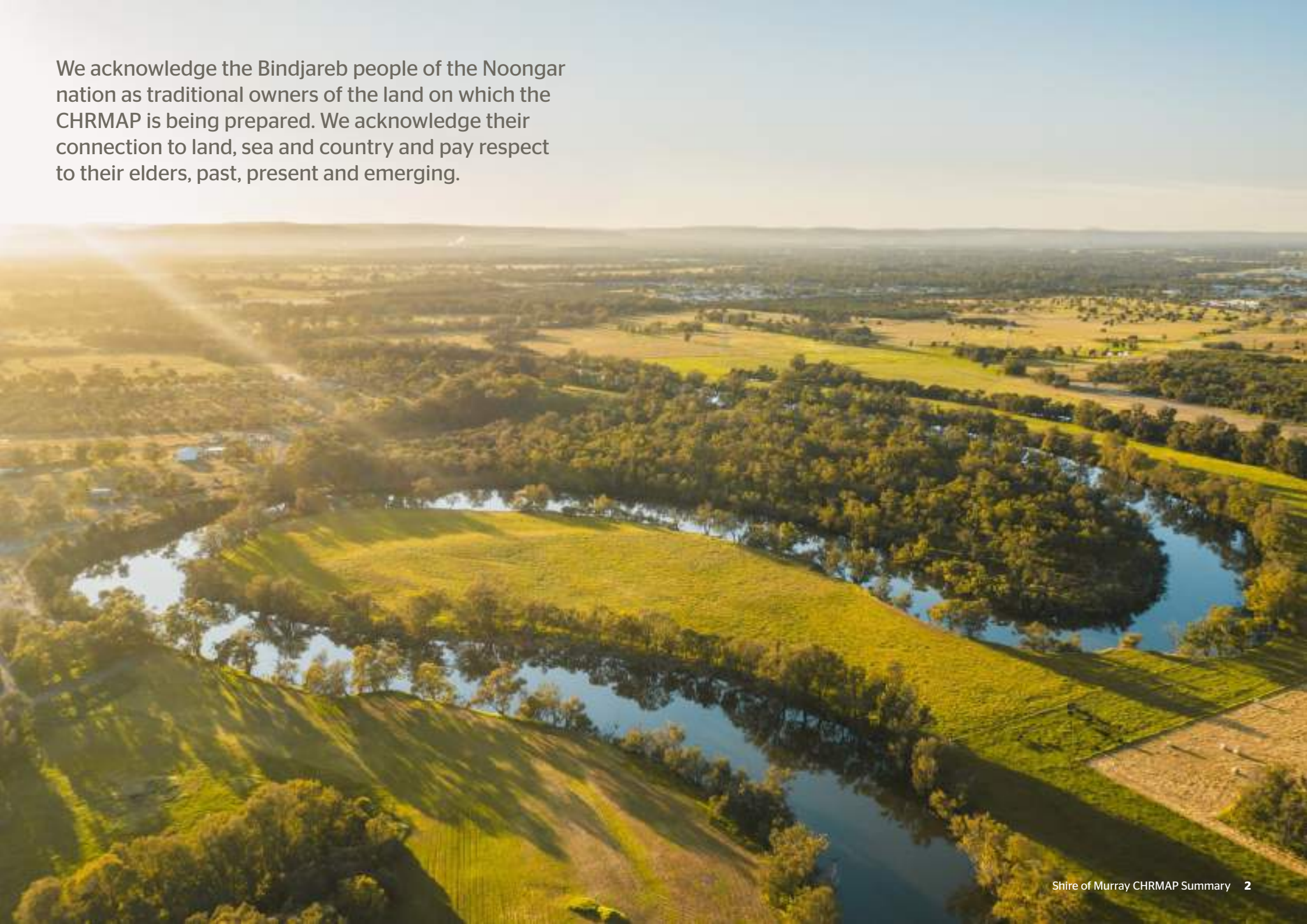
Shire of Murray Coastal Hazard Risk Management Adaptation Plan Summary

June 2024

Shire of Murray

We acknowledge the Bindjareb people of the Noongar nation as traditional owners of the land on which the CHRMAP is being prepared. We acknowledge their connection to land, sea and country and pay respect to their elders, past, present and emerging.



A message from the Shire President

The Shire of Murray (SoM) considers 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, as integral to the Shire's ongoing and future success.

Erosion and inundation are an increasing risk for the Shire of Murray, and to best protect our community we have developed a Coastal Hazard Risk Management Adaptation Plan (CHRMAP) to guide how we manage that risk.

Our community have been involved with this work at every stage in the process helping us develop a plan that is practical, easily understood and based on the latest science.

Looking after our waterways is crucial for our community. Consequently, responding to the likely challenges of a changing climate and probable sea-level rise is a priority for the Shire of Murray. Our aim throughout this process has been to provide our community with the maximum benefits of our unique natural environment for generations to come.

There are two focus areas in this work: public land and infrastructure, and private property.

For public areas, we aim to provide outcomes where environmental, lifestyle, access and economic services will still thrive in an era when sea-level rises and their impacts are likely.

For private property coastal risks will need to be considered in future planning decisions. This will ensure that growth areas are located and designed to minimise vulnerability to coastal risks. For established areas the CHRMAP includes a series of short term actions and longer term pathways designed to improve the resilience of these areas.

We will continue to work with landholders to ensure that they can continue to enjoy and use their properties in the face of the threat of climate change for as long as possible.

The Shire will facilitate this by:

- Providing a framework for development that is adaptable to potential changes in coastal hazard risk
- Advocating for funding for protection, adaptation and resilience measures
- Planning community infrastructure that helps mitigate potential future erosion/inundation impacts
- Making any changes to development rights contingent on physical trigger points being reached

Contents

Abbreviations

BCR	Benefit Cost Ratio
CHRMAP	Coastal Hazard Risk Management and Adaptation Planning
CBA	Cost Benefit Analysis
CRG	Community Reference Group
DPLH	Department of Planning, Lands and Heritage
DoT	Department of Transport
HSD	Horizontal Shoreline Datum
LPP	Local Planning Policy
MCA	Multi-Criteria Analysis
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

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Introduction

The Estuarine and Riverine coastline and shorelines of the Shire of Murray are an intrinsic part of life in the Murray region, supporting 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 Peel-Harvey Estuary and the Murray and Serpentine Rivers provide a unique natural setting for the local community as well as the estimated 400,000 domestic and international visitors that come to the Shire each year.

However, our shoreline areas are vulnerable to both inundation and erosion. The dynamic nature of inland tidal waterways, coupled with man-made impacts including the opening of the Dawesville Channel, land use changes for agriculture and development, and the cumulative impacts of recreation and boating, all increase the vulnerability of our coastal areas.

These impacts are anticipated to continue as sea levels are predicted to rise at an increasing rate (Intergovernmental Panel on Climate Change, 2021). 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 therefore integral to the Shire's ongoing and future success.

This report provides a summary of the CHRMAP. This summary report should be read in conjunction with the full CHRMAP.

What is a CHRMAP?

A Coastal Hazard Risk Management and Adaption Plan, also known as a CHRMAP, is a strategic, long-term plan that guides the response to the existing and potential future risk of impact from erosion and inundation along the coast. In the Shire of Murray these risks are most acute in the tidally influenced parts of the river and estuary system. The CHRMAP assesses risk levels at present and at specific planning timeframes of 10, 30, 50 and 100 years into the future.

The CHRMAP outlines adaptation pathways to be pursued to minimise risk and vulnerability across these timeframes. CHRMAPs are prepared in Western Australia in accordance with the CHRMAP guidelines (WAPC, 2019) and State Planning Policy No. 2.6 – State Coastal Planning Policy (WAPC, 2020).

Purposes and objectives

The Shire has completed a CHRMAP for its tidally influenced estuarine and riverine areas to support its future management and planning decisions. The CHRMAP project has been developed in consultation with the local community and a range of stakeholders, and has been delivered in accordance with local and national guidelines and standards (WAPC 2019, AS5334-2013).

The key objectives of the CHRMAP are to:

Improve understanding of the Peel–Harvey estuarine coastal and Murray and Serpentine riverine features, processes, as well as 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 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 to assign a level of risk.

Identify risk management measures and actions and how these shall be incorporated into short and long-term decision-making.

Engage stakeholders and the community in the planning and decision-making process.

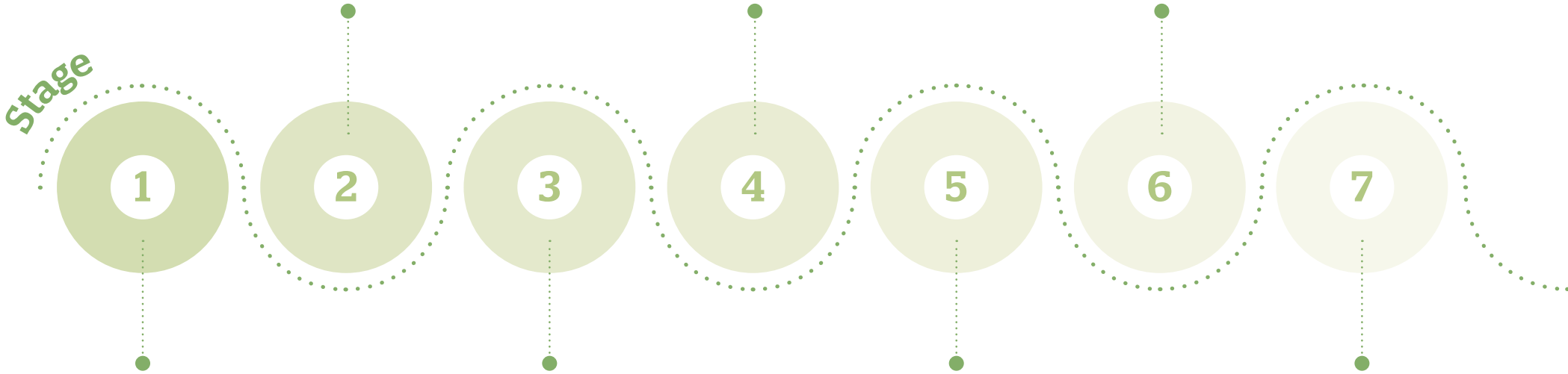
Study area

The study area for the CHRMAP includes the eastern shoreline of the Peel-Harvey estuary and the tidally influenced sections of the Murray and Serpentine Rivers.

The **study area** includes approximately 50km of largely natural shoreline including various nature reserves. A range of residential and commercial developments are sited in the north of the study area including the localities of Furnissdale, North Yunderup and South Yunderup. South of Point Grey, the locality of Birchmont and the campground at Herron Point are adjacent to the Harvey Estuary.

Project staging

The CHRMAP project has been undertaken in seven stages:



Establish the Context

- Establish the Context Report Chapter
- Develop Stakeholder and Community Engagement Plan
- Undertake Coastal Values Assessment

Risk Identification

- Coastal Hazard Assessment
- Asset Identification

Vulnerability Analysis

- Develop Likelihood and Consequence Scales
- Develop Level of Risk Matrix and Risk Tolerance Scale
- Adaptive Capacity and Asset Vulnerability

Risk Evaluation

- Existing Controls
- Priorities for Risk Treatment

Risk Treatment

- Identify Risk Treatment Options
- Multi-Criteria Analysis
- Cost Benefit Analysis
- Benefit Distribution Analysis
- Identification of Long-Term Adaptation Pathways

Implementation Plan

- Short-Term Implementation Plan
- Medium- and Long-term Implementation Plan
- Land Use Planning
- Funding

Monitoring, Reporting and Review

- Monitoring and Reporting Plan

Community and stakeholder engagement

A range of community engagement activities were undertaken to support the project. These have helped improve the understanding of the project within the community and fostered local input to the CHRMAP process.

A Stakeholder and Community Engagement Strategy was prepared to guide the engagement process and ensure that the community and stakeholders were effectively and actively involved throughout each of the key project stages during the CHRMAP preparation process. Their involvement has guided the determination of the final outcomes.

Engagement

150+
Contributors

300+
Responses

2000+
Letters delivered to residents to inform them of information sessions

2
Online surveys

2
Groups formed Technical Advisory Group & Community Reference Group

5
Workshops and information events and engagement with Traditional Owners

Respondents included residents of nearby locations adjacent to the Shire of Murray, including Mandurah, Waroona, Warnbro and Rockingham

Coastal assets and values

Top 3 reasons people interact with the estuary

Fishing/Crabbing, horse riding and boating

Highest value amongst the community

Environmental values and land/water-based recreation opportunities

Top 3 social assets identified

Walking paths, fishing areas and crabbing areas

Top 3 environmental assets identified

Foreshore area, river system and the Murray Delta Islands

Assets and management

The environment was identified by the community as the most important asset.

Erosion was perceived to be the greatest immediate concern of participants.

Houses & properties had the highest priority ranking.

Protect & accommodate were the preferred adaptation strategies.

Nature-based solutions were the most popular adaptation options (i.e. brushwall and revegetation).

Success criteria

Based on the coastal values identified in the community engagement the following success criteria were defined:

- Conserve, enhance and maintain the natural environmental and character of the river regions and Peel-Harvey estuary areas.
- Protect and restore estuary river shorelines and their wetlands and manage coastal processes.
- Manage impacts to the existing residential areas from erosion and inundation.
- Maintain critical infrastructure supporting the community (roads, utilities).
- Manage and maintain coastal infrastructure that provides access to the water and supports the lifestyle enjoyed by people in the region.
- Maintain the ecological values of the rivers, estuary and associated wetlands (e.g. birds, fishing and crabbing).
- Preserve the key heritage sites of significance (e.g. Coopers Mill).
- 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.

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Coastal hazards

Coastal hazards are associated with the natural variability of the ocean and processes that have the ability to impact coastal areas and assets. Coastal hazards have always existed along coastlines and associated shorelines and are not solely influenced by climate change.

Coastal hazards

The impact of sea-level rises has been factored into future coastal planning in this CHRMAP based on the projection of a +0.9m sea-level rise over the next 100 years. The projected sea-level rise in the coming century is expected to increase the vulnerability of assets and foreshore areas to hazards such as inundation and erosion.

Erosion

Shoreline movement where the shoreline shifts landward reducing the width of a coastal foreshore reserve and/or the distance to a fixed feature on the adjoining land. This can be rapid (e.g. due to a storm event) or over a longer period time (e.g. the shoreline gradually retreats due to sea-level rises or variability in local coastal processes). Erosion coupled with assets often results in permanent damage.

Inundation

The flow of water onto previously dry land. It may either be permanent (e.g. due to sea-level rise) or a temporary occurrence during a storm event. This leads to the flooding of low-lying areas, and where assets exist in these areas, they may be impacted temporarily, which often leads to permanent damage.

Coastal hazard assessment

A coastal hazard assessment was undertaken for the Shire of Murray in accordance with the State Coastal Planning Policy (SPP2.6, WAPC 2020), which examined projected coastal erosion and inundation processes over the next 100 years (Seashore 2021).

S1 Erosion Allowance for extreme storm impact (e.g. large storm event)

S2 Erosion Allowance for shoreline movement based on previously measured trends

S3 Erosion Allowance for erosion caused by future sea-level rise

S4 Inundation Allowance for the risk of storm-surge inundation in an extreme event

The sum of each of the components for erosion (S1, S2 & S3) and inundation (S4) were used to derive hazard lines for 2020, 2030, 2050, 2070 and 2120 timeframes. Hazard lines depict the active limit for each coastal hazard at a given timeframe and are used to identify at-risk areas and assets along the Shire's shorelines.

Based on the findings of the coastal hazard report, the current and future extent of coastal hazard over a range of planning periods was determined across the study area. Mapping of the inundation areas (depth of flooding) and the coastal processes allowances (erosion setback distances) along estuarine and river shorelines have been used to inform the impacts to coastal assets in the CHRMAP.

