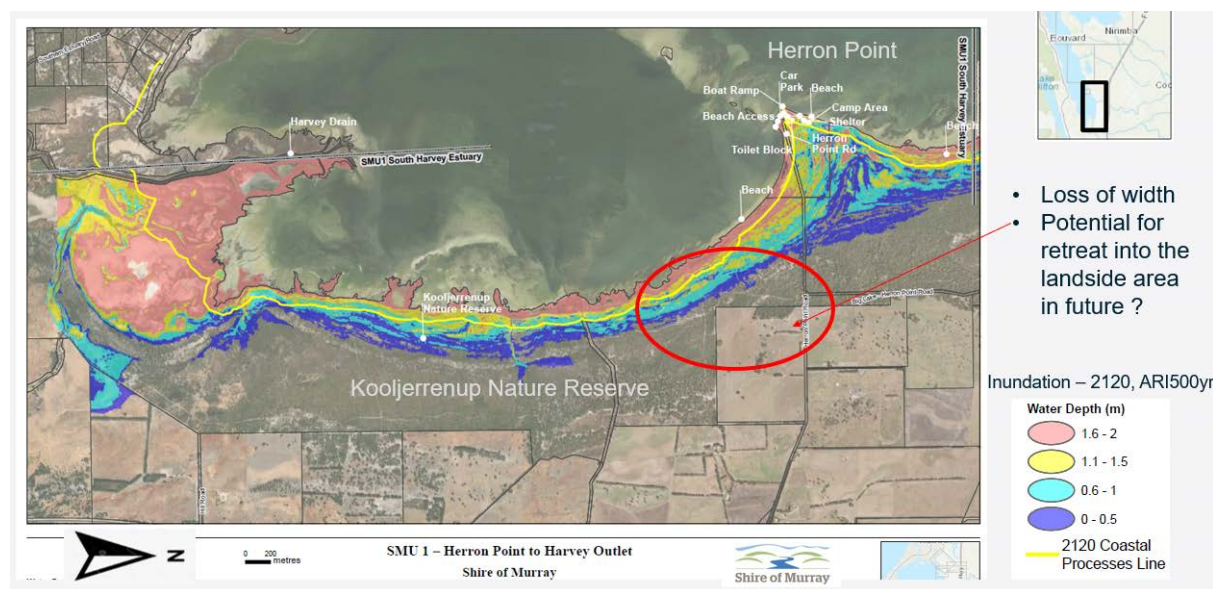


Figure 13.1: Erosion and Inundation at Kooljerrenup Nature Reserve

Options identified to mitigate the issue:

- Do nothing (annual monitoring)
- Managed Retreat, including purchase of farm areas landward to replace the lost shoreline area
- Protect using Nature based solutions (refer Section 3.2).

The summary of the MCA scoring is presented in Table 13.4 to Table 2.7.

Table 13.4: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Technical, Social, Environment Category

Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction and Maintenance	Score
Managed Retreat – Do Nothing	2	-2	2	2	4
Managed Retreat - purchase farm areas landward	0	1	1	-1	1
Protection – nature-based solutions	-1	2	1	-1	1

Table 13.5: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Social Category

Option	Community	Public Amenity	Score ¹
Managed Retreat – Do Nothing	-2	-1	-6
Managed Retreat - purchase farm areas landward	1	1	4
Protection – nature-based solutions	2	1	6

1. For the Environmental and Social categories the scoring is multiplied by 2 to be equivalent to the Technical Category

Table 13.6: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Environmental Category

Option	Natural Environment	Visual Amenity	Score ¹
Managed Retreat – Do Nothing	-2	-1	-6
Managed Retreat - purchase farm areas landward	1	1	4
Protection – nature-based solutions	2	1	6

1. For the Environmental and Social categories the scoring is multiplied by 2 to be equivalent to the Technical Category

Table 13.7: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Cost Score

Option	Score
Managed Retreat – Do Nothing	5
Managed Retreat - purchase farm areas landward	2
Protection – nature-based solutions	3

In terms of the final scoring of the options two approaches with different weightings were considered:

- Approach 1. Technical criteria considered more important than the others. Technical Category 50%, Social Category 25%, Environment 25%
- Approach 2. Equal weighting across categories. Technical Category 33%, Social Category 33%, Environment 33%

The final outcomes are summarised in Table 13.8 for both approaches. The nature-based solutions approach is the highest ranking, with the outcome consistent across both evaluation approaches. Managed retreat with purchase of land areas is the second highest scoring option followed by the Do-Nothing option.

Discussion with the group in the workshop supported the applicability of the equal weighting approach and this was adopted for the other analysis in the MCA.

Table 13.8: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Final Scoring of Options

Option	Technical	Social	Environment	Approach 1	Approach 2	Cost
				T50% S25% E25%	T33% S33% E33%	
Managed Retreat – Do Nothing	4	-6	-6	-1	-2.6	5
Managed Retreat - purchase farm areas landward	1	4	4	2.5	3.0	2
Protection – nature-based solutions	1	6	6	3.5	4.3	3

13.2.2 Item 2 – Inundation of Properties

Brief description of the issue:

- Under projected sea level rise there is increased risk of inundation for properties in low lying areas (Figure 13.2)
- Areas of Interest - Murray Delta Islands, North / South Yunderup, Furnissdale (SMU4, SMU5, SMU6)
- Approximately 2,000 properties in the SoM study area are within the 2120 coastal inundation hazard extent (500yr ARI event) under a projected sea level rise of 0.9m in 100 years

Options identified to mitigate the issue (Figure 13.3):

- Planning Based Approaches for Housing Design - Raise Floor Levels and improve foundation design to withstand flood conditions (as redevelopment)
- Planning Based Approached for Housing Design. Fill Properties to Design Level (as redevelopment)
- Temporary Flood Barriers at the edge of the Murray Delta Islands that can be erected to protect from inundation ahead of the event

- d) Permanent Flood Barriers at the edge of the Murray Delta Islands that can be built and maintained at a level above the design flood (eg dike, revetment in foreshore)
- e) Build Flood Barrier at the Dawesville Cut
- f) Managed Retreat. Islands returned to Nature

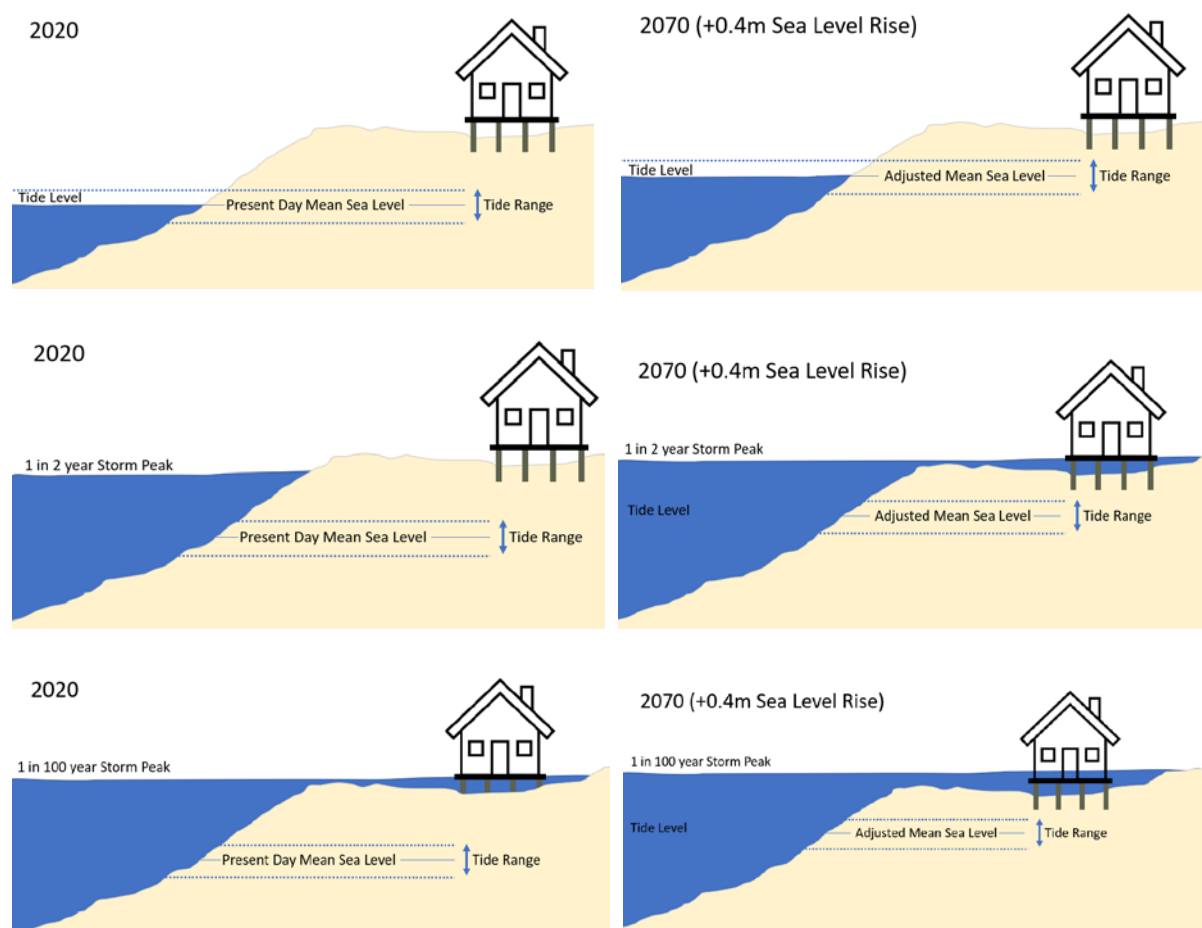


Figure 13.2: Illustration of the influence of sea level rise on low lying properties for general tide range, 1 in 2-year flood level and 1 in 100-year flood level. On the left the present-day scenario (2020) is presented and in the right column the same flood cases with sea level rise allowance is shown (presented as +0.4m which is the projected 2070 allowance).

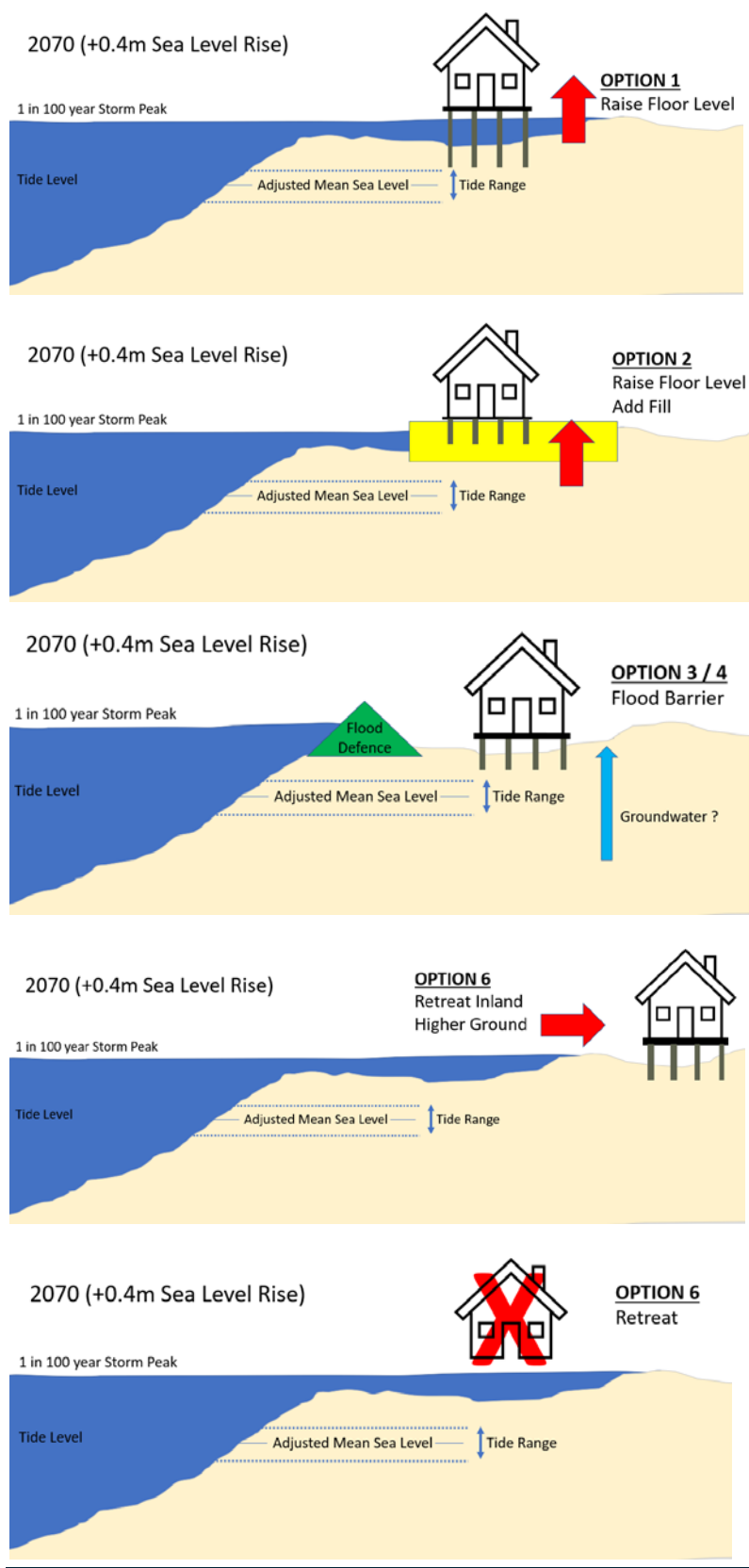


Figure 13.3: Basic overview of the Mitigation Options to address inundation hazard

The summary of the scoring is presented in Table 13.9 to Table 13.13.

Table 13.9: Item 2 – Inundation Low lying properties. MCA Scoring – Technical, Social, Environment Category

Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction and Maintenance	Score
1. Planning Based Approaches for Housing Design - Raise Floor Levels	2	1	1	2	6
2. Planning Based Approached for Housing Design. Fill Properties	1	1	-1	1	2
3. Temporary Flood Barriers	-2	-1	1	-2	-4
4. Permanent Flood Barriers	1	1	1	-1	2
5. Build Flood Barrier at the Dawesville Cut	-2	2	1	-2	-1
6. Managed Retreat. Islands returned to Nature	-1	2	2	-1	2

Table 13.10: Item 2 – Inundation Low lying properties. MCA Scoring – Social Category

Option	Community	Public Amenity	Score ¹
1. Planning Based Approaches for Housing Design - Raise Floor Levels	2	0	4
2. Planning Based Approached for Housing Design. Fill Properties	2	1	6
3. Temporary Flood Barriers	1	0	2
4. Permanent Flood Barriers	1	-1	0

Option	Community	Public Amenity	Score ¹
5. Build Flood Barrier at the Dawesville Cut	2	0	4
6. Managed Retreat. Islands returned to Nature	-2	1	-2

1. For the Environmental and Social categories the scoring is multiplied by 2 to be equivalent to the Technical Category

Table 13.11: Item 2 – Inundation Low lying properties. MCA Scoring – Environmental Category

Option	Natural Environment	Visual Amenity	Score ¹
1. Planning Based Approaches for Housing Design - Raise Floor Levels	0	0	0
2. Planning Based Approached for Housing Design. Fill Properties	-1	-1	-4
3. Temporary Flood Barriers	0	0	0
4. Permanent Flood Barriers	-1	0	-2
5. Build Flood Barrier at the Dawesville Cut	0	-1	-2
6. Managed Retreat. Islands returned to Nature	2	1	6

Table 13.12: Item 2 – Inundation Low lying properties. MCA Scoring – Cost Score

Option	Score
1. Planning Based Approaches for Housing Design - Raise Floor Levels	5
2. Planning Based Approached for Housing Design. Fill Properties	5
3. Temporary Flood Barriers	3
4. Permanent Flood Barriers	2
5. Build Flood Barrier at the Dawesville Cut	1
6. Managed Retreat. Islands returned to Nature	2

Table 13.13: Item 2 – Inundation Low lying properties. MCA Scoring – Final Scoring of Options

Option	Technical	Social	Environment	Weighted Score ¹	Cost
				T33% S33% E33%	
1. Planning Based Approaches for Housing Design - Raise Floor Levels	6	4	0	3.3	5
2. Planning Based Approached for Housing Design. Fill Properties	2	6	-4	1.3	5
3. Temporary Flood Barriers	-4	2	0	-0.7	3
4. Permanent Flood Barriers	2	0	-2	0	2
5. Build Flood Barrier at the Dawesville Cut	1	4	-2	0.3	1
6. Managed Retreat. Islands returned to Nature	2	-2	6	2.0	2

1. In terms of the final scoring of the options equal weighting across categories was adopted.

The final outcomes summarised in Table 13.13 show the Option 1 *Planning Based Approaches for Housing Design* as the highest ranked. Managed retreat is the second highest scoring option followed by the option to examine housing design using fill.

It is noted that Option 5 to construct a storm surge barrier at Dawesville is assessed at high level, with the understanding that the option would require much wider consultation with stakeholders outside of the Shire of Murray to fully assess the potential impacts to the Peel-Harvey as well as the flood protection offered to the Shire and the City of Mandurah. The cost of the structure is very significant and would require major financial contribution at State and / or Federal level.

