Shire of Murray CHRMAP

Coastal Hazard Risk Management and Adaptation Plan

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Shire of Murray CHRMAP

Coastal Hazard Risk Management and Adaptation Plan

Prepared for:

Shire of Murray
1915 Pinjarra Road
Pinjarra WA 6208

Prepared by:

Baird Australia Pty Ltd as Trustee for the Baird Australia Unit Trust
ACN 161 683 889 | ABN 92 798 128 010
For further information, please contact
Jim Churchill at +61 8 6255 5080
jchurchill@baird.com
www.baird.com

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Executive Summary

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

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

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

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

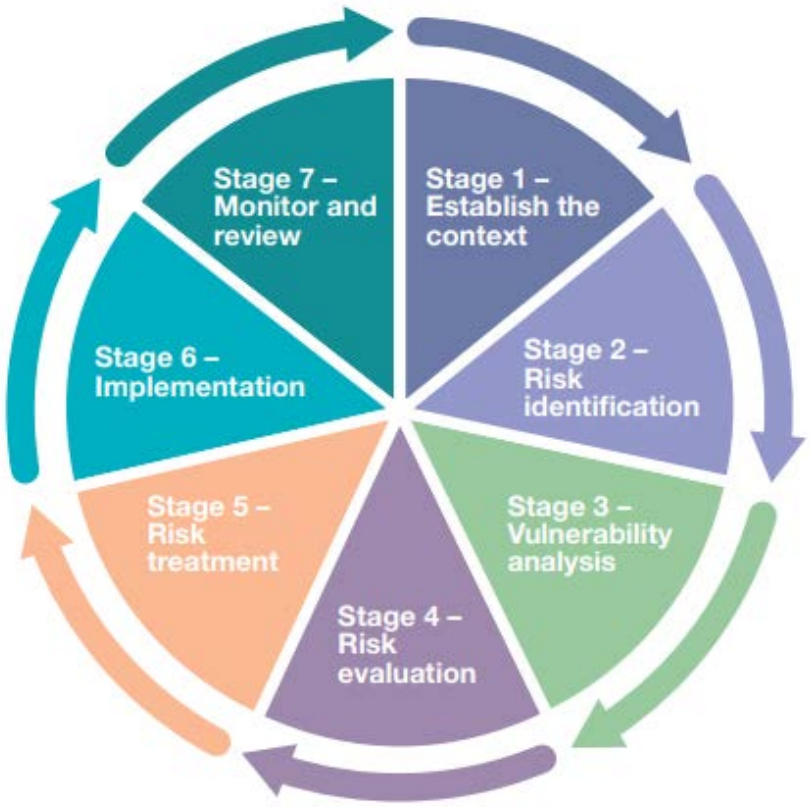


Figure E.1: CHRMAP Stages (WAPC 2019)

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

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

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

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

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

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

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

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

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

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

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

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

b) For the Murray River shoreline of North Yunderup, the nature-based solutions perform well due to the density of properties in this area and their proximity to the river. However, there may be practical challenges in implementing nature-based solutions within the available space in this area. A hard engineering solution is expected to be viable within 10 years. It is recommended that a technical study is undertaken in the next five years (by 2027) to examine an engineered hard structure (river wall) along the North Yunderup section of shoreline. This process would involve representatives from the North Yunderup community and be used to confirm requirements including the design and construction method, estimate of costs and the mechanism for funding the project through residents who would directly benefit from the erosion protection provided.

c) The shoreline along the Murray River at South Yunderup performs well with nature-based solutions indicating these options are supported for implementation today. These solutions suit the shoreline areas with generally greater land buffer in this location compared with the northern side of the Murray River.

d) Erosion of the Kooljerrenup Nature Reserve was assessed against the adaption strategy of purchasing land on the eastern side of the reserve, to mitigate the loss of land due to erosion on the shoreline side. Loss of land area is projected to increases markedly after the 2050 period due to shoreline erosion driven by projected sea level rise. Monitoring of the shoreline areas and their response to sea level rise in the next 20 years will inform the future adaptation strategy with further consideration of the need for potential acquisition of land recommended in the 2040 to 2050 planning period.

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

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

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

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

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

b) Annual Monitoring Program: Projected annual cost of $16,000 – 18,000 annually to monitor:
   - Foreshore berm on the Peel shorelines along the western facing beaches of the Murray Delta Islands. The monitoring of the berm height along the shoreline is recommended every 3-years, through spatial survey data capture (via UAV or LiDAR). Following significant events where erosion may occur on the shorelines survey should also be captured.
   - Murray Delta Island shorelines on Ballee Island, Culeenup Island and Yunderup Island should be monitored through spatial survey data capture (via UAV or LiDAR) approximately every 5 years.
   - Photo Monitoring of shoreline areas for erosion at Herron Point, North and South Yunderup and the Murray Delta Islands (photo capture 2x annually and following significant storm events)

c) Additional Technical Studies: Projected Cost $45,000 to investigate:
   - Assessment, planning and costing for a centralised ATU system (next 5-years)
   - Murray Delta Islands building register (next 5-years)
   - Erosion impacts from boat wakes on the river shoreline (next 5-years)

d) Planning Based Studies and Adaptation Studies: Projected Cost $85,000 for the following:
   - Feasibility study for protection structure along North Yunderup shoreline in front of Coolenup Rd properties (next 5-years)
   - Prepare an Emergency Evacuation Plan (next 5-years)
   - Review of CHRMAP (5-yr Review)
   - Prepare a Managed Retreat Policy (6-10 years).

e) Adaptation Actions in Shoreline Areas.
   - Ballee Island, Coolenup Island and Yunderup Island – Nature Based solutions (now)
   - South Yunderup shoreline section Young Street to Pelicans – Nature Based Solutions (now)
   - Coopers Mill Shoreline – Nature Based solutions (now)

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

a) Introduce a Special Control Area which triggers the requirement for normally exempt development to require planning approval.

b) Prepare a local planning policy (LPP) to establish development standards to ensure new development can address projected coastal hazard from erosion and inundation.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table of Contents

1. Introduction 1

1.1 Introduction 1

1.2 Project Delivery 1

1.3 Project Team 2

1.4 Coastal Management Framework in Western Australia 2

1.4.1 State Coastal Planning Policy (SPP2.6) 2

1.4.2 Coastal Hazard Risk Management and Adaptation Planning Guidelines 3

1.5 Scope – Project Stages 3

2. Establish the Context 6

2.1 Background 6

2.2 Purpose 6

2.3 Objectives 6

2.4 Study Area 7

3. Community and Stakeholder Engagement 9

3.1 Level of Engagement 9

3.2 Engagement objectives 9

3.3 Engagement Tools 10

3.3.1 Online engagement tool – Project Webpage 10

3.3.2 Technical Advisory Group (TAG) 10

3.3.3 Community Reference Group 10

3.3.4 Traditional owner engagement 11

3.3.5 Information event – November 2020 11

3.3.6 Community Workshops May 2021 12

3.3.7 Coastal values Survey 13

3.3.8 Engagement methods 13

4. Coastal Values Assessment 14

4.1 Coastal Values and Assets Overview 14
4.2 Coastal Values Survey 14
4.2.1 Survey Responses 14
4.2.2 Discussion of Survey Results 18
4.3 Coastal Values Summary 18
4.4 Success Criteria 20
5. Coastal Hazard Assessment 21
5.1 Identification of Coastal Hazard for Shire of Murray 21
5.2 Water Level 21
5.2.1 Tidal Planes 21
5.2.2 Water Level Influences and Residual Tide Effects 22
5.2.3 Peel Tide Gauge 23
5.2.4 Sea Level Rise Allowances 23
5.3 Coastal Erosion 24
5.3.1 Coastal Erosion Allowance – Peel-Harvey Shorelines 25
5.3.2 Coastal Erosion Allowance – Lower Murray and Serpentine Rivers 26
5.3.3 Coastal Erosion Allowance - Canal Estates 27
5.4 Coastal inundation hazard 27
5.5 Coastal Hazard Mapping 29
5.5.1 Coastal Processes Allowance – Erosion Allowance for Peel-Harvey Estuary 29
5.5.2 Coastal Processes Allowance – Channel Margins 30
5.5.3 Mapping Process - Inundation 31
5.5.4 Flood Mapping Scenarios - Extreme Events 33
5.5.5 Flood Risk for Low Lying areas under General Tides 33
5.6 Assumptions and Limitations 35
6. Asset Identification 36
6.1 Coastal Assets 36

6.1.1 Asset Types 36
6.1.2 Coastal Asset Functions, Services and Value 36
6.1.3 Asset Identification 37
6.2 Coastal Asset Register 37
6.2.1 Compilation of Asset Data 37
7. Risk Assessment Framework 54
7.1 Vulnerability Assessment 54
7.2 Likelihood 54
7.2.1 Likelihood Definitions 54
7.2.2 Likelihood Scale – Coastal Erosion 55
7.2.3 Coastal Inundation Likelihood Scale 56
7.3 Consequence 57
7.3.1 Consequence Scale 57
7.3.2 Safety and Structural Considerations 58
7.3.3 Consequence Rating – Coastal Asset Register 59
8. Level of Risk 61
8.1 Potential Impact 61
8.2 Risk Acceptance and Tolerance 61
8.3 Adaptive Capacity 62
8.4 Vulnerability Scales 64
9. Risk Assessment Outcomes 65
9.1 SMU1 - South end of Harvey Estuary (Includes Herron Point). 65
9.2 SMU2 – Birchmont 65
9.3 SMU3 – Point Grey to Austin Bay 66
9.4 SMU4 - South Yunderup (including the Canals) 66
9.5 SMU5 - North Yunderup including Murray Delta Islands 67
9.6 SMU6 - Serpentine River and Furnissdale 68
10. Risk Evaluation 70

10.1 Overview 70
10.2 Existing Controls 70
10.3 Existing Controls by SMU 70
10.4 Planning Controls 74
10.4.1 Existing Planning Controls 74
10.4.2 Summary of Statutory Planning Mechanisms 74
11. Residual Risk and Priority for Treatment 77
11.1 SMU1 - South end of Harvey Estuary 78
11.2 SMU2 - Birchmont 79
11.3 SMU3 – Point Grey to Austin Bay 80
11.4 SMU4 – South Yunderup 81
11.5 SMU5 – North Yunderup and the Murray Delta Islands 84
11.6 SMU6 – Serpentine and Furnissdale 88
12. Risk Treatment Process..... 91
12.1 Risk Treatment Overview 91
12.2 Risk Treatment Options 91
12.3 Adaptation Tools 93
12.4 Trigger Points 93
12.5 Planning Based Approaches 102
12.5.1 Statutory Planning Mechanisms 102
12.5.2 Recommended Planning Controls 102
12.5.2.1 Local Planning Strategy 102
12.5.3 Local Planning Scheme Amendment 102
12.5.3.1 Special Control Area (SCA) 102
12.5.4 Coastal Hazard Local Planning Policy (LPP) 108
12.5.5 Planned or Managed Retreat Policy 112
12.5.6 Foreshore Management Plans 113
12.5.7 Emergency Response and Evacuation 113

12.6 Economic Framework 113

13. Multi Criteria Analysis 114

13.1 Overview of the MCA process 114

13.1.1 General Explanation 114

13.1.2 MCA Workshop 115

13.2 MCA Summary of Outcomes 115

13.2.1 Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve 115

13.2.2 Item 2 – Inundation of Properties 118

13.2.3 Item 3 – Erosion of Riverbanks 123

13.2.4 Item 4 – Septic Systems 125

14. Cost Benefit Analysis 128

14.1 Assessment Scenarios 128

14.2 Nature Based Adaptation Options – Building Resilience 129

14.3 Key Assumptions 130

14.4 Calculated Areas of Impact 132

14.4.1 Residential Properties – Impacts from Inundation and Erosion 132

14.4.2 Shire of Murray Assets 133

14.5 Unit Rate Values 133

14.6 CBA – Summary of Analysis 134

14.6.1 Mitigation Option Costs 134

14.6.2 Benefit Costs Ratio (BCR) 134

14.7 Key Findings from CBA 135

14.8 Key Outcomes for CHRMAP 136

14.9 Benefit Distribution Analysis 136

15. Risk Management Summary 137

15.1 South end of Harvey Estuary (SMU 1) 137

15.1.1 Risk Treatment by Asset – SMU1 137

15.1.2 Risk Management Pathways – SMU1 139

15.2 Risk Management Summary - Birchmont (SMU 2) 141
15.2.1 Risk Treatment by Asset – SMU2 141
15.2.2 Risk Management Pathways – SMU2 144
15.3 Risk Management Summary - Point Grey to Austin Bay (SMU 3) 145
15.3.1 Risk Treatment by Asset – SMU3 145
15.3.2 Risk Management Pathways – SMU3 146
15.4 Risk Management Summary - South Yunderup (SMU 4) 148
15.4.1 Risk Treatment by Asset – SMU4 148
15.4.2 Risk Management Pathways – SMU4 150
15.5 Risk Management Summary - North Yunderup and Murray Delta Islands (SMU 5) 151
15.5.1 Risk Treatment by Asset – SMU5 151
15.6.1 Risk Management Pathways – SMU5 156
15.7 Risk Management Summary - Serpentine (SMU 6) 158
15.7.1 Risk Treatment by Asset – SMU6 158
15.7.2 Risk Management Pathways – SMU6 160
16. Short Term Implementation Plan 162
16.1 Implementation Actions 162
16.2 Planning Implementation – Short Term 162
16.3 Annual Monitoring 162
16.3.1 Structural Inspections 164
16.3.2 Trigger Point Summary 164
16.4 Additional Technical Studies 170
16.5 Additional Planning Based Studies and Adaptation Studies 170
16.6 Adaptation Actions - Shoreline Areas 170
16.7 Short Term Implementation Plan 171
16.8 Benefit Distribution Analysis 173
16.8.1 Murray Delta Islands - Nature Based Mitigation Options 173

16.8.2 South Yunderup Shoreline - Nature Based Mitigation Options 174

17. Medium and Long-Term Implementation Plan 176

17.1 Medium Term Implementation 176

17.2 Long Term Implementation 177

18. Land use planning instruments 179

18.1 Planning Mechanisms - Implementation 179

18.1.1 Special Control Area (SCA) 179

18.1.2 Planned or Managed Retreat Policy 179

19. Funding 181

19.1 Funding - Murray Delta Islands and South Yunderup Shoreline Areas 181

19.2 Special Area Rates 181

19.3 Grant Funding 182

20. Monitoring Plan 185

20.1 Overview 185

20.2 Survey Capture - UAV 185

20.3 Key Monitoring locations 185

20.4 Additional Studies 187

20.5 CHRMAP Review 188

21. Summary and Conclusions 189

References 193

Tables

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

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

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

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

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

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

Table 1.1: Project Stages and Tasks 3

Table 3.1: Levels of Engagement for the Project (based on IAP2 Public Participation Spectrum) 9

Table 4.1: Coastal Asset Categories (WAPC 2019) 14

Table 4.2: Coastal Values 19

Table 5.1: Tidal Planes from Mandurah, Peel and Harvey Tide Gauges 22

Table 5.2: Sea level rise allowances over the planning timeframe of the CHRMAP study. 24

Table 5.3: Design Water Level 28

Table 5.4: Design Water Levels for Shire of Murray adopted in CHRMAP (vertical datum mAHD) 29

Table 5.5: Hazard Mapping Assumptions and Limitations 35

Table 6.1: Overview of Coastal Asset functions, services, value based on WAPC (2019) 36

Table 6.2: Shoreline Management Units (SMU) 37

Table 6.3: Coastal Asset Identification. SMU1 – South Harvey Estuary and Herron Point 38

Table 6.4: Coastal Asset Identification. SMU2 – Birchmont 41

Table 6.5: Coastal Asset Identification. SMU3 – Point Grey to Austin Bay 43

Table 6.6: Coastal Asset Identification. SMU4 – South Yunderup 45

Table 6.7: Coastal Asset Identification. SMU5 – North Yunderup and Murray Islands 48

Table 6.8: Coastal Asset Identification. SMU6 – Serpentine River and Furnissdale 52

Table 7.1: Likelihood Scale Definitions (WAPC 2019, AS5334-2013) 55

Table 7.2: Murray CHRMAP Likelihood Scale for Coastal Erosion 56

Table 7.3: Sea level rise allowances over the planning timeframe of the CHRMAP study. 56

Table 7.4: Inundation Likelihood Categories 57

Table 7.5: Inundation Likelihood for Shire of Murray - Water Level (Vertical Datum m AHD) 57

Table 7.6: Consequence Scale 58

Table 7.7: Consequence Rating for Coastal assets – Erosion and Inundation 60

Table 8.1: Potential Impact Scale - Likelihood / Consequences matrix to assess level of risk 61

Table 8.2: Risk Tolerance Scale 62

Table 8.3: Adaptive Capacity Rating for Coastal Assets (based on WAPC 2019) 62

Table 8.4: Adaptive Capacity Ratings of Coastal Assets – Erosion and Inundation 63

Table 8.5: Asset Vulnerability Matrix 64

Table 8.6: Vulnerability Tolerance Scale 64

Table 10.1: Summary of Existing Controls in the Coastal Management Units 70

Table 10.2: Summary of Existing Planning Controls 75

Table 11.1: Vulnerability Rating Summary 77

Table 11.2: Vulnerability Rating – SMU 1: South end of Harvey Estuary 78

Table 11.3: Vulnerability Rating – SMU 2: Birchmont 79

Table 11.4: Vulnerability Rating – SMU 3: Point Grey to Austin Bay 80

Table 11.5: Vulnerability Rating – SMU 4: South Yunderup 81

Table 11.6: Vulnerability Rating – SMU 5: North Yunderup and the Murray Delta Islands 85

Table 11.7: Vulnerability Rating – SMU6: Serpentine and Furnissdale 88

Table 12.1: Adaptation Options Toolbox (Adapted from WAPC 2019) 95

Table 12.2: Trigger Points Decision Making and Measures (Adapted from WAPC 2019) 99

Table 12.3: Planning Controls – Special Control Area (SCA1) 103

Table 13.1: MCA Categories and Key Criteria 114

Table 13.2: MCA Scoring – Performance and Impact 115

Table 13.3: MCA Scoring - Cost 115

Table 13.4: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Technical, Social, Environment Category 116

Table 13.5: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Social Category 117

Table 13.6: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Environmental Category 117

Table 13.7: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Cost Score 117

Table 13.8: Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve. MCA Scoring – Final Scoring of Options 118

Table 13.9: Item 2 – Inundation Low lying properties. MCA Scoring – Technical, Social, Environment Category 121

Table 13.10: Item 2 – Inundation Low lying properties. MCA Scoring – Social Category 121

Table 13.11: Item 2 – Inundation Low lying properties. MCA Scoring – Environmental Category 122

Table 13.12: Item 2 – Inundation Low lying properties. MCA Scoring – Cost Score 122

Table 13.13: Item 2 – Inundation Low lying properties. MCA Scoring – Final Scoring of Options 123

Table 13.14: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Technical, Social, Environment Category 124

Table 13.15: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Social Category 124

Table 13.16: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Environmental Category 124

Table 13.17: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Cost Score 125

Table 13.18: Item 3 – Erosion of Murray and Serpentine shorelines. MCA Scoring – Final Scoring of Options 125

Table 13.19: Item 4 – Septic Systems. MCA Scoring – Technical, Social, Environment Category 126

Table 13.20: Item 4 – Septic Systems. MCA Scoring – Social Category 126

Table 13.21: Item 4 – Septic Systems. MCA Scoring – Environmental Category 126

Table 13.22: Item 4 – Septic Systems. MCA Scoring – Cost Score 126

Table 13.23: Item 4 – Septic Systems. MCA Scoring – Final Scoring of Options 127

Table 14.1: Summary of Options Assessment Locations for Cost Benefit Analysis (CBA) 128

Table 14.2: Key Assumptions in the Cost Benefit Analysis 131

Table 14.3: Adaptation Options and asset values - Unit Costs 133

Table 14.4: Summary of Mitigation Options Costs 134

Table 14.5: Economic assessment results: individual projects ($M, present value at 7% p.a.) 135

Table 14.6: Kooljerrenup Nature Reserve: forecast land lost to erosion 136

Table 15.1: Risk Treatment – South End of Harvey Estuary (SMU1) 138

Table 15.2: Risk management pathway, triggers, decision-making and measures for SMU1 140

Table 15.3: Risk Treatment – Birchmont (SMU2) 142

Table 15.4: Risk management pathway, triggers, decision-making and measures for SMU2 144

Table 15.5: Risk Treatment – Point Grey to Austin Bay (SMU3) 146

Table 15.6: Risk management pathway, triggers, decision-making and measures for SMU3 147

Table 15.7: Risk Treatment – South Yunderup (SMU5) 149

Table 15.8: Risk management pathway, triggers, decision-making and measures for SMU4 150

Table 15.9: Risk Treatment – North Yunderup and Murray Delta Islands (SMU6) 154

Table 15.10: Risk management pathway, triggers, decision-making and measures for SMU5 156

Table 15.11: Risk Treatment – Serpentine (SMU6) 160

Table 15.12: Risk management pathway, triggers, decision-making and measures for SMU6 161

Table 16.1: Indicative program for Annual Monitoring activities 163

Table 16.2: Summary of Trigger Points by SMU, Monitoring and Management Action 165

Table 16.3: Adaptation Actions in the Short term (next 15-years) 171

Table 16.4: Short-term implementation plan and estimated budget. First five years 2023 – 2027. 172

Table 16.5: Murray Delta Islands – Cost Estimates for Sections of Shoreline Mitigation using Nature Based Solutions 173

Table 16.6: Murray Delta Islands – Benefit Distribution analysis for Nature Based Solutions. Public cost and cost for private property 174

Table 16.7: South Yunderup Shoreline – Cost Estimates for Sections of Shoreline Mitigation using Nature Based Solutions 174

Table 16.8: South Yunderup shoreline – Benefit Distribution analysis for Nature Based Solutions. Public cost and cost for private property 175

Table 17.1: Medium Term Implementation Plan 176

Table 17.2: Long Term Implementation Plan 177

Table 19.1: Summary of Funding Mechanisms 182

Table 20.1: Key Locations for Monitoring Activities 186

Figures

Figure E.1: CHRMAP Stages (WAPC 2019) ii

Figure 1.1: CHRMAP Stages (WAPC 2019) 5

Figure 2.1: Study area, highlighting regions of focused urban, rural, and recreational development. 7

Figure 2.2: Shoreline Management Units for the Study Area adopted in the CHRMAP. 8

Figure 3.1: Photos taken during Information Sessions in November 2020..... 11

Figure 3.2: Photos taken during Information Sessions in (Upper) November 2020 and (Lower) Community Workshops in May 2021..... 13

Figure 4.1: Survey Results – Demographic (Question 1) 15

Figure 4.2: Survey Results – Location of Respondent (Question 2) 15

Figure 4.3: Survey Results – Awareness of Project (Question 3) 15

Figure 4.4: Survey Results – Additional Project Info (Question 4)..... 15

Figure 4.5: Survey Results – Interactions with the Estuary (Question 5) 16

Figure 4.6: Survey Results – Areas in Estuary Frequented (Question 6) 16

Figure 4.7: Survey Results – Participation Rates (Question 7) 17

Figure 4.8: Survey Results – Location Specific (Question 8)..... 17

Figure 4.9: Survey Results – What is most valued in the Coastal and Estuary Area (Question 9)..... 17

Figure 5.1: Location of DoT tide gauges in the Peel-Harvey area. Measured water level reported from the Harvey Estuary tide gauge over the period 26 – 30 July 2021 showing the residual tide levels of up to 0.7m associated with the passage of winter storms [inset]. 23

Figure 5.2: Oblique view looking west over the lower Murray and Serpentine Rivers over the Murray Delta Islands to the Peel Inlet (DWER). 26

Figure 5.3: Extreme value analysis of measured water levels from the Peel tide gauge of the period 1994 to 2020 (Seashore 2021). Water level return periods up to the 100-year return period were defined from the analysis. 28

Figure 5.4: Coastal processes allowances in Peel-Harvey Estuary shorelines – Example map showing the Herron Point section of the Harvey Estuary. 30

Figure 5.5: Erosion hazard allowances in the lower Murray and Serpentine Rivers – Example map. 31

Figure 5.6: Example of elevation map showing land level for South Yunderup, North Yunderup and Murray Islands (datum cm AHD) 32

Figure 5.7: Inundation depth for the 500yr-ARI event in the year 2120 (includes 0.9m sea level rise). Example map shown for Murray Delta Islands and North and South Yunderup. 34

Figure 6.1: SMU1 - Coastal Assets within 2120 Coastal Hazard Extents. Harvey Drain to Herron Point ... 39

Figure 6.2: SMU1 - Coastal Assets within 2120 Coastal Hazard Extents. Herron Point..... 40

Figure 6.3: SMU2 - Examples of coastal assets from Birchmont. Clockwise from top left, Birchmont boat ramp, Birchmont boat ramp carpark and foreshore reserve, Lake McLarty Nature Reserve..... 41

Figure 6.4: SMU2 - Coastal Assets within 2120 Coastal Hazard Extents. Birchmont..... 42

Figure 6.5: SMU3 - Examples of coastal assets from Point Grey. Clockwise from top left - Carrabungup Road, signage, natural foreshore areas of Roberts Bay..... 43

Figure 6.6: SMU3 - Coastal Assets within 2120 Coastal Hazard Extents. Point Grey to Austin Bay 44

Figure 6.7: SMU4 - Examples of coastal assets from South Yunderup. Clockwise from top left – Foreshore Reserve Pelican St, Wharf Cove decking, crabbing on the Peel, Peel shoreline Batavia Quays, Wetland area Batavia Quays, Pelican St Park, Pelican St Jetty..... 46

Figure 6.8: SMU4 - Coastal Assets within 2120 Coastal Hazard Extents. South Yunderup..... 47

Figure 6.9: SMU5 - Examples of coastal assets in North Yunderup and Murray Islands. Clockwise from top right – Example of Island house, jetty at Coopers Mill Precinct, Coopers Mill 49

Figure 6.10: SMU5 - Coastal Assets within 2120 Coastal Hazard Extents. North Yunderup 50

Figure 6.11: SMU5 - Coastal Assets within 2120 Coastal Hazard Extents. North Yunderup – Murray Delta Islands..... 51

Figure 6.12: SMU6 - Coastal Assets within 2120 Coastal Hazard Extents. Serpentine River and Furnissdale 53

Figure 7.1: Vulnerability Assessment Flowchart 54

Figure 7.2: Flood Hazard Curve – Vulnerability thresholds as a Product of Inundation Depth and Velocity (from Smith et al 2014)..... 59

Figure 11.1: Example of SMU4 Assets with Coastal Hazard Mapping (plots available in Appendix F)..... 77

Figure 13.1: Erosion and Inundation at Kooljerrenup Nature Reserve..... 116

Figure 13.2: Illustration of the influence of sea level rise on low lying properties for general tide range, 1 in 2-year flood level and 1 in 100 -year flood level. On the left the present-day scenario (2020) is presented and in the right column the same flood cases with sea level rise allowance is shown (presented as +0.4m which is the projected 2070 allowance). 119

Figure 13.3: Basic overview of the Mitigation Options to address inundation hazard 120

Figure 14.1: Shoreline Sections assessed for adaptation options in the CBA..... 129

Figure 14.2: Nature Based Solutions for Riverbanks in the Shire of Murray (Adapted from Syrinx 2018) 130

Appendices

Appendix A Stakeholder and Community Engagement Plan

Appendix B Engagement Outcomes Summary

Appendix C Coastal Hazard

Appendix D Vulnerability Assessment by Shoreline Management Unit

Appendix E Planning Instruments Review

Appendix F Asset Mapping and Coastal Hazard Area

Appendix G Adaptations Option Workshop Summary

Appendix H Hazard Impact Regions

Appendix I Economic Report (Rhelm)

Table of Abbreviations

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

1. Introduction

1.1 Introduction

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

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

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

1.2 Project Delivery

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

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

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

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

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

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

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

1.3 Project Team

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

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

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

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

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

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

1.4 Coastal Management Framework in Western Australia

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

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

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

1.4.1 State Coastal Planning Policy (SPP2.6)

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

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

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

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

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

1.4.2 Coastal Hazard Risk Management and Adaptation Planning Guidelines

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

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

1.5 Scope – Project Stages

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

Table 1.1: Project Stages and Tasks

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

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

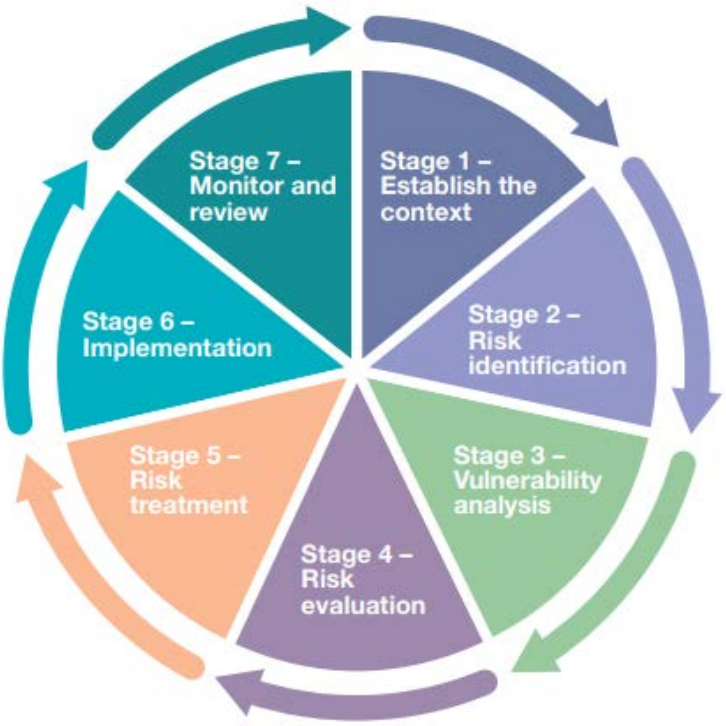


Figure 1.1: CHRMAP Stages (WAPC 2019)

2. Establish the Context

2.1 Background

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

2.2 Purpose

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

2.3 Objectives

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

The specific objectives of the project are to:

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

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

2.4 Study Area

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

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

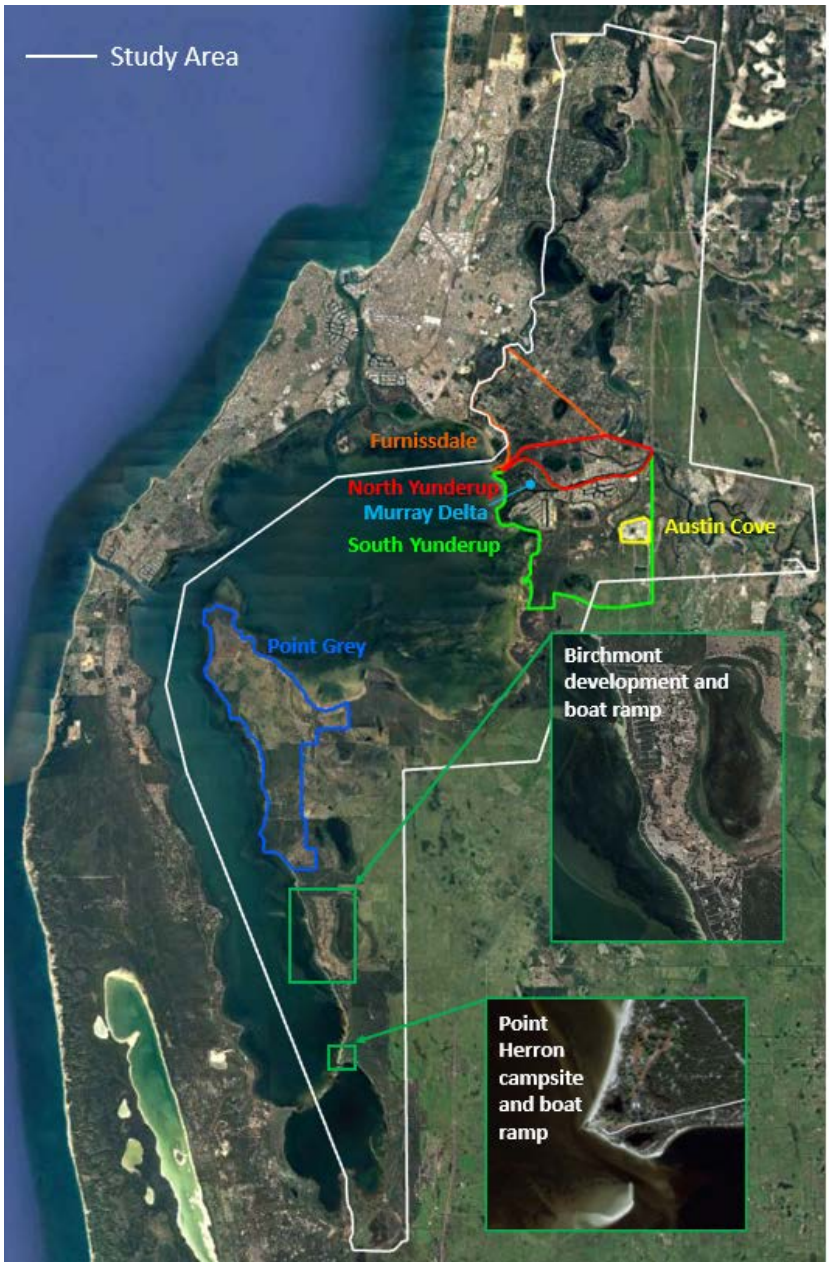


Figure 2.1: Study area, highlighting regions of focused urban, rural, and recreational development.

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

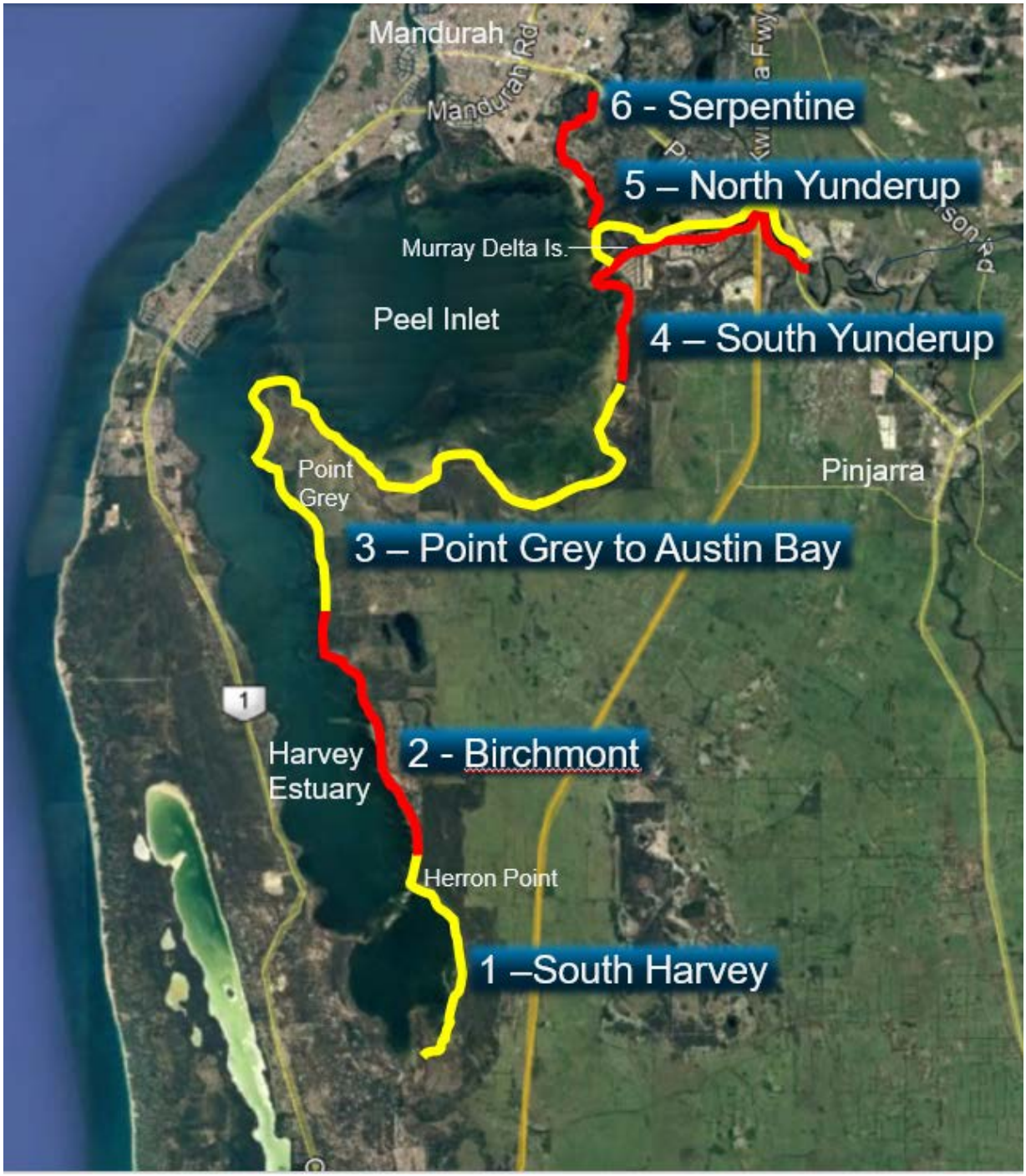


Figure 2.2: Shoreline Management Units for the Study Area adopted in the CHRMAP.

3. Community and Stakeholder Engagement

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

3.1 Level of Engagement

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

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

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

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

3.2 Engagement objectives

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

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

3.3 Engagement Tools

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

3.3.1 Online engagement tool – Project Webpage

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

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

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

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

3.3.2 Technical Advisory Group (TAG)

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

The TAG representatives come from:

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

3.3.3 Community Reference Group

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

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

3.3.4 Traditional owner engagement

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

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

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

3.3.5 Information event – November 2020

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



Figure 3.1: Photos taken during Information Sessions in November 2020

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

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

3.3.6 Community Workshops May 2021

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

The workshop agenda was as follows:

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

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



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

3.3.7 Coastal values Survey

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

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

3.3.8 Engagement methods

The CHRMAP activities were promoted through:

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

4. Coastal Values Assessment

4.1 Coastal Values and Assets Overview

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

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

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

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

Table 4.1: Coastal Asset Categories (WAPC 2019)

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

4.2 Coastal Values Survey

4.2.1 Survey Responses

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

Q1. What age bracket do you fall under?

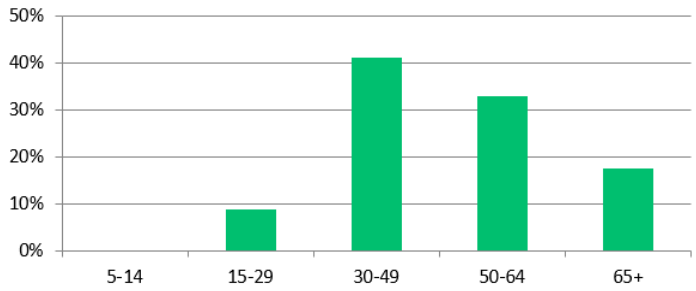


Figure 4.1: Survey Results – Demographic (Question 1)

Q2. Please select the location you live.

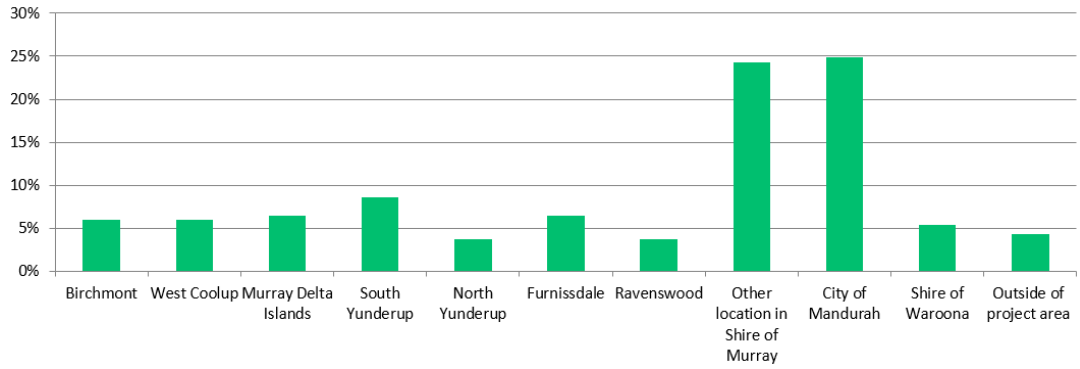


Figure 4.2: Survey Results – Location of Respondent (Question 2)

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

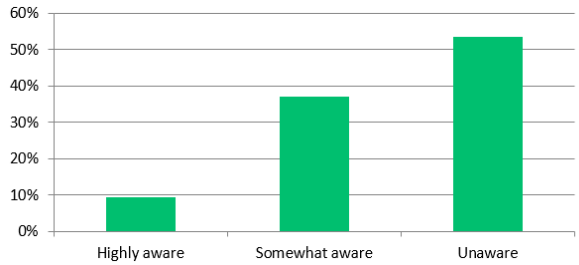


Figure 4.3: Survey Results – Awareness of Project (Question 3)

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

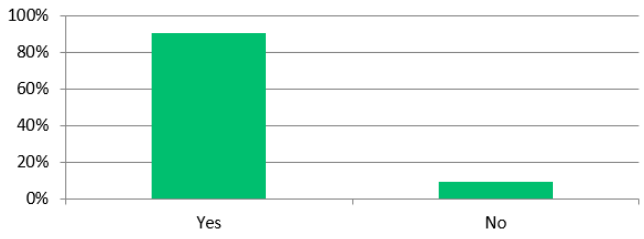


Figure 4.4: Survey Results – Additional Project Info (Question 4)

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

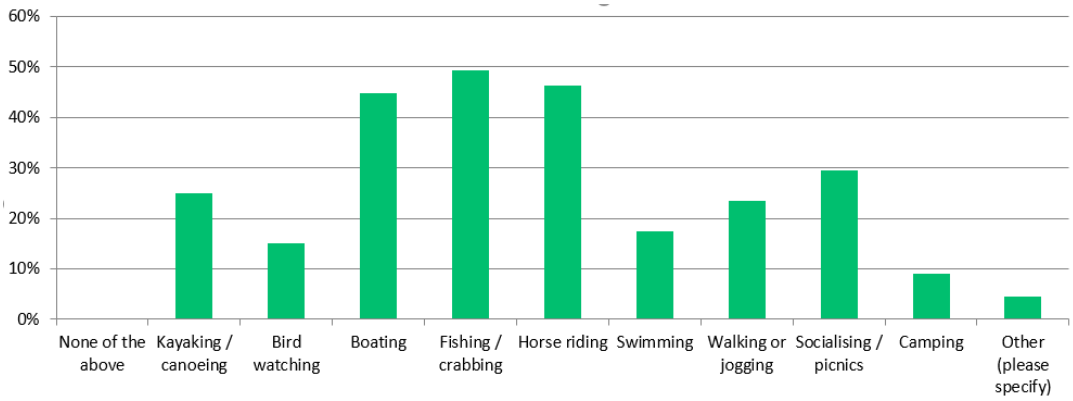


Figure 4.5: Survey Results – Interactions with the Estuary (Question 5)

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

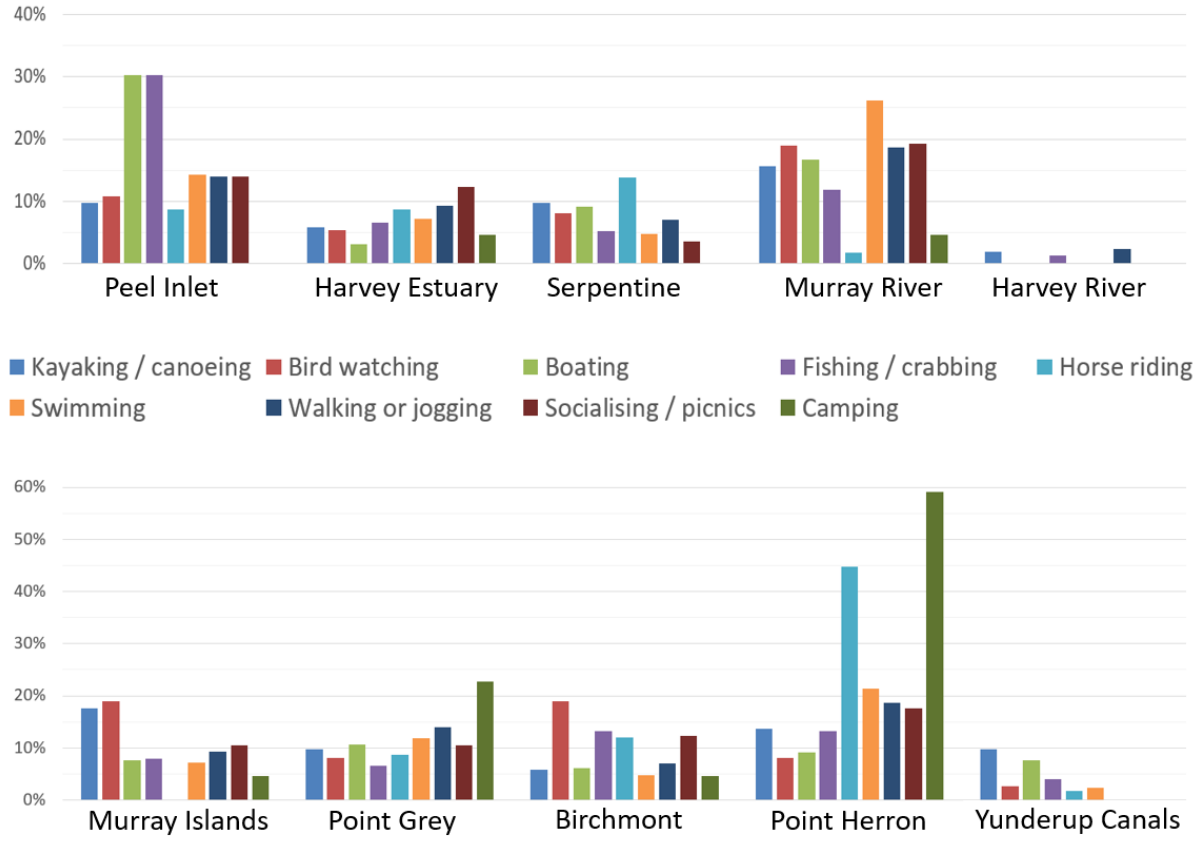


Figure 4.6: Survey Results – Areas in Estuary Frequented (Question 6)

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

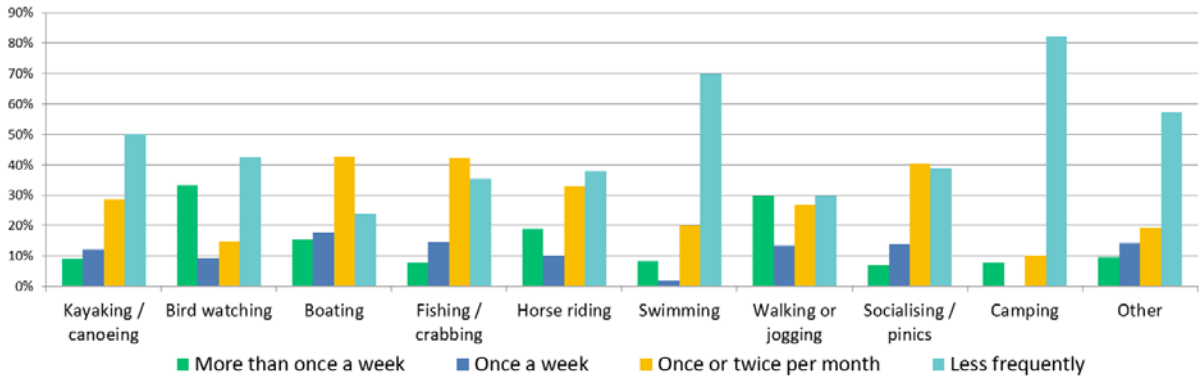


Figure 4.7: Survey Results – Participation Rates (Question 7)

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

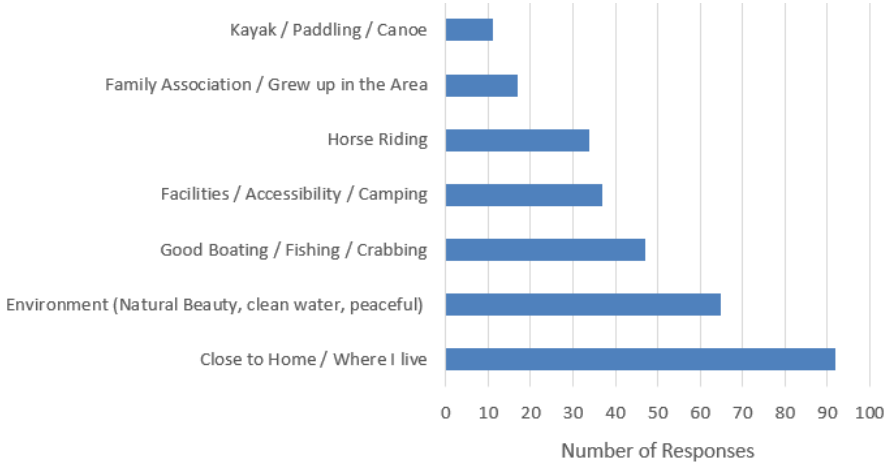


Figure 4.8: Survey Results – Location Specific (Question 8)

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

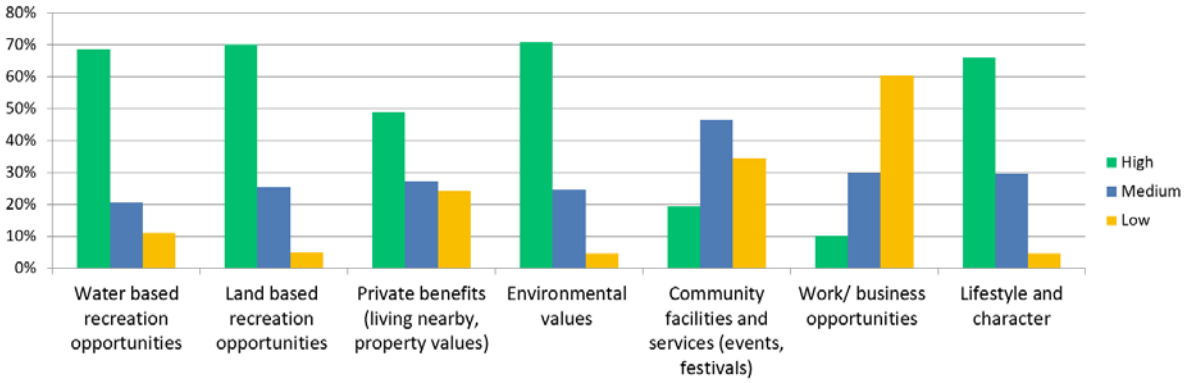


Figure 4.9: Survey Results – What is most valued in the Coastal and Estuary Area (Question 9)

4.2.2 Discussion of Survey Results

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

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

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

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

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

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

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

4.3 Coastal Values Summary

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

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

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

Table 4.2: Coastal Values

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

4.4 Success Criteria

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

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

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

5. Coastal Hazard Assessment

5.1 Identification of Coastal Hazard for Shire of Murray

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

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

5.2 Water Level

5.2.1 Tidal Planes

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

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

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

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

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

5.2.2 Water Level Influences and Residual Tide Effects

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

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

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

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

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

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

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

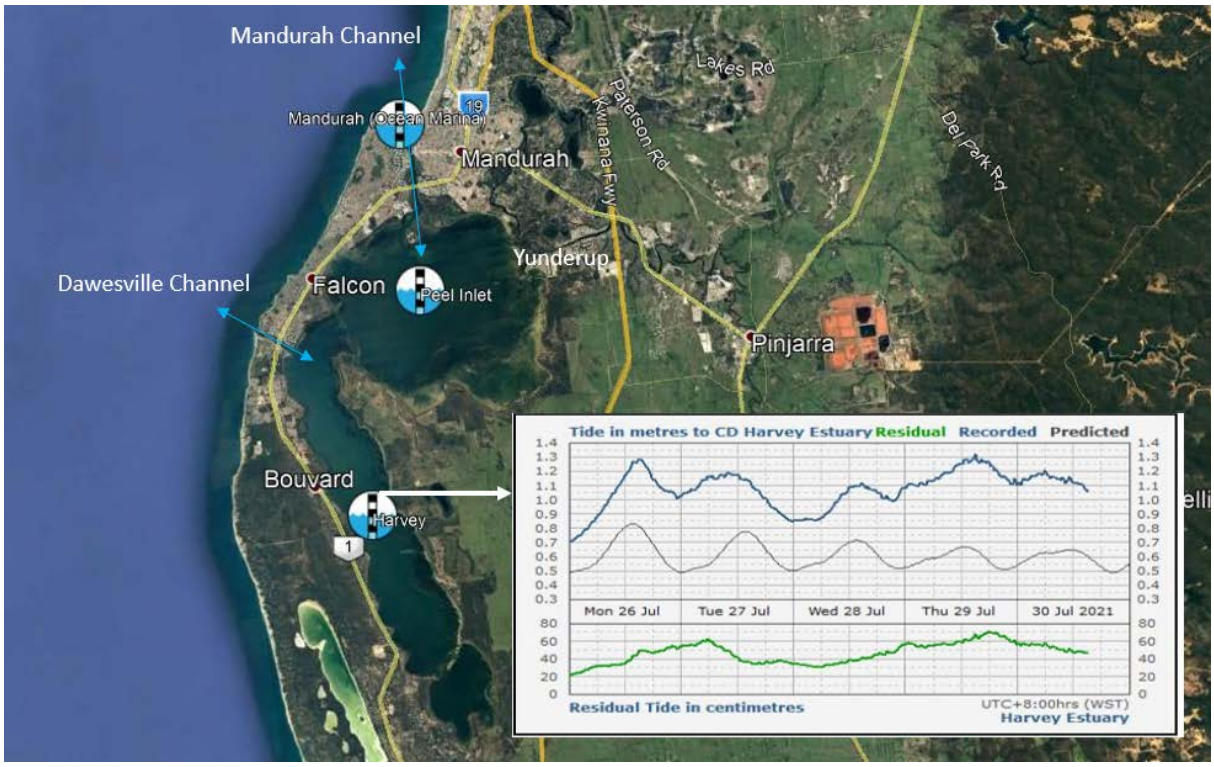


Figure 5.1: Location of DoT tide gauges in the Peel-Harvey area. Measured water level reported from the Harvey Estuary tide gauge over the period 26 – 30 July 2021 showing the residual tide levels of up to 0.7m associated with the passage of winter storms [inset].

5.2.3 Peel Tide Gauge

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

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

5.2.4 Sea Level Rise Allowances

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

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

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

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

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

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

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

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

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

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

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

5.3 Coastal Erosion

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

a) Peel-Harvey shorelines
b) Lower Murray and Serpentine Rivers
c) Canal Estates

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

5.3.1 Coastal Erosion Allowance – Peel-Harvey Shorelines

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

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

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

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

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

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

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

5.3.2 Coastal Erosion Allowance – Lower Murray and Serpentine Rivers

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

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

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

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



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

5.3.3 Coastal Erosion Allowance - Canal Estates

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

5.4 Coastal inundation hazard

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

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

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

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

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

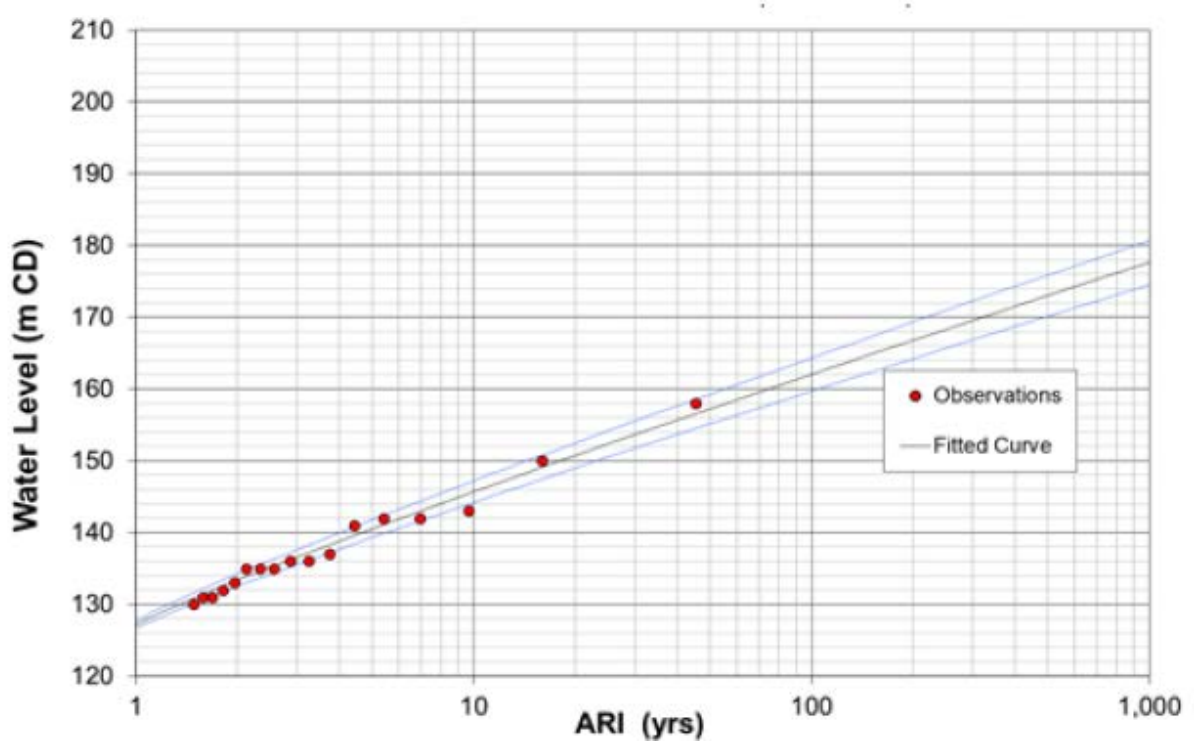


Figure 5.3: Extreme value analysis of measured water levels from the Peel tide gauge of the period 1994 to 2020 (Seashore 2021). Water level return periods up to the 100-year return period were defined from the analysis.

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

Table 5.3: Design Water Level

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

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

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

Planning Year	2020	2030	2050	2070	2120
Sea Level Rise[1]	0m	+0.1m	+0.2m	+0.4m	+0.9m
2yr ARI	0.8m	0.9m	1.0m	1.2m	1.7m
10yr ARI	0.9m	1.0m	1.1m	1.3m	1.8m
100yr ARI	1.1m	1.2m	1.3m	1.5m	2.0m
500yr ARI	1.4m	1.5m	1.6m	1.8m	2.3m

Notes

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

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

5.5 Coastal Hazard Mapping

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

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

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

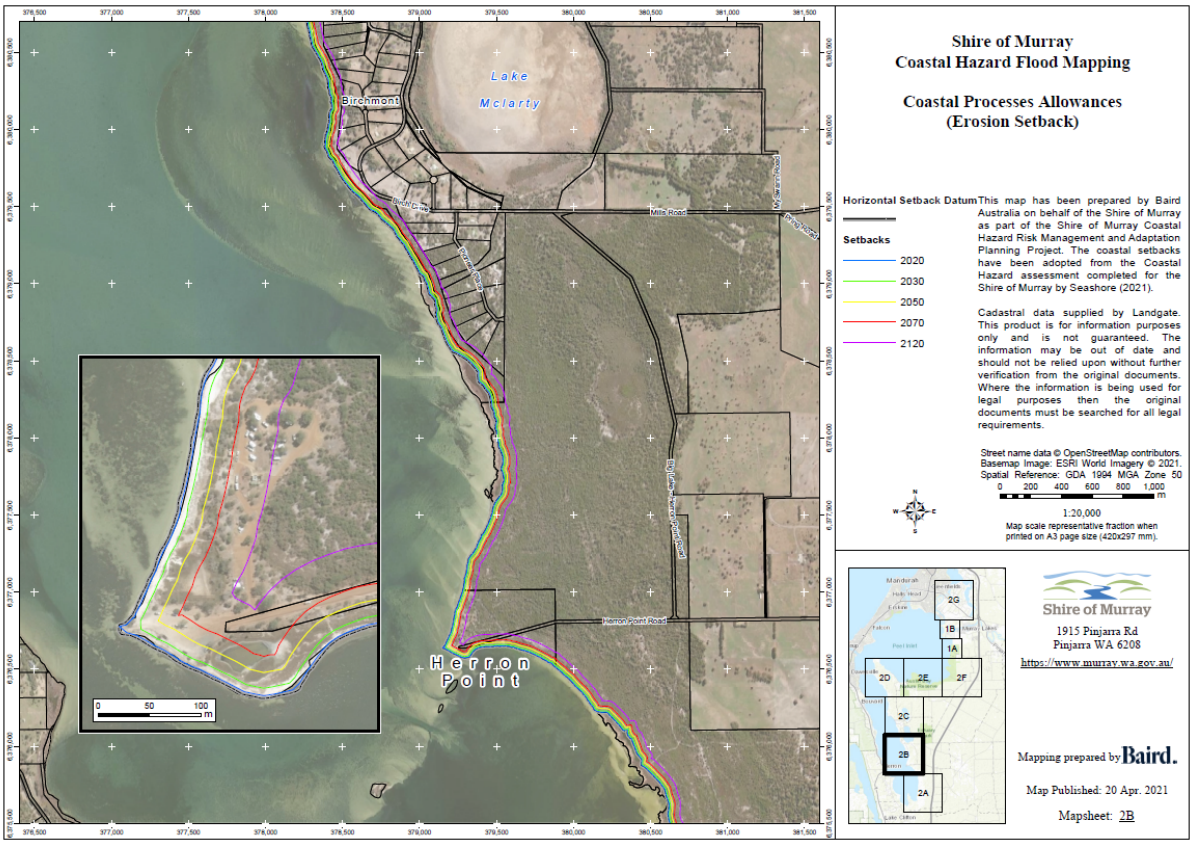


Figure 5.4: Coastal processes allowances in Peel-Harvey Estuary shorelines – Example map showing the Herron Point section of the Harvey Estuary.

5.5.2 Coastal Processes Allowance – Channel Margins

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

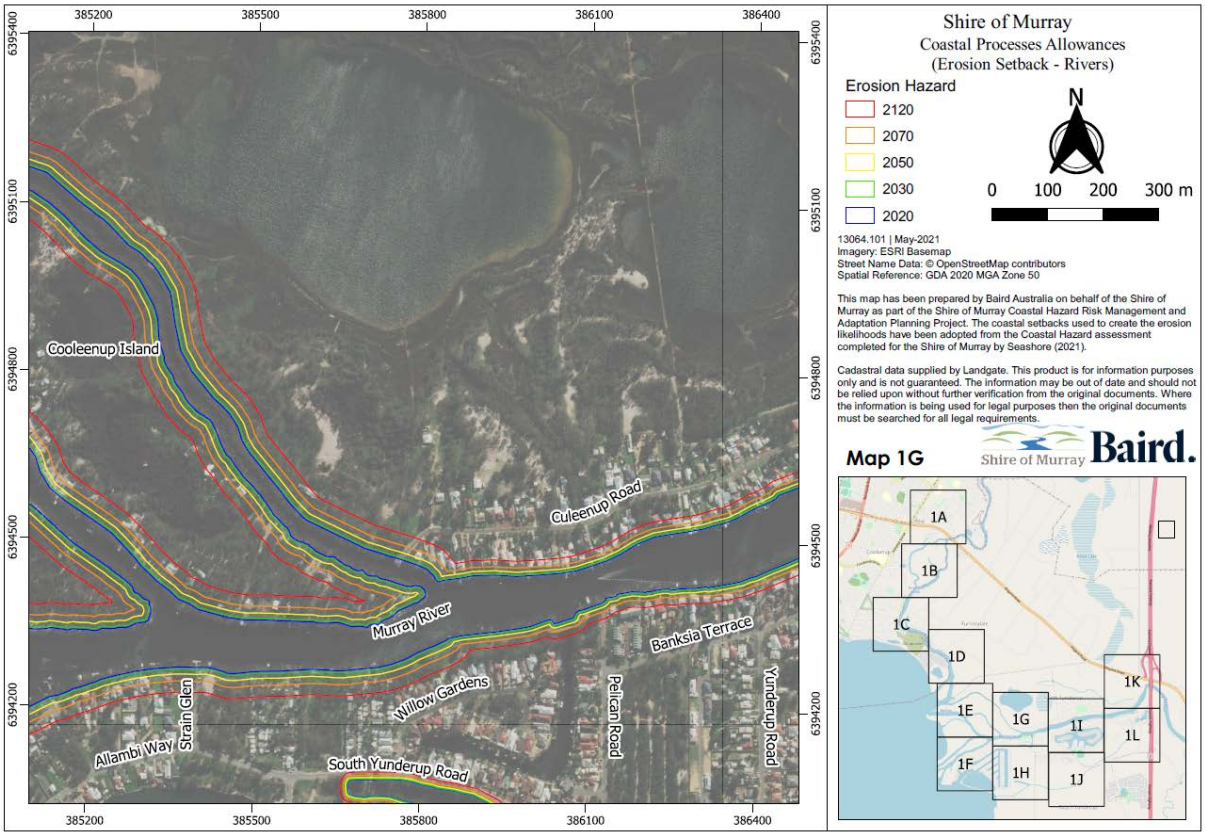


Figure 5.5: Erosion hazard allowances in the lower Murray and Serpentine Rivers – Example map.

5.5.3 Mapping Process - Inundation

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

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

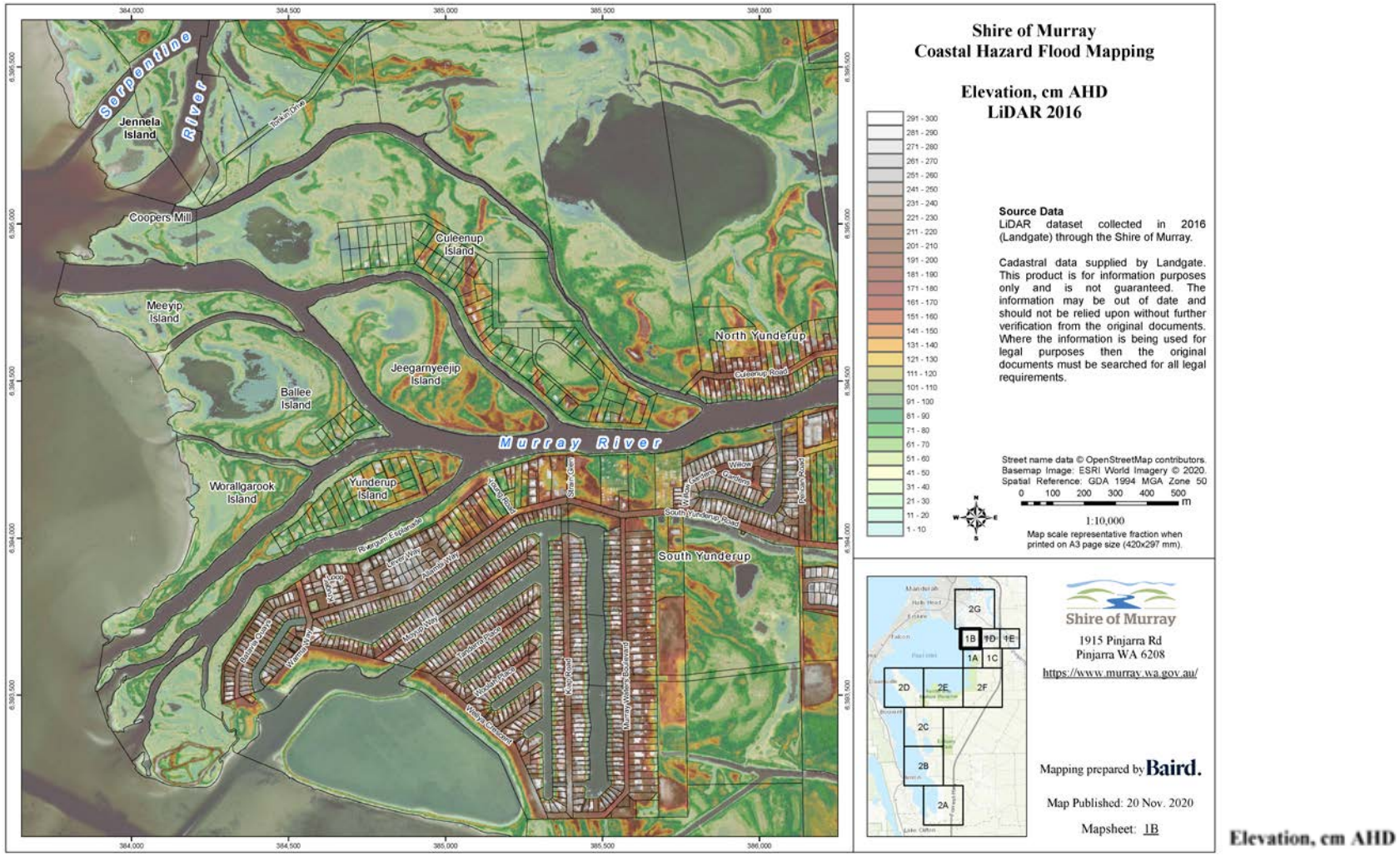


Figure 5.6: Example of elevation map showing land level for South Yunderup, North Yunderup and Murray Islands (datum cm AHD)

5.5.4 Flood Mapping Scenarios - Extreme Events

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

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

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

5.5.5 Flood Risk for Low Lying areas under General Tides

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

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

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

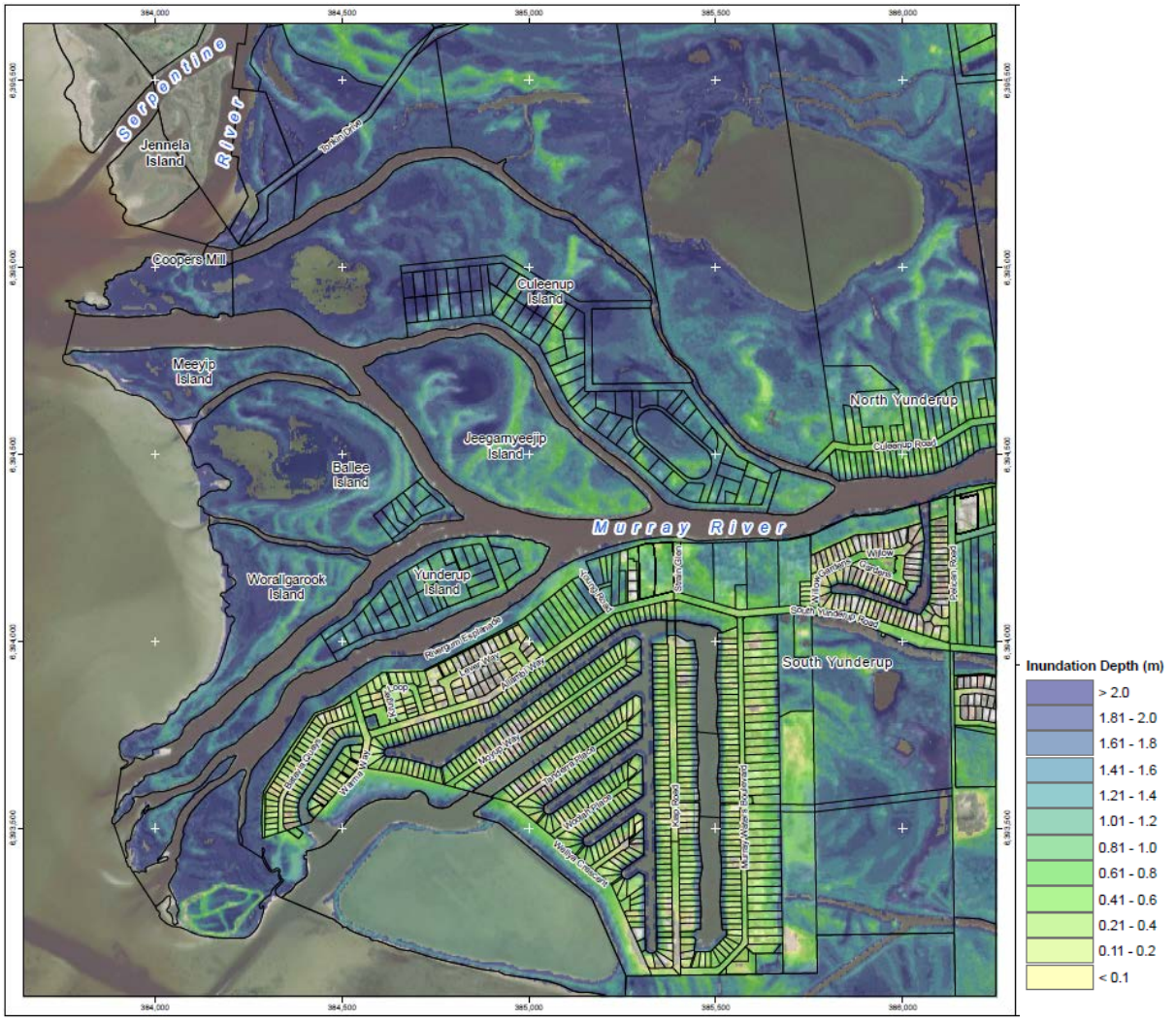


Figure 5.7: Inundation depth for the 500yr-ARI event in the year 2120 (includes 0.9m sea level rise). Example map shown for Murray Delta Islands and North and South Yunderup.