Loss to erosion over 4 years
Cooleenup island

2019

2020

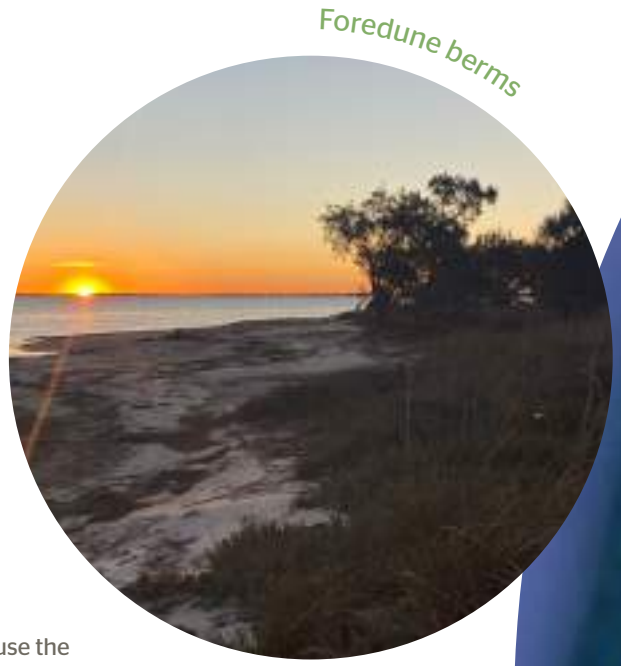
2021

2022

3

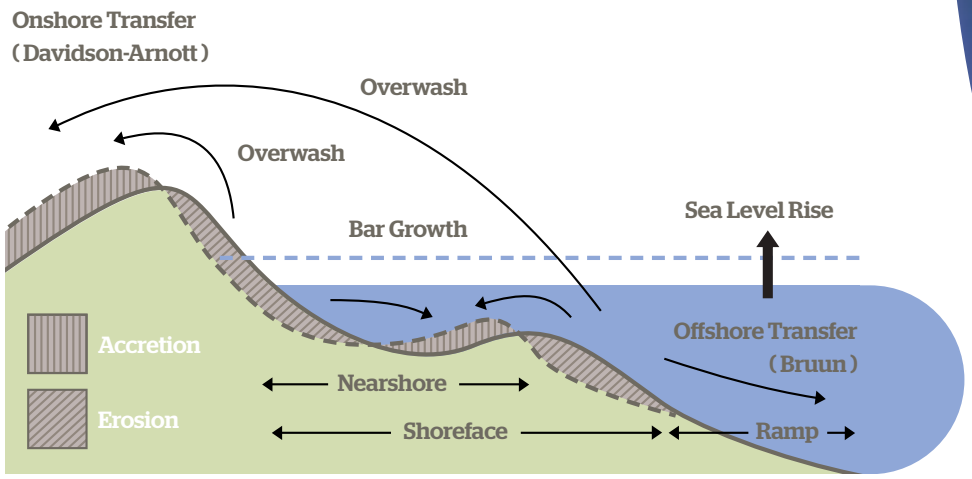
How vulnerable is our shoreline?

Coastal hazard study



The potential response of the shoreline to future sea-level rise is strongly linked to the height and stability of the berms.

For shoreline areas, sea-level rises will cause the coast to rise and roll landward over low-lying areas (Davidson-Arnott model). For the Harvey Estuary shorelines the erosion response is small due to the relatively high foreshore area. For the Murray Delta Islands the erosion response is large due to the low-lying topography around the foreshore berm. Critical to the long-term foreshore dynamics for the Yunderup area is that foredune berms keep pace with any increase in sea-level.



Cross-shore response to sea-level rise (diagram adapted from Dubois 1992).

Analysis of shoreline transects in Coastal Processes Study (Seashore 2021)

Approach to analysis

The study area was broken down into six sections of shoreline. Coastal assets in the shoreline areas were identified in each of the six respective shoreline management units (SMUs) for the CHRMAP as summarised here:

SMU 1 South end of Harvey Estuary (includes Herron Point)

SMU 2 Birchmont

SMU 3 Point Grey to Austin Bay

SMU 4 South Yunderup (including the Canals)

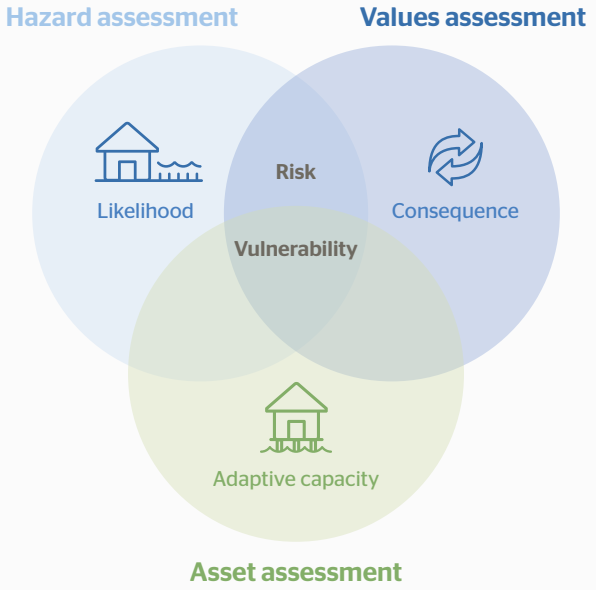
SMU 5 North Yunderup (including Murray Delta Islands)

SMU 6 Serpentine River and Furnissdale

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 analysis was undertaken based on the Australian Standard Guideline Climate Change Adaptation for Settlements and Infrastructure – A risk-based approach (AS5334-2013), and the CHRMAP guidelines (WAPC, 2019) adapted to an estuarine environment.

In risk management terms, 'likelihood' is the chance of something happening, and is similar to the concept of probability. Alternatively, 'consequence' is used to describe the impact to assets when coastal hazard is realised. The assessment of potential impact to coastal assets uses the likelihood and consequence to determine a level of risk.

Likelihood was assigned using the results of coastal processes and coastal hazard inundation. Consequence of coastal hazards are considered across a range of categories representing severity, with risk rating designated to one of four categories adopted from WAPC (2019). Risk ratings were then combined with an asset's adaptive capacity to assign assets with a rating for vulnerability over each planning horizon.



Key outcomes

- Many of the river foreshore areas and associated Shire infrastructure are rated as highly vulnerable to erosion over the planning timeframes, these include minor roads, jetties, drainage features and other associated infrastructure
- Coopers Mill is highly impacted from both erosion and inundation in the short-term timeframe without management
- The majority of private lots across the Shire are only at risk from minor inundation, and this only occurs in the long-term planning timeframe under projected sea-level rises
- There are a number of private lots, particularly in the North Yunderup and Murray Delta Island areas that are vulnerable in the current and short-term timeframes from inundation and erosion without further management
- Regular, programmed and consistent monitoring and maintenance of the foredune berms in the Yunderup area is critical.

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What are the management options?

Whose responsibility is it to manage the shoreline?

There is no legal obligation for Local or State Governments to protect public or private assets within coastal hazard areas, or to compensate for any losses caused by coastal hazards. SPP2.6 however, requires local governments to prepare a CHRMAP to identify areas at risk, outline possible adaptation pathways and share this information with the community.

Given the likely expensive nature of the adaptation works, it is recommended that the Shire determines funding pathways for coastal adaptation to ensure works can be undertaken as they become necessary. The cost of adaptation works can be supported by State and Federal funding programs including the Western Australian-based Coastal Management Plan Assistance Program, Coastal Adaptation and Protection grants and Coastwest grants.

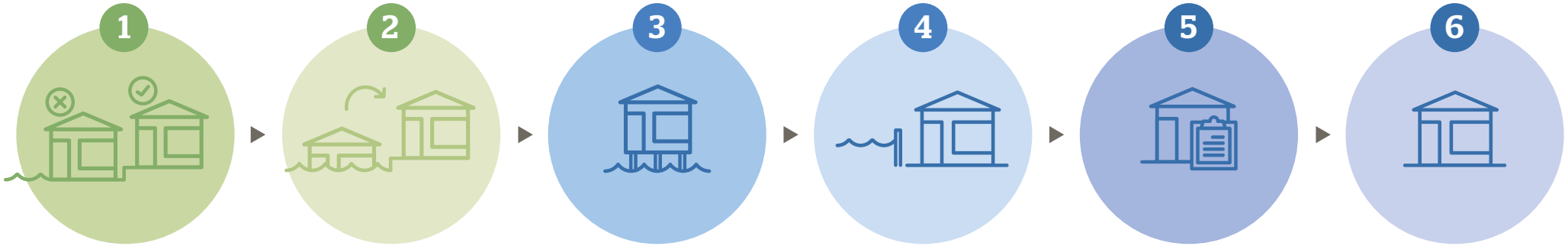
It is also noted that many of the impacted shorelines are highly valued by the community as public assets, with stakeholders ranging from property owners, traditional owners, all levels of government, industry, community and environmental groups, ratepayers and users from within and outside the jurisdictional boundaries. It is crucial that planning and management of these areas is as transparent and equitable as possible, giving the utmost importance to ensuring equity is a central concept of the CHRMAP process.

Responsibility for coastal planning lies with both Local and State Governments, with a requirement to ensure decision making in risk management is undertaken considering the following:

- **Potential benefits**
- **Effectiveness in reducing losses or maximising opportunities**
- **Cost of implementation and ongoing maintenance**
- **Equity implications** (i.e. who pays?; are the costs/benefits shifted between stakeholders? is this fair and acceptable?; whose values are being protected/negatively impacted?)
- **Impact of the treatment option on other objectives, including the introduction of new risks or issues**
- **Intergenerational equity**

Adaptation hierarchy

Effective adaptation planning involves identifying and evaluating a range of suitable options to help manage the risk of coastal hazards. Potential options have been identified from the CHRMAP guidelines (WAPC, 2019) which describe the general risk treatment categories in a risk treatment and adaptation hierarchy under the categories: Avoid, Planned or Managed Retreat, Accommodate and Protect. Two additional management approaches considered in this CHRMAP are No-Regrets and Do Nothing.



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.

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 indefensible. 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.

Accommodate

This option aims to use design and management strategies which render the risks as tolerable/ acceptable, allowing land to continue to be used until risks become intolerable. Design and management strategies may include a mix of structural or non-structural approaches.

Protect

Protection aims to shield assets from damage resulting from erosion 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.

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 are being completed.

Do Nothing

The Do Nothing risk treatment option assumes that all levels of risk are accepted and that no further action will be taken. This risk treatment option provides a basis for comparison of all other risk treatment options.

Management options

Avoid

Adaption Type	Code	Applicable	Measures
Locating assets in areas that are not vulnerable to coastal hazards	**AV.1**	Can be applied to all asset types. Applicable to undeveloped residential and commercial land.	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.

Planned or Managed Retreat

Adaption Type	Code	Applicable	Measures
Leaving assets unprotected	**MR.1**	Low cost, temporary and easily relocatable recreation amenities.	Amend local planning scheme to include Special Control Area. Determine assets that are deemed sacrificial. Monitoring (NR1) to identify when trigger is reached.
Demolition, removal or relocation of assets from inside the hazard area	**MR.2**	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.	Amend local planning scheme to include Special Control Area. 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. Monitoring (NR1) to identify when trigger is reached.
Event limited development approval/ prohibit expansion of existing use rights	**MR.3**	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.
Voluntary acquisition	**MR.4**	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.	Investigate/put in place funding for acquisition of priority properties. Offer voluntary acquisitions reflecting asset value in light of hazard.
Limit further subdivision	**MR.5**	Limit further subdivision of existing lots identified in the hazard area.	Amend local planning scheme to include Special Control Area.

Accommodate

Building design – Relocatable structures	**AC.1**	Design assets to be relocatable. Structures can be moved in future as risk increases and becomes intolerable.	Amend local planning scheme to include Special Control Area. Prepare local planning policy containing relevant inundation and wave overtopping development controls. Approval of local planning policy by Council. Implement local planning policy development controls to all properties within the special control area for coastal hazards within the local government area.
Building design – Design assets to withstand impacts	**AC.2**	Where avoiding or relocating an asset is not an option, design of assets to withstand the impact of inundation. Roads, car parks, residential property, hospitals, aged care facilities, schools, childcare facilities.	
Building design – Appropriate finished floor levels	**AC.3**		
Filling land	**AC.4**		

Protect

Beach management/ sand management	**PR.1**	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.
Erosion control – nature-based solutions	**PR.2**	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.
Coastal revegetation	**PR.3**	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.
Seawalls	**PR.4**	Involves construction of a seawall usually along an entire section of shoreline. The seawall could be applied to protect important built assets from erosion.	Undertake NR2, to investigate viability of existing seawalls on beaches. Consider in accordance with Council's Asset Management Plan. Undertake investigation of rock and sand sources for detailed costings, design of seawall and nourishment, planning approvals and funding mechanisms. Continued monitoring (NR1) for trigger.
Flood mitigation structure	**PR.5**	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.	Undertake investigations of rock and sand sources for detailed costings, design of flood structures and nourishment, planning approvals and developing business case for funding. Continued monitoring (NR1) for trigger.

No Regrets

Monitoring	**NR.1**	Applicable to all areas. Long-term baseline monitoring and event-based monitoring following storm-erosion events.	Set up a baseline monitoring programme for long-term trends and conditions following major events. Review results for particular asset triggers regularly. 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).
Protection structure audit	**NR.2**	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.	Conduct audit of existing protection structures. Update hazard lines where relevant to account for existing protection structures. Update CHRMAP proposed actions to account for condition (life) of existing protection structures.
Notification on title (also relevant to, planned/managed retreat, accommodate and protect options)	**NR.3**	All assets located within an area vulnerable to coastal hazards within the planning timeframe. Indicated 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.
Emergency evacuation plans (also relevant to accommodate options)	**NR.4**	Roads (with regard to managing traffic flows during an event), car parks, residential property, hospitals, ages care facilities, schools, childcare facilities.	Development of evacuation plans for locations without existing inundation mapping as a priority. Update evacuation plans with latest inundation mapping available or include coastal inundation area into existing evacuation plans.
Reduce vessel speeds in the waterways	**NR.5**	Review the speed limits for vessels travelling through the lower Murray River.	Complete studies to examine erosion impacts to the riverbanks from vessels and or vessel activities. Implement revised speed limits through the Shire's waterways (signage, etc).

Do Nothing

Do nothing	**DN.1**	Low value assets and assets that must be located in the shoreline areas for their function/purpose,	Take no action and accept risk.

Planning response

Recommended planning actions include the preparation of a Special Control Area (SCA) and local planning policy to cover all the areas projected to be impacted by erosion and inundation over the next 100 years.