13.2.3 Item 3 – Erosion of Riverbanks

Brief description of the issue:

- Erosion of Murray and Serpentine Shorelines causes erosion threat to property and assets landward
- Affects North / South Yunderup, Murray Delta Islands, Furnissdale

Options identified to mitigate the issue:

- Do Nothing (annual monitoring only)
- Managed Retreat of Properties

- c) Protection – hard engineered walls
- d) Protection through nature-based solutions
- e) Reduce Vessel Speed

The summary of the MCA scoring is presented in Table 13.14 to Table 13.18. The option to *Reduce Vessel speed* was discussed in the workshop and it was determined that this should be implemented as a 'No Regrets' option. A future study of vessel type, vessel speed and projected future boat use on the river was suggested as a way forward to implement this approach.

Table 13.14: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Technical, Social, Environment Category

Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction and Maintenance	Score
1. Do Nothing	2	-2	2	2	4
2. Hard Engineering	1	2	-1	-1	1
3. Soft Edge Treatments	1	1	1	1	4
4. Managed Retreat	-1	2	2	-1	4

Table 13.15: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Social Category

Option	Community	Public Amenity	Score ¹
1. Do Nothing	-2	-2	-8
2. Hard Engineering	0	1	2
3. Soft Edge Treatments	1	2	6
4. Managed Retreat	-2	1	-2

1. For the Environmental and Social categories the scoring is multiplied by 2 to be equivalent to the Technical Category

Table 13.16: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Environmental Category

Option	Natural Environment	Visual Amenity	Score ¹
1. Do Nothing	-1	-1	-4
2. Hard Engineering	-1	-1	-4
3. Soft Edge Treatments	1	2	6
4. Managed Retreat	2	1	6

1. For the Environmental and Social categories the scoring is multiplied by 2 to be equivalent to the Technical Category

Table 13.17: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Cost Score

Option	Score
1. Do Nothing	5
2. Hard Engineering	2
3. Soft Edge Treatments	3
4. Managed Retreat	1

Table 13.18: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Final Scoring of Options

Option	Technical	Social	Environment	Weighted Score ¹	Cost
				T33% S33% E33%	
1. Do Nothing	4	-8	-4	-2.6	5
2. Hard Engineering	1	2	-4	-0.3	2
3. Soft Edge Treatments	4	6	6	5.3	3
4. Managed Retreat	2	-2	6	2.0	1

1. In terms of the final scoring of the options equal weighting across categories was adopted.

The final outcomes show the Option 3 *Soft Edge Treatments* as the highest ranked. Managed retreat is the second highest scoring option.

13.2.4 Item 4 – Septic Systems

Brief description of the issue:

- The septic systems on Murray Delta Islands (and other locations around the study area) pose a risk to River Water Quality in Future under sea level rise scenarios
- An extreme inundation event could flood the septic and release faecal material into the Murray

Options identified to mitigate the issue:

- Upgrade all systems on island to one / several centralised unit (ATU) above inundation hazard level
- Connect to mains (WaterCorp)
- Managed Retreat of all houses

The summary of the MCA scoring is presented in Table 13.19 to

Table 13.23.

The final outcomes summarised in

Table 13.23 show the Option 1 *Upgrade to Centralised ATU* as the highest ranked. Connecting to Mains Sewage is the second highest scoring option.

Table 13.19: Item 4 – Septic Systems. MCA Scoring – Technical, Social, Environment Category

Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction and Maintenance	Score
1. Upgrade to centralised ATU	1	1	2	-1	3
2. Connect to Mains Sewage (WaterCorp)	-1	2	1	-2	0
3. Managed Retreat	-1	2	2	-1	2

Table 13.20: Item 4 – Septic Systems. MCA Scoring – Social Category

Option	Community	Public Amenity	Score ¹
1. Upgrade to centralised ATU	2	1	6
2. Connect to Mains Sewage (WaterCorp)	2	1	6
3. Managed Retreat	-2	1	-2

1. For the Environmental and Social categories the scoring is multiplied by 2 to be equivalent to the Technical Category

Table 13.21: Item 4 – Septic Systems. MCA Scoring – Environmental Category

Option	Natural Environment	Visual Amenity	Score ¹
1. Upgrade to centralised ATU	1	1	4
2. Connect to Mains Sewage (WaterCorp)	2	1	6
3. Managed Retreat	2	2	8

Table 13.22: Item 4 – Septic Systems. MCA Scoring – Cost Score

Option	Score
1. Upgrade to centralised ATU	3
2. Connect to Mains Sewage (WaterCorp)	2
3. Managed Retreat	1

Table 13.23: Item 4 – Septic Systems. MCA Scoring – Final Scoring of Options

Option	Technical	Social	Environment	Weighted Score ¹	Cost
				T33% S33% E33%	
1. Upgrade to centralised ATU	3	6	4	4.3	3
2. Connect to Mains Sewage (WaterCorp)	0	6	6	4.0	2
3. Managed Retreat	2	-2	8	2.6	1

1. In terms of the final scoring of the options equal weighting across categories was adopted

Discussion in the MCA workshop focussed on the septic systems that are on the Islands and how the environmental risk could be best managed in the future under projected sea level rise. The septic systems on Murray Delta Islands (and other locations around the study area) could pose a risk to River Water Quality in Future under sea level rise scenarios if extreme flooding of the septic were to release faecal material into the Murray.

From the final MCA outcomes summarised in Table 13.23 the option to use a single aerobic treatment unit (ATU) or upgrade Islands to a centralised ATU was the highest ranked. Mitigating the risk from septic systems currently in use on the islands is supported by the CHRMAP, an aim that is a key requirement of the State Planning Policy 2.9. An investigation of options and costs for the ATU option is a future study recommendation as part of the CHRMAP.

14. Cost Benefit Analysis

The Cost Benefit Analysis (CBA) undertaken as part of this project follows on from the MCA process by examining the short-listed and highest-ranking options in detail. The CBA refines the evaluation by quantifying the economic value of the various adaptation options considered to mitigate against hazards associated with coastal erosion and inundation. The complete report is available in Appendix I with key information presented in this section.

14.1 Assessment Scenarios

The economic CBA assesses various scenarios against a “base case” scenario. In this case, a “do-minimum” scenario was adopted for the base case condition. Under this scenario, no mitigation is undertaken to protect foreshore areas or property, and erosion and inundation will continue to worsen and impact the study area. Mitigation options are then compared with the base case scenario, to determine the overall economic viability of implementing these mitigation measures. Two key types of mitigation measures were assessed:

- Hard engineering option, which would include typical foreshore treatments like revetments;
- Nature based solutions, which include a combination of vegetation and softer engineering solutions to provide protection.

A separate option was considered for Kooljerrenup Nature Reserve as a part of the CHRMAP. Under this option, an adaption strategy of purchasing land on the eastern side of the reserve is considered, to mitigate the loss of land due to erosion on the shoreline side. This option has not been explicitly assessed as a part of the CBA, but the base case economic loss of land has been estimated to assist in informing this option.

The locations included in the analysis are shown in Figure 14.1 and summarised in Table 14.1.

Table 14.1: Summary of Options Assessment Locations for Cost Benefit Analysis (CBA)

Location	Assessment
South Harvey Estuary (SMU1)	Assessment of the Kooljerrenup Nature Reserve for managed retreat option to buy back areas landward.
South Yunderup (SMU4)	Assessment of shoreline erosion protection for three sections: A. Young Street Carpark / Rivergum Esplanade to Strain Glen (480m) B. Centenary Park to Murray River Caravan Park (350m) C. Foreshore Reserve from Pelicans eastward (920m)
North Yunderup (SMU5)	Shoreline protection for 1820m section of riverbank fronting the residential properties along Coolenup Drive
Murray Delta Islands (SMU5)	Assessment of shoreline erosion protection and inundation protection for three sections: - Ballee Island (250m) - Yunderup Island (1330m) - Coolenup Island (1860m)



Figure 14.1: Shoreline Sections assessed for adaptation options in the CBA

14.2 Nature Based Adaptation Options – Building Resilience

It is noted that there are a range of 'soft protect' or 'nature-based solutions' that can be applied to increase the resilience of shorelines under threat from coastal erosion. Examples include management of the foreshore berm and coastal revegetation. The use of soft edge treatments for rivers are also considered in these terms in this report as these are not traditional 'hard' engineering solutions. These approaches are in

the Protect category and referred to in this report as nature-based solutions (NBS). The Shire has been developing a guideline for protection methods best suited to the river shorelines of the Murray River and Serpentine to address erosion (Syrinx 2018).

The guideline provides the recommendations for the type of edge treatments to control erosion as well as recommended plant species suited to the shoreline areas. These types of measures are aimed at building resilience in the foreshore areas at risk of erosion but do not offer inundation protection.

An example of the nature based and 'soft-protect' shoreline protection options from the guideline are presented in Figure 14.2.

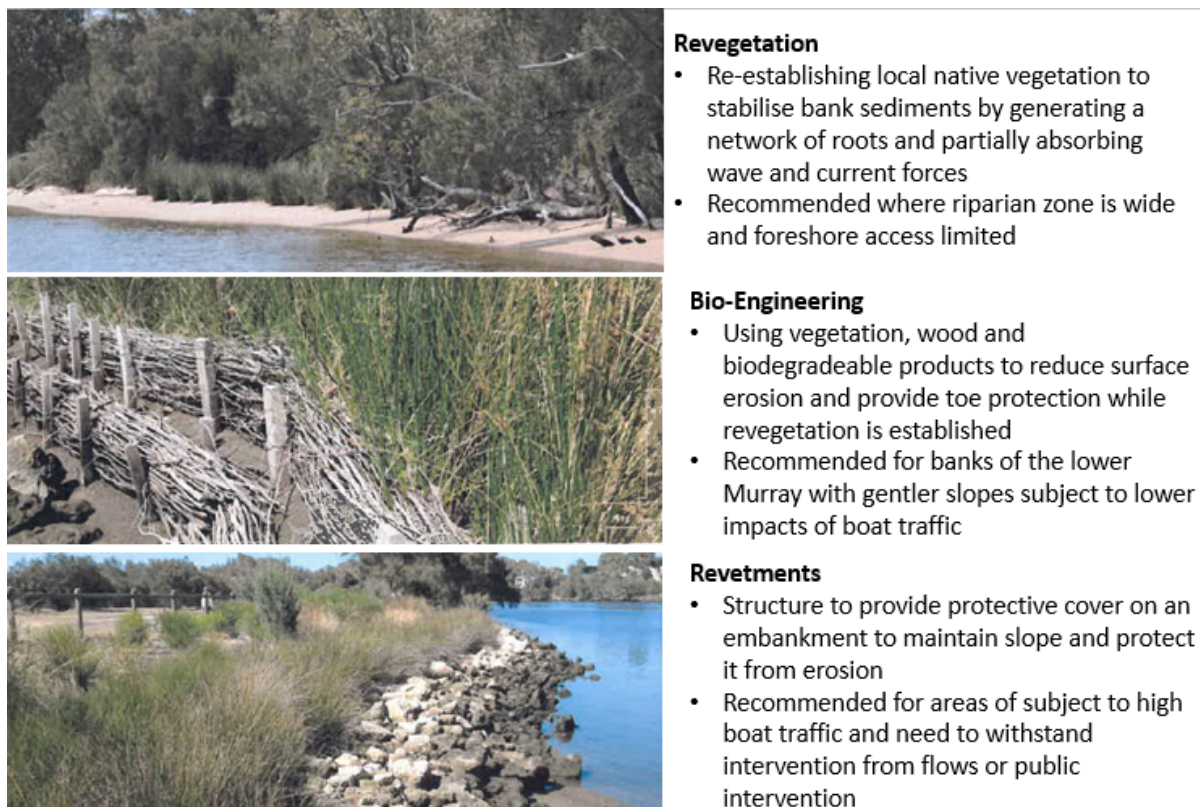


Figure 14.2: Nature Based Solutions for Riverbanks in the Shire of Murray (Adapted from Syrinx 2018)

14.3 Key Assumptions

The key assumptions in the CBA are summarised in Table 14.2.

Table 14.2: Key Assumptions in the Cost Benefit Analysis

Item	Assumptions
Scenarios – Base case and Developed Case	Base case condition – this is the one against which the options are assessed. It assumes no controls in place, and that you get erosion, inundation etc Hard Engineering Options – The more expensive option, which is assumed to provide 100% flood inundation protection and 100% erosion protection. Examples of this are the existing canal walls or dike structure. Natural Based Solutions (NBS) Options – no protection for inundation, 60% protection for erosion.
Benefits	There are two key benefits that have been considered: • Reduction in flood inundation damages • Reduction in erosion/ loss of land.
Erosion	Under the base case, the loss of value associated with the loss of land, as well as the public assets such as the parks etc For the private land, estimated the value of the land (without the building) and then loss of that land over time based on the area within coastal hazard erosion setback lines for future planning periods. Assumption that once the lot is less than 500m², it is no longer viable. This is probably conservative, as you may be able to do something with a property that small, but you wouldn't likely redevelop if it is an eroding area. In addition to the value of the land, allowance for the loss of a house is done in two ways: • if the erosion hits the house and the land area is still above 500m², then reconstruct further back in the lot. Noting that there are some large properties in the study area, this is probably not unreasonable. • If the land area is below 500m², then the property will undergo managed retreat and you lose the value of the house and the remainder of the land in one go. This provides the details of the base case condition. The CBA model examines the proportion of protection as indicated above for the options, where the % reduction is applied directly to the economic loss.
Inundation	Under the base case, the loss of value associated with the inundation of land, as well as the public assets such as the parks etc. For the private land, estimation of the land area impacted for a range of flooding scenarios based on the area within coastal inundation hazard extent today and in future planning periods (with projected sea level rise). The approach looks at the damage associated with overfloor flooding and has been derived based on the most recent guidance from DECC (2007). It assumes a representative property type for almost all properties. Buildings are highly variable throughout the study area, including on the islands. In the absence of detailed information on all building types in the study area the approach has been to assume the representative damage curve (DEEC 2007). There have been a couple of minor adjustments to properties where it was clear that

Item	Assumptions
	they were particularly small etc, but otherwise the same representative damage curve is adopted. The estimate of the damage associated with inundation also removes the damage to a property, where the property erodes to less than 500m² and managed retreat is assumed to occur. In other words, if the property is abandoned you then don't claim flood damages as well. This provides the base case information and the potential protection from inundation is then assessed for each of the options.
Economic Parameters	Discount rate of 7% Assessment period of 50 years, and we have assumed that this is roughly equivalent to the design life of the infrastructure Initial mitigation works would be undertaken in 2025, with a first year of completion assumed as 2026. For climate change, a linear change between the various planning timeframes (2020, 2030, 2050, 2070, 2120).
Limitations	The model is sensitive to land value and building value assumptions. For the Murray Delta Islands there is both a low number of properties on the islands and low sales volumes on which to base house and land values. • It has been assumed a land value of \$80k for the island properties, and a building value of \$200k for the purpose of the CBA. • The property sales on the islands have been in the general range of \$50k through to \$800k with the "representative" value adopted based on analysis of the available data. Sensitivity analysis of house and land value has been used to test the outcomes of the CBA. • It is noted the valuation of property in the current report should not be taken as a future indicator for other purposes outside this CHRMAP. As stated in Rhelm (2022) it is not intended to be a precise property by property estimate, but rather an overall average to provide an indication of the economic loss.

14.4 Calculated Areas of Impact

14.4.1 Residential Properties – Impacts from Inundation and Erosion

The Coastal Hazard impact areas are summarised in Appendix H for properties in the South Yunderup, North Yunderup and Furnissdale SMU's. The impacts are calculated based on the following assumptions:

- Affected properties on Ballee Island, Culleenup Island, Yunderup Island and riverbank properties on South Yunderup, North Yunderup and Furnissdale are assigned unique property pins. For each pin the elevation of the house is estimated based on available LiDAR data.
- A freeboard allowance of 0.3m is added to the elevation to determine the projected finished floor level.
- For inundation impact the inundation is assessed for a range of ARI events at 1yr, 2yr, 5yr, 10yr, 20yr, 50yr, 100yr, 500yr. The depth of over-floor calculations include the 8 ARI scenarios and sea level rise associated with present day (2020), 2030, 2050, 2070 and 2120.
- For erosion, the loss of land area associated with the erosion lines for present day, 2030, 2050, 2070 and 2120 planning periods is calculated based on the Cadastral information.

14.4.2 Shire of Murray Assets

The Coastal Hazard impact areas are summarised in Appendix H for the Shire and community assets. The focus for the assessment is SMU1, SMU4, SMU5 and SMU6 with calculations used to inform the CBA.

14.5 Unit Rate Values

An overview of the cost assumptions adopted in the economic valuation of the Assets in the shorelines is presented in Table 14.3. Asset unit rates are based on the Shire GIS database (replacement value) and from discussions with Shire representatives on current and projected costings from similar work in the Shire (eg nature based / hard edge treatment and Aerobic Treatment Units pricing).

The unit rates are adopted to provide a representative estimate for the CBA. Residential property valuation and land valuation for vacant properties is calculated based on real estate sales data, whilst replacement cost for houses is based on current project costs (refer full report in Appendix I).