5.6 Assumptions and Limitations

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

Table 5.5: Hazard Mapping Assumptions and Limitations

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

6. Asset Identification

6.1 Coastal Assets

6.1.1 Asset Types

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

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

6.1.2 Coastal Asset Functions, Services and Value

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

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

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

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

6.1.3 Asset Identification

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

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

6.2 Coastal Asset Register

6.2.1 Compilation of Asset Data

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

Table 6.2: Shoreline Management Units (SMU)

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

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

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

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



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

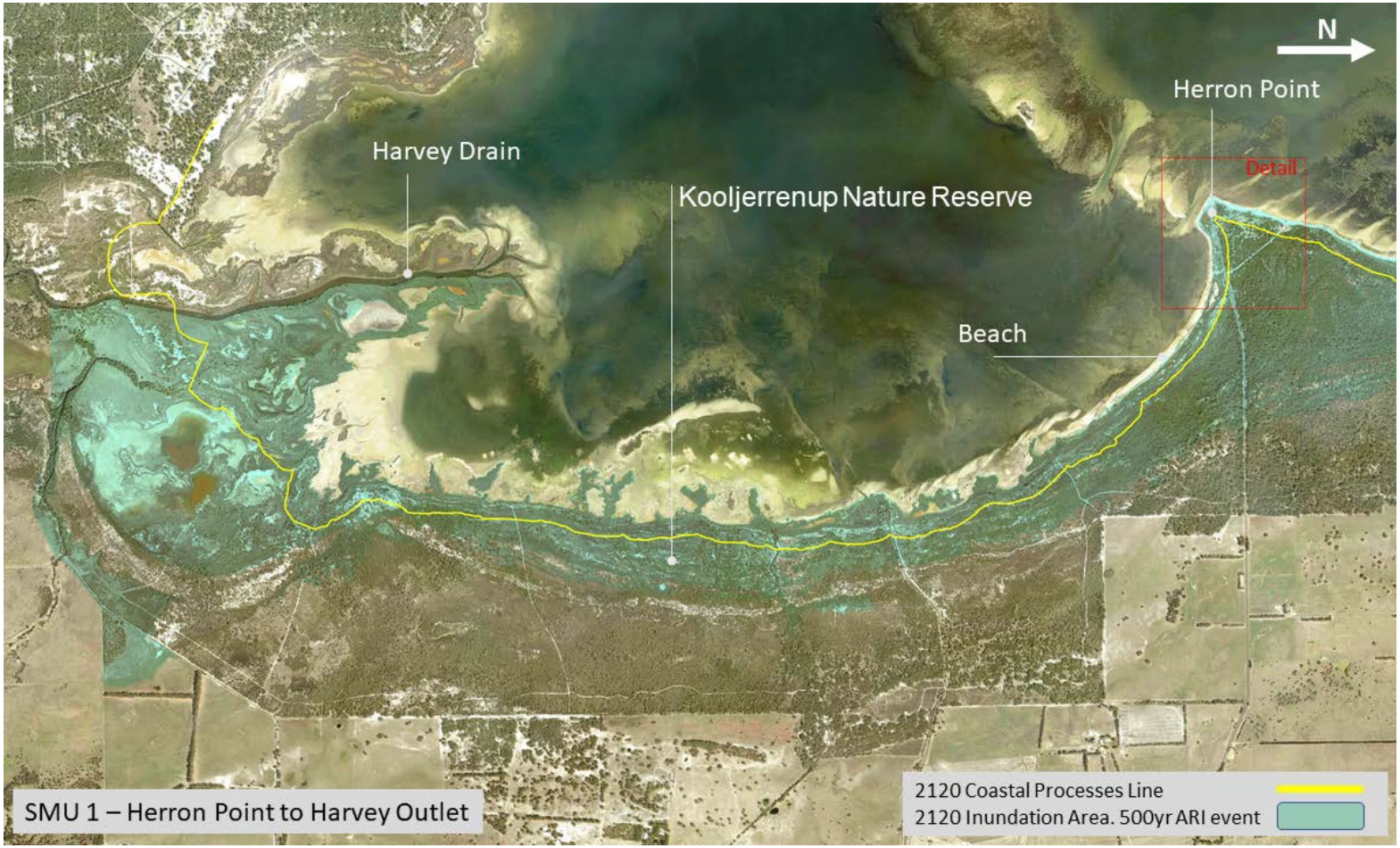


Figure 6.1: SMU1 - Coastal Assets within 2120 Coastal Hazard Extents. Harvey Drain to Herron Point



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

Table 6.4: Coastal Asset Identification. SMU2 – Birchmont

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



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

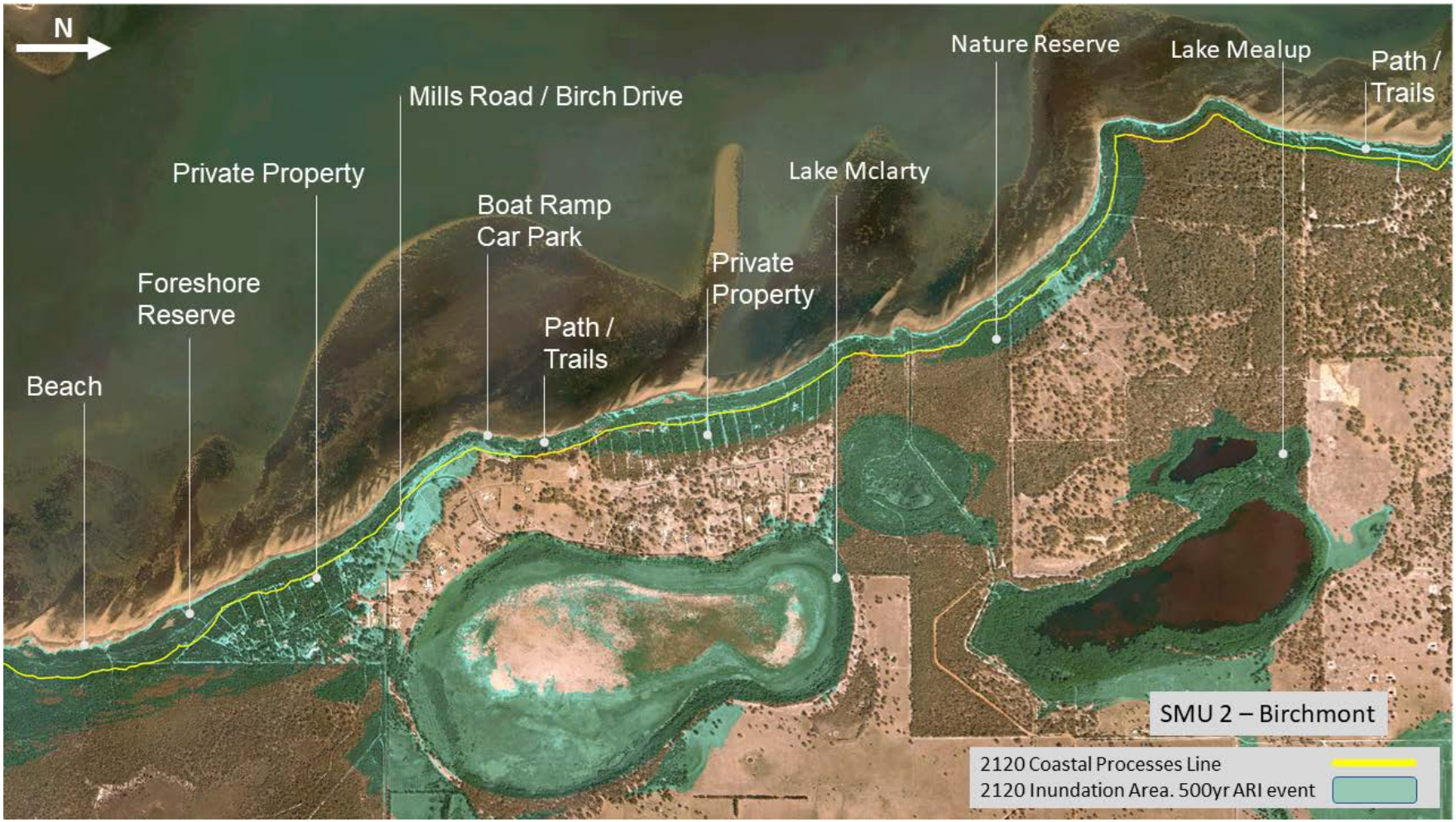


Figure 6.4: SMU2 - Coastal Assets within 2120 Coastal Hazard Extents. Birchmont

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

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



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

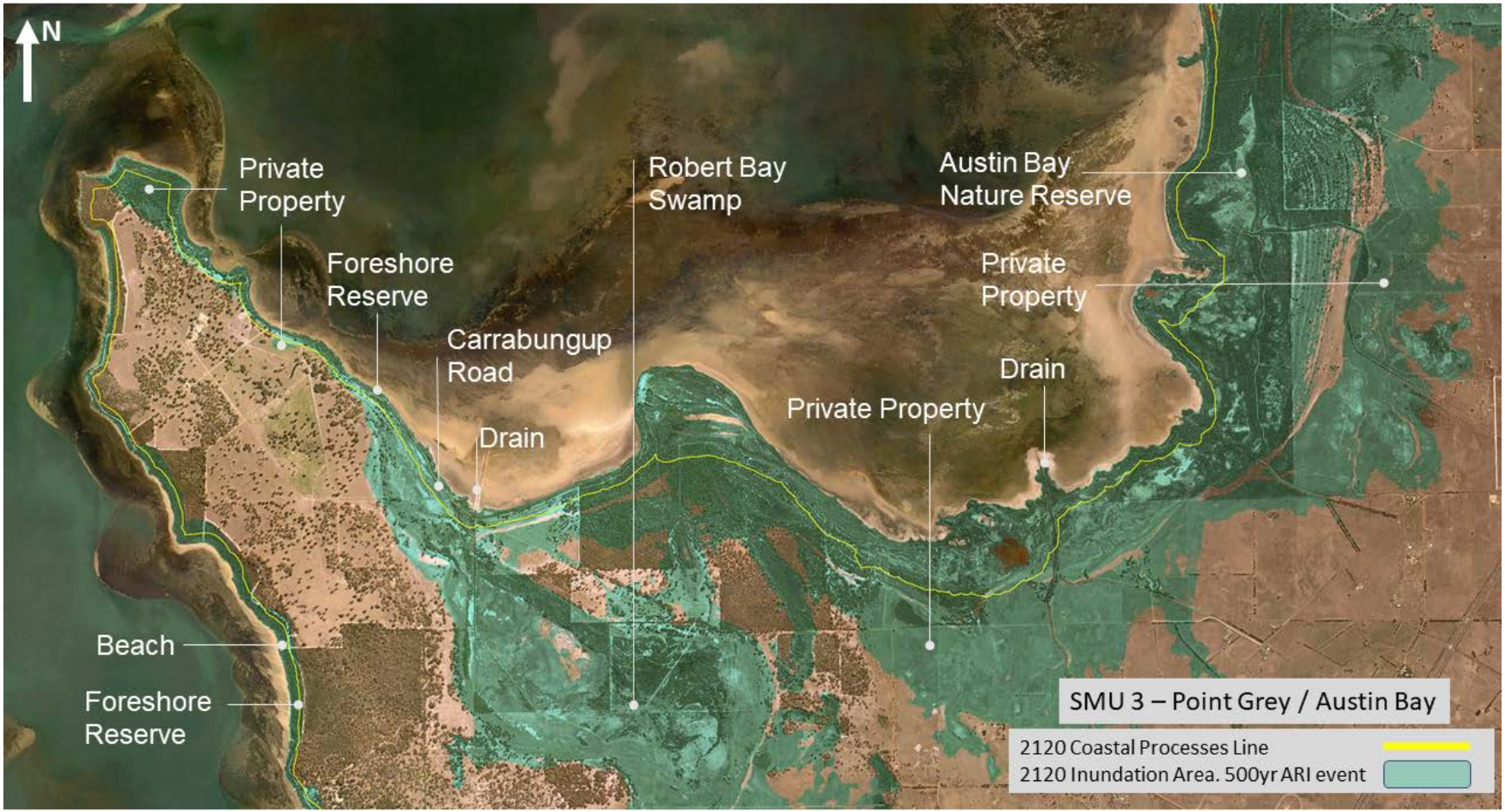


Figure 6.6: SMU3 - Coastal Assets within 2120 Coastal Hazard Extents. Point Grey to Austin Bay

Table 6.6: Coastal Asset Identification. SMU4 – South Yunderup

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



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

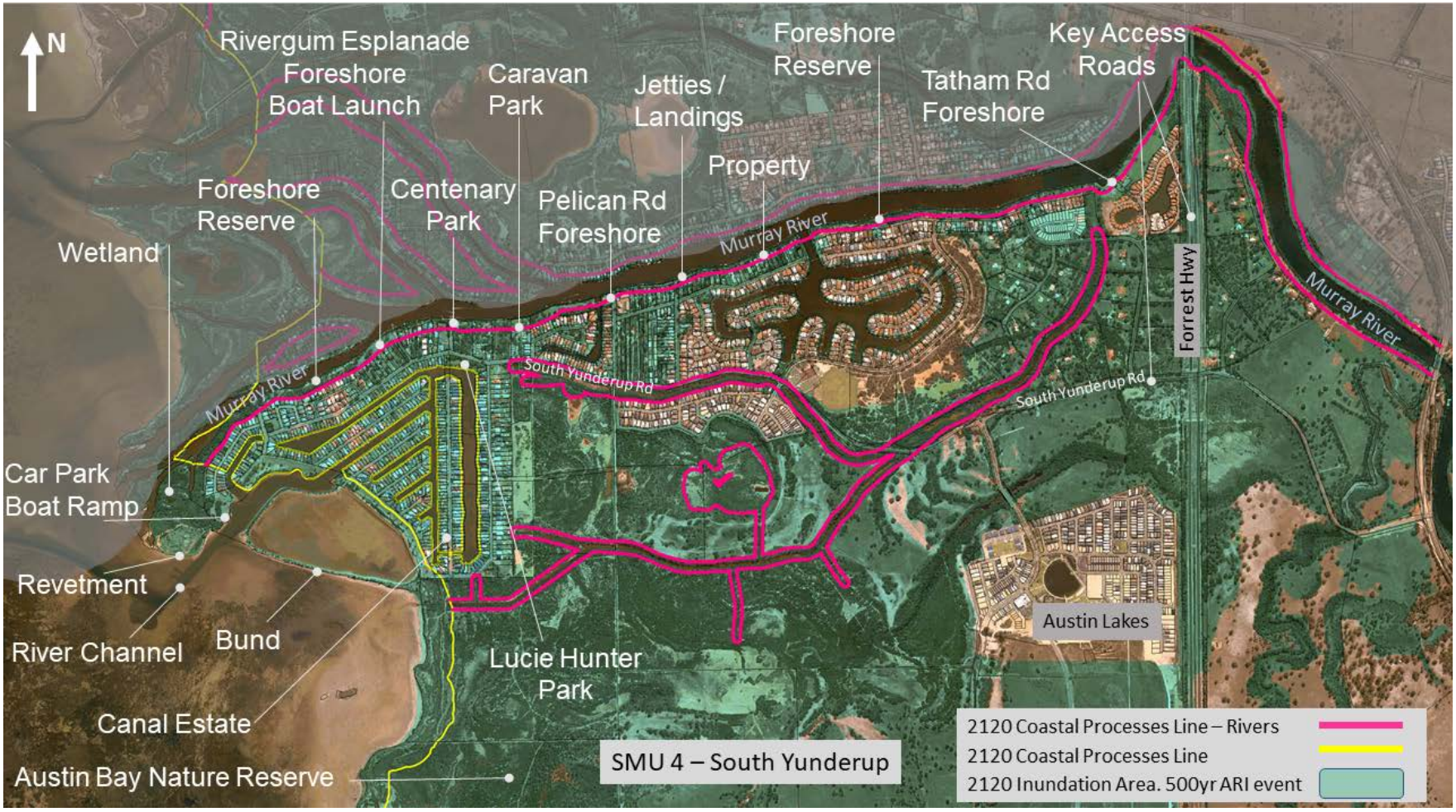


Figure 6.8: SMU4 - Coastal Assets within 2120 Coastal Hazard Extents. South Yunderup

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

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



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

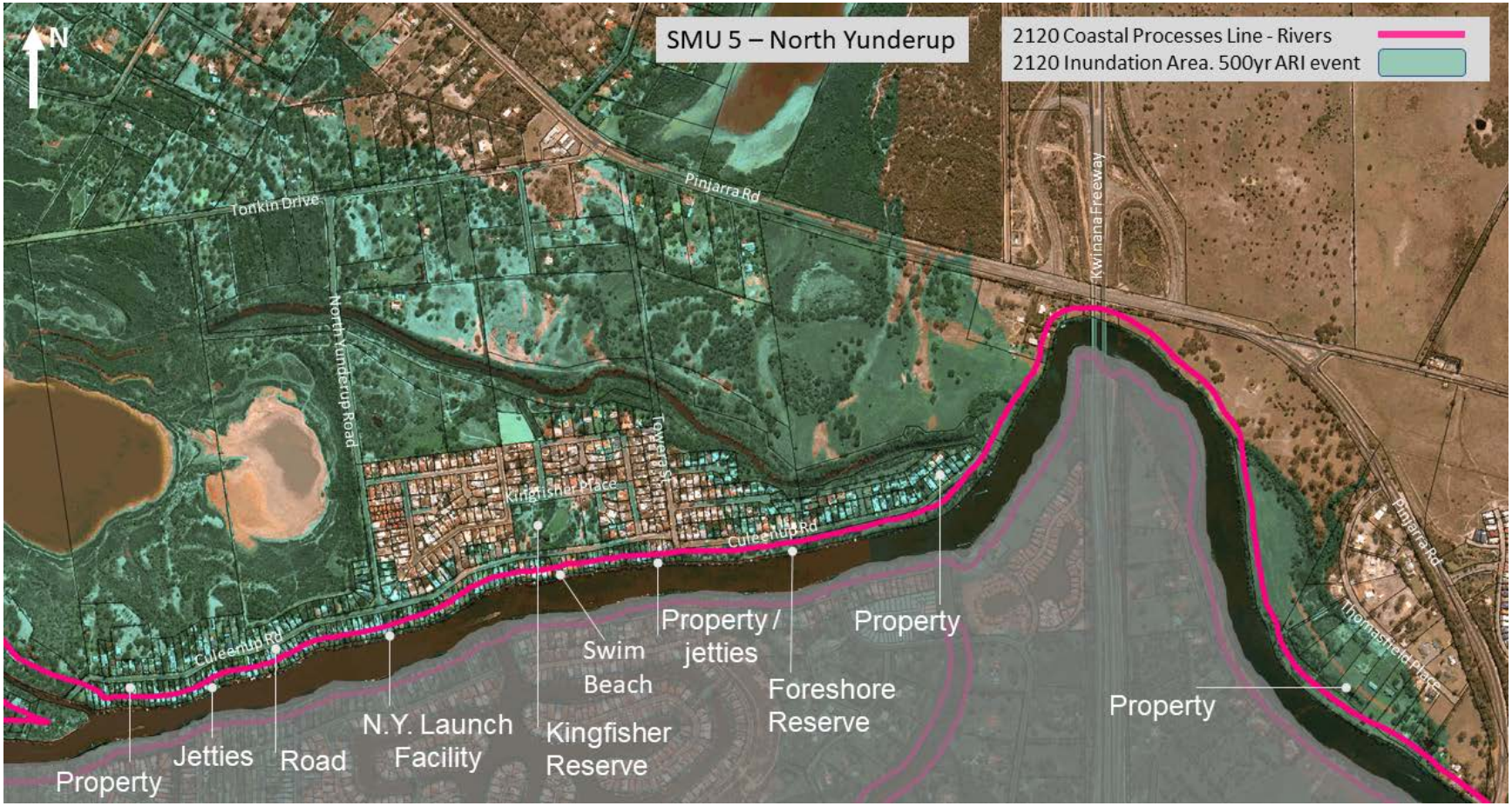


Figure 6.10: SMU5 - Coastal Assets within 2120 Coastal Hazard Extents. North Yunderup

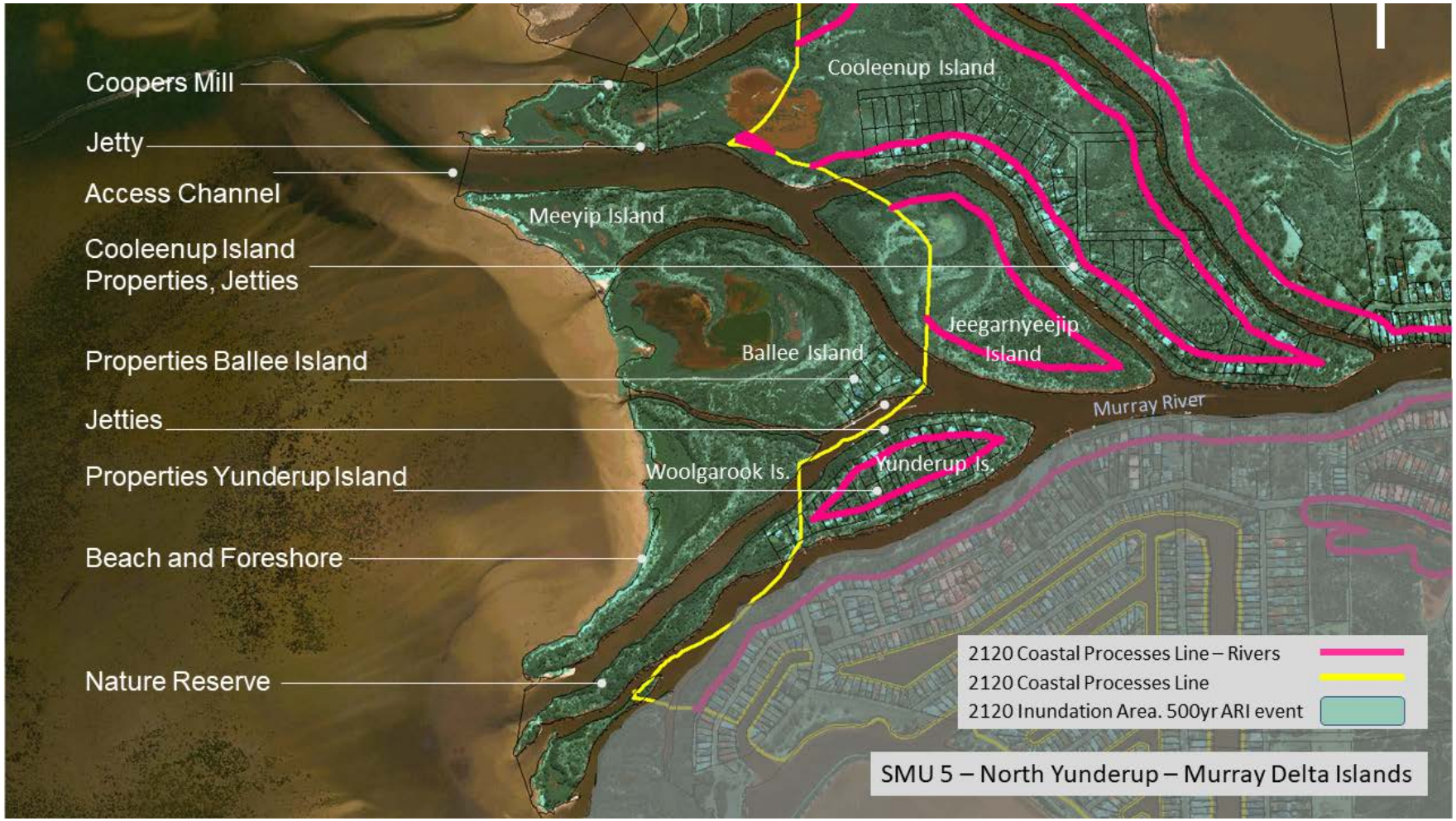


Figure 6.11: SMU5 - Coastal Assets within 2120 Coastal Hazard Extents. North Yunderup – Murray Delta Islands

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

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

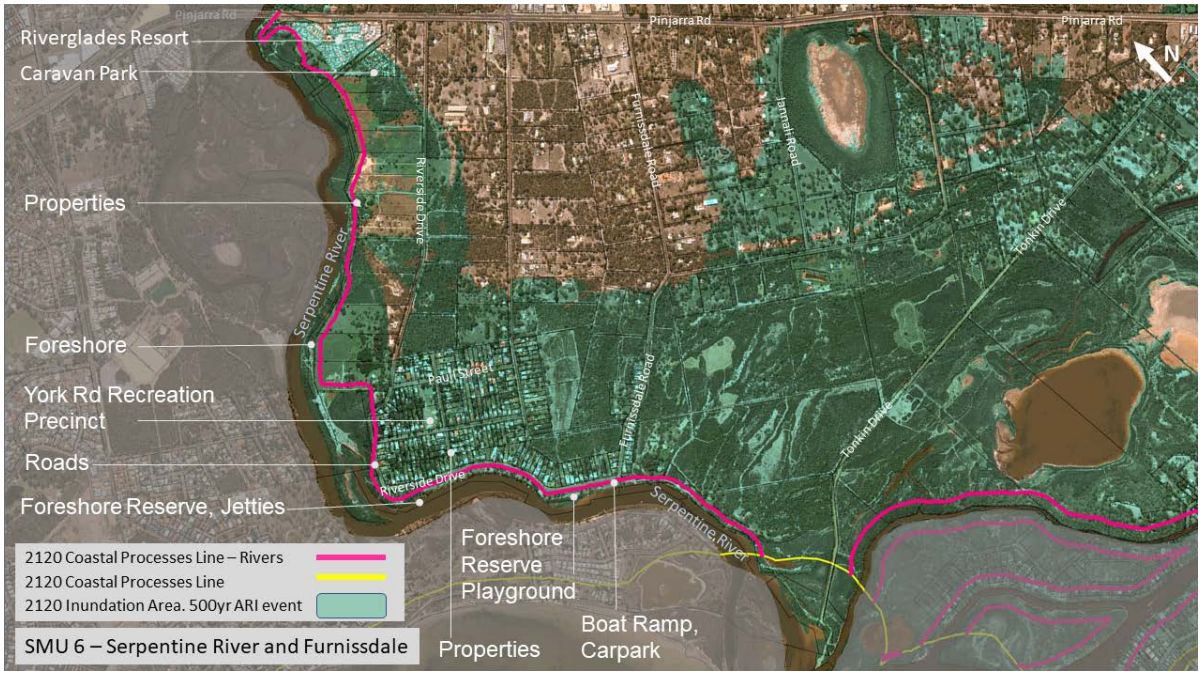


Figure 6.12: SMU6 - Coastal Assets within 2120 Coastal Hazard Extents. Serpentine River and Furnissdale

7. Risk Assessment Framework

7.1 Vulnerability Assessment

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

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

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

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

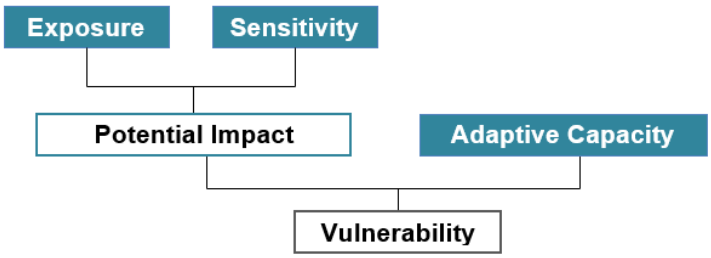


Figure 7.1: Vulnerability Assessment Flowchart

The key components in the vulnerability assessment are:

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

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

7.2 Likelihood

7.2.1 Likelihood Definitions

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

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

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

7.2.2 Likelihood Scale – Coastal Erosion

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

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

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

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

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

Table 7.2: Murray CHRMAP Likelihood Scale for Coastal Erosion

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

7.2.3 Coastal Inundation Likelihood Scale

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

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

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

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

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

Table 7.4: Inundation Likelihood Categories

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

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

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

7.3 Consequence

7.3.1 Consequence Scale

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

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

Table 7.6: Consequence Scale

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

7.3.2 Safety and Structural Considerations

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

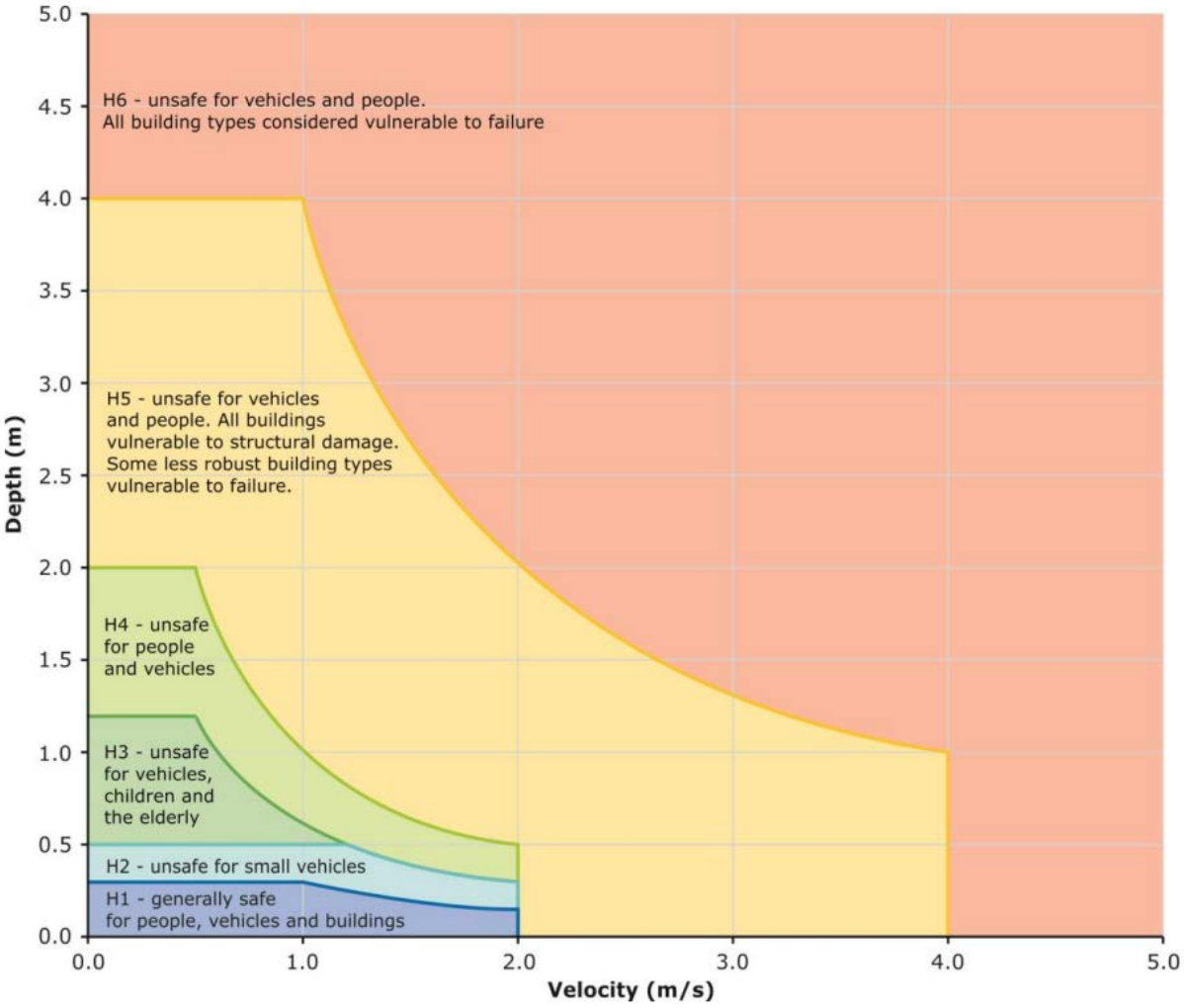


Figure 7.2: Flood Hazard Curve – Vulnerability thresholds as a Product of Inundation Depth and Velocity (from Smith et al 2014)

7.3.3 Consequence Rating – Coastal Asset Register

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

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

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

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

Notes

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

8. Level of Risk

8.1 Potential Impact

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

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

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

The risk level matrix is presented in Table 8.1.

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

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

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

8.2 Risk Acceptance and Tolerance

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

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

Table 8.2: Risk Tolerance Scale

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

8.3 Adaptive Capacity

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

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

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

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

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

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

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

Notes

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

8.4 Vulnerability Scales

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

Table 8.5: Asset Vulnerability Matrix

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

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

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

Table 8.6: Vulnerability Tolerance Scale

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

9. Risk Assessment Outcomes

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

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

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

A summary of the key findings for SMU1 are:

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

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

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

9.2 SMU2 – Birchmont

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

A summary of the key findings for SMU2 are:

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

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

9.3 SMU3 – Point Grey to Austin Bay

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

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

A summary of the key findings for SMU3 are:

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

9.4 SMU4 - South Yunderup (including the Canals)

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

The erosion vulnerability assessment showed:

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

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

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

The findings of the inundation assessment were:

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

9.5 SMU5 - North Yunderup including Murray Delta Islands

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

The erosion assessment outcomes are as follows:

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

The findings of the inundation assessment were:

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

9.6 SMU6 - Serpentine River and Furnissdale

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

The erosion assessment outcomes showed:

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

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

The findings of the inundation assessment were:

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

10. Risk Evaluation

10.1 Overview

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

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

10.2 Existing Controls

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

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

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

10.3 Existing Controls by SMU

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

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

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

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

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

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

10.4 Planning Controls

10.4.1 Existing Planning Controls

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

The following documents are included in the review:

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

10.4.2 Summary of Statutory Planning Mechanisms

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

Table 10.2: Summary of Existing Planning Controls

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

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

11. Residual Risk and Priority for Treatment

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

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

Table 11.1: Vulnerability Rating Summary

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

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

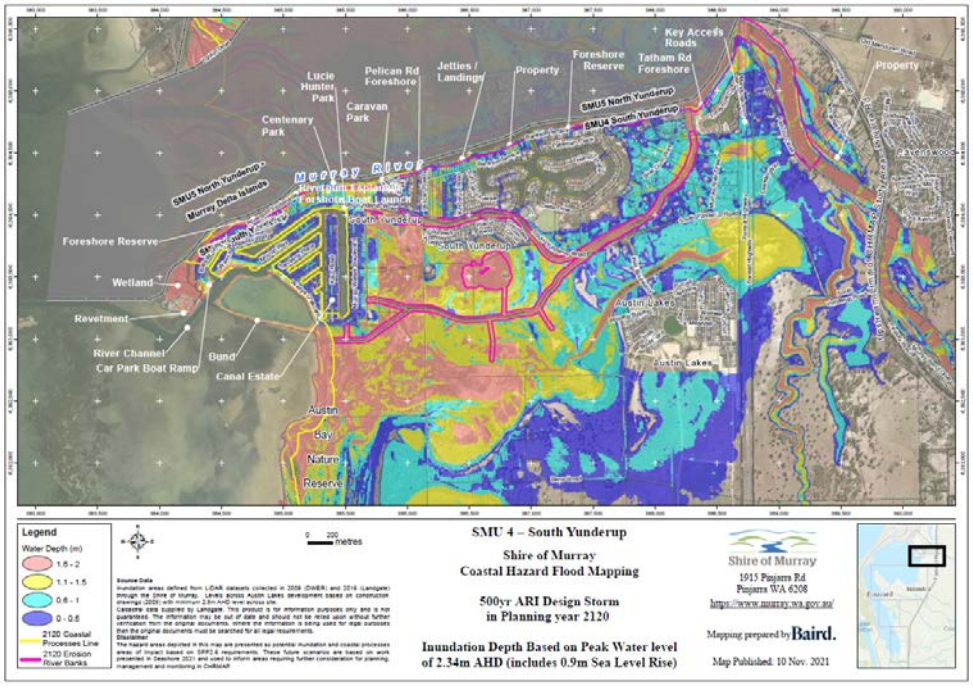


Figure 11.1: Example of SMU4 Assets with Coastal Hazard Mapping (plots available in Appendix F)

11.1 SMU1 - South end of Harvey Estuary

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

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

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

Vulnerability Rating: 🟢 Low 🟡 Medium 🟠 High 🔴 Very High

11.2 SMU2 - Birchmont

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

Table 11.3: Vulnerability Rating – SMU 2: Birchmont

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

Vulnerability Rating: Low Medium High Very High

11.3 SMU3 – Point Grey to Austin Bay

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

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

	Erosion				
	Assets Consideration of Existing Controls	**2030**	**2050**	**2070**	**2120**
1	Beach area	High	High	Very High	Very High
2	Foreshore 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
	Inundation				
	Assets	**2030**	**2050**	**2070**	**2120**
1	Beach area	Low	Low	Low	Low
2	Foreshore 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	Agricultural Properties	Low	Low	Low	Medium
7	Agricultural Land	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

Vulnerability Rating: Low Medium High Very High

11.4 SMU4 – South Yunderup

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

Table 11.5: Vulnerability Rating – SMU 4: South Yunderup

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

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

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

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

Vulnerability Rating: Low Medium High Very High

11.5 SMU5 – North Yunderup and the Murray Delta Islands

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

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

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

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

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

Vulnerability Rating: Low Medium High Very High

11.6 SMU6 – Serpentine and Furnissdale

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

Table 11.7: Vulnerability Rating – SMU6: Serpentine and Furnissdale

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

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

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

Vulnerability Rating: Low Medium High Very High

12. Risk Treatment Process

12.1 Risk Treatment Overview

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

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

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

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

In this Section:

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

12.2 Risk Treatment Options

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

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

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

a) **Avoid**: this approach is to simply avoid new development in areas at risk of coastal hazard. This approach is only applicable to locations where development has not commenced; The aim of this risk treatment option is to avoid the construction of new public and private assets within areas identified to be impacted by coastal hazards. Avoidance risk treatment options are the best form of risk management (mitigation) and where possible should be the risk treatment option of choice (WAPC 2019). Avoidance is particularly applicable to all land use and development in greenfield locations

b) **Planned or Managed Retreat**: the concept of planned or managed retreat allows existing public assets and private property to remain in place until such time as coastal hazard from erosion or inundation is untenable. Planned or managed retreat for existing development involves relocating or sacrificing infrastructure, both public assets and private property, when erosion and recession impacts reach action trigger points. Under this option the use of temporary coastal protection structures and/or restoration of natural controls such as dunes and shoreline areas is supported to maintain or create a buffer against storm erosion. As existing assets reach the end of their functional life (or if they are substantially damaged by a storm event), they would be removed, including any associated coastal protection structures.

c) **Accommodate**: The accommodate risk treatment option aims to utilise design and management strategies which render the risks as tolerable/acceptable, allowing land to continue to be utilised until risks become intolerable. Design and management strategies may include a mix of structural or non-structural approaches. Structural approaches include minimum finished floor levels and elevated electrical circuitry, and relocatable structures which can be moved to a different location on- or off-site to manage risk arising from inundation coastal hazards. Non-structural approaches such as modifications to local planning frameworks can also enable accommodate risk treatment options; and

d) **Protect**: Protect risk treatment options aim to protect assets from damage resulting from erosion and recession and storm surge inundation. Protect risk treatment options should be primarily proposed in the public interest and enhance or preserve beach and foreshore reserve amenity. The Protect option is only available when all other options are exhausted and should be justified in terms of the benefit it delivers to the community.

- Common hard protection structures include seawalls; groynes; offshore breakwaters and artificial headlands; and soft protection measures such as beach nourishment.
- Interim protection structures can be applied to delay shoreline recession over the short to medium term. This might be achieved through soft protection measures such as regular sand renourishment and revegetating coastal dunes.

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

e) No Regrets

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

f) Do Nothing

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

12.3 Adaptation Tools

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

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

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

12.4 Trigger Points

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

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

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

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

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

- Batavia Quays Revetment
- Riverside Drive Boat Ramp

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

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

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

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

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

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

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

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

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

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

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

12.5 Planning Based Approaches

12.5.1 Statutory Planning Mechanisms

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

12.5.2 Recommended Planning Controls

12.5.2.1 Local Planning Strategy

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

Subsequent revisions of the Local Planning Strategy shall include a provision for all SPP 2.6 requirements to be met at the earliest stage possible, including the requirements for the ongoing provision of a coastal foreshore reserve. The revision should commence following the CHRMAP adoption (refer to Implementation (Section 16).

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

12.5.3 Local Planning Scheme Amendment

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

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

The Scheme Map will require updating to include:

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

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

12.5.3.1 Special Control Area (SCA)

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

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

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

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

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

		impact on the functions of public reserves. • To ensure coastal process considerations are taken into account in preparing strategic planning proposals and in assessing subdivision and development applications.	(2) Notwithstanding any other provision of the Scheme, all proposed development within SCA 1 requires the development approval of the local government, unless the development is specified in the local government's Coastal Hazard Local Planning Policy as a type that does not require development approval. (3) In considering any application for development approval, or its advice in relation to a proposed structure plan, or application for subdivision of land within SCA 1, the local government is to have particular regard to: (a) The Shire of Murray Coastal Hazard Risk Management and Adaptation Plan; (b) State Planning Policy 2.6 – State Coastal Planning Policy; (c) The Shire of Murray Coastal Hazard Local Planning Policy; (d) The likely effect on public safety and the risk associated with coastal inundation and erosion; (e) The existing and likely future effect of coastal erosion or inundation on the land; (f) The vulnerability of any roads providing access to the land and any public utility infrastructure servicing the land; (g) The continued suitability of servicing the land with an onsite effluent disposal system, where reticulated sewer is not available; (h) The impact that any proposed earthworks, retaining walls or other protective measures will have on the amenity of

			the locality and water flows; (i) The adequacy of the coastal foreshore reserve to provide for continued coastal foreshore management, public access, recreation, conservation and landscape amenity; (4) An application for development approval for development proposed within SCA 1 may be referred to any statutory, public or planning authority for advice and recommendations before being considered by the local government. (5) Where the local government decides to approve an application for development approval it may impose conditions so as to: (a) constrain the location of development; (b) control the form of construction, including foundations and associated works; (c) determine the form, location and construction of access; (d) require a minimum floor level for development; (e) limit the term of the approval; (f) require the approved development to be removed and the land restored to a condition as near as practicable to its condition immediately before development started to the satisfaction of the local government upon a trigger event occurring; and (g) require the registration of a notification under section 70A of the *Transfer of Land Act*

			1893 on the Certificate of Title of the subject land at the cost of the landowner advising: (i) that the lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years; (ii) of any limited term of a development approval; and (iii) of any requirement to remove approved development and restore the land as near as practicable to its condition immediately before the development started to the satisfaction of the local government upon a trigger event occurring. (6) Where an application for subdivision of land within SCA 1 is referred to the local government, it may recommend that the Commission applies conditions requiring: (a) the finished surface level of the land, or the level of public roads providing access to the land are raised sufficient to reduce the risk of coastal inundation; (b) building envelope/s, where applicable, provide a specified area of land that is located above the coastal inundation level; (c) a notification under section 165 of the *Act* to be placed on the Certificate(s) of Title of the subject land, at the cost of the landowner advising that the lot(s) is located in an area likely to be subject to erosion and/or inundation over the

			next 100 years. (7) If the local government forms the view that a trigger event has occurred it may give to a person who is the owner of land or any other person who undertook development on land within SCA 1, a coastal hazard notice requiring the person to: (a) remove, pull down, take up, alter or relocate the development or portion of the development specified in the notice; and (b) restore the land as nearly as practicable to its condition immediately before the development was undertaken to the satisfaction of the local government; by a specified time, being a time that is not less than 60 days after the day on which the notice is given. (8) If a person fails to comply with a coastal hazard notice, the local government may enter the land and carry out the works specified in the notice. (9) The expenses incurred by the local government in carrying out the works under clause (8) may be recovered as a debt due from the person to whom the notice was given in a court of competent jurisdiction. (10) The local government may — (a) vary a coastal hazard notice to extend the time for carrying out the specified works; or (b) revoke a coastal hazard notice. (11) A person who is given a coastal hazard notice may apply to the State Administrative Tribunal for a review, in accordance with Part 14 of the Act of a decision —

			(a) to give the notice; or (b) to require the works specified in the notice to be carried out; or (c) to require the works specified in the notice to be carried out by the time specified in the notice.

12.5.4 Coastal Hazard Local Planning Policy (LPP)

1.0 Application

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

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

2.0 Background

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

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

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

3.0 Objectives

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

4.0 Definitions

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

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

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

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

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

Commission means the Western Australian Planning Commission.

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

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

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

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

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

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

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

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

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

Trigger event has the same meaning given in the Scheme.

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

5.0 Requirement for Development Approval

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

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

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

5.1 Exempted Development

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

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

6.0 Policy Requirements

6.1 General

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

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

6.2 Strategic Planning Proposals

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

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

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

6.3 Subdivision

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

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

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

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

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

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

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

6.4 Development

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

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

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

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

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

12.5.5 Planned or Managed Retreat Policy

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

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

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

12.5.6 Foreshore Management Plans

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

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

12.5.7 Emergency Response and Evacuation

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

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

12.6 Economic Framework

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

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

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

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

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

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

13. Multi Criteria Analysis

13.1 Overview of the MCA process

13.1.1 General Explanation

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

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

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

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

- Technical
- Social
- Environmental

The assessment categories are outlined in Table 13.1

Table 13.1: MCA Categories and Key Criteria

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

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

Table 13.2: MCA Scoring – Performance and Impact

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

Table 13.3: MCA Scoring - Cost

Score	Technical
1	Most Expensive
2	
3	
4	
5	Least Expensive

13.1.2 MCA Workshop

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

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

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

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

13.2 MCA Summary of Outcomes

13.2.1 Item 1 – Erosion and Inundation of Kooljerrenup Nature Reserve

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

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

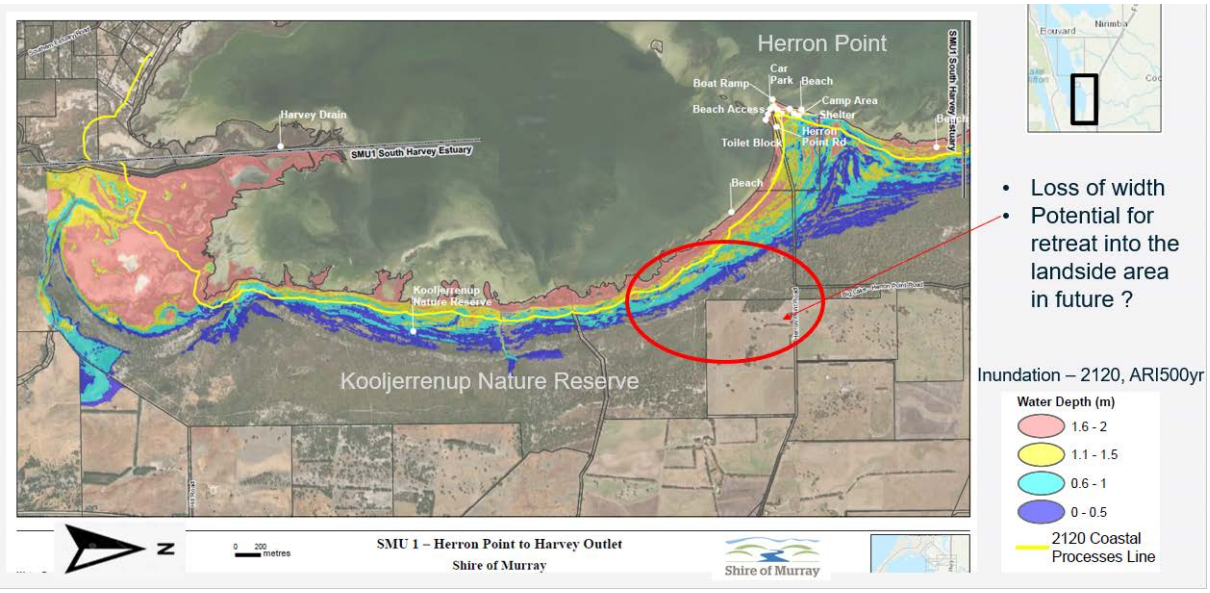


Figure 13.1: Erosion and Inundation at Kooljerrenup Nature Reserve

Options identified to mitigate the issue:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

13.2.2 Item 2 – Inundation of Properties

Brief description of the issue:

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

Options identified to mitigate the issue (Figure 13.3):

a) Planning Based Approaches for Housing Design - Raise Floor Levels and improve foundation design to withstand flood conditions (as redevelopment)

b) Planning Based Approached for Housing Design. Fill Properties to Design Level (as redevelopment)

c) Temporary Flood Barriers at the edge of the Murray Delta Islands that can be erected to protect from inundation ahead of the event

d) Permanent Flood Barriers at the edge of the Murray Delta Islands that can be built and maintained at a level above the design flood (eg dike, revetment in foreshore)

e) Build Flood Barrier at the Dawesville Cut

f) Managed Retreat. Islands returned to Nature

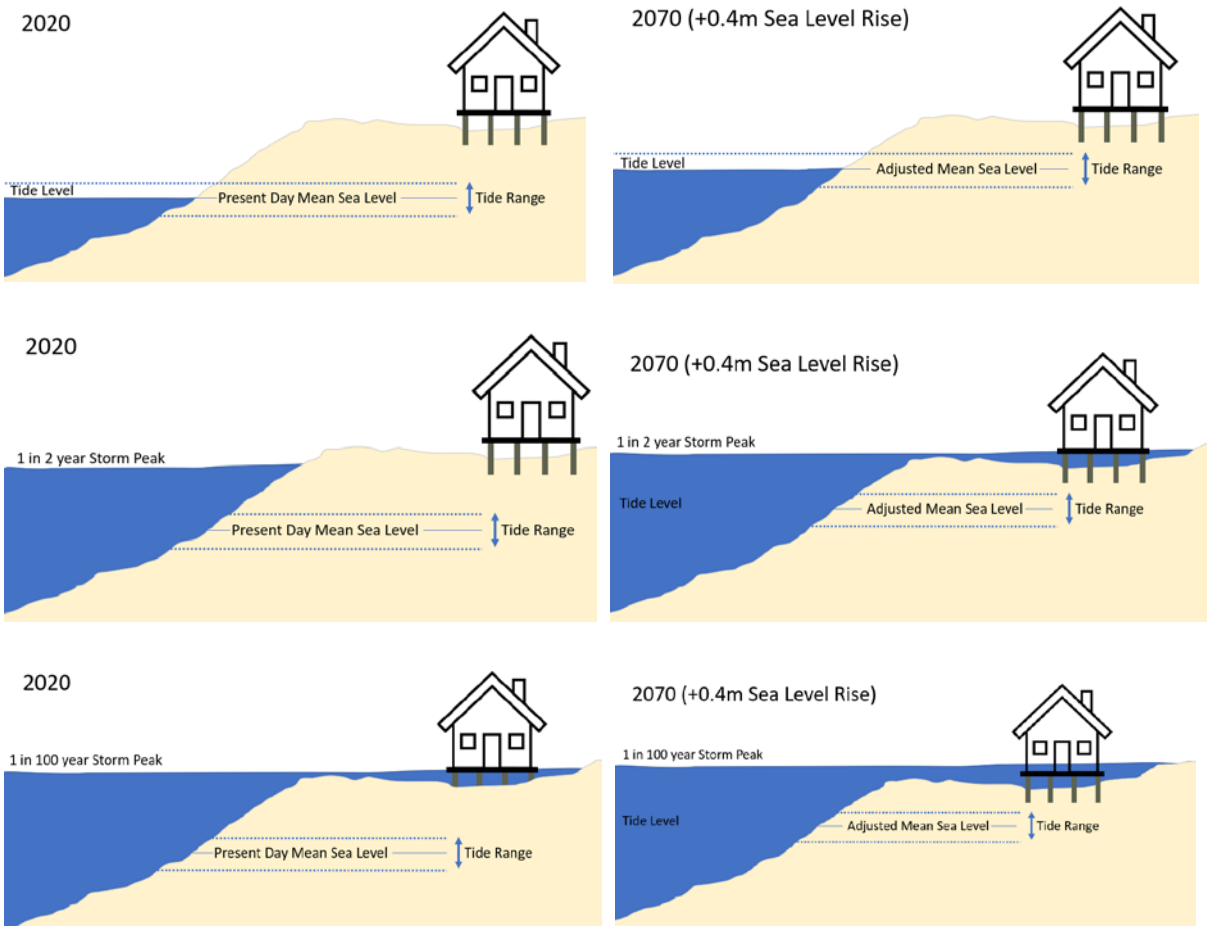


Figure 13.2: Illustration of the influence of sea level rise on low lying properties for general tide range, 1 in 2-year flood level and 1 in 100 -year flood level. On the left the present-day scenario (2020) is presented and in the right column the same flood cases with sea level rise allowance is shown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

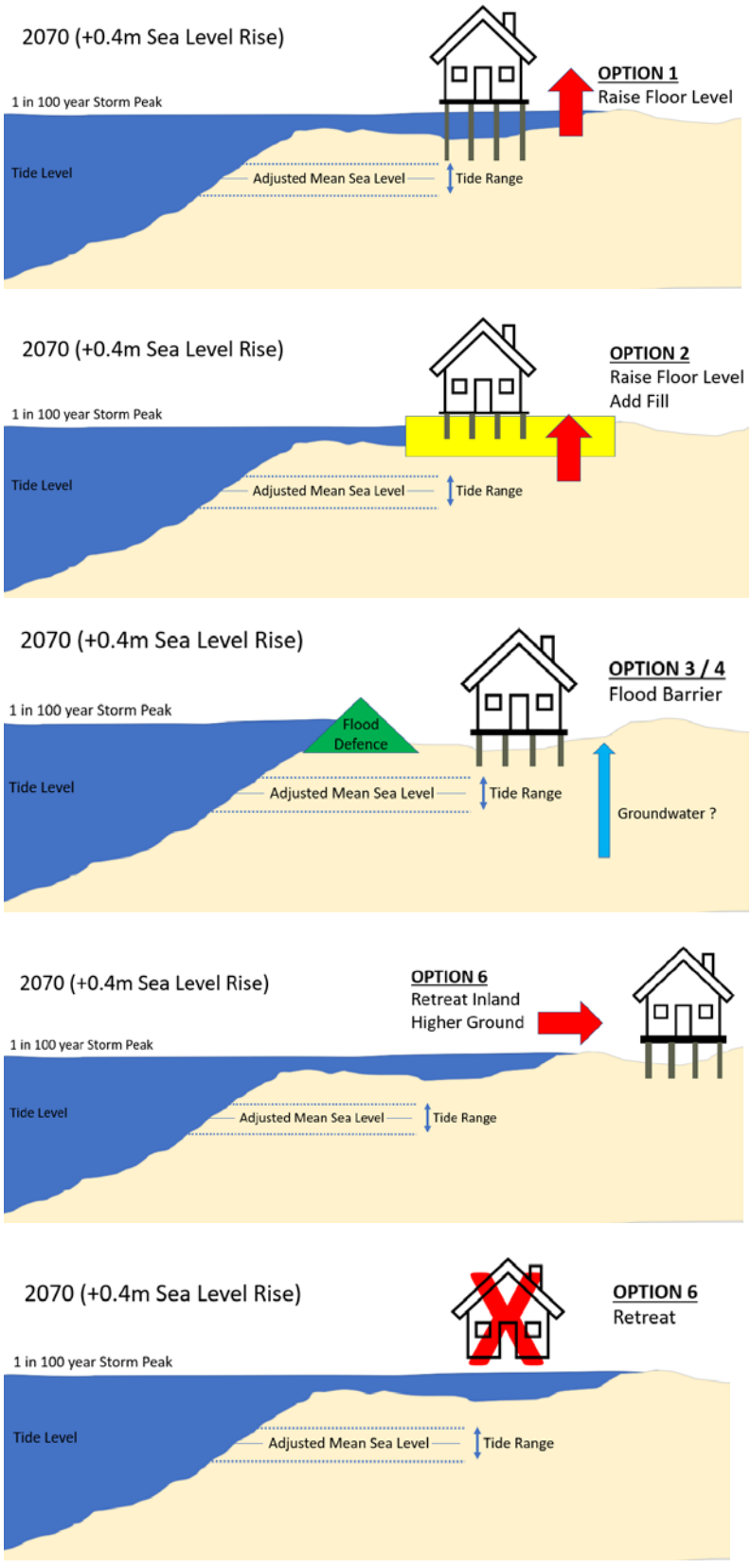


Figure 13.3: Basic overview of the Mitigation Options to address inundation hazard

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

13.2.3 Item 3 – Erosion of Riverbanks

Brief description of the issue:

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

Options identified to mitigate the issue:

a) Do Nothing (annual monitoring only)
b) Managed Retreat of Properties

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

13.2.4 Item 4 – Septic Systems

Brief description of the issue:

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

Options identified to mitigate the issue:

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

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

Table 13.23.

The final outcomes summarised in

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

14. Cost Benefit Analysis

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

14.1 Assessment Scenarios

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

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

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

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

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

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



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

14.2 Nature Based Adaptation Options – Building Resilience

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

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

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

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

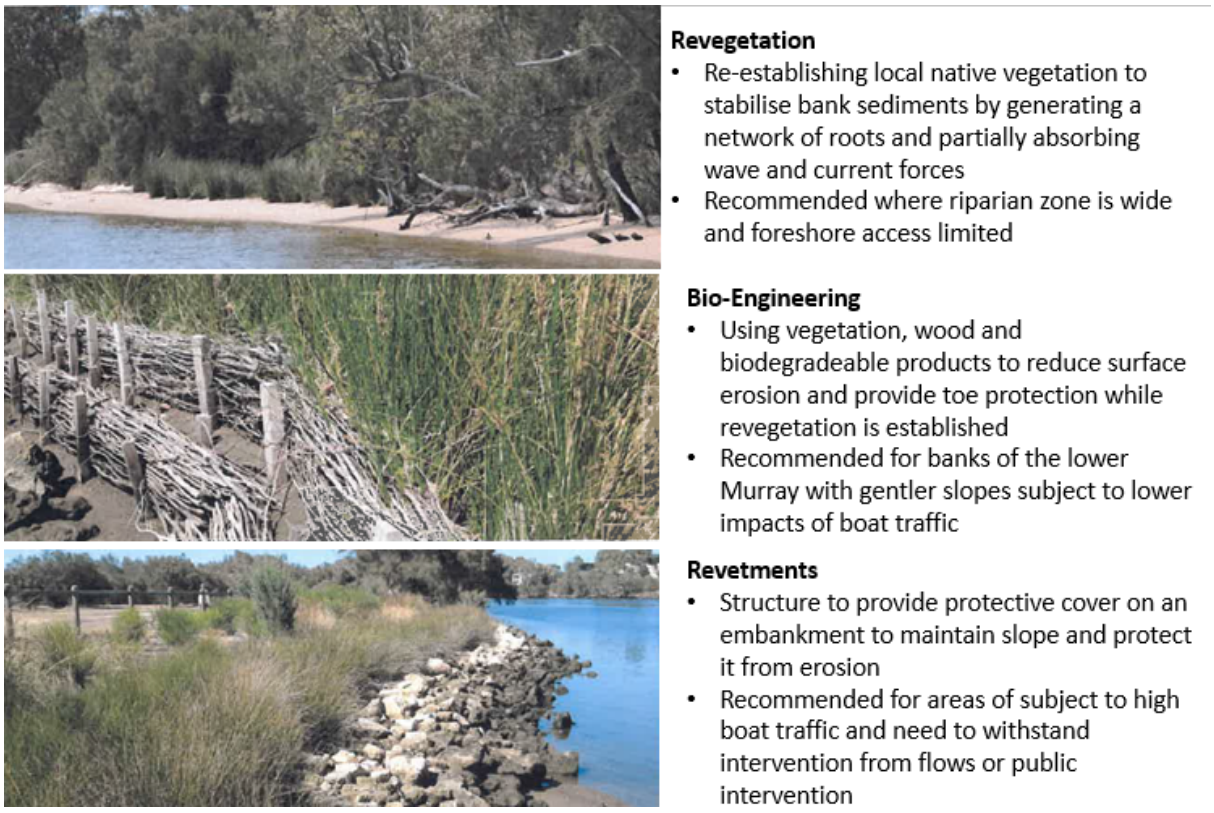


Figure 14.2: Nature Based Solutions for Riverbanks in the Shire of Murray (Adapted from Syrinx 2018)

14.3 Key Assumptions

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

Table 14.2: Key Assumptions in the Cost Benefit Analysis

Item	Assumptions
Scenarios – Base case and Developed Case	Base case condition – this is the one against which the options are assessed. It assumes no controls in place, and that you get erosion, inundation etc Hard Engineering Options – The more expensive option, which is assumed to provide 100% flood inundation protection and 100% erosion protection. Examples of this are the existing canal walls or dike structure. Natural Based Solutions (NBS) Options – no protection for inundation, 60% protection for erosion.
Benefits	There are two key benefits that have been considered: • Reduction in flood inundation damages • Reduction in erosion/ loss of land.
Erosion	Under the base case, the loss of value associated with the loss of land, as well as the public assets such as the parks etc For the private land, estimated the value of the land (without the building) and then loss of that land over time based on the area within coastal hazard erosion setback lines for future planning periods. Assumption that once the lot is less than 500m^2, it is no longer viable. This is probably conservative, as you may be able to do something with a property that small, but you wouldn't likely redevelop if it is an eroding area. In addition to the value of the land, allowance for the loss of a house is done in two ways: • if the erosion hits the house and the land area is still above 500m^2, then reconstruct further back in the lot. Noting that there are some large properties in the study area, this is probably not unreasonable. • If the land area is below 500m^2, then the property will undergo managed retreat and you lose the value of the house and the remainder of the land in one go. This provides the details of the base case condition. The CBA model examines the proportion of protection as indicated above for the options, where the % reduction is applied directly to the economic loss.
Inundation	Under the base case, the loss of value associated with the inundation of land, as well as the public assets such as the parks etc. For the private land, estimation of the land area impacted for a range of flooding scenarios based on the area within coastal inundation hazard extent today and in future planning periods (with projected sea level rise). The approach looks at the damage associated with overfloor flooding and has been derived based on the most recent guidance from DECC (2007). It assumes a representative property type for almost all properties. Buildings are highly variable throughout the study area, including on the islands. In the absence of detailed information on all building types in the study area the approach has been to assume the representative damage curve (DEEC 2007). There have been a couple of minor adjustments to properties where it was clear that

Item	Assumptions
	they were particularly small etc, but otherwise the same representative damage curve is adopted. The estimate of the damage associated with inundation also removes the damage to a property, where the property erodes to less than 500m^2 and managed retreat is assumed to occur. In other words, if the property is abandoned you then don't claim flood damages as well. This provides the base case information and the potential protection from inundation is then assessed for each of the options.
Economic Parameters	Discount rate of 7% Assessment period of 50 years, and we have assumed that this is roughly equivalent to the design life of the infrastructure Initial mitigation works would be undertaken in 2025, with a first year of completion assumed as 2026. For climate change, a linear change between the various planning timeframes (2020, 2030, 2050, 2070, 2120).
Limitations	The model is sensitive to land value and building value assumptions. For the Murray Delta Islands there is both a low number of properties on the islands and low sales volumes on which to base house and land values. • It has been assumed a land value of $80k for the island properties, and a building value of $200k for the purpose of the CBA. • The property sales on the islands have been in the general range of $50k through to $800k with the "representative" value adopted based on analysis of the available data. Sensitivity analysis of house and land value has been used to test the outcomes of the CBA. • It is noted the valuation of property in the current report should not be taken as a future indicator for other purposes outside this CHRMAP. As stated in Rhelm (2022) it is not intended to be a precise property by property estimate, but rather an overall average to provide an indication of the economic loss.

14.4 Calculated Areas of Impact

14.4.1 Residential Properties – Impacts from Inundation and Erosion

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

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

14.4.2 Shire of Murray Assets

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

14.5 Unit Rate Values

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

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

Table 14.3: Adaptation Options and asset values - Unit Costs

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

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

14.6 CBA – Summary of Analysis

14.6.1 Mitigation Option Costs

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

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

Table 14.4: Summary of Mitigation Options Costs

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

14.6.2 Benefit Costs Ratio (BCR)

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

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

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

14.7 Key Findings from CBA

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

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

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

It is noted:

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

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

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

14.8 Key Outcomes for CHRMAP

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

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

b) For the Murray River shoreline of North Yunderup, the nature-based solutions perform well due to the density of properties in this area and their proximity to the river. However, there may be practical challenges in implementing nature-based solutions within the available space in this area. A hard engineering solution, while having a BCR less than 1, is expected to be viable within 10 years, and therefore should be considered in the 2030 to 2040 planning horizon.

c) South Yunderup performs well with nature-based solutions (BCR of 1.74) indicating these options are supported for implementation today. These solutions suit the shoreline areas with generally greater land buffer in this location compared with the northern side of the Murray River.

d) Erosion of the Kooljerrenup Nature Reserve was assessed against the adaption strategy of purchasing land on the eastern side of the reserve, to mitigate the loss of land due to erosion on the shoreline side. Loss of land area is projected to increases markedly after the 2050 period due to shoreline erosion driven by projected sea level rise. Monitoring of the shoreline areas and their response to sea level rise in the next 20 years will inform the future adaptation strategy with further consideration of the need for potential acquisition of land recommended in the 2040 to 2050 planning period.

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

	Sea Level Rise (m)	Total Foreshore Area Projected to be Lost to Erosion (m2)
2020	-	0
2030	+ 0.1	62,000
2050	+ 0.2	196,000
2070	+ 0.4	338,000
2120	+ 0.9	666,000

14.9 Benefit Distribution Analysis

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

15. Risk Management Summary

15.1 South end of Harvey Estuary (SMU 1)

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

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

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

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

15.1.1 Risk Treatment by Asset – SMU1

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

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

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

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

15.1.2 Risk Management Pathways – SMU1

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

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

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

15.2 Risk Management Summary - Birchmont (SMU 2)

15.2.1 Risk Treatment by Asset – SMU2

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

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

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

Table 15.3: Risk Treatment – Birchmont (SMU2)

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

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

15.2.2 Risk Management Pathways – SMU2

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

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

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

Planning Timeframe	2020 - 2030	2030 - 2050	2050 - 2070	2070 - 2120
Pathway	Do Nothing (DN1) – Take no action and accept the risk			

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

15.3.1 Risk Treatment by Asset – SMU3

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

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

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

Adaptation approaches are summarised in

Table 15.5

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

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

15.3.2 Risk Management Pathways – SMU3

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

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

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

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

15.4 Risk Management Summary - South Yunderup (SMU 4)

15.4.1 Risk Treatment by Asset – SMU4

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

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

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

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

Adaptation approaches are summarised in Table 15.7.

Table 15.7: Risk Treatment – South Yunderup (SMU5)

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

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

15.4.2 Risk Management Pathways – SMU4

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

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

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

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

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

15.5.1 Risk Treatment by Asset – SMU5

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

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

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

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

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

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

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

b) It is of key importance to work to maintain the river shorelines and build resilience against future erosion that would threaten the assets landward. There are a range of 'soft protection' NBS approaches that could be used to build resilience of the Murray River shorelines through the Murray Delta Islands and North Yunderup. The Shire has guidelines for appropriate protection options that can be applied along the river shorelines (Syrinx 2018) in keeping with the natural shoreline areas (Pr.2) as well as a guide to planting species suited to the region (Pr.3). This document will be of key importance for guiding appropriate responses for shoreline areas which require attention.

c) The Shire should commence a study to investigate the erosion impacts from boat wakes on the river shorelines. This would be used to understand ways in which reducing vessel speeds along sensitive waterways through the Murray Delta Islands (NR.5) can reduce erosion.

d) For established properties on the three islands, create a building register. The register would be used to provide baseline information of properties to better understand the risk of inundation and erosion in future planning periods. The register should include the following information:

- Record of the finished floor level determined through a surveyor using eg Digital Ground Positioning System (DGPS). This information can refine estimates made as part of the CHRMAP on freeboard levels of the properties (assumed as +0.3m). Can also inform inundation risk on a property-by-property basis for future emergency planning;
- Establish the level of the septic system, determined through a surveyor using eg Digital Ground Positioning System (DGPS);
- Notes on the type of building design (materials). Information on sub-floor (eg stumps) to determine whether it is practical to raise the house in the future above projected flooding hazard in future years;
- Measurement of the distance from the closest point of the habitable structure to the river shoreline (HSD)

e) Specific development controls for the three Islands to be provided in the LPP to provide guidance for appropriate development to the following recommendations:

- For new development or redevelopment of existing properties, provide guidance on building design that is appropriate for the location and can withstand inundation (eg. Building materials that can withstand flooding, siting electrical fixtures above flood level).
- For new development or redevelopment of existing properties, establish minimum finished floor levels to accommodate the inundation risk noting:
    - The islands would be susceptible to more widespread and frequent flooding if the base sea level rises by more than +0.5m from its present level. Under this scenario. large areas of the three islands are expected to experience more frequent inundation in common flood events and in general tides which would likely impact the amenity of residents living on the Islands

f) Establish a managed retreat policy (refer Section 1.5.4.2) that can be applied to manage risk in future planning periods. As part of the process:

- determine the low lying, undeveloped properties (eg northwest end of Culleenup Island) where it may be impractical to accommodate inundation hazard over the planning timeframe for new development.
- the respective triggers which would signal the next adaptation phase of CHRMAP as either protection or managed retreat of properties would be defined from changes to:
    - erosion (measure of S1 distance from closest edge of habitable structure); and
    - inundation (increased flooding frequency, observed and measured increase in mean sea level based on local tide gauges in the Peel-Harvey, allowing for annual and decadal scale tidal influences).

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

Other general notes regarding the CMU:

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

Adaptation approaches are summarised in Table 15.9.

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

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

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

15.6.1 Risk Management Pathways – SMU5

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

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

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

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

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

15.7 Risk Management Summary - Serpentine (SMU 6)

15.7.1 Risk Treatment by Asset – SMU6

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

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

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

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

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

Adaptation approaches are summarised in Table 15.11.

Table 15.11: Risk Treatment – Serpentine (SMU6)

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

15.7.2 Risk Management Pathways – SMU6

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

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

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

16. Short Term Implementation Plan

16.1 Implementation Actions

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

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

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

16.2 Planning Implementation – Short Term

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

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

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

16.3 Annual Monitoring

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

Key locations for focus in the program are:

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

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

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

Table 16.1: Indicative program for Annual Monitoring activities

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

16.3.1 Structural Inspections

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

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

16.3.2 Trigger Point Summary

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

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

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

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

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

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

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

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

16.4 Additional Technical Studies

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

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

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

b) Murray Delta Islands building register. The register would be used to provide baseline information of properties to better understand the risk of inundation and erosion in future planning periods. The register should include the following information:

- Record of the finished floor level of each property determined through a surveyor using eg Digital Ground Positioning System (DGPS).
- Establish the level of the septic system of each property, determined through a surveyor using eg Digital Ground Positioning System (DGPS);
- Notes on the type of building design (materials). Information on sub-floor (eg stumps) to determine whether it is practical to raise the house in the future above projected flooding hazard in future years;
- Measurement of the distance from the closest point of the habitable structure on each property to the river shoreline (HSD)

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

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

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

16.5 Additional Planning Based Studies and Adaptation Studies

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

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

16.6 Adaptation Actions - Shoreline Areas

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

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

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

Notes:

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

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

16.7 Short Term Implementation Plan

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

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

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

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

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

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

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

16.8 Benefit Distribution Analysis

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

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

16.8.1 Murray Delta Islands - Nature Based Mitigation Options

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

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

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

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

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

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

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

16.8.2 South Yunderup Shoreline - Nature Based Mitigation Options

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

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

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

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

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

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

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

17. Medium and Long-Term Implementation Plan

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

17.1 Medium Term Implementation

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

Table 17.1: Medium Term Implementation Plan

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

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

17.2 Long Term Implementation

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

Table 17.2: Long Term Implementation Plan

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

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

18. Land use planning instruments

18.1 Planning Mechanisms - Implementation

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

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

a) Introduce a Special Control Area which triggers the requirement for normally exempt development to require planning approval. This should commence immediately.

b) Prepare a coastal local planning policy (LPP) or modify existing local planning policies to establish development standards to ensure new development can withstand inundation events. This should commence immediately.

c) Prepare an emergency response and evacuation plan to employ measures to manage the safety of the community during extreme events. The Shire's Local Emergency Management Committee (LEMC) has prepared a Local Emergency Management Arrangement (LEMA) and Local Recovery Plan (LRP) which includes useful information in relation to emergency preparation and response, including flooding. The LEMA and LRP should be reviewed in the next 5-years in conjunction with this CHRMAP to ensure areas identified as being at risk have arrangements in place to assist with emergency response and recovery.

d) Foreshore Management Plans. The Shire should prepare a foreshore management plan for each SMU to provide guidance for the ongoing management of foreshore reserves, monitoring of assets and the triggers for the managed retreat of assets and infrastructure at risk of erosion.

18.1.1 Special Control Area (SCA)

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

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

18.1.2 Planned or Managed Retreat Policy

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

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

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

19. Funding

19.1 Funding - Murray Delta Islands and South Yunderup Shoreline Areas

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

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

19.2 Special Area Rates

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

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

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

19.3 Grant Funding

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

Table 19.1: Summary of Funding Mechanisms

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

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

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

20. Monitoring Plan

20.1 Overview

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

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

20.2 Survey Capture - UAV

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

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

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

20.3 Key Monitoring locations

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

Table 20.1: Key Locations for Monitoring Activities

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

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

Notes

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

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

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

20.4 Additional Studies

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

a) Across the Murray Delta Islands, capture the elevation across the Islands using either traditional LiDAR or UAV. It is suggested that UAV would offer a cost-effective means of capturing the data, backed up with traditional survey methods in certain locations (captured on the ground by a surveyor) to ensure accuracy. Data would be used to assess changes to the islands since the initial LiDAR capture (2016) and to then review flood risk and update mapping if/as required.

b) For existing properties on Ballee, Yunderup and Culleenup Islands, get a surveyor to determine the floor level of each property (eg from the doorstep) using a DGPS or similar. This would give a more precise understanding of the risk of inundation in extreme events at property level.

c) For existing properties on Ballee, Yunderup and Culleenup Islands, get a surveyor to determine elevation of the septic system on each property and approximate location using a DGPS or similar. This would give a more precise understanding of the risk of inundation in extreme events at property level.

d) Undertake a study of the erosion from vessel wakes on the river shorelines in the Murray and Serpentine. The study should examine current and projected boat usage and vessel types. The study

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

e) Feasibility Study - North Yunderup river shoreline protection option. Appoint a working group with local representatives and undertake a study to examine the requirements for foreshore protection along the section of river fronting the 100 properties on Culleenup Rd. The engineered wall would be designed to protect against projected riverbank erosion. Study would examine the protection options, community support, preliminary concept design and estimate of cost as well as funding arrangements.

f) The Shire should undertake (or compile where already completed) condition reports of the structures that are key to shoreline control. This includes but is not limited to:
   - Revetment at Batavia Quays in front of the Acid Sulphate Soils site
   - Bund in front of South Yunderup Canals
   - Estuary Edge of Carpark at Herron Point
   - Rock Revetments adjacent Boat Ramps at Herron Point and Birchmont
   - Rock walling in the shorelines along the Murray managed by the Shire

20.5 CHRMAP Review

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

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

21. Summary and Conclusions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

- Technical
- Social
- Environmental

Cost was also considered but as a standalone category.

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

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

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

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

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

h) For the Murray River shoreline of North Yunderup, the nature-based solutions perform well due to the density of properties in this area and their proximity to the river. However, there may be practical challenges in implementing nature-based solutions within the available space in this area. A hard engineering solution, while having a BCR less than 1, is expected to be viable within 10 years. It is recommended that a technical study is undertaken in the next five years (by 2027) to examine an engineered hard structure (river wall) along the North Yunderup section of shoreline. This process would involve representatives from the North Yunderup community and be used to confirm requirements including the design and construction method, estimate of costs and the mechanism for funding the project through residents who would directly benefit from the erosion protection provided. .

i) The shoreline along the Murray River at South Yunderup performs well with nature-based solutions (BCR of 1.74) indicating these options are supported for implementation today. These solutions suit the shoreline areas with generally greater land buffer in this location compared with the northern side of the Murray River.

j) Erosion of the Kooljerrenup Nature Reserve was assessed against the adaption strategy of purchasing land on the eastern side of the reserve, to mitigate the loss of land due to erosion on the shoreline side. Loss of land area is projected to increases markedly after the 2050 period due to shoreline erosion driven by projected sea level rise. Monitoring of the shoreline areas and their response to sea level rise in the next 20 years will inform the future adaptation strategy with further consideration of the need for potential acquisition of land recommended in the 2040 to 2050 planning period.

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

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

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

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

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

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

l) Annual Monitoring Program: Projected annual cost of $16,000 – 18,000 annually to monitor:
   - Foreshore berm on the Peel shorelines along the western facing beaches of the Murray Delta Islands. The monitoring of the berm height along the shoreline is recommended every 3-years, through spatial survey data capture (via UAV or LiDAR). Following significant events where erosion may occur on the shorelines survey should also be captured.
   - Murray Delta Island shorelines on Ballee Island, Culeenup Island and Yunderup Island should be monitored through spatial survey data capture (via UAV or LiDAR) approximately every 5 years.
   - Photo Monitoring of shoreline areas for erosion at Herron Point, North and South Yunderup and the Murray Delta Islands (photo capture 2x annually and following significant storm events)

m) Additional Technical Studies: Projected Cost $45,000 to investigate:

- Assessment, planning and costing for a centralised ATU system (next 5-years)
- Murray Delta Islands building register (next 5-years)
- Erosion impacts from boat wakes on the river shoreline (next 5-years)

n) Planning Based Studies and Adaptation Studies: Projected Cost $85,000 for the following:
- Feasibility study for protection structure along North Yunderup shoreline in front of Coolenup Rd properties (next 5-years)
- Prepare an Emergency Evacuation Plan (next 5-years)
- Review of CHRMAP (5-yr Review)
- Prepare a Managed Retreat Policy (6-10 years).

o) Adaptation Actions in Shoreline Areas.
- Ballee Island, Coolenup Island and Yunderup Island – Nature Based solutions (now)
- South Yunderup shoreline section Young Street to Pelicans – Nature Based Solutions (now)
- Coopers Mill Shoreline – Nature Based solutions (now)

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

p) Introduce a Special Control Area which triggers the requirement for normally exempt development to require planning approval.

q) Prepare a local planning policy (LPP) to establish development standards to ensure new development can address projected coastal hazard from erosion and inundation.

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

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

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Appendix A

Stakeholder and Community Engagement Plan

A.1 SCEP

Shire of Murray CHRMAP

Stakeholder and Community Engagement Plan

May 2021

Document ID: Projects 2020/Documents/20-154 Tender – Shire of Murray/03 Project Work/03 Engagement/ Engagement strategy						
Issue	Date	Status	Prepared by		Approved by	
			Name	Initials	Name	Initials
1	15/09/2020	DRAFT	Hayley Campbell	HC	Cath Blake-Powell	CBP
2	8/10/2020	DRAFT	Hayley Campbell	HC	Catherine Atoms	CA
3	24/11/2020	DRAFT	Hayley Campbell	HC	Cath Blake-Powell	CBP
4	14/12/2020	DRAFT	Hayley Campbell	HC	Cath Blake-Powell	CBP
5	5/5/2021	DRAFT	Hayley Campbell	HC	Cath Blake-Powell	CBP

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Contents

1. Introduction 6
1.1 Project background and context 6
1.2 Scope 7
2. Objectives 8
2.1 Project objectives 8
2.2 Engagement objectives 8
2.3 Key messaging 9
2.4 Key issues and mitigation plan 9
3. Stakeholder Identification and Analysis 11
3.1 Negotiables and non-negotiables 12
4. Engagement Methodology 13
4.1 Level of Engagement 13
4.2 Engagement tools 13
4.3 Communications collateral 16
5. Engagement Action Schedule 17
6. Outcomes reporting 18

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1. Introduction

1.1 Project background and context

The Shire of Murray has appointed the project team of Baird Australia, element, Rhelm and Seashore Engineering to collaboratively produce a Coastal Hazard Risk Management Adaptation Plan (CHRMAP) consistent with Western Australian Planning Commission (WAPC) 2019 guidelines.

This Stakeholder and Community Engagement Strategy (SCEP) has been prepared to guide the engagement process and ensure that the community and stakeholders are effectively and actively involved in the CHRMAP preparation process.

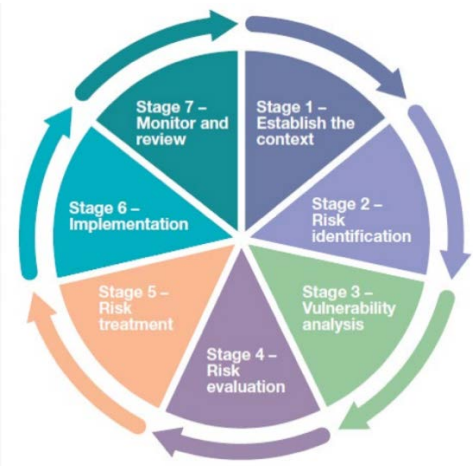
The purpose of the project is to undertake the necessary tasks required to complete the CHRMAP process for the study area in accordance with the coastal hazard risk management and adaptation planning guidelines (WAPC, 2019).

The CHRMAP project delivery will utilise the background studies that the Shire of Murray has previously completed and build on this work to develop a risk assessment framework consistent with WAPC 2019 guidelines. This process will identify the key areas and timeline for coastal hazard risk and guide the identification of adaptation options that will address the short and long-term management of the within the hazard areas.

Adaptation options for the shoreline will consider a full range of planning instruments and be developed in a manner consistent with the views of the stakeholders and community. Identification of preferred options will be guided by a rigorous economic assessment of alternatives, with the final recommendations reviewed by the Steering Committee and presented to the Council for final endorsement. An open and effective community and stakeholder engagement process will contribute to the success of the project.

The CHRMAP process will be completed in 7 stages, where the community will review the draft prepared at the end of each stage. In this way, community and stakeholder involvement will guide the preparation process. See the below diagram for a breakdown of the 7 stages.

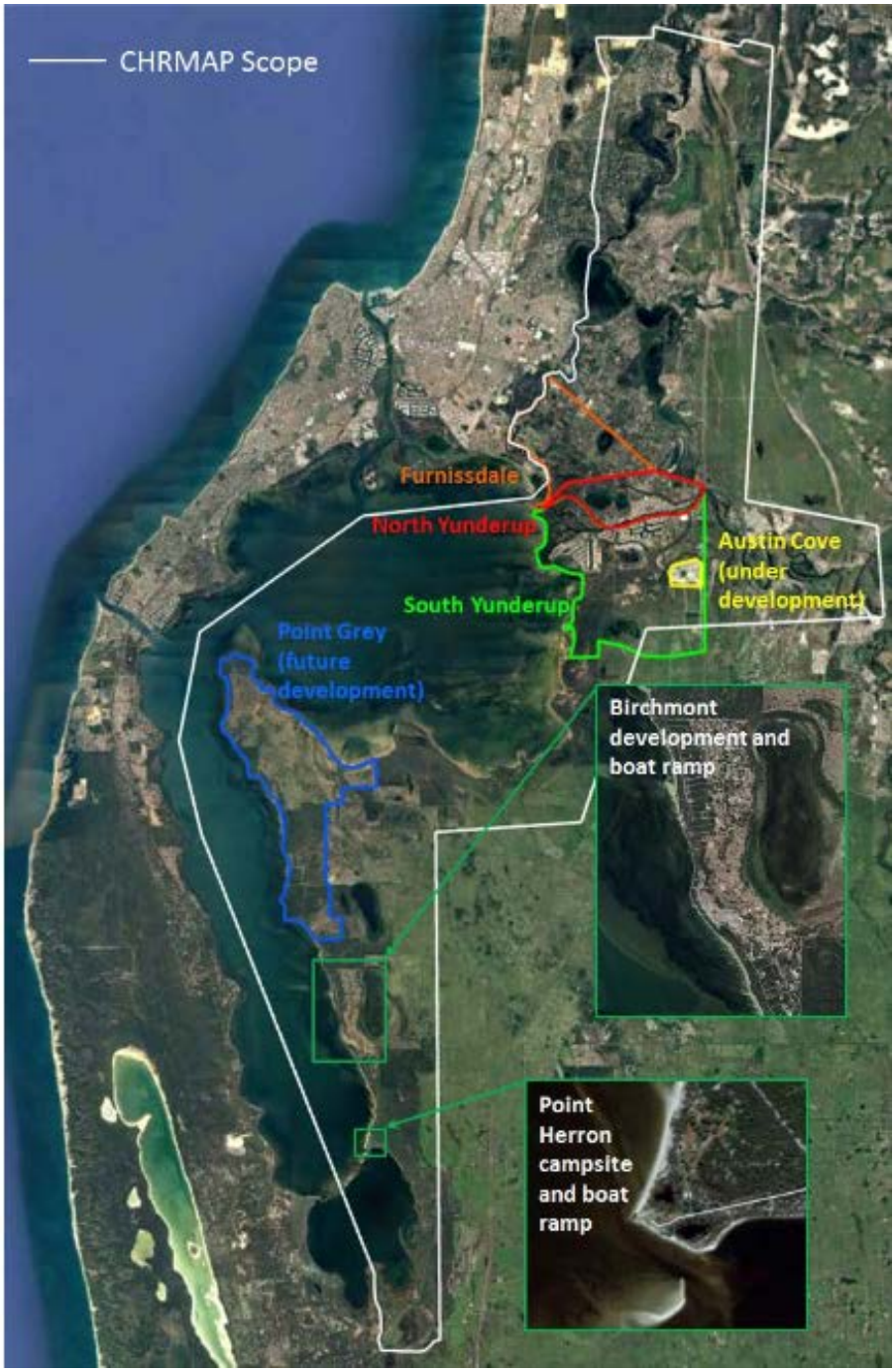
Figure 1 Diagram of the CHRMAP stages



1.2 Scope

The CHRMAP for the Shire of Murray will be carried out for the region encompassing the low-lying estuarine reaches of the Peel Harvey, and the tidally influenced reaches of the Murray and Serpentine Rivers, focusing on natural assets along the length of the estuarine and relevant riverine foreshores, as well as built assets indicated in the below.

Figure 2 CHRMAP study area



2. Objectives

2.1 Project objectives

The specific objectives of the project are to:

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

2.2 Engagement objectives

The engagement plan will detail the key stages of the project and guide stakeholders and the wider community on the CHRMAP process and how they will be involved in the determination of the final outcomes. Following the project objectives, the engagement objectives are to:

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

2.3 Key messaging

Supporting the engagement approach, a series of key messages will form an integral component of this project. These key messages are reviewed through the project's duration and as new information comes to light. The key messages are as follows:

- In collaboration with the project team, the Shire of Murray will be producing a CHRMAP for the low-lying estuarine reaches of the Peel Harvey, and the tidally influenced reaches of the Murray and Serpentine Rivers. They will also focus on natural and built assets along the length of the estuarine and relevant riverine foreshores.
- Coastal hazards including erosion and inundation are impacting these systems, and with their increasing extent and frequency may pose even greater risks into the future.
- In order to protect our environment and mitigate these risks, we need to develop a deeper understanding of these hazards and establish an effective framework and plan.
- A collaborative, objective and comprehensive process, including on-the-ground citizen involvement, will assist in preparing the CHRMAP.
- The CHRMAP project will be undertaken in 7 stages, with stakeholder and community engagement happening early in the process under Stage 1 'Establish the Context'.
- The project will be delivered in accordance with State Coastal Planning Policy 2.6 (SPP 2.6) and WAPC, CHRMAP guidelines.
- We will be engaging with a range of stakeholders including Aboriginal Traditional Owners, industry and specialist stakeholders as well as the local community. We will do so through a range of methods both face-to-face and online.
- The local community will also be involved in the CHRMAP process through a Community Reference Group (CRG) and access to project updates through the Shire of Murray 'Your Say' page, available from https://yoursay.murray.wa.gov.au/murray-chrmap
- The project will inform stakeholders and the community about potential risks arising from hazards in the estuarine and tidally influenced river zones, community and cultural values of the zone and adaptation pathways and management options that the Shire of Murray can pursue over time.

2.4 Key issues and approach

It is common that there are a number of issues and opportunities that may relate to engaging with community and key stakeholders for a project of this type. We would like to identify all possible issues or opportunities early in the planning process and find an approach suitable within the SCEP. We will work with the Shire of Murray and the project team to identify all possible issues/opportunities and the associated approach in the following table.

Table 1 Potential issues and plan to mitigate through engagement.

Issue	Potential Impact	Approach (opportunity)
Community and stakeholders misunderstand the project scope and objectives.	The community are unsure of what can be achieved by the CHRMAP.	We will create a clear set of project key messages and negotiables and non-negotiables which will define the scope of the CHRMAP to be used throughout the engagement communications. Briefings, communications collateral etc will be produced to minimise misunderstandings.

Issue	Potential Impact	Approach (opportunity)
Some members of the community feel they are underrepresented.	Community unable to engage within project timeframe.	Ensure we have an equitable number of community and stakeholder representatives involved in the engagement process. Ensure all key stakeholders are identified by the project team and the Shire of Murray. Use a range of methods to engage with the community and stakeholders.
We ask too much of the community.	Participants in the engagement process become fatigued and/or uncertain in the engagement process.	A clear and concise set of key messages will be agreed upon in the SCEP to guide all communications and engagement collateral will be simple and informative. Project team members will be available at each engagement activity to provide further guidance with project information.
Community and stakeholder apprehension to engage and disappointment in the outcomes.	Community and stakeholders may be sceptical that they can meaningfully influence the project and may become disappointed if the engagement process does not lead to action that reflects their input.	Forming part of the key messages, negotiables and non-negotiables of the project will be defined within the SCEP and communicated to all participants in the engagement process so that they understand which parts of the project they will be able to influence.
There is lack of interest within the community.	There is low community and stakeholder participation and therefore the project team has limited feedback and information from the process.	We will create interesting and effective communications collateral and advertise the engagement process through multiple channels. We will be nimble and flexible in the engagement process and be ready to change direction if needed.
Certain stakeholders are tempted to push a solution that does not serve the community as a whole.	The solution pushed by these stakeholders does not support a long-term solution for everyone. Other 'quiet' stakeholder groups are disadvantaged by the outcome.	A layered approach to the engagement activities on offer and identifying the reason of interest of each stakeholder group to understand their motivation. Ensuring the reach of engagement is broad and at the whole community level, using citizen science to get as much involvement as possible.