Planning changes are developed in order to:

- Ensure land in the shoreline areas is continuously available for foreshore management, public access, recreation and conservation
- Ensure public safety and reduce risk associated with erosion and inundation
- Avoid inappropriate land use and development of land at risk of erosion and inundation
- Ensure land use and development does not accelerate erosion or inundation risk or have a detrimental impact on the functions of public reserves
- Protect new developments from the impacts of erosion and inundation
- Provide for implementation of the Shire of Murray CHRMAP

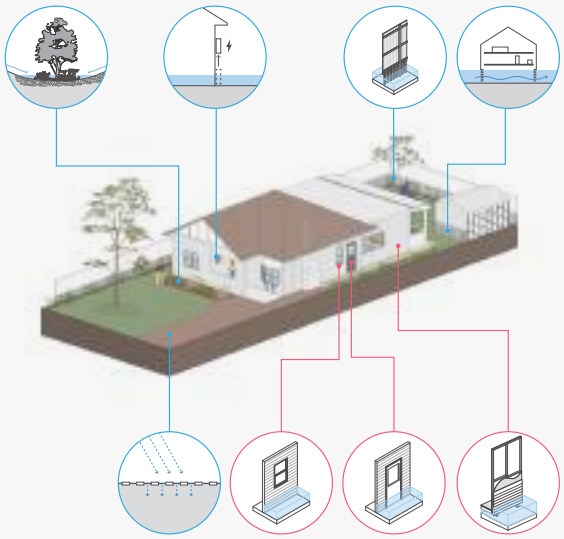


Image credit: www.marriottconstructions.com.au

Examples of relocatable homes and new design guides that can support planning response

Triggers to respond

The concept of a trigger is to have a pre-determined point that is set to 'trigger' the commencement of planning and/or implementation action of a risk management option to avoid crossing a 'threshold'. The ongoing process of monitoring and evaluation of SoM's shoreline areas will be used to determine at which point further action is required. This is one of the important features in the CHRMAP risk management pathways approach in that triggers for the decision points are associated with the observation of key events on the ground rather than being time-based.

Triggers	Code	Decision	Measures	Identification
 **The Horizontal Shoreline Datum (HSD) is within the S1 distance of an asset's most seaward extent** (this will generally be between 3 and 11 metres depending on the specific location)	**T1**	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, car parks), residential and commercial buildings. Remove major infrastructure (roads, car parks), 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.
 **A public road is no longer available or able to provide legal access to a property**	**T2**	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.
 **Water, sewer or electricity to a lot is no longer available as they have been removed or decommissioned by the relevant authority due to coastal hazards**	**T3**	Liaison with/notification by utility providers.	Remove residential and commercial buildings, and transfer land to public realm.	Task included in the annual monitoring program.
 **Residential or commercial property lies seaward of the 100-year coastal erosion hazard line or coastal inundation hazard extent**	**T4**	Definition of hazard extents through CHRMAP using recently updated information regarding sea-level rise predictions and changes in environmental conditions (e.g. tidal planes, mean sea level).	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 will be defined in the SCA as an outcome of the CHRMAP.

	**An asset is damaged, destroyed or becomes unsafe due to coastal erosion**	**T5**	Inspection of coastal assets following storm events or during times of increased longshore erosion. Shire asset management includes inspection and reporting on structure conditions. Notification by the public.	Remove assets and relocate to less hazardous area is possible/appropriate.	Informed by the Asset Management and Structure Condition Assessments undertaken by Shire. Also captured in Annual Monitoring Program.
	**Assets are predicted to become highly or very highly vulnerable within the planning timeframe or the next 10 years**	**T6**	Definition of hazard extents through CHRMAP using recently updated information regarding sea-level rise predictions and changes in environmental conditions (e.g. tidal planes, mean sea level).	Undertake 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).
	**The overall community and stakeholders are no longer supportive of a specific risk management technique or approach**	**T7**	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).
	**A specific risk management technique is forecast to no longer be economically or physically feasible within 10 years**	**T8**	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).
	**The beach and coastal foreshore reserve is significantly diminished with respect to its original state and function**	**T9**	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.
	**Undeveloped land is identified as lying within the hazard extents**	**T10**	Definition of hazard extents through CHRMAP using recently updated information regarding sea-level rise predictions and changes in environmental conditions (e.g. tidal planes, mean sea level).	Implement planning controls to avoid inappropriate development of the land.	This will be defined in the SCA. As part of future CHRMAP review this can be reassessed periodically (every 5-10 years).

5

Area summaries based on Shoreline Management Unit (SMU)

SMU 1

South end of Harvey Estuary (inc Herron Point)

SMU1 extends along the shoreline of the Kooljerrenup Nature Reserve, across approximately 8km of the lower Harvey Estuary.

SMU1 – South end of Harvey Estuary (includes Herron Point)

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. The shoreline is considered to have high adaptive capacity and the risk and vulnerability of the shoreline area through the nature reserve is rated low to medium.

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 rises 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 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.

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.

Erosion

The erosion vulnerability assessment showed:

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.

Inundation

The findings of the inundation assessment were:

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.

Legend

Inundation

Coastal Processes

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

0 200 metres

Source Data

Inundation areas defined from LiDAR datasets collected in 2008 (DWER) and 2016 (Landgate) through the Shire of Murray. Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

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SMU 1 - Herron Point to Harvey Outlet

Shire of Murray
Coastal Hazard Flood Mapping

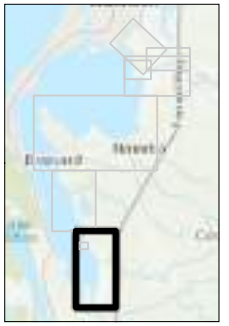
500yr ARI Design Storm in Planning year 2120

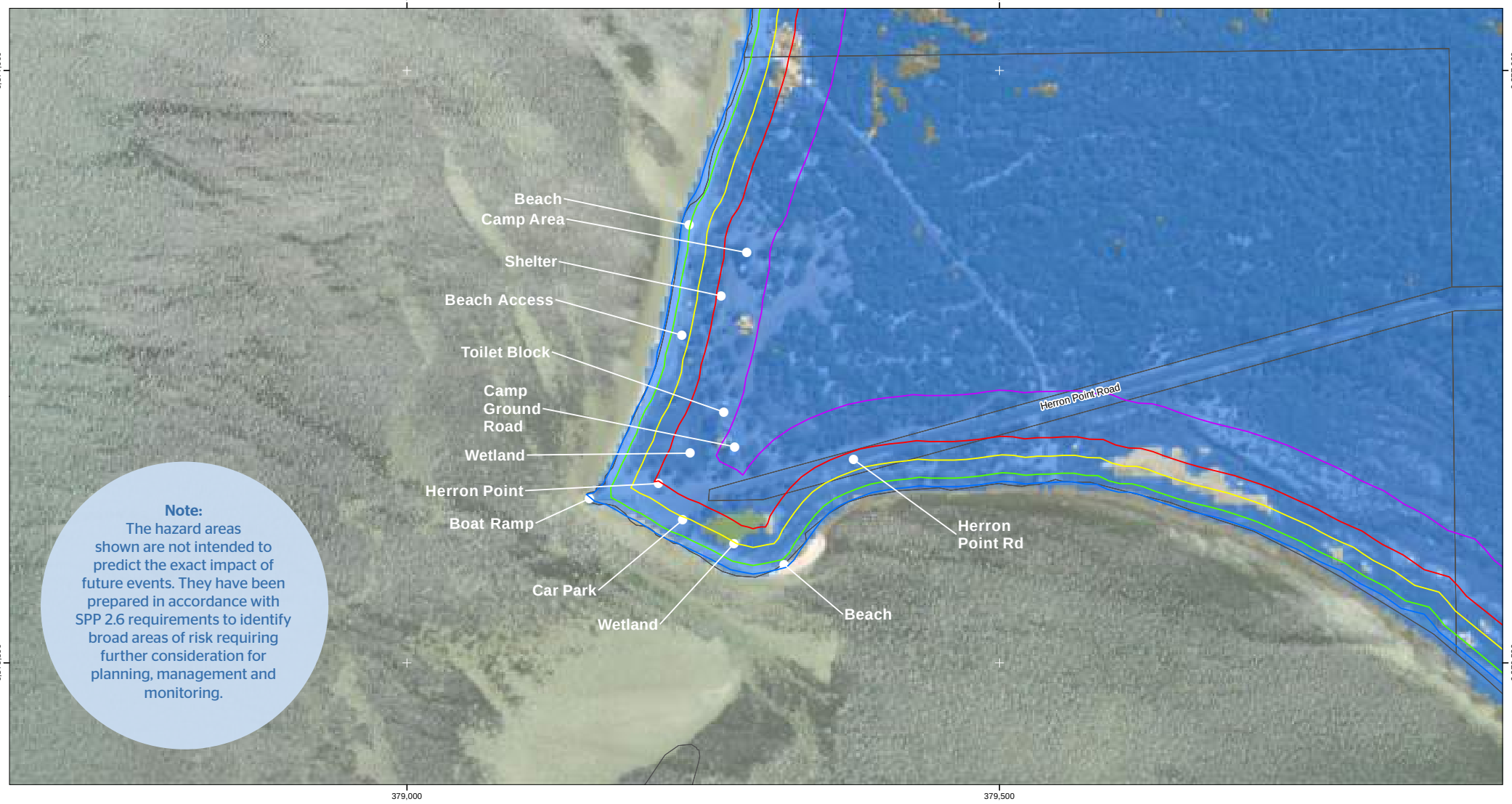
Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 15 Sep. 2022





Legend

Inundation

Coastal Processes

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

N W E S

0 200 metres

Source Data

Inundation areas defined from LiDAR datasets collected in 2008 (DWER) and 2016 (Landgate) through the Shire of Murray. Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

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SMU 1 – Herron Point

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm in Planning year 2120

Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

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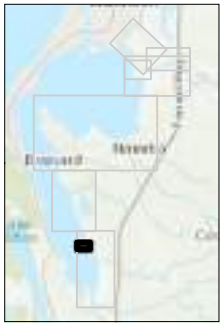
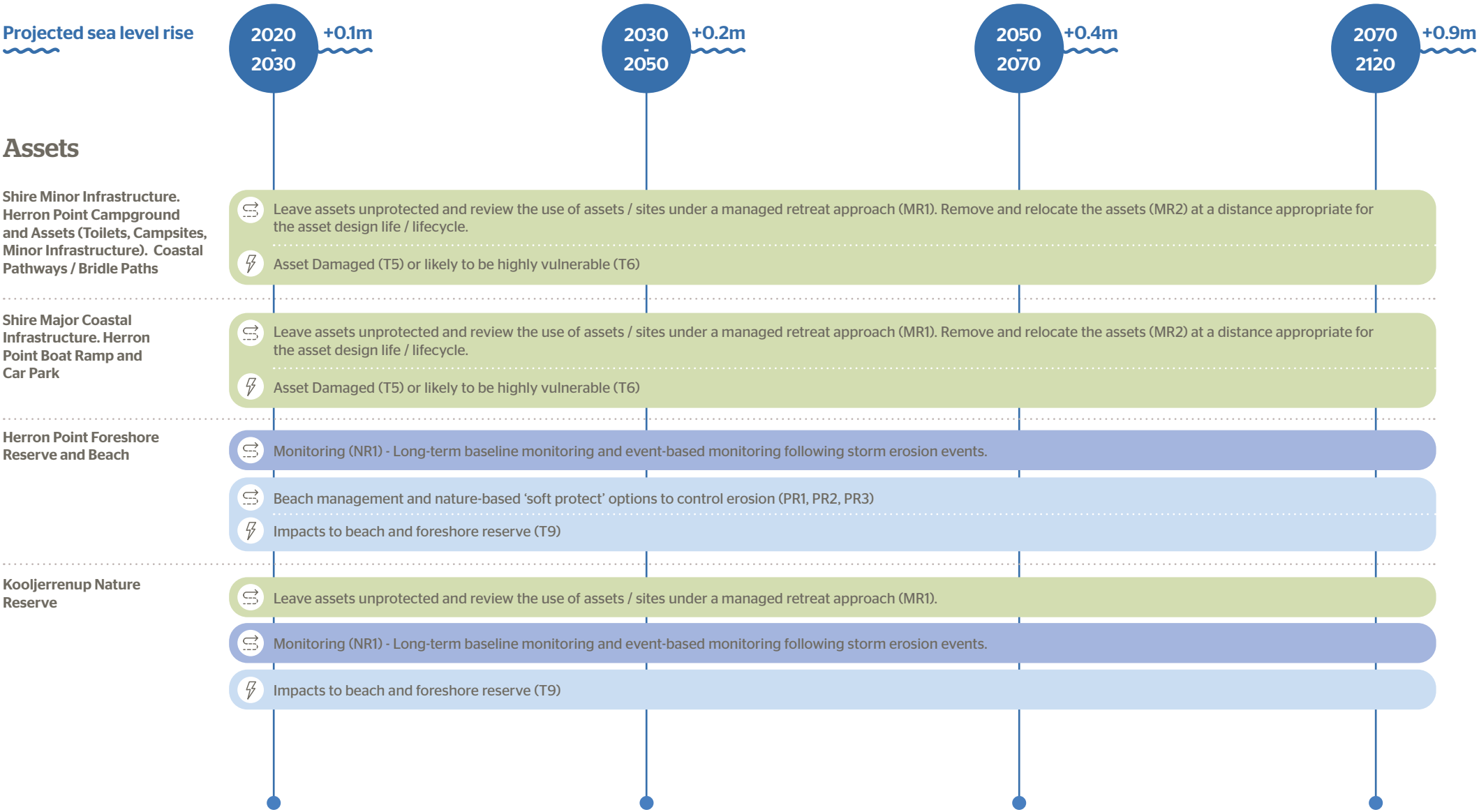
Mapping prepared by Baird.

Map Published: 15 Sep. 2022



Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing | Pathways | Trigger

Risk management and adaptation pathways



Vulnerability rating Low Medium High Very High

Erosion Vulnerability ratings

		2030	2050	2070	2120
1	Beach areas	High	High	Very High	Very High
2	Foreshore Nature Reserve	Medium	High	High	High
3	Harvey Drain	Low	Low	Low	Low
4	Kooljerrenup Nature Reserve	High	High	Very High	Very High
5	Herron Point Camping Ground	Low	Medium	Medium	High
6	Herron Point Foreshore	Medium	High	High	High
7	Coastal Pathways / Bridle Paths	Medium	High	High	High
8	Carpark at Herron Boat Ramp	High	Very High	Very High	Very High
9	Herron Point Boat Ramp	High	High	High	High
10	Campground Toilet / Showers	Medium	Medium	Medium	High
11	Herron Point Minor Infrastructure (signs)	Low	Low	Low	Low
12	Herron Point Road, Campground Road	Medium	High	High	Very High

Inundation Vulnerability ratings

		2030	2050	2070	2120
1	Beach areas	Low	Low	Low	Low
2	Foreshore Nature Reserve	Low	Low	Low	Low
3	Harvey Drain	Low	Low	Low	Low
4	Kooljerrenup Nature Reserve	Medium	High	High	Very High
5	Herron Point Camping Ground	Low	Low	Medium	Medium
6	Herron Point Foreshore	Low	Low	Low	Low
7	Coastal Pathways / Bridle Paths	Low	Low	Low	Low
8	Carpark at Herron Boat Ramp	Medium	Medium	High	High
9	Herron Point Boat Ramp	Medium	Medium	High	High
10	Campground Toilet / Showers	Low	Low	Low	Low
11	Herron Point Minor Infrastructure (signs)	Medium	Medium	High	High
12	Herron Point Road, Campground Road	Medium	Medium	High	High

SMU 2

Birchmont

SMU2 extends along approximately 7km of the Harvey estuary and includes the Birchmont section of coast through to Mealup Point.

SMU 2 – Birchmont

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.

In total around 50 residential properties are within the mapped at-risk areas. The majority of the impacts are in the 2070 to 2120 period with sea-level rises causing minor flooding.

Erosion

The erosion vulnerability assessment showed:

- A high rating for beaches from 2030 onwards. 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.

Inundation

The findings of the inundation assessment were:

- That 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 from 2070 reflecting the influence of projected sea-level rises.
- 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.