Table 14.3: Adaptation Options and asset values - Unit Costs

Option	Cost	Unit
Nature Based Edge Treatment (Mitigation of Erosion Only)	\$180 - \$500	Per / m
Hard protection Edge Treatment (Mitigate Erosion / Inundation)	\$2,000 - \$4,000	Per / m
Centralised Aerobic Treatment Unit (ATU)	\$510k	Per Unit
Carpark / Concrete Footpath	\$53	Per / m ²
Bollard Fence	\$16	Per / m
Timber Bollard	\$21	Per / m
Timber Barrier	\$32	Per / m
Retaining Walls	\$83	Per / m
Pelicans Toilet	\$89,000	1
Batavia Club Shed	\$121,000	1
Batavia Toilet	\$61,000	1
Coopers Mill	\$145,000	1
Coppers Mill Cottage	\$187,207	1
Coopers Mill Toilets	\$67,000	1
Heron Point Toilets	\$54,000	1
Park Bench	\$900	1
Shelter	\$5,200	1
Picnic Table	\$3,100	1
BBQ	\$5,200	1
Bike Rack	\$900	1

Option	Cost	Unit
Playground Equipment	\$500 – \$25000	1
Signs	\$140 - \$700	1

14.6 CBA – Summary of Analysis

14.6.1 Mitigation Option Costs

Capital and maintenance costs were calculated using unit rates for both NBS and hard engineering options, in the different parts of the study area. The low range and high range estimate for the capital costs in Table 14.3 were used to inform the analysis with a middle range estimate adopted for the economics.

The annual maintenance cost of all projects is estimated to be 2% of the undiscounted capital cost for the life of the project. A summary of the capital and maintenance costs, together with the present value equivalent, is shown in Table 14.4.

Table 14.4: Summary of Mitigation Options Costs

Location	Mitigation Option	Maintenance Cost Annual	Maintenance Cost PV (7%pa)	Capital Cost Annual	Capital Cost PV (7%pa)
Yunderup Island	Hard	\$79,800	\$898,988	\$3,990,000	\$3,257,029
	NBS	\$9,044	\$101,885	\$452,200	\$369,130
Ballee Island	Hard	\$33,000	\$371,762	\$1,650,000	\$1,346,891
	NBS	\$1,700	\$19,151	\$85,000	\$69,385
Coolenup Island	Hard	\$246,000	\$2,771,318	\$12,300,000	\$10,040,464
	NBS	\$12,648	\$142,486	\$632,400	\$516,227
North Yunderup Shoreline	Hard	\$109,200	\$1,230,195	\$5,460,000	\$4,456,986
	NBS	\$12,376	\$139,422	\$618,800	\$505,125
South Yunderup	Hard	\$104,700	\$1,179,500	\$5,235,000	\$4,273,319
	NBS	\$11,866	\$133,677	\$593,300	\$484,310

14.6.2 Benefit Costs Ratio (BCR)

The relative costs and benefits of the Project Case in comparison to the Base Case were compared through the CBA. A positive Net Present Value (NPV) and Benefit Costs Ratio (BCR) greater than one support a claim for the project to be considered as economically feasible. When the BCR > 1 it indicates the option delivers a positive NPR.

The CBA modelling examines BCR scores for the present day (2022) for the various options to determine which ones are viable in the present day. It also examines how far the Shire could delay construction to some-time in the future, when the BCR score increases. This is used as a basis for determining which

options should be prioritised now for implementation and sets a timeframe where options may be viable in the future.

14.7 Key Findings from CBA

The benefits for the mitigation options were considered in terms of the protection provided for both erosion, as well as inundation of properties. Economic values were estimated for both the base case condition, as well as the mitigation option, to determine an overall net benefit. These were compared against the estimated costs for the project.

The relative costs and benefits of the Project Case in comparison to the Base Case were compared through a Cost Benefit Analysis (CBA). The results of the CBA are summarised in Table 14.5. A positive NPV and BCR greater than one support a claim for the project to be considered as economically feasible.

An economic analysis was undertaken by “shifting” the start of the assessment forward in time to the point at which the BCR reaches 1. This represents the time at which the project is likely to be economically viable. This can provide useful information from a planning perspective, to allow for SoM to plan for future mitigation that might be required. This timeframe for viability is summarised in planning horizons in the final column of Table 14.5.

It is noted:

- Climate change results in a non-stationary environment, where risks and impacts on the community are expected to change over time. For inundation and erosion, with sea level rise these are anticipated to worsen. From an economic viewpoint, while a project may not be viable to implement today, it may be viable in the future as climate change continues to worsen.
- The time periods indicated here are based on the sea level rise rates that have been adopted in the study. A variation in those rates will result in a change to these timeframes. Therefore, these should be considered to be indicative.

Table 14.5: Economic assessment results: individual projects (\$M, present value at 7% p.a.)

Location	Mitigation Option	Total Costs	Total Benefits	NPV	BCR	Timeframe for Viability
Yunderup Island	Hard	4.16	0.58	-3.58	0.14	30 – 50 years
	NBS	0.47	0.04	-0.43	0.08	30 – 50 years
Ballee Island	Hard	1.72	0.49	-1.23	0.29	20 – 40 years
	NBS	0.09	0.05	-0.03	0.61	10 – 20 years
Coolenup Island	Hard	12.81	2.26	-10.55	0.18	>50 years
	NBS	0.66	0.09	-0.57	0.14	20 – 40 years
North Yunderup Shoreline	Hard	5.69	5.28	-0.40	0.93	10 years
	NBS	0.64	3.11	2.46	4.82	current
South Yunderup	Hard	5.45	1.74	-3.72	0.32	10 – 30 years
	NBS	0.62	0.97	0.36	1.74	current

14.8 Key Outcomes for CHRMAP

The key findings from the CBA in terms of supporting CHRMAP recommendations for adaptation options in the SMU's is summarised as follows:

- a) For the Murray Delta Islands, the low density of development on the islands and the large lot sizes lead to relatively high mitigation option costing relative to the benefit. While that is the case, nature-based solutions would become viable in the next 10 years based on mid-lower range NBS options. It is recommended under the CHRMAP that natural approaches to protect the shoreline areas on the three islands commence now.
- b) For the Murray River shoreline of North Yunderup, the nature-based solutions perform well due to the density of properties in this area and their proximity to the river. However, there may be practical challenges in implementing nature-based solutions within the available space in this area. A hard engineering solution, while having a BCR less than 1, is expected to be viable within 10 years, and therefore should be considered in the 2030 to 2040 planning horizon.
- c) South Yunderup performs well with nature-based solutions (BCR of 1.74) indicating these options are supported for implementation today. These solutions suit the shoreline areas with generally greater land buffer in this location compared with the northern side of the Murray River.
- d) Erosion of the Kooljerrenup Nature Reserve was assessed against the adaption strategy of purchasing land on the eastern side of the reserve, to mitigate the loss of land due to erosion on the shoreline side. Loss of land area is projected to increase markedly after the 2050 period due to shoreline erosion driven by projected sea level rise. Monitoring of the shoreline areas and their response to sea level rise in the next 20 years will inform the future adaptation strategy with further consideration of the need for potential acquisition of land recommended in the 2040 to 2050 planning period.

Table 14.6: Kooljerrenup Nature Reserve: forecast land lost to erosion

	Sea Level Rise (m)	Total Foreshore Area Projected to be Lost to Erosion (m ²)
2020	-	0
2030	+ 0.1	62,000
2050	+ 0.2	196,000
2070	+ 0.4	338,000
2120	+ 0.9	666,000

14.9 Benefit Distribution Analysis

A distributional analysis is a useful tool for understanding the key beneficiaries for a mitigation option. It is undertaken by assessing the beneficiaries for each of the net benefits identified. For the Shire of Murray, the key beneficiaries are predominantly private landowners, and to a lesser degree the Shire of Murray (though the public assets such as reserves). A summary of the distributional analysis is provided in the Implementation Section (Section 16.8).

15. Risk Management Summary

15.1 South end of Harvey Estuary (SMU 1)

SMU1 extends along the shoreline of the Kooljerrenup Nature Reserve, across approximately 8km of the lower Harvey Estuary. The region is predominantly natural shoreline area backed by nature reserve. There is only one area of development at Herron Point where the access road, boat ramp, carpark and camping ground are all located within the projected coastal hazard extent.

The key CHRMAP recommendations for the management of the SMU are summarised as follows:

- The general approach to manage erosion risk for Shire coastal infrastructure around Herron Point is Managed Retreat. This will apply for all infrastructure in foreshore areas. The approach will set erosion triggers that allow the use of coastal assets to continue until coastal erosion of the shoreline reaches a threshold distance from the respective asset. For the Herron Point boat ramp, car park, Herron Point Road and Camping Ground, this would allow continued use until the asset is no longer safe or structurally sound. Minor repair permitted consistent with asset lifecycle and expected planning timeframe would be undertaken.
- For natural shoreline areas and beach areas, these are to be left unprotected as part of a managed retreat approach. The natural shoreline is considered to have high adaptive capacity to respond to the increased vulnerability associated with changes in sea level and climate. A program of monitoring of shoreline erosion through in future years will be used to inform where 'soft protection' options such as sand management and nature-based solutions can improve resilience of the shoreline areas at the Herron Point beaches and foreshore reserve.
- As part of the response of natural shoreline areas to sea level rise, the extent of the Kooljerrenup Nature Reserve could be modified becoming narrower as it moves landward toward the fringing agricultural properties further inland. This may reduce the availability of suitable habitat for birds and other species of fauna. Options for the nature reserve area to be extended landward into adjoining rural property in future planning periods under a managed retreat scenario is recommended for further assessment in the medium-term planning timeframe (from 2050).

It is noted that within the coastal erosion and inundation hazard area there is no residential property identified.

15.1.1 Risk Treatment by Asset – SMU1

A suite of adaptation approaches to treat the coastal hazard risk to assets in the South End of Harvey Estuary SMU is presented in Table 15.1. These have been developed from the adaptation tools listed in Table 15.1.

Table 15.1: Risk Treatment – South End of Harvey Estuary (SMU1)

Asset / Location	Erosion	Inundation
Natural shoreline areas and Foreshore (outside of Herron Point Section)	Monitor erosion to identify local areas that are rapidly eroding (NR1). Leave unprotected as part of managed retreat strategy (MR1)	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Harvey Drain	Leave unprotected as part of managed retreat strategy (MR1)	Short term inundation in large events is acceptable (MR.1).
Kooljerrenup Nature Reserve	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to better understand coastal processes of erosion (NR1). Based on rate of erosion in the foreshore areas and impacts, consider future purchase of landward regions.	Monitor inundation impacts in significant events (NR1). Leave unprotected as part of managed retreat strategy (MR1)
Herron Point Camping Ground and minor infrastructure (camping sites, signage, shelters etc)	Monitor erosion to identify local areas that are rapidly eroding (NR1). Review the use of assets on the site in future under a managed retreat approach (MR1) Relocate assets further landward in future planning periods consistent with coastal hazard (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate assets further landward in future planning periods consistent with coastal hazard (MR2). Ensure an Evacuation Plan (NR4) is in place that can address safety of people using the campground during extreme events.
Herron Point Foreshore Reserve and Beach	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to identify local areas that are rapidly eroding (NR1). Where localised erosion is identified apply low impact / nature based protect options to control erosion (PR1, PR2, PR3)	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1).
Coastal Pathways / Bridle Paths	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to identify local areas that are rapidly eroding (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2).

Asset / Location	Erosion	Inundation
Carpark at Herron Boat Ramp	Monitor erosion to identify local areas of the shoreline that are prone to erosion (NR1). Asset serves special purpose and functions under a Managed Retreat scenario (MR1). Maintain asset function consistent with Asset design life. Asset can be repaired, maintained, upgraded until risk is intolerable Relocate further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Raise level of carpark in future to accommodate the flood risk (AC2) as part of asset upgrade consistent with design life. Relocate further landward in future under a managed retreat approach (MR2).
Herron Point Boat Ramp	Asset serves special purpose and functions under a Managed Retreat scenario (MR1). Maintain asset function consistent with Asset design life. Asset can be repaired, maintained, upgraded until risk is intolerable Conduct audit of the protection structures as part of long-term planning to determine current condition, effectiveness and future protection potential (NR2). Relocate further landward in future under a managed retreat approach (MR2) consistent with Asset design life. Asset can be repaired, maintained, upgraded until risk is intolerable.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Raise level of ramp and access in future to accommodate the flood risk (AC2) as part of asset design life upgrade. Relocate further landward in future under a managed retreat approach (MR2).

15.1.2 Risk Management Pathways – SMU1

Long term adaptation pathways for the key at risk assets identified in SMU1 are summarised in Table 15.2 based on the format recommended in WAPC (2019). The long-term pathways are based on trigger points that would determine the actual change in management response in future planning periods. Trigger points and their monitoring are detailed in the Implementation Plan.

Table 15.2: Risk management pathway, triggers, decision-making and measures for SMU1

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure. Herron Point Campground and Assets (Toilets, Campsites, Minor Infrastructure). Coastal Pathways / Bridle Paths			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Coastal Infrastructure. Herron Point Boat Ramp and Car Park			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Herron Point Foreshore Reserve and Beach			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			
Assets	Kooljerrenup Nature Reserve			
Pathway	Do Nothing (DN1) – Take no action and accept the risk			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			

15.2 Risk Management Summary - Birchmont (SMU 2)

15.2.1 Risk Treatment by Asset – SMU2

The Birchmont management unit (SMU2) extends along approximately 7km of natural shoreline of the Harvey estuary northward from SMU1 through to Mealup Point. There is a development area at Birchmont which includes foreshore reserve and residential lots. The Birchmont boat ramp and carpark which are sited in close proximity to the estuary within the coastal hazard region for inundation and erosion.

The key CHRMAP recommendations for the management of the SMU are summarised as follows:

- The general approach to manage erosion risk for the Shire's coastal infrastructure is Managed Retreat in foreshore areas. The approach will set erosion triggers that allow the use of coastal assets to continue until coastal erosion of the shoreline reaches a threshold distance from the respective asset.
- This approach will cover minor infrastructure (signs etc) as well as key assets of boat ramp and car park would continue to be used under a managed retreat approach until the asset is no longer safe or structurally sound. Minor repair would be permitted consistent with asset lifecycle and expected planning timeframe and the assets relocated further landward in future planning periods as required consistent with design life upgrades.
- For the natural shoreline areas, formal protection options have not been recommended as these are largely natural shoreline areas that are considered to have good adaptive capacity to future pressures from coastal hazard. Monitoring will be used to assess changes in the shoreline in future years and to identify critical areas which may require intervention. A decision can be made in future periods whether there is a requirement to address erosion / build resilience through a soft protect / nature-based solution (Pr.2, Pr.3) or through beach maintenance (Pr.1).
- At Birchmont there are 46 properties located in the 2120 coastal hazard extent. The properties closest the Estuary are generally sited landward of the 2120 coastal erosion hazard line, with some minor areas of encroachment noted at the most western edge of lots. The coastal inundation hazard area for 2120 partially extends across many of the existing lots on the north side of the boat ramp, and fully covers the lots south of Mills Rd / Birch Drive. Development controls for these areas is recommended to be managed through a SCA and LPP. It is recommended the LPP provides guidance for appropriate development for the properties within the SCA that would require:
 - Avoiding development (Av.1) seaward of the 2120 coastal erosion hazard line, plus an additional allowance for future foreshore reserve. For land areas where the hazard line is only present on a part of the lot, siting future development landward of the identified hazard area would be acceptable.
 - Accommodating the inundation risk consistent with planning timeframes to 2120 through design and planning measures which include appropriate Building Design (Ac.2), Appropriate Finished floor levels (Ac.3), Filling Land (Ac.4).
 - Placement of a Notification on title (Ac.1) to indicate to current and future landowners that the property is within a coastal hazard area and likely to be affected by coastal erosion and/or inundation over the planning timeframe

Table 15.3: Risk Treatment – Birchmont (SMU2)

Asset / Location	Erosion	Inundation
Beach areas	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to identify local areas that are rapidly eroding (NR1).	Short term inundation in large events is acceptable (MR.1).
Foreshore Nature Reserve (Lake Mealup and Lake McClarty Nature Reserve)	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to identify local areas that are rapidly eroding (NR1).	Short term inundation in large events is acceptable (MR.1).
Lake Mealup	Not at risk of Erosion	Currently protected from flooding from the Estuary in large events by weir structure on the site (PR5) With sea level rise this weir may need to be upgraded to offer same level of protection consistent with design life.
Coastal Pathways / Bridle Paths	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to identify local areas that are rapidly eroding (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2).
Existing Residential Properties in Birchmont	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) LPP provides guidance for appropriate development for the properties within the SCA Site new structures on portion of the block landward of the coastal hazard area (Av.1).	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) Accommodate inundation consistent with planning timeframes to 2120 through design and planning measures specified in LPP which outlines requirements for: - Building Design (Ac.2) - Appropriate Finished floor levels (Ac.3) - Filling Land (Ac.4)
Undeveloped Land – Potential Future Development Areas	Avoid development in identified coastal hazard area (Av1).	Accommodate inundation consistent with planning timeframes to 2120 through design and planning measures specified in a LPP and SCA which outlines requirements for: - Notification on title (Ac.1) - Building Design (Ac.2) - Appropriate Finished floor levels (Ac.3)

Asset / Location	Erosion	Inundation
		Filling Land (Ac.4) Emergency Evacuation (NR4)
Carpark at Birchmont Boat Ramp	Monitor erosion to identify local areas of the shoreline that are prone to erosion (NR1). Asset serves special purpose and functions under a Managed Retreat scenario (MR1). Maintain asset function consistent with Asset design life. Asset can be repaired, maintained, upgraded until risk is intolerable Relocate further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Raise level of carpark in future to accommodate the flood risk (AC2) as part of asset design life upgrade. Relocate further landward in future under a managed retreat approach (MR2).
Birchmont Boat Ramp	Asset serves special purpose and functions under a Managed Retreat scenario (MR1). Maintain asset function consistent with Asset design life. Asset can be repaired, maintained, upgraded until risk is intolerable Conduct audit of the protection structures as part of long-term planning to determine current condition, effectiveness and future protection potential (NR2). Relocate further landward in future under a managed retreat approach (MR2) consistent with Asset design life. Asset can be repaired, maintained, upgraded until risk is intolerable.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Raise level of ramp and access in future to accommodate the flood risk (Ac3) as part of asset design life upgrade. Relocate further landward in future under a managed retreat approach (MR2).
Minor Infrastructure (signs etc)	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1).
Drainage Features	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Roads	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)

15.2.2 Risk Management Pathways – SMU2

Long term adaptation pathways for the key at risk assets identified in SMU2 are summarised in Table 15.4 based on the format recommended in WAPC 2019. The long-term pathways are based on trigger points that would signal a change in management response. Trigger points and their monitoring are detailed in the Implementation Plan (Section 16).