3. Stakeholder Identification and Analysis

Understanding project stakeholders is a critical consideration of any engagement and communications program. By understanding who these groups or individuals are, we may better understand and analyse their degree of influence and interest, and therefore the involvement they are likely to request and require.

We have worked in collaboration with the project team and the Shire of Murray to compile a full stakeholder list. The following table summarises a non-exhaustive list of key stakeholders, grouped into broad categories.

Table 2 Key stakeholders and analysis

Stakeholder	Level of engagement	Method to engage
Shire of Murray staff and Councillors	Inform and collaborate	All
South West Aboriginal Land and Sea Council	Involve	Traditional Owner Engagement
Department of Primary Industries and Regional Development	Collaborate and inform	Stakeholder memo
Department of Planning, Lands & Heritage	Collaborate	Steering Group
Department of Transport	Collaborate	Steering Group
Department of Water and Environmental Regulation	Collaborate	Steering Group
Peel Harvey Catchment Council	Collaborate	Steering Group
Department of Biodiversity, Conservation and Attractions	Collaborate	Steering Group
Peron Naturaliste Partnership	Collaborate	Steering Group
City of Mandurah	Collaborate and inform	Steering Group
Local groups, such as Chamber of Commerce, Progress Associations etc	Inform, consult, involve	CRG, online survey, online information webinars.
Schools, colleges and youth groups	Consult	Online survey, information webinars.
Landowners shown in the hazard areas predicted to be affected by erosion and inundation over the planning timeframe	Inform, consult, involve.	CRG, online survey, online information webinars
The broader Shire of Murray community	Inform and consult	CRG, online survey, online information webinars.
Interested recreational visitors	Inform	Online survey
Local media	Inform	Media release
Politicians	Inform	Stakeholder memo

3.1 Negotiables and non-negotiables

It is important to keep the community and stakeholders informed about which aspects of the projects are able to be influenced by their input and which are not. The negotiables and non-negotiables of the project will be collaboratively defined here by the project team and the Shire of Murray.

Table 3 Project negotiables and non-negotiables

Negotiables	Non-negotiables
• Asset identification, coastal values and significant places identified by the community • Consequence scale based on community and stakeholder input • Levels of risk deemed acceptable, tolerable and intolerable by the community • Risk treatment - Adaptation options • Risk management pathways (timeframe for adaptation and mitigation)	• State Planning Policy, Coastal Planning SPP2.6 (WAPC 2013) • Allowance for sea level rise in future planning periods (DoT 2010) • Coastal Hazard Risk Management and Adaptation Planning Guidelines (WAPC 2019)

4. Engagement Methodology

4.1 Level of Engagement

We will encourage community and stakeholder engagement on the **inform**, **consult**, **involve** and **collaborate** levels, which will guide the design of the engagement activities. The goals of each level of engagement are described in the table below.

Table 4 Levels of Engagement

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

4.2 Engagement tools

Steering group

A project steering group (Technical Advisory Group) has been formed to involve key stakeholders throughout the CHRMAP process.

Traditional owner engagement

We recognise that Aboriginal engagement requires a specialised set of skills in order to deliver appropriate engagement methods for meaningful insights. The project team will sub-contract an Aboriginal engagement professional to conduct interviews using questions provided by the Shire. The project team will interpret the data for input into the engagement outcomes report. The project team will take direction from the Shire and SWALSC as to whom we shall invite to interview, which may likely include local elders or family group representatives.

Community reference group

Given the high level of interest from the community to date and the diverse range of stakeholders already identified by the project team, we are establishing a Community Reference Group (CRG) for the duration of the engagement activities and delivery of the draft CHRMAP. By engaging the local knowledge and insights of a CRG, the project will demonstrate a greater level of transparency, collaboration and willingness to take on board concerns, values and ideas of the community, via selected representatives.

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

We will work with the Shire to identify key criteria of CRG membership (whether open, invite-only or a combination of both). The project team shall prepare associated documentation such as information packages and terms of reference for the group, as well as run facilitated workshop discussions.

Information event

Early in the CHRMAP process the consultant team will facilitate a public information event, which will inform interested stakeholders and the community on the CHRMAP process including, but not limited to the following:

- What is a CHRMAP?
- Why does a CHRMAP need to be prepared?
- Project aims and delivery process?
- Key issues and Coastal Hazard Mapping.
- FAQ (e.g. queries on insurance premiums, planning considerations).
- Key proposed delivery dates and project milestones.

Our team will invite community members broadly to attend an informal information event, which will include a public display with interactive display boards. The consultant team will be available for stakeholder and community questions and feedback with project leads from the team present to advise on coastal hazard and adaptation (Matt Elliot, Jim Churchill) planning (Mike Davis) and engagement (Cath Blake-Powell).

During the information event:

- The consultant team will display the outcomes of hazard mapping (developed in Stage 2) to the participants to promote understanding of coastal hazard risk for the community now and into the future (over the next 100 years with projected sea level rise).
- Planning considerations, which are influenced by coastal hazard will be described in broad outlines (e.g. setting design floor levels for inundation).
- Environmental impacts for the Peel estuary associated with projected sea level rise will be presented at a high level.

All materials on display in the information event, such as FAQ, will be available for download from the project webpage after the event for those who cannot attend. Any questions taken on notice will be available on the next project webpage update.

The consultant team will be available to respond to and record stakeholder and community questions and feedback. The information event will assist the community and stakeholders in understanding coastal hazard issues affecting their coastal areas, recognising the role the CHRMAP process plays in developing future coastal planning activities and gauging the main concerns of the community. This will enable the consultant team to tailor the engagement to follow in later stages of the project.

Coastal values assessment (online survey and mapping tool)

We will assess the community's coastal values through an online survey and mapping tool, which will be advertised through the following:

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

At the opening of the online survey and mapping tool, community and stakeholders will have access to information online, which they will be encouraged to read while completing the survey.

An online survey and mapping tool will be prepared by the project team, as follows.

- An online survey and map (using Your Say platform) will be published on the Shire's website. The format will be reviewed by the Shire, and include questions around:
    - whether the participant is a local, visitor, tourist or other within the Shire of Murray;
    - coastal regions where individuals frequent in the study area;
    - identifying environmental, social and economic assets they value in the area and explore why these assets are of value;
    - identify the coastal assets which are most important to them; and
    - understanding tolerance to coastal issues.
- The survey will be promoted via the Shire's webpage and social media platforms. Additionally, the survey will be directly sent to identified stakeholders and known interested parties, as well as encouraging these individuals and organisations to distribute amongst their networks. We will use the Shire's existing databases to identify all relevant stakeholders.
- The survey will be collected via the Shire's survey account, the Shire will collate the survey responses and provide to the consultant team for review.

Scenario workshop

A scenario workshop will be undertaken to gain community input and feedback into the hazard and risks to which the community is exposed. The scenario workshop will be used to provide an overview of the hazard mapping and risk assessment completed in the Stage 1 to 4 and give participants an opportunity to comment on the identified high-level risks.

The workshops will use a multi-criteria analysis (MCA) to compare and contrast an identified list of adaptation options. The analysis will incorporate criteria related to economic, social and environmental impacts.

The MCA workshop will work through alternatives in a 'live' setting, to first establish the weighting criteria for the MCA and then rank each adaptation option according to the scoring across the general categories.

At the conclusion of the workshop, a ranked list of options at each critical location will be agreed by the participants.

4.3 Communications collateral

Effective communication is essential to the engagement process. We will use the following communications collateral to promote and encourage participation in a citizen science program. We will prepare information about the project to community and stakeholders.

Broadly, the communications collateral package will include:

- FAQs: In collaboration with the Shire, element will prepare a set of FAQs which will be used on key communication platforms such as the Your Say webpage and
- Flyers: element will work with the Shire to prepare the flyer content and graphic design. The Shire will then coordinate the printing and distribution of the flyers.
- Posters: Posters will be used to advertise the engagement process including key dates and events. With Shire approval, element will prepare the poster content and graphic design and the Shire will coordinate the printing and distribution of the posters.
- Newspaper advertisements: In collaboration with the Shire, element will prepare the contentment for newspaper advertisements of key engagement dates and activities. The Shire will coordinate logistics of the advertisement.
- Messages for social media: Using the key messages and FAQs as a guide for content, the Shire will coordinate messages for social media and targeted posts.
- Shire 'Your Say' online engagement platform: alongside the project team, element will prepare the online survey questions, for the Shire to review and publish via their Your Say webpage.

Appendix B

Engagement Outcomes Summary

B.1 Engagement Outcomes Summary

Shire of Murray CHRMAP

Engagement Outcomes Summary

July 2021

Document ID: 20-154 / Project Work / Engagement / Outcomes

Issue	Date	Status	Prepared by		Approved by	
			Name	Initials	Name	Initials
1	2.07.21	Draft	Hayley Campbell	HC	Cath Blake-Powell	CBP

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Contents

1. Introduction 1
1.1 Project background and context 1
1.2 Scope 2
2. Objectives 3
2.1 Project Objectives 3
2.2 Engagement Objectives 3
3. Methodology 5
3.1 Engagement tools 5
3.2 Communications channels 7
4. Key findings 8
4.1 Online map tool 8
4.2 Coastal values survey 10
4.3 Scenario workshops 13
5. Next steps 6

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1. Introduction

1.1 Project background and context

The Shire of Murray appointed the project team of Baird Australia, element, Rhelm and Seashore Engineering to collaboratively produce a Coastal Hazard Risk Management Adaptation Plan (CHRMAP) consistent with Western Australian Planning Commission (WAPC) 2019 guidelines.

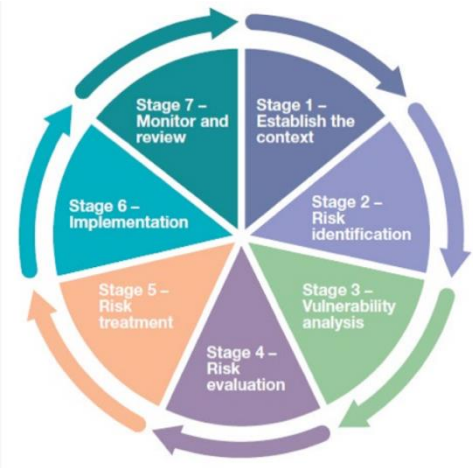
A Stakeholder and Community Engagement Strategy (SCEP) was prepared to guide the engagement process and ensure that the community and stakeholders were effectively and actively involved in the CHRMAP preparation process.

The CHRMAP project delivery utilises background studies that the Shire of Murray previously completed and will build on this work to develop a risk assessment framework consistent with WAPC 2019 guidelines. This process will identify the key areas and timeline for coastal hazard risk and guide the identification of adaptation options that will address the short and long-term management within the hazard areas.

Adaptation options for the shoreline will consider a full range of planning instruments and be developed in a manner cognisant of the views of the stakeholders and community as outlined in the findings of this report. Identification of preferred options will be guided by a rigorous economic assessment of alternatives, with the final recommendations reviewed by the Steering Committee and presented to the Council for final endorsement.

The CHRMAP process is being completed in 7 stages, where the community will review the draft prepared at the end of each stage. In this way, community and stakeholder involvement will guide the preparation process. See the below diagram for a breakdown of the 7 stages.

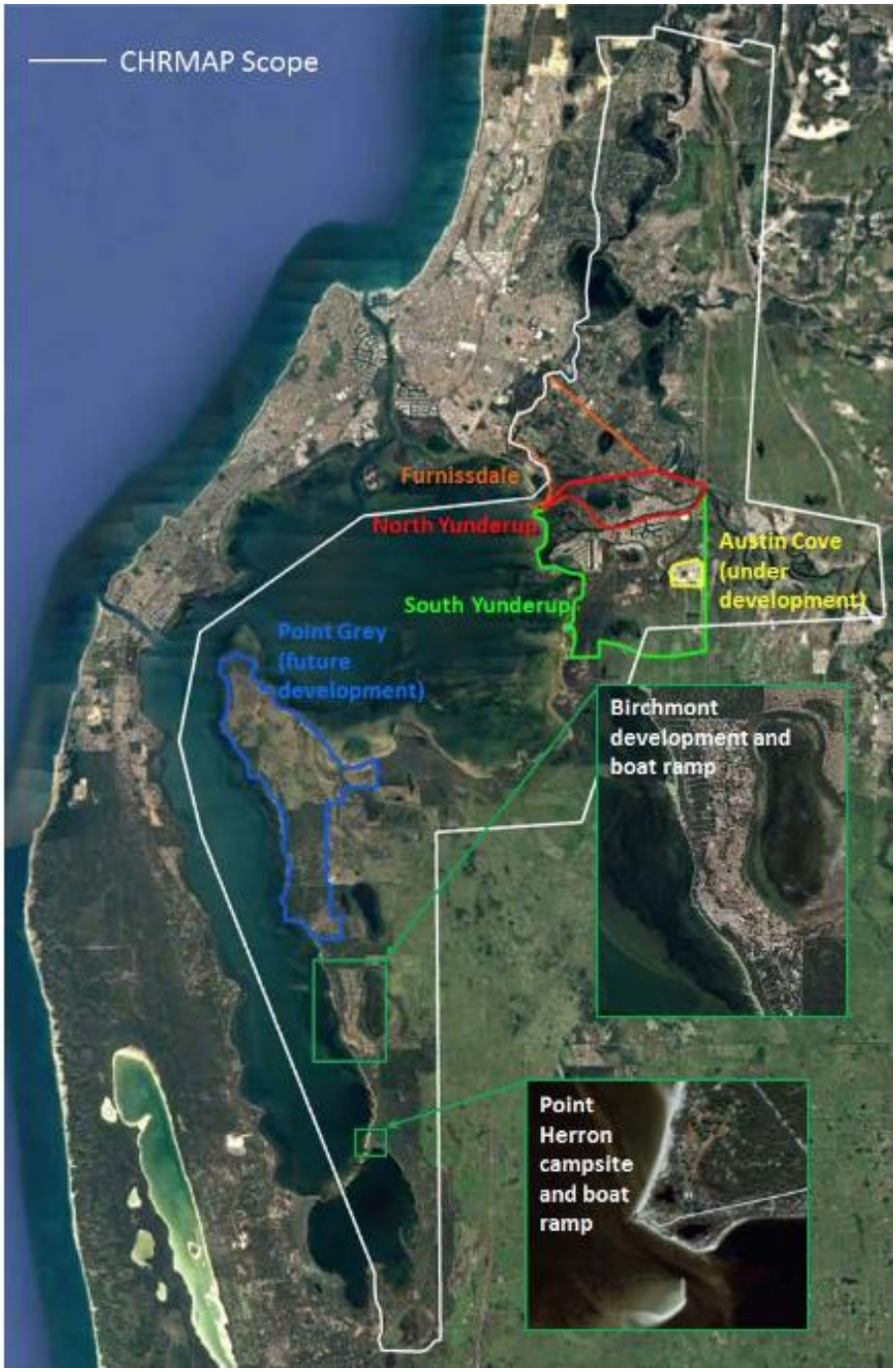
Figure 1 Diagram of the CHRMAP stages



1.2 Scope

The CHRMAP for the Shire of Murray is being carried out for the region encompassing the low-lying estuarine reaches of the Peel Harvey, and the tidally influenced reaches of the Murray and Serpentine Rivers, inclusive of natural assets along the length of the estuarine and relevant riverine foreshores, however with a focus on built assets as indicated below.

Figure 2 CHRMAP study area



2. Objectives

2.1 Project Objectives

The specific objectives of the project were to:

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

2.2 Engagement Objectives

Following the project objectives, the engagement objectives were to:

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

3. Methodology

3.1 Engagement tools

A number of engagement tools have been used throughout the CHRMAP project process, these are identified below. Each of these were designed to inform key CHRMAP project stages



Information event

Early in the project, two drop-in sessions were held to introduce the CHRMAP project and provide information about the project including:

- What is a CHRMAP?
- Why does a CHRMAP need to be prepared?
- Project aims and delivery process?
- Key issues and Coastal Hazard Mapping.
- FAQ (e.g. queries on insurance premiums, planning considerations).
- Key proposed delivery dates and project milestones.

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



Online engagement tool

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

The online mapping tool has been live, collecting 'citizen science', or spatial and values information from the following prompt: "Within the study area (yellow boundary), let us know about:

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



Community Reference Group

Given the high level of interest from the community to date and the diverse range of stakeholders identified, we established a Community Reference Group (CRG) for the duration of the engagement activities and delivery of the draft CHRMAP. By engaging the local knowledge and insights of a CRG, the

project demonstrates a greater level of transparency, collaboration and willingness to take on board concerns, values and ideas of the community, via selected representatives.

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

The CRG is still ongoing for the remainder of the CHRMAP project.

Coastal values survey

A short coastal values survey was held via the YourSay webpage for 5 weeks between 16 April and 18 June 2021.

A summary of the survey questions are as follows:

About you

- What age bracket do you fall under?
- Please select the location you live from one of the following
    - Birchmont
    - West Coolup
    - Murray Delta Islands
    - South Yunderup
    - North Yunderup
    - Furnisdale
    - Ravenswood
    - Other location in Shire of Murray not listed above
    - City of Mandurah
    - Shire of Waroona
    - Outside of project area (e.g. Perth, please specify)
- How familiar are you with the CHRMAP project currently being undertaken by the Shire of Murray?
- Do you think there should be additional information available on the project YourSay page?

Visitation and coastal values

- How do you interact with the estuary?
- Where do you most frequently participate in the following activities?
- How often do you participate in the activities?
- Why do you choose these locations as opposed to other areas?
- Why do you choose these locations as opposed to other areas?

Values

- What do you value in your coastline and estuarine area?

Thank you

- Please register your details to stay up to date

Scenario workshops

Two scenario workshops were held in May at the Yunderup Sports and Recreation Club, the first workshop on Tuesday 25 May 2021 and the second workshop on Saturday 29 May. The workshops were

advertised to the local community and had the purpose of delving deeper into assets, values and adaptation and mitigation strategies.

Across the workshop and total of 23 people attended.

The workshop agenda was as follows:

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

3.2 Communications channels

A range of communications channels have been utilised to reach the local Shire of Murray community and specific stakeholder groups. These include:

- Shire of Murray YourSay webpage – a home for all project information and communications
- FAQs – providing information about the project, hosted on the YourSay webpage
- Social media advertisements – promoting the survey and workshop registrations
- Letterbox drops – to specific community areas promoting the survey and workshop registrations
- Signage at the South Yunderup Sport and Recreation Club (location of the workshops)
- Word of mouth communications via CRG members

4. Key findings

4.1 Online map tool

There were 28 contributors to the online map tool who made a total of 114 contributions in the form of comments about a place they love, how they use and environmental observations.

The contributions noted a range of environmental features and recreational uses within the study area, providing some context to the values and assets of the area.

The comments have been summarised by spatial area in the following table.

Location with study area	Summary of comments
Peel inlet	• Sight of sea grass "Forrest". Care should be taken when anchoring and scoop netting • Great spot for King George whiting until limestone outcrops were destroyed to accommodate the channel constructed for the canals in the early 70's
Harvey Estuary	• (Used for) wading for crabs and whiting fishing
Serpentine River	• (Used for) Bream fishing • Serpentine River end of Woodland Parade access to foreshore and river for kayaking and fishing • (Used for) Kayaking down Serpentine River • Used to see long necked turtles here but have not done so for several years
Murray River	• Severe bank erosion should have been rectified as part of the freeway bridge engineering (Pinjarra Road, Ravenswood Western). • Bright green Bank reeds seen in front of caravan park were common right up to the estuary – very effective against tide and boat erosion, unfortunately cant handle the influx of salt water • Osprey nest- can be observed from the intersection opposite (1996 Angus Place, Ravenswood Western). • Dolphins, particularly mothers with calf, stop and feed in this shallow wide stretch of river daily (due to the

	bathymetry, and deeper hole at the bend) when heading up and down the Murray River. Many species of fish inhabit this area year-round. Blue swimmer crabs can be found in high abundances here in the warmer months of the year. Adult black bream feed on the flats and shallows opposite Murray Bend and Ravenswood Road. Prawns are observed at night. In May each year, flocks of little black cormorants (n- 1000 strong) accompanied by pelicans and white herons can be seen feeding on schools of baitfish (possibly spawning Atherinids). Ospreys and whistling kites live and feed here. In Blue swimmer crab season, they can be seen approximately 5km below Pinjarra, in addition to juvenile tailor, juvenile tarwhine and garfish. Very high abundances of small yellowtail grunter inhabit the stretch of river between Ravenswood and Pinjarra, in addition to Sea mullet (adult and juveniles) and masses of Atherinids (baitfish) (7 Ravenswood Road, Ravenswood). • Important feeding area for black bream (conditioning for spawning) in winter. Dolphins observed using deeper drop -off on opposite bank for ambushing bream and mullet (6206, Ravenswood)
Harvey River	
Murray Islands	• Used as a weekend getaway from the city • Urgent need to stabilise banks at end of Yunderup Island Some erosion here due to tide and boat wash. Nice wildflowers. • Islands and other local bush walk around the whole of Yunderup Islands. • Lots of dog walkers use this area (101 Rivergum Esplanade, South Yunderup)
Point Grey	• The Dawesville Cut and the deep dredging of the Mandurah Channel has made a significant difference to the estuary and rivers environment. Has had some beneficial effects on water quality, but in general for the east side of the estuary the environmental impact has been mostly negative. Water levels through major tidal variations mean flooding can occur at any time of the year and at the other extreme the water can be so low as to make accessing jetties and boat sheds near on impossible. This tidal variation will see half of the Delta islands disappear if sea level rise predictions are right. This is a national disgrace as one of the most important

	delta island river systems in Australia is disappearing before our very eyes.
Birchmont boat ramp	• Crabbing and estuary access (Birch Drive, Birchmont) • Bird Watching (166 Birch Drive)
Herron point boat ramp	• Herron Pt has been local crabbing and net fishing place for many years.
Yunderup canals	• High tides and boat wash removing natural reeds from shoreline • Issues: poor water quality and mosquitos • Algal blooms are bad this year (2021) • North Yunderup boat ramp would be more useable with floating jetty • Along the riverfront is a beautiful place to enjoy. It needs erosion management and care of the water. (212 Culeenup Road, North Yunderup) • There has been a noticeable increase in speeding vessels in the Murray River. The resulting bank erosion, potential threat to swimmers and wildlife, and damage to moored vessels is increasing rapidly. There is an immediate need for increased signage, monitoring, a easy to use public reporting process, education and enforcement. (198 Culeenup Road, North Yunderup)

4.2 Coastal values survey

A coastal values survey ran for 5 weeks from Friday 14 May until Friday 18 June and collected a total of **186 responses** (182 online and 4 hard copy).

Who did we reach?

Respondents were mostly aged between 30-65 years with 41% being aged between 30-49 years. Half of the survey respondents were either form the City of Mandurah or from Shire locations outside of the Study area, indicating that the area is regarded by not only immediate residents. Other respondents included those from nearby locations including Warnbro, Rockingham and West Pinjarra.

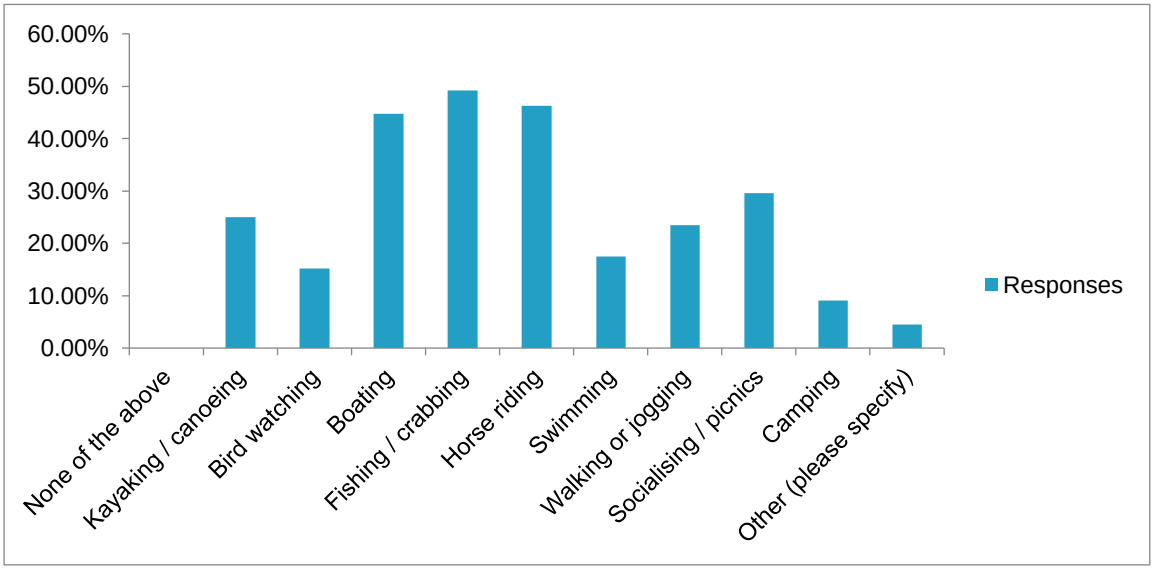
CHRMAP awareness

Most respondents (90%) were either unaware (53%) or only somewhat aware (37%) of the CHRMAP process. 91% of respondents believe there should be additional information available on the Shire's YourSay page, indicating a keenness to learn about the CHRMAP process from the community.

Interaction with the estuary

Survey respondents noted that fishing/crabbing, horse-riding and boating were the top 3 reasons they interacted with the estuary, as shown in figure 3 below.

Figure 3 How do you interact with the estuary? Select your 3 most common interaction options.



The most common places for each activity are as follows.

Activity	Location
Boating	Peel inlet (n=20), Murray River (n=11)
Fishing/crabbing	Peel inlet (n=23), Birchmont Boat Ramp (n=9), Herron Point Boat Ramp (n=10)
Horse riding	Herron Point Boat Ramp (n=26)
Swimming	Murray River (n=11) Herron Point Boat Ramp (n=9)
Walking and jogging	All locations mentioned
Camping	Herron Point Boat Ramp (n=11), Point Grey (n=5)
Socialising / picnics	Herron Point Boat Ramp (n=7)

Respondents mostly participate in all activities once or twice per month. Camping, swimming, and canoeing/kayaking were participated in less frequently.

Values

Respondents chose the above locations for the following reasons:

- Natural beauty of the area
    - "Beautiful place to swim and use the boat, also river fishing"
    - "Nice environment"
    - "It's beautiful"
    - "Peaceful"
- Proximity to their home
    - "Close to home"
    - "On my doorstep"
    - "Close to home, familiarity with the waterway"
- Great conditions and amenities available for the activity (example: nearby trails, horse float parking facilities, boat ramp access).
    - "Playground, toilet BBQ, history"
    - "Close to home, good car park and camping grounds"
    - "Good parking and nice water to ride horses"

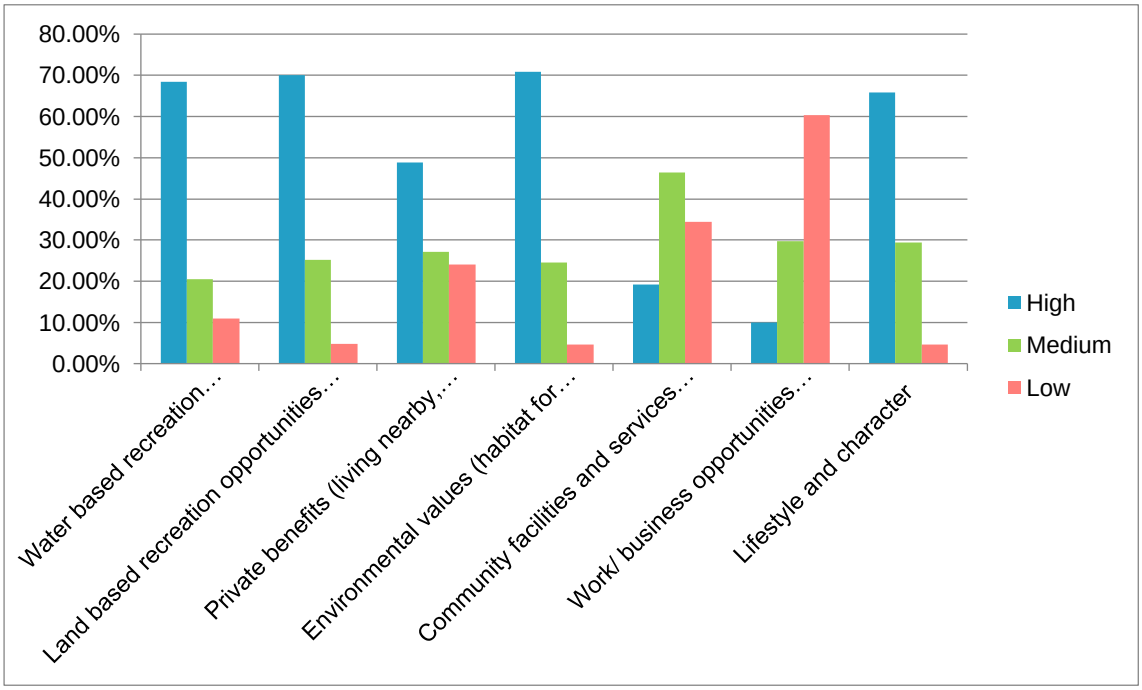
The **highest** respondent values were:

- Environmental values (habitat for wildlife, protection from storms, water/nutrient filtration) (71%)
- Land based recreation opportunities (dog walking, picnicking, fishing, exercising etc near the coastline) (70%)
- Water based recreation opportunities (boating, kayaking etc) (88.5%)

The **lowest** respondent values were:

- Work/ business opportunities (related to coastline and estuarine area) (9%)
- Community facilities and services (events, festivals) (19%)

Figure 4 What do you value in your coastline and estuarine area? Rate each category from high to low.



4.3 Scenario workshops

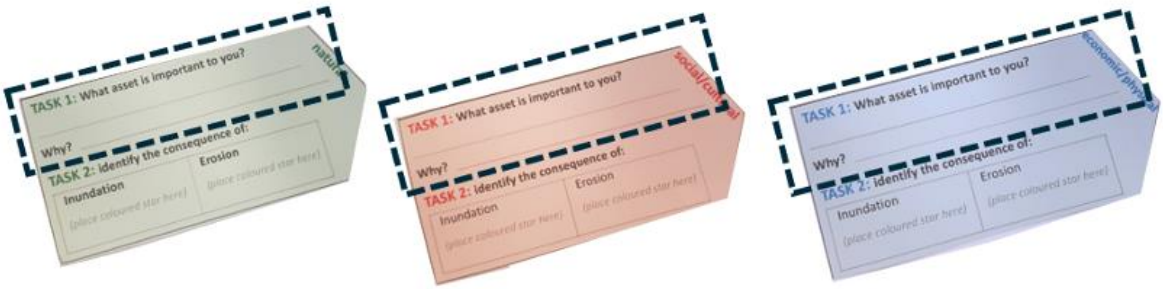
Both workshops were structured to provide information and collaborate with attendees to identify assets, priorities and adaptation options.

Task 1 – Coastal Asset Identification

Following a presentation from Baird on the project background, key findings of the Coastal Hazard Report and an overview the study area, participants were then asked to identify three different classifications of coastal assets (social, environmental and economic) within the study area boundary using the tags pictured below.

They were asked to name the asset and state why it was important.

Figure 5 Coastal Asset Tags



Task 2 – Consequence Scale

The next task asked participants to then rate each of their assets they had identified in two ways:

1. Level of inundation

2. Level of erosion

These rating were informed by the following consequence scale provided in the presentation prefacing the activity.

Consequence	Physical / Economic Impact	Environmental Impact	Social / Cultural Impact
Insignificant	Permanent loss or damage **<$20k**	**Negligible to no loss** of flora and fauna – strong recovery	Minimal short-term inconvenience **<$5% of community affected**
Minor	Permanent loss or damage **$20k - $200k**	**Short term loss** of flora and fauna – strong recovery	Small to medium disruption of function **<10% of community affected**
Moderate	Permanent loss or damage **$200k - $2 million**	**Medium term loss** of flora and fauna – recovery likely	Minor long term or major short-term loss of function **<25% of community affected**
Major	Permanent loss or damage **$2 million - $5 million**	**Long-term loss** of flora and fauna – limited chance of recovery	Medium term or permanent loss of function **<50% of community affected**
Catastrophic	Permanent loss or damage **>$5 million**	**Permanent loss** of flora and fauna – will not recover	Long-term or permanent loss of function **>75% of community affected**

Figure 6 Consequence rating sticker sheet



Task 3 – Asset Prioritisation

Once the consequences of erosion and inundation were determined, participants were asked to re-examine the coastal assets identified on the sticky notes attached to the map on their table.

Working individually, each participant was given five dots and asked to stick one dot beside each of the five assets they valued most. However, if they believed one or more assets to be more important than another, they were able to place more than one dot beside these assets until all five dots were used.

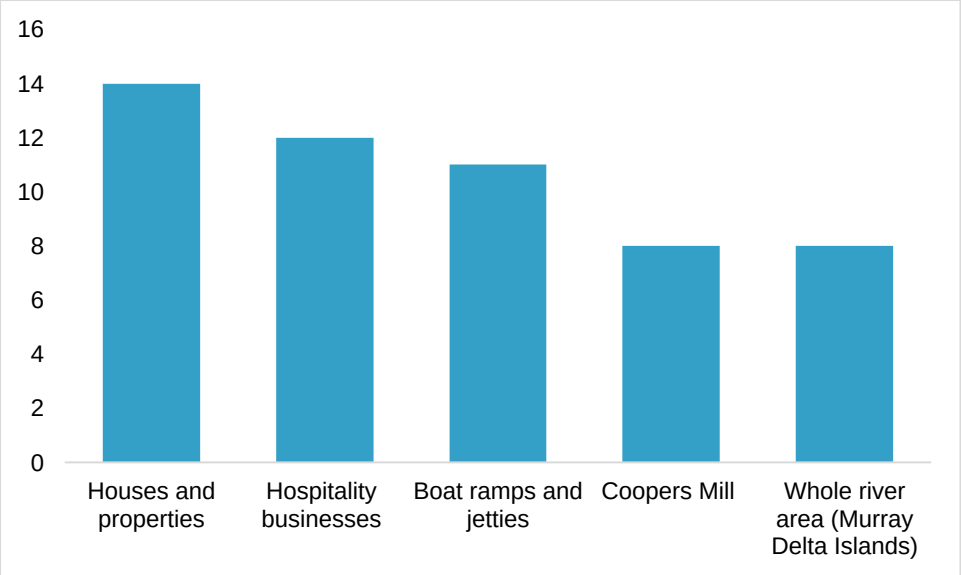
Figure 7 Example of asset prioritisation on asset tags



Results of Tasks 1, 2 and 3

Common themes amongst assets

Overall, 92 valid assets were captured over both workshops. The following graph highlights the range of assets that were named numerous times, including:



The results of the assets have been consolidated into tables based on coastal locations within the study area. The assets identified were relatively evenly spread between social (n=31), environmental (n=32) and economic (n=29).

The results show that generally, the impact of erosion is perceived to have a more severe consequence than the impact of inundation on the coastal location in the study area, particularly in the Murray Delta Islands.

While the asset group 'Houses and Properties' had the most mentions, they also had by far the highest priority ranking with 35 dots.

It is important to note that the workshop attendees were predominantly residents of the Murray Delta Islands.

Figure 8 Results of Tasks 1, 2 and 3 based on coastal location

Murray Delta Island Assets	Classification	No. of sticky notes	No. of dots (priority)	Average inundation score	Average erosion score
Whole river area	Social	5	2	5	2
Why it is important: recreation, fishing, flora and fauna, shallow waters	Environmental	3	4	5	2
Houses and properties	Economic	10	23	3	2
Why it is important: livelihood, shelter, personal financial investment, holiday house	Social	4	12	2	2
Fauna *Why it is important: protect endangered species, peace, retreat, recreation, complete ecosystem*	Environmental	8	9	3	2
Hospitality business (e.g., restaurants, cafes, pubs, school, shops)	Economic	9	3	3	3
Why it is important: provides jobs, serves community, recreation for holidays	Environmental	2	0	1	2
	Social	1	0	3	1
Boating channels / waterways	Environmental	2	3	4	1
Why it is important: for boating access, recreation, swimming, crabbing	Social	3	1	5	2
	Economic	1	1		
Coopers Mill	Social	5	8	3	2
Why it is important: historical value, tourist attraction, culture,	Economic	1	0	4	2
Fishing and crabbing	Social	1	1	3	3
Why it is important: children's development, fun, recreation,	Environmental	1	0	5	1

Boat ramps and jetties	Economic	8	7	4	2
Why it is important: island access, community use for boating/fishing, adds value to properties	Social	3	2	5	3
Riverbanks / wetlands / beaches	Environmental	4	5	4	2
Why it is important: swimming, fishing, dolphin watching, bird watching,	Social	1	1	5	2
Trees and vegetation	Environmental	3	4	2	1
Why it is important: nature reserve, important to environment and fauna, prevents erosion					
Infrastructure, bridges and roads	Economic	2		4	3
Why it is important: Access	Social	1	2	1	1
Coodanup foreshore	Environmental	2		4	4
Why it is important: dog walking, bird watching					
Cricket oval	Social	3	1	5	5
Why it is important: social asset, historical and community value.					

Peel Inlet Assets	Classification	No. of sticky notes	No. of dots (priority)	Average inundation score	Average erosion score
Estuary	Environmental	2	0	4	4
Why it is important: recreation, swimming, crabbing, boating, fishing					

Point Grey Assets	Classification	No. of sticky notes	No. of dots (priority)	Average inundation score	Average erosion score
Shallow waters *Why it is important: crabbing*	Social	1	0	5	4

Harvey Estuary Assets	Classification	No. of sticky notes	No. of dots (priority)	Average inundation score	Average erosion score
Whole area	Environmental	2	1	4	3
Why it is important: lifestyle, social/family recreation, heritage	Social	1	1	4	2

Birchmont Assets	Classification	No. of sticky notes	No. of dots (priority)	Average inundation score	Average erosion score
Whole Eastern Shoreline *Why it is important: no reasons given.*	Environmental	1	0	5	4

Herron Point Assets	Classification	No. of sticky notes	No. of dots (priority)	Average inundation score	Average erosion score

Shallow waters *Why it is important: crabbing*	Social	1	0	5	4
Campgrounds *Why it is important: tourism*	Social	1	0	4	2

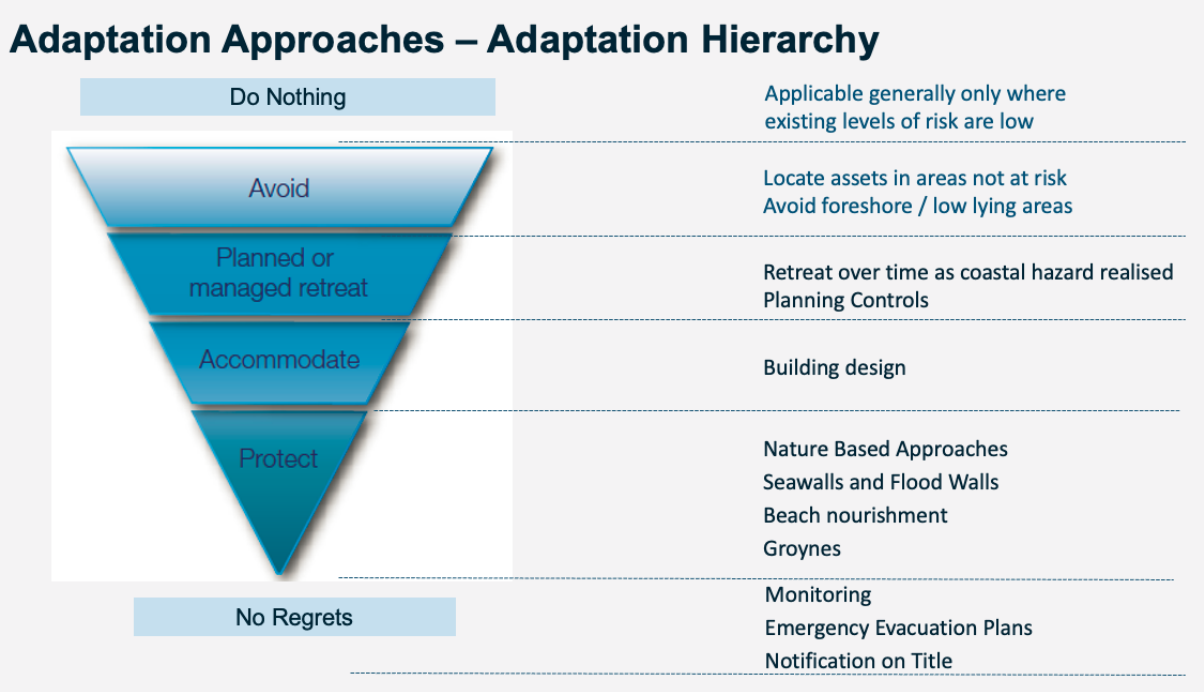
Task 4 Priority Areas Adaptation Ideas

The final workshop task involved developing adaptation strategies and preferred options for prioritised assets. Adaptation approaches and examples were presented to assist with this task, although it was made clear participants could also suggest other adaptation strategies.

The first step was for participants at the table to identify the priority asset (the one with the most dots) and then come to a consensus on which of the four adaptation strategies they wanted to implement to mitigate the risk of erosion and inundation.

They then had to identify an adaptation option or idea they preferred be implemented. They could either choose one of the options presented or develop their own.

Figure 9 Adaptation options presented at the workshop



Task 4 results

Coastal Location: The Whole Estuary	
What is your preferred adaptation strategy?	Protect
What are your table's adaptation option ideas?	• Seawalls and flood walls

Coastal Location: Coopers Mill	
What is your preferred adaptation strategy?	Protect
What are your table's adaptation option ideas?	• Bank stabilisation • Sea walls • Flood walls • Drainage • Rock Wall

	• Backfill in to build dry wall around it

Coastal Location: Estuary, Riverside Island	
What is your preferred adaptation strategy?	Protect
What are your table's adaptation option ideas?	• Provide signs to redirect boats along naval base corner • Provide rock protection • The corner focal points of the islands • Pieces of rocks

Coastal Location: Island Houses	
What is your preferred adaptation strategy?	Protect, Accommodate, Avoid
What are your table's adaptation option ideas?	• Erosion protection based on guidelines • Protect banks, revegetation, bioengineering revetment • Accommodate for new development and renovation • Planning controls • Riverbank vegetation • Rock walls • Restrict water traffic • Technology to dissipate water energy from waves • Control sea entering estuary • Nature based approaches • Sea walls and flood walls • Not to allow managed retreat for residents • Change planning rules to allow more flexible plans and to protect river banks rock walling and provide to build jetties opposite each property • Allow modification by changing planning scheme including building and sanitations • Evaluate current situation and adopt changes as sea level rises over time • Incorporate changes to height of properties and removal of septics as likelihood of occupancy increases • Adopt a measured approach • Planning controls and building design • Some cases avoid based on circumstance • Fill/block drainage and fill • Stilt build

	• Setbacks • Technology solutions (e.g., sewage)

Coastal Location: Jetty / Boat ramps	
What is your preferred adaptation strategy?	Protect, Accommodation, Planned retreat
What are your table's adaptation option ideas?	• Building design – floating erosion protection walls / banks) • Reposition and rebuild as above • Sea walls and flood walls

Coastal Location: Point Grey / Herron	
What is your preferred adaptation strategy?	Managed retreat
What are your table's adaptation option ideas?	• Monitoring • Revegetation

Coastal Location: Businesses	
What is your preferred adaptation strategy?	Protect
What are your table's adaptation option ideas?	• Planning control • Building design • Sea wall / rock wall • Limit speed limits for boat patrons • Salt tolerant plants along water edge (Sedge Grass) • Salt tolerant trees planted along bank • Mangroves

Coastal Location: Foreshore erosion	
What is your preferred adaptation strategy?	Protect
What are your table's adaptation option ideas?	• Where there is boat traffic – use of rocks • Other areas – natural protections

Coastal Location: Waterways (dredging)	
What is your preferred adaptation strategy?	No regrets
What are your table's adaptation option ideas?	• Monitoring (sulphur) environmental • Adapting dredging strategy

Coastal Location: Murray River estuary and banks	
What is your preferred adaptation strategy?	Protect

What are your table's adaptation option ideas?	• Protect the environment and housing and assets • Retain banks through managed environmental and physical retaining walls, including a Tide Wall in the Cut

Coastal Location: All Murray River Delta	
What is your preferred adaptation strategy?	Protect, Accommodate
What are your table's adaptation option ideas?	• Protect riverbanks through sea walls, river bank protection • Work with landowner to assist, protect and supply materials to stabilise banks to reduce erosion, protect vegetation • Bank preservation and vegetation re-planting • Preservation of Murray Delta environment • Keep Dawesville closed until it's needed to be flushed because of a "bloom" • Preserve the riverbanks now! • We need to protect the banks so that there is minimal extra degradation – act on things we can control • Lock system on Dawesville cut first, and then river mouth if necessary – this solves many long term and short term issues such as salinity as well as sea levels rising in the future • Revetment/erosion control – coir logs, non-woven geofabric / textile bags / logs and replanting. Use of softer, natural solutions in keeping with environment • Dike system / sea walls / flood walls • Research vegetation and best planning strategies

Coastal Location: Coolenup Island	
What is your preferred adaptation strategy?	Protect, Accommodate
What are your table's adaptation option ideas?	• Adaptation model presented shows retreat as a preferred option to accommodate. There is no way that moving people out of their homes would be a higher priority that applying mitigation. • Use natural materials where available to create bank protection as an immediate measure ie. fallen trees turned to align with the bank and staked in place then.

	• Control water at the Dawesville Cut • Make more permanent revetment wall? • Protect the riverbanks from boat wake-initiated erosion • Accommodate with planning • Riverbanks need planning and protection from salt water • Work with Council do not approve of managed retreat

The workshop concluded with a 'thank you' to all participants for their active engagement during both session and encouraged them to take the online survey if they hadn't already, as well as sharing the online survey with family, friends and neighbours.

5. Next steps

This findings from this report will inform the draft CHRMAP report and be included as an appendix.

B.2 Coastal Values Survey

Shire of Murray Coastal Values Survey

- Designed to be a quick quantitative survey supplemented by workshop activity.
- To gain a better idea of the local community's coastal values within the CHRMAP study area.
- To provide a communications opportunity to grow interest in the project, and
- Capture people's registration details to grow the project data base

Welcome

As you may be aware, the Shire of Murray is currently in the process of creating a Coastal Hazard Risk Management Adaptation Plan (CHRMAP) for the coastal and estuarine regions within its boundaries. Similar CHRMAPs are currently being undertaken, or have been completed, for many coastal areas around Western Australia.

An important part of the CHRMAP process is understanding the context of the study area, including the values that the community hold for the coastal and estuarine areas.

We invite you to take part in this quick survey to understand YOUR coastal values within the Shire of Murray. This should take you approximately 5 minutes to complete.

If you would like more information on the project, head to our Your Say page at https://yoursay.murray.wa.gov.au/murray-chrmap and please register your details to stay updated about upcoming events and project updates.

Respondent Details

Age Bracket

- 5 to 14
- 15 to 29
- 30 to 49
- 50 to 64
- 65 or older

Please select the location you live from one of the following:

- Birchmont
- West Coolup
- Murray Delta Islands
- South Yunderup
- North Yunderup
- Furnissdale
- Ravenswood
- Other location in Shire of Murray not listed above
- City of Mandurah
- Shire of Waroona
- Outside of project area (eg Perth)

Awareness

How familiar are you with the CHRMAP project currently being undertaken by the Shire of Murray ? Select one option.

- Highly aware
- Somewhat aware
- Unaware

Do you think there should be additional information available on the project YourSay page? Select one option.

- Yes
- No

Visitation and Coastal Values

How do you interact with the estuary? Select your 3 most common interaction options.

- Kayaking / canoeing
- Bird watching
- Boating
- Fishing / crabbing
- Horse Riding
- Swimming
- Walking or jogging
- Socialising/ Picnics
- Camping
- Other (please specify)

3 DROP DOWN sub questions for each option above.

A Map will be included to designate the location of the Activity based on number system (eg 1=Murray Islands, 2=Serpentine River, 3=Herron Point, 4=Birchmont etc)

1. Where do you most frequently do the activity – indicate number from map

2. How often do you participate in the activity?
- (more than once per week, once per week, once to twice per month, less frequently)

3. Why do you choose to use the above locations as opposed to other areas? (can tick more than one)
- Proximity and ease of access
- Environmental values
- Good public facilities/ picnic areas/ boat ramps etc
- Quality of experience
- Social aspects and community
- Other (please specify)

Values

What do you value in your coastline and estuarine area? Rate each category (High, medium, Low)

- Water based recreation opportunities (boating, kayaking etc);
- Land based recreation opportunities (dog walking, picnicking, fishing, exercising etc near the coastline)

- Private benefits (living nearby, property values)
- Environmental values (habitat for wildlife, protection from storms, water/nutrient filtration)
- Community facilities and services (events, festivals)
- Work/ business opportunities (related to coastline and estuarine area)
- Lifestyle and character
- Other (please specify)

Project updates

Please register your details to stay up to date with the project here:

Email address: _____

Baird.

Appendix C

Coastal Hazard

Baird.

C.1 Coastal Hazard Report (Seashore 2021)

Baird.

Appendix A

Coastal Hazard Report

A.1 Coastal Hazard Report (Seashore 2021)

Shire of Murray
Coastal Hazard Assessment

Seashore Engineering
August 2021

Report SE111-01-Rev 1

Prepared for
Shire of Murray

Executive Summary

Coastal hazards affecting the Shire of Murray foreshores have been assessed, to support development of a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). The Shire is located on the eastern sides of Peel Inlet and Harvey Estuary, with foreshore along the banks of the lower Murray and Serpentine Rivers. The Shire's foreshore is substantially undeveloped, with urban development at Yunderup along the lower Murray, including South Yunderup Canal Estate, and a low-density semi-rural development at Birchmont, adjacent to Harvey Estuary.

Evaluation has focused on the coastal hazards of erosion and inundation, which are the two principal hazards requiring assessment under the State Coastal Planning Policy SPP 2.6. General methods used for coastal assessment have been modified to account for the estuarine setting, including consideration of extremely low-lying land present in the lower Murray River and southern parts of Harvey Estuary. A further complication has been brought about due to opening of Dawesville Channel in 1994, which caused an abrupt change in estuarine water levels and consequently modified foreshore evolution. It is noted that the method is intended to provide 'best-estimate' hazard lines suitable for management triggers (i.e. CHRMAP application) rather than a conservative estimate of the coastal hazard zone, corresponding to Schedule One of SPP 2.6.

Erosion hazard has been assessed for 2020, 2030, 2050, 2070 & 2120 using:

- Modelling of cross-shore response to a severe storm, based upon the May 2003 storm, extrapolated to have extreme water levels and winds corresponding to a 100-year average recurrence interval (ARI).
- Extrapolation of shoreline trends based upon historical aerial imagery, generally from 2005-2017 to reduce the influence of Dawesville Channel opening. Shoreline change has historically been small, except in the vicinity of the Murray River delta, where the low-lying berms and islands have progressively folded landward into the wetlands behind them.
- Allowance for erosion in response to sea level rise, using the projected sea level curve described in Transport (2010). This includes an allowance of 0.5m per 0.01m of sea level rise for the whole foreshore, plus a geometric based allowance for low-lying areas where higher water levels will cause narrow foreshore features (berms and islands) to collapse landward. The latter process has been observed for parts of the Murray River delta after opening of Dawesville Channel.

These processes define an erosion hazard zone that varies around the Shire's foreshore, generally with a greater erosion hazard where there is low-lying land and smaller erosion hazard where the shore is higher. Erosion allowances vary from 70 to 120m by 2120.

Potential for an extreme erosion scenario has been identified in response to sea level rise, if tidal flows can cause substantial wetland infilling, with landward collapse of berms and islands up to 1.6km from the existing shore. This mechanism is not presently active, as demonstrated by the extensive intertidal wetland area, but tidal flows will increase with sea level rise. Local management of breaks through the foreshore berm may be used to mitigate the risk of significant sediment wetland infilling.



Total Erosion Allowance Along Shire of Murray Foreshore

Erosion hazard along channel margins for the lower Murray and Serpentine Rivers has been treated separately, acknowledging the differences in foreshore dynamics between the ocean, estuary, and river channels. Distinction has been made based on observed active processes, including 'switching' of channels experiencing flow within the Islands, and local influences of foreshore vegetation. In the absence of detailed measurements of channel change, allowances for erosion hazard have been based upon indicative setback requirements for estuary and river foreshores described in WAPC SPP 2.9 and DC 2.3. These have been distinguished for three sections, considering the likelihood of different erosion mechanisms being active:

- Channels within the Islands area have been defined with an erosion hazard of 50m by 2120, accounting for higher tidal flows and potential for channel switching.
- An erosion hazard allowance of 30m by 2120 has been defined where there is a single main channel for the Murray River (adjacent to Yunderup) and within the Serpentine River.
- Within the secondary channels and small lakes adjacent to the Murray River, an erosion hazard of 15m by 2120 has been defined. These waterbodies typically receive only a small quantity of flow, usually under extreme water level or flood overflow conditions.

Existing foreshore protection structures within Yunderup provide land retention, including canal estate walling and a bund around the man-made lake south of Yunderup. These features have been assumed to be maintained to provide the existing standard of protection. For canal walling, additional upkeep is likely required with higher water levels, but existing wall heights are sufficient for walling to provide protection against erosion. The bund around the man-made lake presently has a crest height of +1.1 to +1.5mAHD, which is likely to require enhancement prior to 2070 to prevent collapse due to frequent overtopping.

Inundation hazard has been identified through analysis of the Peel-Harvey tide gauge record, accounting for changes to flooding that have occurred since opening of Dawesville Channel. The upper limit of 'typical tides' is presently +0.6mAHD, defining wetland areas, and providing an effective limit for land-use. Wetland areas will increase with sea level rise, with a threshold of +1.5mAHD by 2120 based on a projected 0.9m sea level rise. The present-day 100-year ARI storm water level is estimated as +1.09mAHD, which will increase with sea level rise to +1.99mAHD by 2120.

The maximum extent of coastal inundation hazard has been evaluated through consideration of an extreme event based upon 'worst-case' impact of a tropical cyclone similar to TC Alby, but with +10% storm intensity and a track shifted to maximise flooding along the Mandurah coast, to approximate an event with 500yr recurrence. This scenario would produce a high water level of +1.44mAHD under present day conditions, increasing with sea level rise to +2.34mAHD by 2120. This upper limit level of flooding is similar to the potential flood risk area derived for the lower Murray River based upon 100-year ARI rainfall and 0.9m sea level rise.



Extreme Inundation Hazard for Present Day (+1.44mAHD)

Table of Contents

1. Introduction 8
1.1. Coastal Hazards 9
1.2. Summary of Hazard Assessment Approach 9
2. Peel-Harvey Foreshore Dynamics 12
2.1. Existing Origins and Structure 12
2.2. Morphodynamics 14
3. Inundation Hazard 22
4. Present-day Erosion Hazard 31
4.1. CoastaL Erosion Policy 31
4.2. Acute Storm Erosion Allowance 31
4.3. Chronic Erosion Allowance 36
4.4. Projected Erosion Due to Sea Level Rise 36
4.5. Total Estuarine Foreshore Erosion Allowances 42
4.6. Channel Erosion Allowances 48
4.7. Man-Made Structures 52
4.8. Extreme Erosion (Wetland Infill) Scenario 53
5. Conclusions 55
Appendix A – Peel Harvey Estuary Context 56
Appendix B – Meteorology and Oceanography 57
Appendix C – Vegetation Line Change Summary 58
Appendix D – Murray Delta Imagery Sequences 59
Appendix E – Profiles Used to Evaluate of Response to SLR 60
Appendix F – Peel-Harvey Bathymetric Change 61
Appendix G – Variability of Benthic Coverage 62
Appendix H – Wave Hindcast Modelling Report 63
Appendix I – Extreme Surge Flooding Assessment 64
References 65

List of Figures

Figure 1-1: Location Diagram 8
Figure 1-2: Framework of Assessment Approach 10
Figure 1-3: Components of Inundation Assessment 10
Figure 1-4: Components of Erosion Assessment 11
Figure 2-1: Extract from 1:50,000 Surface Geology (GSWA) 12
Figure 2-2: Major Foreshore Features 13
Figure 2-3: Observed Change at Austin Bay Birdsfoot Delta 15
Figure 2-4: Available Imagery Dates and Flow-Diagram to Estimate Shoreline Trends 15
Figure 2-5: Areas of identified vegetation line change (2005-2017) 16
Figure 2-6: Meeyip Island Vegetation Line Change 17
Figure 2-7: Imagery Sequence 1994-2001 for Murray Delta Area (North) 18
Figure 2-8: Vegetation Line Changes for Murray Delta 1994-2017 19
Figure 2-9: Dynamics of Harvey Estuary Sill (1979-2017) 20
Figure 2-10: Beach and Benthic Variability on Stable Shoreline South of Point Grey 21
Figure 3-1: Peel Inlet Tide Gauge Observations & Residuals 1985-2019 23
Figure 3-2: Areas Below 0.6mAHD 24
Figure 3-3: Inundation Frequency of Wetlands Fringing Peel Inlet 25
Figure 3-4: Inundation Frequency of Wetlands Fringing Harvey Estuary 26
Figure 3-5: Peel Inlet Extreme Water Level Best Fit 26
Figure 3-6: Simulated Ocean and Estuarine Water Levels for Design Storm 28
Figure 3-7: Extent of Foreshore below Design Inundation Level 29
Figure 3-8: Sea Level Forecast Curve Used for WA Coastal Planning (Transport 2010) 30
Figure 4-1: May 2020 Storm Wind Record 32
Figure 4-2: Observed Response to May 2020 Storm at Old Mill 32
Figure 4-3: Water Levels for 2003 & 2020 Storms & Synthesised 100-year ARI Storm 33
Figure 4-4: Hindcast Wave Heights for 2020, 2003 and 100-year ARI storms 33
Figure 4-5: Profile Lines used for SBeach Modelling 34
Figure 4-6: SBeach outcomes over full profile 35
Figure 4-7: SBeach outcomes over part-profile 35
Figure 4-8: Typical Models of Cross-Shore Response to Sea Level Rise 36
Figure 4-9: Complexity of Low-Level Topography 38
Figure 4-10: Definitions of Rollover and Infill 39
Figure 4-11: Berm Rollover Rates due to Wave Energy and Sea Level Rise 41
Figure 4-12: 2120 Berm Rollover Estimates by Profile 41
Figure 4-13: Modelled Profile Responses to Design Storm, Chronic Trend and SLR 43
Figure 4-14: Total Erosion Allowances (Whole Foreshore) 45
Figure 4-15: Total Erosion Allowances (Birchmont Area) 46
Figure 4-16: Total Erosion Allowances (South Yunderup Area) 47
Figure 4-17: Schematic Indicating Meso-scale drivers of Channel Foreshore Change 49
Figure 4-18: Typical Eroding Foreshore Sequence 49
Figure 4-19: Channel Changes Within the Murray River Delta 50
Figure 4-20: Channel Classification 51
Figure 4-21: Variation of bund crest levels for Yunderup Lake 53
Figure 4-22: Wetland Infill Scenario for 2120 54

List of Tables

Table 2-1: Active & Future Processes Indicated by Key Features 13
Table 3-1: Peel Inlet Extreme Water Level Best Fit 27
Table 3-2: Change to Inundation Levels with Projected Sea Level Rise 30
Table 4-1: Total Erosion Allowances Table for 2120 44
Table 4-2: Potential Erosion Mechanisms for Lower Murray River 48
Table 4-3: Erosion Allowances for River Channels 52

Limitations of this Report

This report and the work undertaken for its preparation, is presented for the use of the client. The report may not contain sufficient or appropriate information to meet the purpose of other potential users. Seashore Engineering does not accept any responsibility for the use of the information in the report by other parties.

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Rev 1	M.Eliot	09.08.2021			Address Public Comments

1. Introduction

This document summarises coastal hazards affecting the Shire of Murray foreshore, providing a contributing study for the Shire's Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). The Shire of Murray is located along the eastern margins of the Peel-Harvey Estuarine System, which includes the mouths of the Murray and Serpentine Rivers.

The Shire's foreshore is substantially undeveloped, with predominantly rural land-use. Austin Bay Nature Reserve, Mealup Nature Reserve, Lake McLarty Nature Reserve and Kooljerrenup Nature Reserve occupy almost 25km of the Shire's foreshore, which includes narrow foreshore reserves in Austin Bay and at Birchmont (Figure 1-1). There are two existing communities, with urban development in Yunderup and low density semi-rural development at Birchmont. A third development area has been proposed for Point Grey (RPS 2009).



Figure 1-1: Location Diagram

1.1. COASTAL HAZARDS

Coastal hazards occur when coastal processes at the interface between the ocean (or estuary) and the adjacent land can provide physical, environmental, or social loss. For the most part, this is commonly associated with excursion of ocean waters (through waves, tides or storm surges) onto land area, particularly where it adversely affects land use. The two most investigated coastal processes are:

- Erosion, where oceans waters, including wave action, move sediment away from their existing position along the coast, removing a previous area of land.
- Coastal inundation, where land that was typically outside the influence of ocean waters, becomes submerged, typically for minutes to hours (i.e. typically excluding wave action).

Neither erosion nor inundation are a hazard unless they adversely affect an asset.

Management of coastal hazards is a key objective of the State Coastal Planning Policy SPP2.6 (WAPC 2013, 2020). This policy outlines a framework for management, combining land-use zoning and foreshore reserves as the primary tool for mitigation of coastal hazards. The policy recommends consideration of coastal hazards over a time frame of 100 years, including extreme events and projected impacts of climate change, such as sea level rise.

For areas where existing land-use may potentially be affected by coastal processes within the next 100 years, SPP 2.6 recommends development and implementation of a CHRMAP, for identification and ongoing management of coastal hazards. Guidelines regarding CHRMAP development have been published (WAPC 2019).

This coastal hazard assessment has been prepared as a step in the development of a CHRMAP for the Shire of Murray.

1.2. SUMMARY OF HAZARD ASSESSMENT APPROACH

The assessment has followed a conventional approach for forecasting coastal hazards, using observations to identify active processes, which are subsequently extrapolated, with consideration of extreme events and sea level rise (Figure 1-2). However, this is complicated by the Shire of Murray foreshore being located within the Peel-Harvey Estuarine System, which has been substantially modified by opening of Dawesville Channel in 1994.

The estuarine setting challenges the use of ‘standard’ interpretation of coastal drivers (e.g. waves & tides) and responses that are commonly used in coastal modelling, with the comparatively low-energy setting altering the relative significance of waves, tides and river flows (Harris & Heap 2002) with the structure of each estuary being affected by its origins and degree of infilling (Ryan *et al*. 2005). Consequently, estuarine morphology has been used to supplement interpretation of active processes.

The effect of Dawesville Channel complicates interpretation of active processes, as it represents a secular change in conditions, with a comparatively large increase in tidal range. Because of the low-energy conditions within the estuary, its impacts can potentially affect observed trends for decades. Although these are permanent changes, the effect of 'step changes' needs to be considered carefully when extrapolating trends for the next 100 years.

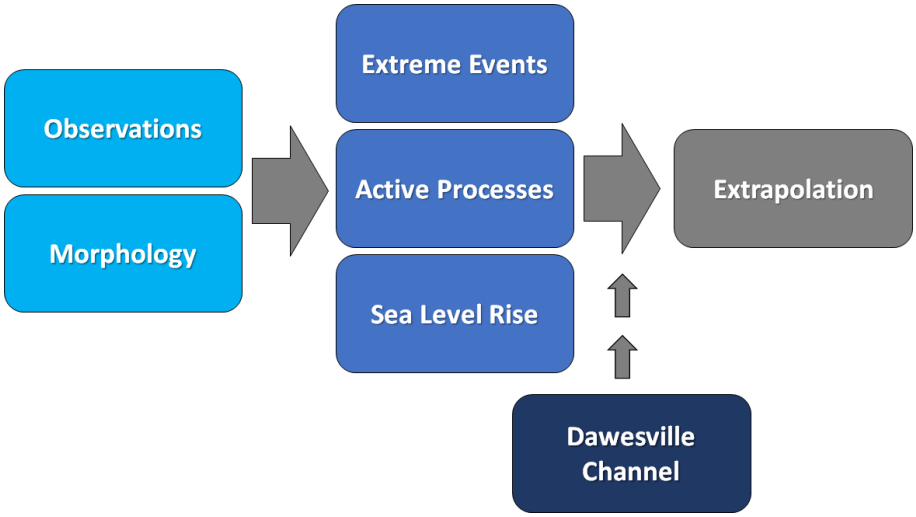


Figure 1-2: Framework of Assessment Approach

Evaluation of inundation hazard has been based upon analyses of extreme water level records and modelling for south-west Western Australia (e.g. Haigh *et al*. 2010; Eliot 2012), including the derived relationship between water levels inside and outside Peel-Harvey system (Eliot & McCormack 2019). Components of the inundation assessment include evaluation of estuary water levels, modelling of ocean extreme events and transfer of the ocean signal through to the estuary using a spectral admittance function.

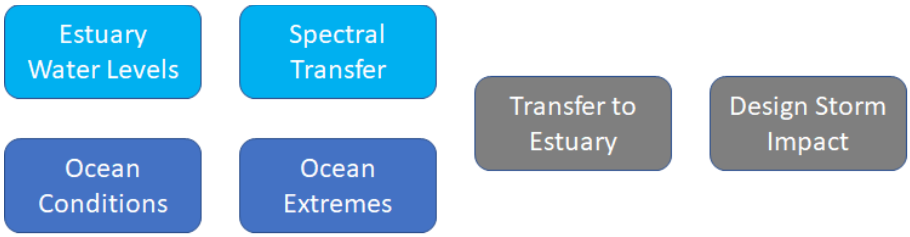


Figure 1-3: Components of Inundation Assessment

The assessment approach for the Shire of Murray foreshore dynamics has been built from previous evaluations in the southwest of Western Australia (Eliot *et al*. 2006; Damara WA 2008, 2009, 2016, 2019; Travers *et al*. 2010), within the wider context of estuarine and low-energy beach literature (Nordstrom & Roman 1992, Jackson *et al*. 2002; Ton *et al*. 2020). For the main basin of the estuaries, foreshore dynamics are strongly related to the directional wave climate and water level variability. Components of the assessment consequently involve directional analysis of winds, fetch analysis based on the estuarine structure and wave hindcasting (Figure 1-4).

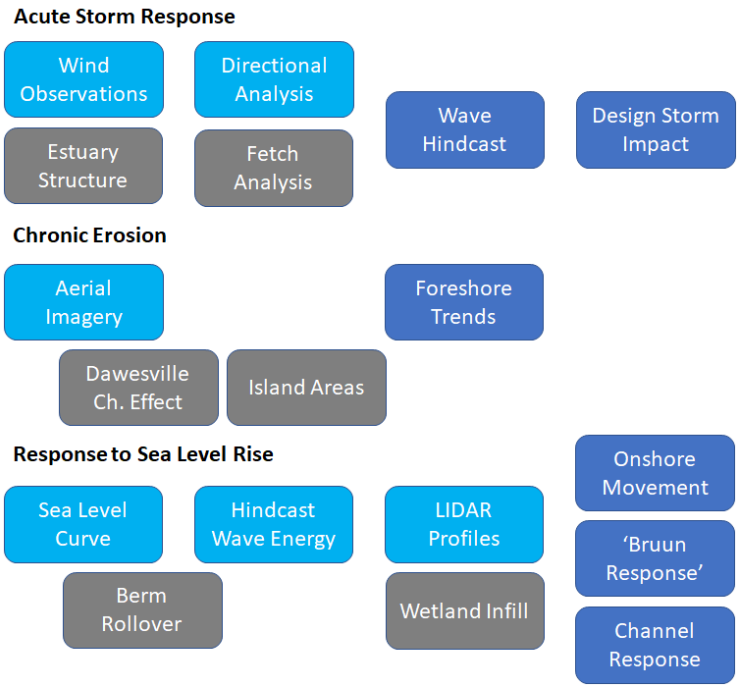


Figure 1-4: Components of Erosion Assessment

2. Peel-Harvey Foreshore Dynamics

2.1. EXISTING ORIGINS AND STRUCTURE

Peel-Harvey Estuarine System is a large waterbody, comprised of two shallow basins, the elongated Harvey Estuary, and the more rounded Peel Inlet, with input from the Harvey, Murray and Serpentine River systems, along with local catchment drainage. The estuarine system is a geologically modern feature on the greater Swan coastal floodplain, which has developed its modern form over the last 2,000 years, when sea levels have remained approximately constant, declining 1-2 m (Wyrwoll *et al*. 1995). Land surrounding the estuary has correspondingly been shaped by coastal, alluvial or lagoonal processes (Figure 2-1):

- Coastal features are prevalent on the west side of the estuarine system, with a narrow strip of dunes along the east side of Harvey Estuary.
- Alluvial features mark the previous limit of estuarine processes, which intuitively suggest an approximate limit of expected foreshore response to sea level rise up to the level of the previous highstand.
- Lagoonal deposits are present along the east and south side of Peel Inlet, along with the south end of Harvey Estuary. These include sediment supply from the Murray and Harvey Rivers, with reworking through estuarine foreshore dynamics. There has apparently been low sediment supply from the shallow grade Serpentine River.

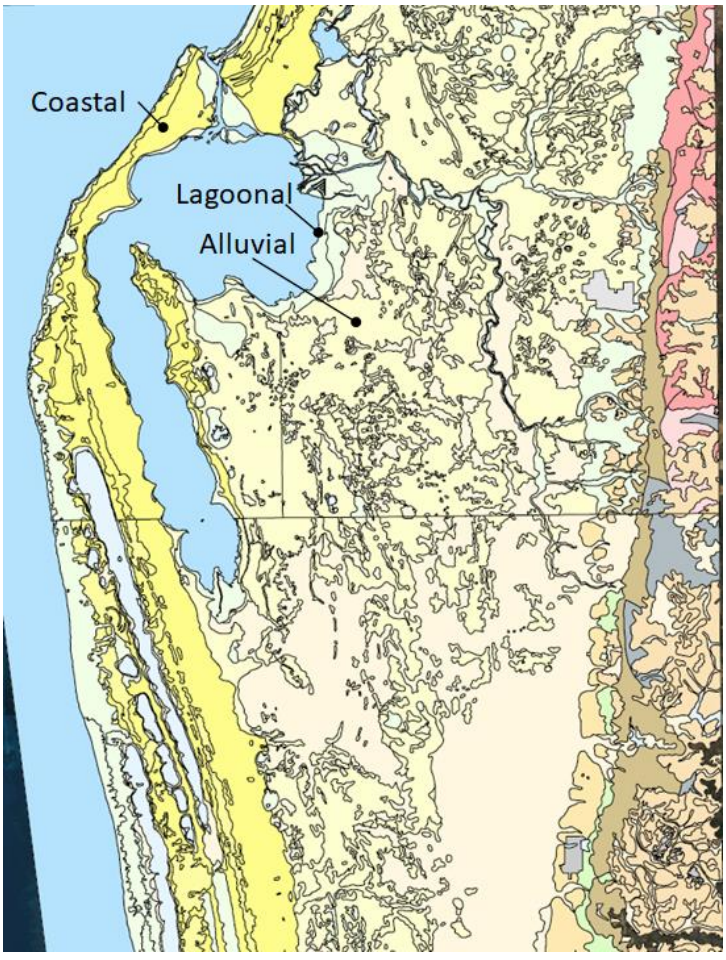


Figure 2-1: Extract from 1:50,000 Surface Geology (GSWA)

The mix of land forming processes has created several different morphotypes along the Shire of Murray foreshore (Figure 2-2). These indicate active processes and influence pathways by which the foreshore can potentially change over time.

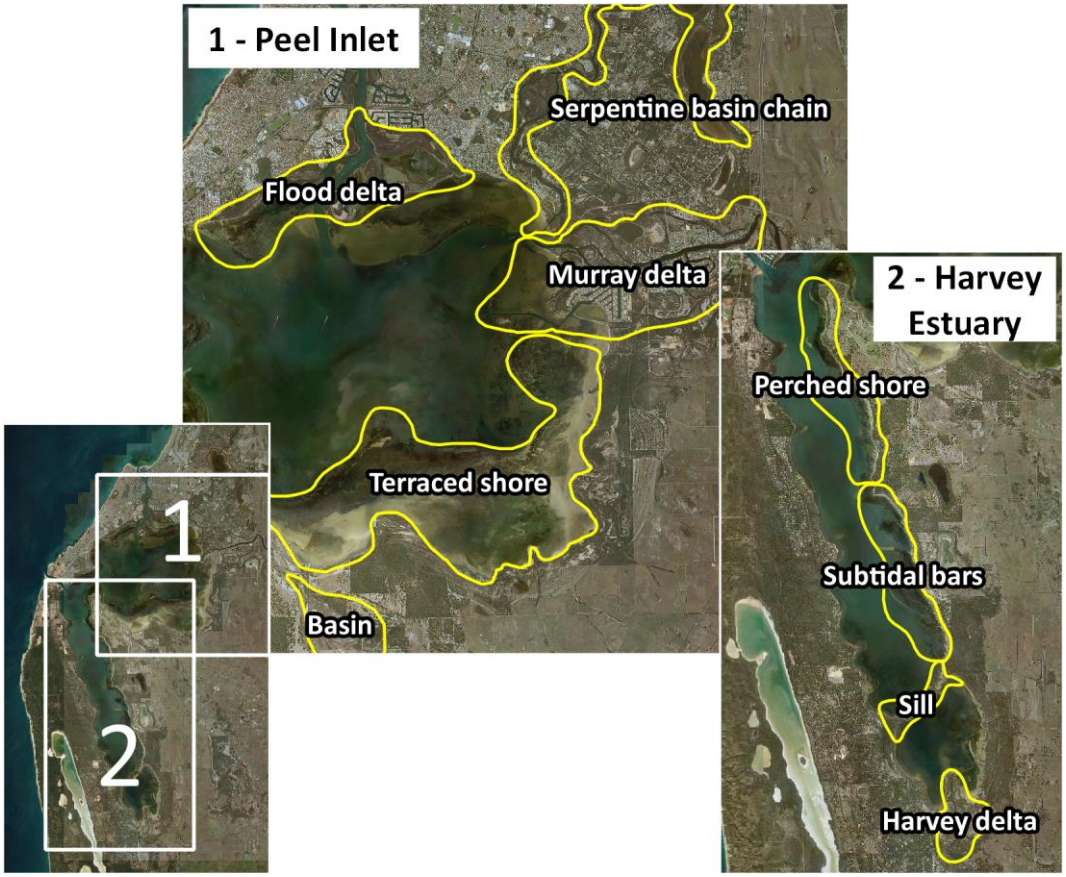


Figure 2-2: Major Foreshore Features

Active and future behaviour can be distinguished between the foreshore of the estuary basins, which is strongly influenced by wave conditions, and foreshore along channel margins, which are affected by flows and sediment supply (Table 2-1). Separate approaches have consequently been used to estimate erosion hazard in Section 4.

Table 2-1: Active & Future Processes Indicated by Key Features

Feature	Active Processes	Future Processes
Flood Delta	Historic marine sediment supply	Increased tidal exchange
Serpentine Basin Chain	Limited river sediment supply Tidal exchange	Increased tidal exchange
Murray Delta	Historic river sediment supply	Increased tidal exchange
Terraced Shore	Shallow depth limits waves	Reduced sheltering (wave)
Perched Shore	Rock control	Reduced control (wave)
Subtidal Bars	Alongshore transport	Modified transport (wave)
Sill	Tidal exchange / overwash	Increased overwash
Harvey Delta	Historic river sediment supply	Increased overwash

2.2. MORPHODYNAMICS

Identification of foreshore dynamics has been undertaken through evaluation of aerial imagery, including comparison of shoreline change, and measurement of bathymetric change, based upon hydrographic surveys. Aerial Imagery suitable to assess dynamics of the Shire of Murray foreshore is available from:

• 1974 (Sep)	North Peel Inlet only	City of Mandurah
• 1975	Peel Inlet only	Department of Transport
• 1979 (Sep)		Department of Transport
• 1985 (Jun)	Peel & North Harvey	City of Mandurah
• 1994 (Apr)		Department of Transport
• 1995 (Feb)		City of Mandurah
• 2000		City of Mandurah
• 2001		City of Mandurah
• 2002		City of Mandurah
• 2004		City of Mandurah
• 2005		City of Mandurah
• 2006		City of Mandurah
• 2007		City of Mandurah
• 2008		City of Mandurah
• 2009		City of Mandurah
• 2010		City of Mandurah
• 2011		Shire of Murray
• 2012		Shire of Murray
• 2013 (Jan)		City of Mandurah
• 2014 (Feb)		City of Mandurah
• 2015 (Feb)		Shire of Murray
• 2015 (Nov)		Shire of Murray
• 2016		Shire of Murray
• 2017 (Feb)		City of Mandurah
• 2017 (Apr)		Shire of Murray

Assessment of historic behaviour provides an evidential basis for the estimation of future shoreline trends. Initial interpretation of foreshore change was conducted through comparison of oldest and most recent imagery (generally 1979-2017). This indicated that much of the estuary foreshore has experienced limited net change of vegetation line, including areas that are geomorphically considered highly sensitive, such as birdsfoot delta formations (Figure 2-3). The Murray delta area provided a marked exception, with some areas of significant change.

Subsequently, historic imagery was used to evaluate foreshore processes and project future shoreline trends. Although there is almost 40 years of aerial imagery, projection of future trends based on historic behaviour is complicated by construction of Dawesville Channel. Shoreline adjustment to higher tidal range after 1994 suggests pathways of response to higher sea levels, and therefore is a useful indicator of expected response to sea level rise, particularly over the next 20-30 years.



Figure 2-3: Observed Change at Austin Bay Birdsfoot Delta

Periods 1994-2005, 2005-2011 and 2011-2017 (reported in Appendix C) were used to check the relative influence of Dawesville Channel on shoreline trends, using the logic sequence shown in Figure 2-4. Overall behaviour is indicated by Figure 2-5, noting there is little difference between the 2005 shoreline (black dash) and the 2017 shoreline (imagery) except at the Murray River delta. Low-lying areas are indicated where the 2017 HSD (pink) is set back from the 2017 shore, in the Murray River delta and along the southern shore of Peel Inlet.

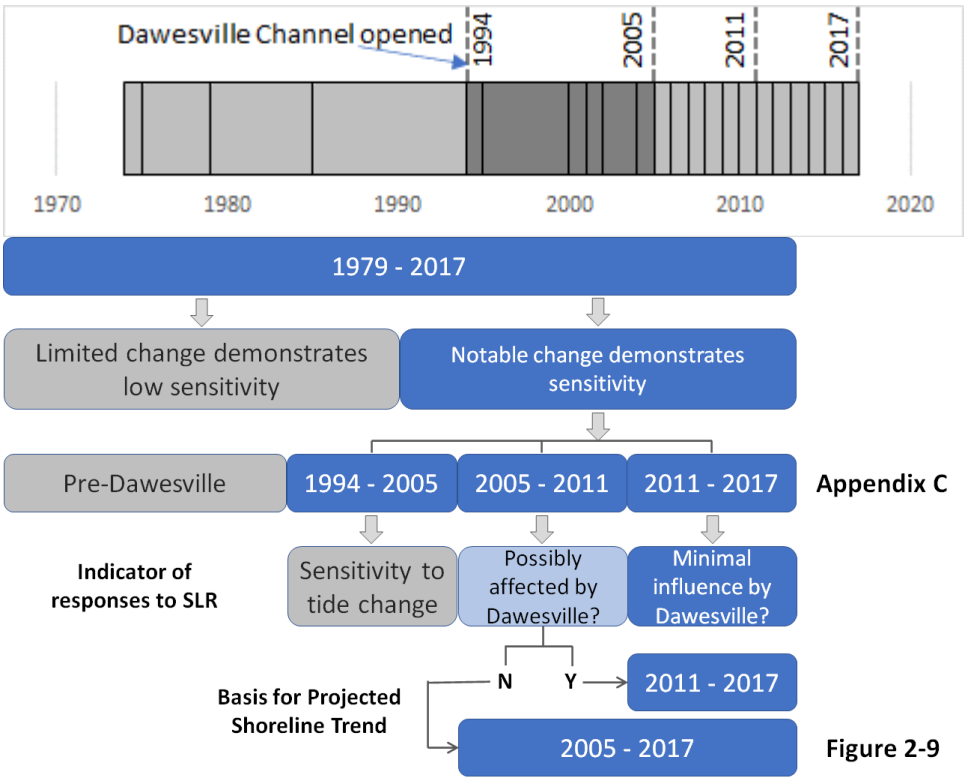


Figure 2-4: Available Imagery Dates and Flow-Diagram to Estimate Shoreline Trends

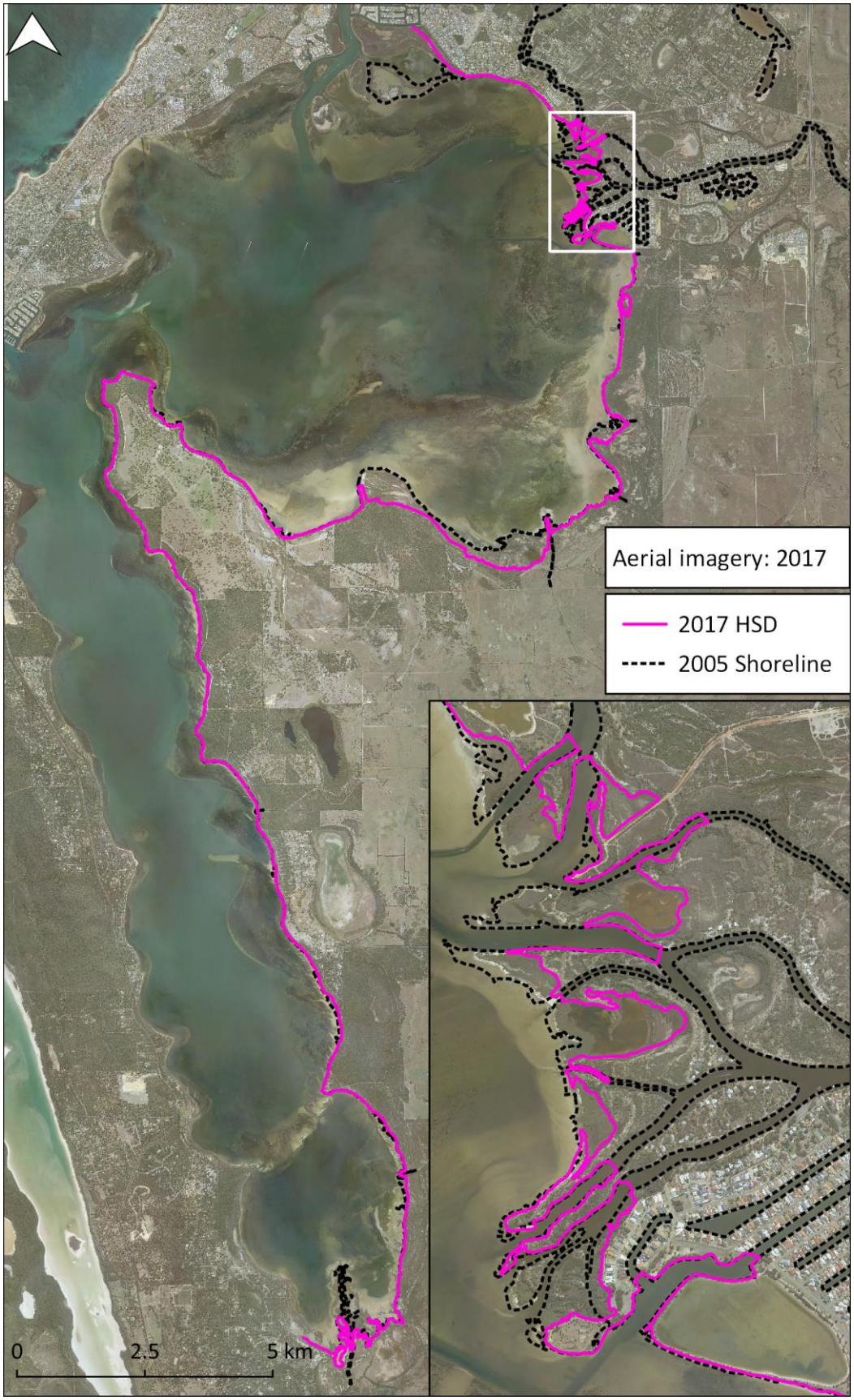


Figure 2-5: Areas of identified vegetation line change (2005-2017)

The full time series was examined for areas where substantial change had occurred, to help identify driver-response patterns, particularly if several alternative mechanisms for change were evident.