Legend

- Inundation

Coastal Processes Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

0 200 metres

Source Data

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SMU 2 – Birchmont

Shire of Murray
Coastal Hazard Flood Mapping

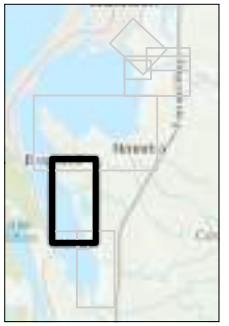
500yr ARI Design Storm in Planning year 2120

Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

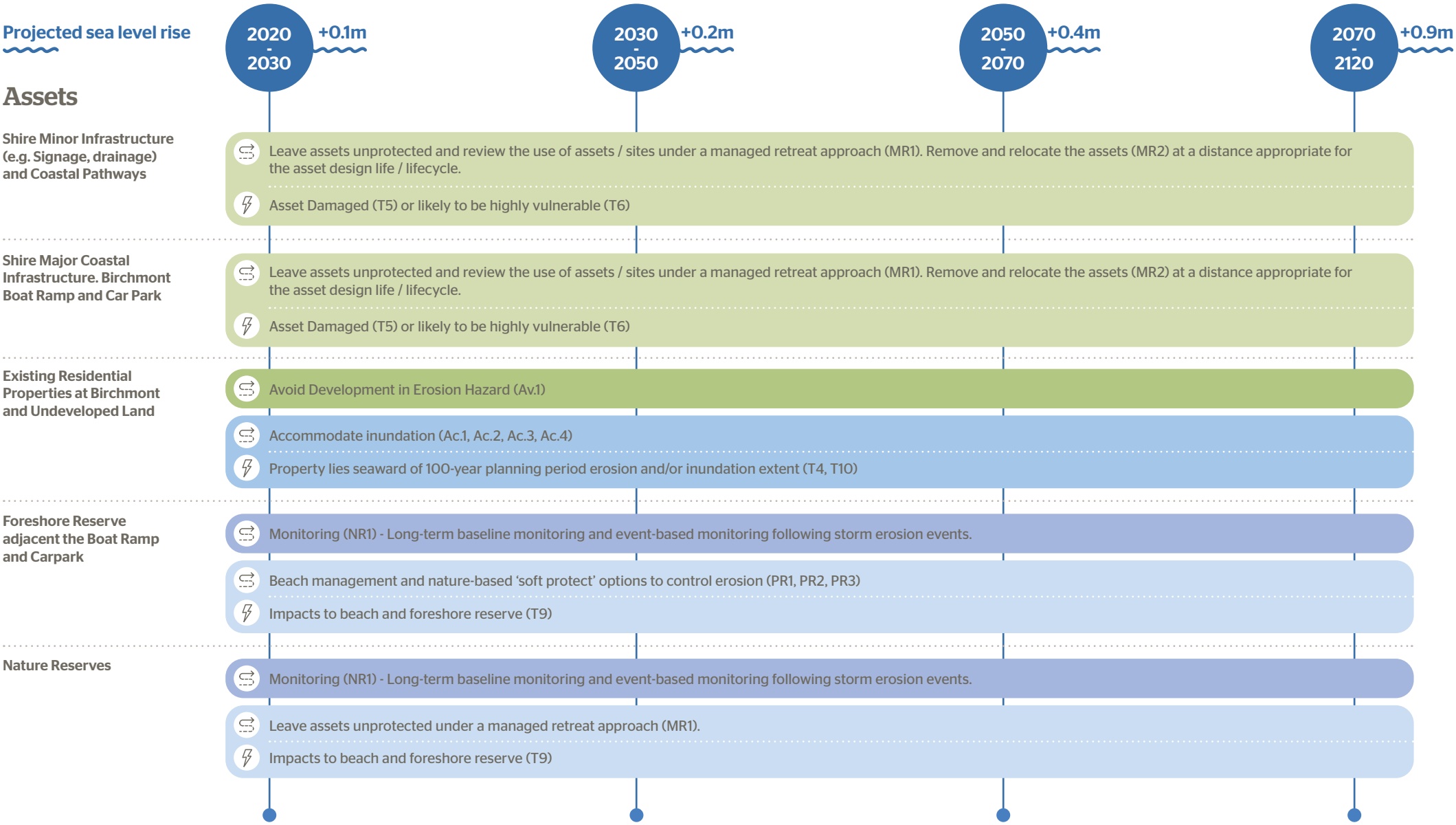
Mapping prepared by Baird.

Map Published: 15 Sep. 2022



Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing | Pathways | Trigger

Risk management and adaptation pathways



Erosion Vulnerability ratings

		2030	2050	2070	2120
1	Beach areas	High	High	Very High	Very High
2	Foreshore Nature Reserve	Medium	High	High	High
3	Lake McLarty and McLarty Nature Reserve	Medium	High	High	High
4	Lake Mealup / Mealup Point Nature Reserve	Medium	High	High	High
5	Foreshore Reserve at Birchmont Boat Ramp	Medium	Medium	High	High
6	Coastal Pathways / Bridle Paths	Medium	High	High	High
7	Residential Properties	Medium	Medium	High	Very High
8	Carpark at Birchmont Boat Ramp	Medium	Medium	High	Very High
9	Birchmont Boat Ramp	Medium	High	High	High
10	Minor Infrastructure (signage, fencing)	Low	Low	Low	Low
11	Roads	Medium	Medium	High	High

Inundation Vulnerability ratings

		2030	2050	2070	2120
1	Beach areas	Low	Low	Low	Low
2	Foreshore Nature Reserve	Low	Low	Low	Low
3	Lake McLarty and McLarty Nature Reserve	Medium	High	High	Very High
4	Lake Mealup / Mealup Point Nature Reserve	Low	Low	Low	Low
5	Foreshore Reserve at Birchmont Boat Ramp	Low	Low	Low	Low
6	Coastal Pathways / Bridle Paths	Low	Low	Low	Low
7	Residential Properties	Medium	Medium	High	High
8	Carpark at Birchmont Boat Ramp	Low	Low	Low	Low
9	Birchmont Boat Ramp	Low	Low	Low	Low
10	Infrastructure (signage, fencing, bus shelter)	Low	Low	Low	Low
11	Drainage features	Low	Low	Low	Low
12	Roads	Low	Medium	Medium	High

SMU 3

Point Grey to Austin Bay

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

SMU 3 – Point Grey to 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.

In total there are around 20 properties including Culjum House within the mapped at-risk areas and the majority of the impacts are in the 2070 to 2120 period with sea-level rises and are due to minor flooding.

Erosion

The erosion vulnerability assessment showed:

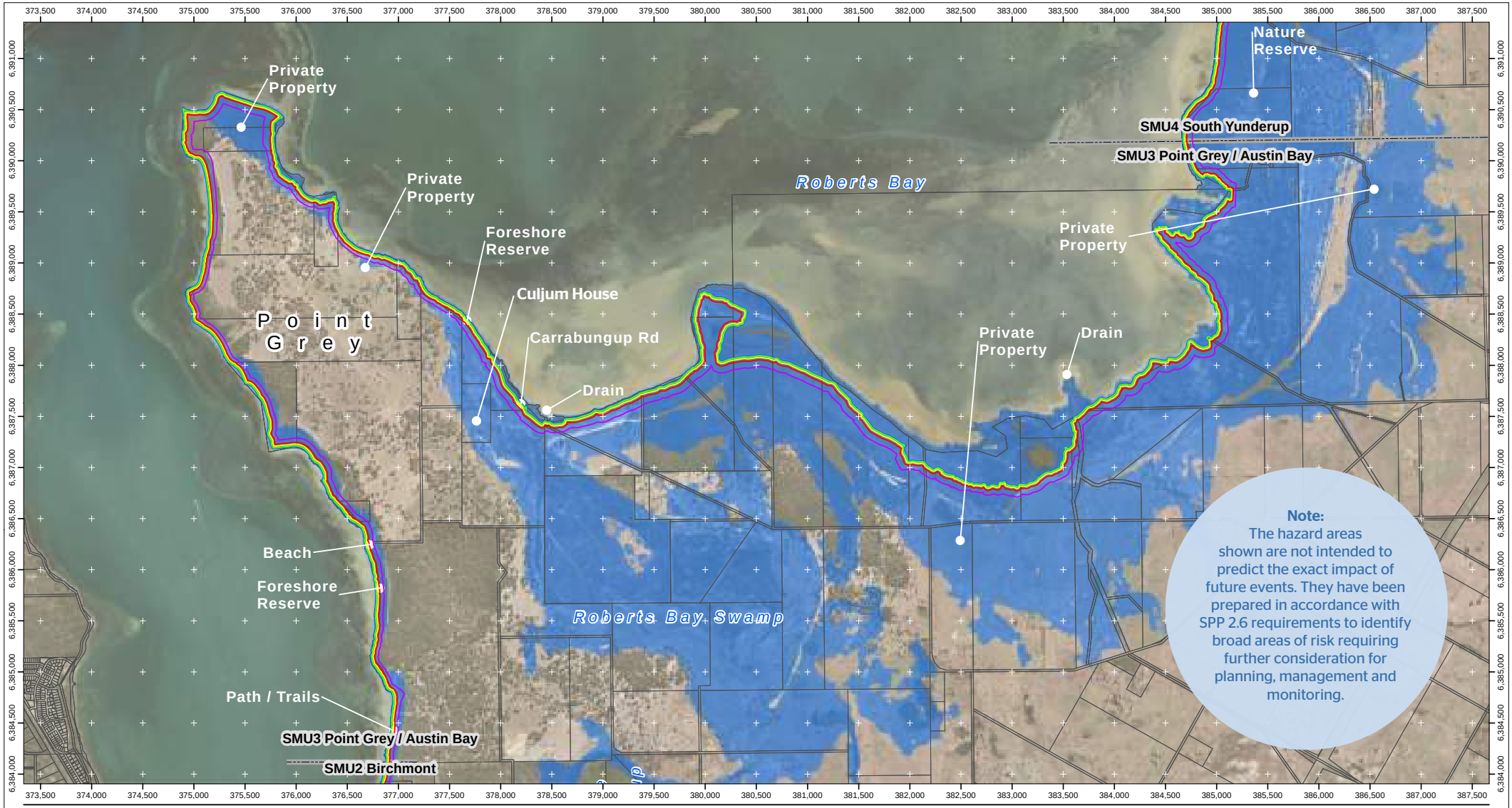
- A high rating for Carrabungup Road in 2030 and very high from 2050 onwards. For the beach areas and drainage features these are also rated highly vulnerable to erosion from 2030 onwards.
- Foreshore reserve, coastal pathways and agricultural land are rated moderate in 2030 and highly vulnerable by 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.

Inundation

The findings of the inundation assessment were:

Most of the coast assets were rated low to moderate, with the exception of:

- Carrabungup Rd which is rated highly vulnerable through all planning periods. The Carrabungup 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 then very highly vulnerable thereafter under projected sea-level rise. This is primarily based on the understanding that increasing salt-water intrusion is a major threat to the ecological character of Roberts Bay swamp.



Legend

Inundation

Coastal Processes Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

N W E S

0 200 metres

Source Data

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SMU 3 – Point Grey / Austin Bay

Shire of Murray
Coastal Hazard Flood Mapping

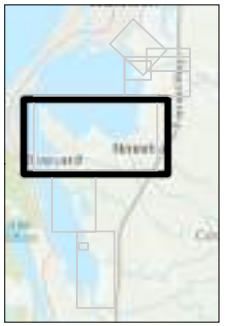
500yr ARI Design Storm in Planning year 2120

Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

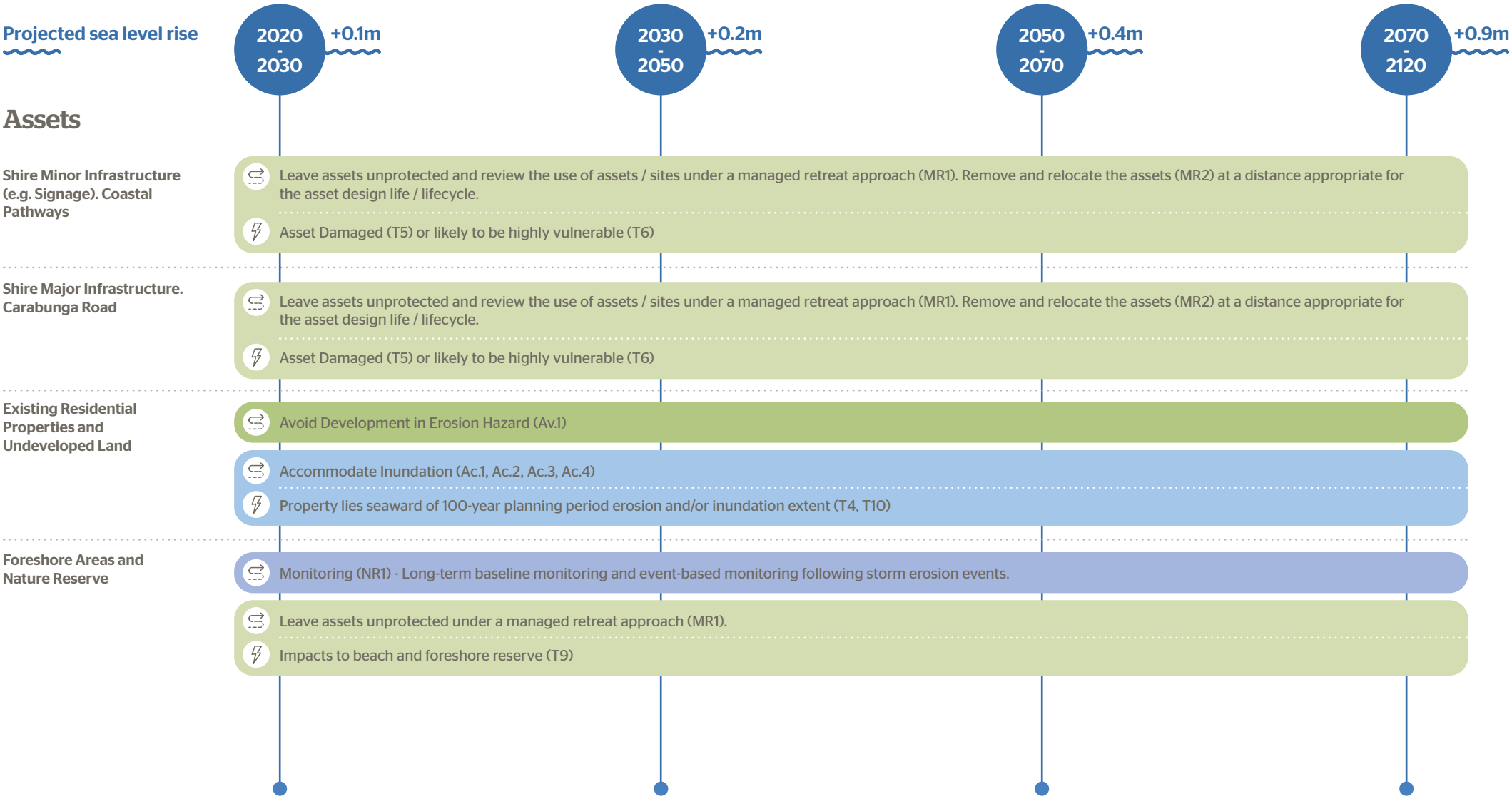
Mapping prepared by Baird.