Table 15.4: Risk management pathway, triggers, decision-making and measures for SMU2

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage, drainage) and Coastal Pathways			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Coastal Infrastructure. Birchmont Boat Ramp and Car Park			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties at Birchmont and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1) 1. - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	Foreshore Reserve adjacent the Boat Ramp and carpark			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			
Assets	Nature Reserves			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			

15.3 Risk Management Summary - Point Grey to Austin Bay (SMU 3)

15.3.1 Risk Treatment by Asset – SMU3

SMU3 extends along approximately 25km of shoreline from the northern side of Mealup Point around Point Grey to the Peel Estuary shorelines of Roberts Bay and Austin Bay. The shoreline through this SMU is natural, undeveloped foreshore reserve and nature reserve providing a buffer between the Peel-Harvey shorelines and areas landward. Around Point Grey, the natural topography rises sharply directly inland of the shoreline, reducing the inundation hazard extent to a minimum. In future planning periods with sea level rise scenarios and extreme storms there is inundation impacts to agricultural land on the edge of the nature reserve of Austin Bay.

The key CHRMAP recommendations for the management of the SMU are summarised as follows:

- The general approach to manage erosion risk for the Shire's coastal infrastructure is Managed Retreat in foreshore areas. The approach will set erosion triggers that allow the use of coastal assets to continue until coastal erosion of the shoreline reaches a threshold distance from the respective asset. This approach will cover minor infrastructure (signs etc) as well as Carabunga Road which would continue to be used under a managed retreat approach until the asset is no longer safe or structurally sound. Minor repair would be permitted consistent with asset lifecycle and expected planning timeframe and the assets relocated further landward in future planning periods as required consistent with design life upgrades.
- For the natural shoreline areas, monitoring in future years as part of a regular monitoring program would be used to inform potential areas of high risk that may require intervention (eg soft protect options or resilience building through nature based solutions). The predominantly natural shoreline areas are considered to have good adaptive capacity to future pressures from coastal hazard.
- There are 20 properties that are located within the coastal hazard extent for the 2120 planning period for which development controls are recommended to be managed through establishment of a SCA and LPP. It is recommended the LPP provides guidance for appropriate development controls within the SCA that would require:
 - Avoiding development (Av.1) seaward of the 2120 coastal erosion hazard line, plus an additional allowance for future foreshore reserve. For land areas where the hazard line is only present on a part of the lot, siting future development landward of the identified hazard area would be acceptable.
 - Accommodating the inundation risk consistent with planning timeframes to 2120 through design and planning measures which include appropriate Building Design (Ac.2), Appropriate Finished floor levels (Ac.3), Filling Land (Ac.4).
 - Placement of a Notification on title (Ac.1) to indicate to current and future landowners that the property is within a coastal hazard area and likely to be affected by coastal erosion and/or inundation over the planning timeframe

Adaptation approaches are summarised in

Table 15.5

Table 15.5: Risk Treatment – Point Grey to Austin Bay (SMU3)

Asset / Location	Erosion	Inundation
Foreshore areas and Nature Reserve	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to identify local areas that are rapidly eroding (NR1).	Short term inundation in large events is acceptable (MR.1).
Coastal Pathways	Leave unprotected as part of managed retreat strategy (MR1) Relocate the pathways further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2).
Minor Infrastructure (signs etc)	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1).
Drainage Features	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Existing Residential Properties and Agricultural Land in the Coastal Hazard extent	Planning controls implemented through SCA and LPP with Notification on title (Ac.1) LPP provides guidance for appropriate development for the properties within the SCA Site new structures on portion of the block landward of the coastal hazard area (Av.1).	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) Accommodate inundation consistent with planning timeframes to 2120 through design and planning measures specified in LPP which outlines requirements for: • Building Design (Ac.2) • Appropriate Finished floor levels (Ac.3) • Filling Land (Ac.4)
Roads (Carabunga Rd)	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)

15.3.2 Risk Management Pathways – SMU3

Long term adaptation pathways for the key at risk assets identified in SMU3 are summarised in Table 15.4 based on the format recommended in WAPC (2019). The long-term pathways are based on

trigger points that would signal a change in management response. Trigger points and their monitoring are detailed in the Implementation Plan (Section 16).

Table 15.6: Risk management pathway, triggers, decision-making and measures for SMU3

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Carabunga Road			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1) - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	Foreshore Areas and Nature Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Do Nothing (DN1) – Take no action and accept the risk			

15.4 Risk Management Summary - South Yunderup (SMU 4)

15.4.1 Risk Treatment by Asset – SMU4

The South Yunderup SMU includes the 4km section of the Peel Estuary shoreline south of the Murray River entrance, and all of the South Yunderup developed area on the southern side of the Murray River from the river entrance to Pinjarra Road (~7.5km). The South Yunderup canal estates and the Austin Cove development are included in the SMU.

The key CHRMAP recommendations for the management of the SMU are summarised as follows:

- For the natural Peel Inlet shoreline areas in the Austin Bay section south of the main area of development in South Yunderup do nothing (DN.1), assess rate of erosion in future years as part of annual monitoring (NR.1).
- The general approach to manage erosion risk for the Shire's coastal infrastructure is Managed Retreat in foreshore areas (MR.1). This includes the carparks, parks, jetty and boat ramps which would be maintained under defined triggers that allow the use of coastal assets to continue until the asset is no longer safe or structurally sound. Minor repair would be permitted consistent with asset lifecycle and expected planning timeframe and the assets relocated further landward in future planning periods as required consistent with design life upgrades (MR.2).
- The Shire should undertake audits of the existing protection structures to determine the current condition, effectiveness and future protection potential. The coastal structures at the following locations have been assumed to be maintained in future years as part of protecting assets landward from coastal hazard:
 - a) The revetment on the Peel shoreline at the Murray entrance adjacent Batavia Quay which protects the site of the dredge spoil sediments (Acid Sulphate Soils)
 - b) The bund feature that is constructed on the Peel shoreline in front of the canal development
 - c) The canal walling in the constructed canal estates in South Yunderup
- There are approximately 1500 properties that are located within the coastal hazard extent for the 2120 planning period. It is recommended an SCA covering the region of the identified inundation and / or erosion hazard is established with a LPP that implements the planning-based controls within the SCA.
- Development controls for these areas is recommended in the LPP that would provide guidance for appropriate development controls within the SCA including:
 - Avoiding development (Av.1) seaward of the 2120 coastal erosion hazard line, plus an additional allowance for future foreshore reserve. For land areas where the hazard line is only present on a part of the lot, siting future development landward of the identified hazard area would be acceptable.
 - Accommodating the inundation risk consistent with planning timeframes to 2120 through design and planning measures which include appropriate Building Design (Ac.2), Appropriate Finished floor levels (Ac.3), Filling Land (Ac.4).
 - Placement of a Notification on title (Ac.1) to indicate to current and future landowners that the property is within a coastal hazard area and likely to be affected by coastal erosion and/or inundation over the planning timeframe
- It is of key importance to work to maintain the river shorelines and build resilience against future erosion that would threaten the assets landward. There are a range of 'soft protection' approaches that could be used to build resilience of the Murray River shorelines through South Yunderup. The Shire are in the process of developing a guideline for appropriate protection options that can be applied along the river shorelines that are in keeping with the natural shoreline areas (Pr.2) as well as a guide to planting species suited to the region (Pr.3).

- The Shire should investigate reducing vessel speeds along sensitive waterways (NR.5) to reduce the erosion impacts from boat wakes on the river shorelines (refer Implementation plan).
- It is noted there are a range of utilities infrastructure that are affected by coastal erosion risk through the SMU. Utilities infrastructure is privately owned, and it is the responsibility of the respective utility owners to determine future adaptation approaches to manage their erosion risk (WaterCorp etc).
- Emergency planning to determine key access routes (eg South Yunderup Road) and their accessibility in extreme events should be undertaken. This is further discussed in the Implementation Plan (Stage 6 Report).

Adaptation approaches are summarised in Table 15.7.

Table 15.7: Risk Treatment – South Yunderup (SMU5)

Asset / Location	Erosion	Inundation
Foreshore areas of the Austin Bay Nature Reserve south of the Murray River	Leave unprotected as part of managed retreat strategy (MR1) Monitor erosion to identify local areas that are rapidly eroding (NR1).	Short term inundation in large events is acceptable (MR.1).
Foreshore Reserve incl. Coastal Pathways (General)	Leave unprotected as part of managed retreat strategy (MR1) Relocate the pathways further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2). Monitor for safety following impacts (NR1)
Foreshore Reserve incl. Coastal Pathways Along Sections examined in CBA	Conduct monitoring of shoreline erosion as part of annual program (NR1) Use NBS (Pr2, Pr3) in current planning timeframe to increase resilience of shorelines.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2). Monitor for safety following impacts (NR1)
Shire Infrastructure (boat ramps, car parks, parks, jetties)	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Protection Structures	Conduct audits of the existing structures to determine the current condition, effectiveness and future protection potential (NR.2)	
Drainage Features	Leave unprotected as part of managed retreat strategy (MR1) . Relocate further landward in future under a managed retreat	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)

Asset / Location	Erosion	Inundation
	approach (MR2) as part of asset replacement.	
Existing Residential Properties and Agricultural Land	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) LPP provides guidance for appropriate development for the properties within the SCA Site new structures on portion of the block landward of the coastal hazard area (Av.1).	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) Accommodate inundation consistent with planning timeframes to 2120 through design and planning measures specified in LPP which outlines requirements for: • Building Design (Ac.2) • Appropriate Finished floor levels (Ac.3) • Filling Land (Ac.4)
Roads	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1) Emergency planning (Nr.4) for key routes (South Yunderup Road)

15.4.2 Risk Management Pathways – SMU4

Long term adaptation pathways for the key at risk assets identified in SMU4 are summarised in Table 15.8 based on the format recommended in WAPC 2019. The long-term pathways are based on trigger points that would signal a change in management response. Trigger points and their monitoring are detailed in the Implementation Plan (Section 16).

Table 15.8: Risk management pathway, triggers, decision-making and measures for SMU4

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways, Drainage Features			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Boat Ramps, Jetties, Carparks, Toilets			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1)			

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
	- Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	River Shorelines and Foreshore Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9). Assets Forecast to become highly or very highly vulnerable in next planning timeframe or next 10 years (T6)			
Assets	Foreshore Areas and Nature Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Do Nothing (DN1) – Take no action and accept the risk			
Assets	Protection Structures and Seawalls - Batavia Quays, South Yunderup Bund, Canals			
Pathway	Conduct a protection structure audit (NR.2)			
Pathway	Continue to maintain the existing seawalls to provide erosion and inundation protection for areas landward (Pr.4)			
Trigger	Assets predicted to become highly or very highly vulnerable within next 10 years (T6)			
Assets	Key Access Roads			
Pathway	Develop Emergency evacuation plan for key routes such as South Yunderup Road (NR.4)			

15.5 Risk Management Summary - North Yunderup and Murray Delta Islands (SMU 5)

15.5.1 Risk Treatment by Asset – SMU5

SMU5 describes the areas on the Murray River at North Yunderup, and also includes the Murray Delta Islands. The North Yunderup residential areas are mostly established above the inundation hazard level whilst the Murray Delta islands are generally low lying. Whilst the Islands are generally set above the

present-day extreme water levels, they are susceptible to flooding in extreme events and under projected sea level rise in future planning periods would be at increased risk of flooding.

The key CHRMAP recommendations for management in North Yunderup are summarised as follows:

- For the North Yunderup shoreline at the eastern end of Culeenup Rd with foreshore reserve, do nothing (DN.1), assess rate of erosion in future years as part of annual monitoring (NR.1).
- The general approach to manage erosion risk for the Shire's coastal infrastructure is Managed Retreat in foreshore areas (MR.1). This includes the carparks, parks, jetty and boat ramps which would be maintained under defined triggers that allow the use of coastal assets to continue until the asset is no longer safe or structurally sound. Minor repair would be permitted consistent with asset lifecycle and expected planning timeframe and the assets relocated further landward in future planning periods as required consistent with design life upgrades (MR.2).
- The Shire should undertake audits of the existing protection structures to determine the current condition, effectiveness and future protection potential.
- In total there are over 300 properties that are located within the coastal hazard extent for the 2120 planning period in North Yunderup SMU
 - There are approximately 100 properties on Culeenup Drive with Murray River frontage which are affected by coastal erosion and/or inundation over the 100-yr planning period.
 - For the Murray Delta Islands there are 6 properties on Ballee Island, 24 properties on Yunderup Island, and 59 properties on Cooleenup Island (based on the analysis of the cadastre) which are affected by coastal erosion and/or inundation over the 100-yr planning period.
- It is recommended an SCA covering the region of the identified inundation and / or erosion hazard is established with a LPP that implements the planning-based controls within the SCA.
- Development controls for these areas is recommended in the LPP that would provide guidance for appropriate development within the SCA including:
 - Placement of a Notification on title (Ac.1) to indicate to current and future landowners that the property is within a coastal hazard area and likely to be affected by coastal erosion and/or inundation over the planning timeframe
 - Avoiding development (Av.1) seaward of the 2120 coastal erosion hazard line, plus an additional allowance for future foreshore reserve.
 - For land areas where the hazard line is only present on a part of the lot, siting future development landward of the identified hazard area would be acceptable. Development considered 'Infill' under SPP2.6 would still be allowed within the erosion SCA on a case-by-case basis
 - Accommodating the inundation risk consistent with planning timeframes to 2120 through design and planning measures which include appropriate Building Design (Ac.2), Appropriate Finished floor levels (Ac.3), Filling Land (Ac.4).

For the Murray Delta Islands, the low-lying nature of these islands and the active coastal processes from both the Peel Inlet side and the Murray River shorelines make these highly vulnerable and susceptible to increased impacts from inundation and erosion with projected sea level rise. Under this CHRMAP the following is recommended for the Murray Delta Islands to manage the inundation and erosion hazard risk:

- a) Increase understanding of the Islands and their risk of inundation and erosion through regular monitoring of shoreline position as part of a structured annual monitoring program. The maintenance of the berm in the foreshore along the western facing beaches in the south of the SMU and along the edge of the Murray Delta Islands facing the Peel Inlet (Ballee Island, Meeyip Island, Yunderup Island, Little Yunderup Island) will be of critical importance. Annual monitoring of the berm including after large storm events will be crucial to ensure the berm is maintained in future years to prevent erosion processes predicted if it is left to erode and move east under the 'berm rollover' process described in the coastal hazard report (Seashore 2021). Monitoring and maintenance of the berm through appropriate soft protection approaches (Pr.1) coupled with appropriate coastal revegetation and

planting (Pr.3) for the western edge of the Murray Delta Islands will be a feature of future coastal management recommendations.

- b) It is of key importance to work to maintain the river shorelines and build resilience against future erosion that would threaten the assets landward. There are a range of 'soft protection' NBS approaches that could be used to build resilience of the Murray River shorelines through the Murray Delta Islands and North Yunderup. The Shire has guidelines for appropriate protection options that can be applied along the river shorelines (Syrinx 2018) in keeping with the natural shoreline areas (Pr.2) as well as a guide to planting species suited to the region (Pr.3). This document will be of key importance for guiding appropriate responses for shoreline areas which require attention.
- c) The Shire should commence a study to investigate the erosion impacts from boat wakes on the river shorelines. This would be used to understand ways in which reducing vessel speeds along sensitive waterways through the Murray Delta Islands (NR.5) can reduce erosion.
- d) For established properties on the three islands, create a building register. The register would be used to provide baseline information of properties to better understand the risk of inundation and erosion in future planning periods. The register should include the following information:
 - Record of the finished floor level determined through a surveyor using eg Digital Ground Positioning System (DGPS). This information can refine estimates made as part of the CHRMAP on freeboard levels of the properties (assumed as +0.3m). Can also inform inundation risk on a property-by-property basis for future emergency planning;
 - Establish the level of the septic system, determined through a surveyor using eg Digital Ground Positioning System (DGPS);
 - Notes on the type of building design (materials). Information on sub-floor (eg stumps) to determine whether it is practical to raise the house in the future above projected flooding hazard in future years;
 - Measurement of the distance from the closest point of the habitable structure to the river shoreline (HSD)
- e) Specific development controls for the three Islands to be provided in the LPP to provide guidance for appropriate development to the following recommendations:
 - For new development or redevelopment of existing properties, provide guidance on building design that is appropriate for the location and can withstand inundation (eg. Building materials that can withstand flooding, siting electrical fixtures above flood level).
 - For new development or redevelopment of existing properties, establish minimum finished floor levels to accommodate the inundation risk noting:
 - The islands would be susceptible to more widespread and frequent flooding if the base sea level rises by more than +0.5m from its present level. Under this scenario. large areas of the three islands are expected to experience more frequent inundation in common flood events and in general tides which would likely impact the amenity of residents living on the Islands
- f) Establish a managed retreat policy (refer Section 1.5.4.2) that can be applied to manage risk in future planning periods. As part of the process:
 - determine the low lying, undeveloped properties (eg northwest end of Culleenup Island) where it may be impractical to accommodate inundation hazard over the planning timeframe for new development.
 - the respective triggers which would signal the next adaptation phase of CHRMAP as either protection or managed retreat of properties would be defined from changes to:
 - o erosion (measure of S1 distance from closest edge of habitable structure); and
 - o inundation (increased flooding frequency, observed and measured increase in mean sea level based on local tide gauges in the Peel-Harvey, allowing for annual and decadal scale tidal influences).
- g) Commence assessment, planning and costing for a centralised ATU system that can manage each of the Island's requirements, to replace the septic systems (short to medium term time frame).