Examined at a local scale, movement of the vegetation line has been significant, particularly at the northern end of Meeyip Island (Figure 2-6). However, the nature of change has been the landward collapse of ridges and spits, with spits developed through flood deposition gradually collapsing back on to the islands (Figure 2-7). Consequently, this is not erosion (sediment volume loss) *per se*, although this movement needs to be considered in the definition of erosion hazards. Consequently, evaluation of foreshore trend has considered the change to island areas (Figure 2-8), averaged along the active foreshore length. This gives a rate of erosion of 0.5 to 1.6 m/yr, increasing from the Murray River mouth to the north, greatest at Meeyip Island.

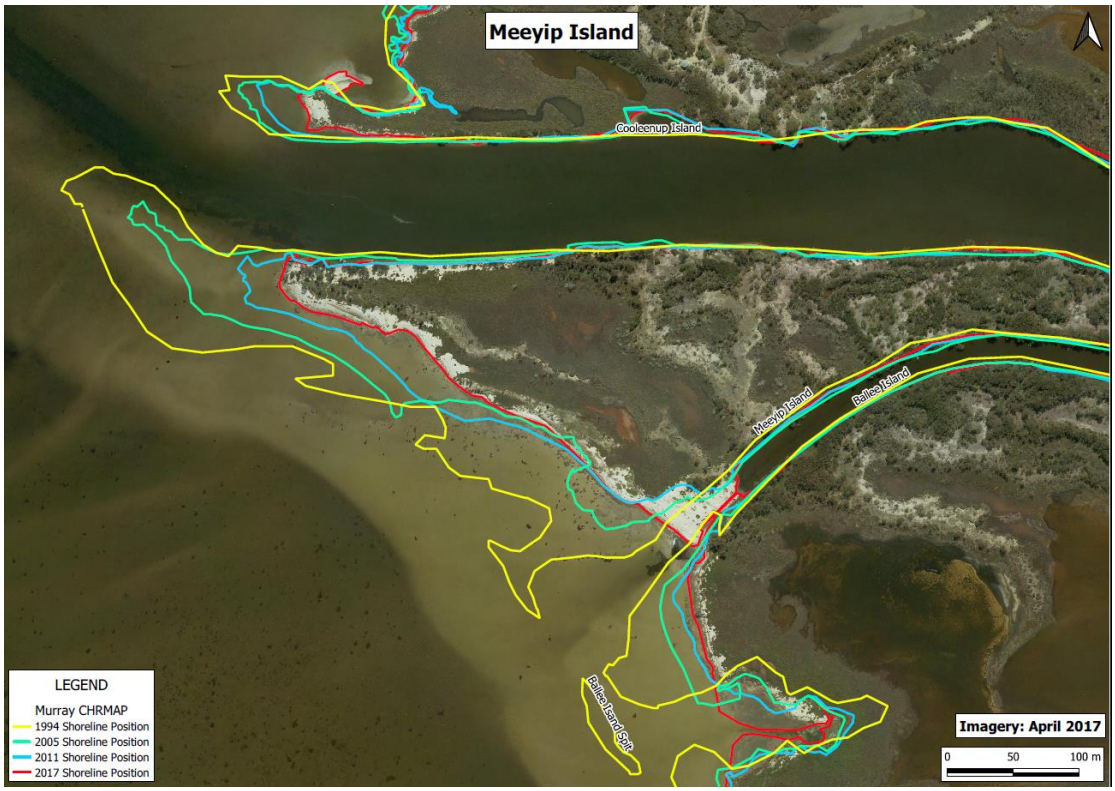


Figure 2-6: Meeyip Island Vegetation Line Change

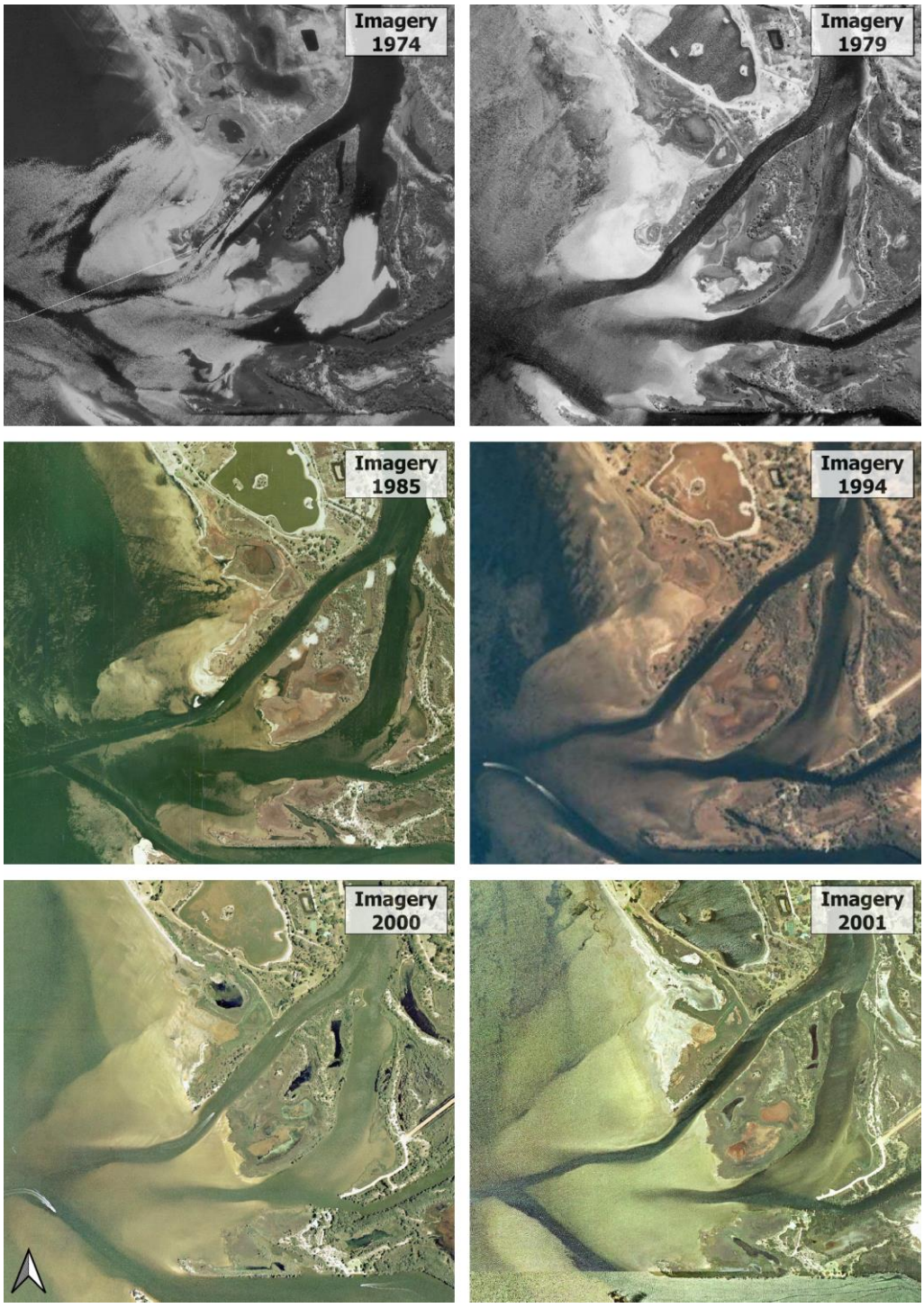


Figure 2-7: Imagery Sequence 1994-2001 for Murray Delta Area (North)

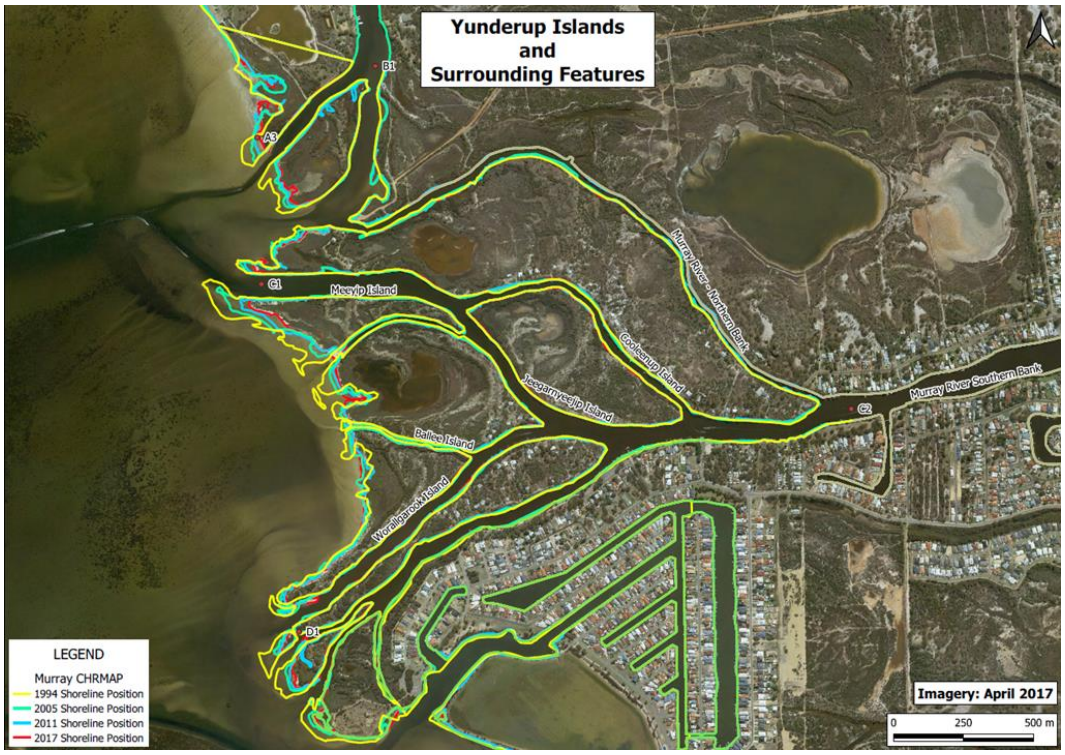


Figure 2-8: Vegetation Line Changes for Murray Delta 1994-2017

Complex foreshore dynamics were also identified at Harvey Estuary Sill, toward the southern end of Harvey Estuary. Significant disruption of the sill and adjacent transverse bars occurred following opening of Dawesville Channel, with associated 'straightening' of the shore north of Herron Point. However, substantial change was delayed until around 2012, which corresponded to a period of elevated mean sea levels during strong La Niña conditions. Changes included increased coverage of benthic vegetation, development of a single main tidal channel through the sill, further breakdown of the sill sand bar chain and degradation of the transverse bars. Local shoreline erosion is mainly a consequence of losing feed from the bars, and therefore has not been extrapolated as a future trend.

However, other sections of shore have also been subject to variability of beach and benthic conditions, without corresponding change to the shoreline itself. This is illustrated along the shore south of Point Grey, with fluctuations in beach width, nearshore bars and terrace structure (Figure 2-9). This has occurred with negligible change to the vegetation line position.

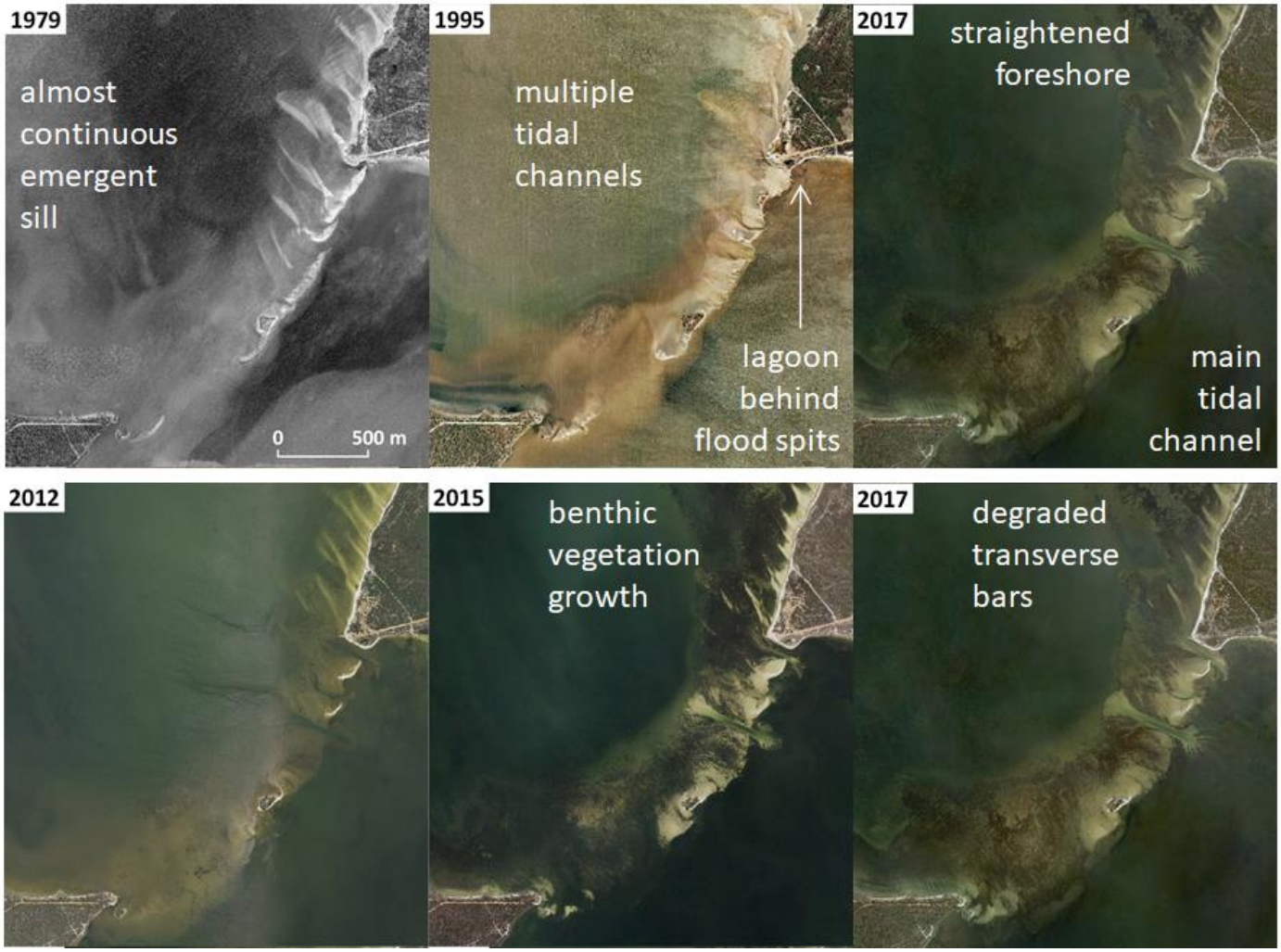


Figure 2-9: Dynamics of Harvey Estuary Sill (1979-2017)

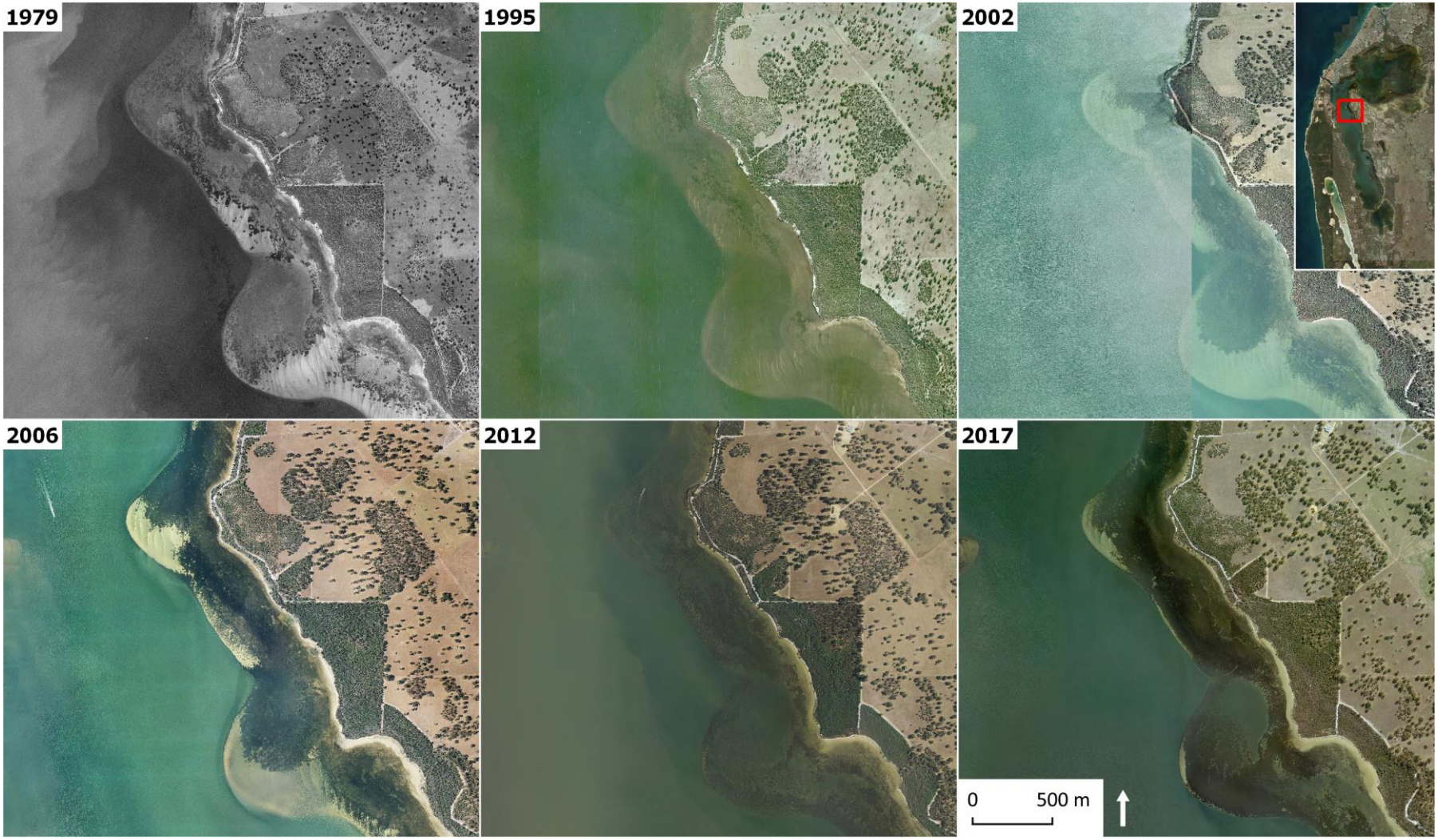


Figure 2-10: Beach and Benthic Variability on Stable Shoreline South of Point Grey

3. Inundation Hazard

Inundation hazard has been considered based upon previous studies of extreme water levels in the southwest of Western Australia (Haigh *et al*. 2010; Eliot 2012, 2018). These have identified that the relative role of different storm types in the generation of high water levels:

- Mid-latitude storms occur all year round but are most frequent and severe during winter months. Coincidence of storms with high mean sea level and the winter solstice tidal peak determines that high water levels mainly occur between May and July (Eliot 2012).
- Tropical storms occur in northerly latitudes mainly between December and March. These storms are highly mobile and occasional late season storms pass into southerly locations, where they may experience extra-tropical transition, interacting and eventually merging with extra-tropical systems. These storms can generate large surges, but they typically occur during a period of low mean sea level and moderate tides, reducing their capacity to generate extreme water levels (Eliot 2010).
- Thunderstorms occur throughout Western Australia. The local pressure drop associated with thunderstorms can generate a travelling surge that can, when travelling at certain speeds and directions, be amplified by the resonant characteristics of coastal bathymetry (Pattiaratchi & Wijeratne 2014). This provides opportunity for high amplitude but rapidly oscillating surges.

Historically, the tide gauge records of almost all southwest stations show that the most frequent cause of high water levels is developed by mid-latitude winter storms. However, the highest total water levels are typically associated with either tropical cyclones or meteotsunami. The most significant event on record was caused by TC Alby in April 1978, which caused extensive flooding from Mandurah through to Busselton (MacPherson *et al*. 2011).

Evaluation of water levels within the Peel-Harvey system has demonstrated that the estuary acts like a spectral filter, with the channel and basin structure modifying how tides, storm surges and other ocean sea level signals are transferred through into the estuarine systems (Eliot & McCormack 2019). This analysis has shown that tide is reduced to 70-90% of the ocean signal and mean sea level variation is unchanged. The effect on surges is variable, according to the time scale of the surge process, with 85% of 'typical' storm surges passing through, with reduced transfer for shorter duration signals.

The likelihood of inundation for events below 100-year ARI has been estimated based upon data from the permanent tide gauge established in Peel Inlet since 1985 (Figure 3-1). A sub-set of the dataset has been used, considering only data since April 1994, following opening of Dawesville Channel.

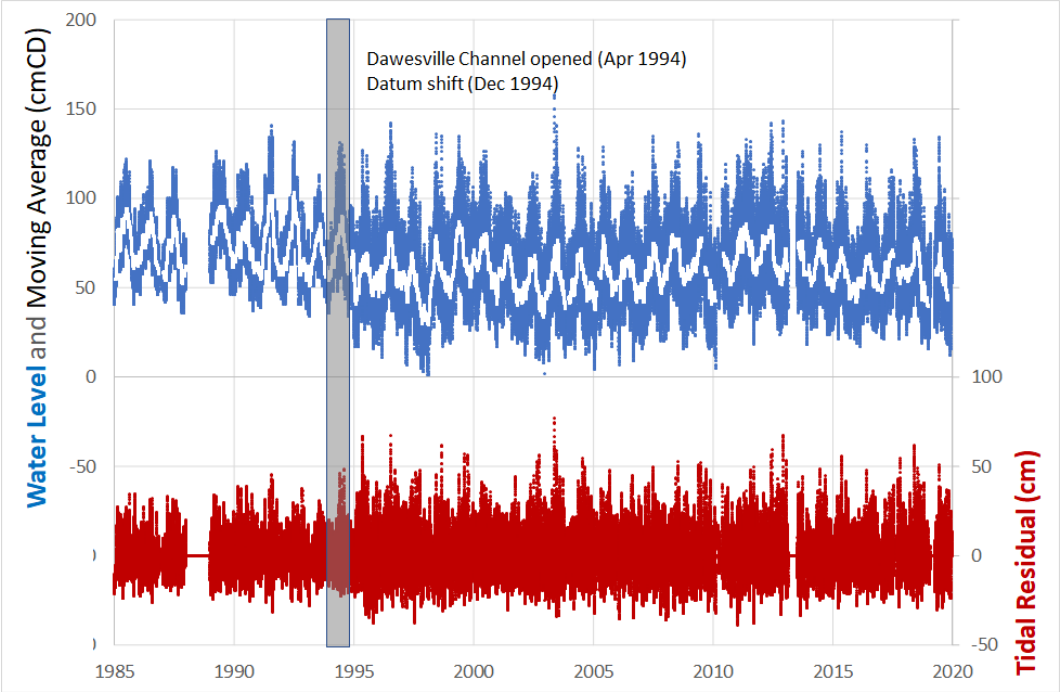


Figure 3-1: Peel Inlet Tide Gauge Observations & Residuals 1985-2019

Evaluation of inundation hazard has been based upon ground levels derived from the 2009 LIDAR land surface, captured by Fugro, on behalf of the Department of Water. It is noted that although LIDAR has capacity to collect topography with fine vertical and horizontal resolutions, there was limited vertical datum control available within the Shire of Murray (John Mullally, DOT Senior Hydrographic Surveyor, pers comm.). Hence, it is estimated that ground levels might have systematic errors in the order of 0.3m, which represents a substantial change in relative flooding incidence. Despite this potential limitation, checking of broad-scale patterns did not identify inconsistencies, and the LIDAR topography has been considered the most accurate available information for use in this assessment.

For land-use planning, water levels are distinguished between those causing 'tidal inundation' and higher levels producing 'flood inundation'. Tidal inundation occurs frequently, limiting the vegetation able to survive, and is typically characterised as wetland. The limit of present-day tidal inundation is approximately level of +0.6m (Figure 3-2), which will increase with sea level rise. Wetland areas are generally unsuitable for typical 'land-use' requiring consideration of inundation, potential erosion hazard and effects of salinity. Identification of adaptive mitigation principles is an objective for the overall CHRMAP supported by this document. Rising tidal inundation is also associated with increased salinisation of the wetlands fringing the Murray River, causing changes to the riparian vegetation, which may locally affect foreshore stability.

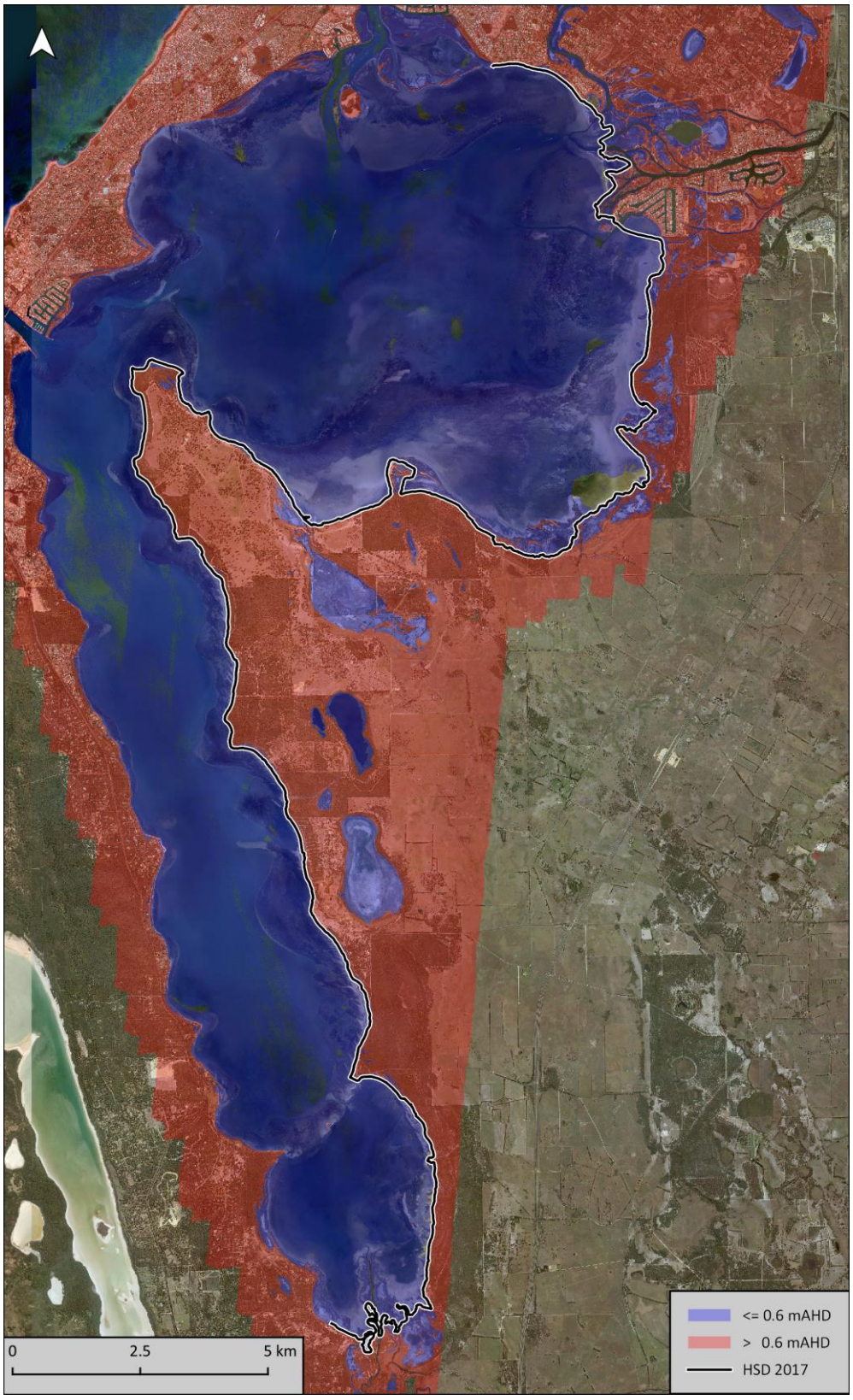


Figure 3-2: Areas Below 0.6mAHD

Note: HSD2017 is defined in front of wetland areas below 0.6mAHD where a largely continuous barrier has been identified.

Exposure of parts of the Shire of Murray foreshore to relatively low levels of inundation is demonstrated by flooded areas observed from satellite imagery, as assessed by Digital Earth Australia (Mueller *et al*. 2019). The south and west fringes of Peel Inlet is suggested to be inundated 5-20% of the time (Figure 3-3), including a large wetland connected to Roberts Bay through a narrow channel. Wetlands adjacent to Harvey Estuary (Lake McLarty and Birchmont) are not directly connected, with inundation patterns suggesting influence of near-surface groundwater (Figure 3-4).

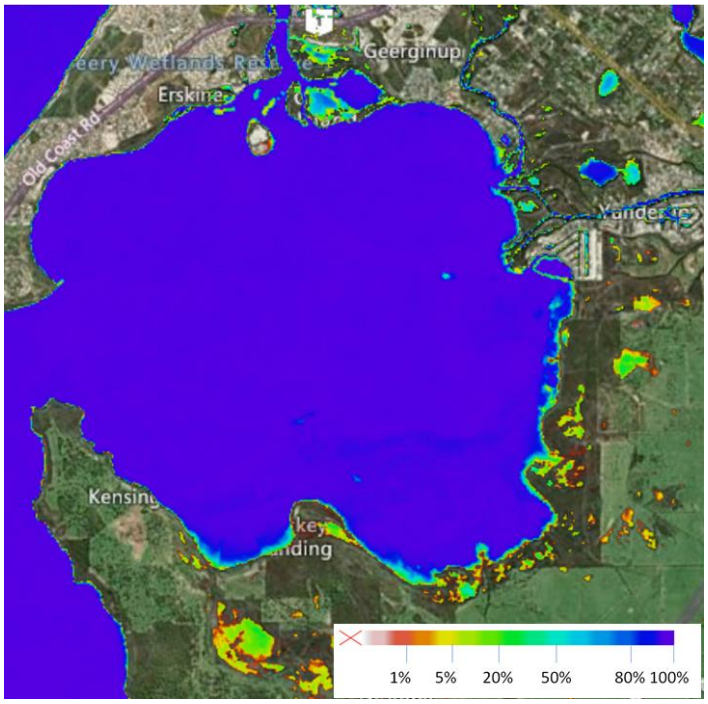


Figure 3-3: Inundation Frequency of Wetlands Fringing Peel Inlet

Flood inundation occurs with lower frequency for high levels. The impacts of flooding depend on the type of land-use, with tolerably rare flooding usually considered nuisance flooding. Incidence of tolerable flooding usually varies from once per year (affecting ground covers) to 1% likelihood per year (possibly tolerable for housing). Flood inundation levels will increase with sea level rise.

Characterisation of flood recurrence was undertaken by identifying maxima, with a minimum window of two days between events, to avoid including the same storm event twice. The highest 24 events within the data set (i.e. approximately 1 per year of data) were then ascribed ranking positions, following the method of Petrauskas & Aagard (1971). Fitting of alternative extreme distribution curves suggested a best fit with Weibull k = 1.1, which is nearly equivalent to a log-linear fit (Figure 3-5 and Table 3-1).

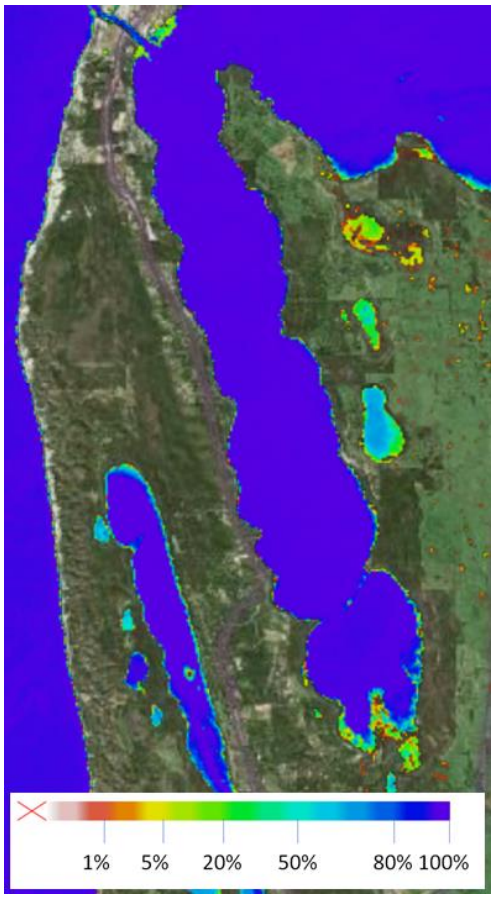


Figure 3-4: Inundation Frequency of Wetlands Fringing Harvey Estuary

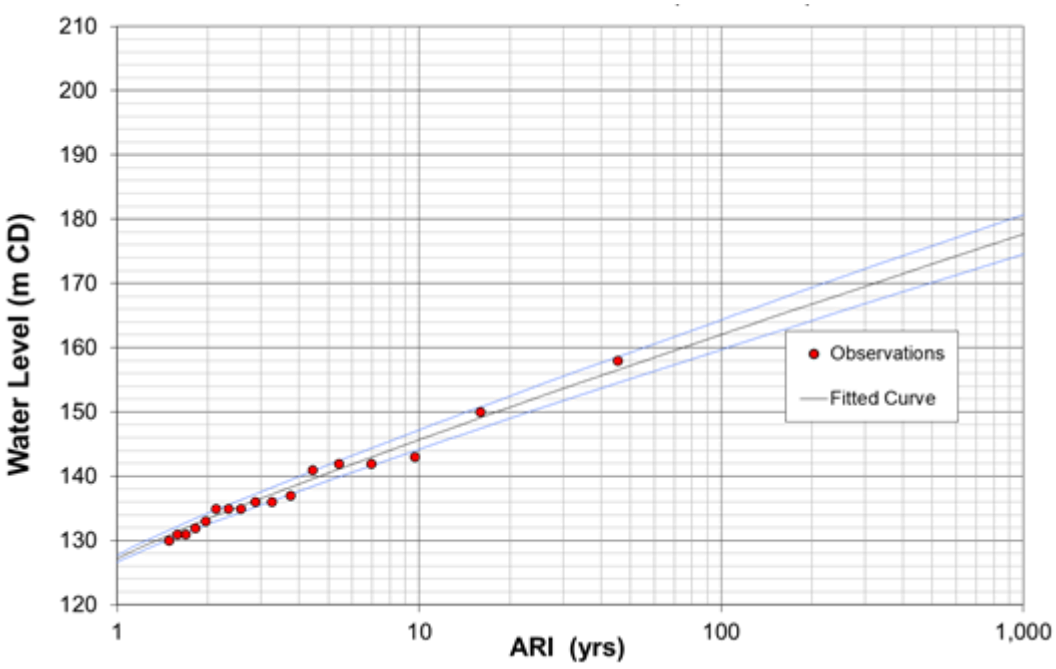


Figure 3-5: Peel Inlet Extreme Water Level Best Fit
Derived from 1994-2020 tide gauge data

Event Recurrence	2 yr ARI	5 yr ARI	10 yr ARI	20 yr ARI	50 yr ARI	100 yr ARI
Water Level (mCD)	1.33mCD	1.42mCD	1.46mCD	1.51mCD	1.59mCD	1.64mCD
Water Level (mAHD)	0.78mAHD	0.87mAHD	0.91mAHD	0.96mAHD	1.04mAHD	1.09mAHD

Table 3-1: Peel Inlet Extreme Water Level Best Fit

The potential for higher water levels associated with passage of a tropical cyclone was evaluated as an 'upper limit' estimate for inundation, following the State Coastal Planning Policy SPP 2.6 (WAPC 2013). Two design storm scenarios were developed, based upon historic events from TC Alby (April 1978) and TC Ned (March 1991).

Following the design storms approach, the storm events were modified through track shifting and varying storm intensity, to achieve a combination that approximates a 500-yr ARI event. For TC Alby, this involved increasing intensity by 10%, and shifting the storm passage such that the radius of maximum winds passed over Mandurah.

Modelling of ocean water levels at the mouth of Mandurah Channel indicated that the surge peak associated with the Alby-based design storm has a relatively short duration of approximately 18 hours (Appendix I). Based upon spectral admittance, the surge within Peel inlet was estimated to be within 60-80% of the ocean surge (Figure 3-6). It is recognised that the level of damping observed during TC Alby was substantially greater with negative surges observed in parts of the estuary. However, opening of Dawesville Channel has significantly increased the opportunity for ocean surges to enter the estuary, and the damping response observed during TC Alby will not occur for the present configuration.

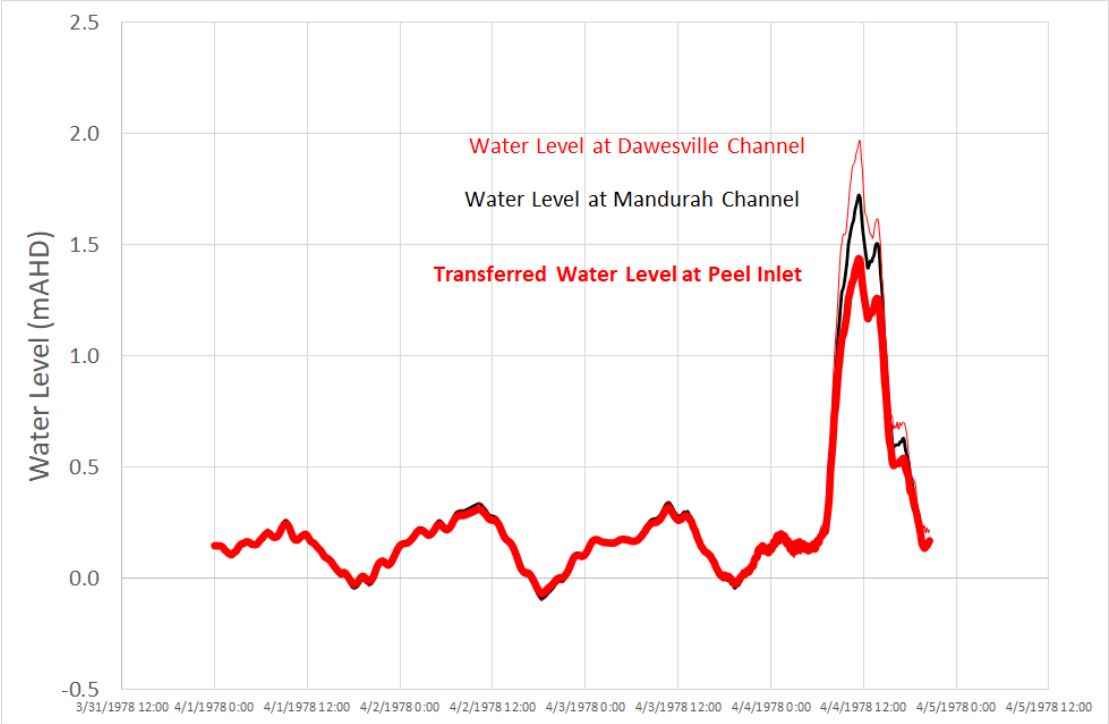


Figure 3-6: Simulated Ocean and Estuarine Water Levels for Design Storm

Using the upper limit of tide and surge transfer rates, the estimated maximum water level associated with the design storm was +1.44mAHD. This extreme storm has synoptic and tidal characteristics approximating a 500-year ARI storm event. The extent of flooding, using a bath-tub approach, covers wide areas of wetland (Figure 3-7), significantly reducing the influence of wave runup, which has consequently been neglected.



Figure 3-7: Extent of Foreshore below Design Inundation Level

The effect of projected sea level rise is to increase all levels of flooding hazard, with a recommended curve for coastal planning in Western Australia (Figure 3-8). The change to flooding levels with sea level rise has been assumed as additive (Table 3-2).

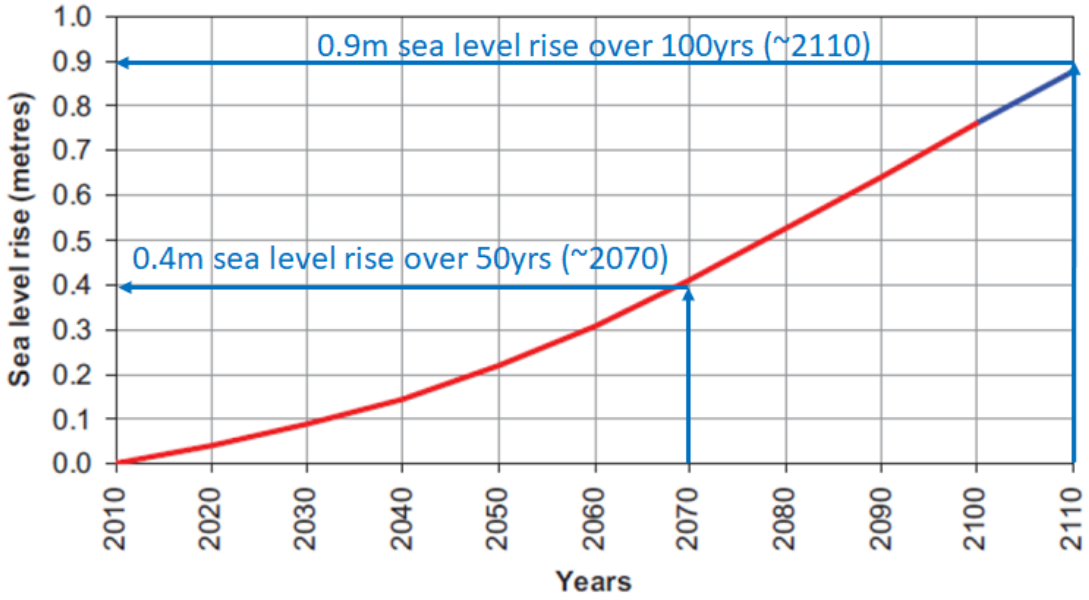


Figure 3-8: Sea Level Forecast Curve Used for WA Coastal Planning (Transport 2010)

Table 3-2: Change to Inundation Levels with Projected Sea Level Rise

Year	Projected Sea Level Rise	Tidal Inundation Limit	10yr ARI Coastal Flooding	100yr ARI Coastal Flooding	Extreme Coastal Flooding
2020	0.0m	+0.60mAHD	+0.91mAHD	+1.09mAHD	+1.44mAHD
2030	+0.07m	+0.67mAHD	+0.98mAHD	+1.16mAHD	+1.51mAHD
2050	+0.15m	+0.75mAHD	+1.06mAHD	+1.24mAHD	+1.59mAHD
2070	+0.50m	+1.10mAHD	+1.41mAHD	+1.59mAHD	+1.94mAHD
2120	+0.90m	+1.50mAHD	+1.81mAHD	+1.99mAHD	+2.34mAHD

Use of a projected sea level curve for modelling of future coastal change is a simplification. The historic record of water levels from Fremantle demonstrates that south-west Western Australia experiences significant inter-annual variability, including the effects of storminess, oceanographic variability (ENSO-related) and tidal modulation (Eliot 2012). These components determine that effects of sea level rise may be felt sooner or later than projection time frames, increasing importance of using adaptive management, which is part of the CHRMAP framework.

The relative significance of changes due to Dawesville Channel is indicated by increase of the 10yr ARI flooding level by 0.37m from pre-1994 to post-1994, acknowledging that around 0.1-0.2m of this difference is due to variability of storminess and higher mean sea level during the 2011-2013 La Niña phase (Eliot & McCormack 2019).

4. Present-day Erosion Hazard

Evaluation of erosion hazard has followed the general form of schedule one of SPP2.6 (WAPC 2013), varied to account for apparently different mechanisms causing response to sea level rise (see Section 4.4). Erosion hazard components are therefore comprised of:

- Acute Storm Erosion Allowance
- Chronic Erosion Allowance
- Response to Sea Level Rise Allowance

4.1. COASTAL EROSION POLICY

SPP2.6 requires a coastal hazard zone to be identified for greenfield development sites using 'Schedule One', which includes allowances for acute erosion (S1), chronic shoreline trend (S2) and response to sea level rise (S3). There is an additional factor for inundation (S4) which does not represent an erosive process. Although erosion allowances are similar to processes evaluated in this section, the required approach differs, as erosion hazard definition under SPP2.6 is prescriptively defined, with an objective to conservatively estimate the area subject to future foreshore change. In contrast, erosion allowances presented in this report are based on 'best-estimate' values, simulating active and projected geomorphic processes to predict change, supporting their use to guide management triggers within a CHRMAP.

4.2. ACUTE STORM EROSION ALLOWANCE

The prescribed approach for evaluating storm erosion is to model the impacts of a severe storm, with an approximate 100-year ARI recurrence. For coastal settings, this is typically undertaken using a profile-based storm response model, plus allowance for alongshore response where there are headlands, protective structures, or changes in shoreline orientation. However, validation for profile models has typically been developed for ocean coasts, where a significant mechanism for erosion is developed by the transition from spilling to plunging waves, with flattening of the beach face resulting in offshore transfer of sediment. In contrast, wave conditions within estuaries rarely experience this transition, and often remain spilling under storm conditions – erosion response is more typically associated with (i) an expansion of the hydraulic zone or (ii) alongshore sediment transfer. Application of a profile model along the Shire of Murray foreshore was therefore expected to require validation and interpretation.

4.2.1. Process Validation Event

A severe storm event occurring on 24 May 2020 provided an opportunity to evaluate the applicability of the SBEACH profile model for the Shire of Murray foreshore. This storm caused strong winds (Figure 4-1) and occurred near to the annual peak predicted tide, resulting in the second highest water level on record inside Peel Inlet.

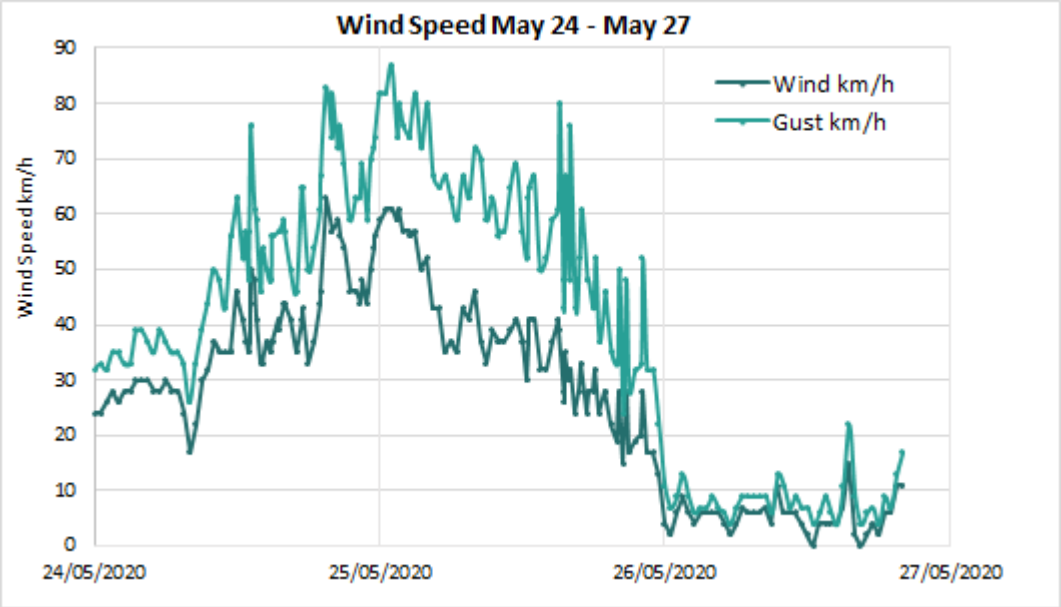


Figure 4-1: May 2020 Storm Wind Record

During site visit in June 2020, impacts to the Murray River delta foreshore were observed, which included foreshore retreat and development of storm bar to landward. This corresponds to the foreshore rollover sequence described by Davidson-Arnott (2015).



Figure 4-2: Observed Response to May 2020 Storm at Old Mill

SBEACH modelling was conducted using a hindcast derived from the wind record, combined with the measured water levels. A median sediment size of 0.15mm was assumed, although field assessment using visual grading indicated highly variable sizing. Model outcomes suggested landward transfer of a similar volume of material, although the depositional structure was steeper, with a sharp back-slope. This response is a consequence of SBEACH's formulation, which includes an empirical estimate of cross-shore sediment transport rates but does not include the process of overwash (Larson & Kraus 1989). Consequently, the total cross-sectional area of change derived from profile response modelling was converted to a horizontal erosion allowance.

4.2.2. Design Storm Definition

Development of a design storm to examine acute erosion involved evaluation of previous storm events. The storm of 16 May 2003 was identified as an outstanding event, with the highest water level on record in Peel Inlet (Figure 4-3) and sustained strong winds for nearly two days. Wind and water levels have been used to hindcast wave conditions for the 2003 and 2020 storms.

A synthetic design storm was developed, by scaling up the 2003 storm winds and water levels to correspond to 100-year ARI levels (Figure 4-4), with hindcast outputs developed for each of 73 profiles (Figure 4-5). The design storm was then applied as a sequence of three storms – this approach was applied to cater for potential underestimation of cross-shore transport rates simulated by SBEACH.

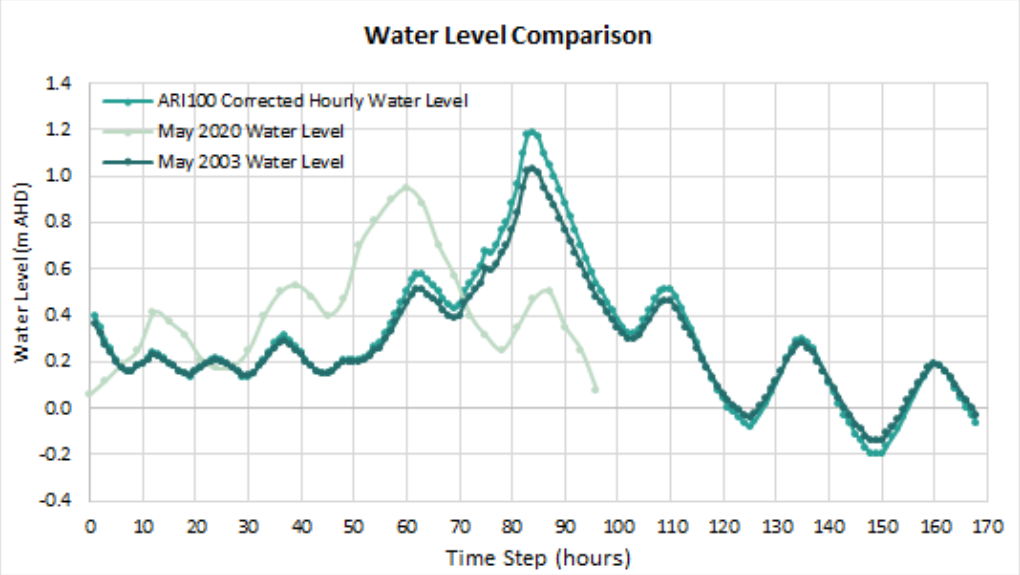


Figure 4-3: Water Levels for 2003 & 2020 Storms & Synthesised 100-year ARI Storm

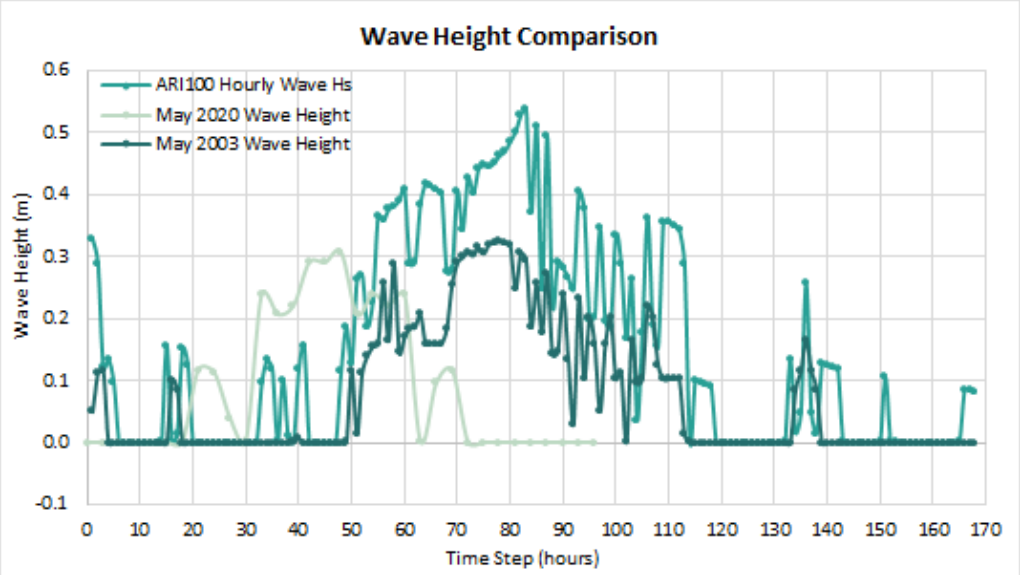


Figure 4-4: Hindcast Wave Heights for 2020, 2003 and 100-year ARI storms

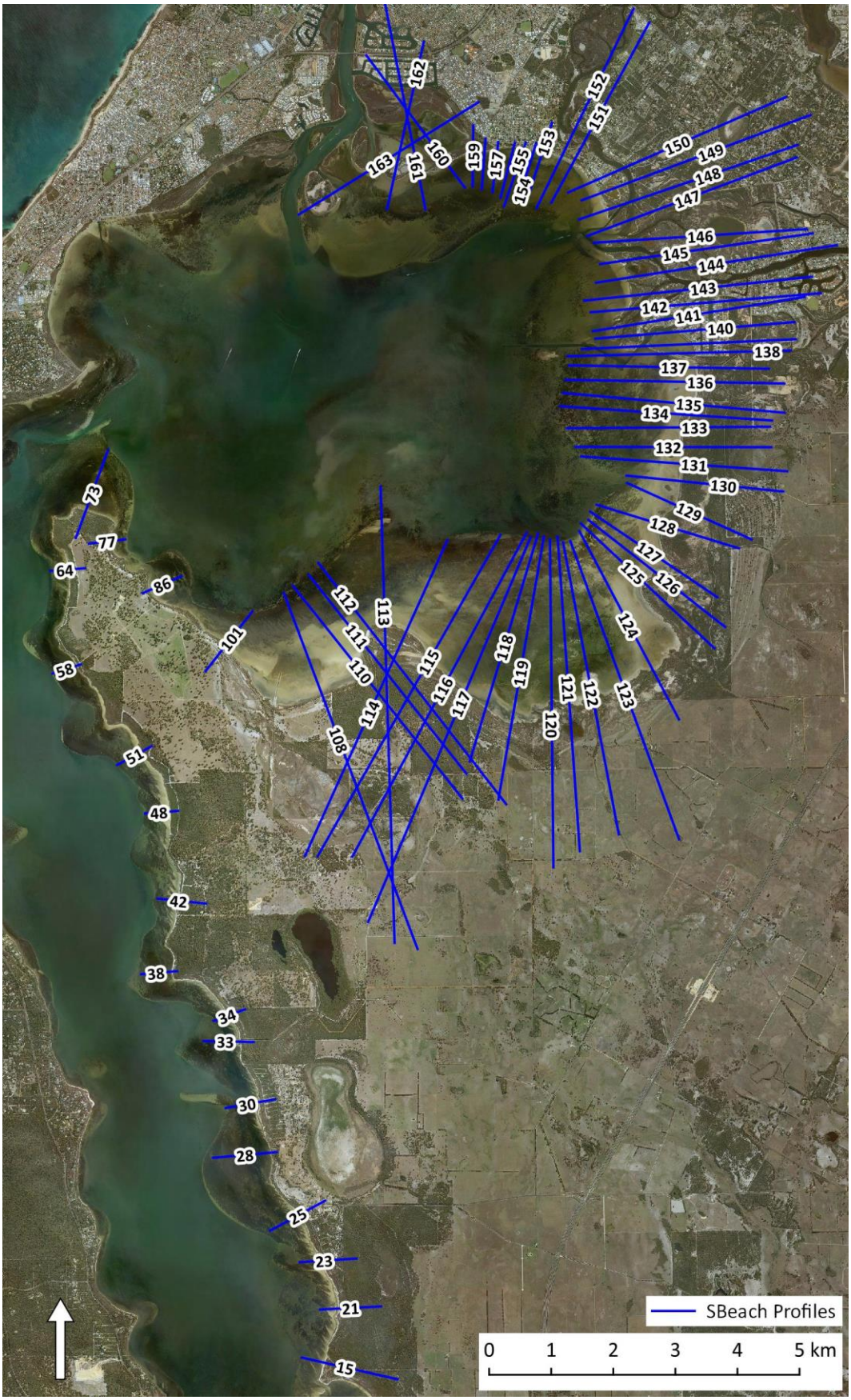


Figure 4-5: Profile Lines used for SBeach Modelling

4.2.3. Profile Response Modelling

SBEACH modelling was conducted for all profiles along the Shire of Murray foreshore (Figure 4-5). As had been suggested by trial modelling for the May 2020 storm, use of the semi-empirical model SBeach is challenged by the low elevation of the foreshore profiles, with profile change modelled to occur wherever a steep gradient is subject to wetting (Figure 4-6). At the shoreline itself, predicted profile change more typically corresponds to the main process used within SBEACH, which is movement toward an 'equilibrium profile' (Figure 4-7).

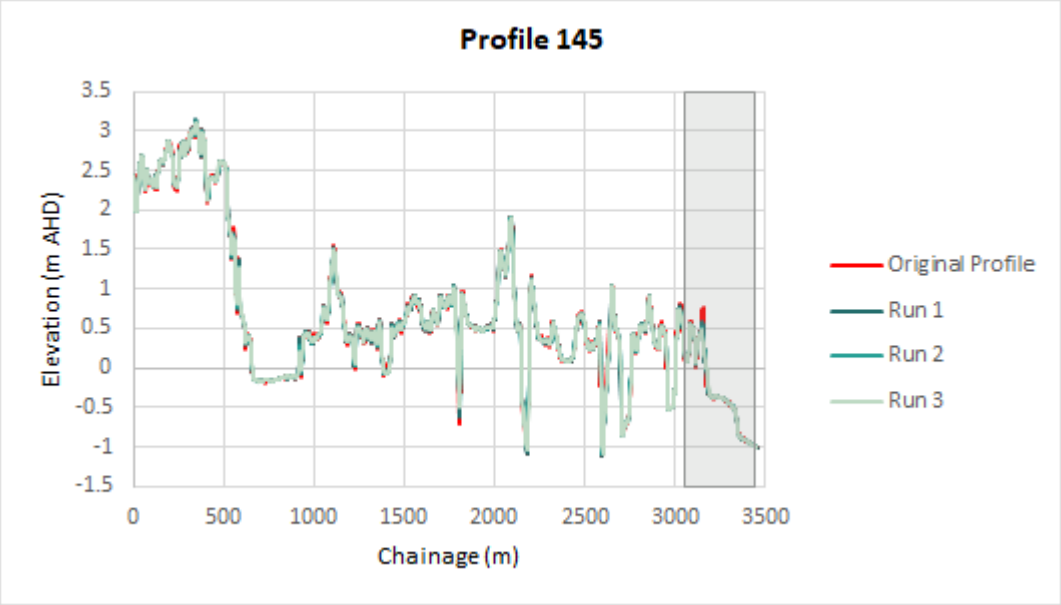


Figure 4-6: SBeach outcomes over full profile

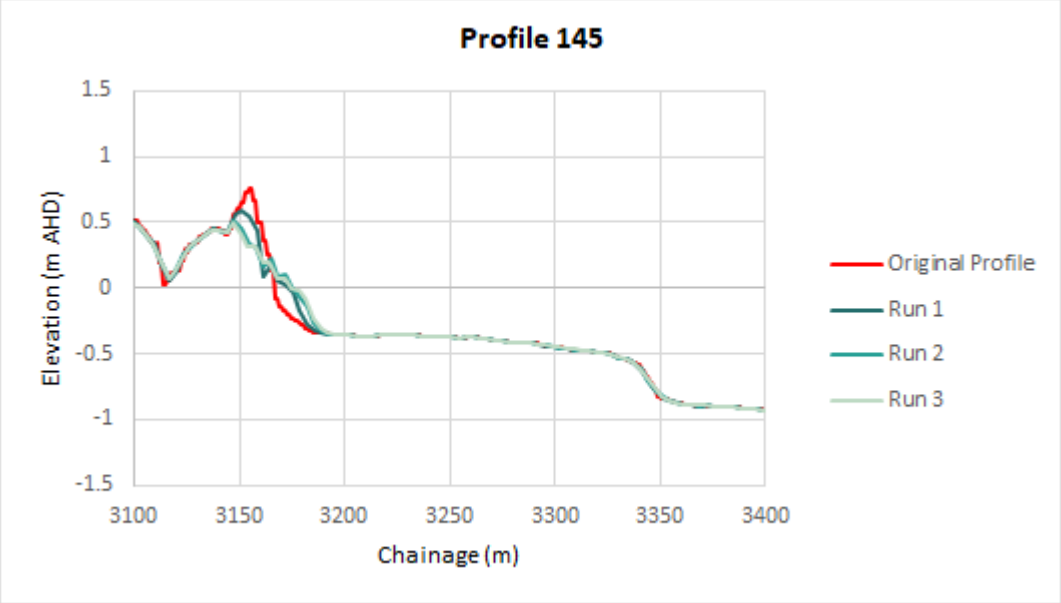


Figure 4-7: SBeach outcomes over part-profile

Estimated erosion response to a storm was developed by summing cross-section change over the whole profile, and then applying this change solely to the front face of the profile. This provided outcomes ranging from 4m to 22m erosion response, with the largest response modelled at Roberts Bay wetlands (Figure 4-13). Variation of response occurs through a range of factors, including the width of the subtidal terrace (causing damping), the beach face gradient and the elevation of the nearshore land.

Riparian vegetation can also substantially modify the foreshore response, with well-established vegetation able to resist short-term erosion pressure from waves up to 0.3-0.5m (Shafer *et al*. 2003). This resistance has not been incorporated in the SBEACH modelling.

4.3. CHRONIC EROSION ALLOWANCE

Observations of foreshore change, summarised in Appendix C, demonstrated that much of the estuary foreshore has been subject to small changes, with the clear exception of the Murray River mouth and the Islands. However, these islands have demonstrated 'roll over' behaviour (see Section 4.4.1), where low elevation spits and berms are gradually pushed landward, rather than the processes of offshore or alongshore loss which cause loss of sediment volume and are more typically considered as 'erosion'.

Determination of a chronic erosion allowance used the overall change in area for the Islands, divided by the active foreshore length, to calculate a trend. For other locations, although some variability was identified, changes were not characteristic of trends. Following SPP 2.6, a rate of 0.2m/yr was used as the minimum allowance for potential future change, which allows for the 'uncertainty' associated with shoreline trend estimation (Figure 4-13).

4.4. PROJECTED EROSION DUE TO SEA LEVEL RISE

The effect of projected sea level rise is to modify wave energy distribution along the estuary shore, causing reconfiguration of existing foreshore landforms. Response may occur through a number of pathways (Figure 4-8), including offshore, onshore or alongshore sediment transport, as well as shift in the foreshore profile.

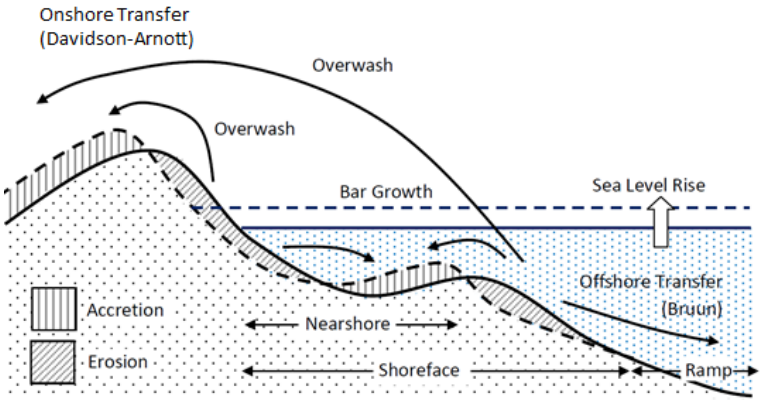


Figure 4-8: Typical Models of Cross-Shore Response to Sea Level Rise
Diagram adapted from Dubois (1992)

Localised response to sea level rise is also expected where coastal landforms facilitate sediment supply or storage. Estuaries will generally experience increased marine sediment influx, however if this is insufficient to keep up with sea level rise the estuary will 'drown' (Leuven *et al*. 2019). For the Peel-Harvey system, there is limited opportunity for marine sediments to enter the estuarine basin, with the ebb-delta occupying only a small part of Peel Inlet's northwest shore. Consequently, most of the estuary is expected to respond at a local scale, where adjustment is caused through foreshore rollover and transfer to the adjacent shore.

Areas of low-lying foreshore provide enhanced opportunity for onshore sediment movement. Occurrence of this mechanism is indicated by the topography, with a low berm providing a narrow barrier to extensive wetland located to landward (Figure 4-9).

SPP2.6 describes a simple allowance for response to sea level rise on the open coast, using 1m horizontal erosion per 0.01m sea level rise. This is often considered to occur through offshore loss (described by Bruun). However, a uniform treatment would not capture the enhanced erosion hazard along low-lying sections of the Murray foreshore. It was consequently determined to determine erosion response to sea level rise by combining a derived erosion allowance for onshore sediment movement with a fixed erosion allowance for offshore or alongshore sediment transfer.



Figure 4-9: Complexity of Low-Level Topography

4.4.1. Onshore Sediment Transfer

Shoreline adjustment through onshore sediment transfer is affected by the topography formed along the shore. Where mild conditions occur, which is consistent alongshore and subject to limited disturbance under ambient conditions (e.g. seasonal variability of alongshore transport), a small berm is created along the shore with a gently sloped back face (Figure 4-10 top). This requires a moderate amount of sediment to build, which must be supplied from the shore, creating retreat. A smaller amount of sediment is required if the back slope of the berm can be steeper, such as a constructed dune, or a vegetated berm.

Response of a low-berm foreshore to sea level rise occurs through two mechanisms:

- *Berm Rollover*, where mild overtopping of the berm causes it the crest to move landward. Erosion from the front face of the berm enables the crest height to rise.
- *Wetland infill*, where large overtopping or tidal currents through a breach cause sediment to dispersed through the wetland area behind the berm.

A considerably larger amount of sediment is required if wetland infill occurs over the entire area behind the berm, which may occur if a storm-built berm becomes unstable. This sequence has been illustrated on the Murray delta islands.

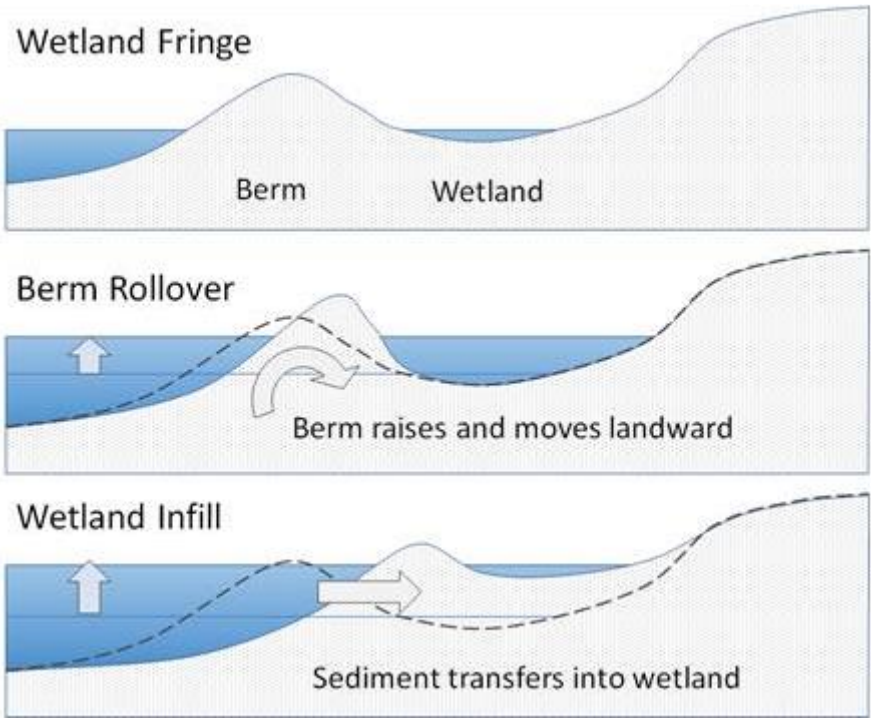


Figure 4-10: Definitions of Rollover and Infill

Instability of berm features increases the higher the berm is above the adjacent land level, with a general progression from occasional overwash, foredune building and then berm collapse and infilling. This results in an exponential increase in sediment demand and shoreline retreat with sea level rise.

Evaluation of potential erosion along the Murray foreshore has been conducted using profiles extracted from LIDAR survey (Appendix E), with aggregated behaviour considered within each of the foreshore segments. Estimation of the potential for wetland infill was calculated for each profile by the cross-sectional area below SLR + 0.6mAHD (i.e. +1.5m AHD by 2120, after 0.9m sea level rise). This provides a significant sediment demand, which has the potential to cause substantial erosion, in the order of 1800m for the Murray River delta area and approximately 400m for Roberts Bay (by 2120).

However, individual profiles highlighted significant low-lying areas, where a narrow berm prevents complete infilling. This suggests that wetland infill is not presently active widely, and that berm rollover is the most likely response to sea level rise, at least in the next 10-50 years. Because berm rollover requires a substantially smaller quantity of sediment, the potential erosion response to sea level is strongly linked to berm stability.

Evaluation of berm rollover was undertaken considering typical profile changes modelled under the design storm, compared with associated storm wave energy, parameterised by the sum of H^2T over the storm period. However, wave energy is only capable of causing overtopping when it occurs simultaneous to high water levels (relative to the berm crest). The long-term hindcast (Appendix B) has been used to derive a cumulative distribution of wave energy with water level (i.e. a berm crest at +0.3mAHD will experience all wave energy for conditions exceeding +0.3mAHD, but will have negligible wave energy input during lower water level conditions. Equating the modelled rate of berm rollover to the available wave energy, potential infill rates for different berm crest levels have been estimated (Figure 4-11). These demonstrate a substantial increase for lower berm levels, with negligible rollover for berm crest levels typically identified along the Murray foreshore of +0.6mAHD to +1.0AHD.

Response to sea level rise has been considered as equivalent to having a lower(ing) berm. This suggests that existing rates of berm rollover will remain relatively low for the next 10-30 years but have the capacity to substantially accelerate with greater sea level rise. In addition to the influence of wave energy, low-lying areas behind foreshore berms are subject to tidal influences, with increasing opportunity for berms to collapse as the difference between the estuary water level and the bed level of the landward basin increases, potentially creating the mechanism of wetland infill.

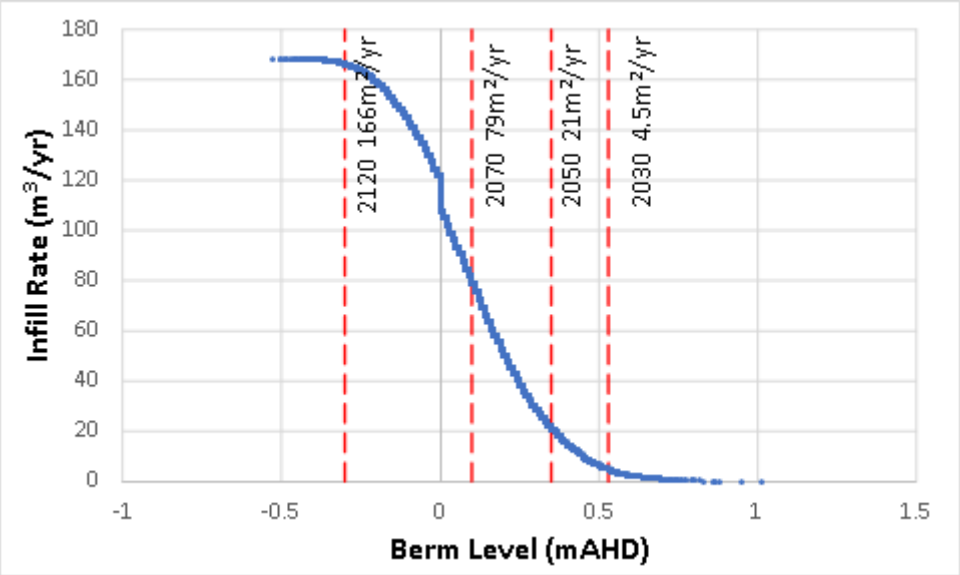


Figure 4-11: Berm Rollover Rates due to Wave Energy and Sea Level Rise

Evaluation of the potential foreshore erosion associated with sea level rise has been conducted – with a *critical assumption* that berm rollover will remain the major mechanism for foreshore change. The high alongshore variability results in large differences between nearshore processes – to correct for spatial connectivity, a moving average has been used to estimate the allowance for response to sea level rise.

A small response to sea level rise is expected along the majority of Harvey foreshore due to the height of the existing foreshore. Larger responses are expected towards Herron Point and Roberts Bay, where their lower profile topography is modelled to experience greater rollover. Modelled response to sea level increases from Austin Cove towards the Murray and Serpentine. A small amount of response is estimated for the section of City of Mandurah foreshore where a revetment has been built and the foreshore has been raised above +1.6mAHD.

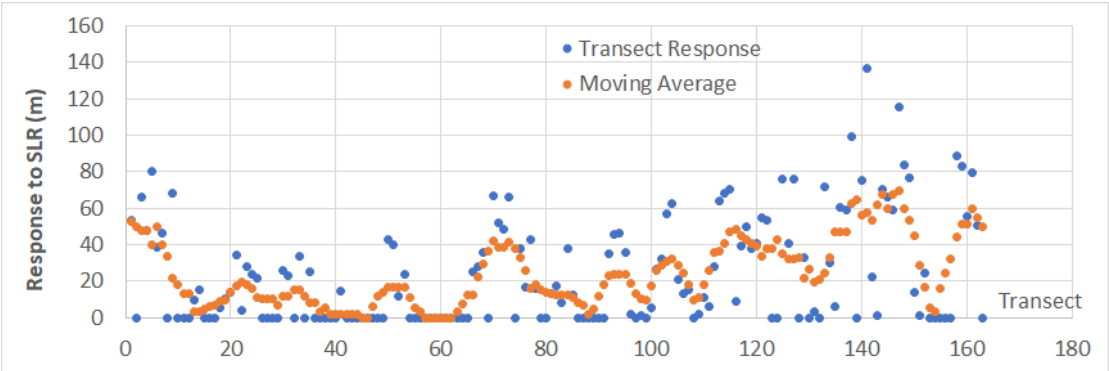


Figure 4-12: 2120 Berm Rollover Estimates by Profile
(Locations in Figure 4-5)

The mechanism of wetland infilling is critical to the long-term foreshore dynamics for the Yunderup area. If the foredune berms are unable to keep pace with sea level rise, the intertidal area of the wetlands has a potential infill volume that is an order of magnitude greater than the volume required for a foreshore berm. Implicitly, this means that the projected response to sea level rise could increase to the scale of 1-2 kilometres.

4.4.2. Offshore or Alongshore Sediment Transfer

Although onshore sediment transfer has potential to be extremely significant for parts of the Shire of Murray foreshore, response to sea level rise may also occur through other transfers, including offshore or alongshore sediment transfers. It is expected that offshore loss is likely to occur where the foreshore is perched, such as near Point Grey, and alongshore loss is likely to occur where existing features suggest alongshore transport, such as north of Herron Point. However, as identified by aerial imagery, these areas have experienced small foreshore change over the historic period, limiting the capacity to project future response.

A fixed allowance of 50m has been assumed as a response to offshore or alongshore sediment transfer for all of the estuary foreshore.

4.5. TOTAL ESTUARINE FORESHORE EROSION ALLOWANCES

Influences of storm erosion, chronic change and response to sea level rise have been added horizontally to develop erosion allowances for the Shire of Murray foreshore for time frames of 2030, 2050, 2070 and 2120 (Figure 4-14). Erosion allowances for 2120 are also presented as a table according to foreshore segments (Table 4-1). Erosion distances have been mapped by buffering the erosion distances landward from a nominal shoreline at +0.6mAHD, which was treated as a horizontal setback datum (HSD) using the terminology of SPP 2.6. This is the approximate upper level at which present-day shoreline erosion is observed.

Erosion allowances are comparatively small along the Harvey Estuary foreshore, including the Birchmont area (Figure 4-15), where the relatively higher foreshore resists substantial response to sea level rise and limited historic shoreline change has been observed.

Larger erosion allowances have been determined for Austin Cove and in the vicinity of the Murray and Serpentine Rivers (Figure 4-16), developed mainly due to the low-lying topography and projected response due to sea level rise.

It is reiterated that the process of wetland infilling, which has not been incorporated in derived erosion allowances, has the capacity to massively increase the response of the foreshore to sea level rise.