Map Published: 15 Sep. 2022



Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing | Pathways | Trigger

Risk management and adaptation pathways



Erosion Vulnerability ratings

		2030	2050	2070	2120
1	Beach areas	High	High	Very High	Very High
2	Foreshore Nature Reserve	Medium	High	High	High
3	Austin Bay Nature Reserve	Medium	High	High	High
4	Foreshore Reserve	Medium	High	High	High
5	Coastal Pathways / Bridle Paths	Medium	High	High	High
6	Residential Properties	Medium	Medium	High	Very High
7	Agricultural Properties	Medium	High	High	Very High
8	Minor Infrastructure (signage, fencing)	Low	Low	Medium	Medium
9	Drainage features	High	Very High	Very High	Very High
10	Roads (Carabunga Road)	High	Very High	Very High	Very High
11	Culjum House	Low	Low	Low	Low

Inundation Vulnerability ratings

		2030	2050	2070	2120
1	Beach areas	Low	Low	Low	Low
2	Foreshore Nature Reserve	Low	Low	Low	Low
3	Austin Bay Nature Reserve	Low	Low	Low	Low
4	Robert Bay Swamp	High	Very High	Very High	Very High
5	Coastal Pathways / Bridle Paths	Low	Low	Low	Low
6	Residential Properties	Low	Low	Low	Medium
7	Agricultural Properties	Low	Low	Low	Low
8	Minor Infrastructure (signage, fencing)	Low	Low	Low	Low
9	Drainage features	High	High	High	High
10	Roads (Carabunga Road)	High	High	High	High
11	Culjum House	Low	Low	Low	Medium

SMU 4

South Yunderup

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 Lakes development are included in the SMU.

SMU 4 – South Yunderup

In South Yunderup there are around 1500 private lots within the mapped at-risk areas, however the majority are impacted in the 2070 to 2120 period with sea-level rises and are due to minor flooding. There are significant implications for the dredge spoil site at Batavia Quay should the revetment fail; therefore, specific monitoring and maintenance needs to be built in to specific site management.

Erosion

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.
- 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 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.

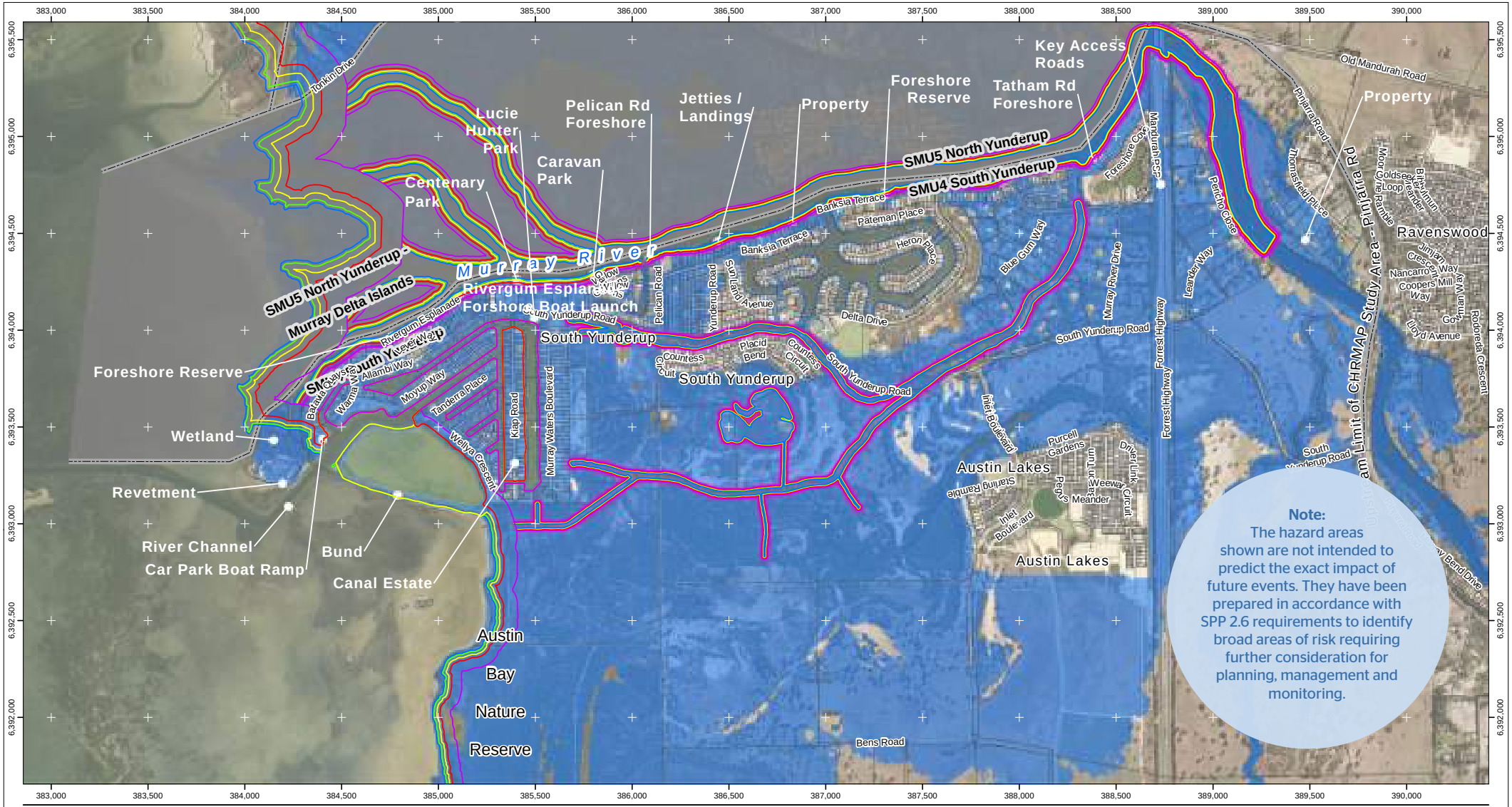
Inundation

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.
- The revetment on the Peel shoreline at the Murray entrance adjacent to 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.
- 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 (e.g. 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

Flooding over jetty

Bowser underwater during flood



Legend

- Inundation

Coastal and River Processes Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

N W E S

0 200 metres

Source Data

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SMU 4 – South Yunderup

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm in Planning year 2120

Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
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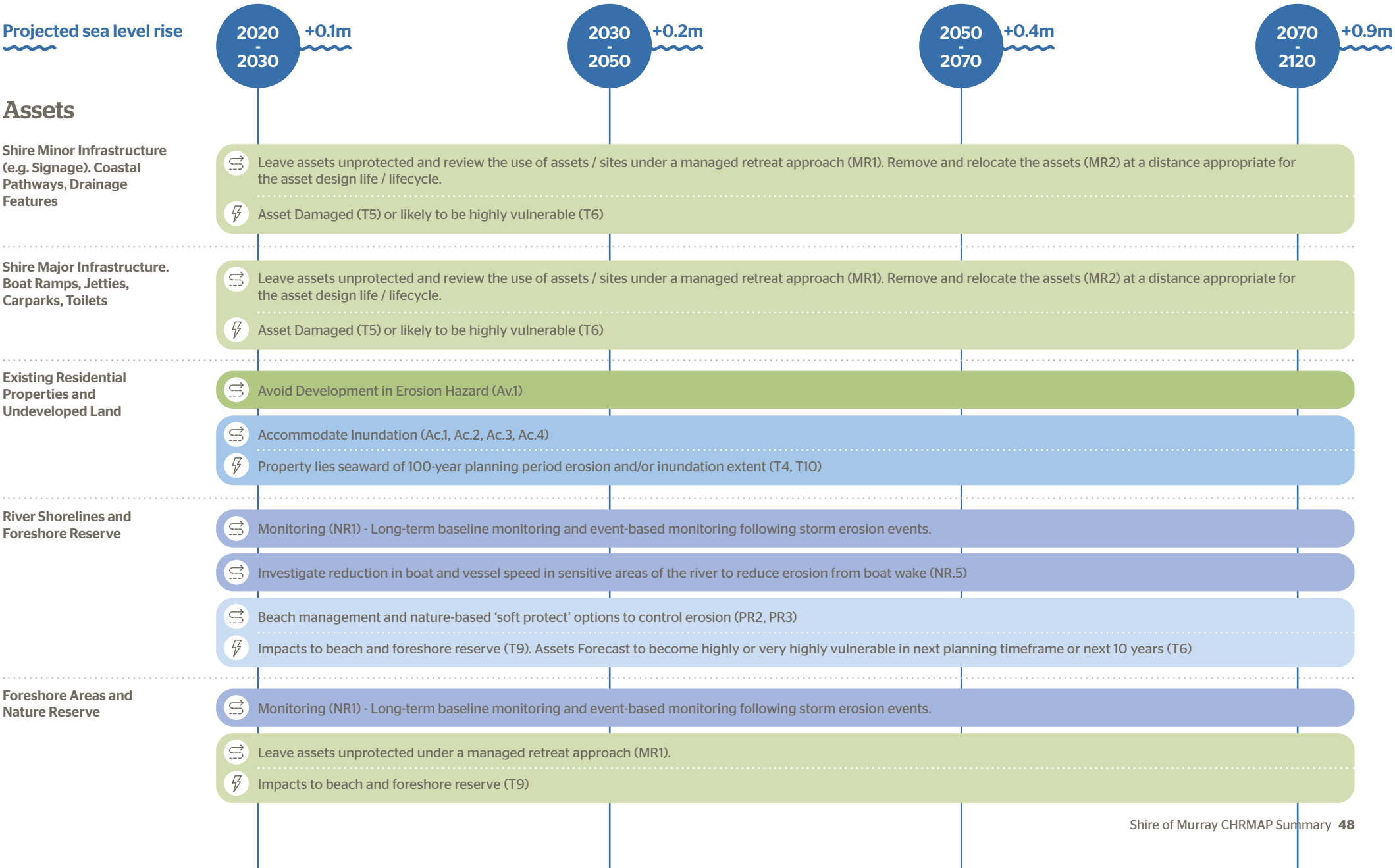
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 30 Sep. 2022

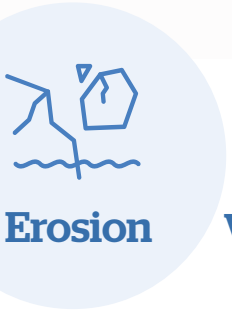
Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing | Pathways | Trigger

Risk management and adaptation pathways



	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Protection Structures and Seawalls - Batavia Quays, South Yunderup Bund, Canals	Conduct a protection structure audit (NR2) Continue to maintain the existing seawalls to provide erosion and inundation protection for areas landward (PR4) Assets predicted to become highly or very highly vulnerable within next 10 years (T6)			
Key Access Roads	Develop Emergency evacuation plan for key routes such as South Yunderup Road (NR.4)			

Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing | Pathways | Trigger



Erosion Vulnerability ratings

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

		2030	2050	2070	2120
21	Shire Jetties - Tatham Rd, Pelican Rd, Centenary Park	High	High	High	High
22	Boat Launch - Rivergum Esplanade	High	High	High	High
23	Boat Launch - Batavia Quays Launch Facility	High	High	High	High
24	Batavia Quays Club Shed	Medium	Medium	High	High
25	Toilets - Batavia Quays	Medium	Medium	Medium	High
26	Toilets - Pelican Road 4.5c	Low	Low	Low	Low
27	Car Park - Batavia Quays	High	Very High	Very High	Very High
28	Car Park - Rivergum Esplanade Foreshore	High	Very High	Very High	Very High
29	Car Park - Centenary Park	High	Very High	Very High	Very High
30	Car Park - Pelican Road 4.5c	Low	Low	Low	Low
31	Park Furniture - Centenary Park	Low	Medium	Medium	Medium
32	Playground Equipment - Centenary Park	Low	Medium	Medium	Medium
33	Park Furniture - Wellya Crescent Park 4.2	Low	Low	Low	Low
34	Playground Equipment - Wellya Crescent 4.2	Low	Low	Low	Low
35	Park Furniture - Pelican Rd Park 4.5c	Low	Low	Low	Low
36	Playground Equipment - Pelican Rd Park 4.5c	Low	Low	Low	Low
37	Park Furniture - South Yunderup Foreshore	Medium	Medium	Medium	Medium
38	Footpaths	Low	Low	Low	Low
39	Minor Infrastructure (Signage, fencing etc)	Low	Low	Low	Low
40	Drainage features (pits, pipes, culverts)	High	Very High	Very High	Very High
41	Water Corp Infrastructure	High	Very High	Very High	Very High

Inundation Vulnerability ratings

		2030	2050	2070	2120
1	Beach areas - Peel Inlet facing beach Batavia	Low	Low	Low	Low
2	Riverbanks - Murray River	Low	Low	Low	Low
3	Austin Bay Nature Reserve	Low	Low	Low	Low
4	Batavia Quays Wetland	Low	Low	Low	Low
5	Batavia Quays Dredge Spoil Site [4.1]	Low	Low	Low	Low
6	S.Y. Canal Bund - Water Quality [4.2]	Low	Low	Low	Low
7	Coastal Pathway - Bund, S.Y. canals	Low	Low	Medium	Medium
8	Coastal Pathway - Wellya Crescent Park	Low	Low	Low	Low
9	Foreshore Reserve (Tatham Rd, Rivergum Esplanade, Centenary Park)	Low	Low	Low	Low
10	Coastal Pathways Murray River (Tatham Rd, Rivergum Esplanade)	Low	Low	Low	Low
11	Coastal Pathway, Batavia Quay Headland [4.1]	Low	Low	Low	Low
12	Res. Properties South Yunderup Canal	Low	Low	Low	Medium
13	Res. Properties Placid Bend, Chipper Way, Countess Circuit	Low	Low	Low	Medium
14	Res. Properties Batavia Quay	Low	Low	Low	Medium
15	Res. Properties Warma Wy to Young Rd	Low	Low	Low	Medium
16	Res. Properties Young Rd to Strain Glen	Low	Low	Medium	High
17	Res. Properties Pelican Rd, Banksia Terrace	Low	Low	Medium	High
18	Tathams, Murray River Caravan Park	Low	Low	Medium	Medium
19	Jetties and Moorings Privately Held	Low	Low	Low	Medium
20	Minor Roads (Rivergum Esplanade, Young Rd, Strain Glen, Pelican Rd, Banksia Tce)	Medium	Medium	Medium	High
21	Shire Jetties - Tatham Rd, Pelican Rd, Centenary Park	Low	Low	Low	Low
22	Boat Launch - Rivergum Esplanade	Low	Low	Low	Low
23	Boat Launch - Batavia Quays Launch Facility	Low	Low	Low	Low
24	Batavia Quays Club Shed	Low	Low	Low	Medium
25	Toilets - Batavia Quays	Low	Low	Low	Medium
26	Toilets - Pelican Road	Low	Low	Low	Low
27	Car Park - Batavia Quays	Low	Low	Low	Low
28	Car Park - Rivergum Esplanade Foreshore	Low	Low	Low	Low
29	Car Park - Centenary Park	Low	Low	Low	Low
30	Car Park - Pelican Road	Low	Low	Low	Low
31	Park Furniture - Centenary Park	Low	Low	Low	Low
32	Playground Equipment - Centenary Park	Low	Low	Low	Low
33	Park Furniture - Wellya Crescent Park [4.2]	Low	Low	Low	Low
34	Playground Equipment - Wellya Crescent	Low	Low	Low	Low
35	Park Furniture - Pelican Rd Park	Low	Low	Low	Low
36	Playground Equipment - Pelican Rd Park	Low	Low	Low	Low
37	Park Furniture - South Yunderup Foreshore	Low	Low	Low	Low
38	Footpaths	Low	Low	Low	Low
39	Minor Infrastructure (Signage, fencing etc)	Low	Low	Low	Low
40	Drainage features (pits, pipes, culverts)	Low	Low	Low	Low
41	Water Corp Infrastructure	Low	Low	Low	Low
42	Residential Properties Murray River Drive, Leander Way, Pericho Close [4.4]	Low	Low	Low	Medium
43	Agricultural / Vacant Land - Beacham Rd to Austin Cove [4.4]	Low	Low	Low	Medium
44	Major Roads (South Yunderup Road, Forrest Highway)	Low	Medium	Medium	High
45	South Yunderup Fire Station	Low	Low	Low	Low
46	Toilets - Centenary Park	Low	Low	Low	Medium
47	Car Park - Willow Gardens	Low	Low	Low	Low
48	Car Park - Fire Station	Low	Low	Low	Low
49	Park Furniture - Lucie Hunter Park	Low	Low	Low	Low

SMU 5

North Yunderup & 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.