Other general notes regarding the CMU:

- The Shire should investigate reducing vessel speeds along sensitive waterways (NR.5) to reduce the erosion impacts from boat wakes on the river shorelines (refer Implementation plan).
- Coopers Mill is an asset with identified Heritage value, which is susceptible to inundation in extreme events in the present day. Short term inundation in large events is deemed an acceptable risk with monitoring of the foreshore and use of NBS (Pr.2 Pr.3) to increase resilience of the foreshore area recommended.
- It is noted there are a range of utilities infrastructure that are affected by coastal erosion risk through the SMU. Utilities infrastructure is privately owned, and it is the responsibility of the respective utility owners to determine future adaptation approaches to manage their erosion risk (WaterCorp etc).
- Emergency planning to determine key access routes (eg Tonkin Road, North Yunderup Road, Culeenup Road) and their accessibility in extreme events should be undertaken and their accessibility in extreme events should be undertaken. This is further discussed in the Implementation Plan (Section 16).

Adaptation approaches are summarised in Table 15.9.

Table 15.9: Risk Treatment – North Yunderup and Murray Delta Islands (SMU6)

Asset / Location	Erosion	Inundation
Foreshore areas of the western edge of the Murray Delta Islands in Peel Inlet	Monitor berm to identify any changes (NR1). Maintain Berm through soft protect approaches (Pr.1)	Short term inundation in large events is acceptable (MR.1). Maintain Berm through soft protect approaches (Pr.1)
Shoreline Ballee Island, Culeenup Island and Yunderup Island adjacent residential properties	Conduct monitoring of shoreline erosion as part of annual program (NR1) Use NBS (Pr2, Pr3) to increase resilience of shorelines. Indicative planning horizons are Ballee Island (next 5-years), Coolenup (2030), Yunderup (2035).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1).
Coopers Mill	Conduct monitoring of shoreline erosion (NR1). Use NBS (Pr2, Pr3) to increase resilience of shorelines	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1).
Foreshore Reserve incl. Coastal Pathways	Leave unprotected as part of managed retreat strategy (MR1) Relocate the pathways further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2).
River section of Culeenup Road Properties	Monitoring and assessment of erosion along the riverbank (NR1).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1).

Asset / Location	Erosion	Inundation
with River Frontage	Commence planning study for Hard Engineering edge treatments to protect against erosion (PR.4) in 2030 – 2040 timeframe.	
Shire Infrastructure (boat ramps, car parks, parks, jetties)	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Protection Structures	Conduct audits of the existing structures to determine the current condition, effectiveness and future protection potential (NR.2)	
Drainage Features	Leave unprotected as part of managed retreat strategy (MR1). Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Existing Residential Properties	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) LPP provides guidance for appropriate development for the properties within the SCA Site new structures on portion of the block landward of the coastal hazard area (Av.1).	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) Accommodate inundation consistent with planning timeframes to 2120 through design and planning measures specified in LPP which outlines requirements for: • Building Design (Ac.2) • Appropriate Finished floor levels (Ac.3) • Filling Land (Ac.4)
Roads	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1) Emergency planning (Nr.4) for key routes

15.6.1 Risk Management Pathways – SMU5

Long term adaptation pathways for the key at risk assets identified in SMU5 are summarised in Table 15.10 based on the format recommended in WAPC 2019. The long-term pathways are based on trigger points that would signal a change in management response. Trigger points and their monitoring are detailed in the Implementation Plan (Section 16).

Table 15.10: Risk management pathway, triggers, decision-making and measures for SMU5

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways, Drainage Features			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Boat Ramps, Jetties, Carparks, Toilets			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Berm along the western shoreline of the Murray Delta Islands in Peel Inlet			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore (T9)			
Assets	Existing Residential Properties and Undeveloped Land – North Yunderup Culeenup Rd			
Pathway	Avoid Development in Erosion Hazard (Av.1) Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of future planning period erosion and/or inundation extent (T4, T10)			
Assets	River Shoreline section of Culeenup Road Properties with River Frontage			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based	Engineering edge treatments to protect against erosion and inundation (PR.4)		

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
	monitoring following storm erosion events.			
Trigger	Residential or commercial property lies seaward of the most up to date 100-year coastal erosion hazard line or coastal inundation hazard extent (T4)	Assets predicted to become highly or very highly vulnerable within next planning timeframe or within 10-years (T6)		
Assets	River Shorelines, Peel Inlet Shorelines and Foreshore Reserve			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			
Assets	Murray Delta Islands – Residential Properties			
Pathway	Avoid Development in Erosion Hazard (Av.1) - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			Removal or relocation of Asset (MR2)
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			HSD is within the S1 distance, asset becomes highly vulnerable or damaged due to erosion (T1, T5, T6).
Assets	Murray Delta Islands – Shorelines Balle Island, Yunderup Island, Culeenup Island Adjacent Residential Properties			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and river shorelines (T9)			

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
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Assets	Coopers Mill			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events and inundation events.			
Pathway	Berm management, planting and nature based 'soft protect' options to control erosion (PR1, PR2, PR3)			
Trigger	Impacts to beach and river shorelines (T9)			
Pathway	Do Nothing (DN1) – For inundation : Take no action and accept the risk			
Assets	General River Shorelines and Nature Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Do Nothing (DN1)			
Assets	Key Access Roads			
Pathway	Develop Emergency evacuation plan for key routes such as North Yunderup Road (NR.4)	Design Assets to withstand Coastal Hazard Impacts (AC2, AC3, AC4)		
		Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.		
Trigger	Assets predicted to become highly or very highly vulnerable within next 10 years (T6)	Asset is damaged or unsafe (T5)		

15.7 Risk Management Summary - Serpentine (SMU 6)

15.7.1 Risk Treatment by Asset – SMU6

The Serpentine SMU is fronted by the approximate 5km section of the Serpentine River from the river mouth entrance to Pinjarra Road and includes the suburb of Furnissdale, with a mix of residential and large rural blocks. The inland area in the region bounded by Tonkin Rd, Goodooga Rd and Furnissdale Rd is low-lying and largely undeveloped and is susceptible to flooding. The developed areas along the river at Riverside Drive are susceptible to inundation risk in future planning periods.

The key CHRMAP recommendations for the management of the SMU are summarised as follows:

- It is of key importance to work to maintain the river shorelines and build resilience against future erosion that would threaten the assets landward. There are a range of 'soft protection' approaches that could be used to build resilience of the Serpentine River shorelines through the SMU. The Shire are in

the process of developing a guideline for appropriate protection options that can be applied along the river shorelines that are in keeping with the natural shoreline areas (Pr.2) as well as a guide to planting species suited to the region (Pr.3).

- The general approach to manage erosion risk for the Shire's coastal infrastructure is Managed Retreat in foreshore areas. This includes the carparks, parks, jetty and boat ramps which would be maintained under defined triggers that allow the use of coastal assets to continue until the asset is no longer safe or structurally sound. Minor repair would be permitted consistent with asset lifecycle and expected planning timeframe and the assets relocated further landward in future planning periods as required consistent with design life upgrades. As part of the managed retreat process, the application of temporary protect options such as nature-based solutions to improve the resilience of the shorelines and increase the lifespan of assets at risk is encouraged.
- There are approximately 500 properties that are located within the coastal hazard extent for the 2120 planning period, with the vast majority being affected only by coastal inundation. It is recommended an SCA covering the region of the identified inundation and / or erosion hazard is established with a LPP that implements the planning-based controls within the SCA.
- Development controls for these areas is recommended in the LPP that would provide guidance for appropriate development controls within the SCA including:
 - Avoiding development (Av.1) seaward of the 2120 coastal erosion hazard line, plus an additional allowance for future foreshore reserve. For land areas where the hazard line is only present on a part of the lot, siting future development landward of the identified hazard area would be acceptable.
 - Accommodating the inundation risk consistent with planning timeframes to 2120 through design and planning measures which include appropriate Building Design (Ac.2), Appropriate Finished floor levels (Ac.3), Filling Land (Ac.4).
 - Placement of a Notification on title (Ac.1) to indicate to current and future landowners that the property is within a coastal hazard area and likely to be affected by coastal erosion and/or inundation over the planning timeframe
- The Shire should investigate reducing vessel speeds along sensitive waterways (NR.5) to reduce the erosion impacts from boat wakes on the river shorelines.
- It is noted there are a range of utilities infrastructure that are affected by coastal erosion risk through the SMU. Utilities infrastructure is privately owned, and it is the responsibility of the respective utility owners to determine future adaptation approaches to manage their erosion risk (WaterCorp etc).
- Emergency planning to determine key access routes and their accessibility in extreme events should be undertaken.

Adaptation approaches are summarised in Table 15.11.

Table 15.11: Risk Treatment – Serpentine (SMU6)

Asset / Location	Erosion	Inundation
Foreshore Reserve incl. Coastal Pathways	Leave unprotected as part of managed retreat strategy (MR1) Relocate the pathways further landward in future under a managed retreat approach (MR2).	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1). Relocate the pathways further landward in future under a managed retreat approach (MR2). Monitor for safety following impacts (NR1)
Shire Infrastructure (boat ramps, car parks, parks, jetties)	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Drainage Features	Leave unprotected as part of managed retreat strategy (MR1) . Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1)
Existing Residential Properties and New Development	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) LPP provides guidance for appropriate development for the properties within the SCA Site new structures on portion of the block landward of the coastal hazard area (Av.1).	Planning controls implanted through SCA and LPP with Notification on title (Ac.1) Accommodate inundation consistent with planning timeframes to 2120 through design and planning measures specified in LPP which outlines requirements for: • Building Design (Ac.2) • Appropriate Finished floor levels (Ac.3) • Filling Land (Ac.4)
Roads	Leave unprotected as part of managed retreat strategy (MR1) Relocate further landward in future under a managed retreat approach (MR2) as part of asset replacement.	Short term inundation in large events is acceptable (MR.1). Monitor for safety following impacts (NR1) Emergency planning (Nr.4) for key routes (Riverside Drive, Furnissdale Road)

15.7.2 Risk Management Pathways – SMU6

Long term adaptation pathways for the key at risk assets identified in SMU6 are summarised in Table 15.12 based on the format recommended in WAPC 2019. The long-term pathways are based on trigger points that would signal a change in management response. Trigger points and their monitoring are detailed in the Implementation Plan (Section 16).

Table 15.12: Risk management pathway, triggers, decision-making and measures for SMU6

Planning Timeframe	2020 – 2030	2030 - 2050	2050 - 2070	2070 - 2120
Assets	Shire Minor Infrastructure (eg Signage). Coastal Pathways, Drainage Features			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Shire Major Infrastructure. Boat Ramps, Jetties, Carparks, Toilets			
Pathway	Leave assets unprotected and review the use of assets / sites under a managed retreat approach (MR1). Remove and relocate the assets (MR2) at a distance appropriate for the asset design life / lifecycle.			
Trigger	Asset Damaged (T5) or likely to be highly vulnerable (T6)			
Assets	Existing Residential Properties and Undeveloped Land			
Pathway	Avoid Development in Erosion Hazard (Av.1) - Amend local planning scheme to include Special Control Area which encompasses all areas affected by either erosion or inundation hazard over the 100-year planning period. - Establish planning-based controls that only allow development in the SCA that can address coastal hazard.			
Pathway	Accommodate Inundation (Ac.1, Ac.2, Ac.3, Ac.4)			
Trigger	Property lies seaward of 100-year planning period erosion and/or inundation extent (T4, T10)			
Assets	River Shorelines and Foreshore Reserve			
Pathway	Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events.			
Pathway	Investigate reduction in boat vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)			
Pathway	Beach management and nature based 'soft protect' options to control erosion (PR2, PR3)			
Trigger	Impacts to beach and foreshore reserve (T9)			

16. Short Term Implementation Plan

16.1 Implementation Actions

The short-term implementation actions over the period 2022 to 2040 are summarised in this section. They include recommendations for:

- a) Planning Actions;
- b) Annual Monitoring Program;
- c) Additional Technical Studies;
- d) Additional Planning Based Studies and Adaptation Studies; and
- e) Adaptation Actions in Shoreline Areas.

An overview of the actions is presented, with a summary of the projected timing and estimated cost.

16.2 Planning Implementation – Short Term

There are a number of planning recommendations in the short-term which involve updates to existing planning instruments and development of new policies. The recommendations are outlined in detail in Section 18.

The key items for the short-term timeframe implementation program and indicative timeframe are as follows:

- Initiate amendment to LPS4 to introduce a Special Control Area (immediately).
- Prepare a LPP (immediately).
- Prepare an Emergency Evacuation Plan (next 5-years).
- Prepare a Foreshore Management Plan (next 5-years)
- Prepare a Managed Retreat Policy (6 – 10 years)

16.3 Annual Monitoring

An annual monitoring program to develop the understanding of the coastal processes in the Shire at key locations for erosion and inundation risk is recommended. The monitoring outcomes will be used to assess trigger points and to inform future revisions of the CHRMAP.

Key locations for focus in the program are:

- a) Foreshore berm on the Peel shorelines along the western facing beaches of the Murray Delta Islands. The monitoring of the berm height along the shoreline is recommended every 2-years, through spatial survey data capture (via UAV or LiDAR). Following significant events where erosion may occur on the shorelines survey should also be captured.
- b) Murray Delta Island shorelines on Ballee Island, Culeenup Island and Yunderup Island should be monitored through spatial survey data capture (via UAV or LiDAR) approximately every 5 years.
- c) Photo Monitoring of shoreline areas for erosion at Herron Point, North and South Yunderup and the Murray Delta Islands (photo capture 2x annually and following significant storm events)
- d) Opportunities to involve the Bindjareb Nyungar traditional owners in shoreline monitoring activities should be sought.

As part of the scheduled annual monitoring program, the capture of survey in the shoreline areas is recommended using UAV which is expected to offer an efficient and cost-effective means of capturing this data.

The monitoring activities and projected costing is summarised in Table 16.1. It is estimated the annual monitoring activities would cost \$16,000 to \$18,000 (ex GST). Co-funding of up to 50% of the cost of the program is available through the DoT CAP grants (discussed further in Section 4).

Table 16.1: Indicative program for Annual Monitoring activities

Task	Description	Budget
Year 1	2023 Activities	\$ 18k
Annual Monitoring	Shoreline survey UAV. Berm on Peel Shore	\$ 4,500
	Desktop Analysis, Annual Monitoring Report	\$ 8,000
	Transect Surveys (UAV Accuracy Verification)	\$ 2,000
	Photo Monitoring	\$ 3,500
	Structure Inspections	Shire Internal
Year 2	2024 Activities	\$ 16k
2.1	Survey Shorelines UAV-Ballee Island	\$ 4,500
2.2	Desktop Analysis, Annual Monitoring Report	\$ 8,000
2.3	Photo Monitoring (5 Sites)	\$ 3,500
2.4	Structure Inspections	Shire
Year 3	2025 Activities	\$ 16k
3.1	Survey Shorelines UAV- Yunderup Island	\$ 4,500
3.2	Desktop Analysis, Annual Monitoring Report	\$ 8,000
3.3	Photo Monitoring (5 Sites)	\$ 3,500
3.4	Structure Inspections	Shire
Year 4	2026 Activities	\$ 16k
4.1	Shoreline survey UAV. Berm on Peel Shore	\$ 4,500
4.2	Desktop Analysis, Annual Monitoring Report	\$ 8,000
4.3	Photo Monitoring (5 Sites)	\$ 3,500
4.4	Structure Inspections	Shire
Year 5	2027 Activities	\$ 16k
5.1	Survey Shorelines UAV-Culleneup Island	\$4,500
5.2	Desktop Analysis, Annual Monitoring Report	\$ 8,000
5.3	Photo Monitoring (5 Sites)	\$ 3,500
5.4	Structure Inspections	Shire

16.3.1 Structural Inspections

As part of the monitoring program, condition reports for structures maintained by the SoM through the shorelines of the study area should be included. It is understood the Shire currently has an inspection protocol established and this will not incur additional cost or effort to obtain this information. The structures of interest include the following:

- Herron Point Boat Ramp
- Herron Point Car Park
- Birchmont Boat Ramp
- Boat Ramp at Young St
- Boat Ramp at North Yunderup
- South Yunderup Canal Walls
- Bund in front of the South Yunderup Canals
- Small Revetment structures in North and South Yunderup river shorelines
- Batavia Quays Revetment
- Riverside Drive Boat Ramp

16.3.2 Trigger Point Summary

Trigger points in each of the CMU will be monitored through the annual monitoring program, asset management and inspection process or as part of the review of the CHRMAP (approximately every 5 years).

A summary of the key assets, triggers and the mechanism by which they will be assessed is provided in Table 16.2 for the 6 SMU's.