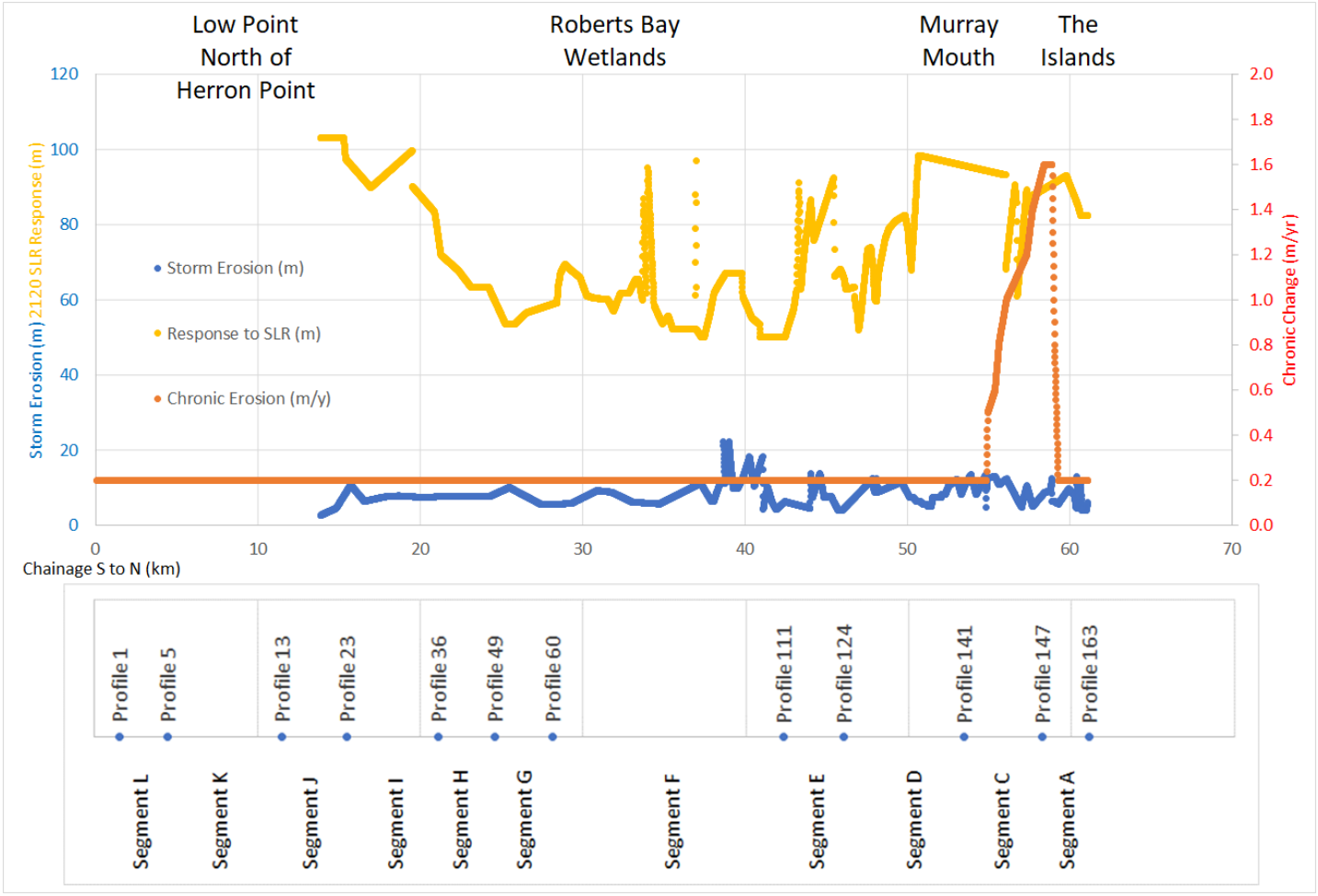


Figure 4-13: Modelled Profile Responses to Design Storm, Chronic Trend and SLR

Note that 'spikes' in the response to sea level rise occur where there is a local low point

Table 4-1: Total Erosion Allowances Table for 2120

Segment	Profiles	S1 (m)	S2 (m/yr)	S3 (m)	Total (m)
A	148-163	4-13	0.2-1.6	54-100	78-261
C	142-147	5-14	0.2-1.5	95-118	139-256
D	125-141	4-12	0.2	70-112	95-141
E	112-124	4-14	0.2	61-93	87-123
F	61-111	4-22	0.2	50-98	76-139
G	50-60	6-10	0.2	50-67	75-97
H	37-49	7-8	0.2	50-97	78-125
I	24-36	6-11	0.2	54-95	81-122
J	14-23	3-9	0.2	54-69	76-97
K	6-13	2-3	0.2	54-100	76-122
L	1-5	2-3	0.2	90-102	112-125

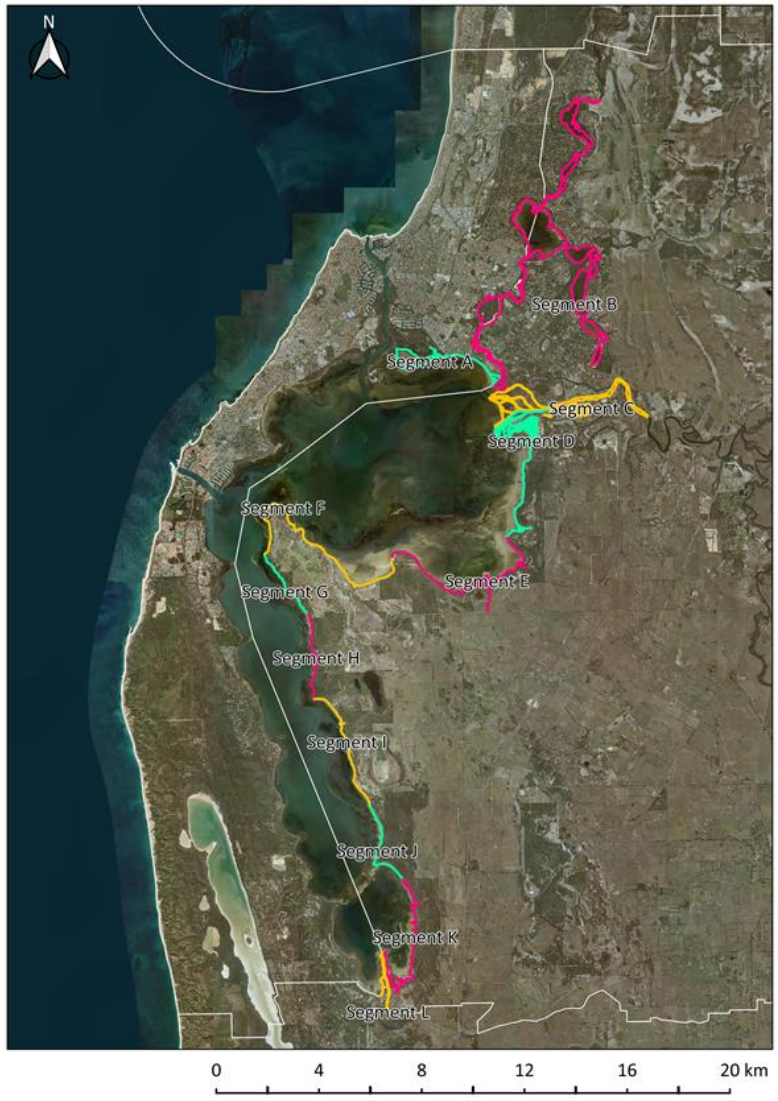




Figure 4-14: Total Erosion Allowances (Whole Foreshore)



Figure 4-15: Total Erosion Allowances (Birchmont Area)

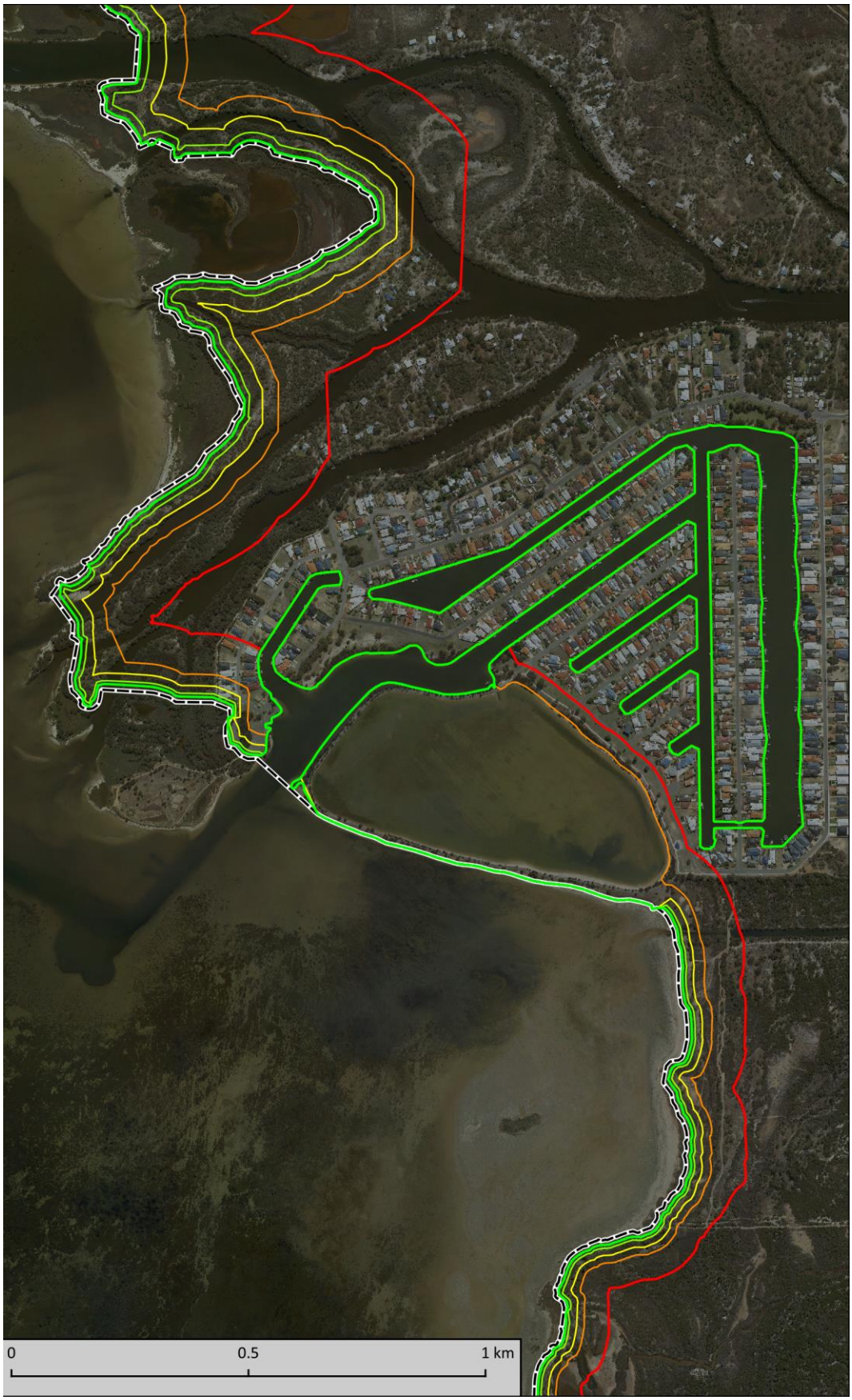


Figure 4-16: Total Erosion Allowances (South Yunderup Area)

4.6. CHANNEL EROSION ALLOWANCES

Erosion pressure has been identified along river channel sections in the lower Murray and Serpentine Rivers (Syrinx Environmental 2019). Sensitivity to erosion hazard is high along the lower Murray River due to active recreational and residential use, substantial presence of foreshore infrastructure and occurrence of high water mark freehold titles. Small scale erosion can cause jetties to disconnect from shore, or the undermining or riparian vegetation, which are perceived as substantial impacts, often prompting reactive works.

Erosion pressure has perceptibly increased due to large-scale hydraulic changes (currents and water levels) after opening of Dawesville Channel. However, the lower section of the river channels also has a history of natural channel evolution, and there have been extensive examples of local transfers of erosion pressure due to foreshore infrastructure. Erosion pressure is expected to increase further due to sea level rise.

The ability to suitably project future erosion hazard (i.e. to define foreshore setbacks) is challenged by a diversity of potential contributing mechanisms (Table 4-2). There is a limited evidence base with which to distinguish between mechanisms or parameterise the scale of response to each mechanism. The PNP Regional Coastal Monitoring Program (Damara WA 2016) provides a recommended monitoring framework for estuaries that may assist with future distinction of active drivers.

Table 4-2: Potential Erosion Mechanisms for Lower Murray River

Erosion Mechanisms	Monitoring	Distinction
Macro-scale:		
• Channel avulsion[1]	Channel widths	Different channels expand/contract
• Dawesville Channel impacts	Channel widths	After 1994, all channels responding
• Sediment supply variability	Flow record	Following flood / low flow periods
Meso-scale:		
• Hydraulic variability	Tide record	All channels responding
• Siltation / deposition	Hydrosurvey	Widespread bed shallowing
• Bed mobility	Hydrosurvey	Adjacent to known bed features
• Boat wakes	Visual inspection	Wide impact
• Channel migration	Thalweg	Local bed deepening
• Bank undermining	Visual inspection	Nearshore deepening
Micro-scale:		
• Instability of riparian vegetation (e.g. trampling)	Visual inspection	Local impact
• Erosion pressure transfer from structures	Visual inspection	Updrift trapping / downdrift erosion

[1] Avulsion is the process where hydraulic flows are redistributed between two or more channels. Typically this involves expansion of one channel and corresponding contraction of another.

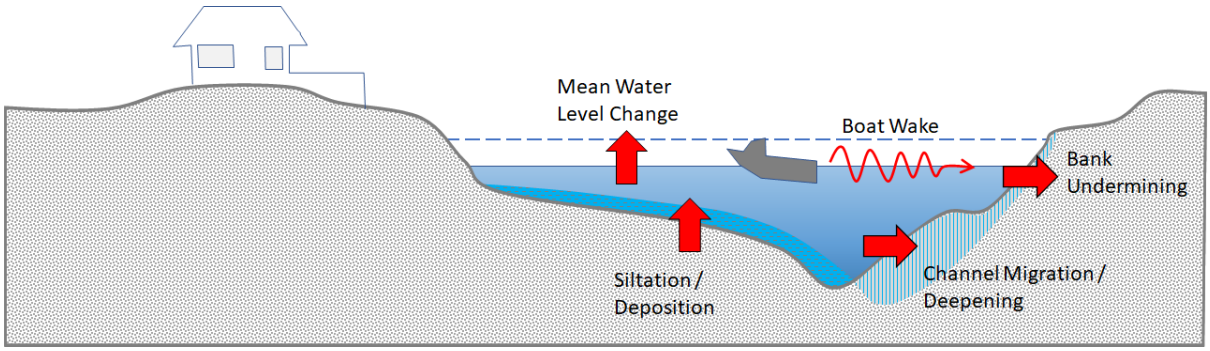


Figure 4-17: Schematic Indicating Meso-scale drivers of Channel Foreshore Change

Identification of erosion hazard along the most developed section of the lower Murray River is partly challenged by a limited ability to measure foreshore change using remote-sensing techniques commonly used for erosion assessment. In particular, the transition from a well-established riparian foreshore through to a degraded foreshore (Figure 4-18) is often obscured by tree canopy. In many cases, the root mass of trees is capable of resisting erosion stress for a considerable period, withstanding deepening of the adjacent foreshore. Change in vegetation can therefore be 'sudden' once the tree is lost, although stress may have been occurring over a much longer period.

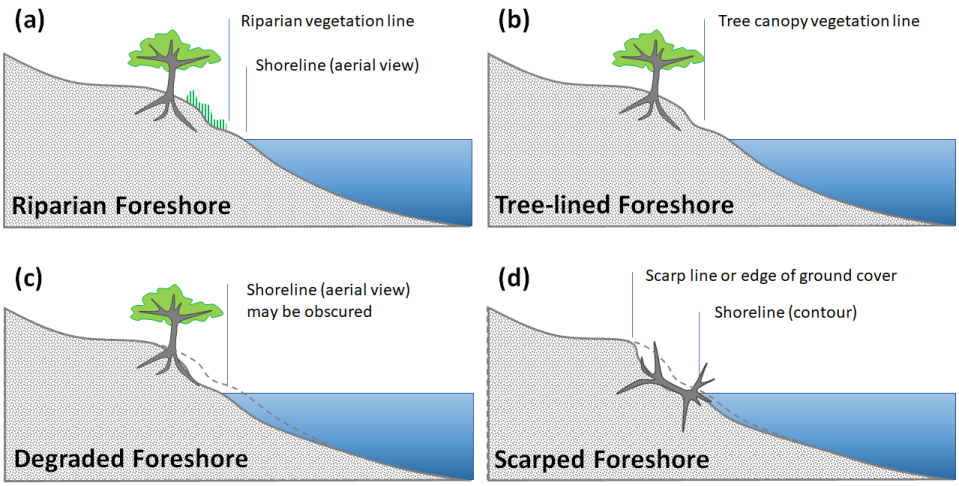


Figure 4-18: Typical Eroding Foreshore Sequence

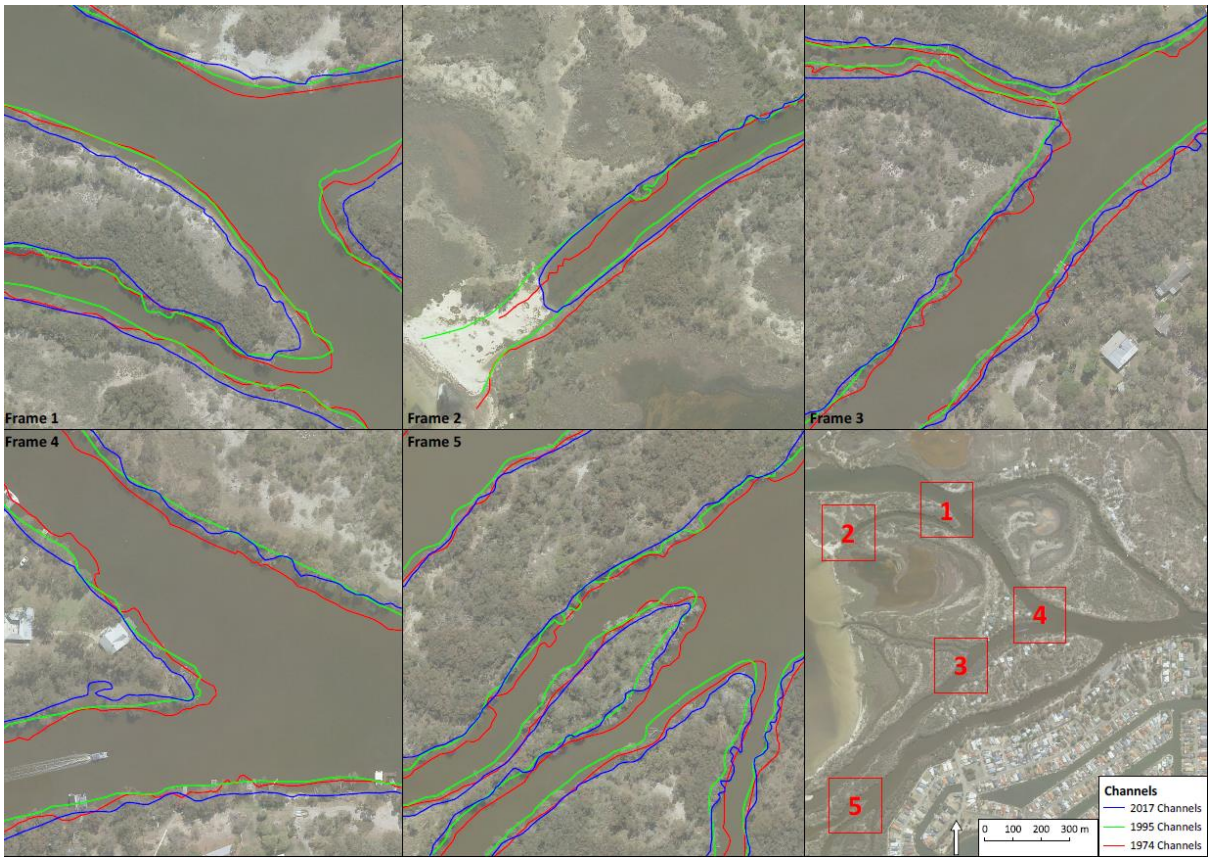


Figure 4-19: Channel Changes Within the Murray River Delta

Shorelines mapped from aerial imagery from 1974, 1995 and 2017 illustrates that the Islands foreshores have been historically dynamic. Overall, there has been general expansion of the channels, with occasional, typically local reversals. A significant change was apparent for the smaller channels 'cutting through' Meeyip Island, with the northern channel contracting after its entrance was plugged by sediment (Figure 4-19 Frame 2), and the southern channel consequently expanding (i.e. local scale channel avulsion).

Although all channels have generally widened over time, particularly following opening of Dawesville Channel, a wider scale avulsion appears to be occurring across the Islands. The northern channels have generally expanded less than those to the south, suggesting that a greater portion of flow (tidal and riverine) is passing through the southern channels.

The lower Serpentine River is comprised of a series of basins, connected by channels. Observed change within this area is small, mainly characterised by sill development near the entrance or exit of channels, which indicates tidal flows are active. Potential response to sea level rise has been evaluated using geometry of the basins and channels. As the percentage increase of channel cross-section is larger than the percentage increase of basin area with sea level rise, it is expected that the lower Serpentine River will have comparatively low sensitivity to sea level rise.



Figure 4-20: Channel Classification

Erosion hazard along channel margins for the lower Murray and Serpentine Rivers has been defined as three separate classes (Figure 4-20), acknowledging the differences in foreshore dynamics between the ocean, estuary, and river channels. Distinction has been made based on observed active processes, including 'switching' of channels, experiencing flow within the Islands, and local influences of foreshore vegetation. In the absence of detailed measurements of channel change, allowances for erosion hazard have been based upon likelihood for different mechanisms for erosion being active, distinguished for three sections, with transition between estuary and wetland buffers outlined in DC 2.3 (WAPC 2002) and SPP 2.9: Water Resources (WAPC 2006):

- Channels within the Islands area have been defined with an erosion hazard of 50m by 2120, accounting for higher tidal flows and potential for channel switching.
- An erosion hazard allowance of 30m by 2120 has been defined where there is a single main channel for the Murray River (adjacent to Yunderup) and within the lower Serpentine River.
- Within the secondary channels and small lakes adjacent to the Murray River, an erosion hazard of 15m by 2120 has been defined. These waterbodies typically receive only a small quantity of flow, usually under extreme water level or flood overflow conditions.

Variation of the erosion allowance over time has been scaled with sea level rise (Table 4-3).

Table 4-3: Erosion Allowances for River Channels

Date	2020	2030	2050	2070	2120
Sea Level Rise	0.00m	0.07m	0.15m	0.50m	0.90m
% Allowance	10%	17%	25%	60%	100%
Murray Delta	5.0m	8.5m	12.5m	30m	50m
Primary Channels	3.0m	5.1m	7.5m	18m	30m
Secondary Channels	1.5m	2.1m	3.8m	9m	15m

4.7. MAN-MADE STRUCTURES

Existing foreshore protection structures within Yunderup provide land retention, including canal estate walling, a bund around the man-made lake south of Yunderup and a containment bund at the southern entrance to the Murray River. These features have been assumed to be maintained to provide the existing standard of protection. For canal walling, additional upkeep is likely required with higher water levels, but existing wall heights are sufficient for walling to provide protection against erosion, illustrated by the extent of land above the present-day severe flood level (Figure 3-7). The bund around the man-made lake presently has a crest height of +1.1 to +1.5mAHD (Figure 4-21), which will require enhancement prior to 2070 to prevent collapse through frequent overtopping.

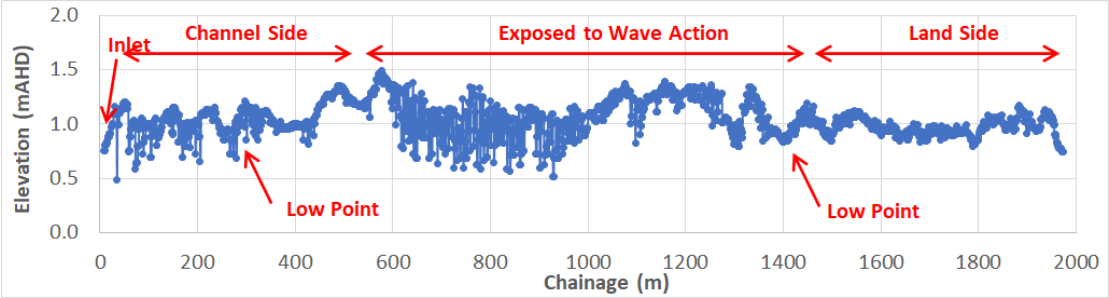


Figure 4-21: Variation of bund crest levels for Yunderup Lake

4.8. EXTREME EROSION (WETLAND INFILL) SCENARIO

Potential for wetland infill to cause extreme erosion hazard has been identified. Mapping of the potential extent of erosion under a 'full infill' scenario for a sea level rise of 0.9m by 2120 has been undertaken (Figure 4-22). This shows significant potential for erosion along the east side of Peel Inlet, of 1-2km width. Wetland infill may also occur along the south and southwest foreshore areas, with 0.4-0.8km potential erosion. A smaller potential for wetland infill was identified toward the southern end of Harvey Estuary. The extent of potential erosion due to wetland infill approximately corresponds to the boundaries of modern foreshore landforms, which developed during the present sea level era.



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Figure 4-22: Wetland Infill Scenario for 2120

5. Conclusions

Analysis of the Shire of Murray foreshore has been undertaken, to support development of a Coastal Hazard Risk Management and Adaptation Plan. Evaluation has included characterisation of estuarine morphology, determination of historic foreshore dynamics and analysis of tide gauge records. This observational basis has been supplemented by hindcast modelling of wave conditions within the estuary, to determine potential erosion response to severe storms.

Inundation characteristics were determined from the Peel Inlet tide gauge, including extreme distribution fitting for water levels of 2 to 100-year ARI, corresponding to +0.78m to +1.09mAHD. The potential for more severe inundation associated with the passage of a tropical cyclone was evaluated by modelling coastal conditions, with the transfer into the estuary modulated by the spectral characteristics of the storm surge. Simulation of a design storm based upon TC Alby, with intensity increased by 10% and an approximate 'worst-case' track gave a flooding level of +1.44mAHD. This approximates an event of recurrence 500-year ARI.

Erosion modelling was based upon modelling of a synthetic storm, developed from the May 2003 storm, which is the most severe storm on record. Wind speeds and water levels were scaled up to 100-year ARI conditions, to provide an approximation for a storm event with recurrence of approximately 100 years. Modelled erosion due to the synthetic storm was in the range of 8-22m, with larger response occurring on lower-lying foreshore areas.

Assessment of aerial imagery from 1977-2017 identified that historic foreshore changes have been large in the vicinity of the Murray River mouth and generally small (<0.2m/yr) in other locations. Movement has generally been characteristic of foreshore rollover, where narrow spits and berms collapse landward (i.e. although there are large changes in area, they represent small changes in volume). Estimated rates of change, when projected landward, are in the order of 0.8-1.6m/yr around the Murray River mouth.

Future response to sea level rise has been modelled, based upon a critical assumption that the mechanism of foreshore rollover continues to be active, with moderate infill of the wetland located to landward. Rollover can potentially cause erosion in the range of 10-160m, with greater erosion expected where the foreshore is lower. The process of wetland infilling, which has not been incorporated into the modelling, has the potential to increase substantially under projected sea level rise.

Appendix A – Peel Harvey Estuary Context

Appendix B – Meteorology and Oceanography

Appendix C – Vegetation Line Change Summary

Appendix D – Murray Delta Imagery Sequences

Appendix E – Profiles Used to Evaluate of Response to SLR

Appendix F – Peel-Harvey Bathymetric Change

Appendix G – Variability of Benthic Coverage

Appendix H – Wave Hindcast Modelling Report

Appendix I – Extreme Surge Flooding Assessment

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Appendix A – Peel Harvey Estuary Context

GEOLOGY & SURFACE SEDIMENTS

Geology of the Swan Coastal Plain, which includes the Mandurah Region, is divided by the Darling Scarp between the Yilgarn Block to the east (Precambrian granites) and the Perth Basin to the west, with mostly Cretaceous limestone (Gozzard 2011). The shelf margin is characterised by calcareous material, including limestone reefs from relict shorelines, extensive limestone pavement across the inner shelf and a veneer of mobile sediments transitioning to landward as a series of substantial dunes (Searle & Semeniuk 1985; Collins 1988). Three distinct ages are apparent in the superficial sediments of the Swan Coastal Plain, with a sequence of weathered coastal dune systems, including the Bassendean, Spearwood and Quindalup sands, listed in order of decreasing age and proximity to the coast (McArthur & Bettenay 1974; McArthur & Bartle 1980). Peel-Harvey Estuary is situated between the Spearwood and Bassendean dune systems.

Surface geology adjacent to the east side of Peel Inlet and Harvey estuary is characterised as coastal, lagoonal and alluvial (Figure A-1):

- Coastal landforms occur along the northern margin of Harvey Estuary, to Point Grey. This is parallel to the series of limestone ridges and waterbodies occurring in the Yalgorup region, including Lake Clifton and Leschenault Estuary.
- Lagoonal landforms are present along the southern and eastern margins of Peel Inlet, formed by active reworking by estuary waves and tides.
- Alluvial landforms, formed through floodplain processes are dominant for much of the Shire of Murray, including both active modern channels and older floodplain deposits.

Evaluation of sediments throughout the Peel-Harvey estuarine system has previously been conducted using a network of boreholes (Robertson 1972; Logan *et al*. 1976; Treloar 1978; Brown *et al*. 1980; Semeniuk & Semeniuk 1990). Interpretation indicated that:

- Underlying sediments are low permeability muds and silts.
- An intermediate layer of silts, sands and organic material is expressed on much of the estuary bed. This material is subject to wave scour and redistribution, with limited capacity for further deposition.
- An upper layer of sand, characteristic of marine origin, fringes much of the two basins. This material is swept by wave action, forming relatively broad inter-tidal terraces along the margins of Harvey Estuary.
- Zones of fluvial deposition are located at the bay-head deltas for the Murray-Serpentine system and Harvey River.
- An extensive area of marine sand and shell fragments is present in the vicinity of Mandurah Channel, suggesting a significant supply of marine sediment over geomorphic time scales (thousands of years).

Depositional behaviour inferred from boreholes is largely supported by modern observations, although there are clear differences in the rates of deposition. Aerial photography since 1973 has shown active deposition at the mouth of the Murray River, with lesser accretion in the Harvey birdsfoot delta, particularly since diversion and damming works on the Harvey River. Gradual accumulation within Mandurah Channel and growth of Fairbridge Bank has been measured through hydrographic survey, with more gradual accumulation in Sticks Channel.

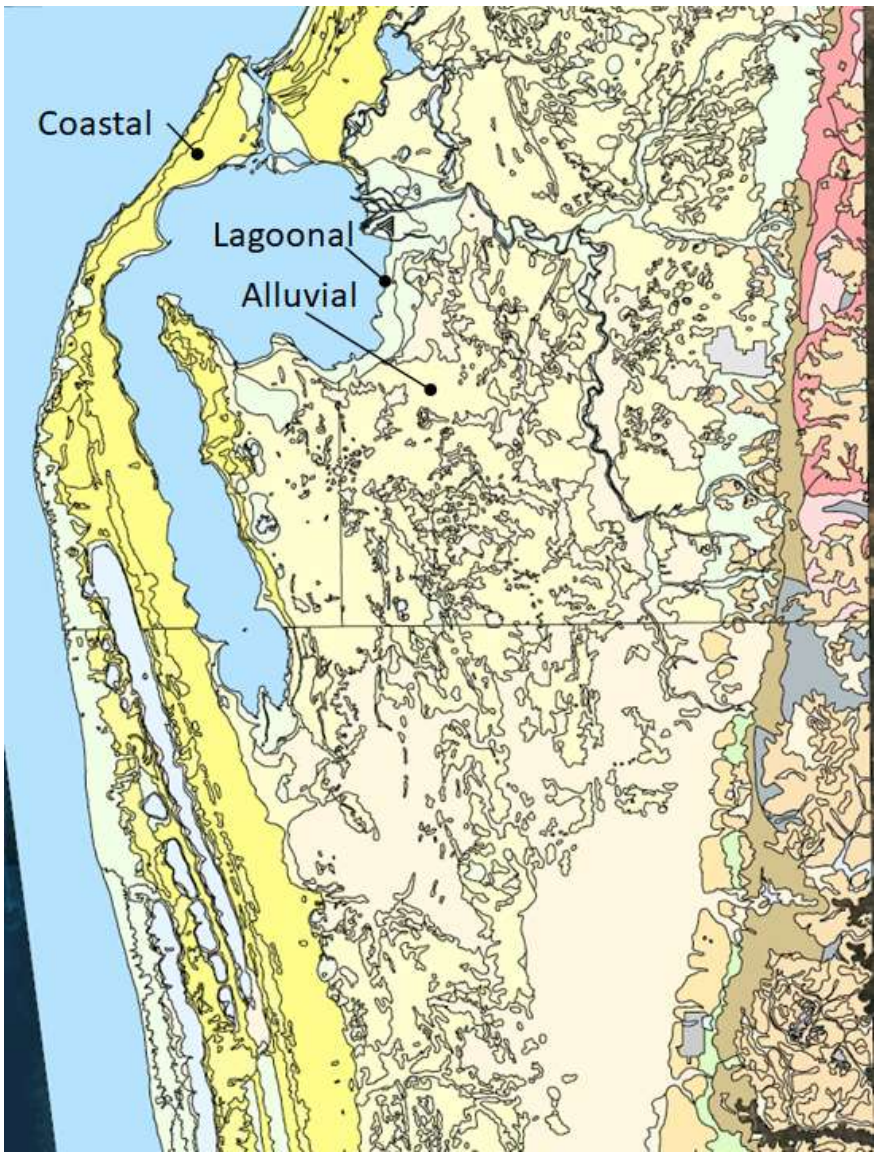


Figure A-1: Extract from 1:50,000 Surface Geology (GSWA)

There has been limited previous description of bed sediment mobility within the estuary, although most of the boating channels requiring minor maintenance dredging (APASA 2010; BMT Oceanica 2015). The entrance to South Yunderup Canals is an exception to this, with significantly increased accretion following a loss of benthic vegetation after Dawesville Channel was opened (Damara WA 2008). Aerial photography indicates that events causing benthic vegetation to be stripped also occurred prior to construction of the Channel, and in recent years well after the Channel (see Appendix E).

ESTUARINE DRIVERS, CONTROLS AND FORESHORE DYNAMICS

Peel-Harvey estuarine foreshore is generally comprised of sedimentary material, subject to forcing from wave and current hydrodynamics of the estuary water body. As with other geomorphic structures, this sediment takes on a form that responds and interacts with the hydrodynamic forcing and is influenced by the composition and supply of the sedimentary material (Wright & Thom 1977). However, estuarine systems, particularly those with shallow basins, have several characteristics influencing their behaviour (Figure A-3):

- Hydrodynamics of the estuary are low energy, allowing contributions from waves, tides and wind-generated currents to variously influence estuary morphology. Variation of these drivers, such as caused by weather events or seasonality, may cause behaviour to switch, particularly when acting in different directions.
- Hydrodynamic influence on the bed may vary over short spatial scales, due to differences in fetch length, or flow structure changes with water depth.
- The relatively small spatial scale gives variation in foreshore aspect, affecting alongshore sediment mobility due to waves or currents.
- Riparian and benthic vegetation may locally modify bed stress or stability.
- Limited tidal range inside the estuary may enhance the significance of flood conditions, whether driven by runoff or coastal flooding, i.e. a small flood event can cause water levels outside the range occurring during ambient tidal conditions.
- The modern (in a geomorphic sense) and depositional nature of estuaries (Dalrymple *et al*. 1992) supports spatial variability in the composition of material within the estuary. Differences in material mobility may influence behaviour.

Consequently, in an estuarine setting, variability of drivers typically interacts with a wider range of controls (geometry, vegetation or material) than in a coastal setting. For this reason, foreshore dynamics may effectively respond over several different temporal and spatial scales.

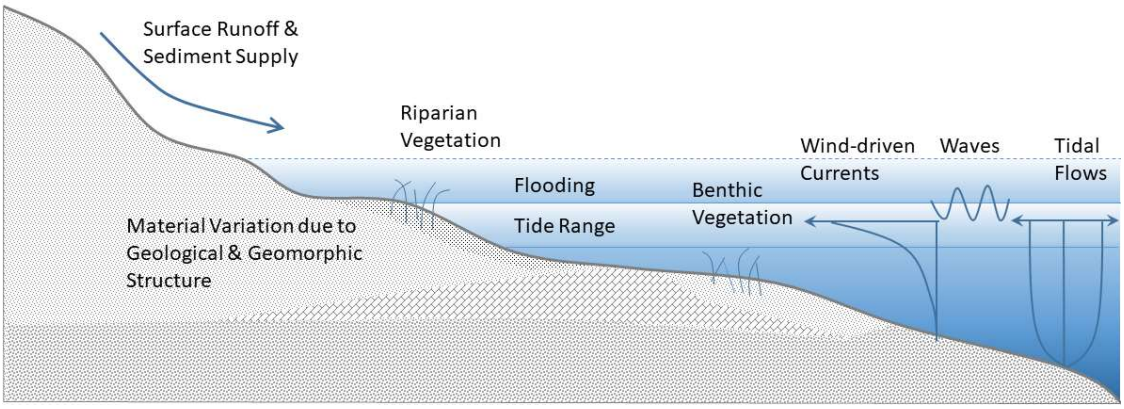


Figure A-2: Schematic of Foreshore Influences

ESTUARINE STRUCTURE & GEOMORPHOLOGY

Peel-Harvey Estuarine System is a large waterbody, draining a catchment of 11,930 km^2. It includes input from the Harvey, Murray and Serpentine River systems, along with local catchment drainage. The estuarine system is a geologically modern feature on the greater Swan coastal floodplain and is likely to have evolved from a floodplain structure towards its current form following Post-glacial inundation over the late Holocene (Robertson 1972; Logan *et al.* 1976; Treloar 1978; Brown *et al*. 1980). Although parts of its structure may be considerably older, the present structure is likely to have developed over the last 2,000 years, when sea levels have remained approximately constant, possibly declining 1-2 m (Wyrwoll *et al*. 1995).

The modern estuary has two distinct but connected estuarine basins, with a relatively narrow channel extending from Peel Inlet to the Indian Ocean. In 1994, Dawesville Channel was opened, providing an artificial connection from Harvey Estuary to the ocean. This excavation has artificially caused foreshore morphodynamics, beyond the general pattern of accretion normally expected in a modern estuarine system (Dyer 1973; Perillo 1995a, 1995b; Ryan *et al.* 2003). Further up-stream the shallow Peel Inlet has an irregularly shaped area of approximately 70km^2, and the slightly deeper Harvey Estuary an elongated structure with an area of approximately 50 km^2 (Figure A-3). The Murray and Serpentine Rivers debouch into the northeast of Peel Inlet, and the Harvey River flows into the southern end of Harvey Estuary, although much of the catchment flow is abstracted through Harvey Diversion Drain. Both basins are substantially sheltered from the direct influence of ocean waves, notably the prevailing swell.

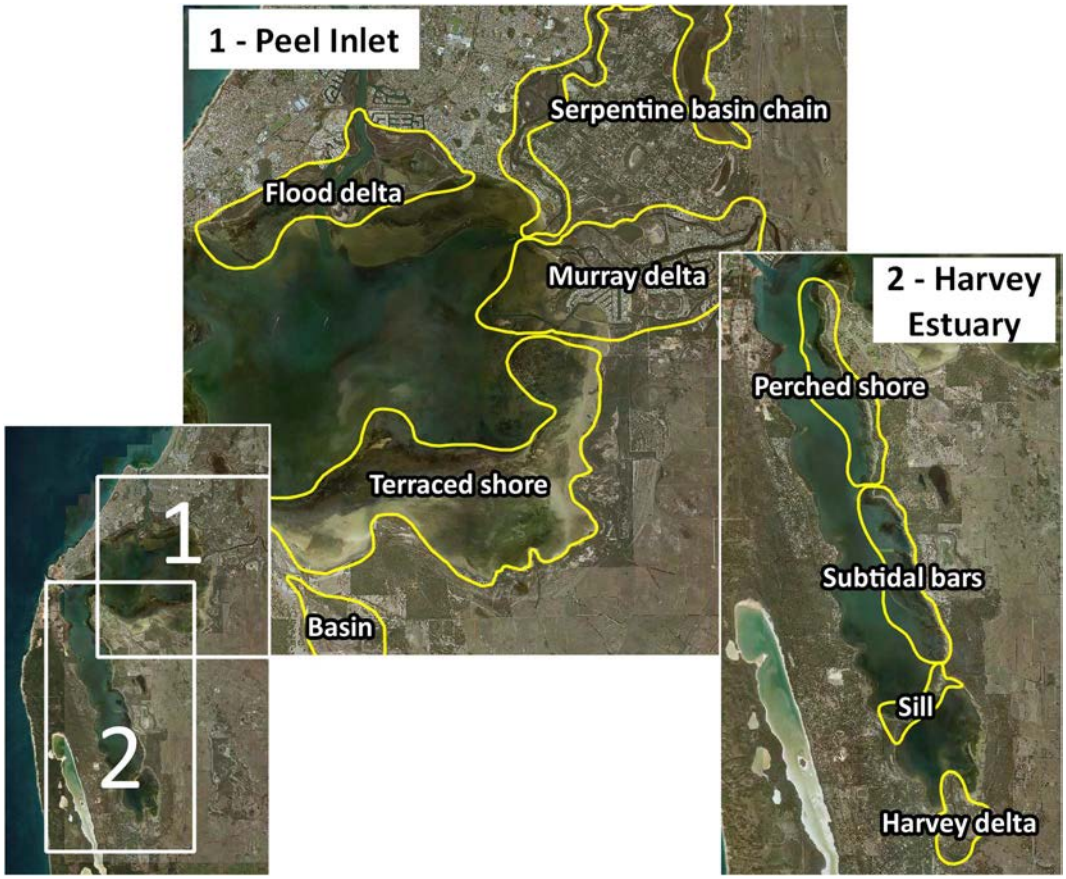


Figure A-3: Major Foreshore Features

Importantly, the low energy dynamics of sheltered estuarine beaches such as the Peel-Harvey system differ from those on the open coast; as has been reported from a wide variety of estuarine environments around the world (Davidson-Arnott & Fisher 1992; Nordstrom & Roman 1992; Makaske & Augustinus 1998; Jackson *et al*. 2002; Eliot *et al*. 2006; Travers *et al*. 2010). Key factors include:

- Absence of prevailing swell.
- Fetch limits for wind-wave generation, and
- Frequent presence of sub-tidal terraces.

These factors should be considered in any appraisal of estuarine shoreline change in the estuaries of Southwestern Australia. Their significance in the Peel-Harvey system is described below.

Peel Inlet

Peel Inlet is a nodular shaped basin, approximately 8-10 km across from any direction, and generally 1-2 m deep throughout. Extensive sub-tidal terraces are present along the southern, eastern and northern shores of the inlet, including large areas of samphire marshes (McComb *et al*. 1995). The Murray and Serpentine rivers debouch along the northeast shore of the inlet, with the Murray forming a complex prograding delta. Much of the land surrounding Peel Inlet is very low relief, reflecting its floodplain origins, and the geologically recent development of the inlet during a period of nearly stable sea levels.

Until opening of the Dawesville Channel, Peel Inlet was connected to the Indian Ocean only through Mandurah Channel, a narrow waterway which substantially restricted the transmission of ocean tides into the estuary basins. Mobility of channel sediments was evident throughout Mandurah Channel, with shoals occurring at the ocean entrance and wetlands with shallow inter-braided channels occurring at the entrance to Peel Inlet. The structure of the estuary, with its large basin and narrow entrance channel is characteristic of a wave-dominated estuary (Ryan *et al*. 2003). This classification is further supported by a ternary classification based on waves, tides and run-off (Harris *et al*. 2002) although it is recognised that the existing structure is substantially influenced by geology, with a limestone ridge forming the western boundary of the estuary (Section 2.2) and sheltering the estuarine basins.

Absence of background swell means that there is limited energy to define a ‘prevailing’ configuration and the shores are instead forced by wind-waves. Due to fetch limitation, there is an effective wave limit, such that there is little difference between the waves generated by moderately strong or extreme winds. For the purpose of driving sediment transport, this determines that above a characteristic threshold, the persistence of wind is of greater significance than the speed.

For those foreshore areas with subtidal terraces, which are common in the Peel-Harvey system, the terrace provides separation between sediment transport mechanisms along the outer and inner margins of the flats. Transport on the shoreward margin is limited by depth limitation and friction except under high water level conditions. This discrepancy inhibits the ‘recovery’ phase typically observed on open coast beaches after storm erosion, and is part of the mechanisms sustaining the terrace structure. As a consequence, estuarine beaches may exhibit relict features from severe events for many years, if not decades.

Prior to opening of Dawesville Channel, historically observed dynamics along the Peel Inlet shore mainly occurred in the vicinity of the Murray-Serpentine delta, and Mandurah Channel. In general, the delta area experienced ongoing accretion as fluvial sediments were deposited in the basin. Mandurah Channel experienced a mixture of accretion and erosion, but the pattern is obscured by human intervention, including dredging, construction of shore structures and boat wakes. Subsequent to opening Dawesville Channel, much of Peel Inlet shore showed erosive characteristics including scarping and the loss of fringing saltmarsh areas (Calvert 2002). These were anticipated results of the increased water level ranging and tidal flows caused by the channel excavation. Aerial photographs of the inlet also show zones of benthic vegetation loss, but it is noted that such events also occurred intermittently prior to Dawesville Channel (Damara WA 2008).

It is important to recognise that the historical stability of the estuarine shorelines may understate the active dynamics. The extensive sub-tidal terraces act to dissipate wave energy, and hence the majority of sediment transport is likely to occur along the edge and surface of the sub-tidal terrace, except during extreme water level events (Nordstrom & Roman 1992). Evolution of the sub-tidal terrace therefore may occur without a corresponding shoreline change until an extreme event occurs, and consequently can result in a relatively sudden shoreline movement.

The expected pattern of evolution is determined by the fetch-limited nature of the estuary basin, which may provide variation of the wave climate over relatively short distances. This determines dependence of shore stability upon the distribution of wind directions and enables the formation of extensive cross-shore features such as bars and spits, which are capable of episodic change during storm events (Niederoda & Tanner 1970; Prats 2003). The formation or collapse of ephemeral features can allow localised erosion or deposition over relatively short periods of time, and consequently, allowance for coastal setbacks should consider any reliance upon such ephemeral features. Erosion potential is enhanced where there is variability of alongshore transport, such as caused by a change in shore aspect, a difference in riparian vegetation or soils. Drainage systems including streams and river channels may also provide erosion potential due to seasonal variability of flow.

Harvey Estuary

Harvey Estuary is an elongated cigar-shaped basin with crenulated shores, roughly 20 km long, and 2-3 km wide, and typically about 3 m deep towards the centre of the estuary. A shallow sill defines a small basin at the southern end, which has provided sufficient shelter for an unusual birdsfoot delta to form where the Harvey River enters the estuary (Figure A-4). The sides of the estuary are characteristic of coastal barrier dune systems from previous eras, and provide high relief compared to the floodplain east of Peel Inlet. Low relief land is restricted to a narrow fringe along the shore, and salients where the crenulated shores project further into the estuary.



Figure A-4: Birdsfoot delta in Harvey Estuary

Processes Influencing Peel-Harvey Morphology

The relative influence of different driving processes varies substantially across the estuary, including local-scale influences of landform and bedform structures on hydrodynamics. Features indicative of difference types of forcing and land forming processes include:

- A flood delta present at the southern end of Mandurah Channel, indicates high tidal flows through the channel, with flow speeds reducing as they enter Peel Inlet. This depositional area includes the series of low-lying wetlands and intertidal flats of the Creery wetlands.
- The lower Serpentine River is a very gently graded river system comprised of a series of basins, with interconnected flood channels. These basins provide hydraulic detention, which reduces the capacity for riverine floods to convey sediment to the estuary. Basins to the east of the present mouth potentially suggest a previous flow path, which may act as a breakout pathway under extreme events. Historic modification of the Serpentine catchment included excavation of trenches between basins to drain wetlands and increase the agricultural area.
- A 'bay head delta' occurs at the mouth of the Murray River. This landform is characteristic of high sediment supply from upstream and indicates potential for relatively high flows.
- The east and southeast shores of Peel Inlet have extremely wide subtidal terraces, particularly south of Yunderup, Austin Bay and Robert Bay. These are typical of low energy estuarine shores.

- Foreshore terraces with transverse bars occur on the east side of Harvey estuary, indicating low wave energy conditions, frequently occurring from a southerly direction.
- A 'birdsfoot delta' occurs at the mouth of Harvey River. Such landforms are characteristic of sediment supply from upstream and very low energy conditions within the estuary basin.

These features largely suggest the estuarine basins provide separation between runoff processes active in the river channels and the tidal flows active in Mandurah Channel, Grey Channel between the two basins, and Dawesville Channel. Transition between flow dominated behaviour and wave dominated behaviour occurs near channel entrances and is likely to vary spatially over time.

In addition to broad-scale structural features associated with the rivers and channels, there are smaller-scale convex foreshore features at locations around both estuarine basins (e.g. Sandy Point). Some of these features are potentially underpinned by natural rock formations, but for most, active foreshores include mobile sedimentary features, with retention enhanced by either vegetation or constructed edge treatments. Modelling of Harvey Estuary hydrodynamics has suggested that local-scale convexities may induce gyres in estuary circulation, reinforcing the structure through sediment transport (Hearn & Lukatelich 1990).

RIPARIAN VEGETATION

Sheltered conditions within an estuarine setting provide increased opportunity for the sustained presence of riparian vegetation, ranging from sedges and saltbush through to salt tolerant trees, such as melaleuca. Vegetation typically provides a stabilizing role on estuary foreshores, whether through binding of sediment to the root mass, enhancement of dune-building processes, or wave sheltering from fallen logs, and therefore the presence of riparian vegetation is influential in foreshore dynamics.

The capacity for different species to establish and subsequently thrive is a function of ecological and geomorphic conditions. Influencing factors include surface water and groundwater chemistry; inundation frequency; soil type; nutrient supply; traffic; undercutting pressure; or sediment smothering (Trudgeon 1988). Different species, sometimes at various stages of maturity, are affected by different factors. Consequently, the effects of inundation and sediment dynamics often result in characteristic cross-shore zonation of vegetation species (Figure A-5). Changing conditions may cause pressure on this zonation to migrate, subject to resilience of the vegetation, which may result in phases of dieback and recolonization.

Mechanisms affecting riparian vegetation include:

- Plant life cycles, including developing maturity and response to seasonal pressures;
- Substantial variation of environmental conditions, such flooding or drought cycles, or anthropogenic factors such as nutrient loads or major engineering works;

- Foreshore dynamics, including seasonal or longer-term movements of foreshore sediments, which may build or erode spits, beaches or estuarine berms (these are sometimes described as foreshore 'dunes');
- Micro-climate variation, such as pond-channel structure within a wetland, or nutrient load associated with stormwater management and debris. There is often feedback between vegetation species development and microclimate, as more established vegetation is typically capable of stabilizing larger features such as dunes or banks.

These mechanisms are often inter-related, limiting identification of cause and effect and therefore obscuring appropriate management responses in situations where it is considered appropriate.

Within Peel-Harvey Estuarine System, characteristic forms of riparian vegetation include marshlands, wetlands and estuarine woodlands, which may occur singly, or in a sequence related to species eco-geomorphological capacity (Figure A-5):

- Estuarine marshlands, including samphire and *halosarcia* communities are extensive near the southern end of Mandurah Channel (Creery Wetland), Robert Bay, Murray-Serpentine and Harvey river mouths, (McComb *et al*. 1995). These are very flat, intertidal areas.
- Fringing estuarine wetlands, typically populated by sedge species such as *juncus krausii* occur adjacent to marshlands, but also intermittently along segments of Peel Inlet and Harvey Estuary shores (Calvert 2002).
- Estuarine woodlands, with *melaleuca* common (Calvert 2002).

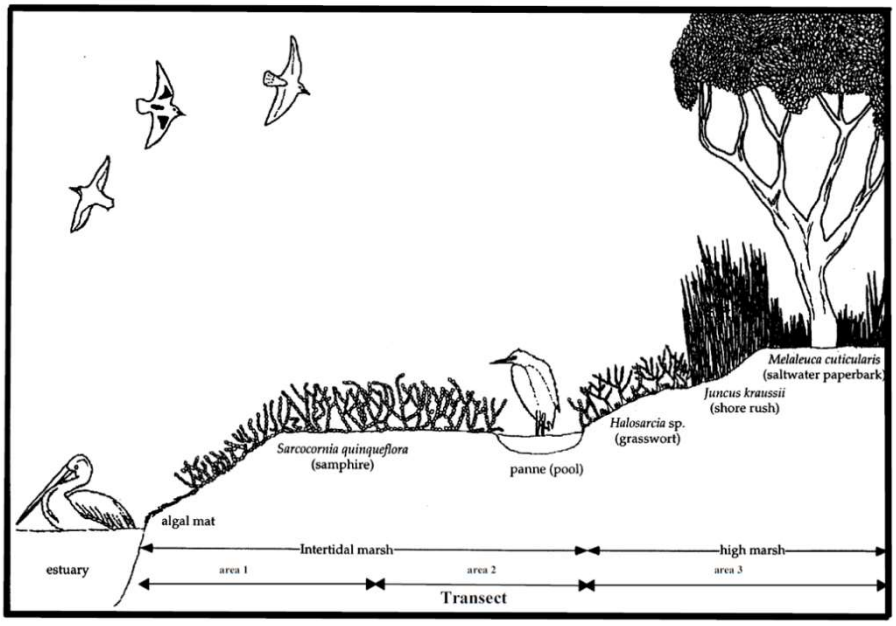


Figure A-5: Characteristic Riparian Zonation for Peel-Harvey Wetlands

(From McComb *et al*. 1995)

Development of the estuary has resulted in a complex geomorphic arrangement, including basin-channel structures and ridge-swale sequences that have developed under varying conditions, resulting in a mixture of active and relict riparian basins (Semeniuk & Semeniuk 1990). This arrangement enables substantial ecological change to occur in the foreshore zone, with switching between 'dry' and 'inundated' conditions able to occur with relatively subtle changes in hydrology or sea level. Riparian vegetation has been observed to respond to such changing conditions with migration of riparian zones (McComb *et al*. 1995). Species death may occur if adverse conditions are sustained for a critical period – this may vary from days through years, depending on robustness.

Opening of Dawesville Channel caused a substantial change to both inundation frequencies and seasonal salinity variation. Of particular importance, there was no longer a coincidence between winter high water levels and brackish conditions (Young 1986), with a result of saline stress and dieback for less tolerant species (Gibson 2001; Calvert 2002; Carter *et al*. 2006).

ESTUARY MODIFICATIONS

Peel-Harvey Estuarine System has been substantially modified since European settlement in Western Australia. Initial modifications largely involved land clearing and drainage to support agricultural use of the catchment. This was followed by substantial modification of the ocean entrance and Mandurah Channel, to improve the reliability of small craft navigation and improve estuary-ocean water exchange (DMH 1985).

Foreshore infrastructure has been progressively installed as residential and recreational pressure adjacent to the estuary has increased. This has included walling to stabilize foreshore parks and road reserves, and boat ramps to support small craft use of the estuary. Construction of canal estates commenced in the 1970s at Yunderup, with subsequent proliferation of facilities along Mandurah Channel from the 1980s. Additional canal estates were developed following opening of Dawesville Channel in 1994, and Mandurah Ocean Marina was opened in 2001.

Between the 1900s and 1970s, the hydrology of Harvey and Serpentine Rivers was modified, for reasons of land drainage, flood management and water supply. Major works included construction of a southward-draining network from Kwinana and de-snagging along the Serpentine, damming of the Harvey River and construction of Harvey Diversion Drain. In addition, agricultural drains were established for land along the eastern side of Harvey Estuary.

Changes to the hydrology and land-use altered estuarine water chemistry, resulting in progressive eutrophication of the waterway (Hodgkin *et al*. 1980). Holistic assessment of Peel-Harvey catchment was undertaken, ultimately leading to a set of management actions (DCE 1984b, 1985; Gorham *et al*. 1988). The action with the most profound consequences for Peel-Harvey foreshore dynamics was construction of Dawesville Channel, opened in 1994, which substantially increased tidal exchange into the estuary to enhance water quality.

Dawesville Channel

As of 1985, more than half the phosphorus discharged into the Peel-Harvey estuary system came through Harvey River into the south of Harvey Estuary, where there was very little exchange with ocean waters due to the isolation of these waters from Mandurah Channel. High levels of phosphorus input with limited oceanic exchange resulted in the reported *Nodularia* blooms (DCE 1984a). Initially observed in the Harvey Estuary by DEC in 1978, *Nodularia* was subsequently carried into Peel Inlet after which blooms were reported in both water bodies (DCE 1984a).

Options to manage the increasingly eutrophic state of the Estuary were evaluated, with Peel Inlet and Harvey Estuary Management Strategy (CALM 1985) developed to enhance Estuary water quality through short and long term measures. The strategy included an engineering intervention to excavate a channel between Harvey Estuary and the Indian Ocean. The proposed Dawesville Channel was intended to enhance tidal flushing and create a more marine environment, inhibiting growth of *Nodularia*. This measure was coupled with continued harvesting of nuisance weed and modified agricultural practices, to reduce nutrient input to the Estuary.

Predictions associated with the Dawesville Channel (Paul & Hutton 1985, Tong 1985, Gorham *et al*. 1988, Ryan 1993) include:

- The estuarine coastline between the Dawesville Channel and Mandurah Channel would not be eroded.
- Siltation in Mandurah Channel would not increase detrimentally.
- Training walls and entrance cross-section could be designed in tidal equilibrium, such that the channel would flush out sediment entering the channel.
- Tidal range inside the Estuary would increase from 15-20% of oceanic levels to 45-50% following construction of the Channel. This approximately corresponds to an increase of average daily tidal range from 0.1m to 0.3m.
- The altered tidal regime was predicted to create a greater number of areas conducive to saltwater mosquito breeding (saline wetlands/marshes).
- Estuary flushing time was predicted to decrease from 90 to 30 days in Peel Inlet and from 150 to 50 days in Harvey Estuary.
- Water exchange per tidal cycle during typical summer conditions was predicted to increase from 5.5×10^6 m^3 to 6.3×10^6 m^3 through Mandurah Channel, and from 3.3×10^6 m^3 to 6.4×10^6 m^3 through Grey Channel between the two estuary basins. Water exchange through Dawesville Channel was predicted to be 16.5×10^6 m^3.
- Clearer water was expected with enhanced mixing due to increased tidal movement and greater flushing of organic matter.
- An ecological transition in species was predicted, from those that could withstand the variation from fresh to hypersaline water, to predominantly marine species. This was considered likely to impact commercial fisheries, reducing resident species numbers but creating a higher diversity in marine species.
- Increased quality of the overall estuary environment was expected to lead to increased recreational use of the Estuary by the public.

In 2003, a report was released demonstrating the progress and compliance with Environmental Conditions (EPA 2003). This report listed predicted changes and corresponding observations following Dawesville Channel construction. Predictions include:

Factor	**Predicted change following Dawesville Channel Construction**	**Observed change following Dawesville Channel Construction**
Tidal	Daily tidal range increase from 17% to 45-50% of ocean tide in the Peel, and from 15% to 60-70% of ocean tide in the Harvey. Decreased duration of tidal inundation/exposure. Increased frequency of tidal inundation/exposure.	Increase to 48% of ocean tide in the Peel, and to 55% of ocean tide in the Harvey. As predicted As predicted
Flooding	Transition to being driven predominantly by river flow to an influence from daily or storm surge tides affecting the eastern estuary edge. Transition from average water level decrease of 0.4m in 10 days to average water level decrease of 0.4m in 3 days.	As predicted As predicted
Hydraulic Characteristics	Decrease in average residence time from 30 days to 10 days in the Peel, and from 50 days to 17 days in the Harvey. Increase in water exchange per tidal cycle from $5.5x10^6$ m^3 to $6.3x10^6$ m^3 in the Mandurah Channel, and from 3.5 $x10^6$ m^3 to 6.4 $x10^6$ m^3 in the Grey Channel. Water exchange through the Dawesville Channel expected to be 16.5 $x10^6$ m^3. Period of stratified conditions to reduce by approx. 2 months, with stratification to be more intense.	As predicted As predicted As predicted
Sediment Characteristics	Non-apatite phosphorus stores in estuarine sediment expected to gradually deplete, with subsequent reduced periods of anoxia and less release of phosphorus from sediments to the water column	Assessment incomplete in 2003
Water Quality	Transition from salinity extremes towards marine salinity prevailing for most of the year, with associated strong stratification. Hypersalinity to end. Reduced frequency and duration of deoxygenation periods, reduced turbidity (reduction in *Nodularia blooms)* and more rapid return to low nutrient levels, associated with estuarine flushing.	As predicted, except for some occurrence of hypersaline conditions (less extreme than previously). As predicted, except for summer turbidity in the Harvey due to winds resuspending sediment.

Modified from EPA (2003)

Impacts of Dawesville Channel that are important for foreshore dynamics include:

- A step change in the character of water level variability within the Estuary. This extended the foreshore's hydraulic zone, over which surface waves provide bed stress and may mobilise sediment.
- Substantial modification of tidal currents. and
- Alteration of ecological conditions, affecting riparian and benthic vegetation.

Distinguishing the impact of Dawesville Channel upon the estuarine system has been partly obscured by climate variability, including decadal-scale rainfall decline, and anthropogenic development of the estuary (Elliott *et al*. 2016).

Other Anthropogenic Factors

In addition to Dawesville Channel, land use change has occurred along the Shire of Murray, affecting the foreshore. The most substantial change adjacent to the shore is development of Yunderup Canals and the Islands, at the mouth of the Murray River, which includes a dredged navigation channel (Figure A-6.



Figure A-6: Land use change near Yunderup demonstrating land development and waterway modification since 1974.

Semi-rural development at Birchmont has been established with a foreshore reserve of approximately 65m width (Figure A-7).



Figure A-7: Land use change near Birchmont demonstrating semi-rural development and pasture change

Other anthropogenic activities include construction of agricultural drains and small boat ramps at Birchmont and Herron Point. Some foreshore response to the drains is apparent, with development of sediment fans at the drain mouths in Austin Bay and Robert Bay. However, these features have remained relatively stable since the 1970s.

GEOMORPHIC UNITS

The foreshore has been divided into geomorphic units, approximately corresponding to length scales of 1-2km, characterising sections of the foreshore that behave in related ways or are affected by similar stresses (Figure A-8). Divisions were based on apparent points of substantial change, including foreshore morphology and separation between embayments. This corresponds to the 'Segment' scale used for classification of City of Mandurah and Swan River foreshores.

Embayment structure and morphology was used to split the foreshore into segments, mapped at a scale of 1:30,000. Segments were defined by locating sediment splits:

- Where a substantial change to landform processes is apparent, specifically separation between deltaic and foreshore landforms.
- Where a significant barrier to alongshore sediment transport was identified.
- If the shore changed aspect by more than 45°.
- Where a perceptible change in active stresses is apparent (e.g. at tidal channels).

At this scale, the finite volume of mobile sediment determines that foreshore change is developed through a coherent combination of erosion and accretion (i.e. change is related but may not be in the same direction). For example, embayment structure may support changes to shore alignment or variation of total sediment volume without corresponding effect on adjacent segments, although these are typically not wholly disconnected, as they experience similar environmental forcing, and are connected by sediment bypassing between segments.

The segments provide a basis for spatial 'smoothing' of erosion estimates, which have been determined at individual profiles along the length of the Murray foreshore. Morphology was evaluated using the Department of Water LIDAR, collected in 2008/09. (Figure A-9). Transects were extracted from the LIDAR from approximately -1m AHD to +3mAHD landward, resulting in profiles of varying length.

Inconsistent return from the LIDAR intermittently results in a 'rough' profile. This is a mixture of data issues and complex low level topography, as illustrated by the ridges and basins present across the Islands in the elevation band of 0.5-1.5mAHD (Figure A-10). Features in this band are presently subject to low rates of overtopping, which will increase with projected sea level rise, providing a significant mechanism for coastal change.

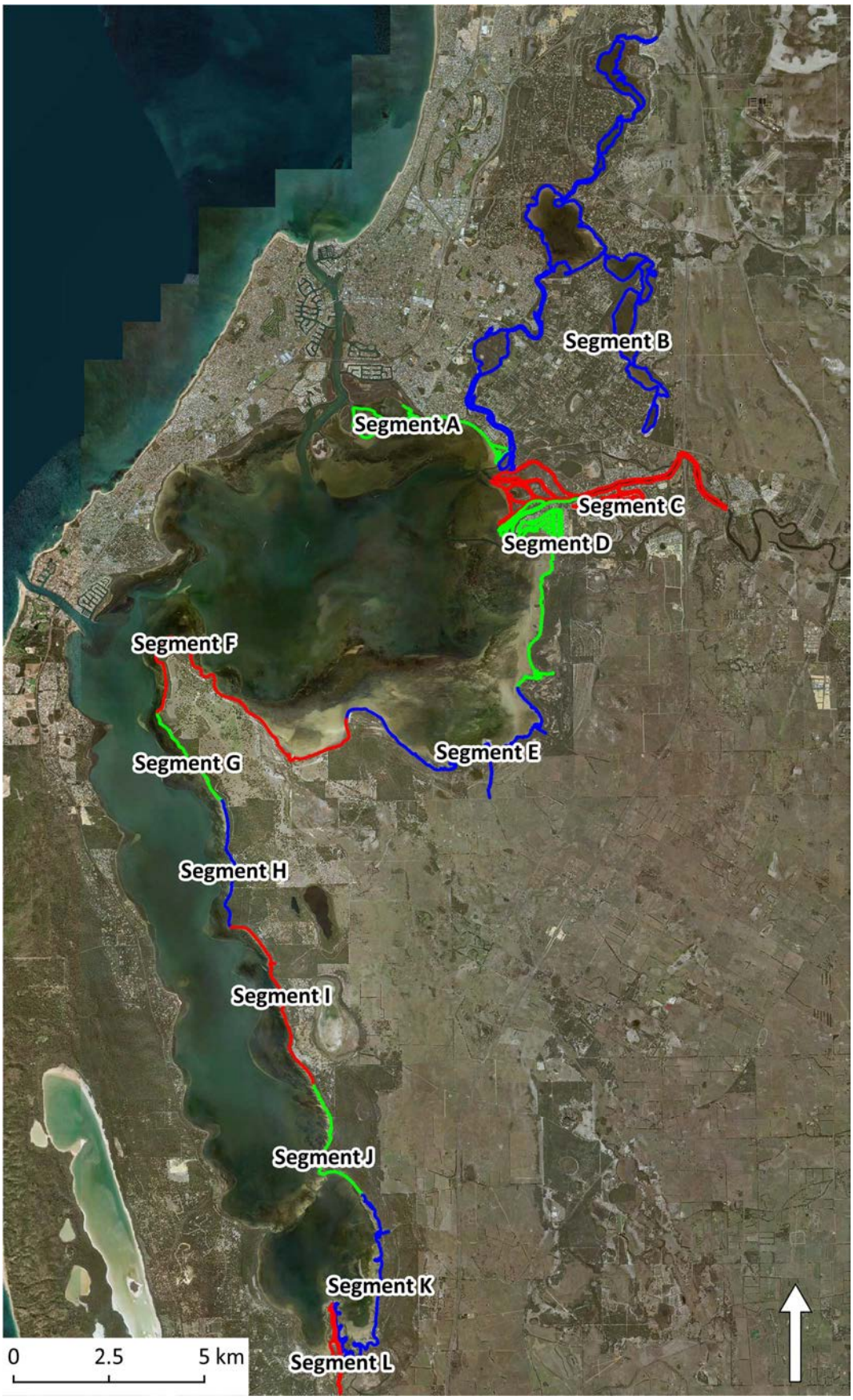


Figure A-8: Shire of Murray Foreshore Segments

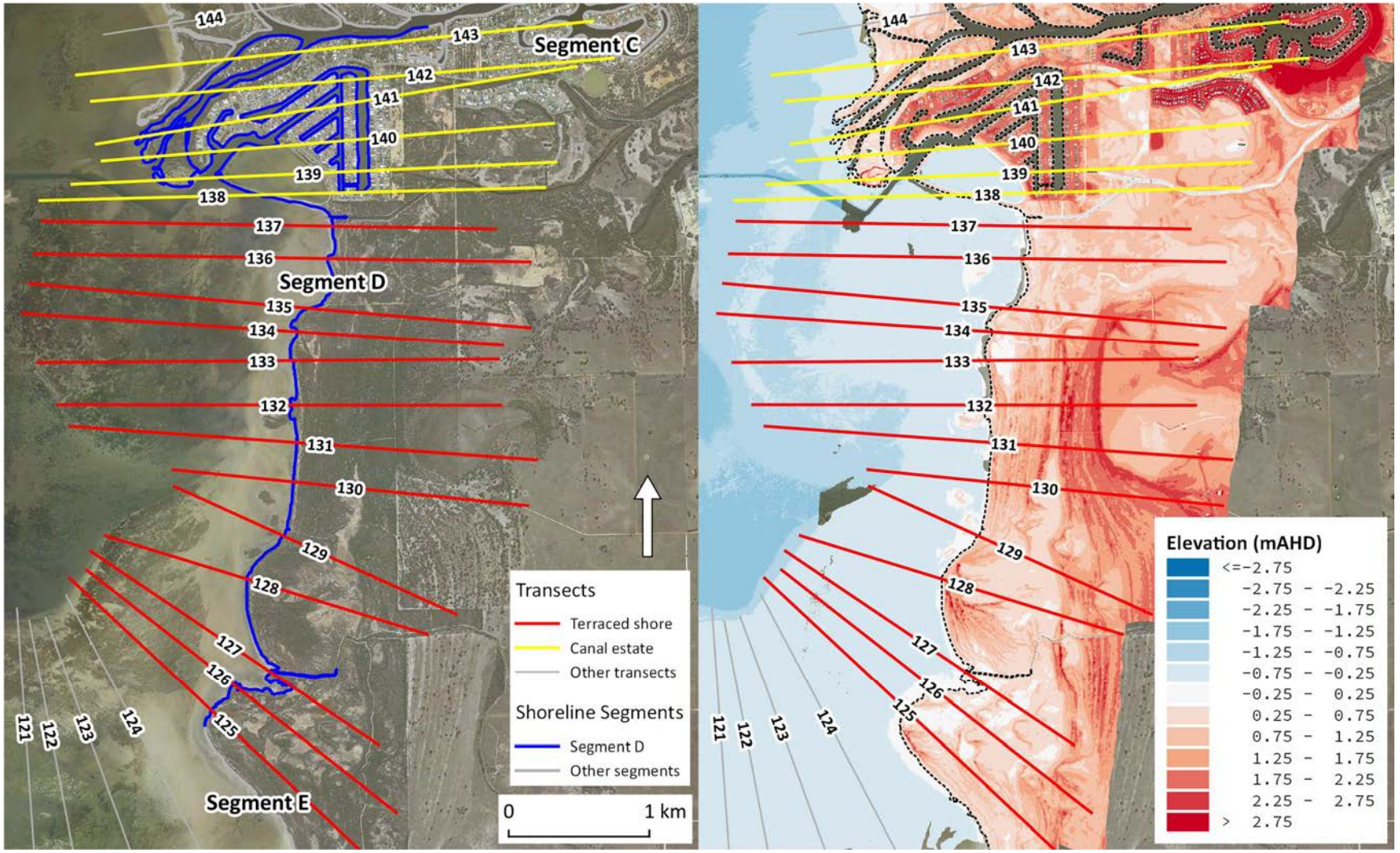


Figure A-9: Location of Segment D and Profiles 125 – 143 with shoreline variability



Figure A-10: Complexity of Low-Level Topography

Appendix B – Meteorology and Oceanography

Meteorologic and oceanographic conditions determine the hydrodynamics (water levels, waves and currents) of Peel-Harvey Estuarine system, and therefore are drivers of foreshore dynamics. Mandurah region has been historically well instrumented, using a mix of permanent and temporary installations. Information used for this assessment includes wind records measured by the Bureau of Meteorology and water levels measured by the Department of Transport (Figure B-1). Other available information includes river flow information measured by the Department of Water and Environmental Regulation.

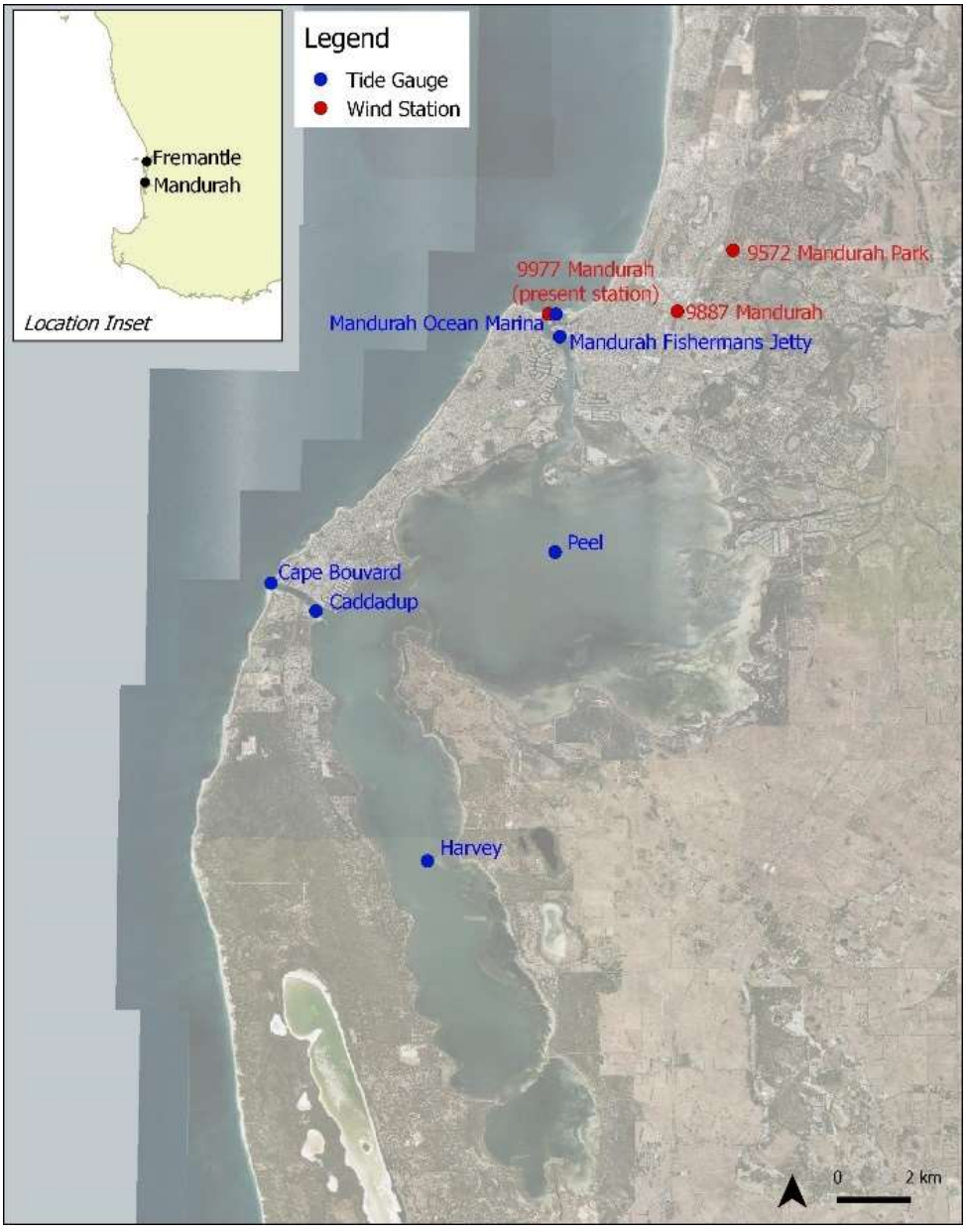


Figure B-1: Meteorological and Oceanographic Measurement Locations

Winds

Wind is significant in the Peel-Harvey Estuarine System due to its role in generation of waves and currents, with both wind speed and direction having influence. Wind observations in the Peel-Harvey region are historically available from three Bureau of Meteorology weather stations, with one Automatic Weather Station presently operating (Table B-1).

Table B-1: Summary of Mandurah BOM Weather Stations

Station	Name	Location	Operation	Elevation	Frequency of Observations
WS 9572	Mandurah Park	32.5031°S 115.7664°E	Jan-1965 to Dec-1985	15m	9am & 3pm only
WS 9887	Mandurah	32.5211°S 115.7500°E	Nov-1987 to Oct-2001	21m	3-hourly
WS 9977	Mandurah	32.5219°S 115.7119°E	Oct-2001 to present	3m	3-hourly

Comparison of wind records from the three stations at Mandurah showed:

- geographic and topographic effects of measurements from different locations.
- differences in frequency of observations.
- differences in velocity and direction scales

These have contributed to differences evident in a wind speed time series (Figure B-2), and speed and direction frequency plots (Figure B-3) for the three stations.

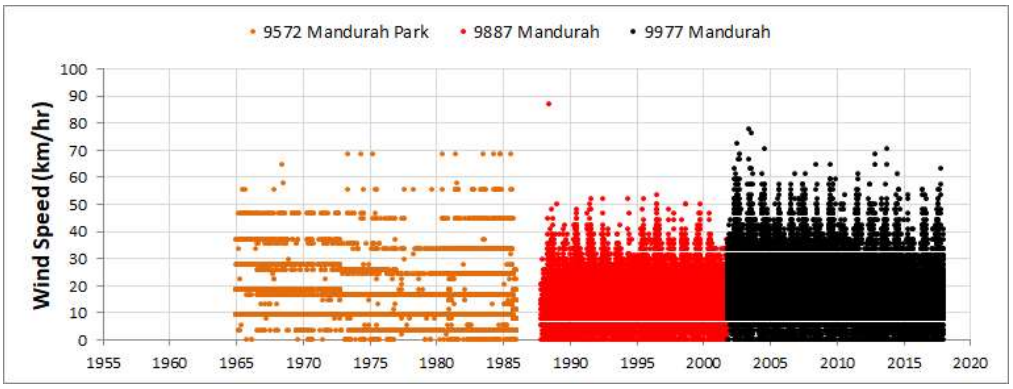


Figure B-2: Mandurah Wind Speed Time Series (All Stations)

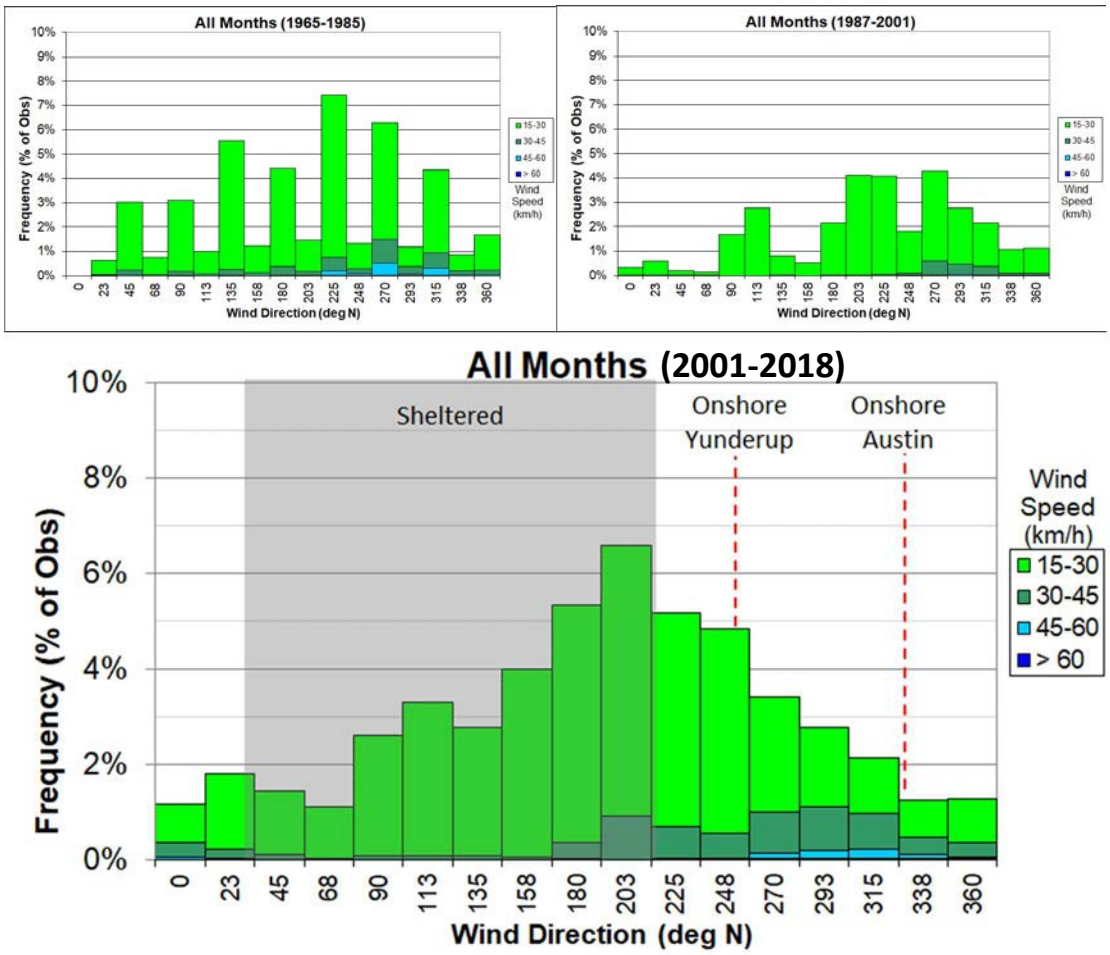


Figure B-3: Mandurah Speed and Direction Frequency Plots (All Stations)

Observations from the present station (WS 9977) located at Mandurah Ocean Marina, immediately adjacent to the shore provides a consistent set of coastal observations since 2001. This station is considered to provide a reasonable representation of winds occurring in the study area, with some minor discrepancies possible due to differences in overland sheltering and changes in exposure of winds (i.e. across the Peel Inlet and Harvey Estuary).

Monthly wind speed and direction frequency plots from the present station illustrate the seasonal shift in wind patterns (Figure B-4). Southerly sea breezes are prevalent from October through to April, with easterlies mainly occurring in February and March. Between May and September, westerlies are dominant, with strong winds generally from the west to northwest. From May to July, northeast winds have a significant secondary occurrence.