Storm surge in North Yunderup

SMU 5 – North Yunderup and 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.

In this SMU there are around 300 lots impacted by erosion and inundation scenario mapping, this includes 89 private lots on the Murray Delta Islands and four heritage sites being Coopers Mill, CWA Hall, Windsor Park Estate and just outside SMU5 the Ravenswood Hotel. A number of these lots are impacted at present by minor flooding and the impacts can potentially rise in the short term.

Erosion

The erosion vulnerability assessment showed:

- 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 to 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.

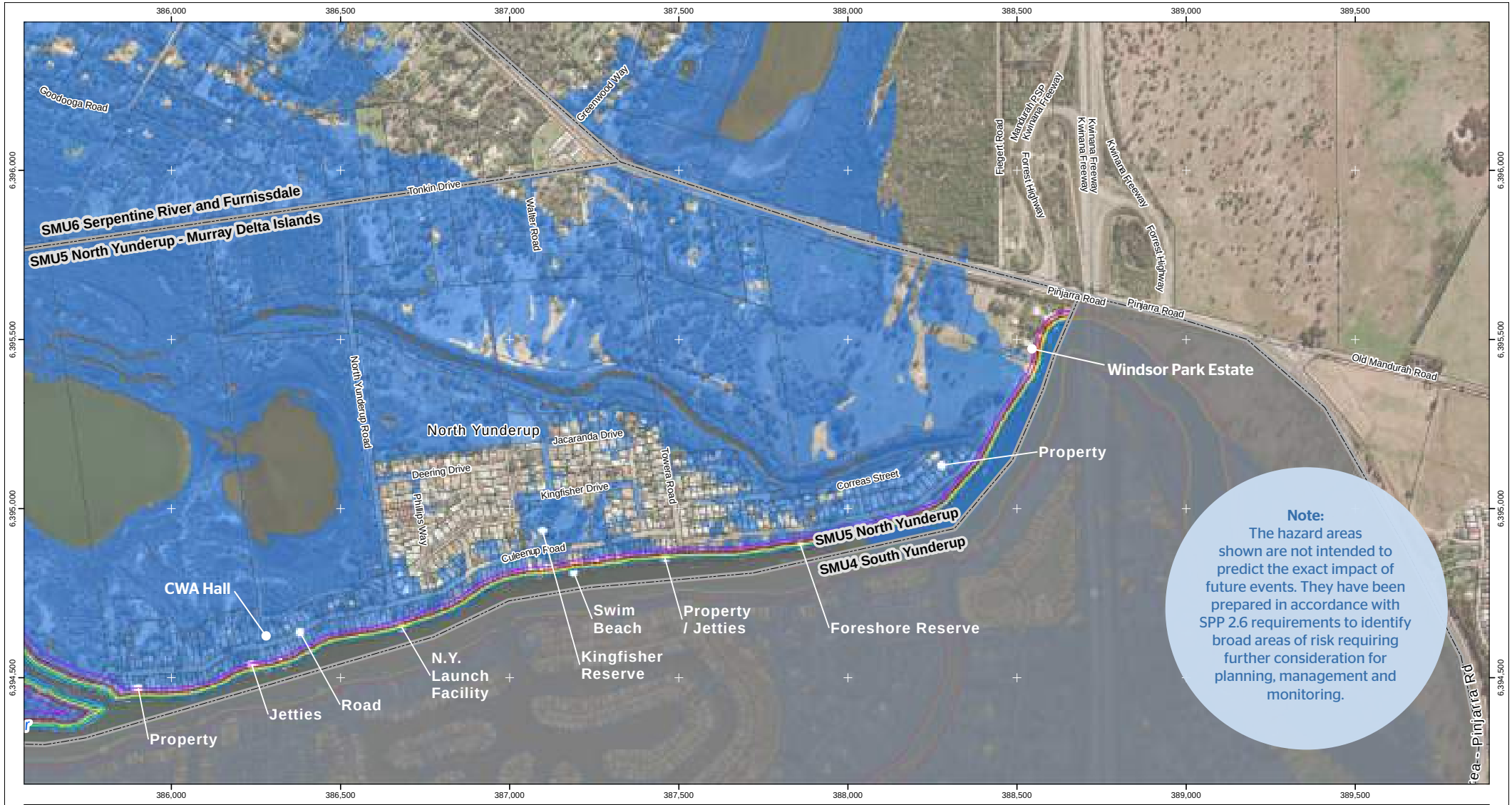
Inundation

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 rises. 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 (e.g. pad height of developed properties). It is noted that the land area around the house is generally at a lower elevation.
- 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.

Cooleenup Island is also the location of the heritage-listed Coopers Mill which is unique in Western Australia and currently impacted by storm surge and inundation.

Cooper's Mill 1910, published in the Western Mail by E.L. Mitchell



Legend

- Inundation

Coastal and River Processes Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

N, W, E, S

0 200 metres

Source Data

Inundation areas defined from LiDAR datasets collected in 2008 (DWER) and 2016 (Landgate) through the Shire of Murray. Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

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Disclaimer

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SMU 5 – North Yunderup

Shire of Murray
Coastal Hazard Flood Mapping

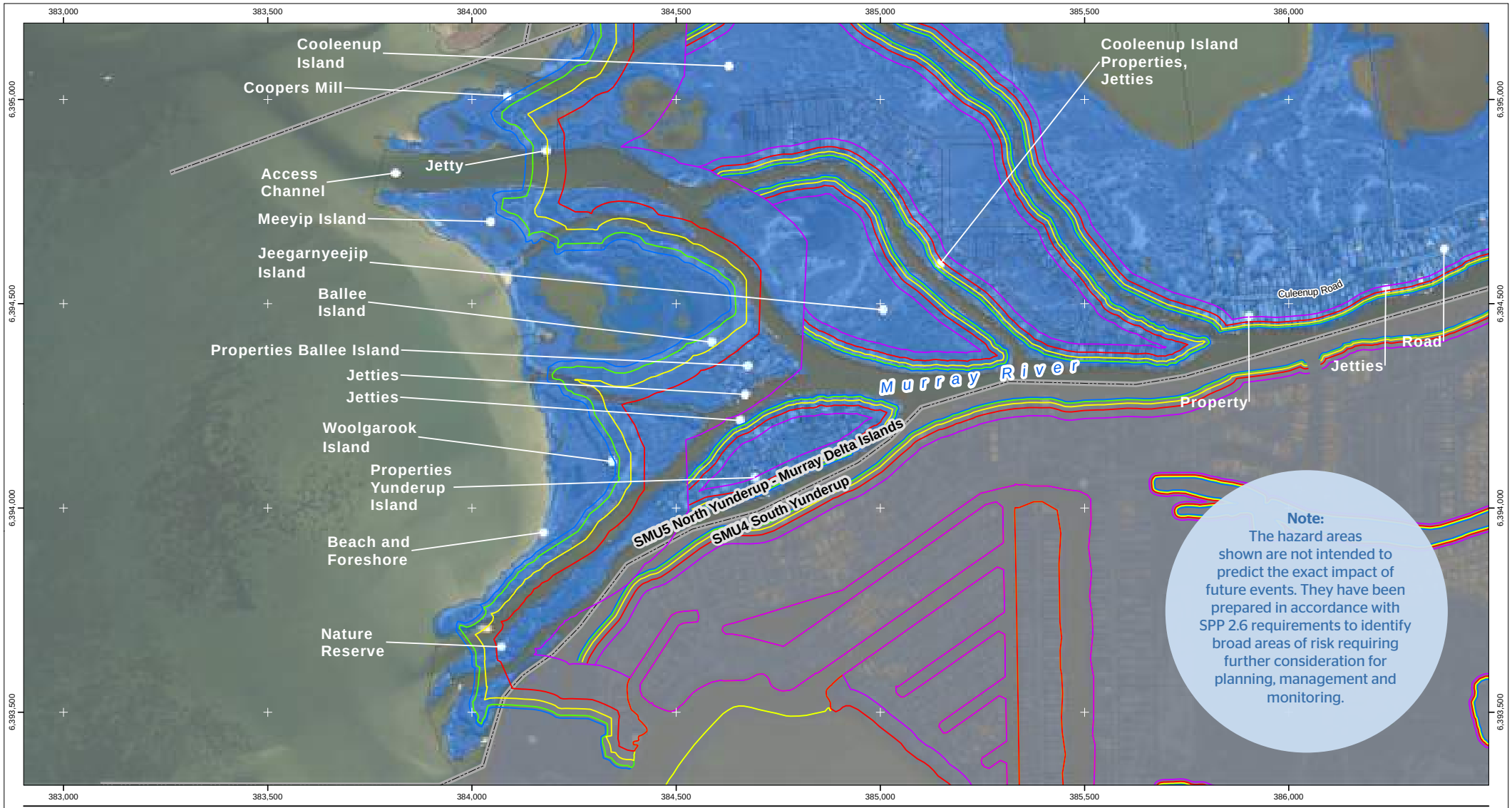
500yr ARI Design Storm in Planning year 2120

Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 28 Sep. 2022



Legend

Inundation

Coastal and River Processes Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

N W E S

0 200 metres

Source Data

Inundation areas defined from LiDAR datasets collected in 2008 (DWER) and 2016 (Landgate) through the Shire of Murray. Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

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Disclaimer

The hazard areas depicted in this map are presented as potential inundation and coastal processes areas of impact based on SPP2.6 requirements. These future scenarios are based on work presented in Seashore 2021 and used to inform areas requiring further consideration for planning, management and monitoring in CHRMAP.

SMU 5 – North Yunderup – Murray Delta Islands

Shire of Murray
Coastal Hazard Flood Mapping

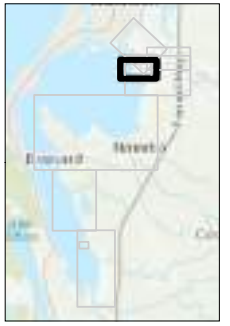
500yr ARI Design Storm in Planning year 2120

Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

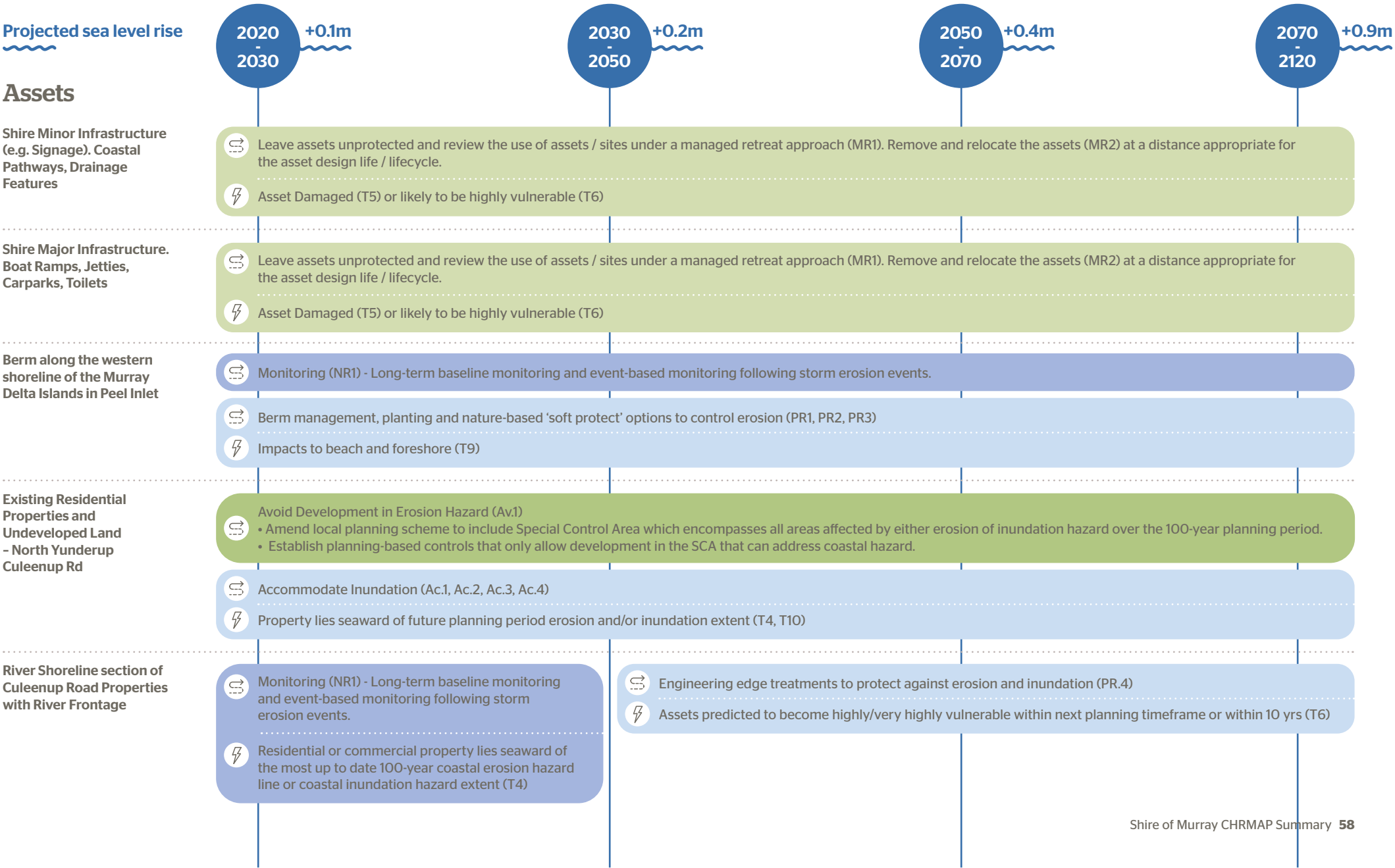
Map Published: 30 Sep. 2022

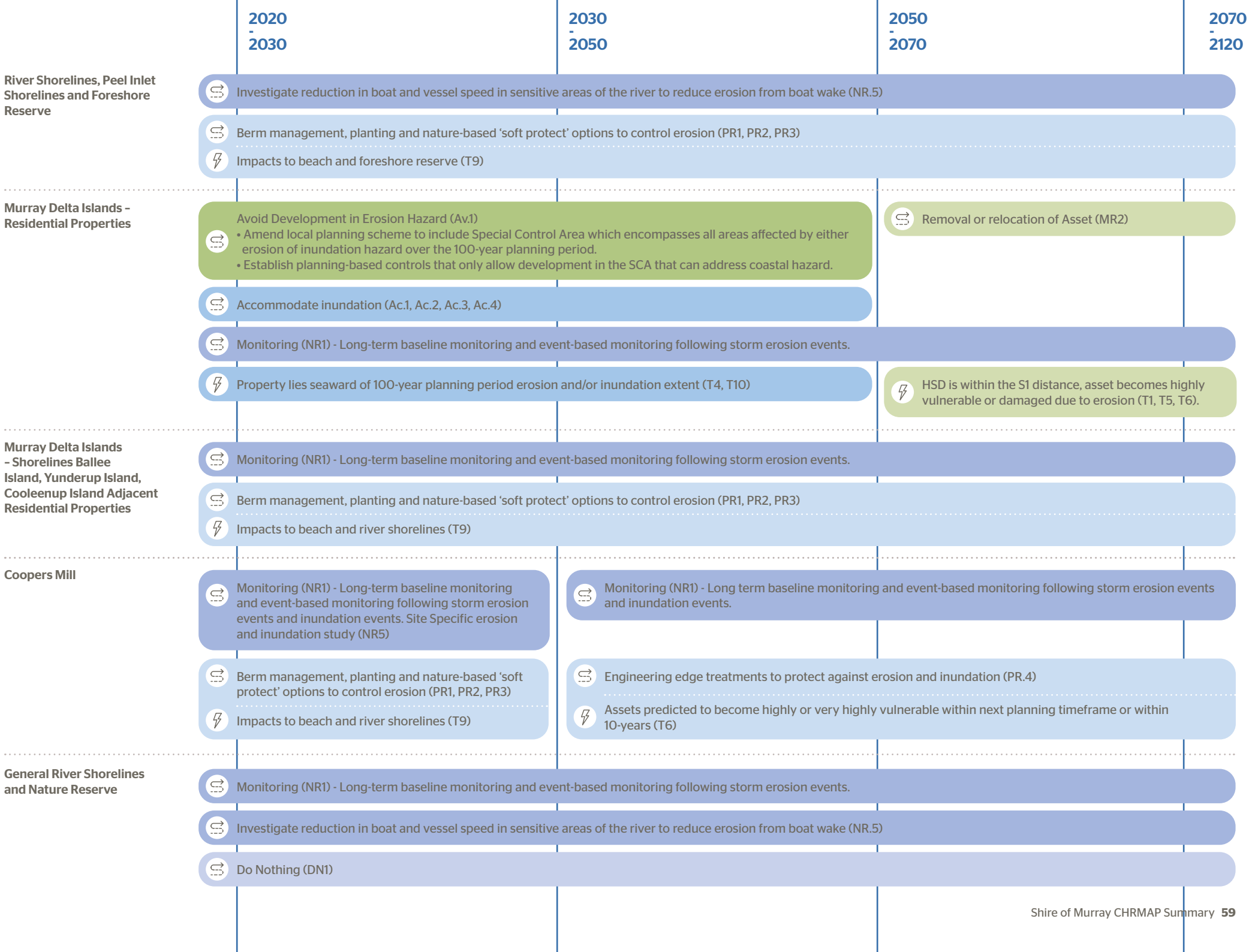


Flooding at Coopers Mill during Tropical Cyclone Seroja storm event in May 2021 as a result of storm surge.

Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing | Pathways | Trigger

Risk management and adaptation pathways




2020 - 2030
2030 - 2050
2050 - 2070
2070 - 2120
River Shorelines, Peel Inlet Shorelines and Foreshore Reserve
Investigate reduction in boat and vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)
Berm management, planting and nature-based 'soft protect' options to control erosion (PR1, PR2, PR3)
Impacts to beach and foreshore reserve (T9)
Murray Delta Islands – Residential Properties
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)
Accommodate inundation (Ac.1, Ac.2, Ac.3, Ac.4)
Monitoring (NR1) - Long-term baseline monitoring and event-based monitoring following storm erosion events.
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).
Murray Delta Islands – Shorelines Ballee Island, Yunderup Island, Cooleenup Island Adjacent Residential Properties
Monitoring (NR1) - Long-term baseline monitoring and event-based monitoring following storm erosion events.
Berm management, planting and nature-based 'soft protect' options to control erosion (PR1, PR2, PR3)
Impacts to beach and river shorelines (T9)
Coopers Mill
Monitoring (NR1) - Long-term baseline monitoring and event-based monitoring following storm erosion events and inundation events. Site Specific erosion and inundation study (NR5)
Monitoring (NR1) - Long term baseline monitoring and event-based monitoring following storm erosion events and inundation events.
Berm management, planting and nature-based 'soft protect' options to control erosion (PR1, PR2, PR3)
Impacts to beach and river shorelines (T9)
Engineering edge treatments to protect against erosion and inundation (PR.4)
Assets predicted to become highly or very highly vulnerable within next planning timeframe or within 10-years (T6)
General River Shorelines and Nature Reserve
Monitoring (NR1) - Long-term baseline monitoring and event-based monitoring following storm erosion events.
Investigate reduction in boat and vessel speed in sensitive areas of the river to reduce erosion from boat wake (NR.5)
Do Nothing (DN1)

	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Key Access Roads	Develop Emergency evacuation plan for key routes such as North Yunderup Road (NR.4) Assets predicted to become highly or very highly vulnerable within next 10-years (T6)		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. Asset is damaged or unsafe (T5)	

Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing

Pathways | Trigger

Erosion Vulnerability ratings

		2030	2050	2070	2120
1	Beaches, Peel Inlet Murray Delta Islands	High	Very High	Very High	Very High
2	Riverbank - Delta Islands and Murray River	High	Very High	Very High	Very High
3	Nature Reserve, West end Yunderup Island	Medium	High	High	High
4	Ballee Island Wetland	High	High	High	High
5	Pathway - Culeenup Rd east of Towerup St	Medium	Medium	High	High
6	Foreshore Reserve - Culeenup Rd	Medium	High	High	High
7	Foreshore Reserve - Yunderup Island, Ballee Island, Cooleenup Island	Medium	High	High	High
8	Residential Properties North Yunderup, Culeenup Rd	Very High	Very High	Very High	Very High
9	Residential Properties Thomasfield Pl, Ravenswood	Medium	High	Very High	Very High
10	Residential Properties Yunderup Island	Medium	High	Very High	Very High
11	Residential Properties Ballee Island	High	Very High	Very High	Very High
12	Residential Properties Cooleenup Island	High	Very High	Very High	Very High
13	Jetties and Moorings - Privately Held	Medium	Medium	Medium	Medium
14	Minor Roads Culeenup Rd West [5.3b]	Low	Low	Low	Medium
15	Shire Jetties - Culeenup Rd, Coopers Mill Precinct, North Yunderup Launch Facility.	High	High	High	High
16	Boat Launch - North Yunderup Launch	High	High	High	High
17	Toilets - Coopers Mill Precinct	High	High	High	High
18	Car Park - North Yunderup Launch Facility	Medium	High	High	Very High
19	Park Furniture - North Yunderup Foreshore	Low	Medium	Medium	Medium
20	Park Furniture- North Yunderup Launch	Low	Low	Low	Medium

Nature-based solutions

		2030	2050	2070	2120
21	Park Furniture - Coopers Mill Precinct	Medium	Medium	Medium	Medium
22	Playground Equipment - Coopers Mill	Medium	Medium	Medium	Medium
23	Footpaths	Low	Low	Low	Low
24	Minor Infrastructure (Signage, fencing etc)	Low	Low	Low	Low
25	Drainage features (pits, pipes, culverts)	High	Very High	Very High	Very High
26	WaterCorp Infrastructure	High	Very High	Very High	Very High
27	Coopers Mill	Very High	Very High	Very High	Very High
28	Coopers Mill Caretakers House	Medium	High	High	High
29	Windsor Park Estate	Medium	High	Very High	Very High

Inundation Vulnerability ratings

		2030	2050	2070	2120
1	Beaches, Peel Inlet Murray Delta Islands	Low	Low	Low	Low
2	Riverbank - Delta Islands and Murray River	Low	Low	Low	Low
3	Nature Reserve, West end Yunderup Island	Low	Low	Low	Low
4	Ballee Island Wetland	Low	Low	Low	Low
5	Foreshore Reserve - Culeenup Rd Towerup	Low	Low	Low	Low
6	Foreshore Reserve - Yunderup Island, Ballee Island, Cooleenup Island	Low	Low	Low	Low
7	Residential Properties North Yunderup, Culeenup Rd	Low	Low	Low	Medium
8	Residential Properties Thomasfield Pl, Ravenswood [5.1]	Low	Low	Low	Medium
9	Rural Properties Pinjarra Rd, Tonkin Drv, Walter Rd [5.1]	Low	Low	Low	Medium
10	Residential Properties Thomasfield Pl, Ravenswood [5.1]	Low	Low	Low	Medium
11	Residential Properties Yunderup Island	Medium	High	High	Very High
12	Residential Properties Ballee Island	Medium	High	High	Very High
13	Residential Properties Cooleenup Island	High	High	High	Very High
14	Septic Systems Yunderup Island	High	High	High	High
15	Septic Systems Ballee Island	High	High	High	High
16	Septic Systems Cooleenup Island	High	High	High	High
17	Jetties and Moorings along River Privately	Low	Low	Low	Low
18	Minor Roads (Culeenup Rd - Western end)	Low	Medium	Medium	High
19	Major Roads (Pinjarra Rd, Forrest Hwy)	Low	Low	Low	Medium
20	Shire Jetties - Culeenup Rd, Coopers Mill Precinct, North Yunderup Launch Facility.	Low	Low	Low	Low

		2030	2050	2070	2120
21	Boat Launch - N.Y Launch Facility	Low	Low	Low	Low
22	Toilets - Kingfisher Park	Low	Low	Low	Low
23	Toilets - Coopers Mill Precinct	Low	Low	Medium	Medium
24	Toilets - North Yunderup Launch Facility	Low	Low	Low	Medium
25	Car Park - North Yunderup Launch Facility	Low	Low	Low	Low
26	Park Furniture - North Yunderup Foreshore	Low	Low	Low	Low
27	Park Furniture - North Yunderup Launch	Low	Low	Low	Low
28	Park Furniture - Coopers Mill Precinct	Low	Low	Low	Low
29	Playground Equipment - Coopers Mill	Low	Low	Low	Low
30	Park Furniture - Kingfisher Park	Low	Low	Low	Low
31	Playground Equipment - Kingfisher Park	Low	Low	Low	Low
32	Footpaths	Low	Low	Low	Low
33	Minor Infrastructure (Signage, fencing etc)	Low	Low	Low	Low
34	Drainage features (pits, pipes, culverts)	High	High	High	High
35	WaterCorp Infrastructure	High	High	High	High
36	Coopers Mill	High	High	High	High
37	Coopers Mill Caretakers House	Medium	Medium	Medium	High
38	CWA Hall North Yunderup	Low	Low	Medium	Medium

SMU 6

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.

SMU 6 – Serpentine River and Furnissdale

The SMU is a mix of residential and large rural and semi-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. In total there are around 500 properties within the mapped at-risk areas and the majority of the impacts are in the 2070 to 2120 period with sea-level rises causing minor flooding.

Erosion

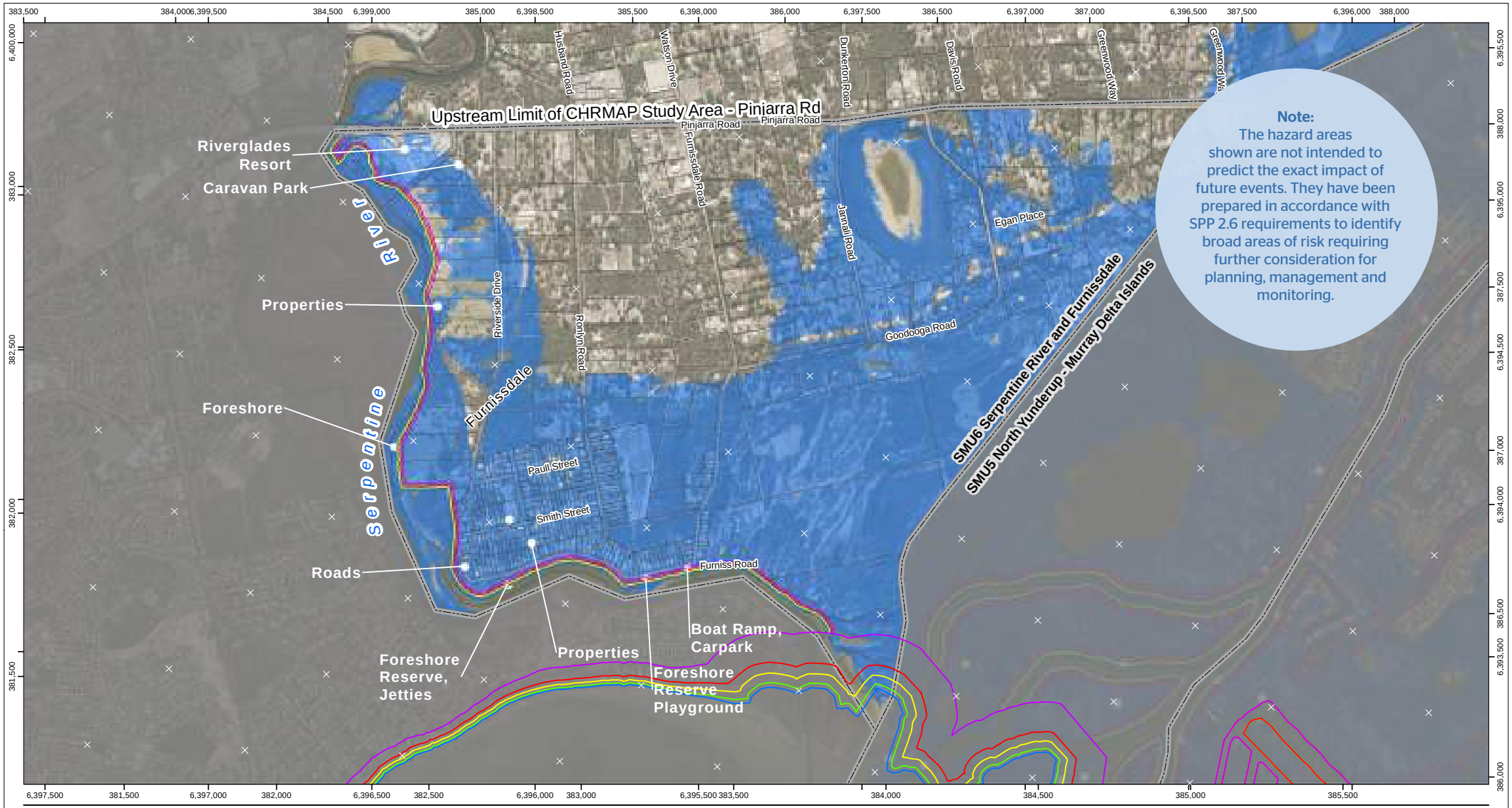
The erosion vulnerability assessment showed:

- 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.

Inundation

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.



Legend

- Inundation
- **Coastal and River Processes Setbacks**
  - 2020
  - 2030
  - 2050
  - 2070
  - 2120

0 200 metres

Source Data
Inundation areas defined from LiDAR datasets collected in 2008 (DWER) and 2016 (Landgate) through the Shire of Murray. Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.
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The hazard areas depicted in this map are presented as potential inundation and coastal processes areas of impact based on SPP2.6 requirements. These future scenarios are based on work presented in Seashore 2021 and used to inform areas requiring further consideration for planning, management and monitoring in CHRMAP.