Table 16.2: Summary of Trigger Points by SMU, Monitoring and Management Action

SMU	Asset and Management Strategy	Monitoring Approach, Trigger and Action
SMU1 - South End of Harvey Estuary	Kooljerrunup Nature Reserve Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 10-years as part of the CHRMAP review (NR1). Determine HSD from examination of vegetation lines in latest available aerial image (use as proxy). Trigger: When the shoreline position has advanced 50m landward from the 2020 position (nominally 2050) Action: Determine managed retreat option in more detail eg cost to acquire farm land and funding.
	Coastal Pathways and Bridle Paths Herron Point Campground and Minor Infrastructure (signage, fences etc) Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 10-years as part of the CHRMAP review (NR1). Determine shoreline position from examination of vegetation lines in latest available aerial image. Trigger: The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent (T1) Action: Relocate assets further landward consistent with coastal hazard (MR2).
	Herron Point Boat Ramp, Herron Point Car Park Strategy: Managed Retreat (MR1)	Method: Monitor the condition of the structures through the Shires asset management program. Trigger: When assessment of structure indicates assets are damaged (T5) or predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years (T6) Action: Undertake detailed studies (MCA, CBA) of the options to determine whether to remove and rebuild the structures further landward (MR2) and above the inundation hazard (AC2).
	Foreshore Reserve and shoreline areas Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine HSD from examination of vegetation lines in latest available aerial image (use as proxy). Trigger: The beach and coastal foreshore reserve is significantly diminished with respect to its original state and function (T9) Action: Examine use of nature-based protection methods (PR1, PR2, PR3) to provide resilience.

SMU	Asset and Management Strategy	Monitoring Approach, Trigger and Action
SMU2 – Birchmont	Coastal Pathways and Bridle Paths Minor Infrastructure (signs etc) Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 10-years as part of the CHRMAP review (NR1). Determine shoreline position from examination of vegetation lines in latest available aerial image. Trigger: The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent (T1) Action: Relocate assets further landward consistent with coastal hazard (MR2).
	Birchmont Boat Ramp, Car Park adjacent Boat Ramp Strategy: Managed Retreat (MR1)	Method: Monitor the condition of the structures through the Shires asset management program. Trigger: When assessment of structure indicates assets are damaged (T5) or predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years (T6) Action: Undertake detailed studies (MCA, CBA) of the options to determine whether to remove and rebuild the structures further landward (MR2) and above the inundation hazard (AC2).
	Foreshore Reserve and shoreline areas Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine HSD from examination of vegetation lines in latest available aerial image (use as proxy). Trigger: The beach and coastal foreshore reserve is significantly diminished with respect to its original state and function (T9) Action: Examine use of nature-based protection methods (PR1, PR2, PR3) to provide resilience.
SMU3 – Point Grey to Austin Bay	Coastal Pathways, Minor Infrastructure (signs etc) Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 10-years as part of the CHRMAP review (NR1). Determine shoreline position from examination of vegetation lines in latest available aerial image. Trigger: The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent (T1). When assessment indicates assets are damaged (T5) Action: Relocate assets further landward consistent with coastal hazard (MR2).
	Carabunga Road. Drainage Strategy: Managed Retreat (MR1)	Method: Monitor the condition of the structures through the Shires asset management program. Trigger: When assessment of structure indicates assets are damaged (T5) or predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years (T6) Action: Undertake detailed studies (MCA, CBA) of the options to determine whether to remove and rebuild the structures further landward (MR2) and above the inundation hazard (AC2).

SMU	Asset and Management Strategy	Monitoring Approach, Trigger and Action
SMU4 – South Yunderup	Foreshore pathways, Minor Infrastructure (signs, chairs etc) Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine shoreline position from examination of vegetation lines in latest available aerial image. Trigger: The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent (T1). When assessment indicates assets are damaged (T5) Action: Relocate assets further landward consistent with coastal hazard (MR2).
	Foreshore Reserve and shoreline areas Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine HSD from examination of vegetation lines in latest available aerial image (use as proxy). Trigger: The beach and coastal foreshore reserve is significantly diminished with respect to original state / function (T9) Action: Examine use of nature-based protection methods (PR1, PR2, PR3) to provide resilience.
	Foreshore Reserve and shoreline areas from Young Street Carpark to Pelicans Reserve (assessed in CBA) Strategy: Build resilience and provide protection through nature-based methods (PR1, PR2, PR3)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine HSD from examination of vegetation lines in latest available aerial image (use as proxy) or local observations through eg Photo Monitoring. Trigger: The beach and coastal foreshore reserve is significantly diminished with respect to its original state and function (T9) Action: Consider use of more robust nature-based protection methods (PR2) to provide resilience.
	Young Street Boat Ramp, Car Parks, Roads, Drainage Features Strategy: Managed Retreat (MR1)	Method: Monitor the condition of the structures through the Shires asset management program. Trigger: When assessment of structure indicates assets are damaged (T5) or predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years (T6) Action: Undertake detailed studies (MCA, CBA) of the options to determine whether to remove and rebuild the structures further landward (MR2) and above the inundation hazard (AC2).
	Batavia Quays revetment, Canal walling, Bund in front of South Yunderup Canals Strategy: Protect (PR4.)	Method: Monitor the condition of the structures through the Shires asset management program (NR2). Trigger: When assessment of structure indicates assets are damaged (T5) or predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years (T6) Action: Maintain / Rebuild structures (PR4.)

SMU	Asset and Management Strategy	Monitoring Approach, Trigger and Action
SMU5 – North Yunderup and Murray Delta Islands	Foreshore pathways, Minor Infrastructure (signs, chairs etc) Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine from f spatial data collected as planned UAV capture. Trigger: The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent (T1). When assessment indicates assets are damaged (T5) Action: Relocate assets further landward consistent with coastal hazard (MR2).
	Foreshore Reserve and shoreline areas including Coopers Mill Site Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine HSD from examination of vegetation lines in latest available aerial image (use as proxy) or UAV where surveyed. Trigger: The beach and coastal foreshore reserve is significantly diminished with respect to original state / function (T9) Action: Examine use of nature-based protection methods (PR1, PR2, PR3) to provide resilience.
	Shoreline areas – Section of river front properties along Culeenup Rd Strategy: Protect (PR4)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine HSD from spatial data collected as planned UAV capture. Trigger: When distance from habitable structure to HSD is approaching S1 (T1) Action: Move to Protect Option. Examine use of hard-engineered seawall (PR4). Feasibility study to be completed with involvement of residents group (next 5-yrs) to investigate options, assess preliminary design for built structure, investigate / secure funding arrangements.
	Shoreline areas – Ballee, Coolenup, Yunderup Islands. Strategy: Build resilience and provide protection through nature-based methods (PR1, PR2, PR3)	Method: Monitor the movement of the HSD line as part of the annual monitoring and CHRMAP review (NR1). Determine HSD from UAV data capture. If not available conduct examination of vegetation lines in aerial imagery (use as proxy for HSD). Also consider local observations through eg Photo Monitoring. Trigger: The beach and coastal foreshore reserve is significantly diminished with respect to its original state and function (T9) Action: Consider use of more robust nature-based protection methods (PR2) to provide resilience.
	Boat Ramp, Car Parks, Roads, Drainage Features Strategy: Managed Retreat (MR1)	Method: Monitor the condition of the structures through the Shires asset management program. Trigger: When assessment of structure indicates assets are damaged (T5) or predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years (T6)

SMU	Asset and Management Strategy	Monitoring Approach, Trigger and Action
SMU6 – Serpentine		Action: Undertake detailed studies (MCA, CBA) of the options to determine whether to remove and rebuild the structures further landward (MR2) and above the inundation hazard (AC2).
	Properties on Murray delta Islands Strategy: Managed Retreat (MR1.)	Method: Monitor the distance from the most seaward edge of habitable structures to the HSD as part of annual monitoring program. Trigger: When distance from habitable structure to HSD is within S1 (T1) and/ or assets are damaged (T5) Action: Adopt further Managed Retreat option (MR2. MR3. MR4) and / or redevelop and meet development conditions in the Local planning policy (LPP). Redevelopment would need to meet LPP requirements to accommodate hazard on the site (Ac1, Ac2, Ac3, Ac4) on a case-by-case basis.
	Foreshore Reserve and shoreline areas Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine HSD from examination of vegetation lines in latest available aerial image (use as proxy). Trigger: The beach and coastal foreshore reserve is significantly diminished with respect to original state / function (T9) Action: Examine use of nature-based protection methods (PR1, PR2, PR3) to provide resilience.
	Foreshore pathways, Minor Infrastructure (signs, chairs, shelters etc) Strategy: Managed Retreat (MR1)	Method: Monitor the movement of the HSD line every 5-years as part of the CHRMAP review (NR1). Determine shoreline position from examination of vegetation lines in latest available aerial image. Trigger: The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent (T1). When assessment indicates assets are damaged (T5) Action: Relocate assets further landward consistent with coastal hazard (MR2).
	Riverside Drive Boat Ramp, Car Parks, Roads, Drainage Features Strategy: Managed Retreat (MR1)	Method: Monitor the condition of the structures through the Shires asset management program. Trigger: When assessment of structure indicates assets are damaged (T5) or predicted to become highly or very highly vulnerable within the next planning timeframe or within 10 years (T6) Action: Undertake detailed studies (MCA, CBA) of the options to determine whether to remove and rebuild the structures further landward (MR2) and above the inundation hazard (AC2).

16.4 Additional Technical Studies

The following technical studies are recommended over the next 5-years:

- a) **Erosion impacts from boat wakes on the river shorelines.** This would be used to understand ways in which reducing vessel speeds along sensitive waterways through the Murray Delta Islands (NR.5) can reduce erosion. The assessment should include analysis of current and projected vessel type and boat usage.

An estimate of the cost of the study is less than \$25,000 (ex GST).

- b) **Murray Delta Islands building register.** The register would be used to provide baseline information of properties to better understand the risk of inundation and erosion in future planning periods. The register should include the following information:
- Record of the finished floor level of each property determined through a surveyor using eg Digital Ground Positioning System (DGPS).
 - Establish the level of the septic system of each property, determined through a surveyor using eg Digital Ground Positioning System (DGPS);
 - Notes on the type of building design (materials). Information on sub-floor (eg stumps) to determine whether it is practical to raise the house in the future above projected flooding hazard in future years;
 - Measurement of the distance from the closest point of the habitable structure on each property to the river shoreline (HSD)

An estimate of the cost of the study is less than \$10,000 (ex GST).

- a) **Assessment, planning and costing for a centralised ATU system** that can manage each of the Island's requirements, to replace the septic systems (short to medium term time frame).

An estimate of the cost of the study is less than \$10,000 (ex GST).

16.5 Additional Planning Based Studies and Adaptation Studies

In addition, the following planning-based studies are recommended in the next 5 years (by 2028):

- Prepare a Foreshore Management Plan. Estimated cost less than \$25,000 (ex GST).
- Prepare an Emergency Evacuation Plan. Estimated cost less than \$10,000 (ex GST).
- Feasibility study for protection option along North Yunderup shoreline. Estimated cost less than \$25,000 (ex GST).
- CHRMAP Review approximately every 5-years. Estimated cost less than \$25,000 (ex GST)

16.6 Adaptation Actions - Shoreline Areas

The key shoreline areas where adaptation approaches are recommended along with the approximate cost and timing are summarised in Table 16.3.

Table 16.3: Adaptation Actions in the Short term (next 15-years)

CMU	Type Adaptation / Location	Approximate Cost 1, 2	Indicative Timing
5	Ballee Island - Where: Shoreline adjacent developed properties - What: Application of nature-based revegetation and foreshore stabilisation techniques	\$50k – \$130k	2023 to 2027
4	South Yunderup - Where: Shoreline Young Street Carpark to Banksia Terrace - What: Application of nature-based revegetation and foreshore stabilisation techniques	\$320k – \$870k	2023 to 2027
5	Coolenup Island - Where: Shoreline adjacent developed properties - What: Application of nature-based revegetation and foreshore stabilisation techniques	\$340k – \$930k	2023 to 2027
5	Yunderup Island - Where: Shoreline adjacent developed properties - What: Application of nature-based revegetation and foreshore stabilisation techniques	\$240k – \$670k	2023 to 2027
5	Coopers Mill Shoreline (Coolenup Island) - Where: Shoreline adjacent developed properties - What: Application of nature-based revegetation and foreshore stabilisation techniques	\$140k – \$400k	2028 to 2032

Notes:

¹ Nature based solutions for revegetation and foreshore stabilisation estimated cost between \$180/m and \$500/m.

². Costs are rounded to nearest \$10,000. Refer cost basis in Table 1.5

16.7 Short Term Implementation Plan

A proposed short-term implementation plan with indicative costs for the period over the first 5-years 2023 to 2027 inclusive is presented in Table 1.4.

The budget is estimated at \$207,000 for studies and monitoring (\$82,000 annual monitoring, \$ 125,000 for technical studies and planning studies). Additionally, a budget estimate of between \$460,000 to \$1.34 million is forecast to fund adaptation approaches.

Table 16.4: Short-term implementation plan and estimated budget. First five years 2023 – 2027.

Task	Description	Budget
Year 1	2023 Activities	
Annual Monitoring	Year 1 Monitoring Activities	\$ 18,000
Technical Studies	Building Register of Island Properties	\$ 10,000
	Riverbank Erosion - Vessel Wake Study	\$ 25,000
Planning	Initiate amendment to LPS4 to introduce a Special Control Area.	Shire Internal
	Prepare LPP (modify existing local planning policies)	Shire Internal
Adaptation	Ballee Island – Nature Based Solutions in Shorelines	\$50k – \$130k
Year 2	2024 Activities	
Annual Monitoring	Year 2 Monitoring Activities	\$ 16,000
Technical Studies	Study on ATU options for Islands	\$ 10,000
Adaptation	South Yunderup – NBS along shorelines Yr1 of 3	\$100k - \$300k
Year 3	2025 Activities	
Annual Monitoring	Year 3 Monitoring Activities	\$ 16,000
Planning	Foreshore Management Plan	\$ 20,000
Planning	Update Emergency Evacuation Plan	\$ 15,000
Adaptation	South Yunderup – NBS along shorelines Yr2 of 3	\$100k - \$300k
Year 4		
Annual Monitoring	Year 4 Monitoring Activities	\$ 16,000
Planning	Feasibility Study for North Yunderup erosion protection option	\$ 25,000
Adaptation	South Yunderup – NBS along shorelines Yr3 of 3	\$100k - \$300k
Year 5	2027 Activities	
Annual Monitoring	Year 5 Monitoring Activities	\$ 16,000
Adaptation	Coolenup Island – NBS along shorelines Yr1 of 3	\$110k - \$310k
Planning	CHRMAP Review	\$ 25,000

It is noted that the Shire would be eligible for up to 50% of the cost of the studies presented in Table 16.4. Additionally for the adaptation approaches (nature-based solutions), there are opportunities to also co-fund these activities through grant schemes outlined in more detail in Section 19.

The implementation budget over the full 17-year duration of the short-term period from 2023 to 2040 is estimated at approximately \$400,000. This will address the cost of annual monitoring, complete the recommended additional technical and planning studies and review of the CHRMAP three times in the period. As previously noted, there are grant schemes that would allow the Shire to co-fund this commitment by up to 50% over the period (covered in more detail in Section 19).

It is noted that the beneficiaries of the NBS adaptation actions in the shorelines are predominantly private landowners (Table 16.3). Funding for these options would be sought from the private landowners that will directly benefit as outlined in the next section of Benefit Distribution Analysis.

16.8 Benefit Distribution Analysis

A distributional analysis was completed as part of the economic reporting (Rhelm 2022) to understand the key beneficiaries for the proposed mitigation options. This found the key beneficiaries are predominantly private landowners, and to a lesser degree the Shire of Murray (though the public assets such as reserves).

The benefit distribution analyses has been expanded subsequently to investigate in more detail the beneficiaries for locations where mitigation is recommended. An estimate of the benefit distribution for mitigation options between the private (landholders, property owners) and the public (Shire and general community) has been undertaken.

16.8.1 Murray Delta Islands - Nature Based Mitigation Options

For the Murray Delta Islands the proposed mitigation options are summarised in Table 16.5 for the application of suitable river edge treatments around the islands. The low-cost to high-cost range is based on the type of edge treatment from simple revegetation through to more detailed approaches including rock spalling in the foreshore. The length of proposed sections of river are shown in Table 16.5 as well as the number of properties which are directly landward that the works would be providing benefit (ie protection from erosion). For the residential sections on the three islands there are between 6 and 59 private properties. For the Coopers Mill area there are no private properties.

Table 16.5: Murray Delta Islands – Cost Estimates for Sections of Shoreline Mitigation using Nature Based Solutions

Murray Delta Islands	Length (m)	Nature Based Option		Properties	Low Cost Total (\$)	High Cost Total (\$)
		Low Cost per m (\$)	High Cost per m (\$)			
Ballee Island Residential	250	\$ 180	\$ 500	6	45,000	125,000
Yunderup Island Residential	1330			24	239,400	665,000
Coolenup Island Residential	1860			59	334,800	930,000
Coopers Mill Site - Mill Caretakers Cottage and Access Channel	800			0	144,000	400,000

The beneficiary distribution is summarised in Table 16.6 based on the cost estimates in Table 16.5. For the sections of river which protect private property it has been assumed an 80% private and 20% public distribution. For the Section of shoreline adjacent the Coopers Mill the distribution is 100% public (ie cost to be met by the Shire in full).

For each of the Murray Delta Islands the range of costs per property is calculated in Table 16.6. The cost range between the low-cost to high-cost options is between \$4,500 to \$8,000 and \$12,600 to \$22,200 for each respective property. The costs allocated to public funding for the three islands (20%) and the Coopers Mill section (100%) is between \$268,000 to \$744,000 for the low-cost to high-cost options. This cost is proposed to be met by the Shire, with funding options discussed further in Section 19.