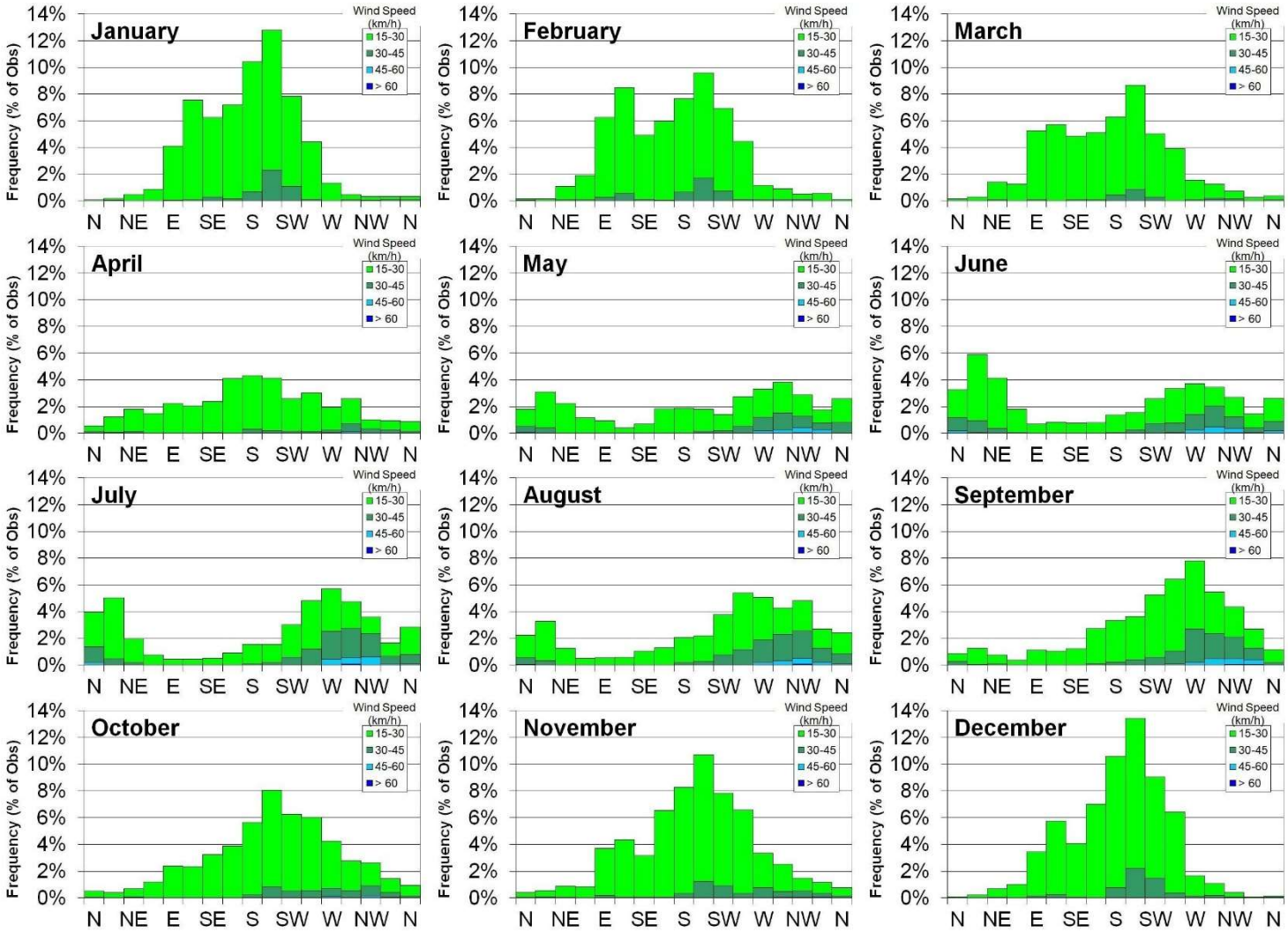


Figure B-4: Monthly Speed and Directional Frequency (Station 9977 – 2001 to 2018)

A speed and directional frequency plot for wind speeds above 45km/hr shows that strong winds are generally limited to from the northwest quadrant (Figure B-5). Low incidence of strong winds from the southwest quadrant may partly be due to sheltering adjacent to the weather station. The Shire of Murray foreshores experience onshore winds from the west through northwest directions, although modal winds arrive at an angle to the shore, suggesting a tendency for alongshore transport.

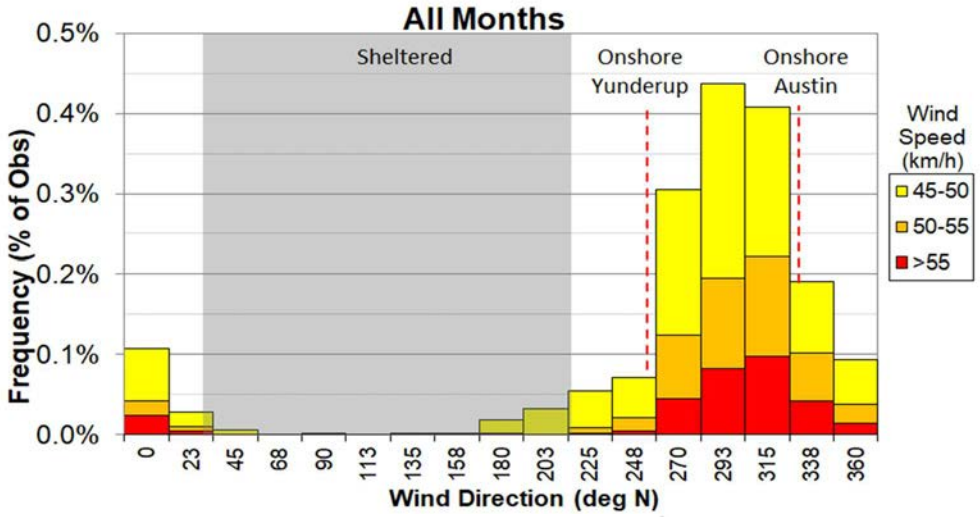


Figure B-5: Speed and Directional Frequency of Strong Winds (BOM Station 9977– 2001 to 2018)

Prevailing / frequent (Figure B-3) and dominant / strong (Figure B-5) onshore winds have the opposite directional distribution on Yunderup and Birchmont foreshores. This suggests capacity for alongshore reversal. For Austin and Robert Bay, modal prevailing and dominant winds are both west of onshore, however there is a weaker association of wind direction to waves because of the very wide shallow terrace.

Variation of wind speed with direction has been examined through evaluation of the Mandurah 2001-2018 wind record, to generate a directional extreme wind distribution (Figure B-6). Analysis steps involved:

1. Separating the wind record into 45° bands, overlapping by 22.5°.
2. Estimating the wind speed relative to the middle of the directional band using the function U' = U cos (ϕ-ϕ') where U is measured wind from direction ϕ and U' is the component of wind in direction ϕ'.
3. Identify maxima that occur with a minimum of 2 days separation between wind events.
4. Using a rank-based plotting probability, undertake extreme value curve fitting within each directional band, using the method of Petrauskas & Aagaard (1971).

This analysis demonstrates the significant difference in extreme wind speeds from the east-southeast compared with the west-northwest.

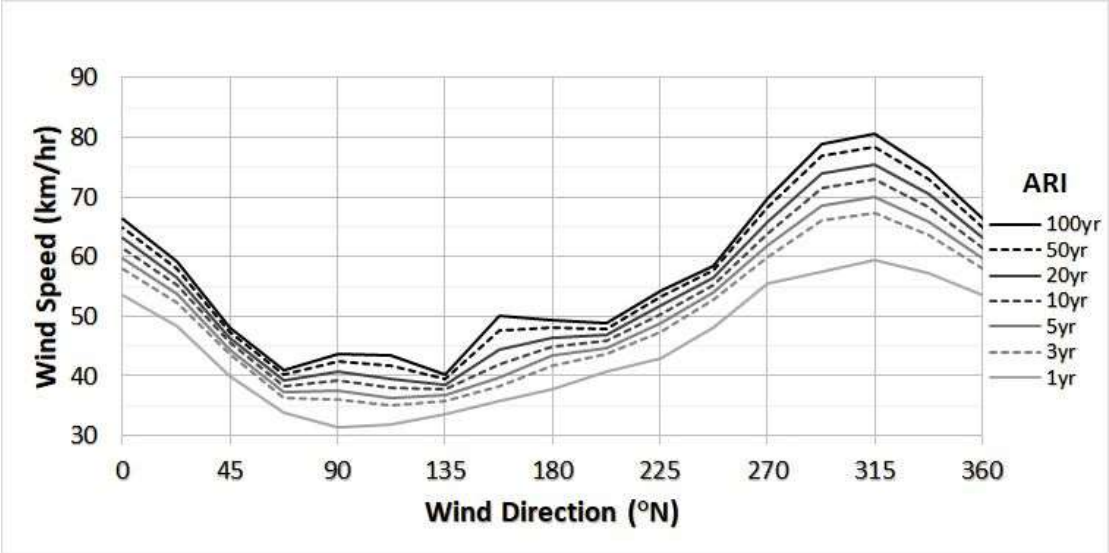


Figure B-6: Directional Extreme Wind Analysis

Annual cumulative summations of the 9am wind speed cardinal components (E-W and N-S) have been used to examine whether there are any apparent patterns of change or standout years. By summing wind vector measured at the same time for each day over a year, a 'wind drift' is calculated. This provides a directional tendency of the wind over the time considered: i.e. a positive net annual easterly wind drift value, for a specific year, indicates that for that year there was a tendency towards stronger easterly winds than during average conditions (Figure B-7). Periods where different weather stations have been used are marked by the dashed vertical lines. The observations are generally partitioned by these breaks, with mild differences between each of the sites.

DRAFT

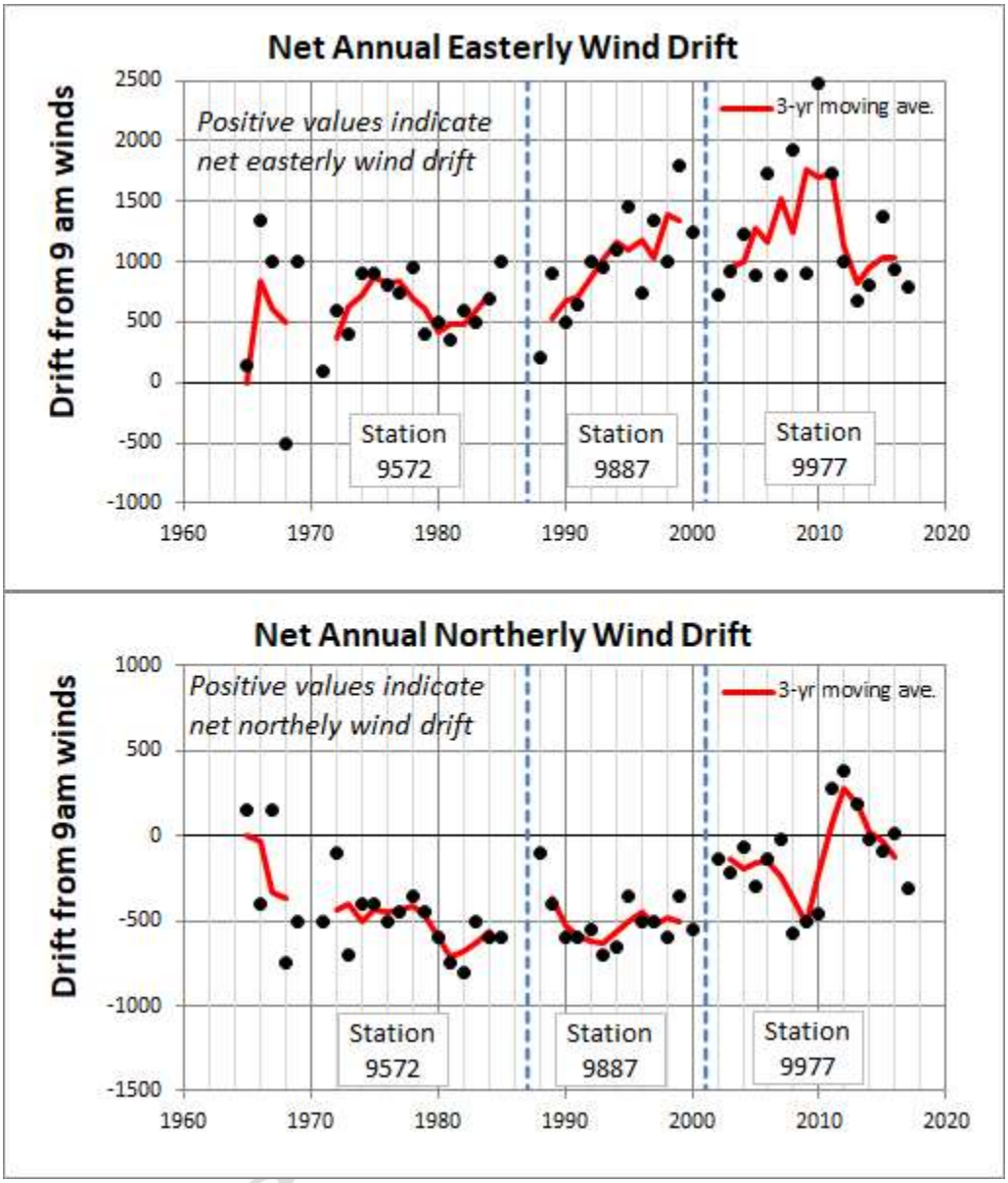


Figure B-7: Mandurah Annual Net 9am Wind Drift

These plots show considerable inter-annual variability, with peaks in the 3-year moving average for the E-W and N-S components in 2009-2011 and 2011 respectively. Standout years in the present record (WS 9977) for each cardinal direction (N,S,E,W) are shown in Figure B-8. A "Strong Year" is defined by the magnitude of the *Wind Drift* relative to the average; hence, a "Strong East Year" is characterized by the easterly cumulative wind run (Red) being consistently above the easterly average (top black line). Conversely, a "Strong West Year" would have a cumulative wind run consistently below the average.

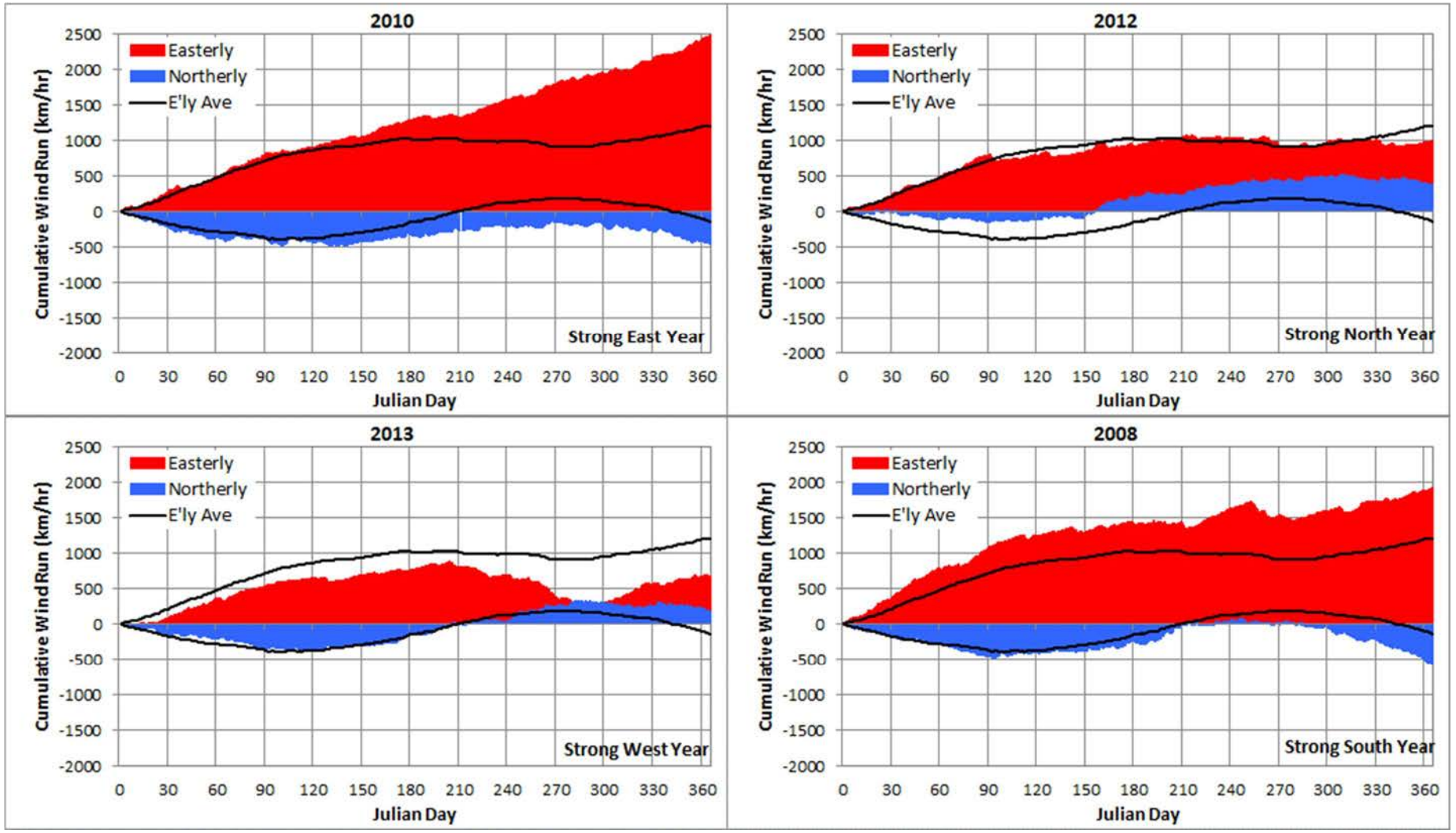


Figure B-8: Strong and Weak Annual 9am Wind Cumulative Summations

Water Levels

Water level observations from five tidal stations throughout the Mandurah region have previously been shown to have high coherence, with a reduction in tidal range from the coast to the estuary basins (Damara WA 2009). There was a significant change in character of water levels in the Peel-Harvey basins due to opening of Dawesville Channel in 1994 (Eliot & McCormack 2018). Key features affecting the water level in the study area include:

- A micro-tidal, mainly diurnal climate with solstitial tidal peaks in June and December. Tidal planes have been derived for three tide gauges in Peel-Harvey Estuary (Table B-2).

Table B-2: Tidal Planes for Peel-Harvey Tide Gauges

Derived from Harmonic Analysis of 1995-2016 records

		Mandurah	Peel	Harvey
Highest Astronomical Tide	HAT	1.14mCD	1.02mCD	1.07mCD
Mean Higher High Water	MHHW	0.78mCD	0.70mCD	0.73mCD
Mean Lower High Water	MLHW	0.71mCD	0.68mCD	0.70mCD
Mean Sea Level	MSL	0.55mCD	0.55mCD	0.55mCD
Australian Height Datum	AHD	0.54mCD	0.54mCD	0.54mCD
Mean Higher Low Water	MHLW	0.39mCD	0.42mCD	0.40mCD
Mean Lower Low Water	MLLW	0.32mCD	0.39mCD	0.37mCD
Lowest Astronomical Tide	LAT	-0.04mCD	0.08mCD	0.03mCD

- Significant meteorological surges, associated with low barometric pressure and westerly storm events, with depressed water levels during sustained easterly winds or high barometric pressure (Hamon 1966). This influences the joint occurrence of winds and water levels.
- Minor, occasional surges associated with the passage of continental shelf waves (i.e. not directly associated with local meteorological conditions), including remote generation from tropical and sub-tropical zones by tropical cyclones (Eliot & Pattiaratchi 2010).
- Seasonal mean sea level range of approximately 0.3m, peaking in June, apparently related to pressure belt latitudinal movement and variation of Leeuwin Current structure and intensity (Pattiaratchi & Buchan 1991).
- Inter-annual mean sea level variability, correlated with the El Niño-Southern Oscillation (ENSO) phenomenon, also correlated with variability of Leeuwin Current structure and intensity (Feng *et al.* 2004). High mean sea levels occur during the la Niña phase.
- An 18.6-year cycle of daily tide range, with the annual tidal range varying by approximately 20% (~0.2m). The lunar nodal cycle last peaked around 2006, with the next peak due in 2025 (Eliot 2010).
- Local wind set-up associated with strong winds across basins. The influence of wind set up was evident during the passage of TC Alby in April 1978 when strong north-

northwest winds across the Harvey Estuary resulted in an increase in water levels from north to south of almost 0.6m (Damara WA 2009).

Hourly water levels observations from the Peel tide gauge, along with the 30 day running mean, are shown in Figure B-9. The largest event observed occurred on 16 May 2003, when maximum water levels of 1.55m CD to 1.61m CD were recorded during the passage of a significant winter storm. There were several high water level events (exceeding 1.20m CD) during a peak in mean sea level associated with a strong la Niña event over 2011-2013.

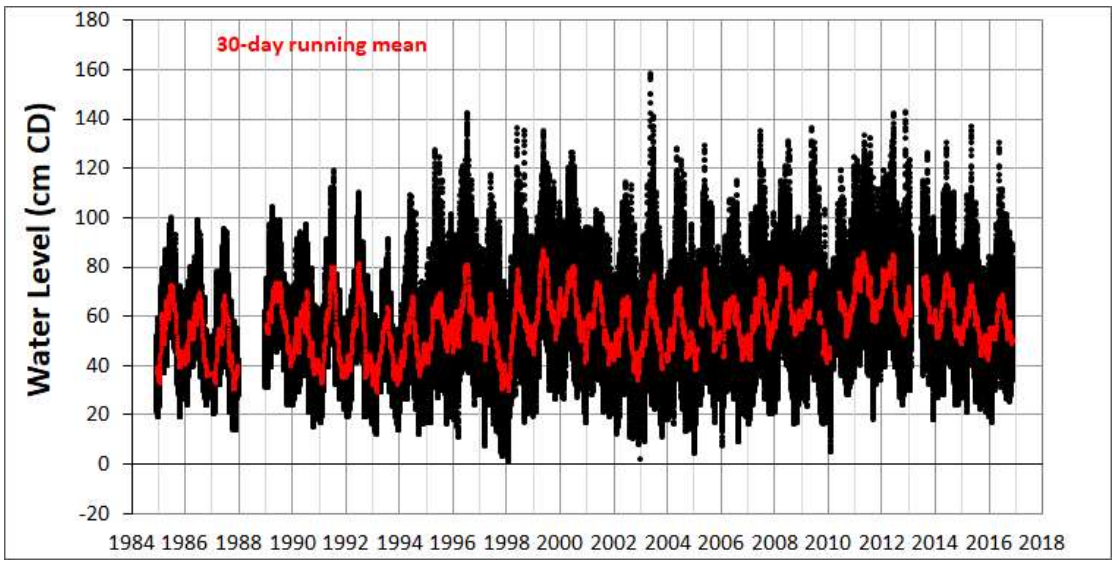


Figure B-9: Peel Inlet Water Levels (1984-2016)

Although storm events may occur all year, extreme water levels are generally restricted to between May-July, when seasonal peaks for mean sea level, surge and tide are in phase (Table B-3).

Table B-3: Summary of Seasonal Changes in Water Level Processes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tide	Peak		Low		Peak				Low		Peak	
Surge	Low*				Peak						Low*	
MSL	Low				Peak						Low	

**Occasional tropical cyclone shelf waves during summer months (December-March)*

The frequency and magnitude of high water level events are particularly influenced by sources of inter-annual variability, in combination with variation between individual storms (Eliot 2012). Identified sources of variability include:

- Up to 0.3m of variability in the mean sea level signal between high and low years, largely corresponding to ENSO phenomenon; and

- Up to 0.15m of variability in the *oceanic* tidal signal between high and low years attributed to the 18.6-year lunar nodical cycle. A smaller influence occurs within the estuary. The latest peak in the cycle occurred in 2006.

The likelihood of high water level events increases during periods of elevated mean sea levels (la Niña) and highs in the lunar nodical tidal cycle and particularly when the two are in phase.

The nature of the water level change due to opening of Dawesville Channel is illustrated by the distinct change observed during 1994 (Figure B-10). The water level signature clearly became more 'spiky' after opening of the channel, with greater variation over short time scales.

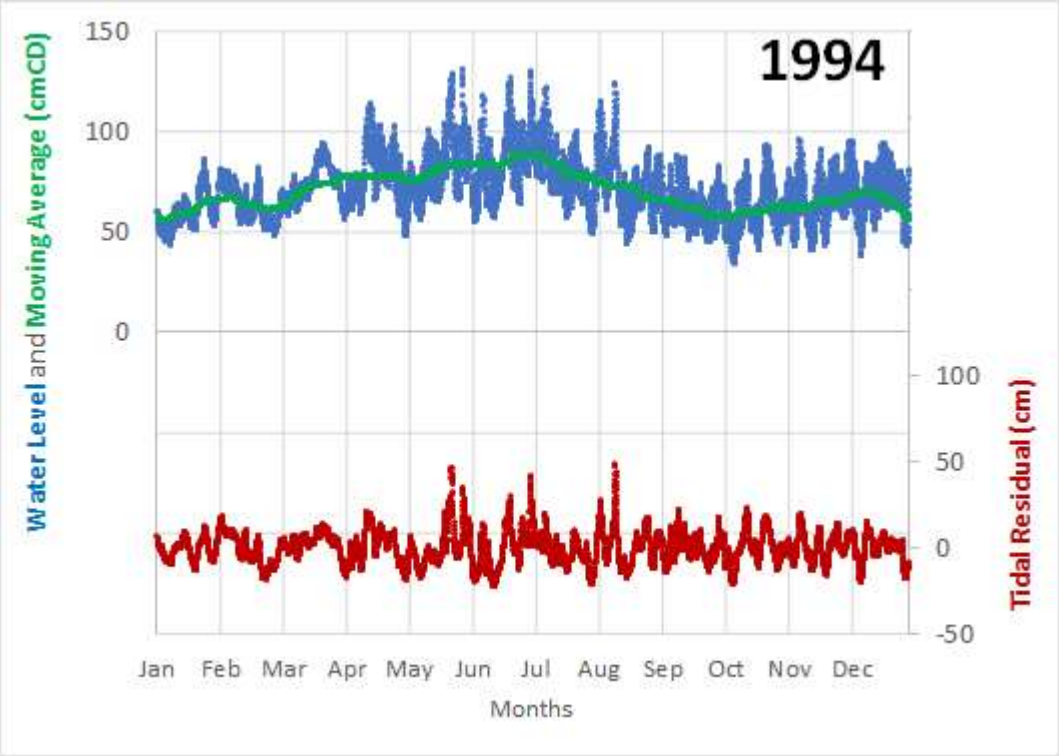


Figure B-10: Observed Water Level and Tidal Residual in Peel Inlet 1994

Harmonic analysis of the water level record has been used to further explore the changes, with separation into mean sea level, tidal and tidal residual components (Figure B-11, Figure B-12). Two large changes are demonstrated by the tidal signal, including (i) a datum shift; and (ii) large-scale increase in the tidal signal.

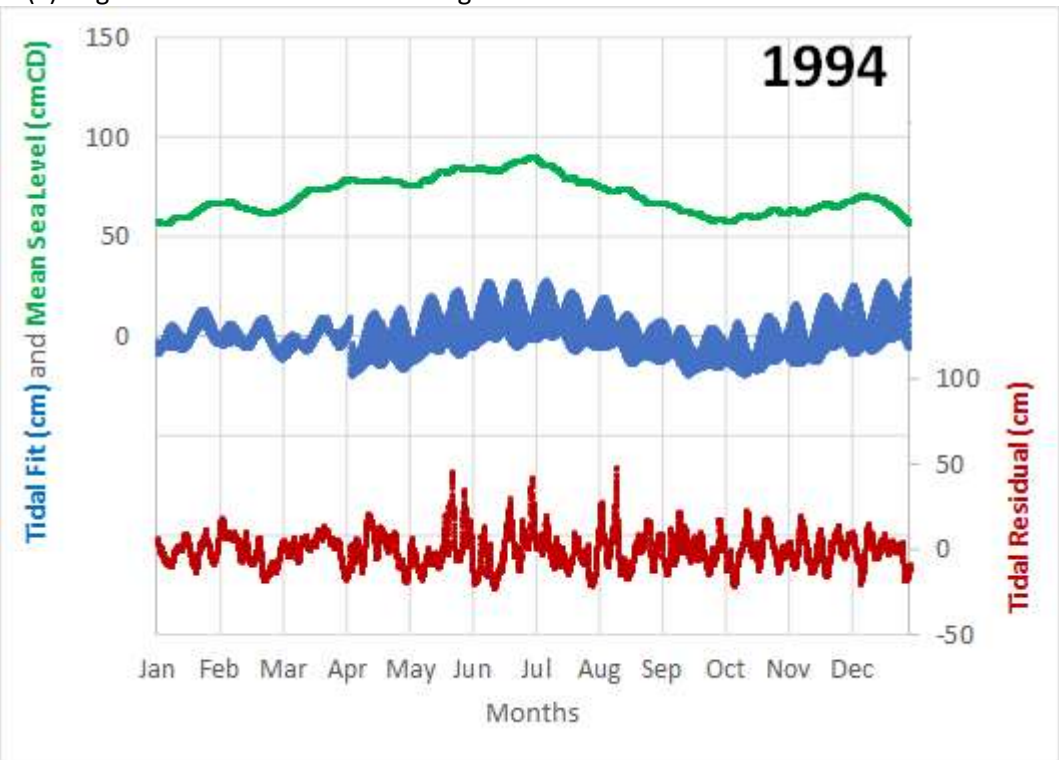


Figure B-11: Change to Water Level Processes after Dawesville Channel Opening

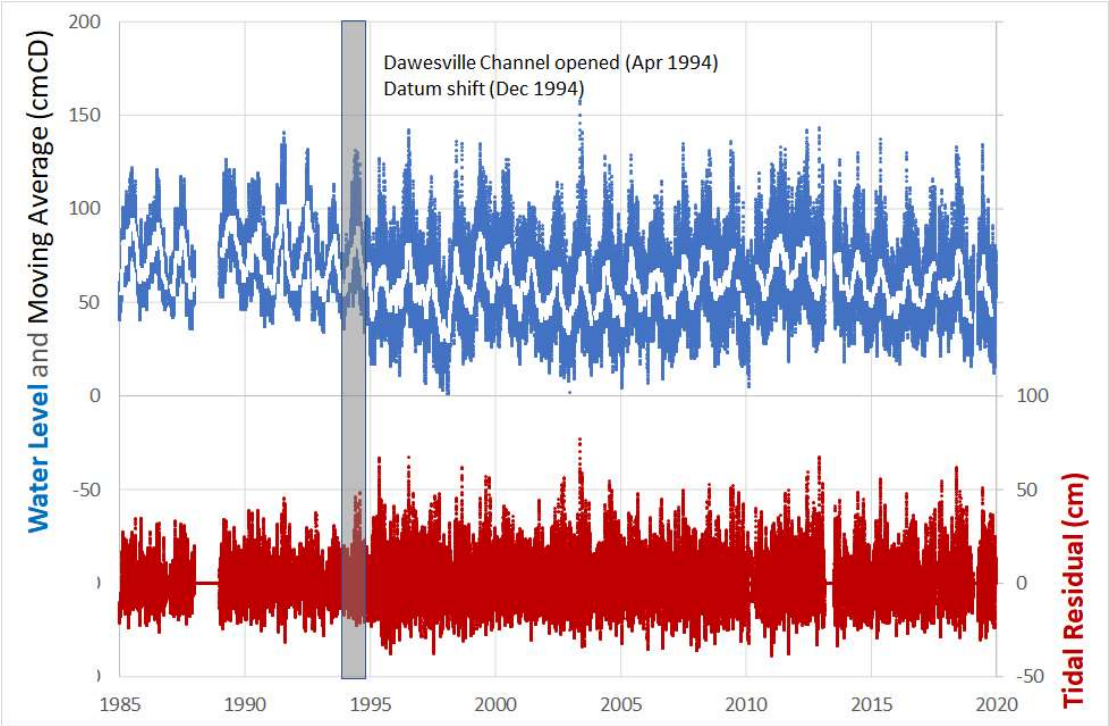


Figure B-12: Water Level Record and Tidal Residuals from Peel Tide Gauge

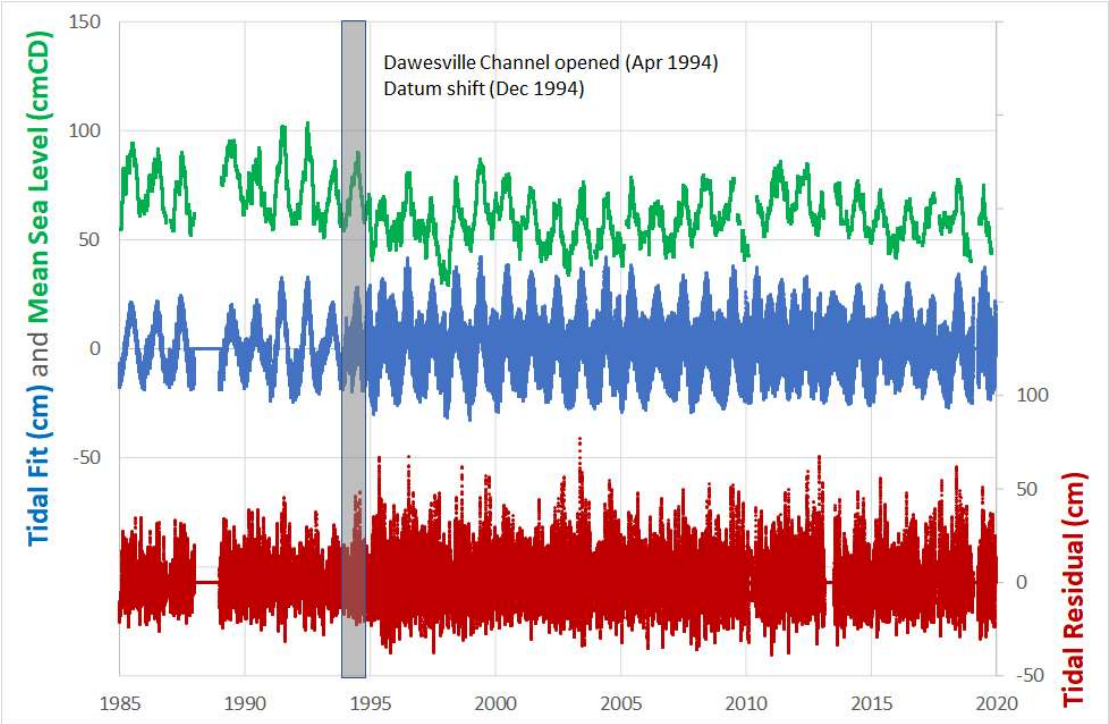


Figure B-13: Water Level Decomposition from Peel Tide Gauge

Winds and Water Levels

Relative timing of strong winds and high water levels influences spatial variation of nearshore processes in Peel-Harvey Estuarine System, including foreshore erosion-recovery patterns and wave overtopping. Specifically, foreshores with a westerly aspect are likely to experience more severe conditions due to potential for coincident high wave and water level conditions associated with westerly storms. These are the major cause of extreme wind speeds (Steedman & Associates 1982; Lemm *et al*. 1999) and cause positive storm surge through onshore wind and wave set-up and lower central pressure.

The joint probability of high wave and water levels for all directions has been assessed using a cross-plot of strong winds at and water levels from Mandurah for the available overlapping data period of 2001-2019 (Figure B-14). Maximum water level envelopes have been derived for wind speeds above 30km/hr and 50km/hr, representing reasonable upper limits.

This assessment indicates exposure of Peel-Harvey foreshores to waves is:

- Greatest along south-west to north facing foreshores, with all wind speeds above 50km/hr observed from 180°N clockwise through to 22.5°N (Figure 6 1). The most extreme wind and water level combination occurred during a severe winter storm on 16 May 2003, when a maximum water level of 1.55m AHD coinciding with a 52km/hr wind from 259°N. For these foreshores, beaches are likely to be dominated by waves.
- Lowest along east to southeast facing foreshores. For these foreshores, beaches will display a mixture of responses to wave and tide processes, with beach berm formation during high water levels potentially playing an important role in beach recovery.

This simple assessment helps explain the relationship between foreshore aspect and wave exposure within the Peel-Harvey Estuarine System. It also informs selection of flood risk scenarios and required foreshore walling design criteria.

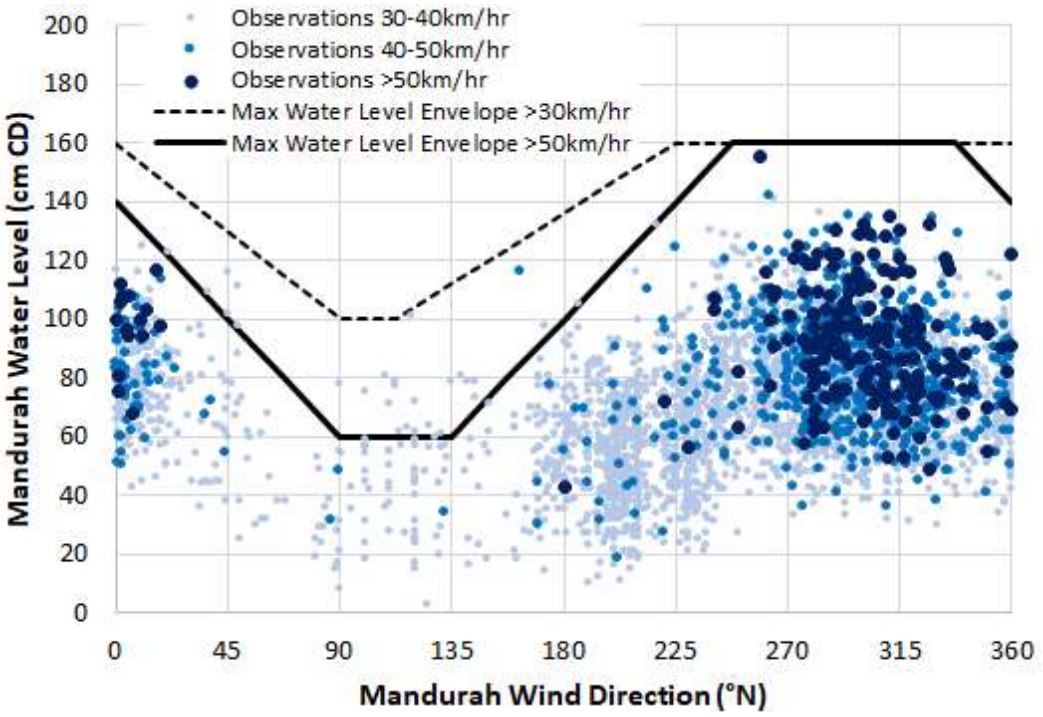


Figure B-14: Joint Occurrence of Winds and Water Levels

Spectral Admittance

Detailed evaluation of the changes in water level associated with opening of Dawesville Channel has demonstrated that both tides and surges inside the Peel-Harvey Estuarine System were increased (Eliot & McCormack 2019). The change to residuals was demonstrated to be spectrally related (Figure B-15), with negligible increase to long-period water level fluctuations (e.g. 30 days) and substantial enhancement of shorter period fluctuations (e.g. 6-12 hours).

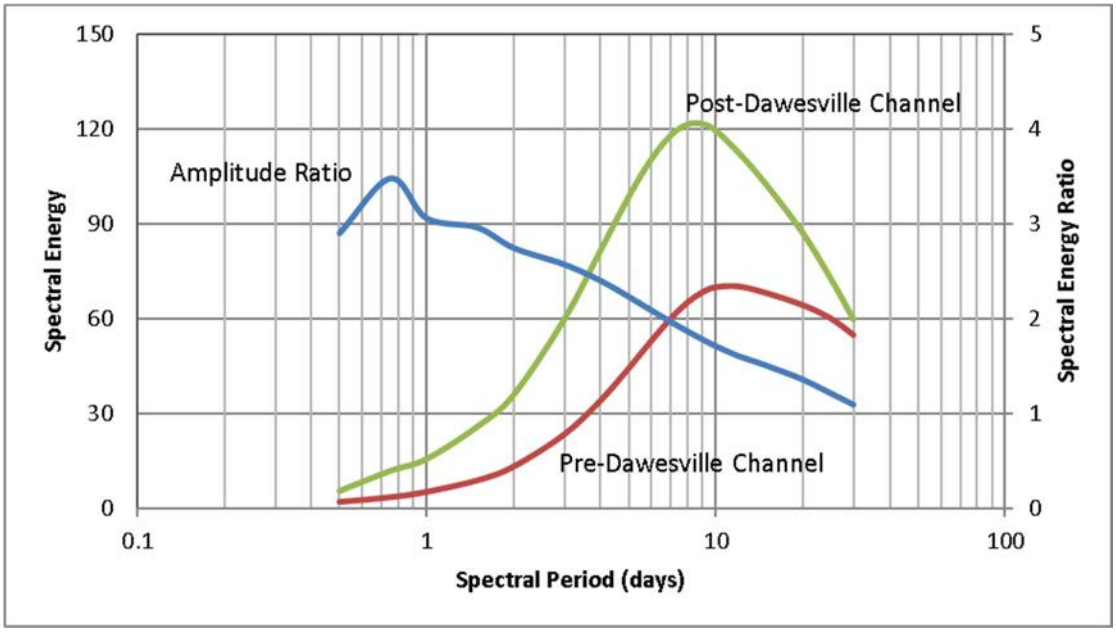


Figure B-15: Spectral Change of Tidal Residuals in Peel Inlet after Dawesville Channel

The pattern of spectral enhancement was also illustrated by the changes in tides (Figure B-16). However, this process is less well defined, as harmonic analysis may effectively transfer energy between modes of a similar frequency – such that the change needs to be considered as a combined function of multiple near-period constituents.

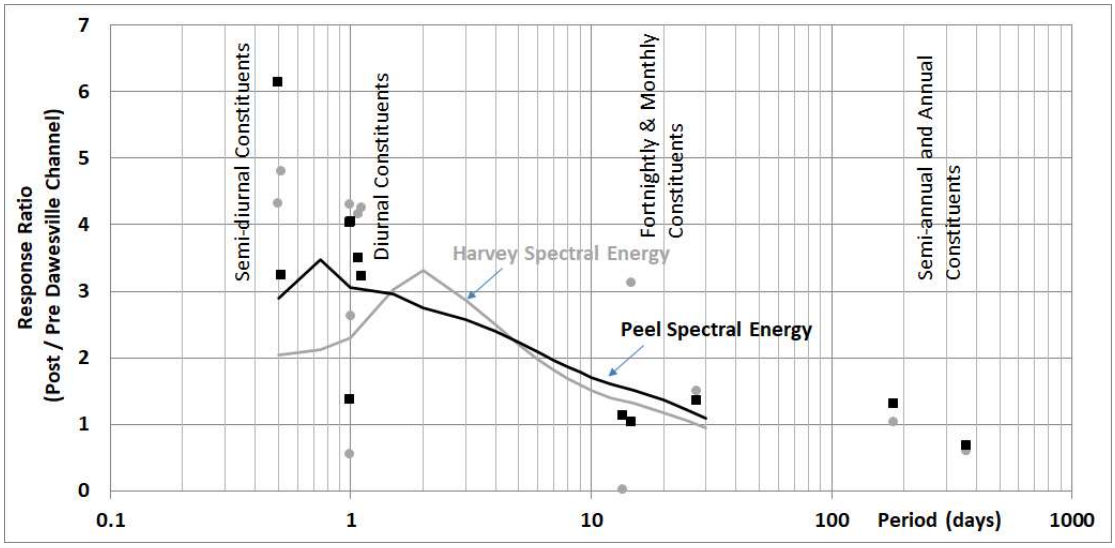


Figure B-16: Spectral Change of Tides and Residuals after Dawesville Channel

The conclusion that the estuary acts similarly to a spectral filter was consequently considered as a basis for transfer from ocean conditions to flood levels within the estuary. Harmonic analysis of the Mandurah tide gauge record from 2015 was compared with that of Peel Inlet, to assess transfer through into the estuary. This analysis was conducted for tidal harmonics, to enable identification of finer time scales. Ratios of tidal constituents demonstrated the effects of near-period constituents, plus enhancement of small-scale overtides, caused by distortion of the tidal signal entering shallow water.
An approximately log-linear response function was developed, which has been used for determination of the extreme coastal flooding condition (Report Section 3**Error! Reference source not found.**).

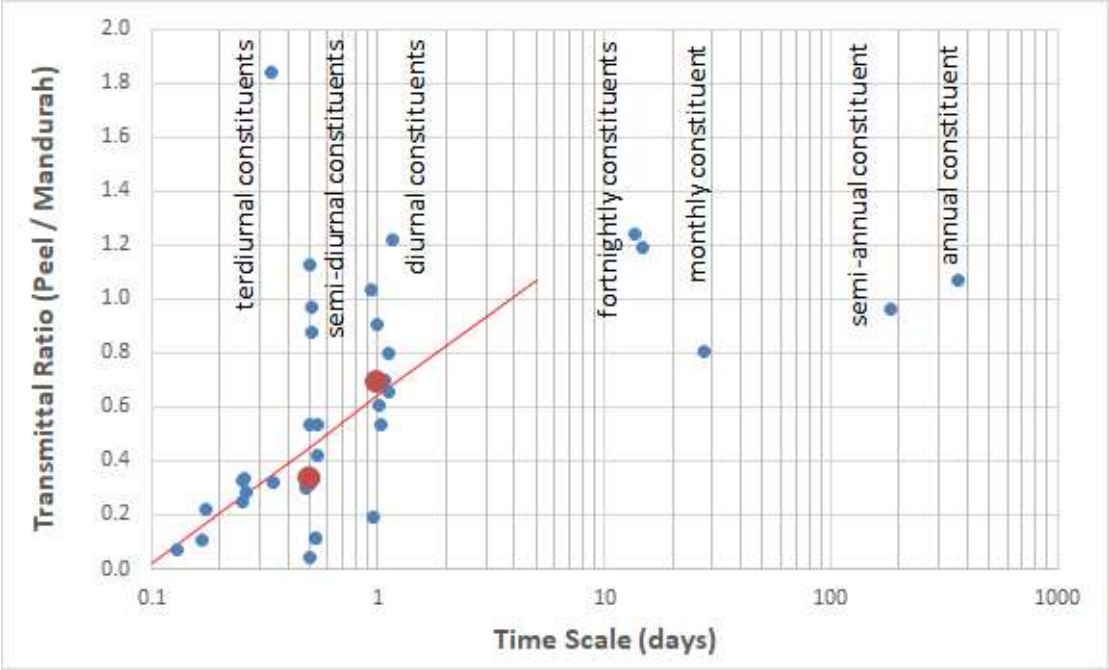


Figure B-17: Ocean-Estuary Admittance of Tidal Constituents 2015: Mandurah to Peel Inlet

Wave Conditions

There are no long-term measurements of waves within Peel-Harvey Estuary, with conditions expected to be highly affected by the position within the estuary due to wind fetch limitation (Travers *et al*. 2010). Consequently, numerical modelling has been used to explore potential wave conditions within the estuary (refer to Appendix H).

The SWAN (Surface Wave and Nearshore) model has been used to hindcast wave conditions within the estuary. Hindcasting was undertaken using a matrix of 10-minute average wind speeds and directions, covering the range measured from the Mandurah anemometer (Figure B-3). Modelling was unvalidated, as no suitable wave measurements were identified. However, this is a conventional application of SWAN, where use of typical parameters is likely to produce a fair representation, suitable for spatially comparative analysis. The model bathymetry and indicative mesh is based on the 20m gridded surface derived from 2016 LIDAR (Figure B-18).

Outputs corresponding to each wind speed and direction 'bin' have been used to hindcast wave conditions at each of ~900 points at approximately 100m intervals around the estuary margin. This has been used to create an equivalent wave height-direction-frequency matrix for each point (Figure B-19). Conversion from wind conditions observed from 2001-2018 to estimated wave conditions allows development of a hindcast time series for each point around the estuary (Figure B-20). It is noted that this approach neglects the time for waves to reach steady state under sustained wind conditions, however this is typically rapid for the relatively short fetches across the estuary (generally less than 30 minutes).

Some known limitations of the wave hindcasting approach are caused by local topographic influences on the wind observations and the requirement for waves to be described at some distance from the shore, such that they are not constrained by water depth. For the hindcast undertaken, expected biases include:

- Wave conditions from the south and east are expected to be slightly underestimated due to damping in the wind data set from the local topography at Mandurah Ocean Marina, where the Bureau of Meteorology anemometer is located. For the Peel-Harvey Estuarine System, some topographic sheltering is provided by the large ridge running along the western side of Harvey Estuary. These effects are acknowledged but have not been accounted for in the wave hindcast.
- Wave hindcast outputs have been provided at an approximate depth of 1.0m during mean sea level conditions, which can be up to 1km offshore along the western foreshore and is almost 2km in Austen Bay. The width of the estuarine margin may provide substantial damping to incident wave conditions, therefore affecting conclusions from the hindcast.

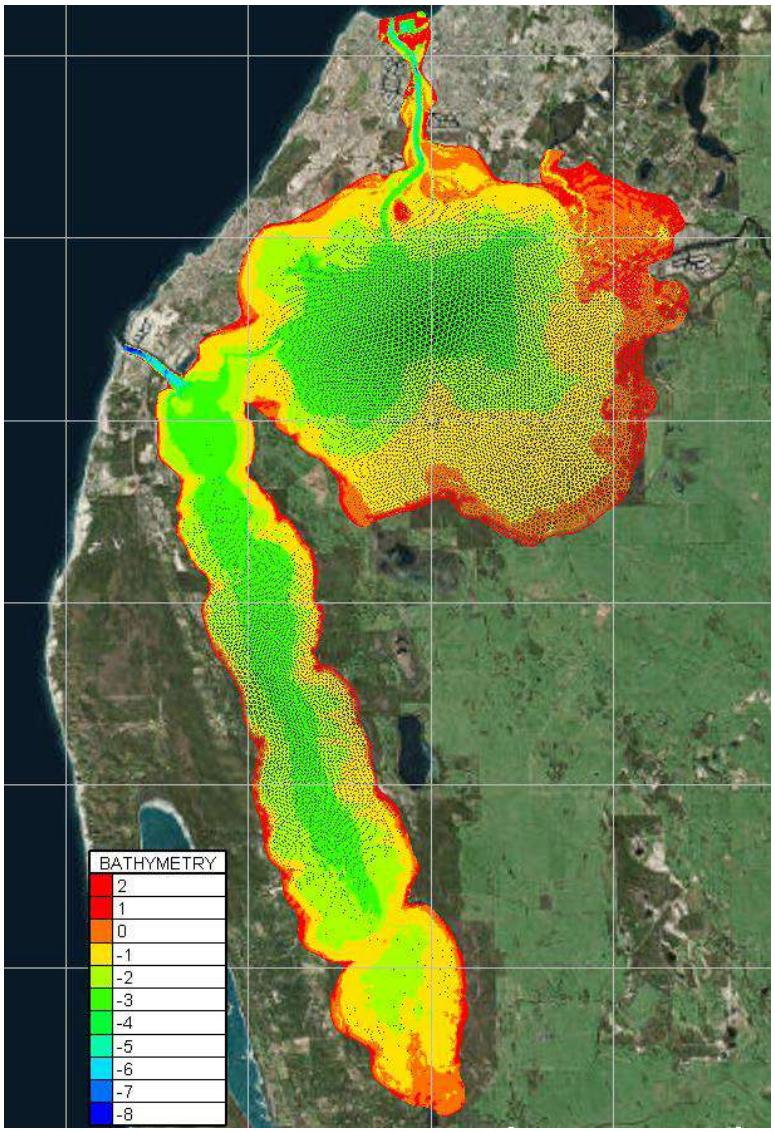


Figure B-18: Wave Hindcast Model Bathymetry

Wind Speed (m/s)		Wind Direction (deg)																
		0.0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5	315.0	337.5	360.0
Wind Frequency	100yr	19.5	17.6	14.6	12.3	11.4	11.7	12.2	13.0	13.8	14.8	15.7	17.6	20.2	21.0	21.7	20.9	19.5
	30yr	18.7	16.8	13.9	11.8	10.9	11.2	11.7	12.5	13.2	14.2	15.0	16.8	19.3	20.1	20.7	19.7	18.7
	10yr	17.8	16.0	13.3	11.2	10.4	10.6	11.1	11.9	12.5	13.5	14.3	16.0	18.4	19.1	19.7	19.0	17.8
	3yr	16.7	15.1	12.5	10.6	9.8	10.0	10.5	11.2	11.8	12.7	13.5	15.1	17.3	18.0	18.6	17.9	16.7
	1yr	15.6	14.0	11.6	9.8	9.1	9.3	9.7	10.4	11.0	11.8	12.5	14.0	16.1	16.7	17.2	16.6	15.6
	0.003	14.2	12.8	10.6	8.9	8.3	8.4	8.9	9.4	10.0	10.8	11.4	12.7	14.6	15.2	15.7	15.1	14.2
	0.01	12.5	11.3	9.3	7.9	7.3	7.5	7.8	8.3	8.8	9.5	10.0	11.2	12.9	13.4	13.9	13.3	12.5
	0.03	10.4	9.4	7.8	6.6	6.1	6.2	6.5	6.9	7.3	7.9	8.4	9.4	10.8	11.2	11.5	11.1	10.4
	0.1		6.9	5.7	4.8	4.4	4.5	4.8	5.1	5.4	5.8	6.1	6.8	7.9	8.2	8.4		

Wave Height (m)		Wind Direction (deg)																
		0.0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5	315.0	337.5	360.0
Wind Frequency	100yr	0.19	0.18	0.18	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19	0.18	0.18	0.20	0.21	0.21	0.19
	30yr	0.19	0.17	0.17	0.16	0.16	0.17	0.17	0.18	0.18	0.19	0.18	0.18	0.17	0.19	0.20	0.19	0.19
	10yr	0.19	0.17	0.16	0.16	0.15	0.16	0.17	0.17	0.17	0.18	0.17	0.17	0.17	0.17	0.19	0.19	0.19
	3yr	0.16	0.16	0.16	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	0.16	0.16	0.17	0.17	0.18	0.16
	1yr	0.14	0.15	0.15	0.14	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.16	0.18	0.10	0.14
	0.003	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.16	0.15	0.15	0.15	0.07	0.08	0.13
	0.01	0.11	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.14	0.13	0.15	0.15	0.15	0.15	0.07	0.03	0.11
	0.03	0.10	0.12	0.13	0.12	0.10	0.11	0.13	0.14	0.14	0.13	0.12	0.15	0.15	0.13	0.02	0.02	0.10
	0.1		0.07	0.11	0.01	0.02	0.03	0.05	0.07	0.10	0.12	0.11	0.09	0.07	0.04	0.02		

Wave Period (s)		Wind Direction (deg)																
		0.0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5	315.0	337.5	360.0
Wind Frequency	100yr	1.20	1.28	1.30	1.26	1.25	1.30	1.33	1.35	1.34	1.31	1.29	1.26	1.20	1.10	1.07	1.10	1.20
	30yr	1.19	1.27	1.28	1.24	1.24	1.28	1.31	1.34	1.33	1.29	1.27	1.25	1.19	1.08	1.06	1.09	1.19
	10yr	1.13	1.26	1.25	1.22	1.21	1.25	1.29	1.32	1.31	1.27	1.26	1.23	1.18	1.08	1.03	1.08	1.13
	3yr	1.13	1.24	1.23	1.19	1.19	1.22	1.27	1.30	1.29	1.25	1.24	1.22	1.17	1.07	1.02	1.01	1.13
	1yr	1.14	1.21	1.20	1.15	1.16	1.19	1.25	1.28	1.27	1.22	1.22	1.20	1.15	1.04	0.98	1.04	1.14
	0.003	1.14	1.18	1.16	1.11	1.11	1.17	1.21	1.25	1.24	1.20	1.19	1.18	1.14	1.04	0.97	0.99	1.14
	0.01	1.11	1.14	1.12	1.05	1.11	1.08	1.12	1.17	1.20	1.18	1.13	1.14	1.11	1.02	0.93	1.15	1.11
	0.03	1.02	1.10	1.07	1.05	0.95	0.95	0.98	1.04	1.10	1.14	1.11	1.06	1.04	0.96	1.10	1.25	1.02
	0.1		0.91	1.05	0.87	0.84	0.83	0.82	0.86	0.91	0.96	0.98	1.02	1.03	1.04	1.08		

Wave Dir (deg)		Wind Direction (deg)																
		0.0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0	202.5	225.0	247.5	270.0	292.5	315.0	337.5	360.0
Wind Frequency	100yr	39	67	78	89	106	123	138	152	162	181	195	211	230	275	320	1	39
	30yr	39	68	78	89	106	123	139	152	162	181	196	211	228	270	315	8	39
	10yr	38	68	77	88	106	123	139	152	162	180	196	211	227	258	316	9	38
	3yr	51	68	76	87	105	124	139	152	162	180	197	211	226	255	289	5	51
	1yr	58	68	75	86	105	124	140	152	162	178	198	211	226	252	298	49	58
	0.003	60	67	74	83	105	122	142	152	163	178	198	212	225	244	241	56	60
	0.01	62	67	73	81	99	139	145	155	165	176	197	213	226	236	227	81	62
	0.03	64	66	71	77	142	143	148	160	169	175	186	209	224	225	201	93	64
	0.1		72	68	138	141	146	150	166	175	179	179	181	192	184	180		

Figure B-19: Wave Matrix for Yunderup (Location 407)

Box defines points that would be used for hindcast under wind of 10.5m/s from 165°

Wave modelling was conducted for steady wind conditions corresponding to each of the wind speed and direction combinations in the upper table. Model outputs of significant wave height, period and wave direction are plotted in each of the subsequent tables. The relationship between wind and wave estimates allows estimation of waves. For example, wind conditions of 10.5 m/s from a direction of 165° are within the box marked inside the upper table. The corresponding box in the lower three tables indicates the interpolation space for significant wave height, wave period and wave direction, respectively.

For each location around the estuary margin, the wave matrices have been used as look-up tables, combined with the 17 years of wind observations to provide wave hindcast time series (Figure B-20). Water level variation was included in the hindcast, through consideration of the modelled MSL +/-0.3m cases. Wave conditions within the estuary are generally low energy, with average wave heights of 0.2-0.3m and annual maxima of 0.4-0.6m. These conditions are suitable for development of riparian vegetation (Shafer *et al*. 2003), with disturbance such as undercutting expected when waves are above ~0.5m.

Time series illustrate seasonal differences in hindcast wave conditions:

- The greatest seasonal variation of wave height occurs where there are the largest northwesterly fetches (e.g. Austin Cove). Smaller seasonality is apparent where fetches are generally shorter, or there is a narrow directional over which waves could be generated (e.g. Birchmont).
- Seasonality of wave conditions is similar for each year, suggesting limited inter-annual variability. This is unsurprising, as fetch limitation within the estuary means that there is typically only a small increase in wave height even for large differences in wind speeds.

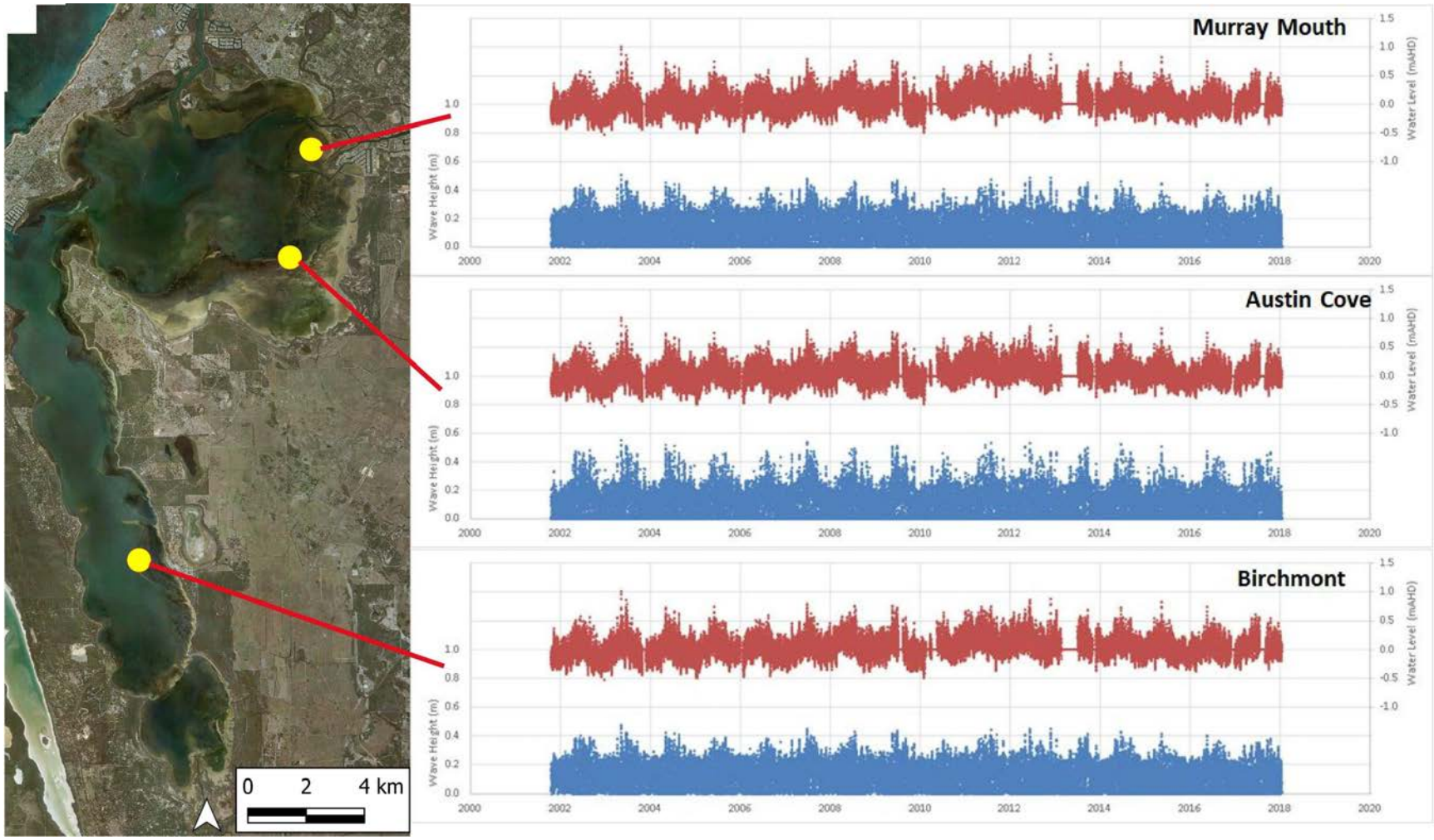
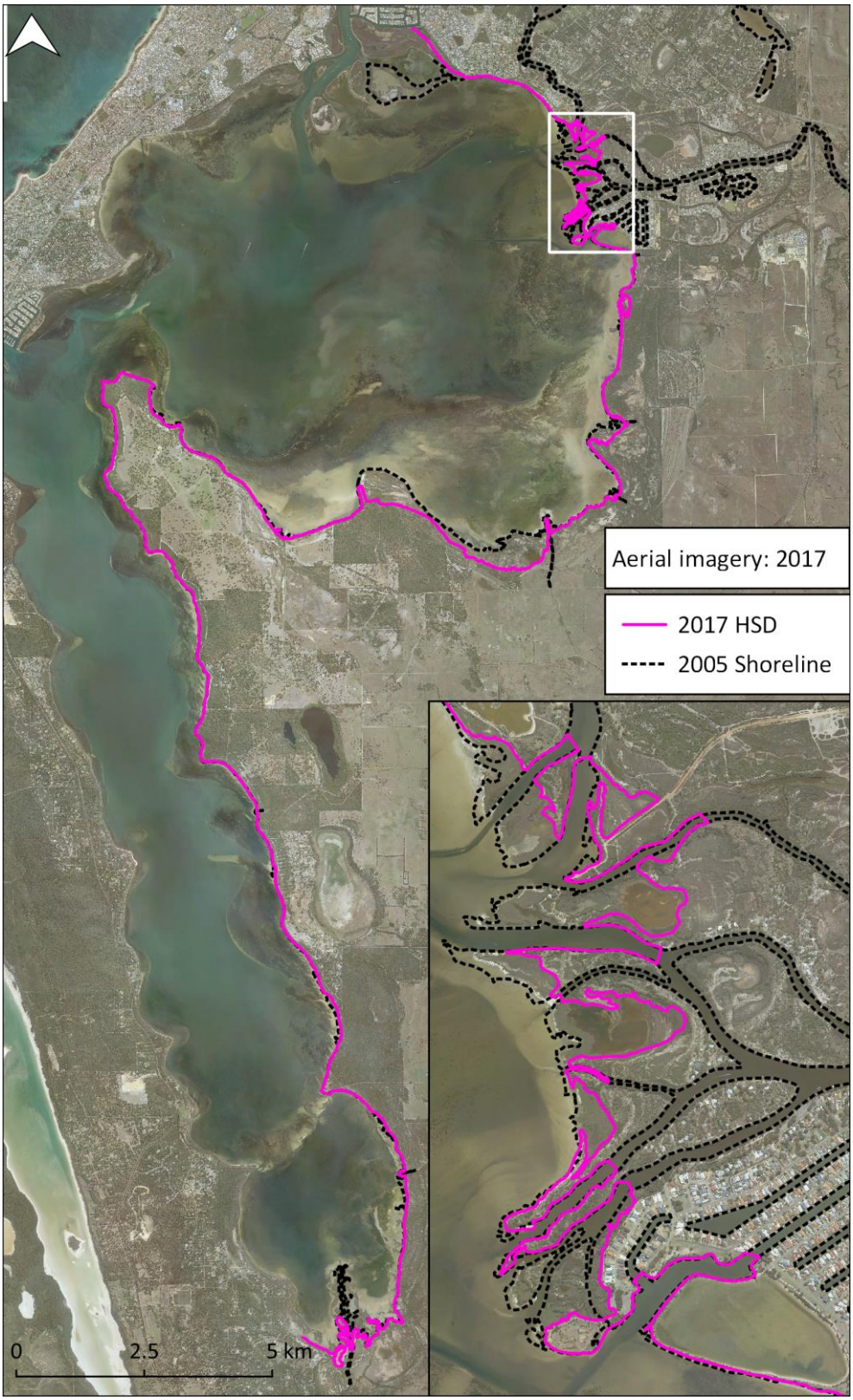


Figure B-20: Hindcast Time Series for Three Sites & Corresponding Wind Components

Appendix C – Vegetation Line Change Summary



Areas of identified vegetation line change (2005-2017)

A0 to A1 - Minor Change

1994 to 2005



1994 Imagery
1994 - Yellow Line
2005 - Green Line

Little change, some seasonal variation to sand spit at eastern end of Creery Island, although little movement of vegetation line.

Little change around Peel Parade near A1.

Variations in submerged features.

1994 to 2005



2005 Imagery
1994 - Yellow Line
2005 - Green Line

2005 to 2011



2011 Imagery
2005 - Green Line
2011 - Blue Line

Little change, more submerged features due to higher average water levels in 2011.

2005 to 2017

Little change, some retreat of vegetation on Creery Island towards 2017.



2017 Imagery
2005 - Green Line
2017 - Red Line

A1 to A2 - Minor Change

1994 to 2005



1994 Imagery
1994 - Yellow Line
2005 - Green Line



2005 Imagery
1994 - Yellow Line
2005 - Green Line

Some minor movement of shoreline. Variations in submerged features; historic dredge scars evident in 1994 imagery.

2005 to 2011



2011 Imagery
2005 - Green Line
2011 - Blue Line

Little change, submerged features due to higher average water levels in 2011.

2005 to 2017



Minor change, seawalls installed along much of this foreshore between 2011 and 2017. These seawalls have pushed shoreline south by between 4.0m and 8.5m in some locations, removing the high tide sandy beach.

2017 Imagery
2005 - Green Line
2017 - Red Line

A2 to A3 - Minor Change North End, Seawall Refurbished, Major Change at Point north of Serpentine River Entrance

1994 to 2005



1994 Imagery
1994 - Yellow Line
2005 - Green Line



2005 Imagery
1994 - Yellow Line
2005 - Green Line

Minor recession of shoreline in northern part of segment.

Reshaping of point feature on northern side of Serpentine River entrance, with 18m of erosion at tip of point, and 45m of erosion adjacent to this. The sand appears to have shifted to a new vegetated area on this point, with an increase in width of 27m due to accretion - **major change**.

2005 to 2011



2011 Imagery
2005 - Green Line
2011 - Blue Line

Shoreline recession up to 10m along the northern part of this foreshore section skewed by high water levels of 2011.

Rock armouring installed along northern section of foreshore between 2005 and 2011, presumedly to protect adjacent asphalt road. This seawall discontinues at parkland with inland lake.

Further erosion of point feature at northern side of Serpentine River Entrance. Point tip has receded 28m, northern edge of point has receded between 19m and 13m, small spit of length 26m has accreted in the middle of this point feature, in a NW direction - **major change**.

2005 to 2017



2017 Imagery
2005 - Green Line
2017 - Red Line

Upgraded seawall installed along northern part of this segment between 2011 and 2017. This seawall has reclaimed eroded foreshore since 2011, but shoreline is still between 2m and 8m landward of 2005 position.

Note refurbished seawall is from A2 point, in a southerly direction to 1/3 of the way along John Street.

Erosion at parkland with lake up to 17m landward of its 2005 position in its most affected part, however it has accreted from the 2011 high water level position.

At the point north of the Serpentine River entrance, erosion of 50m from the 2005 position has been experienced. This is 24m of erosion between 2011 and 2017 - **major erosion**.
The spit that was forming on the NW side of this point in 2011 imagery has migrated further north, and has stabilised with the growth of vegetation. It is 36m from the 2005 shoreline position at its longest point - **major change**.

A3 to C1 (not including the inner banks of the Serpentine River) - Major Change

1994 to 2005



1994 Imagery
1994 - Yellow Line
2005 - Green Line



2005 Imagery
1994 - Yellow Line
2005 - Green Line

Erosion of the NW and SE points on the SW end of Jennala Island. Between 1994 and 2005, the NW point's vegetation line has eroded approximately 70m, while the SE point's vegetation line has eroded approximately 30m. The centre section of the SW end of Jennala Island has eroded by between 16m and 20m - **major erosion**.

The point that the vehicle barge docking area at the end of Tonkin Drive is located on, has eroded by between 5m and 7m during this time period.

Erosion has impacted Cooleenup Island's western end between 1999 and 2005, with its southern point eroding by 6m, northern point eroding 8m and variable erosion along the shoreline.

2005 to 2011



2011 Imagery
2005 - Green Line
2011 - Blue Line

The rate of erosion at the SW end of Jennala Island has decreased; 3m of erosion at its N part, 11m in its middle section and 13m erosion at the W corner.

The point which has the barge dock at the end of Tonkin Dr, has eroded a further 2m to 4m, with scalloping of foreshore experienced.

	The W end of Cooleenup Island has eroded; its point has receded by 13m and its protruding features have receded by 3m to 17m - **major erosion**.

2005 to 2017



2017 Imagery
2005 - Green Line
2017 - Red Line

The rate of erosion at the SW end of Jennala Island has remained steady from 2005 to 2011 to 2017. Erosion from 2005 to 2017 amounts to 7m of erosion at its N part, 15m in its middle section and 27m erosion at the W corner. This can be considered as **major erosion**.

Between 2005 and 2017, approximately 5m of erosion has been experienced around the point which has the barge dock at the end of Tonkin Dr.

Further erosion at the W end of Cooleenup Island. The point has receded 44m between 2005 and 2017, the majority of this erosion (32m) occurring between 2011 and 2017 - **major erosion**. A new spit has formed between 2011 and 2017 on the northern side of the Point, it is 11m in length. The western shoreline of Cooleenup Island has eroded at a rate of 25 and 2m from 2005 to 2017, with 8m of this erosion experienced between 2011 and 2017 - **major change**.

C1 to D1 (not including the inner banks of the Murray River) - Major Change

1994 to 2005



1994 Imagery
1994 - Yellow Line
2005 - Green Line



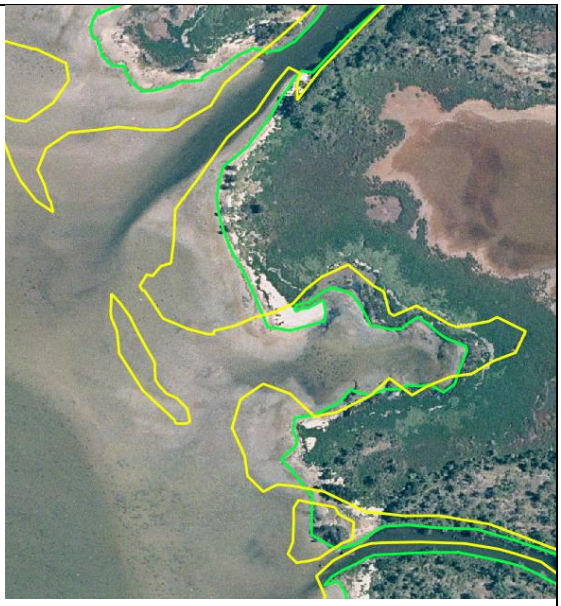
2005 Imagery
1994 - Yellow Line
2005 - Green Line

Major change with **major erosion** experienced along the western sides of all of the Murray River delta islands, being Meeyip, Ballee, Worallgarook and Little Yunderup Islands.

Major change per island:



Meeyip Island (western side, 2005 Imagery): **Major erosion** at the northern end, with an area of 150m long and 35-50 m wide eroded. 176m long section from the centre to the southern end has eroded, with an entire "T-head" spit removed from 76m landward erosion.



Ballee Island (western side, 2005 Imagery): **major erosion** including the loss of a small sand island at the northern end. The vegetation line has receded 50m at the northern end and 33m at the southern end. Some repositioning of the natural channel of Worallgarook Branch with reforming of a small vegetated feature at the SW corner of Ballee Island.



Worallgarook Island (western end, 2005 imagery):
Major erosion on the NW corner, reshaping of the centre of this foreshore, with an area 85m long and over 15m wide eroded. The centre section has accreted some 19m, and the south western point end has reshaped with the shrinkage of a small island by 40m in length.



Little Yunderup Island (south-western end, 2005 Imagery):
Major erosion to much of this small island, (note the poor resolution of the 1994 imagery reduces confidence in the position of the 1994 vegetation line). There may have been over 60m eroded from the SW end of this island between 1994 and 2005.

2005 to 2011



2011 Imagery
2005 - Green Line
2011 - Blue Line

Major erosion at the NW tip of **Meeyip Island** between 2005 and 2011, this point receded by 90m and experienced a 17m reduction in width along the north half of its SW facing beach. The remaining half of the SW facing beach, experienced **major change** with the formation of a sand bar and a thing long lagoon feature running parallel to the beach. The southern corner of the island experienced accretion from 2011 to 2017, essentially closing the 15m wide entrance to the natural channel of Meeyip Branch. This was a reversal of the erosion trend in this area from 2005 to 2011.

Ballee Island eroded by up to 15m on its NW and SW areas, with a small accretion zone in its centre - **major change**.

Worallgarook Island eroded by up to 15m on its NW half, and reshaped with minor accretion in the middle of its westerly facing centre beach. The SW point had areas that eroded between 24m and 14m - **major change**.

Little Yunderup Island's NW facing side eroded some 9m, with this eroded sand presumedly accreting between this small island and the larger Yunderup Island, fusing the two islands together.

2005 to 2017



2017 Imagery
2005 - Green Line
2017 - Red Line

The **major erosion** trend continued at the NW tip of **Meeyip Island** between 2011 and 2017, this point receded by a further 30m (totalling 120m of recession 2005 to 2017). An area of 200m length by average width of 15m eroded from 2011 to 2017 (total width of shoreline lost 2005 to 2017 is 25m to 40m along this beach. The southern corner of the island also eroded, with a range of 11m to 23m.

Erosion on **Ballee Island** continued on the northern and southern corners sections, with the accreted beach in the centre moving slightly, and the intertidal marsh in the centre of the island's eastern side building up in elevation - **major change**.

Worallgarook Island appears to have had accretion along the intertidal marshes of its western side. Some erosion has towards the southern end of this beach, and protruding features that were previously located on the SW point in 2005 and 2001 have eroded away.
A small sand spit of width 18m, has accreted on Worallgarook Island's side of the Yunderup Branch natural channel - **major change**.

Little Yunderup Island's NW facing side eroded some 9m from 2011 to 2017, bring the total eroded width up to 18m (2005 to 2017). The sand bank fusion between the smaller and larger Yunderup Islands (forming 2005 to 2011) accreted further from 2011 to 2017.

D1 to D2 (not including the inner banks of the Murray River) - Major Change

1994 to 2005



1994 Imagery
1994 - Yellow Line
2005 - Green Line



2005 Imagery
1994 - Yellow Line
2005 - Green Line

Erosion of the SW end of **Goongoolup Island** occurred, with the vegetation line receding at least 26m between 1994 and 2005. On the mainland of South Yunderup, the SW section receded by 20m - **major change**.

Within the artificial canal system, the non-armoured shoreline (no seawall) near the South Yunderup boat ramp and at Marma Way/Moyup Way has eroded slightly during this timeframe. Aside from an additional canal arm being constructed parallel to Batavia Quays, the canal system has not eroded due to its artificial hard walling.

Some erosion has been experienced around the reclaimed bund/pond area that is located opposite the South Yunderup Boat Ramp. The perimeter of this bund is not armoured with a seawall; its SW corner eroded by 20m between 1994 and 2005 - **major change.** The remainder of the southerly facing bund wall experienced minor erosion during this timeframe - **minor change**.

2005 to 2011



2011 Imagery
2005 - Green Line
2011 - Blue Line

Elevated water levels in 2011 combined with erosional pressures between 2005 and 2011 to cause an overall recession of the SW end of **Goongoolup Island**. Between 13m and 6m of vegetated shoreline was removed. Two spits also formed, one on each side of this island. Each of the spits extend past the 2005 shoreline position by approximately 18m - **major change**.

On the mainland of South Yunderup, SW section receded by 13m, with recession decreasing around to the southern section to 7m of vegetated shoreline removed. Reshaping of the spit system at the Murray River delta occurred. At the entrance to the Canal System, the shoreline has evolved to form an additional spit some 220m SE of South Yunderup Boat Ramp - **major change.**

Erosion within the artificial canal system, near the South Yunderup boat ramp and at Marma Way/ has been experienced, with around 10m eroded from both sides of the Batavia Quays canal entrance corners and the adjacent vegetated canal banks(along Moyup Way (these canal banks are not armoured) - **major change**.

On the opposite side of the main entrance canal, the non-armoured canal banks have

eroded by 6m to 2m. Around the perimeter of the pond bund all the way to its intersection with the historic shoreline, similar rates of erosion have been experienced, while up to 10m of shoreline has been removed from the bund wall's SW corner - **localised major change**.

2005 to 2017



2017 Imagery
2005 - Green Line
2017 - Red Line

The 2017 imagery shows that erosion at the SW end of **Goongoolup Island** has continued - **major change**. The breakthrough penetration of the beach into a small lagoon between 2011 and 2017 has then morphed into shoreline erosion exceeding 20m in this immediate area. The spits on either side of the island have also accreted by approximately 10m during this timeframe (overall both new spits accreted by approximately 30m from 2005 to 2017).

On the mainland section of South Yunderup, the 2005 to 20011 trend of foreshore erosion has continued, , but at a slightly lesser rate. A tidal lagoon has formed on the SW corner of this area, with accretion closing off the existing spit. On the eastern side, just south of South Yunderup boat ramp, another intertidal lagoon and mud flat has been formed through accretion of sediment - **major change**.

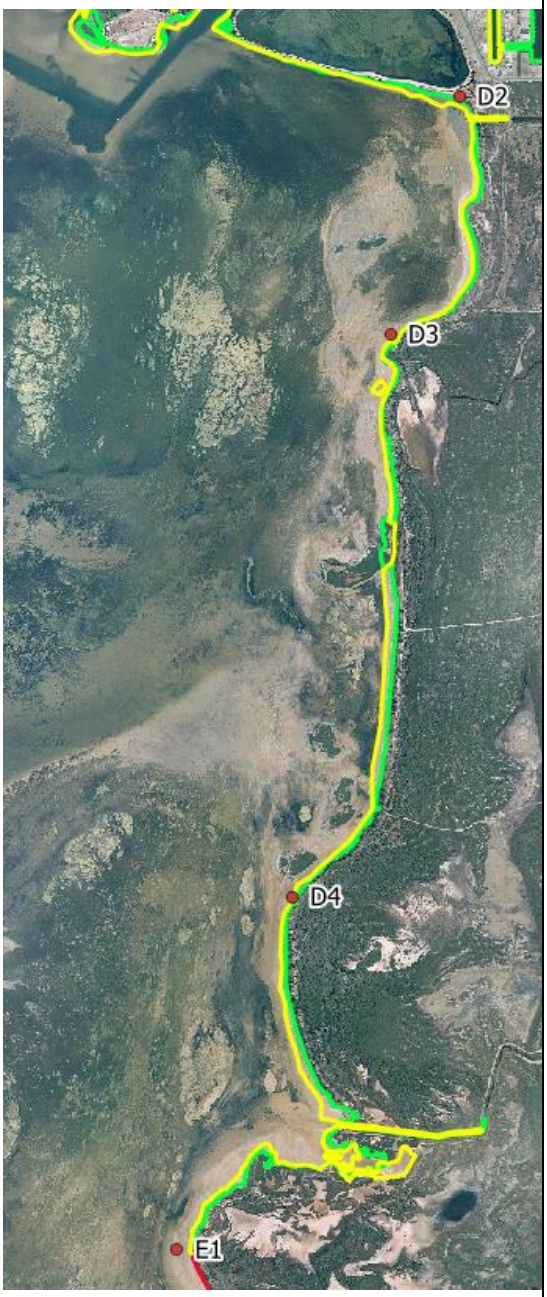
	Erosion has continued along the non-armoured parts of the main navigation channel into South Yunderup Canals - **minor change**. The shoreline around the bunded pond has stabilised since 2011, due to the lower water levels up to 2017 - **minor change**.

D2 to E1 - Minor Change

1994 to 2005



1994 Imagery
1994 - Yellow Line
2005 - Green Line



2005 Imagery
1994 - Yellow Line
2005 - Green Line

Minor change along this stretch of foreshore between 1994 and 2005.

2005 to 2011



2011 Imagery
2005 - Green Line
2011 - Blue Line

Minor change along this stretch of foreshore between 2005 and 2011.