SMU 6 – Serpentine River and Furnissdale

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm in Planning year 2120

Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

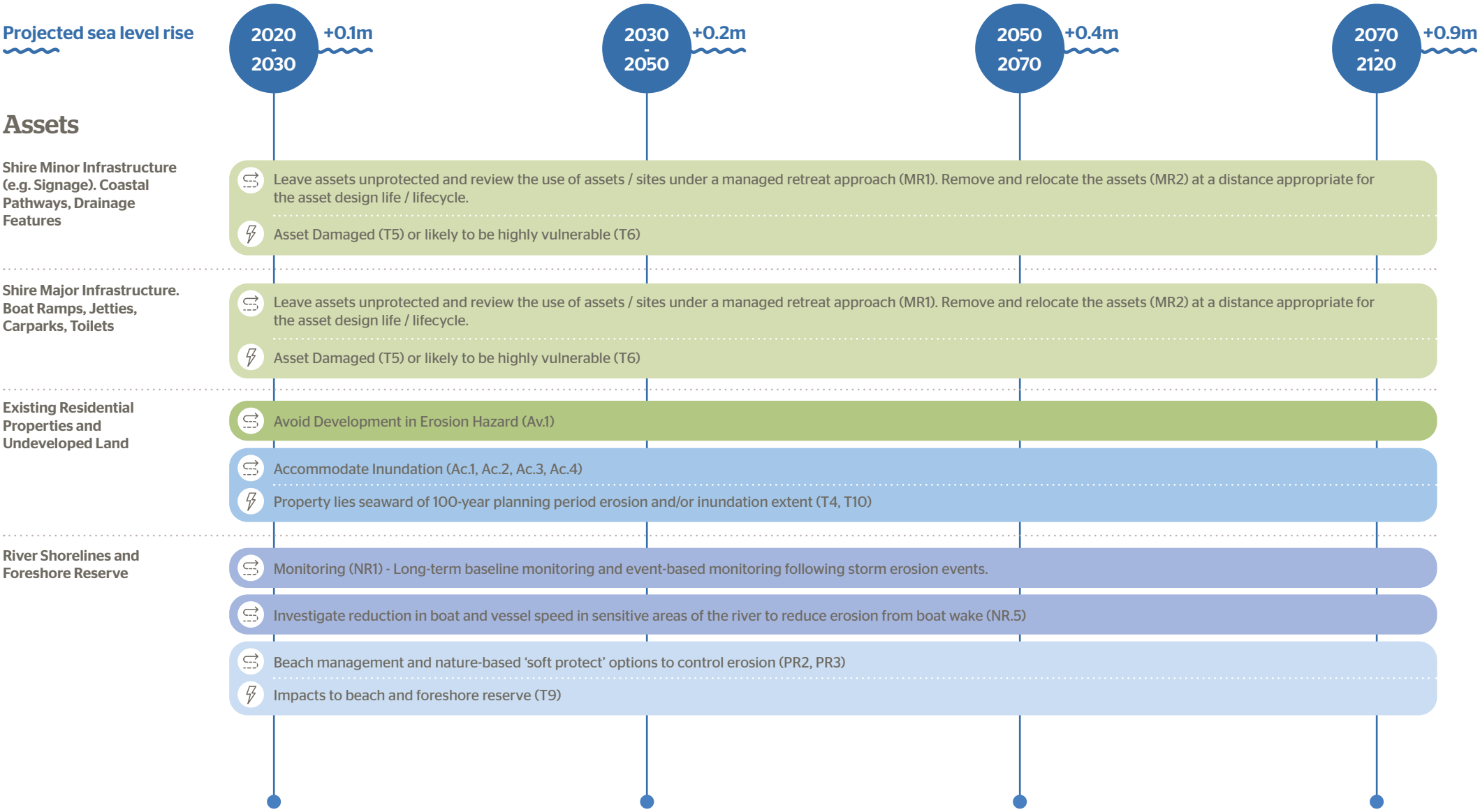
Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 28 Sep. 2022

Avoid | Planned/Managed Retreat | Accommodate | Protect | No Regrets | Do Nothing | Pathways | Trigger

Risk management and adaptation pathways



Erosion Vulnerability ratings

		2030	2050	2070	2120
1	Riverbank - Serpentine River	High	Very High	Very High	Very High
2	Foreshore Reserve - Furnissdale Foreshore	Medium	High	High	High
3	Residential Properties Riverside Drive along	Medium	Medium	Medium	Medium
4	Residential Properties along Serpentine	High	Very High	Very High	Very High
5	Residential Properties Riverside Drive Smith	Medium	High	Very High	Very High
6	Residential Properties Riverside Drive NE of Paull St	High	Very High	Very High	Very High
7	River Glades Resort	Medium	High	High	High
8	Jetties and Moorings along River - Private	Medium	Medium	Medium	Medium
9	Minor Roads (Riverside Drive Near Smith St)	High	Very High	Very High	Very High
10	Shire Jetties - Furnissdale Launch Facility, Floating Jetty	Medium	High	High	High
11	Shire Jetties - Furnissdale Launch Facility, Timber Jetty	Medium	High	High	High
12	Shire Jetties - Tonkin Drive Foreshore, Timber Jetty	Medium	High	High	High
13	Boat Ramp - Furnissdale Launch Facility	Medium	High	High	High
14	Car Park - Furnissdale Launch Facility	High	High	Very High	Very High
15	Car Park - Riverside Drive	Medium	Medium	High	High
17	Car Park - Tonkin Drive Foreshore	High	Very High	Very High	Very High
18	Car Park - Furnissdale Bridge Foreshore [6.3a]	Low	Low	Low	Medium
19	Park Furniture - Furnissdale Launch Facility Foreshore Reserve	Low	Medium	Medium	Medium
20	Playground Equipment - Furnissdale Foreshore	Low	Medium	Medium	Medium

		2030	2050	2070	2120
21	Footpaths	Low	Low	Low	Low
22	Minor Infrastructure (Signage, fencing etc)	Low	Low	Low	Low
23	Drainage features (pits, pipes, culverts)	High	Very High	Very High	Very High
24	WaterCorp Infrastructure	Medium	High	High	Very High

Inundation Vulnerability ratings

		2030	2050	2070	2120
1	Riverbank - Serpentine River	Low	Low	Low	Low
2	Foreshore Reserve - Furnissdale Foreshore	Low	Low	Low	Low
3	Residential Properties Riverside Drive along Furnissdale Foreshore	Medium	Medium	Medium	High
4	Residential Properties along Serpentine River, Tonkin Drive to Furnissdale Road	Low	Low	Low	Medium
5	Residential Properties Riverside Drive Smith St to Paull St	Low	Medium	Medium	High
6	Residential Properties Riverside Drive NE of Paull St [6.1]	Low	Medium	Medium	High
7	Rural Properties Pinjarra to Goodooga Rd [6.1]	Low	Low	Low	Medium
8	Caravan Park	Low	Low	Low	Low
9	Riverglades Resort	Low	Low	Low	Low
10	Jetties and Moorings along River - Privately	Low	Low	Low	Low
11	Minor Roads (Riverside Drive Near Smith St)	High	High	High	High
12	Minor Roads (Riverside Drive foreshore, Furnissdale Rd, Ronlyn Rd)	Medium	Medium	High	High
13	Major Roads (Pinjarra Rd)	Low	Low	Low	Low
14	Shire Jetties - Furnissdale Launch Facility, Floating Jetty	Low	Low	Low	Low
15	Shire Jetties - Furnissdale Launch Facility, Timber Jetty	Low	Low	Low	Low
16	Shire Jetties - Tonkin Drive Foreshore, Timber Jetty	Low	Low	Low	Low
17	Boat Ramp - Furnissdale Launch Facility	Low	Low	Low	Low
18	Toilets - York Road	Low	Low	Low	Low
19	Car Park - Furnissdale Launch Facility	Low	Low	Low	Low

		2030	2050	2070	2120
20	Car Park - Riverside Drive	Low	Low	Low	Low
21	Car Park - Tonkin Drive Foreshore	Low	Low	Low	Low
22	Car Park - Furnissdale Bridge Foreshore	Low	Low	Low	Low
23	Park Furniture - Furnissdale Launch Facility	Low	Low	Low	Low
24	Playground Equipment - Furnissdale	Low	Low	Low	Low
25	Park Furniture - York Road Park	Low	Low	Low	Low
26	Playground Equipment - York Road Park	Low	Low	Low	Low
27	Footpaths	Low	Low	Low	Low
28	Minor Infrastructure (Signage, fencing etc)	Low	Low	Low	Low
29	Drainage features (pits, pipes, culverts)	High	High	High	High
30	WaterCorp Infrastructure	High	High	High	High
31	York Road Clubrooms and Sports Courts	Low	Low	Low	Medium

6

Managing the Shire of Murray shoreline areas

Community and stakeholder preferences

Multi-criteria assessment

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.

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. For each of the focus locations, the range of risk-mitigation approaches were discussed. Outcomes agreed in the sessions can be seen here.

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** North and South Yunderup, including Murray Delta Islands	**Septic tanks**
Highest ranked	A nature-based solutions approach	Planning-based approaches for housing design	Nature-based solutions (soft-edge treatments)	Upgrade to Centralised ATU was the highest ranked
Second highest-scoring	Managed Retreat with purchase of land areas followed by the Do-Nothing option	Managed-Retreat followed by the option to examine housing design using fill	Managed Retreat	Connecting to Mains Sewage

Economic assessment - Cost benefit analysis

The Cost Benefit Analysis (CBA) followed 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 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.

Key mitigation measures that 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

The benefits for the mitigation options were considered in terms of the protection provided for both erosion and inundation of properties. Economic values were estimated for 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 key findings from the CBA in terms of supporting CHRMAP recommendations for adaptation options in the CMU's is summarised as follows:

Murray Delta Islands

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.

The Murray River shoreline of North Yunderup

Nature-based solutions perform well due to the density of properties, however there may be practical challenges due to the available space in this area. 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.

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.

Monitoring of the shoreline areas and their response to sea-level rise in the coming years will inform the future adaptation strategy for the shoreline areas.

Benefit distribution analysis

A high level benefit distribution analysis was completed to understand the key beneficiaries for the proposed mitigation options. This concluded that the key beneficiaries are private landowners and the Shire of Murray (through the public assets such as reserves).

It is recommended the Shire seek funding contribution from private landholders who will directly benefit from the adaptation approaches. For the proportion of the public benefit for each respective adaptation option these would be funded by the Shire.

There are several funding mechanisms at State and Federal level available to the Shire to support the adaptation approaches which can provide public benefit. These are generally based on a co-funded approach whereby the Shire contributes 50% of the funding which is matched. It is also recommended that the Shire advocate for:

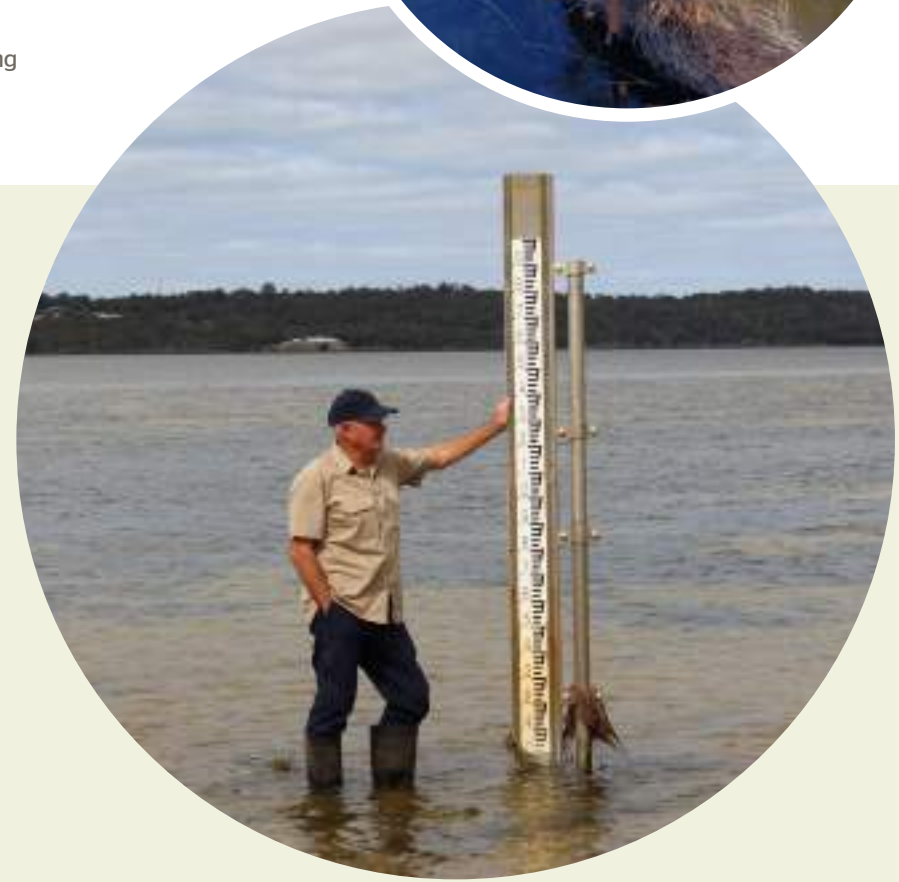
- a suitable financial mechanism to be put in place at the State or National level to provide funding to enable private land-owners to progressively transition from areas that will become highly vulnerable to coastal processes in future under projected sea level rise; and
- for research on the adverse impacts of the Dawesville Cut and for funding to address erosion and inundation impacts that are considered to have occurred as a result of changes to the estuary following the opening of the Dawesville Cut.

Monitoring

To further understanding of the coastal processes in the Shire and support the aims of the CHRMAP, a structured monitoring process will be developed to target key locations 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 where a change in management pathway may be required.

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 five years, would be used to implement the findings from the monitoring
program and address updates to the CHRMAP recommendations where required.

A key feature of the monitoring is the capture of aerial survey data using a drone (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.



Priority recommendations for action

Implementation Actions

The short-term implementation actions over the period 2022 to 2040 include recommendations for:

a. Planning Actions

b. Annual Monitoring Program

c. Additional Technical Studies

d. Additional Planning Based Studies and Adaptation Studies

e. Adaptation Actions in Shoreline Areas

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

Planning Implementation

There are a number of planning recommendations in the short-term which involve updates to existing planning instruments and development of new policies. The key items and indicative timeframe are as follows:

Initiate amendment to LPS4 to introduce a Special Control Area (immediately)

Prepare a Local Planning Policy (immediately)

Prepare a building and development guideline

Prepare an Emergency Evacuation Plan (next 5-years)

Prepare a Foreshore Management Plan (next 5-years)

Prepare a Managed Retreat Policy (6 – 10 years)

Nature based erosion protection: walling example. Image credit: Peel-Harvey Catchment Council.

Management of shoreline areas over the next 10 years

The use of nature based erosion protection to protect against erosion of shorelines is recommended for:

South Yunderup Foreshore

Ballee Island

Cooleenup Island

Yunderup Island

Coopers Mill

Approx. cost **$1.09m - $3m**

Potential co-funding through Grants (e.g.. Dept of Transport, Coastwest)

Foreshore Management at South Yunderup and Murray Delta Islands - recommended approaches, indicative cost and timing

SMU 5 Ballee Island

Where Shoreline adjacent developed properties

What Application of nature-based revegetation and foreshore stabilisation techniques

$50k - $130k

Year 1

SMU 4 South Yunderup

Where Shoreline Young Street Carpark to Banksia Terrace

What Application of nature-based revegetation and foreshore stabilisation techniques

$320k – $870k

Year 2-4

SMU 5 Cooleenup Island

Where Shoreline adjacent developed properties

What Application of nature-based revegetation and foreshore stabilisation techniques

$340k - $930k

Year 5-7

SMU 5 Yunderup Island

Where Shoreline adjacent developed properties

What Application of nature-based revegetation and foreshore stabilisation techniques

$240k – $670k

Year 8-10

SMU 5 Coopers Mill Shoreline (Cooleenup Island)

Where Shoreline adjacent developed properties

What Application of nature-based revegetation and foreshore stabilisation techniques

$140k – $400k

Year 2

Further studies

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

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.

Building and Development Guideline
To support the recommended planning updates and to provide clarity for the community, the Shire will prepare a Building and Development Guideline document that provides examples of appropriate development within areas at risk of coastal processes. The guidelines will inform landowners on methods for mitigating risk through building design for new builds and present approaches for retrofitting existing buildings to make them more resilient to coastal processes.

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.

Feasibility study for North Yunderup river shoreline protection options
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.

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

Coopers Mill Study
Detailed strategy for managing the risk of erosion and inundation specific to Coopers Mill. This will assess the coastal hazard risk in detail and provide design options and nominal costs for shoreline protection and hazard mitigation.

over 5 years

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Shire of Murray