Table 16.6: Murray Delta Islands – Benefit Distribution analysis for Nature Based Solutions. Public cost and cost for private property

	Benefit Distribution (%)		Treatment Cost for Low-Cost Option (\$180/m)			Treatment Cost for High-Cost Option (\$500/m)		
	Public	Private	Public Total (\$)	Private Total (\$)	Cost Per Property (\$)	Public (\$)	Private (\$)	Cost Per Property (\$)
Murray Delta Islands								
Ballee Island Residential	20%	80%	9,000	36,000	6,000	25,000	100,000	16,700
Yunderup Island Residential	20%	80%	47,900	191,500	8,000	133,000	532,000	22,200
Coolenup Island Residential	20%	80%	67,000	267,800	4,500	186,000	744,000	12,600
Coopers Mill - Access Channel	100%		144,000	-	-	400,000	-	-

16.8.2 South Yunderup Shoreline - Nature Based Mitigation Options

For the South Yunderup Shoreline where nature-based solutions are recommended, the benefit distribution analysis is summarised in Table 16.7. The public / private benefit distribution has been assessed as 50% / 50%. The foreshore reserve along the South Yunderup shoreline is an area in which many coastal assets managed by the Shire are located including high value assets (boat ramps, jetties, carparks, road, pathways, park play equipment) and lower cost assets (benches, shelters and bbq's). Landward of the foreshore reserve area there are private properties (61) that would directly benefit from the protection of the river shoreline. Protection of the shoreline in this area provides benefit to both the public and the private landholders, which is the basis for the 50/50 benefit distribution estimate.

Table 16.7: South Yunderup Shoreline – Cost Estimates for Sections of Shoreline Mitigation using Nature Based Solutions

	Length (m)	Nature Based Option		Properties	Low Cost Total (\$)	High Cost Total (\$)
		Low Cost per m (\$)	High Cost per m (\$)			
South Yunderup Shoreline	1750	\$ 180	\$ 500	61	315,000	875,000

For each of the residents the range of costs per property is calculated in Table 16.8. The cost range between the low-cost to high-cost options is \$2,600 to \$7,200 for each respective property. The costs

allocated to public funding is between \$157,500 to \$437,500 for the low-cost to high-cost options. This public cost is proposed to be met by the Shire, whilst the private cost would be sought from the property owners, with funding options discussed further in Section 19.

Table 16.8: South Yunderup shoreline – Benefit Distribution analysis for Nature Based Solutions. Public cost and cost for private property

	Benefit Distribution (%)		Treatment Cost for Low-Cost Option (\$180/m)			Treatment Cost for High-Cost Option (\$500/m)		
	Public	Private	Public Total (\$)	Private Total (\$)	Cost Per Property (\$)	Public (\$)	Private (\$)	Cost Per Property (\$)
South Yunderup Shoreline	50%	50%	157,500	157,500	2,600	437,500	437,500	7,200

17. Medium and Long-Term Implementation Plan

The medium-term implementation actions cover the 30-year period of 2040 to 2070. The long-term plan covers the period 2070 to 2120. Summary advice to SoM for its management strategy and adaptation response is given here.

17.1 Medium Term Implementation

A summary of the Medium-Term actions is presented in Table 17.1.

Table 17.1: Medium Term Implementation Plan

Item	Description	Trigger	Projected Timing
Planning for Managed Retreat	Amendment to the Peel Region Scheme to rezone land to 'Parks and Recreation' for land acquired through a managed retreat process.	Once land is acquired through managed retreat plan.	2040
Planning for Managed Retreat	Managed retreat – planning for areas that may become impacted by Coastal Hazard in the 2040 – 2070 timeframe.	Review of coastal hazard impacts projected over the 2040 – 2070 timeframe as part of the CHRMAP review process (approximately every 5-years).	2040 – 2070
Kooljerrenup Nature Reserve	Decision on whether to examine purchase of farmland landward of the nature reserve area to replace area lost to erosion	Analysis of the rate of sea level rise and the observed erosion along the shoreline. To be determined as part of the annual monitoring and CHRMAP review process (approximately every 5-years).	2040 – 2050
Shire Structures – replacement of existing structures in the foreshore	Replacement of Shire assets in the foreshore as part of asset lifecycle. Replacement to consider the projected planning timeframes and associated coastal hazard from erosion and inundation.	Annual monitoring and CHRMAP review process to be used as basis for confirming future allowances for erosion and inundation in development requirements.	2040 – 2070
Bund in front of South Yunderup Canals	Raise height of the bund and maintain structural integrity of the bund to meet the storm level of the river under projected sea level rise.	Sea level rise above rate of +0.4m from 2020 baseline.	2060 – 2070
Maintain foreshore Berm along	To maintain the integrity of the island shorelines from erosion and inundation pressures,	Regular survey of the berm height as part of annual monitoring (including post	2040 – 2070

Item	Description	Trigger	Projected Timing
western edge of Islands facing Peel inlet	maintain the height of the berm on the shoreline	large storm events) to determine where berm height is lost.	

17.2 Long Term Implementation

A summary of the Long-Term actions is presented in Table 17.2.

Table 17.2: Long Term Implementation Plan

Item	Description	Trigger	Projected Timing
Planning for Managed Retreat	Amendment to the Peel Region Scheme to rezone land to 'Parks and Recreation' for land acquired through a managed retreat process.	Once land is acquired through managed retreat plan.	2070
Planning for Managed Retreat	Managed retreat – planning for areas that may become impacted by Coastal Hazard in the 2070 – 2120 timeframe.	Review of coastal hazard impacts projected over the 2070 – 2120 timeframe as part of the CHRMAP review process (approximately every 5-years).	2070 - 2120
Kooljerrenup Nature Reserve	Decision on whether to examine purchase of farmland landward of the nature reserve area to replace area lost to erosion	Analysis of the rate of sea level rise and the observed erosion along the shoreline. To be determined as part of the annual monitoring and CHRMAP review process (approximately every 5-years).	2070
Shire Structures – replacement of existing structures in the foreshore	Replacement of Shire assets in the foreshore as part of asset lifecycle. Replacement to consider the projected planning timeframes and associated coastal hazard from erosion and inundation.	Annual monitoring and CHRMAP review process to be used as basis for confirming future allowances for erosion and inundation in development requirements.	2070 - 2120
Bund in front of South Yunderup Canals	Raise height of the bund and maintain structural integrity of the bund to meet the storm level of the river under projected sea level rise.	Sea level rise above rate of +0.4m from 2020 baseline.	2070 onwards

Item	Description	Trigger	Projected Timing
Maintain foreshore Berm along western edge of Islands facing Peel inlet	To maintain the integrity of the island shorelines from erosion and inundation pressures, maintain the height of the berm on the shoreline	Regular survey of the berm height as part of annual monitoring (including post large storm events) to determine where berm height is lost.	2070 onwards

18. Land use planning instruments

18.1 Planning Mechanisms - Implementation

The Risk Treatment Stage (Section 12.5) provides a summary of recommendations for the Shire of Murray, to update its current planning instruments to manage coastal hazard risks identified for erosion and inundation in the CHRMAP.

The key planning controls that are recommended as part of implementation are:

- a) Introduce a Special Control Area which triggers the requirement for normally exempt development to require planning approval. This should commence immediately.
- b) Prepare a coastal local planning policy (LPP) or modify existing local planning policies to establish development standards to ensure new development can withstand inundation events. This should commence immediately.
- c) Prepare an emergency response and evacuation plan to employ measures to manage the safety of the community during extreme events. The Shire's Local Emergency Management Committee (LEMC) has prepared a Local Emergency Management Arrangement (LEMA) and Local Recovery Plan (LRP) which includes useful information in relation to emergency preparation and response, including flooding. The LEMA and LRP should be reviewed in the next 5-years in conjunction with this CHRMAP to ensure areas identified as being at risk have arrangements in place to assist with emergency response and recovery.
- d) Foreshore Management Plans. The Shire should prepare a foreshore management plan for each SMU 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.

18.1.1 Special Control Area (SCA)

The introduction of a Special Control Area (SCA) for all zoned land affected by erosion or inundation over the 100-year planning period will provide the most effective response to coastal and riverine hazards. The SCA will stipulate provisions to respond to the risks identified in this CHRMAP, including the trigger for normally exempt development to require development approval.

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

18.1.2 Planned or Managed Retreat Policy

There is no immediate need for the Shire to prepare a Planned or Managed Retreat Policy given the erosion hazard lines are not expected to impact habitable buildings until at least 2040. The Shire should however commence planning for the managed retreat of at-risk properties once habitable buildings are mapped as being impacted within the 10-year planning timeframe. Based on the current modelling, the Shire should aim to prepare and adopt a Managed Retreat Policy by 2030.

In view of this timeframe, a recommendation for a Managed Retreat Policy has been included in this CHRMAP for development in the 2028 to 2030 period. Whilst the policy approach would need to consider local circumstances, WAPC (2019) includes guidance on the Planned and Managed Retreat approach for properties that are subject to erosion and inundation, and this would provide a basis for the policy development.

The CHRMAP Guidelines provide a framework for triggering the voluntary or compulsory acquisition of private land affected by erosion where the public foreshore can no longer provide a natural barrier to coastal and riverine processes. This will however require careful consideration and close engagement with the community to ensure an approach that meets community aspirations, provides a strategic and proactive response to the coastal risks, and is financially viable to implement.

19. Funding

19.1 Funding - Murray Delta Islands and South Yunderup Shoreline Areas

The benefit to the residents on the three islands is estimated at 80% for the application of nature-based solutions (see Table 16.6). For the South Yunderup shoreline area the private benefit is estimated at 50%. For the Shire, the recommended mechanism to recover cost from private beneficiaries for these activities is through either special area rates (see Section 19.2) or upfront contributions.

Funding for the public benefit portion of the works would be the responsibility of the Shire. There are a number of State and National grant funding sources that could be accessed to co-fund the work that provides public benefit, with a summary of these presented in Section 19.3.

19.2 Special Area Rates

General advice received from the Western Australian Local Government Association (WALGA) regarding special area rates (WALGA 2022) is noted as follows:

- Under Section 6.37 of the Local Government Act 1995 it is possible to impose a specified area rate for the purpose of contributing to the funding of specific coastal protection works. Section 6.37 further outlines the points below:
- The specified area rate can only be applied to the rateable land that will benefit from the coastal protection works (s6.37 (1)).
- The money raised must be used for the purpose specified, within the financial year or placed in a reserve account for that purpose (s6.37 (2)).
- If money has been placed in a reserve account you cannot change the purpose of the reserve account or use the money in the reserve account for a purpose other than the service for which the specified area rate was imposed (s6.37 (3)).
- A Local Government may only use the money raised to meet the cost of the work or to repay money borrowed to meet the cost of the works and interest on that money (s6.37 (4)).
- If more money is raised than is needed to fund the works then a refund or credit should be made to the owner (s6.37 (5)).
- The Local Government Act does not provide a maximum or minimum value that can be raised through a Specified Area Rate.
- If the Shire was to borrow the money to fund the cost of the coastal protection works a specified area rate implemented annually could be used to repay the loan over time. This would reduce the need for ratepayers to contribute a large amount upfront.
- The payment of a Special Area Rate can be enforced through the Local Government Act.
- The Local Government Act does not require the agreement of affected property owners in order to impose the Specified Area Rate nor are they required to provide a public notice of the Special Area Rate. Extract from the Department of Local Government, Sport and Cultural Industries Rating Policy Guideline states:
 - 3. Every differential general rate and/or minimum payment that is intended to be imposed must be stated in the public notice. (s.6.36(3)(b)(ii)). Local public notice is not required for specified area rates.
- However, a Local Government may choose to provide notification/undertake consultation when implementing Special Area Rates even though it is not a statutory requirement.
- The Local Government cannot impose a service charge to fund coastal protection works, as it is not a prescribed service for which a service charge may be made (Local Government Act 1995 s6.16, Local Government (Financial Management) Regulations 1996, reg 54).

- The Shire may also want to consider if there are any Native Title implications or heritage considerations.

19.3 Grant Funding

The grant funding options that the Shire can apply for to support the funding of coastal management activities is summarised in Table 19.1. These funding mechanisms generally require a co-funded approach whereby the Shire contributes 50% of the funding which is matched. The grant programs are designed to support outcomes that support public rather than private beneficiaries. A brief overview of the grants and how these can be implemented is presented in Table 19.1.

Table 19.1: Summary of Funding Mechanisms

State Government	Brief Description	Potential Application for SoM
Coastal Management Plan Assistance Program (CMPAP)	CMPAP grants support eligible coastal land managers to develop adaptation and management plans and strategies for coastal areas that are, or are predicted to become, under pressure from a variety of challenges. CMPAP grants are administered by the Department of Planning, Lands and Heritage. CMPAP grants provide up to 50% of the budget for planned projects (co-funded with 50% contribution by the Shire)	• Funding of future CHRMAP review (every 5-years). • Funding of additional studies to develop management strategy for shoreline areas and the Murray Delta Islands.
Coastal Adaptation and Protection (CAP) grants	CAP grants provide financial assistance for local projects that identify and manage coastal hazards. The program seeks to preserve and enhance coastal assets for the community. It aims to build partnerships with local coastal managers and help them understand and adapt to coastal hazards. CAP grants provide up to 50% of the budget for planned projects (co-funded with 50% contribution by the Shire)	• Annual Monitoring Program. • Funding for shoreline restoration / revegetation programs. • Funding of additional studies to develop management strategy for shoreline areas and the Murray Delta Islands.
Coastwest Grants	Coastwest grants support eligible coastal land managers and community organisations to undertake projects that manage and enhance WA's coastal environments through rehabilitation, restoration and preventative actions. Coastwest grants are administered by the Department of Planning, Lands and Heritage. Grants provide up to 50% of the budget for planned projects (co-funded with 50% contribution by the Shire)	• Funding for shoreline restoration / revegetation programs with input from community organisations (eg Murray Delta Islands Groups).

State Government	Brief Description	Potential Application for SoM
Department of Local Government, Sport and Cultural Industries Local Government Financial Assistance Grants	Grants funded by the Commonwealth Government are distributed among 137 local governments in Western Australia each year. The grants are un-tied in the hands of local government, allowing councils to spend the grants according to local priorities.	Signage around the estuary at culturally significant places to share stories from Bindjareb Nyungar Elders.
National Disaster risk Reduction (NDRR) Grant Program	The Western Australian Government has a National Partnership Agreement (NPA) for Disaster Risk Reduction with the Commonwealth to fund disaster reduction activities that are specifically intended to deliver the outcomes of the National Disaster Risk Reduction Framework (NDRRF). The NPA is the primary funding mechanism for the National Disaster Risk Reduction (NDRR) Grants Program. Offers funding to eligible community groups, not-for-profit organisations and state and local government agencies for natural disaster risk reduction projects and initiatives. The funding has been made available under the NDRR grants program. Eligible applicants may apply for funding from \$10,000 to \$250,000 (ex. GST).	- Funding for shoreline restoration / revegetation programs which provide public benefit. - Funding for coastal Protection Structures which offer a public benefit

State Government	Brief Description	Potential Application for SoM
Coastal and Estuarine Risk Mitigation Program 22-23 (NEMA)	This Program was established under the Australian Government's Emergency Response Fund. It targets high priority locally and nationally significant coastal and estuarine disaster risk mitigation projects.	
	The Coastal and Estuarine Risk Mitigation Program will help drive long term resilience and sustainability by delivering priority projects that mitigate the impact of disasters on communities and economies.	
	Areas of focus for the Program include:	
	Adaptation and resilience actions, including investment in grey infrastructure and green-blue infrastructure (which includes nature based solutions)	• Funding for shoreline restoration / revegetation programs which provide public benefit.
	Planning, including local and regional risk assessments and mapping, business case development, preparation of community focused regional coastal management programs; and	• Funding for coastal Protection Structures which offer a public benefit
	Investment in monitoring infrastructure and activities to understand the coastal and estuarine zone over time.	
	This \$50 million for the Coastal and Estuarine Risk Mitigation Program is in addition to the \$100 million that has already been committed from the Emergency Response Fund for national flood mitigation infrastructure projects over two years in 2020-21.	

20. Monitoring Plan

20.1 Overview

To further understanding of the coastal processes in the Shire and support the aims of the CHRMAP, a structured monitoring process will be developed. The monitoring program would be used to target key locations in the SoM to improve understanding of coastal erosion and inundation impacts in the coming years. It will also provide the mechanism to assess where established triggers are being approached, to provide early indication of a change in management.

The monitoring and review process will ensure that the management and adaptation actions remain relevant. In conjunction with annual monitoring activities, a general review of the CHRMAP approximately every 5-years would be used to implement the findings from the monitoring program and address updates to the CHRMAP recommendations where required.

20.2 Survey Capture - UAV

It is noted that a key feature of the monitoring is the capture of aerial survey data by UAV. The capture of survey using UAV across the Murray Islands and shorelines of North Yunderup is expected to offer an efficient and cost-effective means of capturing this data when compared to traditional methods of capture by a surveyor along fixed transects. In the first year of capture there may be a requirement to sample areas of the UAV capture using traditional survey methods (surveyor with staff) to make a comparison between the two methods and provide confidence in the accuracy of the UAV spatial data collection method.