2005 to 2017

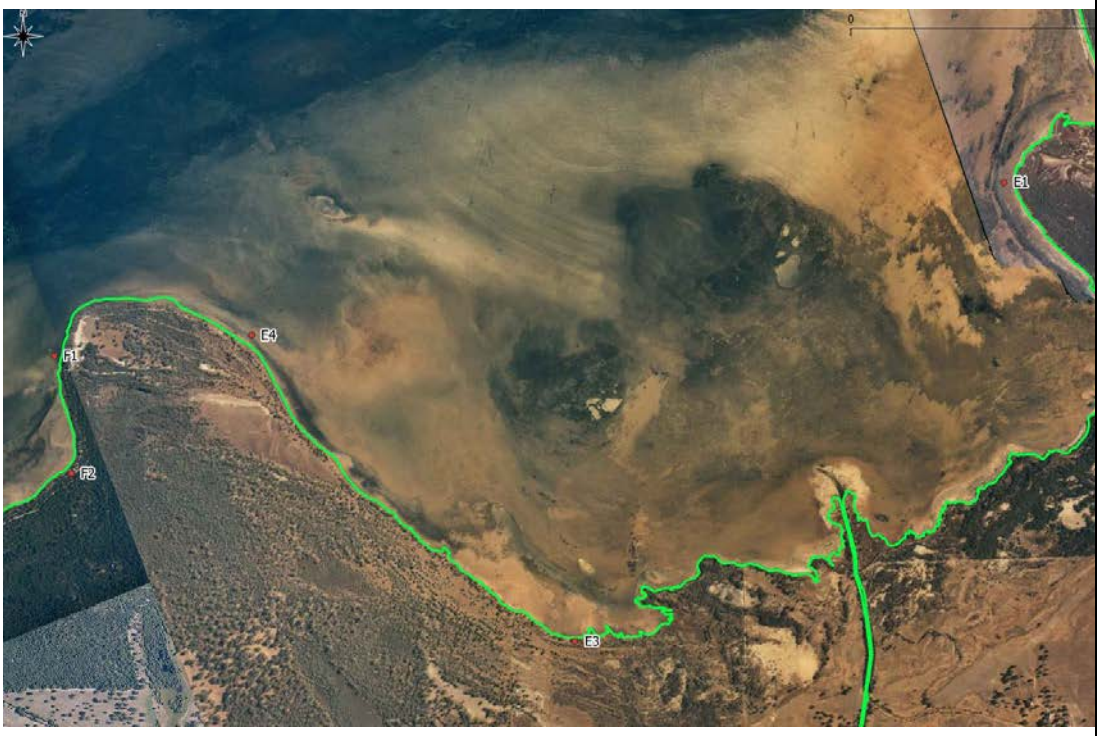


2017 Imagery
2005 - Green Line
2017 - Red Line

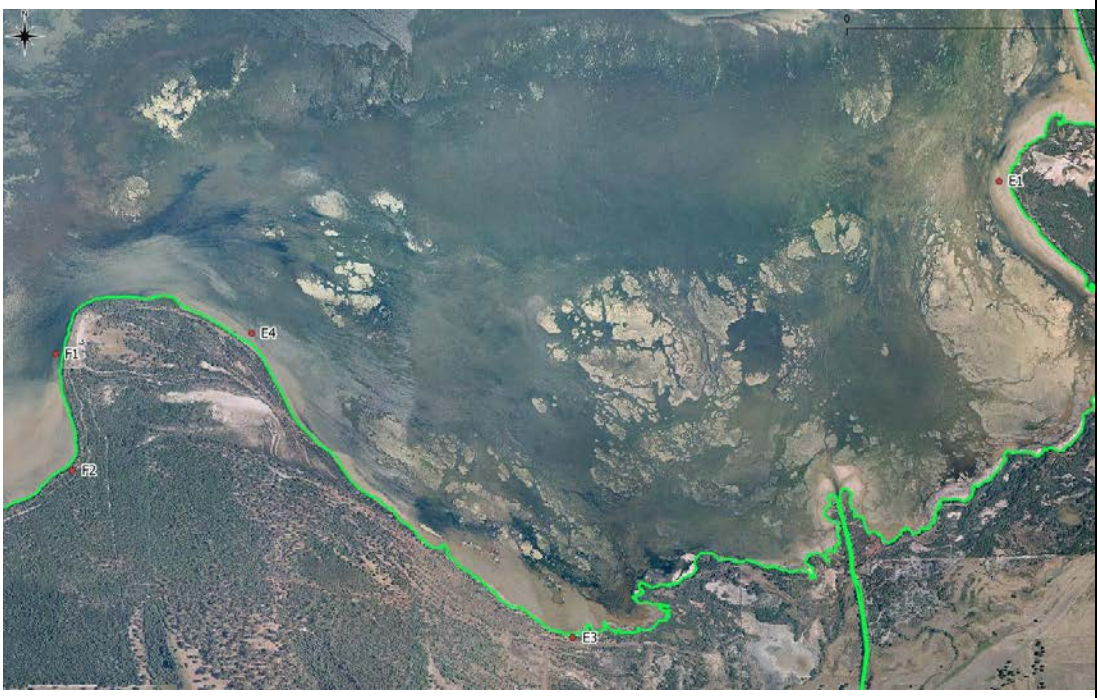
Minor change along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little vegetation retreat.

E1 to F1 - Minor Change

1994 to 2005



1994 Imagery
2005 - Green Line



2005 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 1994 and 2005.

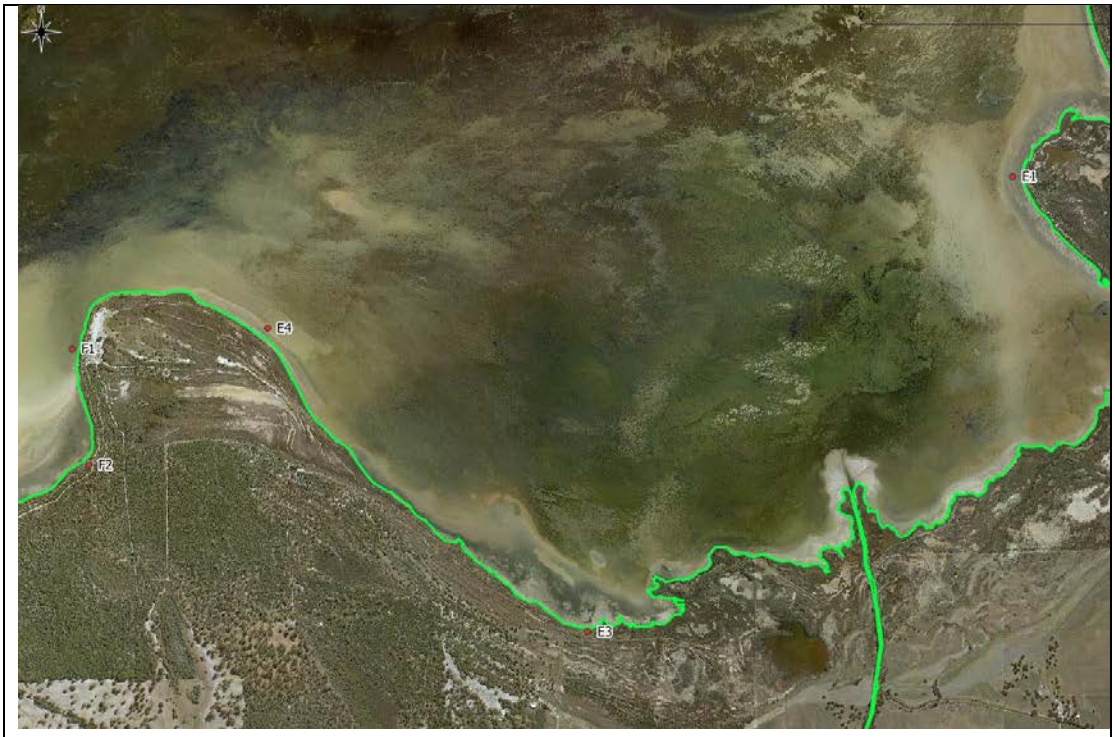
2005 to 2011



2011 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2011.

2005 to 2017



2017 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little vegetation retreat.

F1 to G1 - Minor Change

1994 to 2005



1994 Imagery
2005 - Green Line



2005 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 1994 and 2005.

2005 to 2011



2011 Imagery

2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2011.

2005 to 2017



2017 Imagery

2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little vegetation retreat.

G1 to H1 - Minor Change

1994 to 2005



1994 Imagery
2005 - Green Line

1994 to 2005



2005 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 1994 and 2005.

2005 to 2011



2011 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2011.

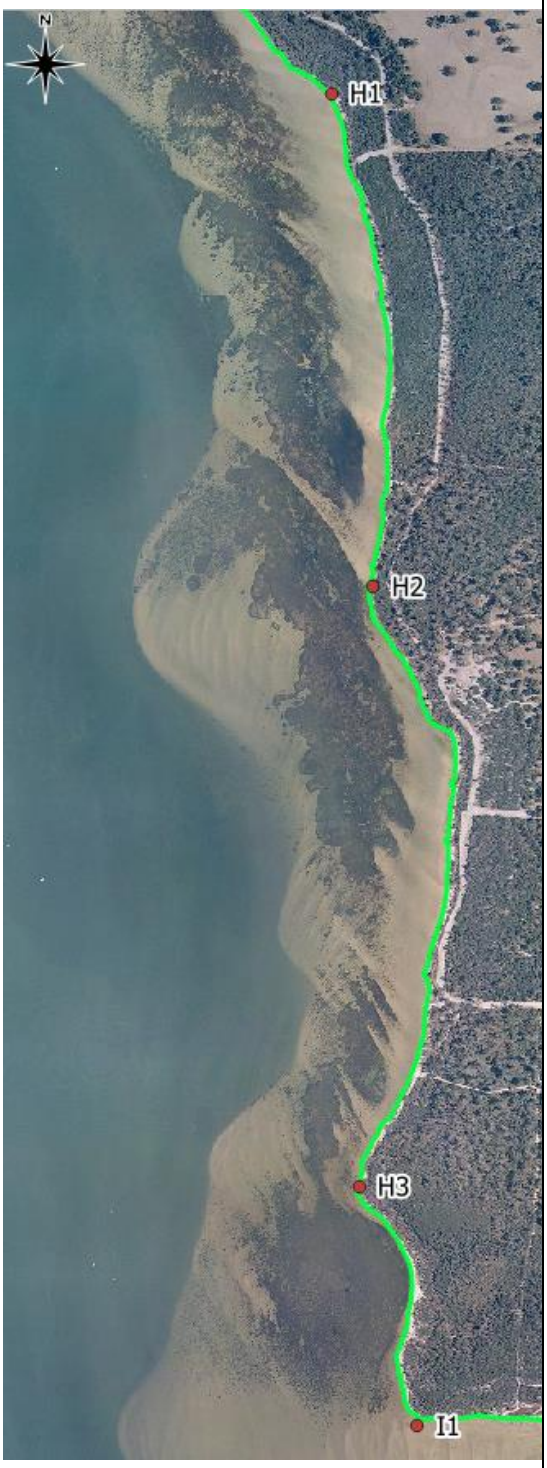
2005 to 2017



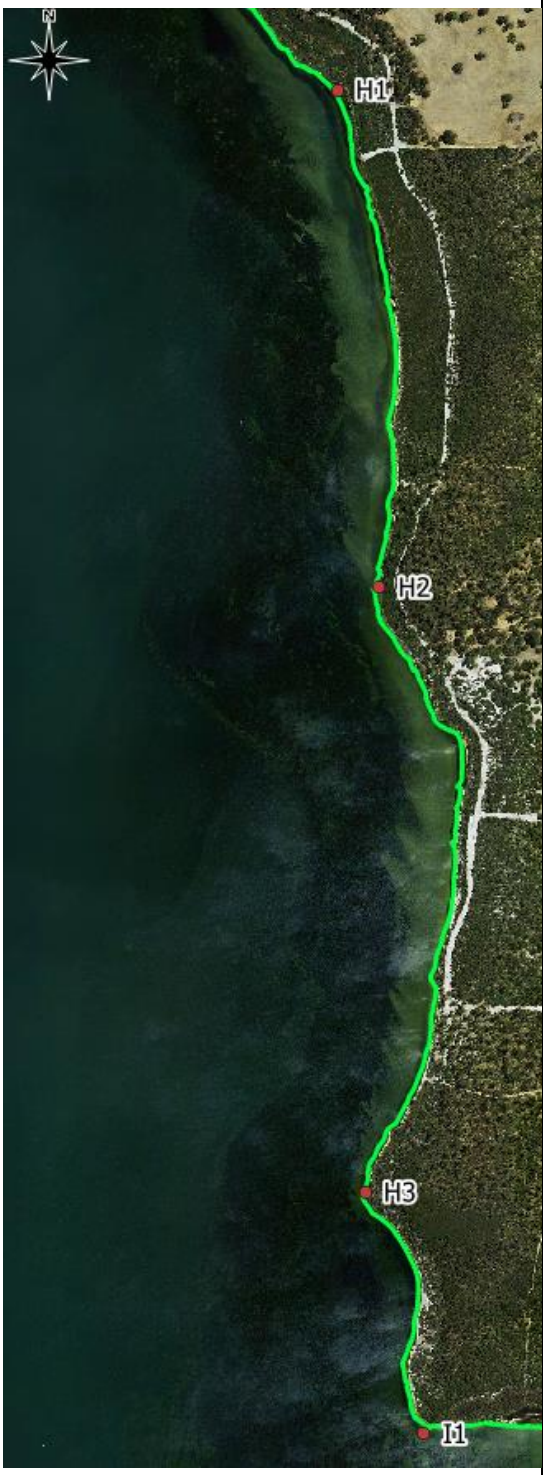
2017 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little permanent vegetation line retreat.

H1 to I1 - Minor Change

1994 to 2005	1994 to 2005
	
1994 Imagery 2005 - Green Line	**2005 Imagery** 2005 - Green Line **Minor change** along this stretch of foreshore between 1994 and 2005.

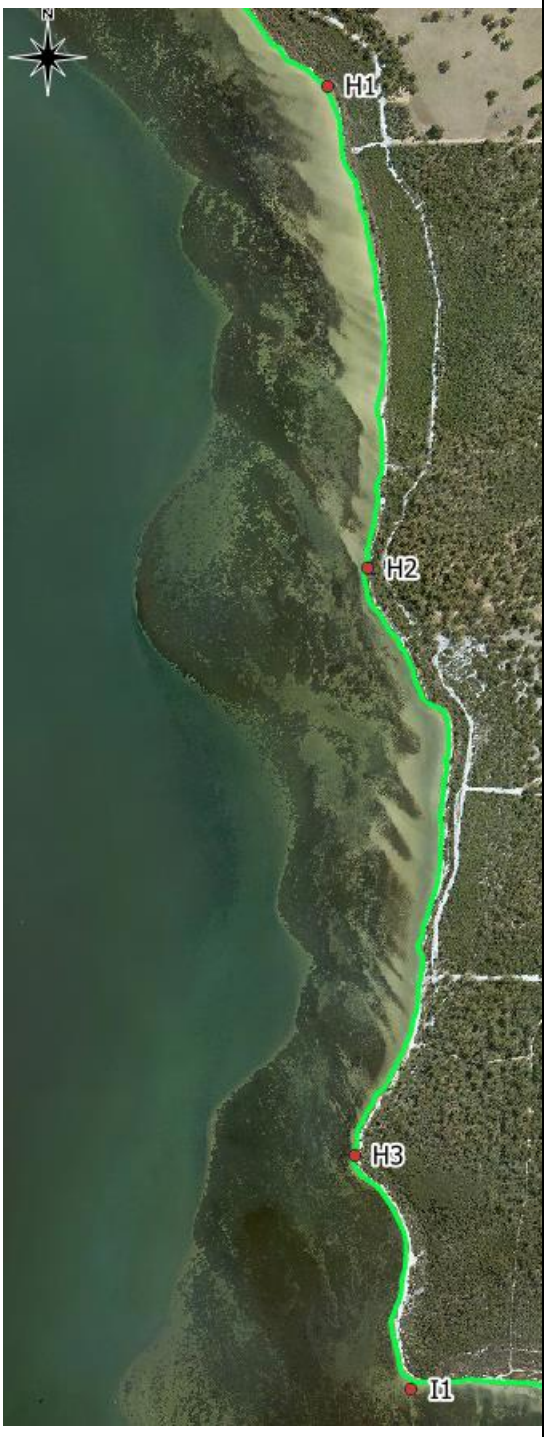
2005 to 2011



2011 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2011.

2005 to 2017

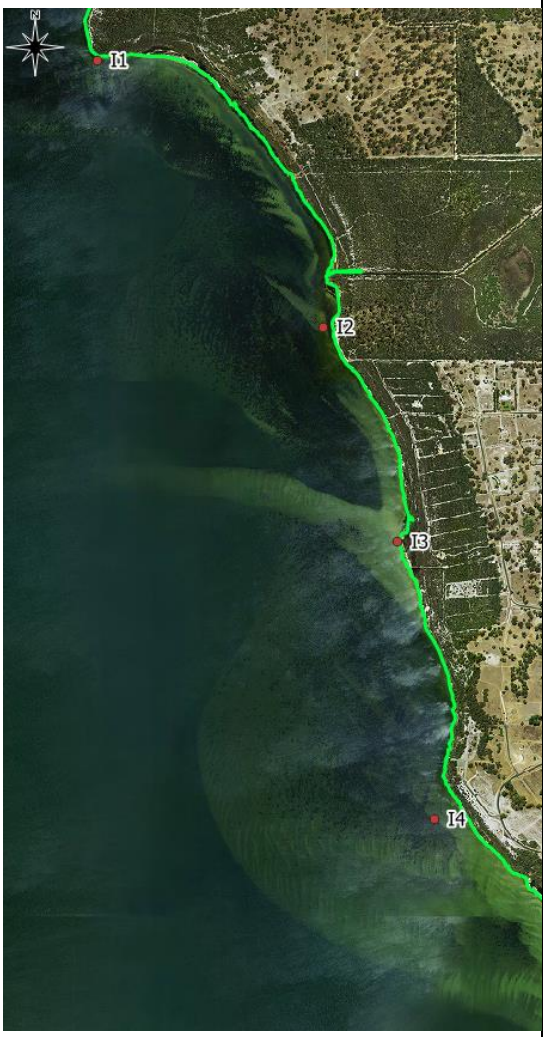
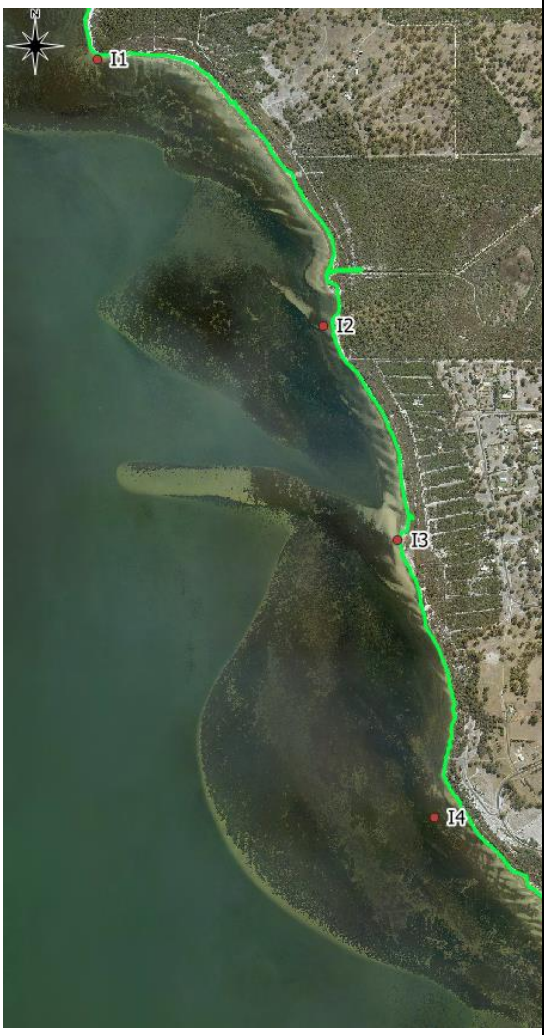


2017 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little permanent vegetation line retreat.

I1 to J1 - Minor Change

1994 to 2005	1994 to 2005
	
1994 Imagery 2005 - Green Line	**2005 Imagery** 2005 - Green Line **Minor change** along this stretch of foreshore between 1994 and 2005.

2005 to 2011	2005 to 2017
	
2011 Imagery 2005 - Green Line **Minor change** along this stretch of foreshore between 2005 and 2011.	**2017 Imagery** 2005 - Green Line **Minor change** along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little permanent vegetation line retreat.

J1 to J4 - Minor Change

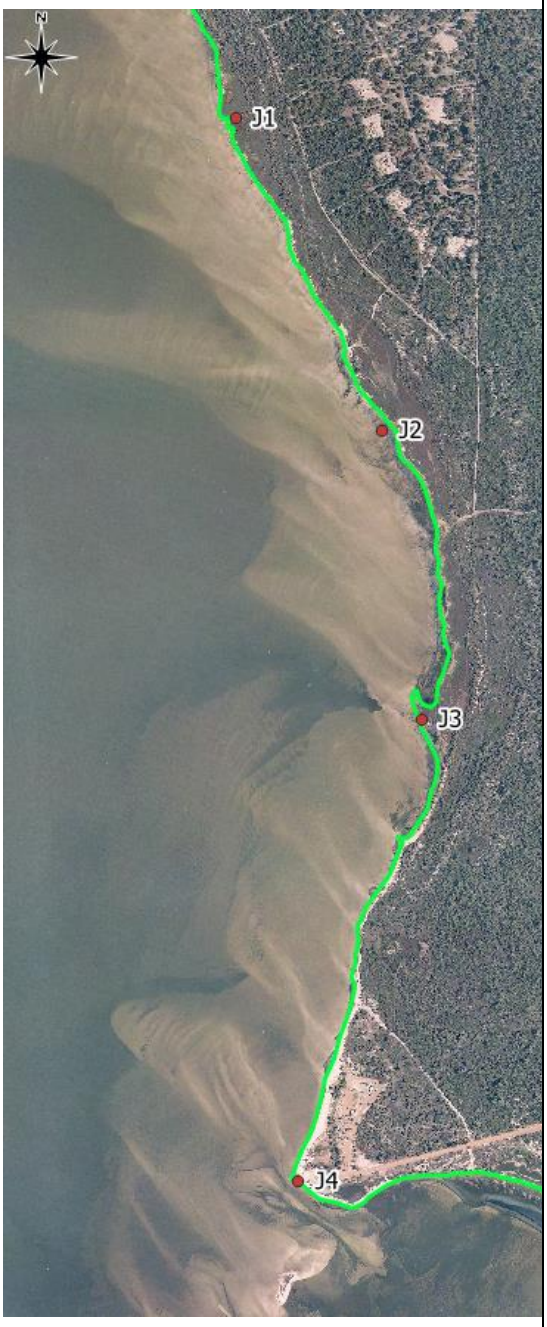
1994 to 2005



2005 - Green Line
1994 Imagery*

(* 1994 Imagery digitisation error around J4)

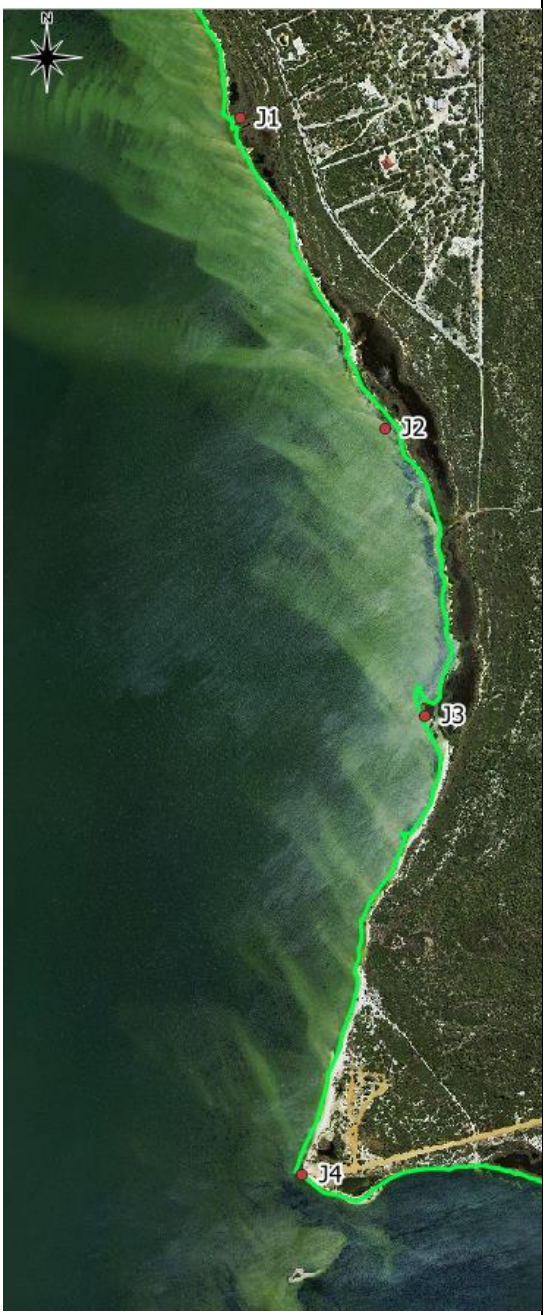
1994 to 2005



2005 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 1994 and 2005.

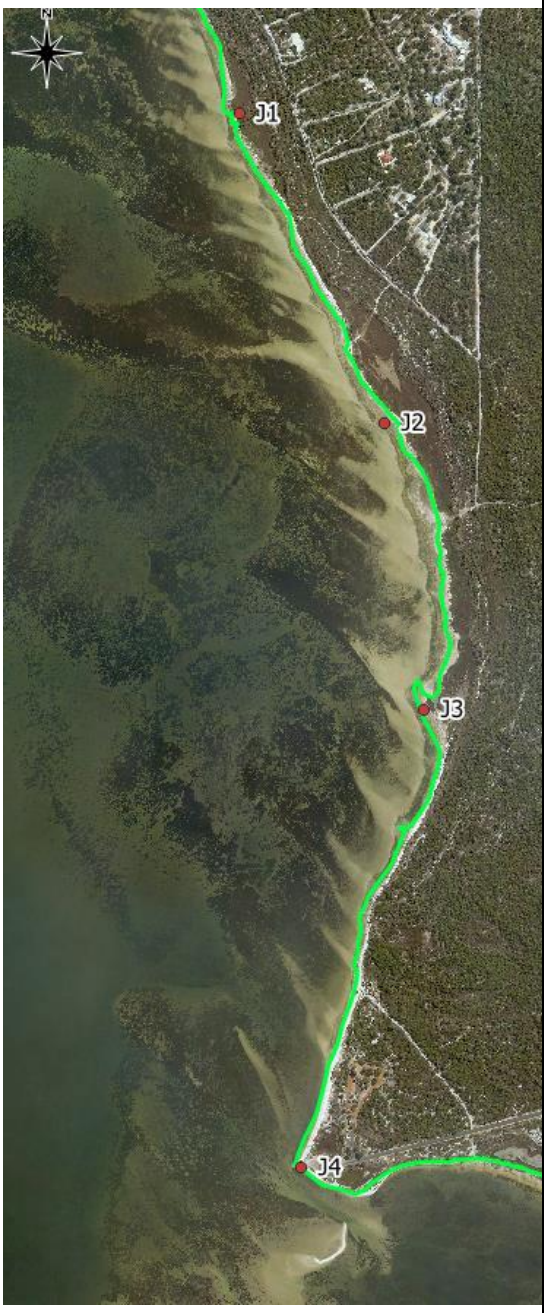
2005 to 2011



2011 Imagery
2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2011.

2005 to 2017



2017 Imagery
2005 - Green Line
Minor change along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little permanent vegetation line retreat.

J4 to K3 - Minor Change

1994 to 2005



1994 Imagery*
2005 - Green Line

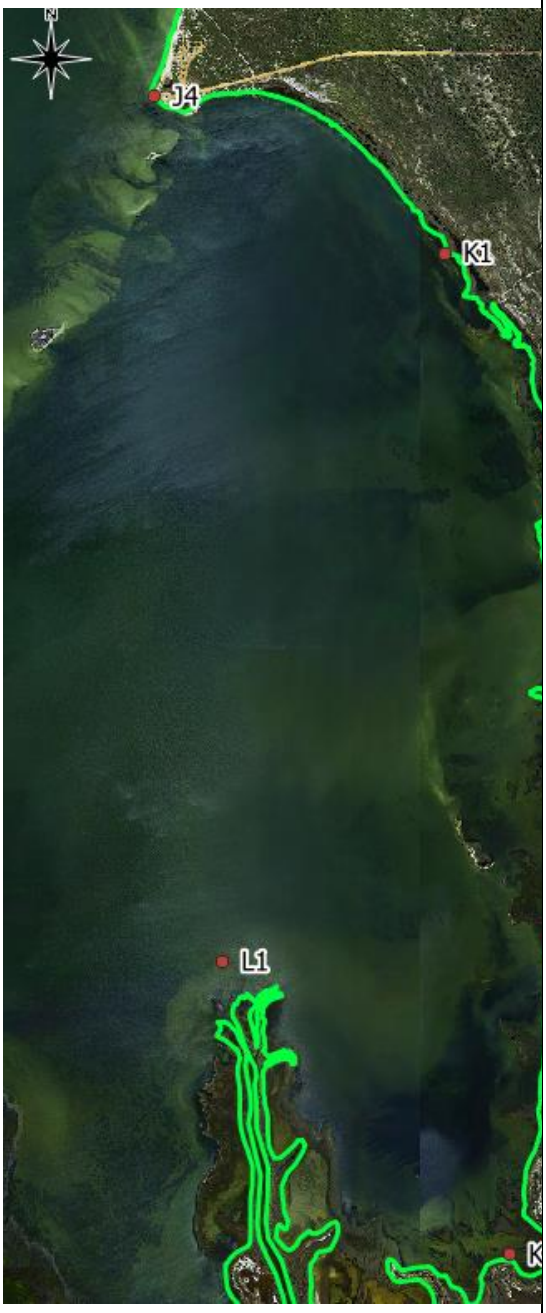
(* 1994 Imagery digitisation error around J4)

1994 to 2005



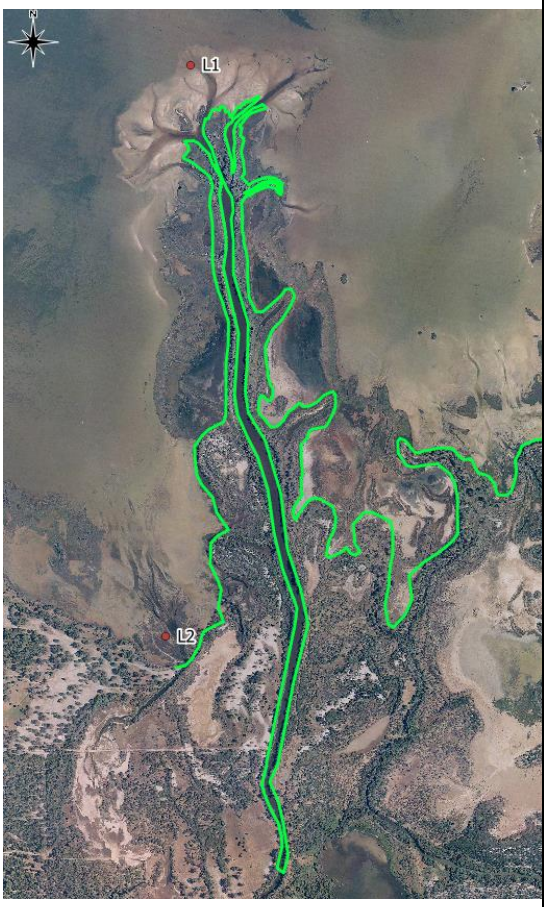
2005 Imagery
2005 - Green Line

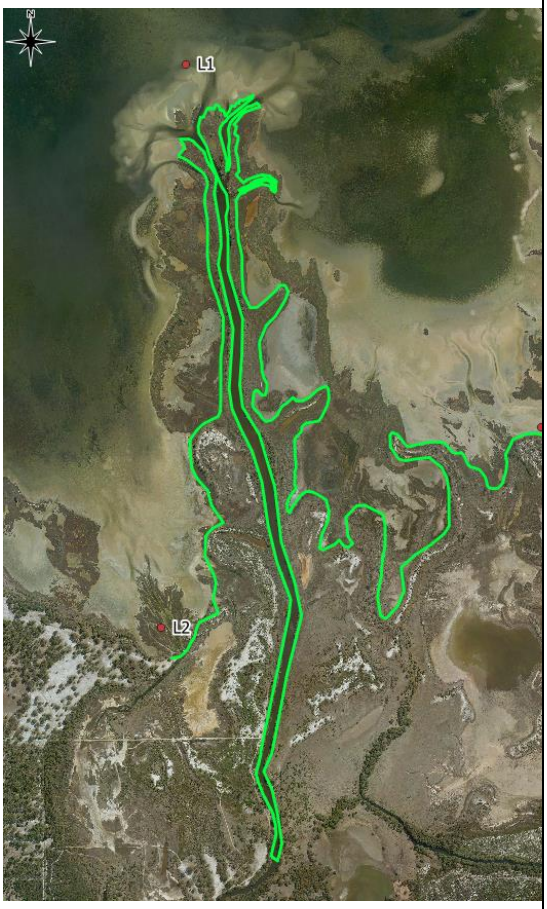
Minor change along this stretch of foreshore between 1994 and 2005.

2005 to 2011	2005 to 2017
	
2011 Imagery 2005 - Green Line **Minor change** along this stretch of foreshore between 2005 and 2011.	**2017 Imagery** 2005 - Green Line

Minor change along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little permanent vegetation line retreat.

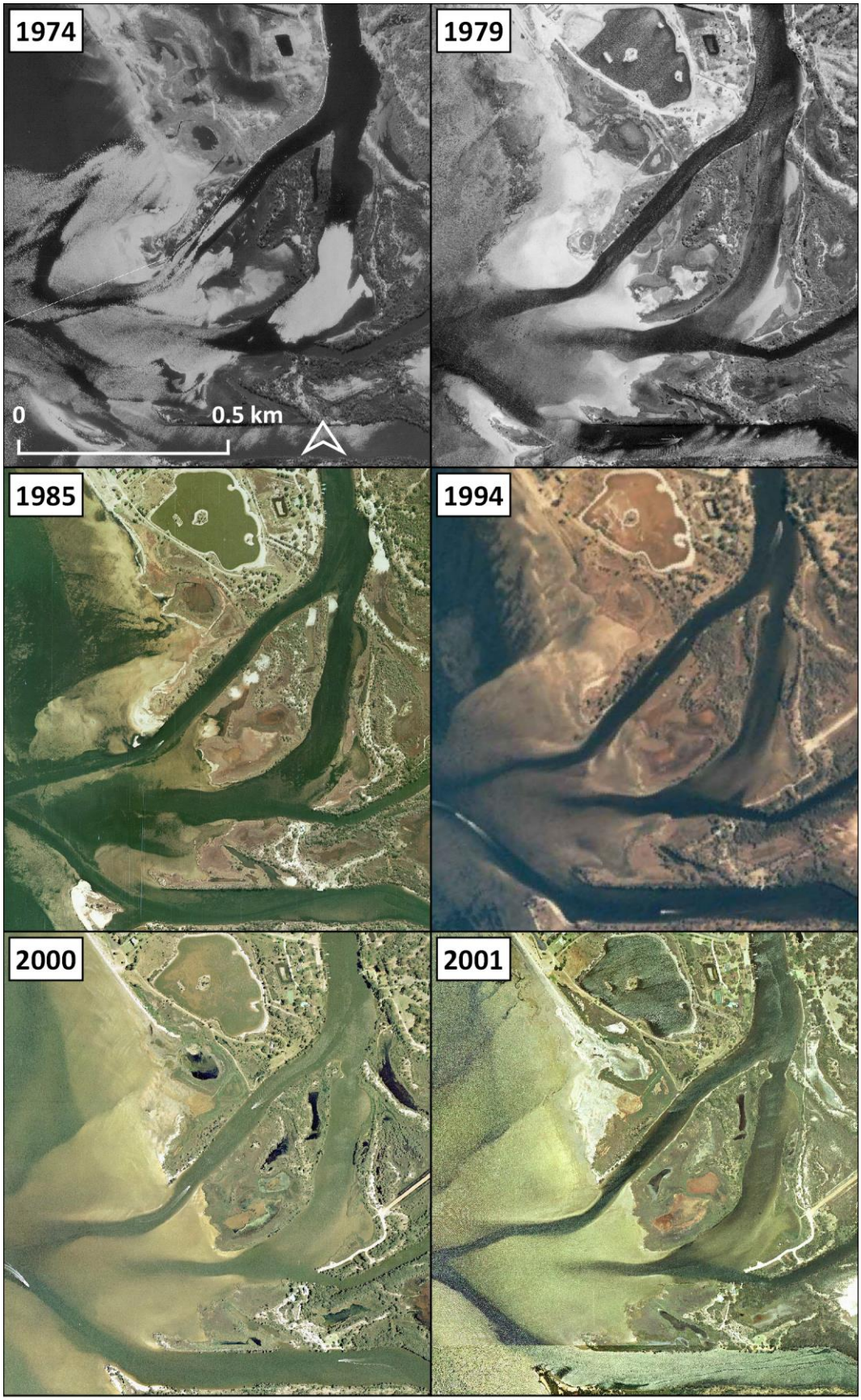
K3 to L2 - Minor Change

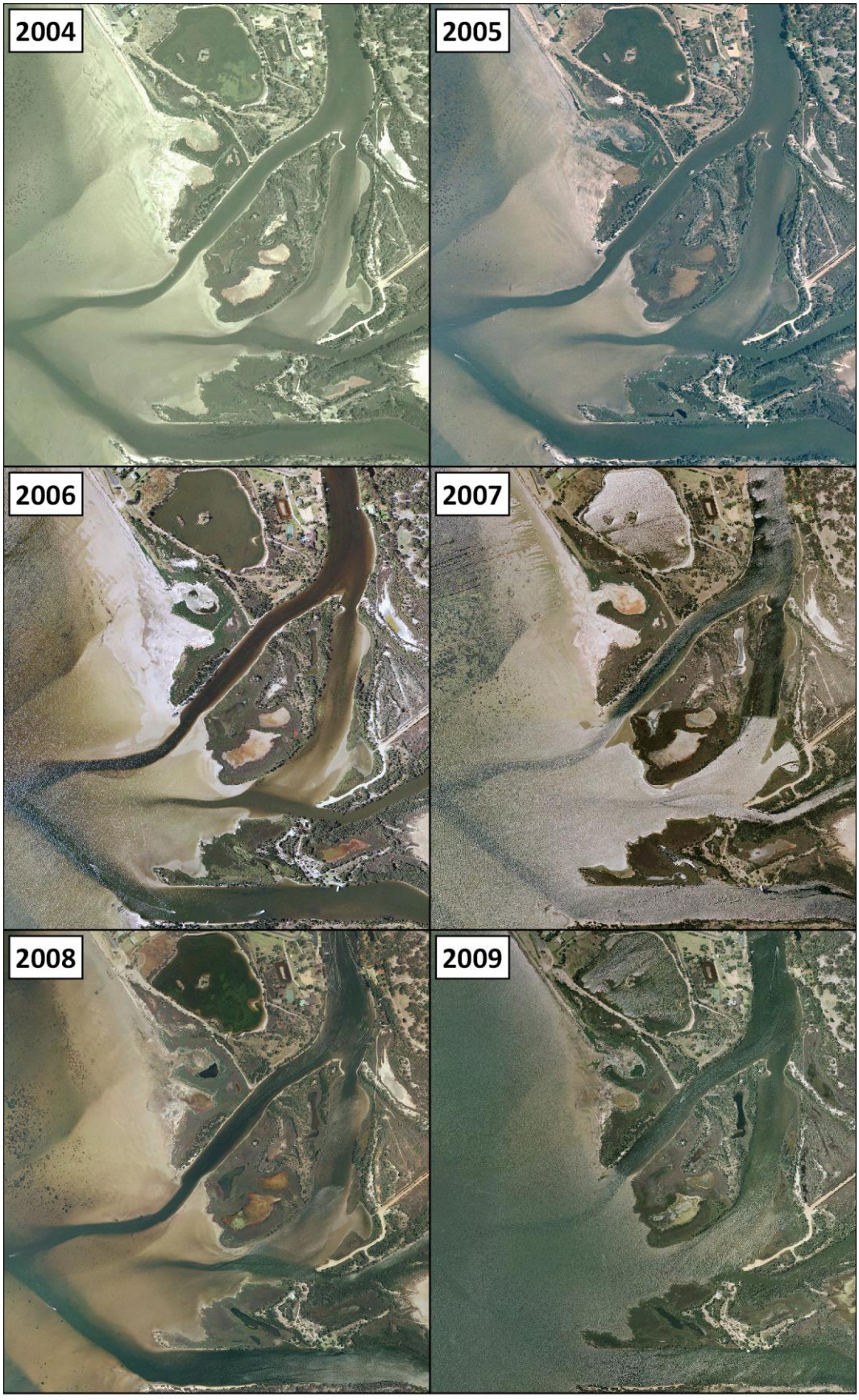
1994 to 2005	1994 to 2005
	
1994 Imagery* 2005 - Green Line (* 1994 Imagery digitisation error around J4)	**2005 Imagery** 2005 - Green Line **Minor change** along this stretch of foreshore between 1994 and 2005.

2005 to 2011	2005 to 2017
	
2011 Imagery 2005 - Green Line **Minor change** along this stretch of foreshore between 2005 and 2011.	**2017 Imagery** 2005 - Green Line **Minor change** along this stretch of foreshore between 2005 and 2017. Elevated water levels in 2011 caused little permanent vegetation line retreat.

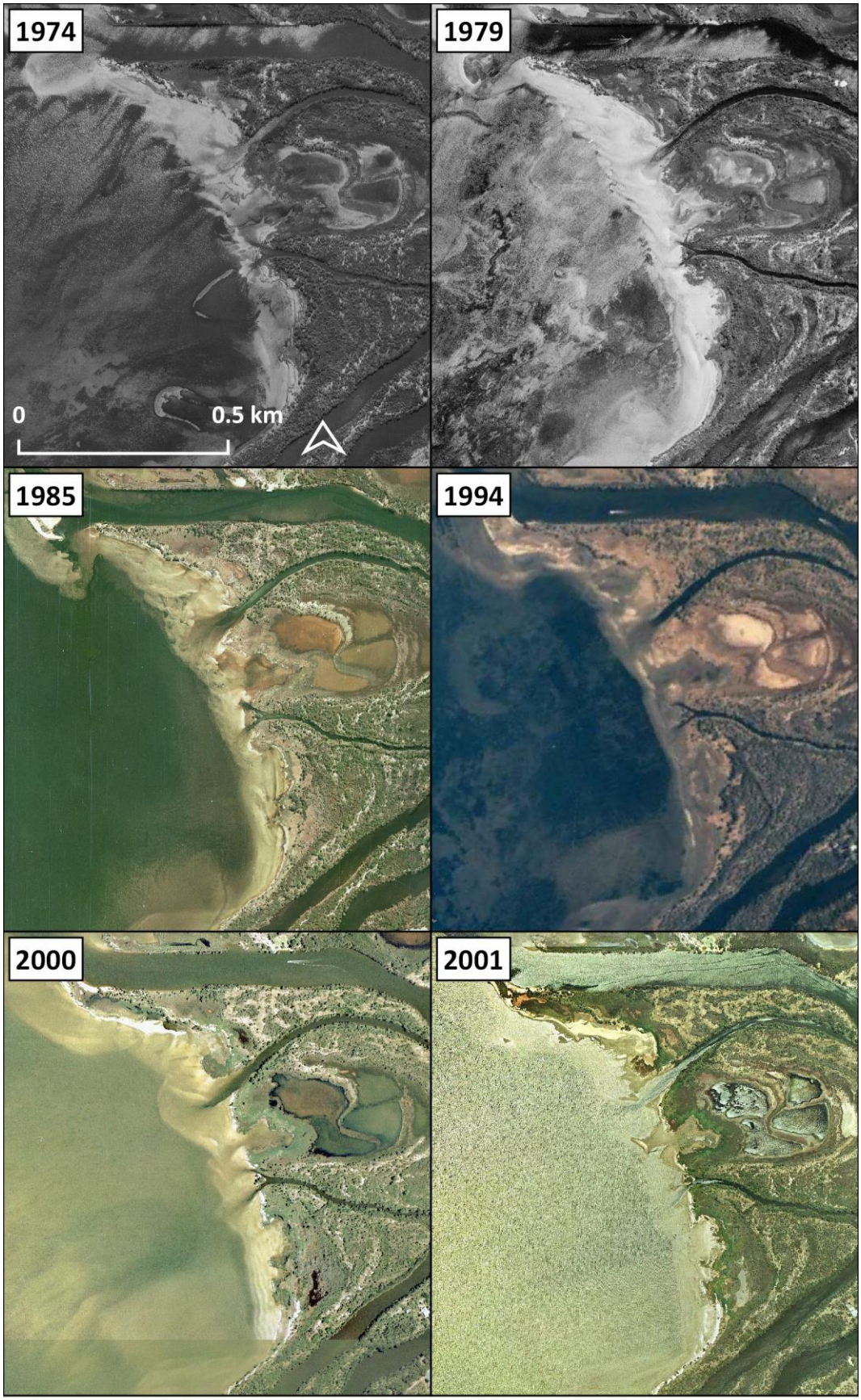
Appendix D – Murray Delta Imagery Sequences




1974
0
0.5 km
1979
1985
1994
2000
2001

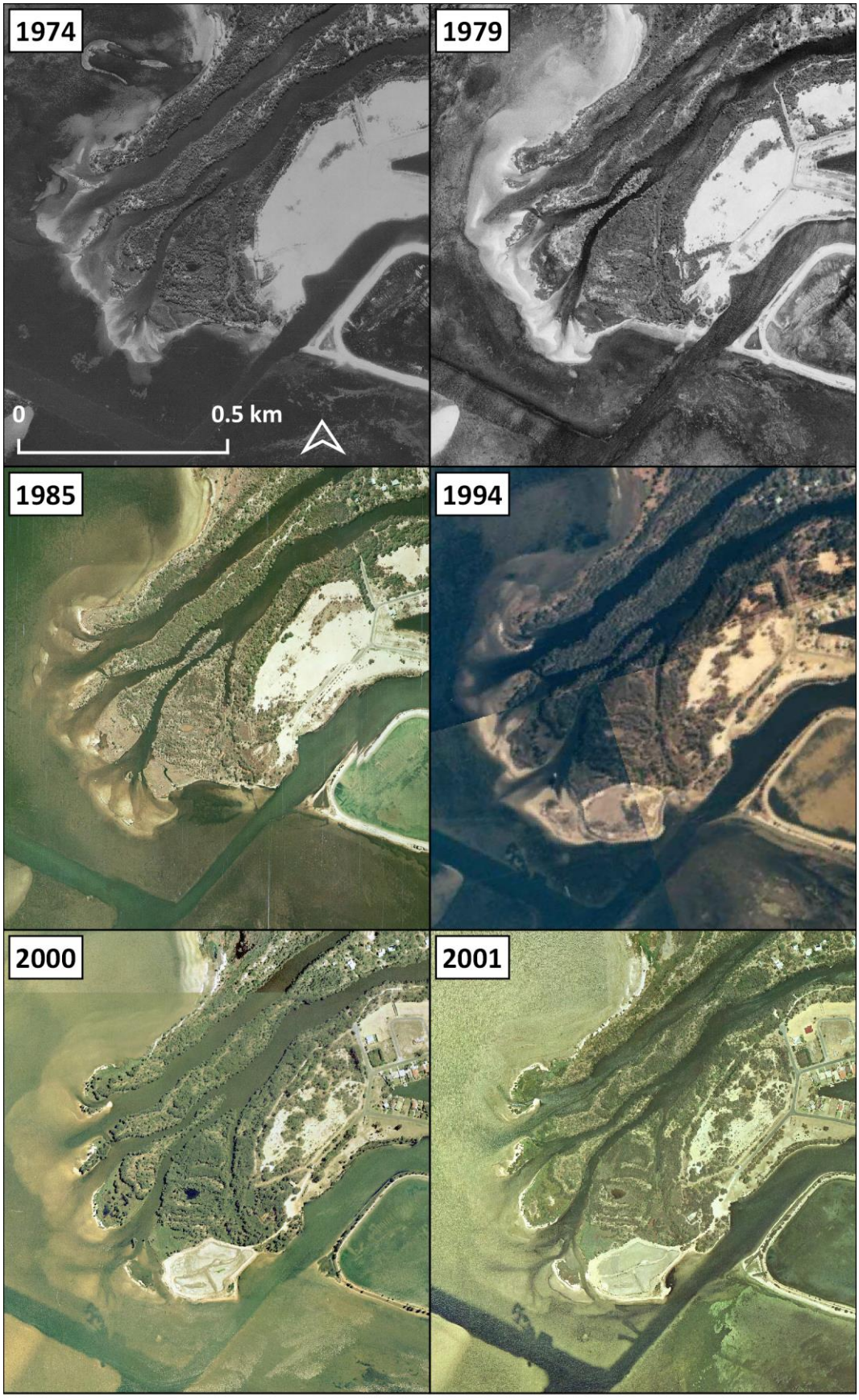

2004
2005
2006
2007
2008
2009


2010
2011
2012
2015
2016
2017


1974
1979
0
0.5 km
1985
1994
2000
2001


2004
2005
2006
2007
2008
2009

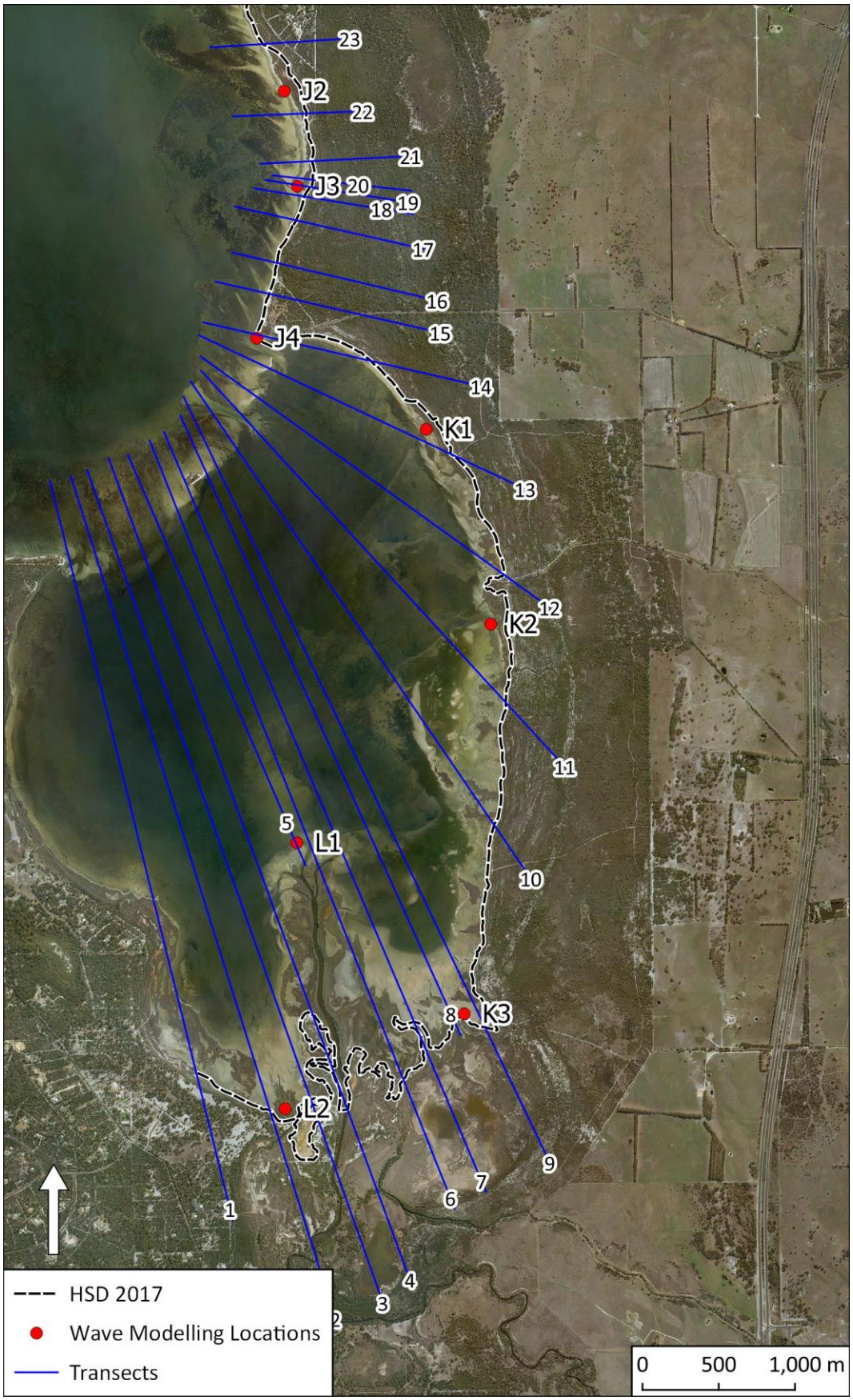

2010
2011
2012
2015
2016
2017

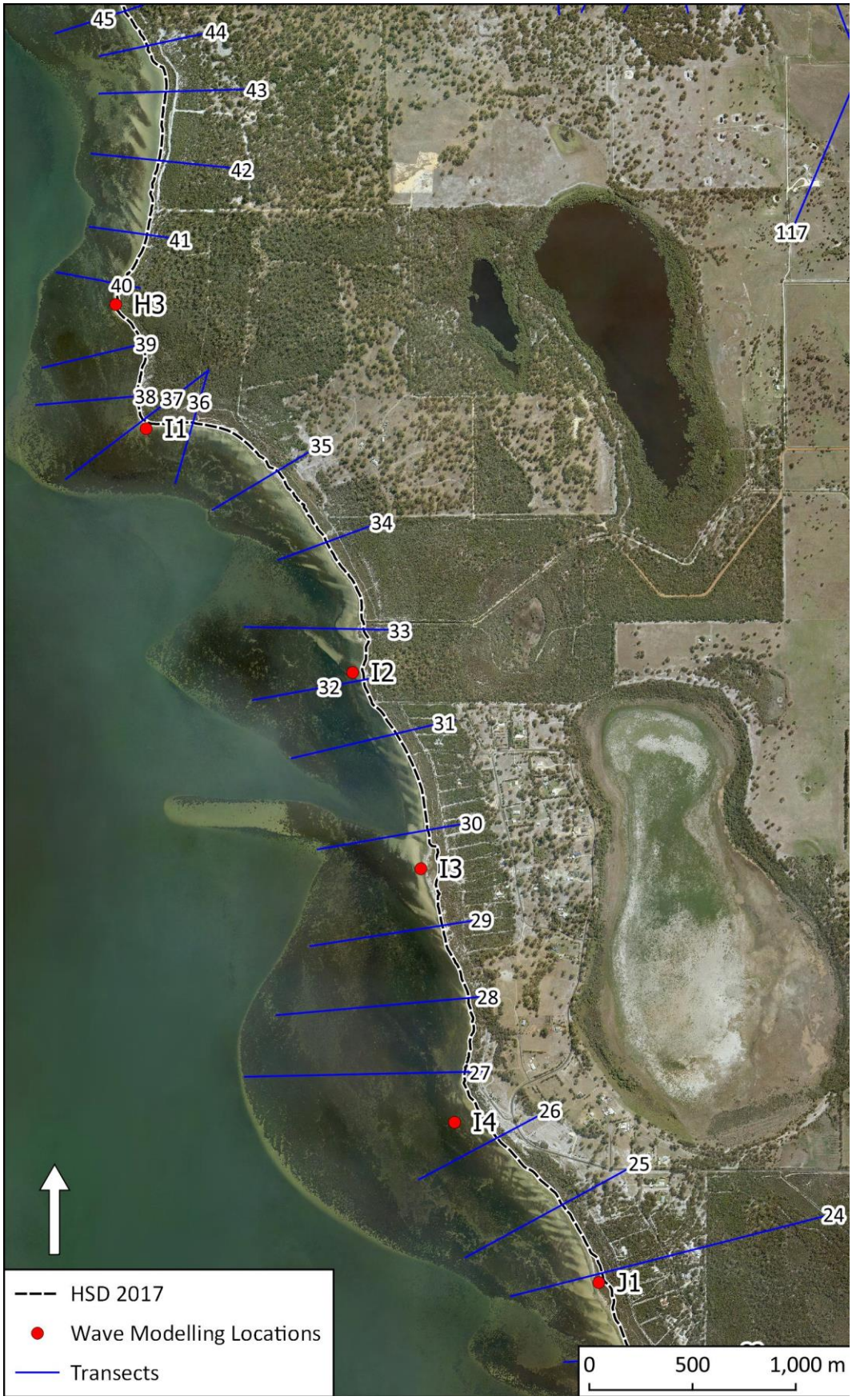

1974
0
0.5 km
1979
1985
1994
2000
2001

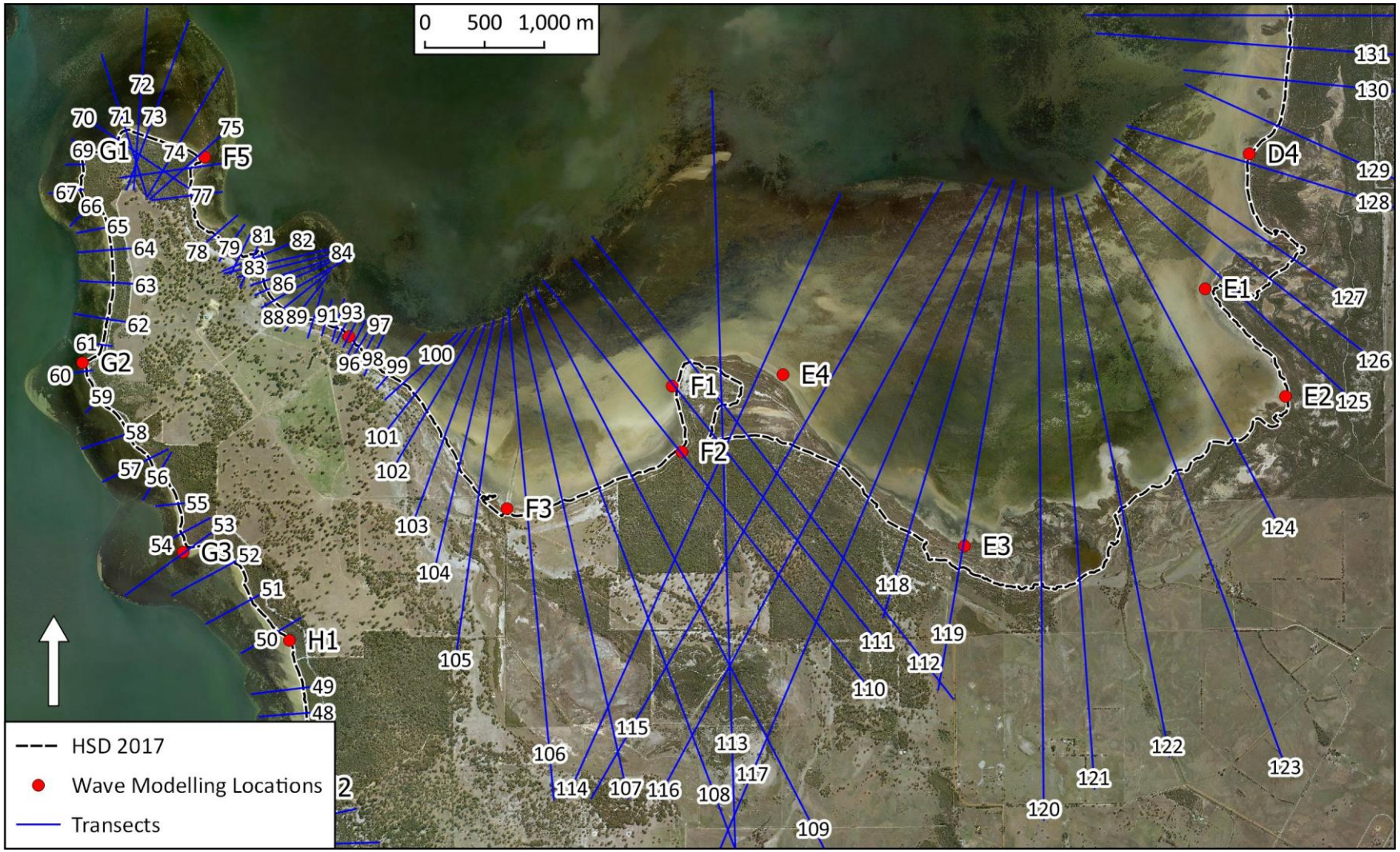

2004
2005
2006
2007
2008
2009

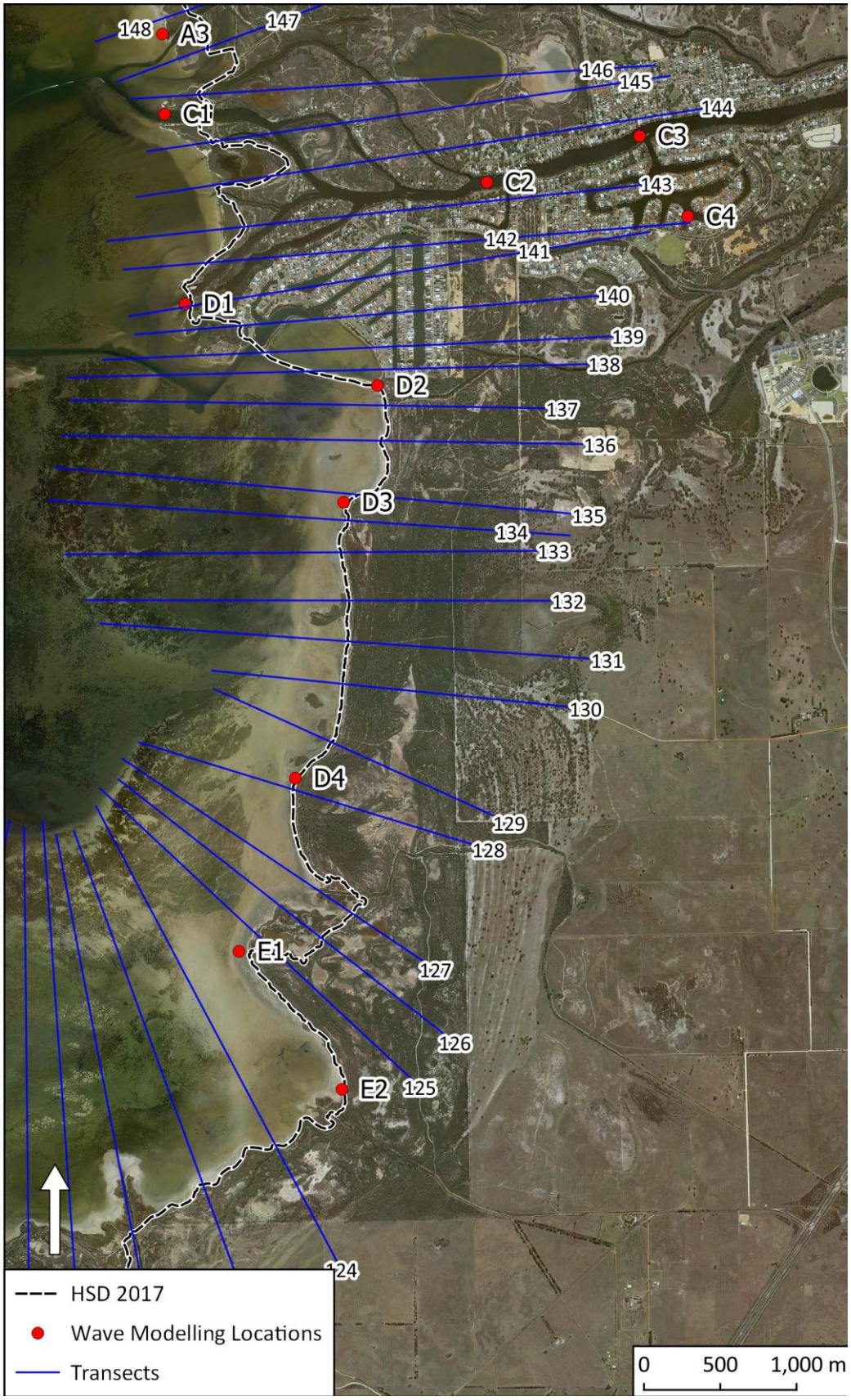

2010
2011
2012
2015
2016
2017

Appendix E – Profiles Used to Evaluate Response to SLR




45
44
43
42
41
40
H3
39
38
37
36
I1
35
34
33
I2
32
31
30
I3
29
28
27
I4
26
25
24
J1
117
HSD 2017
Wave Modelling Locations
Transects
0
500
1,000 m


0 500 1,000 m
HSD 2017
Wave Modelling Locations
Transects
G1
G2
G3
H1
F1
F2
F3
F5
E1
E2
E3
E4
D4



Note: Profiles 138 to 143 include oblique angles to parts of the shore, which will bias local determination of storm erosion & response to sea level rise. However, these effects were refined locally, due to influences of structures and low-lying topography.


HSD 2017
Wave Modelling Locations
Transects
0
500
1,000 m
B5
B4
B3
B2
B1
A0
A1
A2
A3
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163

Appendix F – Peel-Harvey Bathymetric Change

Evaluation of large-scale estuarine bed change within Peel Inlet and Harvey Estuary was reported previously in Damara WA (2019) and has been included here.

Measurement of the whole estuary bed has been conducted twice:

1. Through a set of leadline surveys in the 1970s, prior to undertaking substantial dredging works for navigation. This set of surveys, along with post-dredging surveys, was later collated by the Department of Marine and Harbours to support numerical modelling for the proposed Dawesville Channel.
2. Detailed LIDAR bathymetry survey conducted in 2016, on behalf of the Department of Water.

Comparison of estuary bed levels between the two surveys summarises estuarine change over more than 40 years, including changes that resulted from Dawesville Channel construction. However, differences in survey techniques constrain this comparison, with the earlier set of surveys having coarse coverage and relatively lower vertical precision.

For comparative analysis, two surfaces were developed with a grid spacing of 20m. The 1970s surface was generated through automated interpolation between coarse survey lines. The 2016 surface was generated through kriging, which develops a weighted average of the levels within each cell. A consequence of the different surveys and surface generation was a very smooth 1970s surface, including planar sections across areas of sparse data. By contrast, even after averaging over the grid cells, the 2016 surface retains substantial texture, indicating ripples, ridges, splays and other bedforms.

A difference plot was generated by subtracting the levels of the 1970s surface from those of the 2016 surface. Initial comparison of net change highlighted that the overall change was inconsistent with reporting to the relative vertical datums (i.e. the difference plot indicated a massive bed lowering across most of the estuary, which does not reflect observations). Identification of bed change was subsequently developed by assuming near zero volume change. The resulting vertical difference was approximately 0.21m, which matches a datum jump identified in Peel inlet tide gauge record (Appendix A).

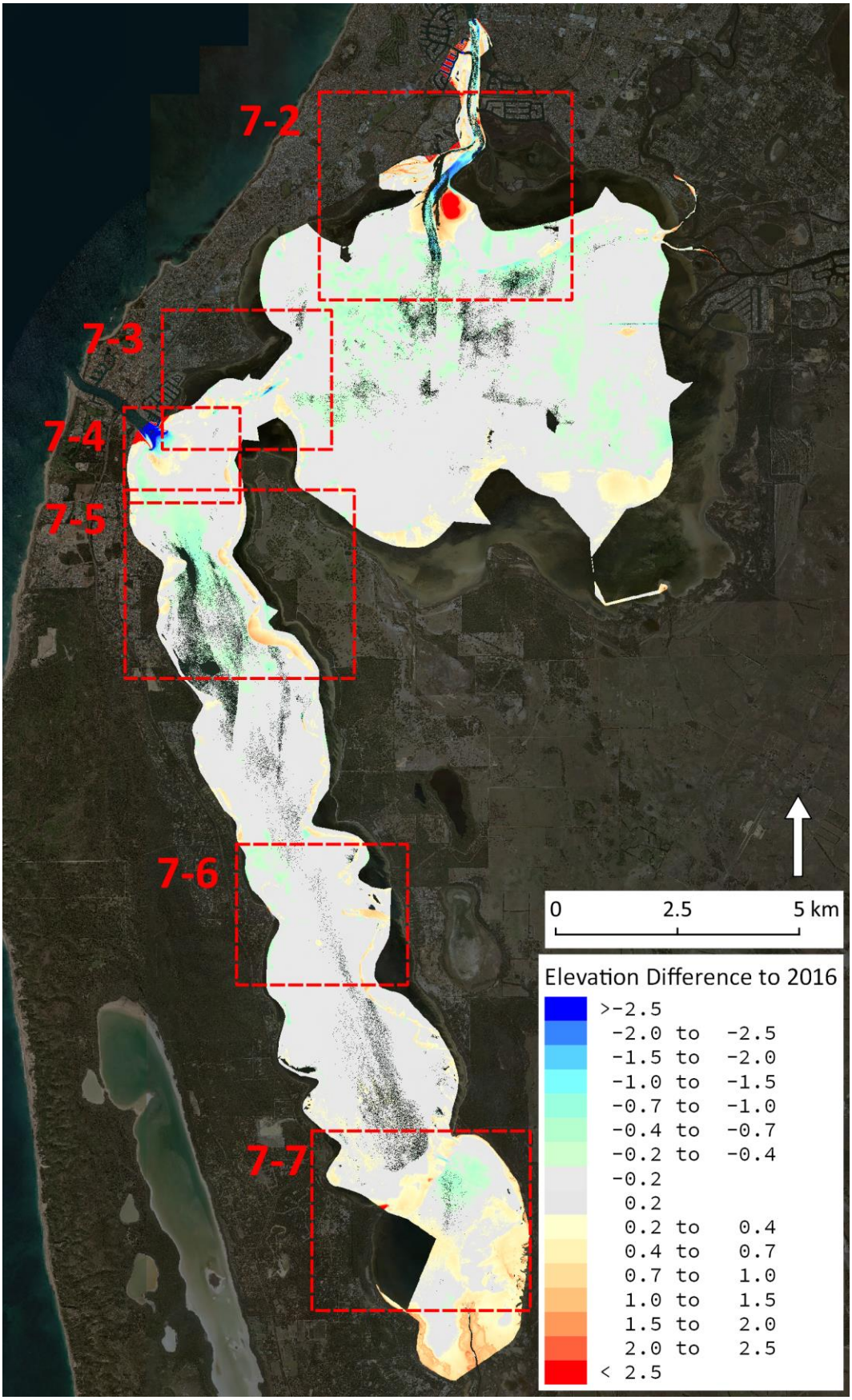


Figure F-1: Bathymetric Comparison

The survey comparison shows six areas of substantial change:

1) Sticks Channel and Channel Island (Figure F-2) were developed through dredging and reclamation in the 1980s (Paul & Hutton 1985).

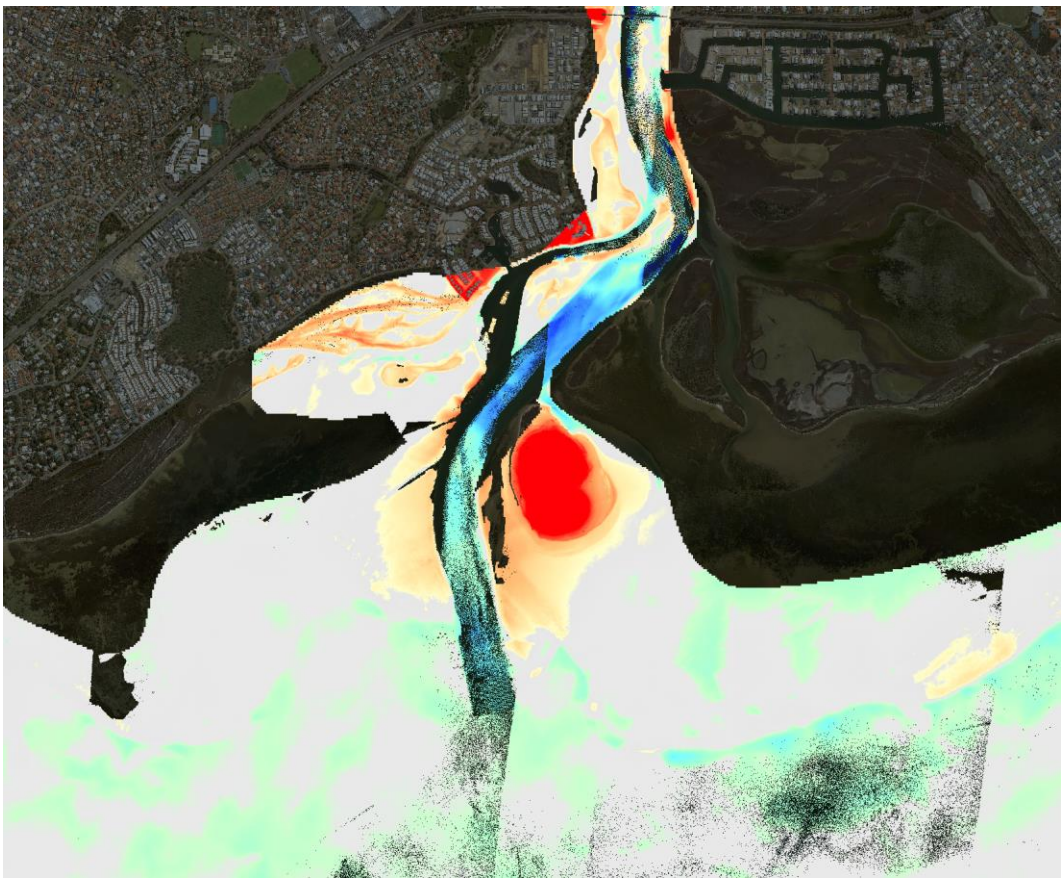


Figure F-2: Bathymetric Change near Sticks Channel

2) Grey Channel, between Peel Inlet and Harvey Estuary has experienced deepening, with some minor sedimentation of adjacent areas. This pattern is consistent with predictions of increased flow speeds through Grey Channel predicted as a response to construction of Dawesville Channel.

   A broad area of minor deepening was indicated east of Grey Channel, for approximately the western third of Peel Inlet. The cause of this pattern is unclear, as it may plausibly be a result of bed scour following construction of Dawesville Channel, loss of benthic vegetation; or a systematic vertical difference due to the difference between survey techniques.

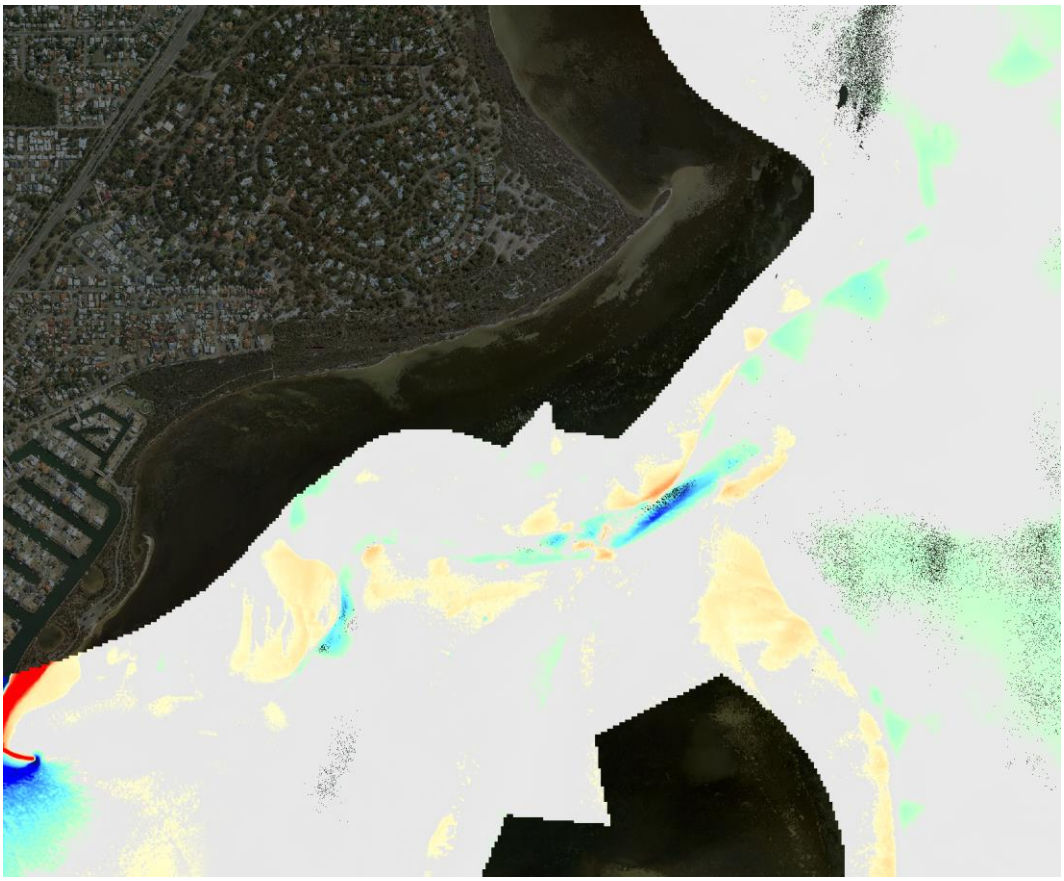


Figure F-3: Bathymetric Change near Grey Channel

The eastern end of Dawesville Channel exhibits characteristics of construction and subsequent evolution. The major 'bell mouth' feature that was constructed is now surrounded by a raised arc typical of flood sill. Secondary features occur inside the channel, including a sand shoal on the southern side, with a series of ridges connected to the shoal running part way across the channel. This creates a rippled bed structure for the flow in and out of the channel.

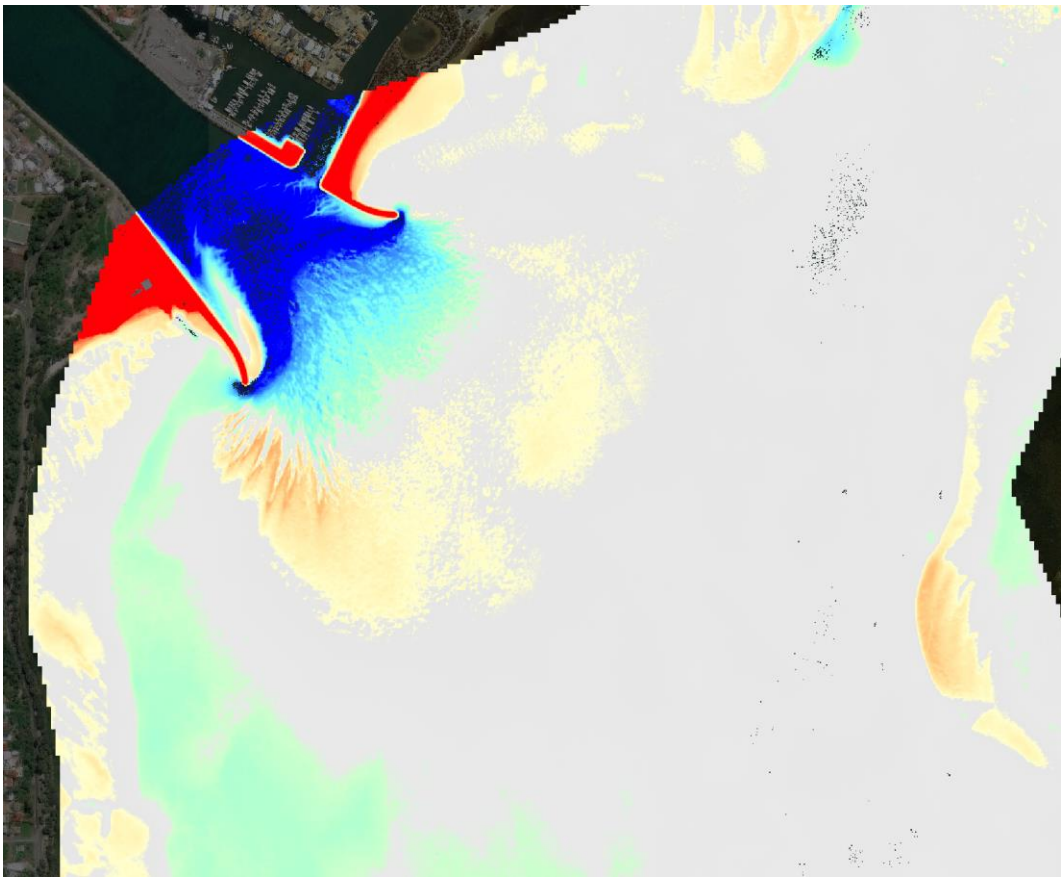


Figure F-4: Bathymetric Change near Dawesville Channel

3) South of Dawesville Channel, an area of bed lowering is indicated at the slight constriction across Harvey Estuary developed between two forelands. This is consistent with locally increased tidal currents following excavation of Dawesville Channel. The survey comparison also indicates deposition along the intertidal terrace east of the eroded area. Although this deposition is possibly where the eroded sediment was moved towards, it is also possible that this feature is created due to differences between the surveys, as coverage was extremely sparse on the terrace during the 1970s survey.