The UAV data will be used to provide description of the ground level, with the information analysed to determine the position of the Horizontal Shoreline Datum (HSD) at the shoreline which is a contour at the level of the highest astronomical tide (this is the definition adopted for the SoM in the Coastal Hazard report). In future revisions of the CHRMAP the HSD capture will be reviewed and where required the mapping of erosion hazard may be updated. The UAV capture method allows the same areas to be captured in subsequent surveys for direct comparison of differences (erosion / accretion) between the survey capture spatially, which is key for developing the understanding of the shoreline coastal processes. The UAV capture provides an aerial image of the collection area which is another useful tool in monitoring the shoreline changes.

It is noted that the UAV survey can only capture land areas above the water surface. As part of future monitoring activities, there may be value in understanding the seabed description below the waterline and how the profile changes offshore with sediment sources adjacent nearshore areas. This may be considered in future revisions of the program, employing traditional survey methods with an operator in the water with a survey staff moving offshore along the profile to capture survey points (where practical).

20.3 Key Monitoring locations

The key locations suggested for future monitoring as part of a regular annual monitoring campaign and summarised in Table 20.1.

Table 20.1: Key Locations for Monitoring Activities

CMU	Location	Monitoring Requirements
1.1	Shoreline Areas through Kooljerrenup section in the south of the Harvey Estuary	Review the location of the HSD through aerial survey if / as this information becomes available. Assess where significant erosion is occurring.
1.2	Shoreline Areas in front of car park at Heron Point, at boat ramp and north of boat ramp	Suggested monitoring via regular Photo capture as part of the annual monitoring program.
2.1	Birchmont Boat Ramp	Suggested monitoring via regular Photo capture as part of the annual monitoring program.
3.1	Shoreline adjacent Carrabungup Rd	Review the location of the HSD through aerial survey if / as this information becomes available. Assess where significant erosion is occurring. After significant storm / flooding event determine if inundation of road has occurred due to elevated estuary water level.
4.1	Batavia Quay Revetment	The revetment on the Peel shoreline has been established to protect the area inland, which was the site of the dredge spoil for the original canals of South Yunderup and is known to contain Acid Sulphate Soils. Monitor after large events for structural damage / overtopping as part of annual monitoring
4.2	Rivergum Esplanade. Section incl. Young Street Carpark	Suggested monitoring or erosion of riverbank via regular Photo capture as part of the annual monitoring program.
4.3	Bund in front of the South Yunderup canals	Monitor after large events for structural damage / overtopping as part of annual monitoring
5.1	Peel Inlet – west facing estuary shorelines of Murray Delta Islands	Monitoring of the berm height and position along the west facing estuary shorelines at Cooleenup Island, Meeyip Island, Ballee Island, Worallgarook Island, Yunderup Island, Little Yunderup Island. Suggested capture via UAV annually. Capture after severe events (post-winter storms).
5.2	Yunderup Island	Review of shoreline erosion. Suggested capture via UAV once every 2-years ¹ . For erosion 'hotspots' support with photo capture (suggested 2 times per year). Results would be used to examine change to the position of the HSD.
5.3	Ballee Island	Review of shoreline erosion for section adjacent established properties. Suggested capture via UAV once every 2-years ¹ . For erosion 'hotspots' support with photo capture (suggested 2 times per year). Results would be used to examine change to the position of the HSD.
5.4	Coolenup Island	Review of shoreline erosion for section adjacent established properties. Suggested capture via UAV once

CMU	Location	Monitoring Requirements
		every 2-years ¹ . For erosion 'hotspots' support with photo capture (suggested 2 times per year). Results would be used to examine change to the position of the HSD.
5.5	North Yunderup – Riverbank in front of properties along Culeenup Road	Suggested capture via UAV every 5-years ² .
5.6	Shoreline area west of the Coopers Mill Caretaker property	Currently a photo-monitoring site. To be continued as part of analysis of shoreline erosion of Cooleenup Island.
5.7	Shoreline adjacent to Coopers Mill	Review of shoreline erosion including photo monitoring after large flood events. Aim to capture survey of shoreline by UAV every two-years ¹ .
6.1	Riverside Drive Foreshore Reserve Boat Launch, Carpark, foreshore area	Suggested monitoring of erosion of riverbank via Photo capture following large erosion events. Suggested capture via UAV every 5-years ² .

Notes

1. The frequency of capture is proposed at 2-year intervals in the first 6 years of the program to develop the understanding of the changes to Island shorelines within the first review cycle of the CHRMAP (nominally 5-years)

2. The 5-yr capture frequency is aimed at allowing capture of the shoreline prior to the first review cycle of the CHRMAP.

The Shire currently undertakes photo monitoring at 6 locations (5 around the Murray Delta Islands and 1 at Herron Point). The annual monitoring program would be intended to continue this data gathering and complement this dataset through the capture of survey data to monitor changes to the shoreline areas.

20.4 Additional Studies

Additional studies by the Shire over the next five years to inform the next review of the CHRMAP and improve understanding of the coastal hazard risk are listed as follows:

- Across the Murray Delta Islands, capture the elevation across the Islands using either traditional LiDAR or UAV. It is suggested that UAV would offer a cost-effective means of capturing the data, backed up with traditional survey methods in certain locations (captured on the ground by a surveyor) to ensure accuracy. Data would be used to assess changes to the islands since the initial LiDAR capture (2016) and to then review flood risk and update mapping if/as required.
- For existing properties on Ballee, Yunderup and Culeenup Islands, get a surveyor to determine the floor level of each property (eg from the doorstep) using a DGPS or similar. This would give a more precise understanding of the risk of inundation in extreme events at property level.
- For existing properties on Ballee, Yunderup and Culeenup Islands, get a surveyor to determine elevation of the septic system on each property and approximate location using a DGPS or similar. This would give a more precise understanding of the risk of inundation in extreme events at property level.
- Undertake a study of the erosion from vessel wakes on the river shorelines in the Murray and Serpentine. The study should examine current and projected boat usage and vessel types. The study

should aim to examine the relationship between vessel speed and erosion with recommendations for revised speed limits through sections of the river if this could offer practical mitigation against erosion.

- e) Feasibility Study - North Yunderup river shoreline protection option. Appoint a working group with local representatives and undertake a study to examine the requirements for foreshore protection along the section of river fronting the 100 properties on Culleenup Rd. The engineered wall would be designed to protect against projected riverbank erosion. Study would examine the protection options, community support, preliminary concept design and estimate of cost as well as funding arrangements.
- f) The Shire should undertake (or compile where already completed) condition reports of the structures that are key to shoreline control. This includes but is not limited to:
 - Revetment at Batavia Quays in front of the Acid Sulphate Soils site
 - Bund in front of South Yunderup Canals
 - Estuary Edge of Carpark at Herron Point
 - Rock Revetments adjacent Boat Ramps at Herron Point and Birchmont
 - Rock walling in the shorelines along the Murray managed by the Shire

20.5 CHRMAP Review

Approximately every five-years a general review of the CHRMAP should be undertaken by the Shire. As part of the review the following should be covered (as a minimum):

- The improved knowledge of coastal hazards in the shoreline areas from the annual monitoring and additional studies should be incorporated into the review and where this may impact any of the recommendations in the CHRMAP
- The guidance on sea level rise projections by the DoT (DoT 2010) should be reviewed for any updates. Any change to the projected sea level rise allowances would require assessment of updates to the CHRMAP.
- Review of changes in the SPP2.6 advice (WAPC 2020) or updates to the CHRMAP guidelines (WAPC 2019) would be assessed as part of the review process.
- Engagement with the community to provide an overview of learnings from the annual monitoring program and outline how these are captured in the CHRMAP review process. A review of the community values to determine if they are consistent with values collected in the previous version of the CHRMAP would be sought as part of the engagement activities.

21. Summary and Conclusions

The Shire of Murray (SoM) has developed a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to develop a greater understanding of its coastal areas and support its future coastal management and planning decisions. The study area includes the eastern shoreline of the Peel-Harvey estuary and the tidally influenced sections of the Murray River and Serpentine River.

The CHRMAP examines the processes of erosion and inundation within the study area to understand coastal hazard risk affecting the shoreline areas today and the forecast impacts over the next 100 years (to 2120) associated with projected climate change and sea level rise.

The CHRMAP project was developed in consultation with SoM, the local community and a range of stakeholders, in accordance with local and national guidelines. The project was delivered through a multi-discipline approach incorporating science, engineering, community engagement, land use planning and economic expertise. The project aim is to improve the understanding of coastal hazard risk for the community and stakeholders and to develop coastal adaptation approaches and pathways which can mitigate risk over the short to medium term (next 10-20 years) and provide management and adaptation strategies to mitigate hazard in future planning periods (next 100 years).

A summary of the coastal hazard is presented in Section 5 of this report. A range of planning timeframes are considered (present day, 2030, 2050, 2070, 2120). The study area is divided into six Shoreline Management Units (SMU) for the purpose of the CHRMAP covering the locations:

- 1. South Harvey.
- 2. Birchmont.
- 3. Point Grey to Austin Bay.
- 4. South Yundrup.
- 5. North Yunderup.
- 6. Serpentine.

A range of Community Engagement activities have been undertaken to support the project which have developed the understanding of the project within the community and fostered local input to the CHRMAP process. The process with stakeholders and community is outlined in Section 3 and has sought engagement on:

- Potential risks arising from hazards in the estuarine and tidally influenced riverine zones;
- Key shoreline infrastructure and assets at risk within these zones;
- Community and cultural values within these zones; and
- Adaptation pathways and management options that the SoM and other stakeholders can pursue to address the risks from coastal hazard over time.

There are a range of coastal assets through the SoM that will be impacted by coastal erosion and/or inundation in future planning periods. In Section 6 of this report the coastal assets are broadly described in the categories Social, Economic, Environmental and Heritage. Coastal asset types through the SoM study area and their functions, services and values were determined by the stakeholders and through community engagement activities.

The risk assessment framework is detailed in Section 7, with likelihood and consequence applied in a vulnerability assessment to determine how the effects of coastal hazards are predicted to impact assets in current and future planning periods. The assessment first considers the potential impact to coastal assets as a combination of the *likelihood* and the *consequence* of that hazard occurring. The vulnerability

assessment then considers the adaptive capacity of coastal assets; that is, the ability of a coastal asset to accommodate coastal hazard impact.

The Risk Treatment in Section 10 outlines risk treatment options that are considered in this CHRMAP within general risk treatment categories 'Avoid', 'Planned or Managed Retreat', 'Accommodate' and 'Protect'. A range of adaptation tools available to mitigate coastal risk were applied in the CHRMAP under the key category definitions. Within each of the SMU there are risk treatment actions that are recommended to mitigate the risk to respective coastal assets.

A multi-criteria analysis (MCA) to contrast and compare adaptation options was completed for four key focus areas highlighted in the Risk Assessment phase (Section 13). The key focus areas that were identified for the MCA application were:

- Erosion / Inundation of Nature Reserves (Kooljerrenup)
- Inundation of low-lying properties (Murray Delta Islands, South / North Yunderup and Furnissdale)
- Erosion of riverbanks through North and South Yunderup (including Murray Delta Islands)
- Septic Tanks

Criteria were assigned a "score" based on the expected performance against three key categories:

- Technical
- Social
- Environmental

Cost was also considered but as a standalone category.

An MCA workshop was completed in November 2021, delivered by the study team in person at the Shire offices with attendees comprised of the CRG and stakeholders from the Shire. Representatives from the MDDRA attended the MCA workshop, but stated at the start of the session they would participate without endorsing the outcomes.

a Cost Benefit Analysis (CBA) followed on from the MCA process by examining the short-listed and highest-ranking options in detail. The CBA is detailed in Section 14 and refines the evaluation by quantifying the economic value of the various adaptation options considered to mitigate against hazards associated with coastal erosion and inundation. The economic CBA assesses various scenarios against a "base case" scenario. In this case, a "do-minimum" scenario was adopted for the base case condition. Under this scenario, no mitigation is undertaken to protect foreshore areas or property, and erosion and inundation will continue to worsen and impact the study area. Mitigation options are then compared with the base case scenario, to determine the overall economic viability of implementing these mitigation measures.

The benefits for the mitigation options were considered in terms of the protection provided for both erosion, as well as inundation of properties. Economic values were estimated for both the base case condition, as well as the mitigation option, to determine an overall net benefit. These were compared against the estimated costs for the project. The relative costs and benefits of the Project Case in comparison to the Base Case were compared through a Cost Benefit Analysis (CBA). A positive NPV and BCR greater than one support a claim for the project to be considered as economically feasible.

The key findings from the CBA in terms of supporting CHRMAP recommendations for adaptation options in the SMU's is summarised as follows:

- g) For the Murray Delta Islands, the low density of development on the islands and the large lot sizes lead to relatively high mitigation option costing relative to the benefit. While that is the case, nature-based approaches would become viable in the next 10 years (based on low cost to mid-range projections). It is recommended under the CHRMAP that natural approaches to protect the shoreline areas on the three islands commence now.

- h) For the Murray River shoreline of North Yunderup, the nature-based solutions perform well due to the density of properties in this area and their proximity to the river. However, there may be practical challenges in implementing nature-based solutions within the available space in this area. A hard engineering solution, while having a BCR less than 1, is expected to be viable within 10 years. It is recommended that a technical study is undertaken in the next five years (by 2027) to examine an engineered hard structure (river wall) along the North Yunderup section of shoreline. This process would involve representatives from the North Yunderup community and be used to confirm requirements including the design and construction method, estimate of costs and the mechanism for funding the project through residents who would directly benefit from the erosion protection provided. .
- i) The shoreline along the Murray River at South Yunderup performs well with nature-based solutions (BCR of 1.74) indicating these options are supported for implementation today. These solutions suit the shoreline areas with generally greater land buffer in this location compared with the northern side of the Murray River.
- j) Erosion of the Kooljerrenup Nature Reserve was assessed against the adaption strategy of purchasing land on the eastern side of the reserve, to mitigate the loss of land due to erosion on the shoreline side. Loss of land area is projected to increase markedly after the 2050 period due to shoreline erosion driven by projected sea level rise. Monitoring of the shoreline areas and their response to sea level rise in the next 20 years will inform the future adaptation strategy with further consideration of the need for potential acquisition of land recommended in the 2040 to 2050 planning period.

A benefit Distribution Analysis has been completed to examine the beneficiaries of the recommended adaptation options. This has shown that the private landholders are the key beneficiaries of many of the high-cost adaptation options recommended:

- For nature-based solutions on the Murray Delta Islands there is estimated to be an 80% / 20% distribution of the benefit between the private landholders and public.
- Nature based options for the South Yunderup shorelines are estimated to deliver 50% private and 50% public benefit.

It is recommended the Shire seek funding contribution from private landholders who will directly benefit from the adaptation approaches.

The final recommendations for long-term adaptation pathways is discussed in Section 15.

A summary of the short-term implementation tasks (next 10-15 years) is as follows:

- k) Planning Recommendations: The key items for the short-term timeframe implementation program and indicative timeframe are as follows:
 - Initiate amendment to LPS4 to introduce a Special Control Area (immediately).
 - Prepare a local planning policy (immediately).
 - Update and amend Emergency Evacuation Plan (next 5-years).
 - Prepare a Foreshore Management Plan (next 5-years)
- l) Annual Monitoring Program: Projected annual cost of \$16,000 – 18,000 annually to monitor:
 - Foreshore berm on the Peel shorelines along the western facing beaches of the Murray Delta Islands. The monitoring of the berm height along the shoreline is recommended every 3-years, through spatial survey data capture (via UAV or LiDAR). Following significant events where erosion may occur on the shorelines survey should also be captured.
 - Murray Delta Island shorelines on Balle Island, Culeenup Island and Yunderup Island should be monitored through spatial survey data capture (via UAV or LiDAR) approximately every 5 years.
 - Photo Monitoring of shoreline areas for erosion at Herron Point, North and South Yunderup and the Murray Delta Islands (photo capture 2x annually and following significant storm events)
- m) Additional Technical Studies: Projected Cost \$45,000 to investigate:

- Assessment, planning and costing for a centralised ATU system (next 5-years)
 - Murray Delta Islands building register (next 5-years)
 - Erosion impacts from boat wakes on the river shoreline (next 5-years)
- n) Planning Based Studies and Adaptation Studies: Projected Cost \$85,000 for the following:
- Feasibility study for protection structure along North Yunderup shoreline in front of Coolenup Rd properties (next 5-years)
 - Prepare an Emergency Evacuation Plan (next 5-years)
 - Review of CHRMAP (5-yr Review)
 - Prepare a Managed Retreat Policy (6-10 years).
- o) Adaptation Actions in Shoreline Areas.
- Ballee Island, Coolenup Island and Yunderup Island – Nature Based solutions (now)
 - South Yunderup shoreline section Young Street to Pelicans – Nature Based Solutions (now)
 - Coopers Mill Shoreline – Nature Based solutions (now)

A summary of planning-based mechanisms recommended for implementation by the Shire to manage the impacts of erosion and inundation is presented in the CHRMAP. The key planning controls are:

- p) Introduce a Special Control Area which triggers the requirement for normally exempt development to require planning approval.
- q) Prepare a local planning policy (LPP) to establish development standards to ensure new development can address projected coastal hazard from erosion and inundation.

An annual monitoring program should be a commitment post-CHRMAP to develop the understanding of the coastal processes in the Shire at key locations for erosion and inundation risk. The monitoring outcomes will be used to assess trigger points and to inform future revisions of the CHRMAP. The monitoring and review process will ensure that the management and adaptation actions identified in the CHRMAP remain relevant.

Funding for additional technical studies and shoreline management actions would be the responsibility of the Shire. There are a number of State and National grant funding sources that could be accessed to co-fund the work that provides public benefit, with a summary of these presented in Section 19.3.

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