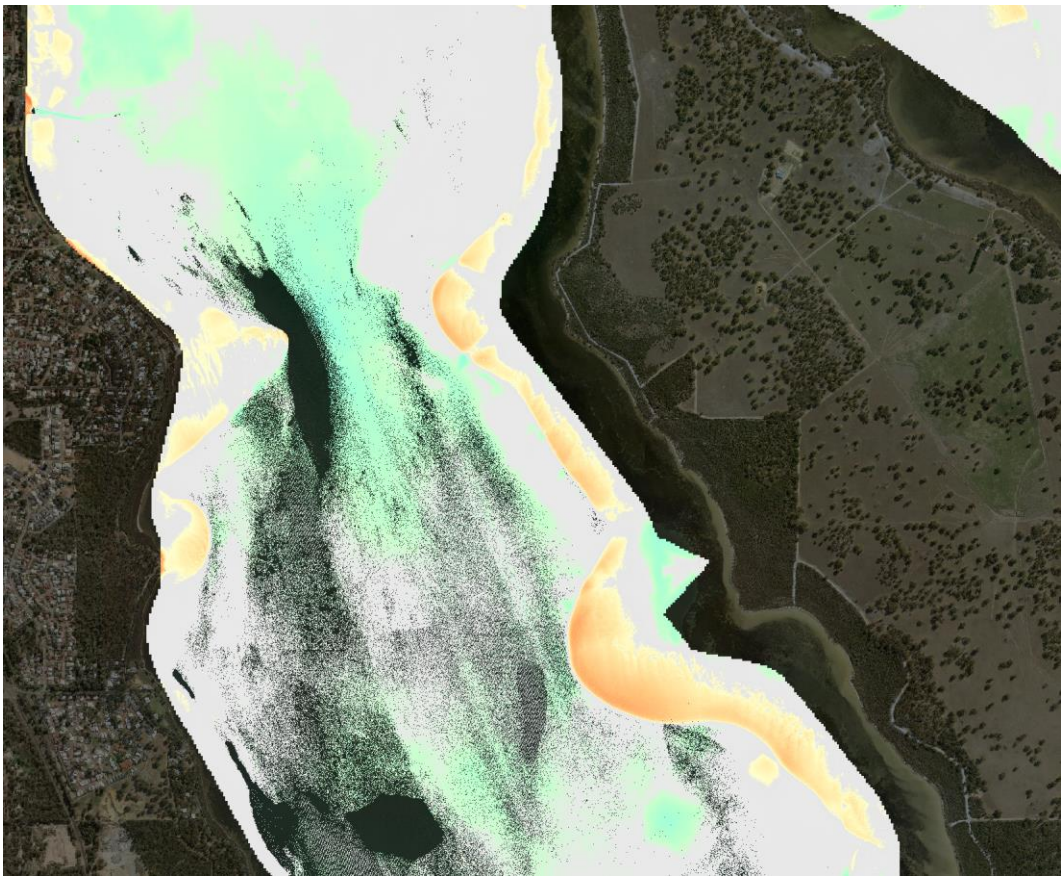


Figure F-5: Bathymetric Change south of Dawesville Channel

4) An extended linear shoal has developed on the eastern side of Harvey Estuary, which is also evident in aerial imagery. This feature started to develop in the 1980s and consequently its origin is unrelated to Dawesville Channel. The orientation of the shoal is similar to smaller transverse bars nearby along the eastern shore of Harvey Estuary. These are typically developed through a combination of wave action and tidal flows. Extended transverse bars normally occur where there is regular sediment supply such as a drainage outlet, however no such drain has been identified at this shoal.

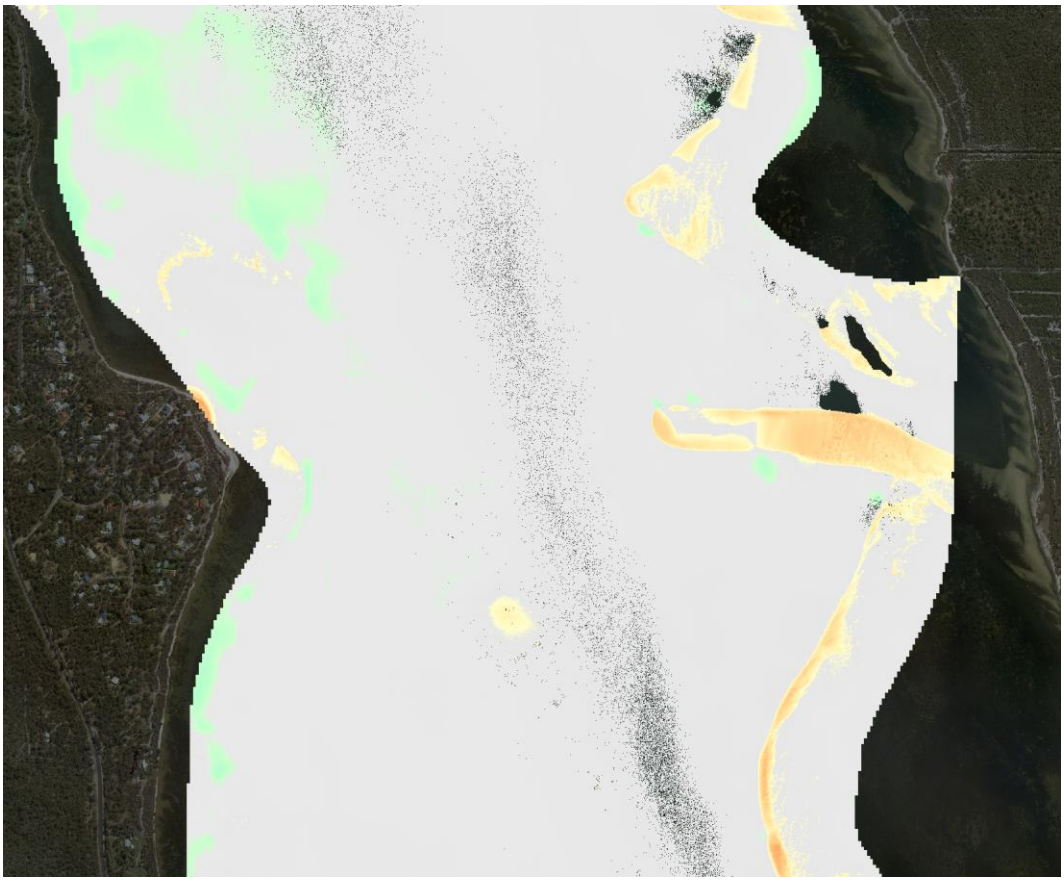


Figure F-6: Bathymetric Change near Birchmont

5) The ‘Ford’ between Island Point and Herron Point is a tidal sill, with survey comparison showing areas of erosion and accretion. Some of this change is due to survey differences, as the 1970s surveys had limited resolution of the channels. However, the dynamic nature of the sill feature is apparent from aerial imagery, with changes in the width of the sill and channel positions. Surveys should therefore be considered snapshots, rather than indicative of a long-term trend.

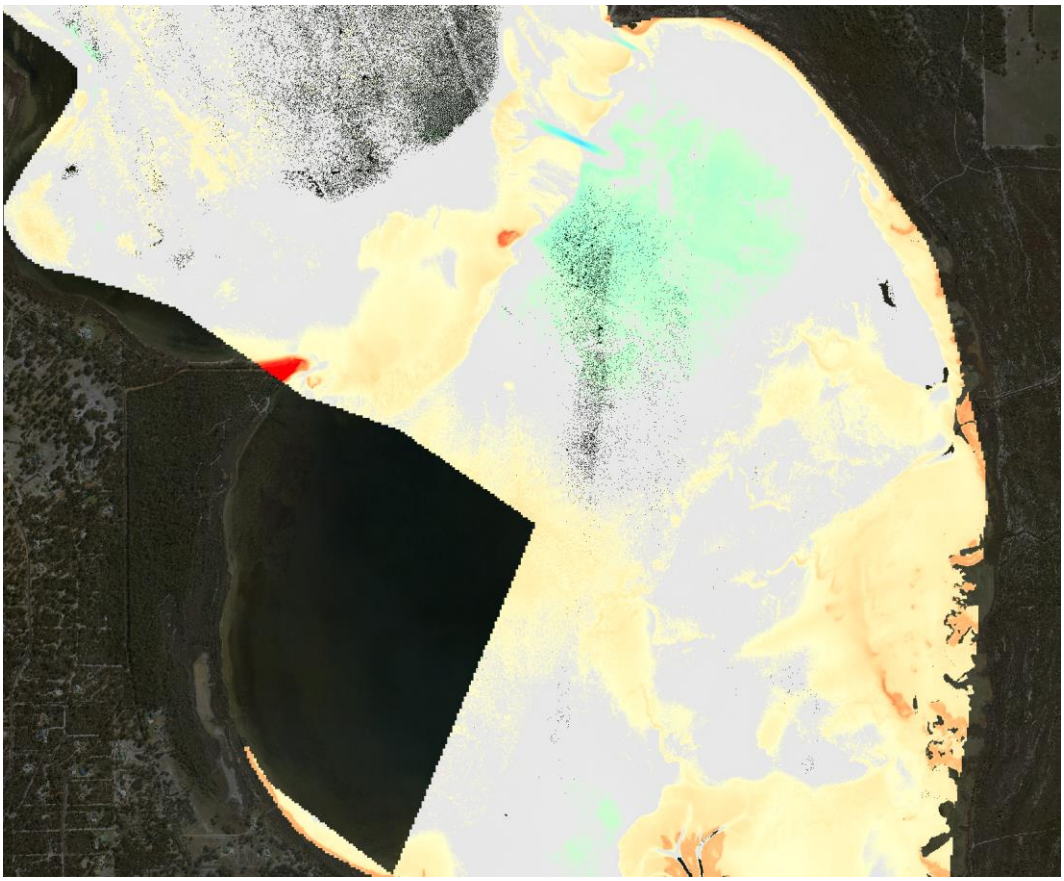
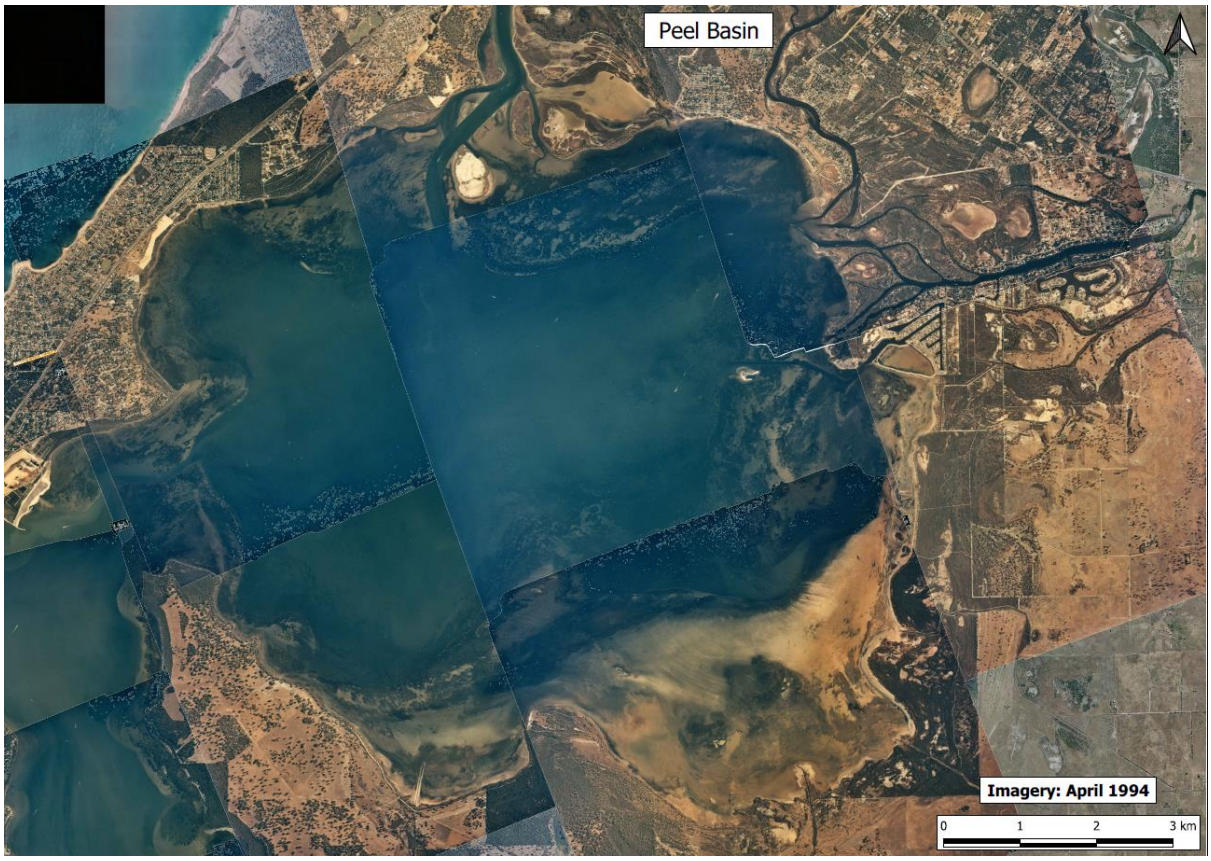
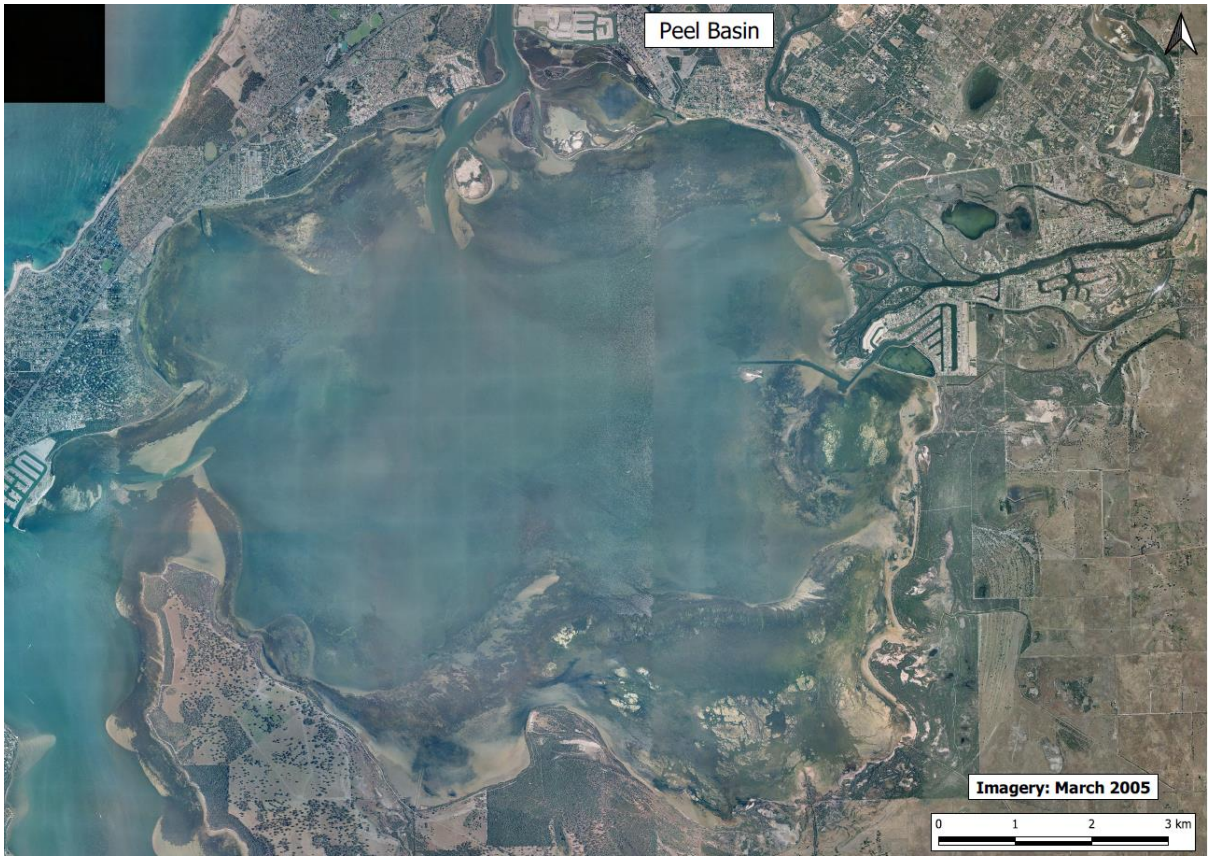


Figure F-7: Bathymetric Change near Island Point

Appendix G – Variability of Benthic Coverage






Peel Basin
Imagery: May 2011
0
1
2
3 km


Peel Basin
Imagery: May 2012
0
1
2
3 km

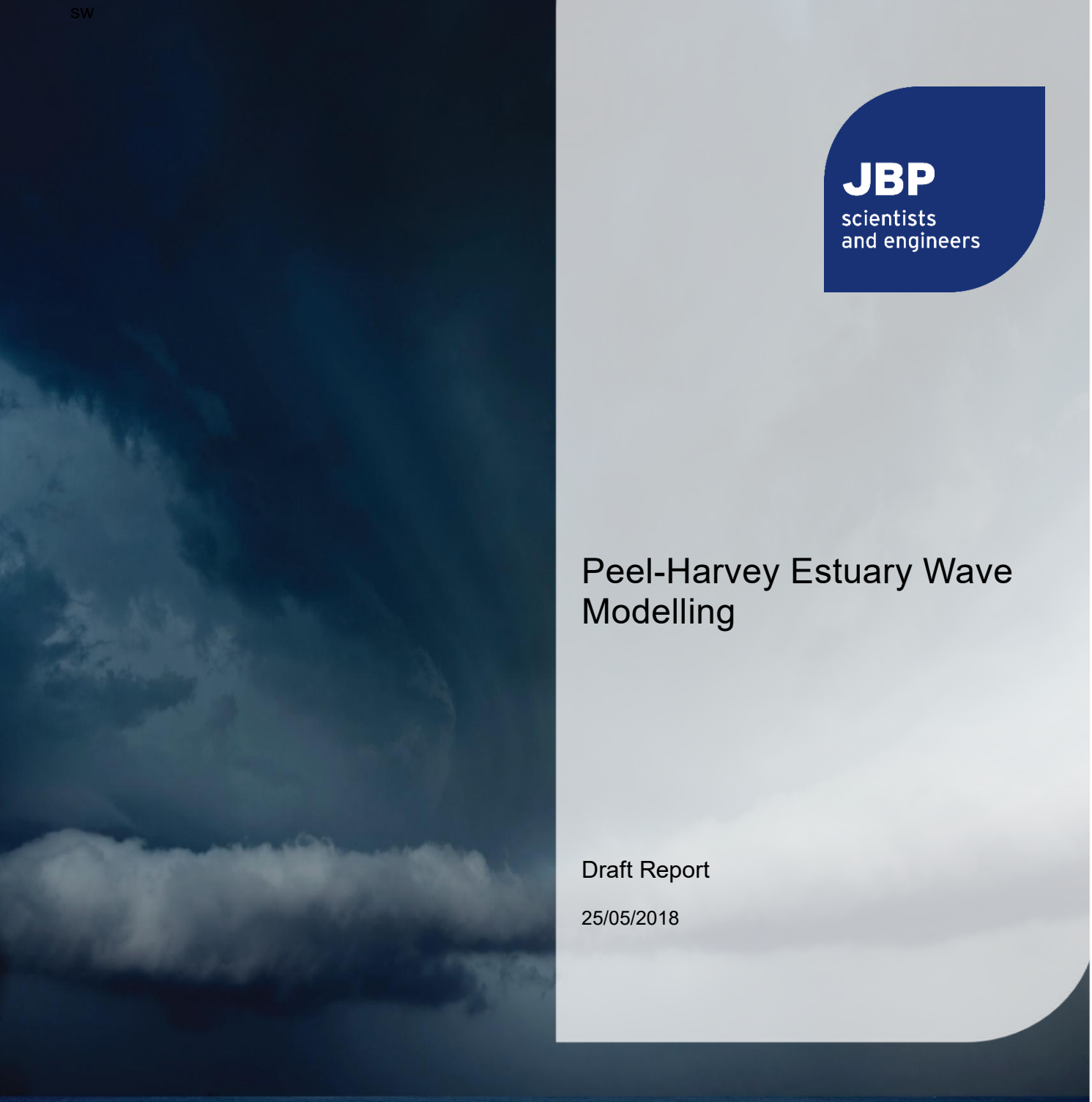

Peel Basin
Imagery: November 2015
0
1
2
3 km


Peel Basin
Imagery: October 2016
0
1
2
3 km


Peel Basin
Imagery: April 2017
0
1
2
3 km

Appendix H – Wave Hindcast Modelling Report

SW

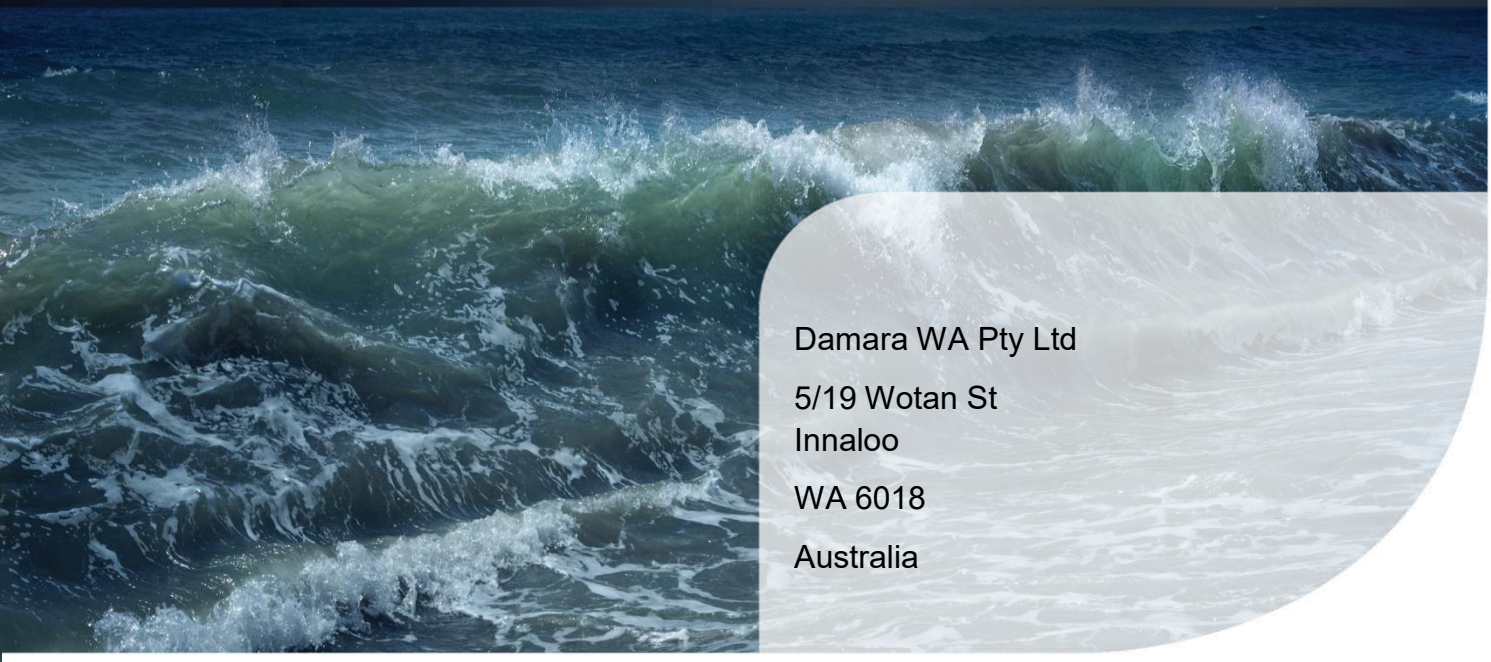


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scientists
and engineers

Peel-Harvey Estuary Wave Modelling

Draft Report

25/05/2018



Damara WA Pty Ltd

5/19 Wotan St
Innaloo

WA 6018

Australia

JBP Project Manager

Daniel Rodger
Jeremy Benn Pacific
Level 2, 433 Boundary Street
Spring Hill QLD 4004
Australia

Revision History

Revision Ref / Date Issued	Amendments	Issued to
1.0 (Draft) / 25 May 2018	-	ME

Contract

This report describes work commissioned by Matt Eliot, on behalf of Damara WA Pty Ltd, by an email from Matt Eliot on the 3rd of April 2018. Damara WA Pty Ltd's representative for the contract was Matt Eliot. Johnny Coyle and Daniel Rodger of JBP carried out this work.

Prepared by ..... Johnny Coyle BSc MSc
Assistant Analyst

Approved by ..... Daniel Rodger BSc MEng CEng CMarEng MIEAust MICE IMarEST
RPEQ 17794

Director

Purpose

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Trading as Jeremy Benn Pacific and JBP Scientists and Engineers

ABN: 56 610 411 508

ACN: 610 411 508

Executive Summary

JBP has been commissioned by Damara WA Pty Ltd to undertake wave modelling of the Peel-Harvey estuary to produce nearshore wave estimates along the shoreline for a range of scenarios. The modelling has used SWAN (Simulating WAves Nearshore), a third-generation wave model incorporating various wave transformation processes including wave-wave growth, propagation, shoaling, refraction, and breaking. The wave model was then used to simulate 224 design scenarios with varying wind speeds, directions and water levels, producing outputs at 964 locations.

Contents

Executive Summary iii

1 Introduction 1

1.1 Background 1
1.2 Site under investigation 1

2 Wave transformation modelling 2

2.1 Approach 2
2.2 Computational mesh 2
2.3 Model setup 4
2.4 Model simulations 4

3 Summary 6

A Appendix A: SWAN output samples I

B Appendix B: Sample output data V

List of Figures

Figure 1-1: Peel-Harvey Estuary 1
Figure 2-1: Model mesh and bathymetry 3
Figure A-1: Significant Wave Height for run 25 using a 12 m/s wind from 045º I
Figure A-2: Mean wave period for run 25 using a 12 m/s wind from 045º II
Figure A-3: Significant Wave Height for run 70 using a 11.8 m/s wind from 157.5º III
Figure A-4:: Mean Wave period for run 70 using a 11.8 m/s wind from 157.5º IV

List of Tables

Table 2-1: Model sensitivity to bottom friction and physics parameters 4
Table 2-2: Modelled wind speeds and directions for Mean Sea Level simulations 5
Table 2-3: Modelled wind speeds and directions for high and low sea level simulations (+/- 0.3m) 5

1 Introduction

1.1 Background

JBP has been commissioned by Damara WA Pty ltd to produce a wave model of the Peel-Harvey Estuary near Mandurah, in Western Australia. The wave model was used to estimate nearshore wave conditions along the shoreline for a range of wind speed, wind direction and water level scenarios.

1.2 Site under investigation

The Peel-Harvey Estuary is a tidal water body in Western Australia, 60km south of Perth. It is relatively shallow, with depths rarely exceeding 3m below AHD. Described in terms of its component areas, the Harvey estuary is 21km long and 3km wide orientated north-north-east, and the Peel estuary is 7-10km wide (refer to Figure 1-1).



Figure 1-1: Peel-Harvey Estuary

2 Wave transformation modelling

Numerical wave modelling was undertaken to estimate wave growth and transformation within the estuary. The modelling approach, assumptions and results are described in this chapter.

2.1 Approach

Modelling has been undertaken using the SWAN (Simulating WAves Nearshore) wave model. SWAN is a third-generation wave model incorporating complex physics for the description of wave growth and transformation processes. It is an open source package and is capable of simulating various wave transformation processes in 2D, including, shoaling, refraction, wind-wave interaction, breaking and dissipation.

The following assumptions have been made:

1. Uniform still water levels exist throughout the estuaries.

The modelling assumed a uniform water level throughout the estuary. No information on water level gradients was available, and given the small scale of the model domain, was deemed appropriate.

2. No influence of ocean generated swell waves:

Only waves generated from wind within the estuary was considered. No additional boundary conditions were applied to consider ocean swell.

3. Uniform wind field:

The model assumed a uniform wind speed and direction throughout the domain.

2.2 Computational mesh

The mesh was constructed as an ADCIRC grid in SMS, with the landward boundary extending to the 2-3mAHD contours adjacent to the estuary.

Mesh spacing was varied around the model boundary, with higher mesh resolution in Mandura, Dawesville, Brunswick Island and Point Grey. Maximum node spacing along the shoreline was approximately 200m at the southern estuary, increasing to a 20m resolution at the Dawesville Channel, Mandura Channel and Serpentine River. The computational mesh is shown in Figure 2-1.

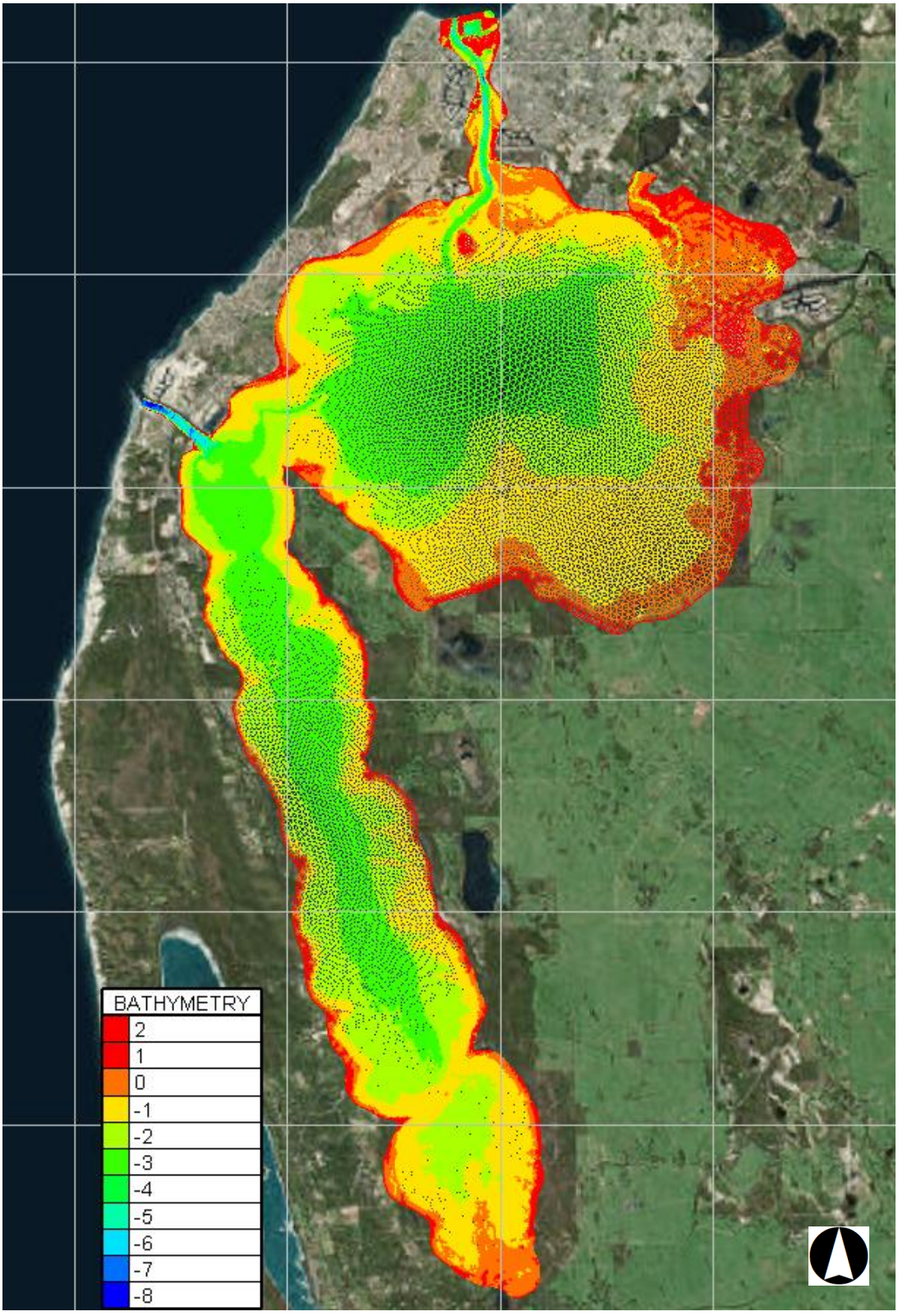


Figure 2-1: Model mesh and bathymetry

2.3 Model setup

2.3.1 Bathymetry

Model bathymetry was obtained from a 20m resolution point-cloud containing X,Y,Z data, supplied by the client. This was integrated into the model by sampling the depth at the mesh node locations.

2.3.2 Water level

A constant water level was applied throughout the domain.

2.3.3 Calibration

No observed wave parameters were available within the estuary for use in calibration. As a result, no formal calibration wave undertaken against observed data, and default model parameters were adopted for wave growth and bottom friction schemes (JONSWAP and Komen, respectively).

2.3.4 Convergence

Testing of the default parameters under a range of wind conditions was undertaken, with the model shown to converge to 99 or 99.5%. This was deemed acceptable for the model purpose.

2.3.5 Model sensitivity

The sensitivity of the model to different model parameters was tested at a location in the middle of the Harvey estuary at -2.27mAHD (374422E , 6386530S MGA zone 50, SWAN Node 13564). A constant water level, wind speed and direction were applied across the domain, and a range of physics and bottom friction terms altered. The resulting change in wave conditions are presented in Table 2-1.

Table 2-1: Model sensitivity to bottom friction and physics parameters

Physics	Bottom Friction	Hs (m)	Tp (sec)	Peak Direction
***JONSWAP**	***Komen et al.**	0.71	2.63	355
Janssen	*Komen et al.*	0.83	2.62	005
Westhuysen	*Komen et al.*	0.77	2.59	355
JONSWAP	*Collins*	0.72	2.65	355
JONSWAP	*Madsen et al.*	0.54	2.16	355
* Default				

2.4 Model simulations

The wave model was run for 224 iterations of wind and water level. The Mean Sea Level MSL (-0.17mAHD) was used for 144 simulations, with an additional 40 simulations under a high water level (+0.13m) and low water level (-0.47m) condition. The forcing conditions for these runs are displayed in Table 2-2 to Table 2-3.

Output wave conditions have been produced at of 964 locations situated around the shoreline of the estuary. These locations were all situated at approximately -1mAHD contour.

Outputs were supplied as 964 CSV datasheets, listing the toe number, output coordinates, input conditions, and estimated wave conditions.

Table 2-2: Modelled wind speeds and directions for Mean Sea Level simulations

Direction (Deg/N)	Windspeed (Km/hr)									
	10% of year	*3.0% of year*	*1.0% of year*	*0.3% of year*	*0.1% of year*	*1-yr ARI*	*3-yr ARI*	*10-yr ARI*	*30-yr ARI*	*100-yr ARI*
000.0			37.5	45.0	51.0	56.0	60.3	64.0	67.4	70.3
022.5		24.7	33.7	40.5	45.9	50.4	54.3	57.6	60.6	63.3
045.0		20.4	27.9	33.5	38.0	41.7	44.9	47.7	50.2	52.4
067.5		17.3	23.7	28.4	32.2	35.4	38.1	40.4	42.5	44.4
090.0		16.0	21.9	26.3	29.8	32.7	35.2	37.4	39.3	41.1
112.5		16.4	22.4	26.8	30.4	33.4	36.0	38.2	40.2	42.0
135.0	7.6	17.1	23.4	28.1	31.9	35.0	37.7	40.0	42.1	44.0
157.5	8.1	18.3	25.0	30.0	34.0	37.4	40.2	42.7	44.9	46.9
180.0		19.3	26.4	31.7	35.9	39.4	42.5	45.1	47.4	49.5
202.5		20.8	28.5	34.2	38.7	42.5	45.8	48.6	51.1	53.4
225.0		22.0	30.1	36.1	41.0	45.0	48.4	51.4	54.1	56.5
247.5		24.7	33.7	40.5	45.9	50.4	54.2	57.6	60.6	63.3
270.0		28.3	38.7	46.5	52.7	57.9	62.3	66.2	69.6	72.7
292.5		29.4	40.2	48.3	54.7	60.1	64.7	68.7	72.3	75.5
315.0		30.4	41.5	49.9	56.5	62.1	66.8	71.0	74.6	78.0
337.5			40.0	48.0	54.4	59.8	64.3	68.3	71.9	75.1

Table 2-3: Modelled wind speeds and directions for high and low sea level simulations (+/- 0.3m)

Direction (Deg/N)	Windspeed (Km/hr)				
	1.0% of year	*0.1% of year*	*1-yr ARI*	*10-yr ARI*	*100-yr ARI*
000.0	37.48	51.00	55.99	64.02	70.34
045.0	27.94	38.02	41.74	47.73	52.44
067.5	23.66	32.20	35.36	40.43	44.42
090.0	21.88	29.78	32.70	37.38	41.08
112.5	22.35	30.41	33.39	38.18	41.95
135.0	23.42	31.87	35.00	40.01	43.96
157.5	25.00	34.01	37.35	42.70	46.92
180.0	26.39	35.91	39.43	45.08	49.53

3 Summary

A wave model was developed for the Peel-Harvey Estuary to estimate nearshore wave conditions along the shoreline for a range of wind speed, wind direction and water level scenarios.

Output wave conditions have been produced at of 964 locations situated around the shoreline of the estuary. These locations were all situated at approximately -1mAHD contour.

A Appendix A: SWAN output samples

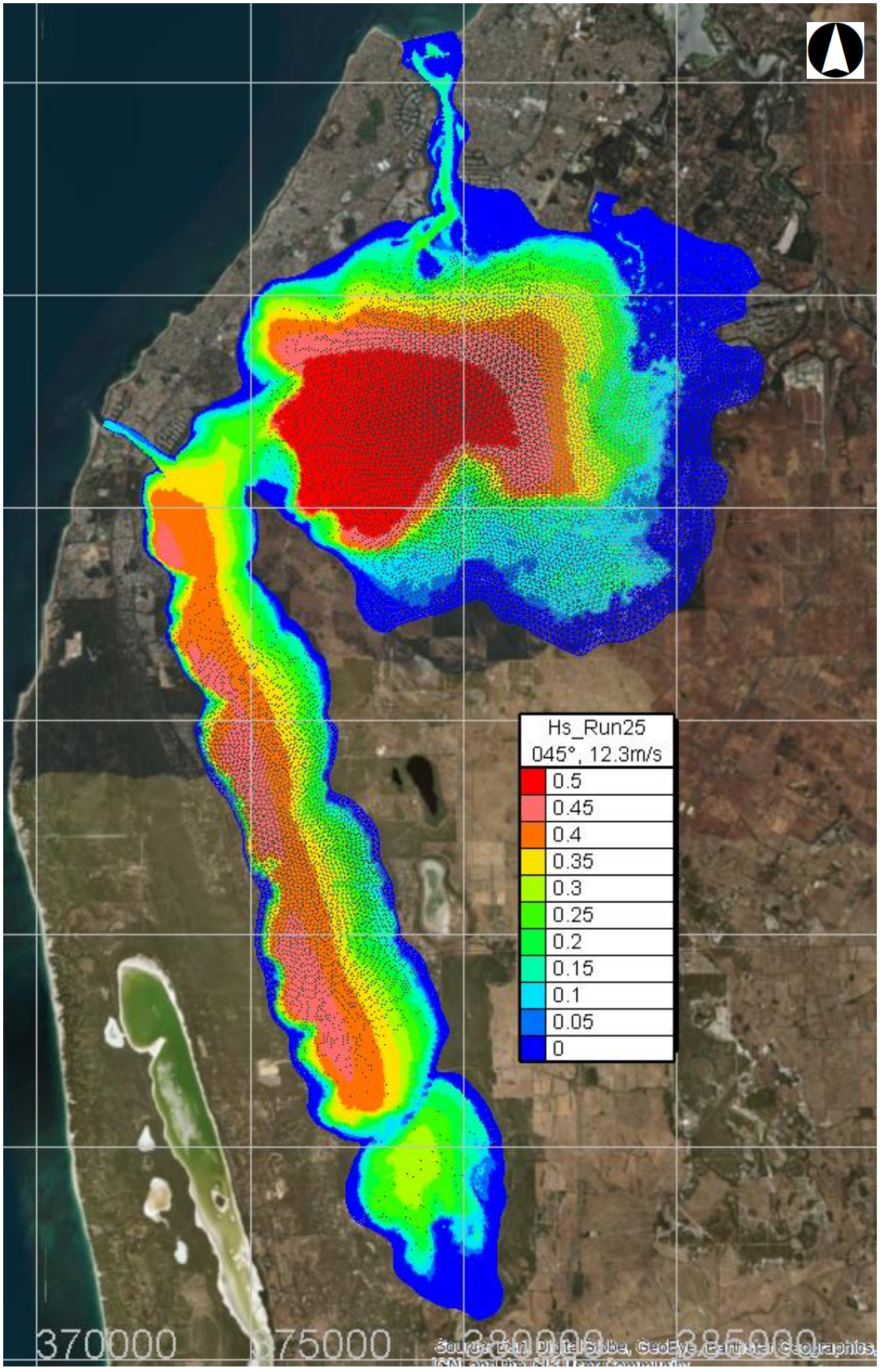


Figure A-1: Significant Wave Height for run 25 using a 12 m/s wind from 045º

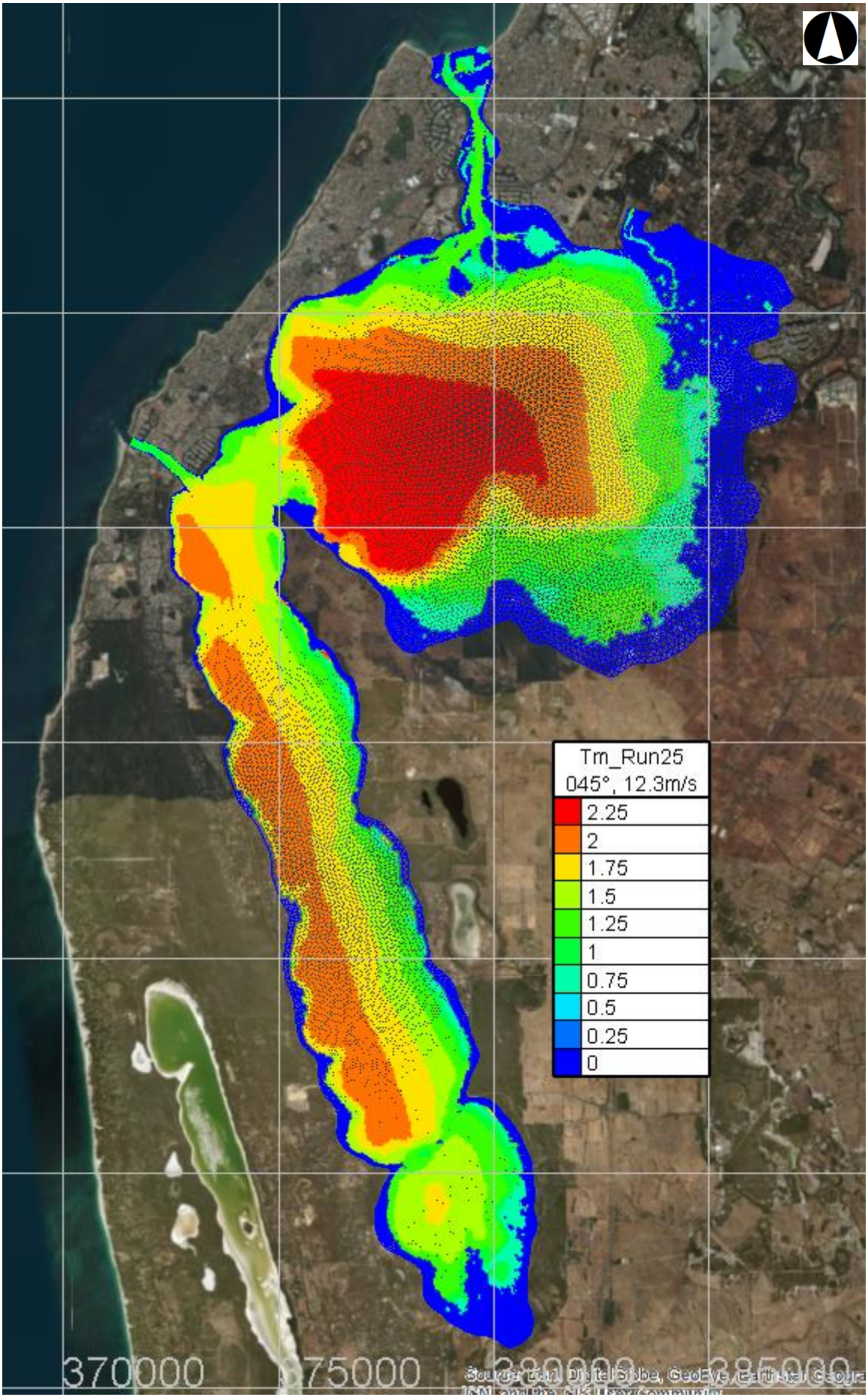


Figure A-2: Mean wave period for run 25 using a 12 m/s wind from 045º

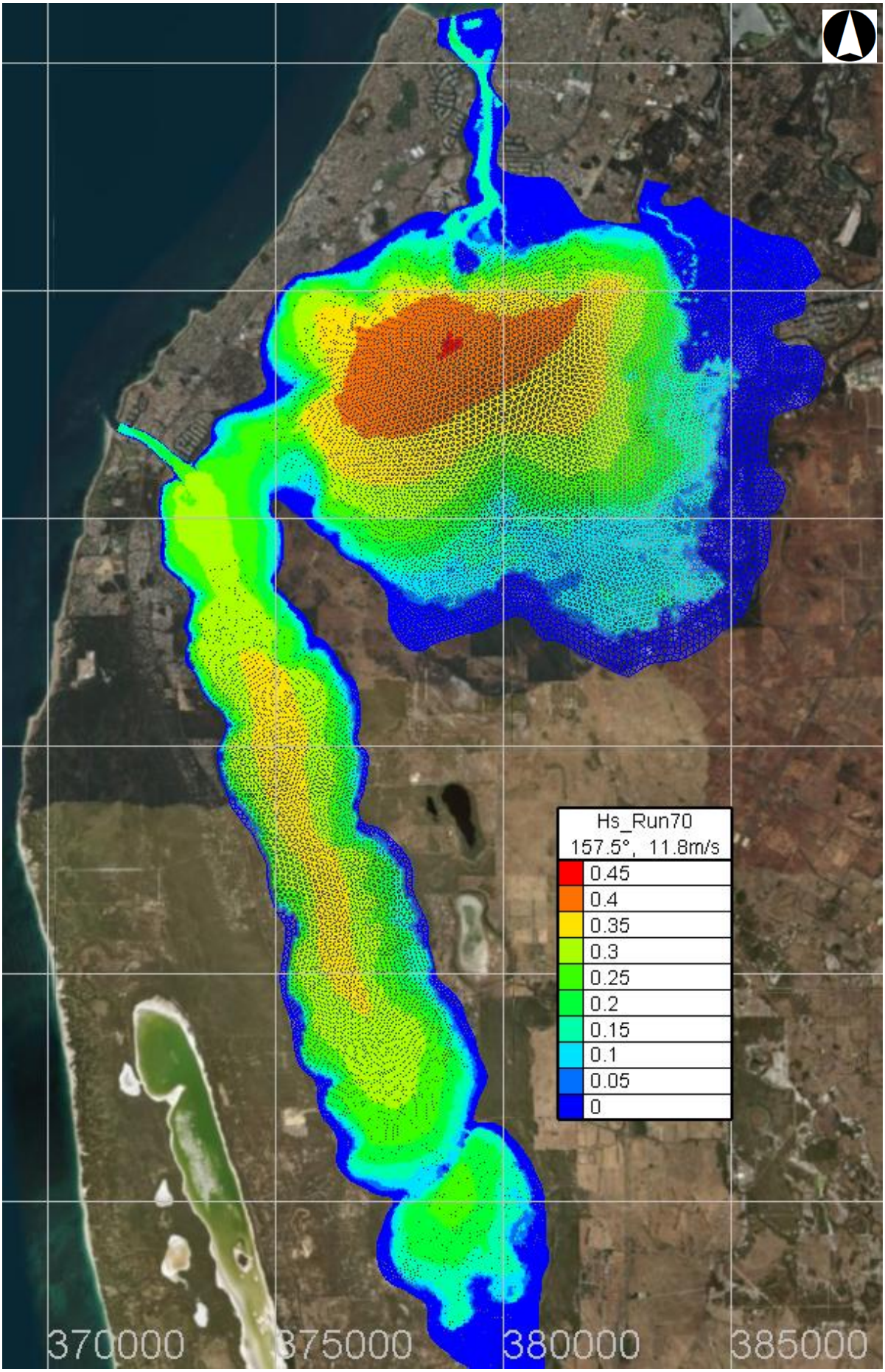


Figure A-3: Significant Wave Height for run 70 using a 11.8 m/s wind from 157.5º

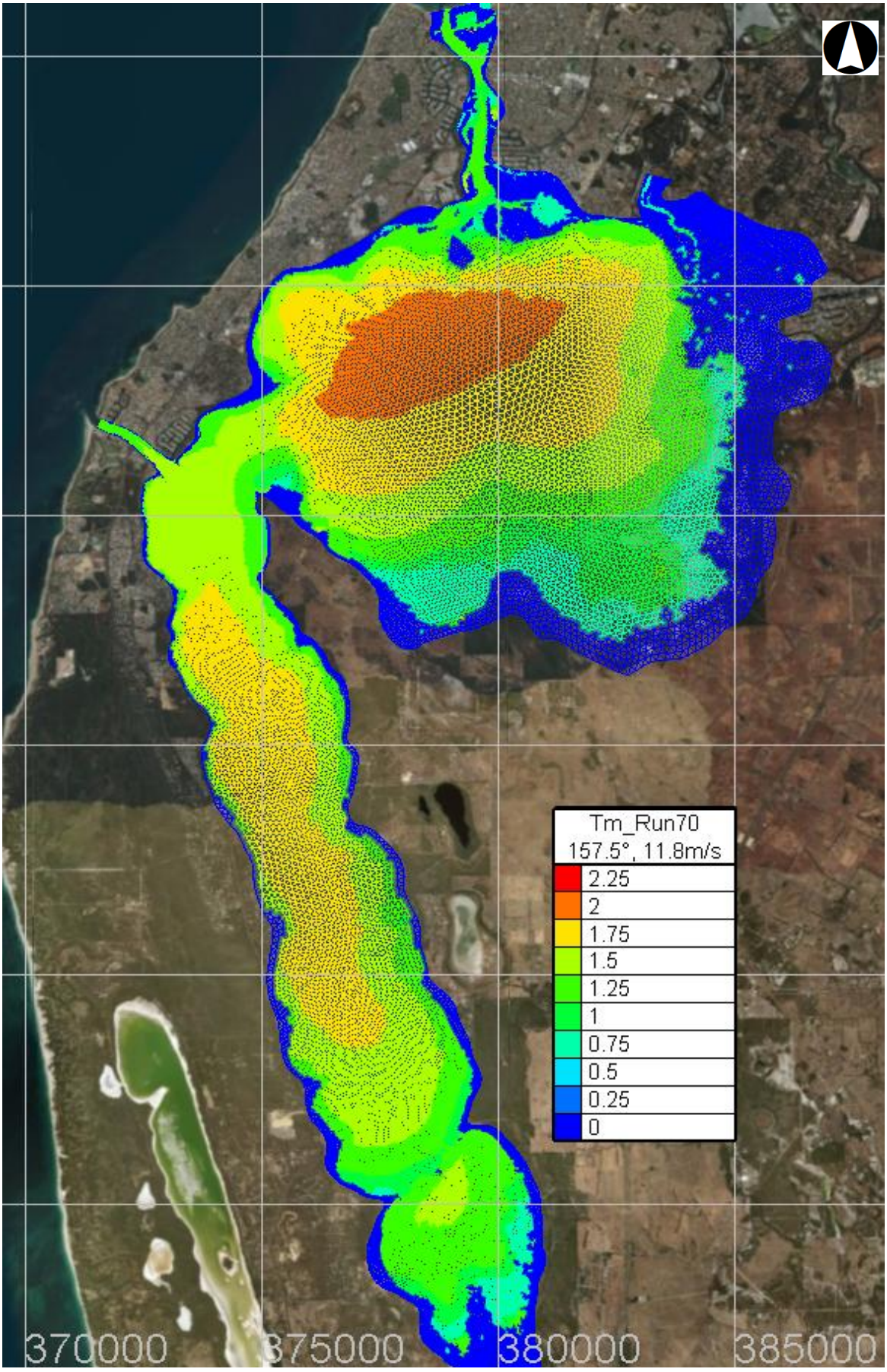


Figure A-4:: Mean Wave period for run 70 using a 11.8 m/s wind from 157.5º

B Appendix B: Sample output data

RunID	SWAN Node	Output Node	X	Y	Hs	Tm	PkDir	Dir	Wave length	Bottom Level	dHS	WL	Wdir	WSpeed_m/s
1	6737	16	378999	6377094	0.30	1.94	305	311	2.85	1.17	0.00	-0.17	0	12.5
2	6737	16	378999	6377094	0.33	2.03	295	308	3.05	1.17	0.00	-0.17	0	14.2
3	6737	16	378999	6377094	0.35	2.09	295	307	3.12	1.17	0.00	-0.17	0	15.6
4	6737	16	378999	6377094	0.36	2.12	295	306	3.16	1.17	0.00	-0.17	0	16.7
5	6737	16	378999	6377094	0.36	2.14	295	306	3.15	1.17	0.00	-0.17	0	17.8
6	6737	16	378999	6377094	0.37	2.15	295	306	3.14	1.17	0.00	-0.17	0	18.7
7	6737	16	378999	6377094	0.37	2.15	295	307	3.15	1.17	0.00	-0.17	0	19.5
8	6737	16	378999	6377094	0.14	1.36	315	330	1.52	1.17	0.00	-0.17	23	6.9
9	6737	16	378999	6377094	0.20	1.54	315	332	1.87	1.17	0.00	-0.17	23	9.4
10	6737	16	378999	6377094	0.23	1.67	315	329	2.16	1.17	0.00	-0.17	23	11.3
11	6737	16	378999	6377094	0.26	1.76	315	328	2.35	1.17	0.00	-0.17	23	12.8
12	6737	16	378999	6377094	0.28	1.83	305	326	2.53	1.17	0.00	-0.17	23	14.0
13	6737	16	378999	6377094	0.30	1.88	305	324	2.61	1.17	0.00	-0.17	23	15.1
14	6737	16	378999	6377094	0.31	1.93	305	323	2.74	1.17	0.00	-0.17	23	16.0
15	6737	16	378999	6377094	0.32	1.96	305	322	2.79	1.17	0.00	-0.17	23	16.8
16	6737	16	378999	6377094	0.33	1.98	305	321	2.79	1.17	0.00	-0.17	23	17.6
17	6737	16	378999	6377094	0.07	1.13	315	324	1.06	1.17	0.00	-0.17	45	5.7
18	6737	16	378999	6377094	0.12	1.25	325	342	1.27	1.17	0.00	-0.17	45	7.8
19	6737	16	378999	6377094	0.16	1.34	335	349	1.47	1.17	0.00	-0.17	45	9.3
20	6737	16	378999	6377094	0.18	1.42	335	352	1.68	1.17	0.00	-0.17	45	10.6
21	6737	16	378999	6377094	0.20	1.47	335	352	1.76	1.17	0.00	-0.17	45	11.6
22	6737	16	378999	6377094	0.21	1.50	335	352	1.80	1.17	0.00	-0.17	45	12.5

Offices in
Australia
Cambodia
Ireland
Singapore
UK
USA

Registered Office
Level 2,
433 Boundary Street,
Spring Hill QLD 4004
Australia

t: +61 (0)7 3838 2578
e:info@jbpacific.com.au

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ABN: 56 610 411 508
ACN: 610 411 508

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Appendix I – Extreme Storm Flooding Assessment

Working Note

Baird.
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Project/Proposal Number :	13064.101	**Date**	7 October 2020
Staff Member :	RLW		
Title :	Shire of Murray Design Storm Summary		
Summary / Description :	Overview of the modelling carried out to define a water level under design storm conditions at Mandurah, WA, for defining a design storm water level within the Peel-Harvey Estuary		
File Reference :	13064.101.W.RLW.RevA_ShireofMurrayDesignStormSummary		

Model Setup

Baird's established and validated numerical model of the West Australian coast, developed and validated for a recent inundation study for the Shire of Gingin, has been utilised for modelling of the design storm water level outside of the Peel-Harvey Estuary. The Delft-FM model extent covers the entire west coast of Western Australia from Northwest Cape to Cape Leeuwin as shown in Figure 1. There is varying model resolution, highest along the coastline areas, with Figure 2 showing resolution and observation points used in the modelling outside of the Peel-Harvey Estuary.

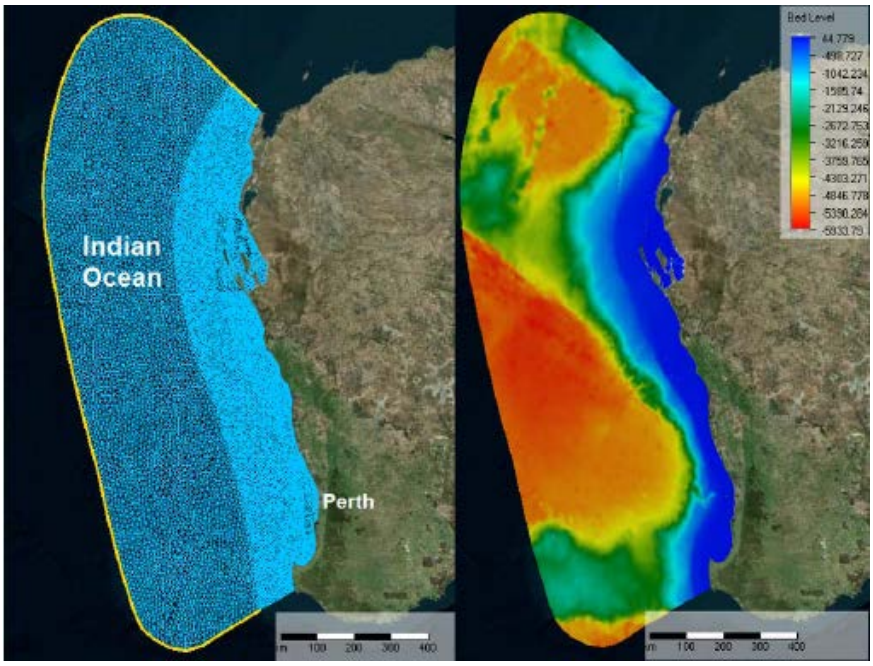


Figure 1: Model resolution and bathymetry

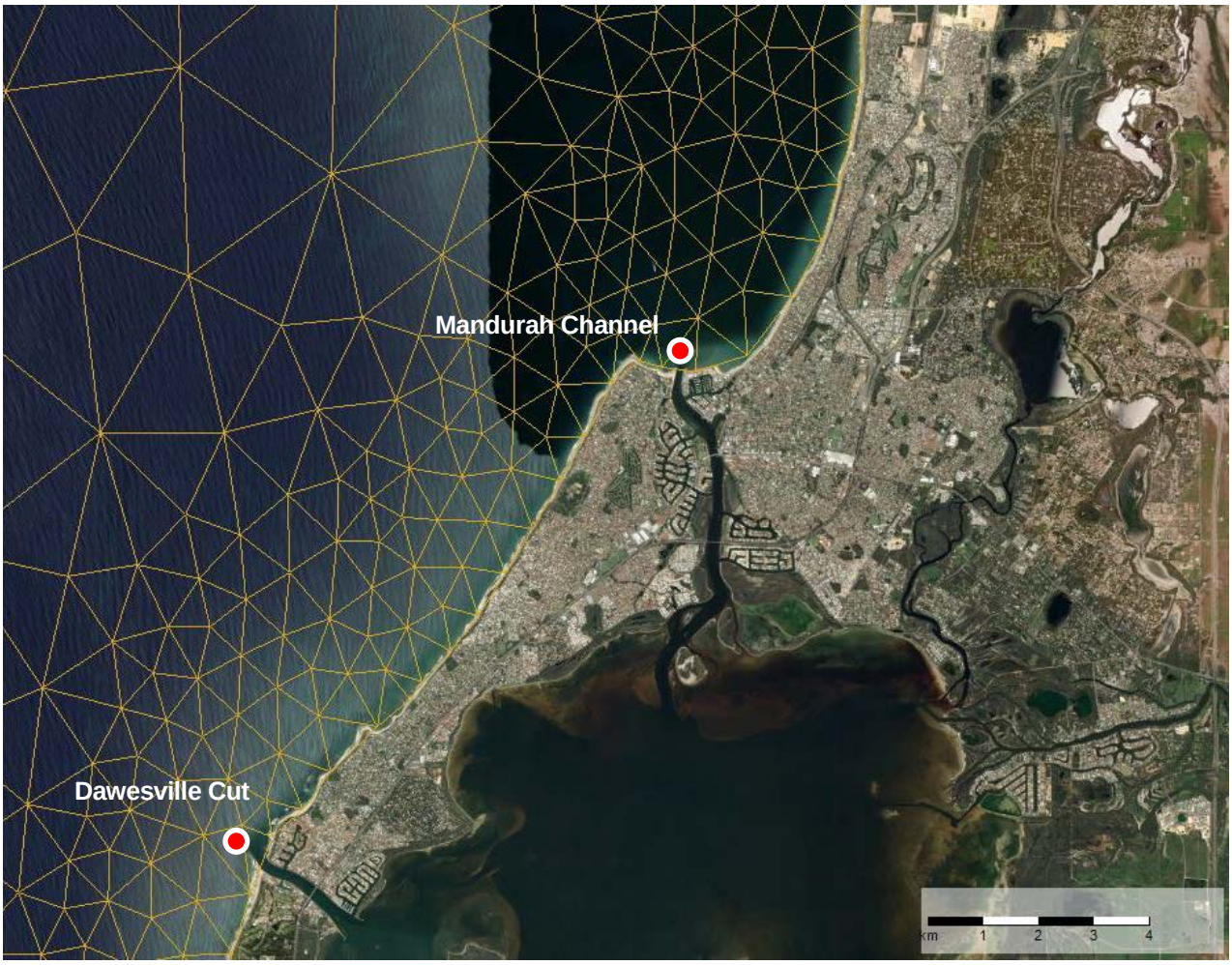


Figure 2: Model resolution outside of the Peel-Harvey Estuary, with observation points used in the modelling

Wave Model

The wave model adopted for the simulation of wave conditions in this assessment is the industry standard SWAN wave model (Simulating Waves Near Shore) developed at Delft University of Technology in the Netherlands. SWAN is a third-generation spectral wave model which computes wave propagation, wave generation by wind, non-linear wave-wave interactions and dissipation, for a given bottom topography, wind field, water level and current field (Deltares 2019).

The SWAN model accounts for (refractive) propagation due to current and depth and represents the processes of wave generation by wind, dissipation due to whitecapping, bottom friction and depth-induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations. Wave blocking by currents is also explicitly represented in the model (Deltares 2019).

For the Gingin study, a coupled SWAN model was established across the same extent as the hydrodynamic model, comprised of five nested grids which increase in resolution approaching the Gingin Study area at 5km,

1km, 500m, 100m and 50m resolutions. For this study, the outer grid, covering the coast down to Mandurah, has been used to model the waves (Figure 3). It should be noted that this outer grid resolution is low to accurately estimate wave setup. In line with this, it is likely that the wave setup is being overestimated by the model as the wave model resolution is too low to define the breaking zone in detail. This model limitation should be taken into consideration when assessing model results.

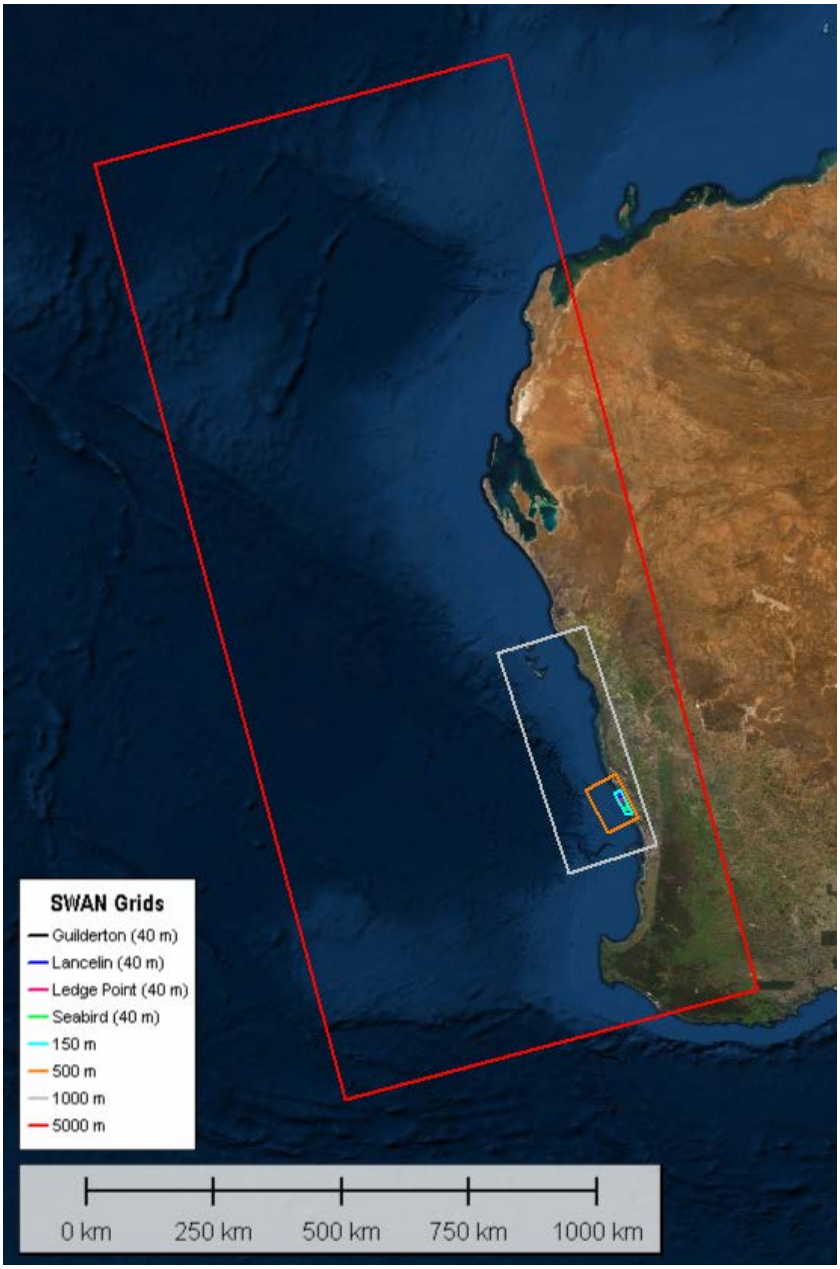


Figure 3: SWAN Model Grid extending across entire D-FM Model Domain (5000m grid size)

Wind Model

The wind model adopted in this study is Baird's Cycwind model system that adopts a Holland (2010) spatial cyclone vortex model. The cyclone wind field has adopted track parameters from the BoM's best track database (BoM, 2019) with adjustment of the Radius to Gales (R34) and Radius to Outer Closed Isobar (ROCI) parameters to better describe the windfield along the coastal waters of southwestern WA as the system track south. The design cyclone tracks for the Peel study area presented in Seashore Engineering (2020) are based on the TC Ned track and the TC Alby Track. Further information on the cyclone wind field model including validation for historical events is presented in Baird (2020b).

Maximum winds experienced for the Peel region during the passage of the design cyclones are detailed in Table 1.

Table 1: Maximum wind speeds across the Peel Region during passage of Seashore Engineering Design Cyclones

Design Cyclone	Peel Region Maximum Wind Speed (m/s)
TC Alby	39.5
TC Ned	43

Design Storms

Design storms based on Tropical Cyclone Ned (Figure 4) and Tropical Cyclone Alby (Figure 5) are presented below, including the central pressure associated with the cyclone track. Table 2 and Table 3 tabulate the central pressure and radius to maximum winds associated with each design storm.

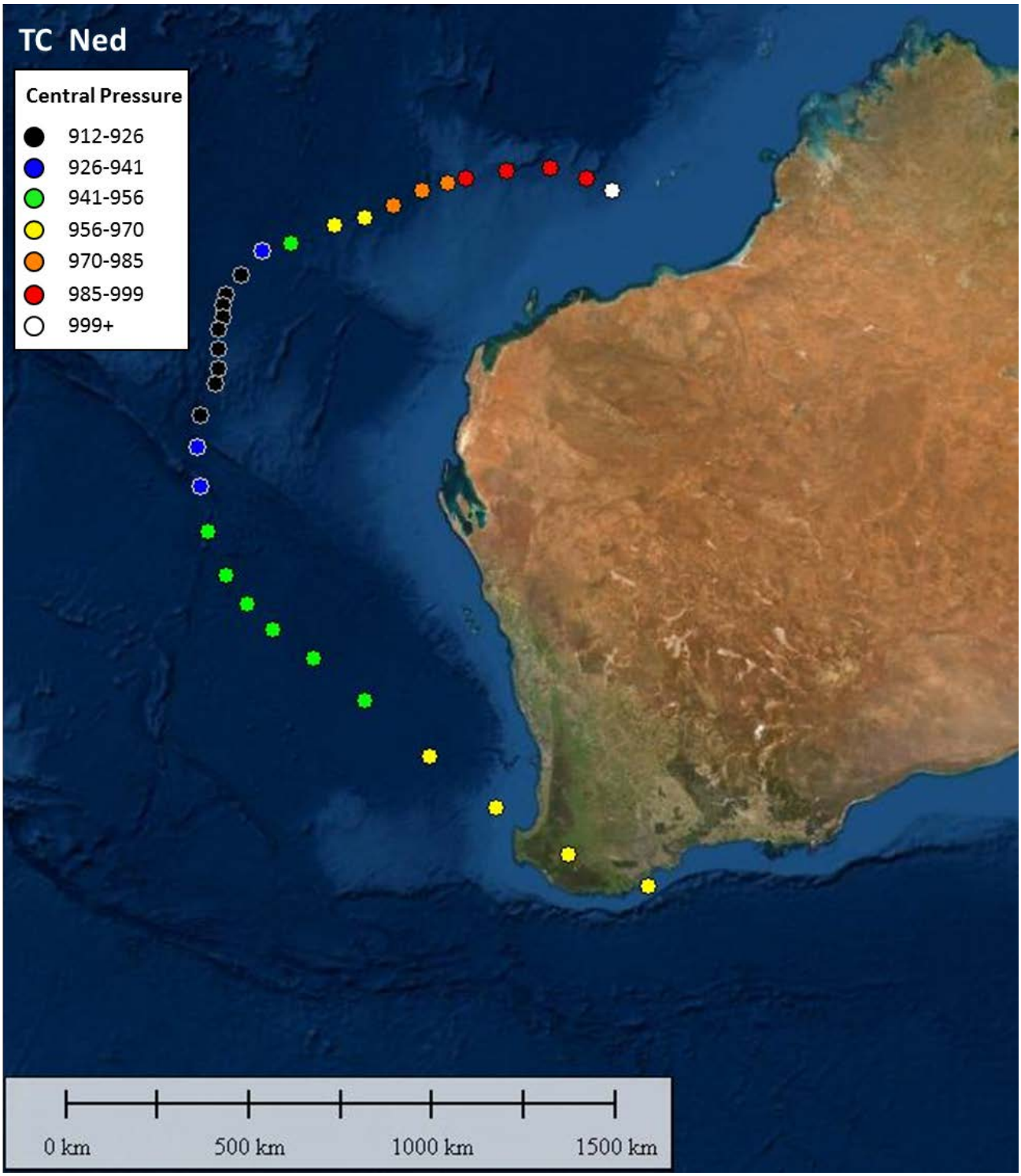


Figure 4: Path of Design Storm for Peel, based on Tropical Cyclone Ned, showing a scale of central pressure

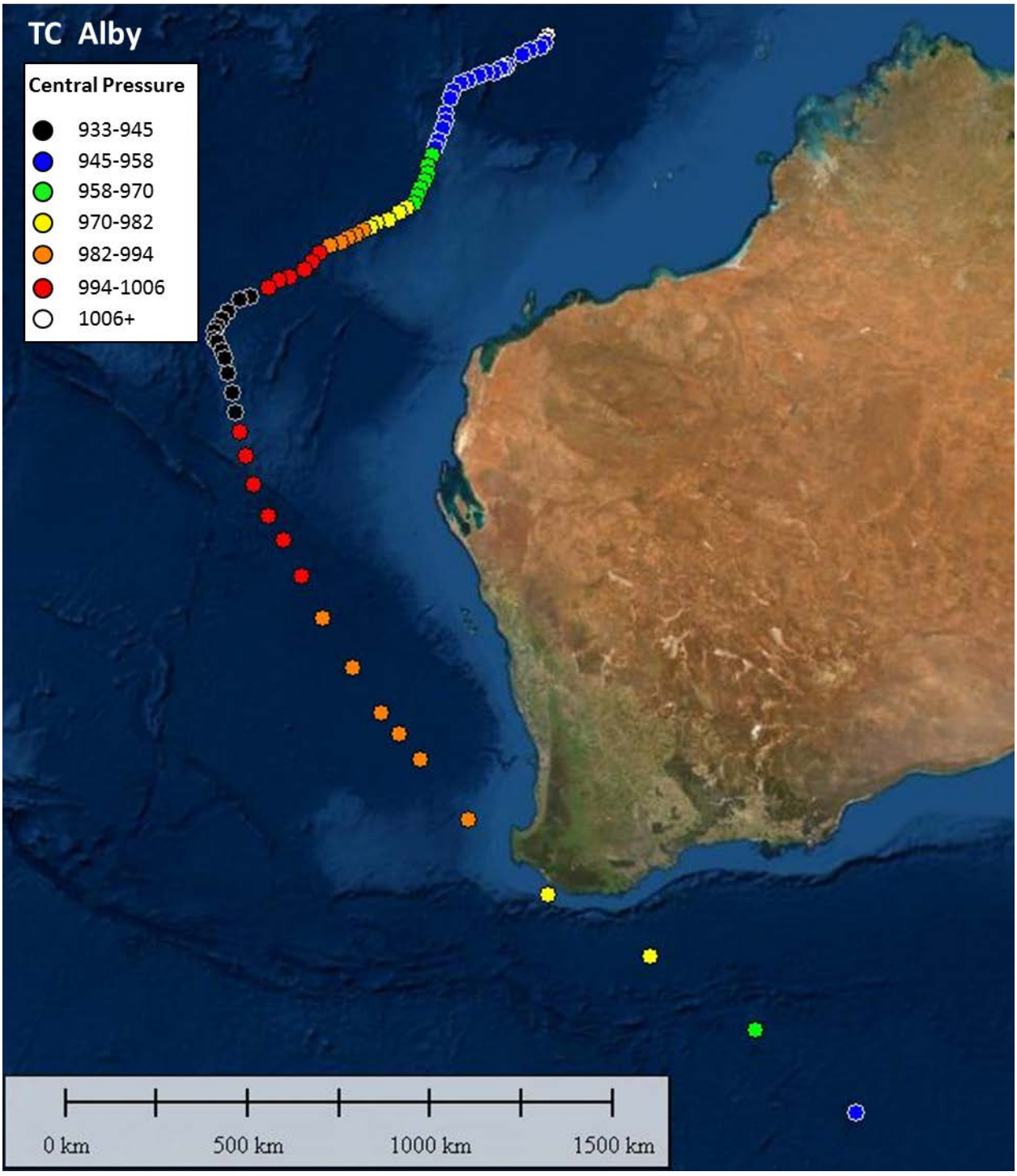


Figure 5: Path of Design Storm for Peel, based on Tropical Cyclone Ned, showing a scale of central pressure

Table 2: Central Pressure and Radius to Maximum Winds for the Design Storm for Peel Based on TC Alby

Date / Time	Long	Lat	CP	Rmax
27/03/1978 1:00	116.0	13.6	1006.3	54
27/03/1978 4:00	115.9	13.7	1006.3	54
27/03/1978 7:00	115.9	13.8	1005.4	54
27/03/1978 10:00	115.8	13.9	1005.4	54
27/03/1978 13:00	115.5	14.0	1004.4	54
27/03/1978 16:00	115.3	14.1	1004.4	54
27/03/1978 19:00	114.9	14.4	1004.4	54
27/03/1978 22:00	114.8	14.5	1003.5	54
28/03/1978 1:00	114.7	14.5	1002.5	54
28/03/1978 4:00	114.5	14.6	1001.5	54
28/03/1978 7:00	114.3	14.6	1000.6	54
28/03/1978 10:00	114.1	14.7	998.7	54
28/03/1978 13:00	113.8	14.8	998.7	54
28/03/1978 16:00	113.6	14.9	998.7	54
28/03/1978 19:00	113.4	15.1	997.7	54
28/03/1978 22:00	113.3	15.3	997.7	54
29/03/1978 1:00	113.2	15.7	997.7	54
29/03/1978 4:00	113.2	15.9	996.8	54
29/03/1978 7:00	113.1	16.1	995.8	54
29/03/1978 10:00	113.0	16.4	995.8	54
29/03/1978 13:00	112.9	16.6	994.9	54
29/03/1978 16:00	112.8	16.8	993.9	54
29/03/1978 19:00	112.7	17.1	993.0	54
29/03/1978 22:00	112.7	17.3	992.0	54
30/03/1978 1:00	112.6	17.5	991.0	54
30/03/1978 4:00	112.5	17.7	988.2	54
30/03/1978 7:00	112.4	17.9	985.3	54
30/03/1978 10:00	112.3	18.1	983.4	54
30/03/1978 13:00	112.1	18.2	981.5	54
30/03/1978 16:00	111.9	18.3	978.6	54
30/03/1978 19:00	111.6	18.5	975.8	54
30/03/1978 22:00	111.3	18.6	973.9	54
31/03/1978 1:00	111.1	18.7	972.0	54
31/03/1978 4:00	110.9	18.8	969.1	54
31/03/1978 7:00	110.7	18.9	967.2	54
31/03/1978 10:00	110.5	19.0	964.3	54
31/03/1978 13:00	110.3	19.1	962.4	54

31/03/1978 16:00	110.0	19.2	959.5	54
31/03/1978 19:00	109.7	19.4	957.6	54
31/03/1978 22:00	109.5	19.6	954.8	54
1/04/1978 1:00	109.3	19.8	952.9	54
1/04/1978 4:00	108.9	20.0	950.0	54
1/04/1978 7:00	108.6	20.1	948.1	54
1/04/1978 10:00	108.3	20.3	946.2	54
1/04/1978 13:00	107.8	20.5	943.3	54
1/04/1978 16:00	107.5	20.6	940.5	54
1/04/1978 19:00	107.2	20.9	937.6	54
1/04/1978 22:00	107.0	21.1	935.7	54
2/04/1978 1:00	106.9	21.3	933.8	54
2/04/1978 4:00	106.8	21.4	934.7	54
2/04/1978 7:00	106.8	21.6	935.7	54
2/04/1978 10:00	106.9	21.7	936.6	54
2/04/1978 13:00	107.0	21.9	938.5	54
2/04/1978 16:00	107.1	22.1	939.5	54
2/04/1978 19:00	107.2	22.5	940.5	54
2/04/1978 22:00	107.3	23.0	941.4	54
3/04/1978 1:00	107.4	23.5	943.3	54
3/04/1978 4:00	107.5	24.0	945.2	54
3/04/1978 7:00	107.7	24.6	947.1	54
3/04/1978 10:00	107.9	25.3	950.0	55
3/04/1978 13:00	108.3	26.1	952.9	65
3/04/1978 16:00	108.7	26.7	954.8	75
3/04/1978 19:00	109.2	27.6	957.6	85
3/04/1978 22:00	109.8	28.6	959.5	100
4/04/1978 1:00	110.6	29.8	962.4	120
4/04/1978 4:00	111.4	30.9	964.3	160
4/04/1978 6:00	111.9	31.4	965.3	190
4/04/1978 7:00	112.5	32.0	967.2	220
4/04/1978 10:00	113.8	33.4	969.1	240
4/04/1978 13:00	116.0	35.1	972.0	280
4/04/1978 16:00	118.8	36.5	979.6	360
4/04/1978 19:00	121.7	38.1	990.1	360
4/04/1978 22:00	124.5	39.9	1000.6	360

Table 3: Central Pressure and Radius to Maximum Winds for the Design Storm for Peel Based on TC Ned

Date / Time	Long	Lat	CP	Rmax
25/03/1989 6:00	117.7	17.8	999.0	54
25/03/1989 12:00	117.0	17.5	996.2	54
25/03/1989 18:00	116.0	17.2	993.4	54
26/03/1989 0:00	114.8	17.3	990.6	54
26/03/1989 6:00	113.7	17.5	987.8	54
26/03/1989 12:00	113.2	17.6	983.6	54
26/03/1989 18:00	112.5	17.8	979.4	54
27/03/1989 0:00	111.7	18.2	975.2	54
27/03/1989 6:00	110.9	18.5	969.6	54
27/03/1989 12:00	110.1	18.7	962.6	54
27/03/1989 18:00	108.9	19.2	948.6	54
28/03/1989 0:00	108.1	19.4	930.4	54
28/03/1989 6:00	107.5	20.0	922.0	54
28/03/1989 12:00	107.1	20.5	917.8	54
28/03/1989 18:00	107.0	20.8	913.6	54
29/03/1989 0:00	107.0	21.1	912.2	54
29/03/1989 6:00	106.9	21.4	915.0	54
29/03/1989 12:00	106.9	21.9	920.6	54
29/03/1989 18:00	106.9	22.4	922.0	54
30/03/1989 0:00	106.8	22.8	922.0	54
30/03/1989 6:00	106.4	23.6	926.2	54
30/03/1989 12:00	106.3	24.4	931.8	61
30/03/1989 18:00	106.4	25.4	936.0	68
31/03/1989 0:00	106.6	26.5	943.0	75
31/03/1989 6:00	107.1	27.6	947.2	90
31/03/1989 9:00	107.7	28.3	947.2	100
31/03/1989 12:00	108.4	28.9	950.0	110
31/03/1989 15:00	109.5	29.6	954.2	120
31/03/1989 18:00	110.9	30.6	954.2	140
31/03/1989 21:00	112.7	31.9	961.2	180
1/04/1989 0:00	114.5	33.1	961.2	230
1/04/1989 3:00	116.5	34.2	964.0	250
1/04/1989 6:00	118.7	34.9	968.2	270

Model Validation

The hydrodynamic model has been validated against predicted water levels at key locations in southwest WA as reported in Baird Australia (2020a and 2020b). The model validation is shown in Figure 6 and Figure 7and and shows excellent agreement with time series and validation statistics for modelled and predicted tides from the model at Hillary's, Jurien Bay, Lancelin and Two Rocks Marina. The validation metrics are excellent with little bias and RMS error of about 0.01-0.02 m between Fremantle and Bunbury. The model validation provides confidence the hydrodynamic model can be applied as a basis for the study in the phases to follow. Model validation for storm surge is presented in Baird (2020a and 2020b).

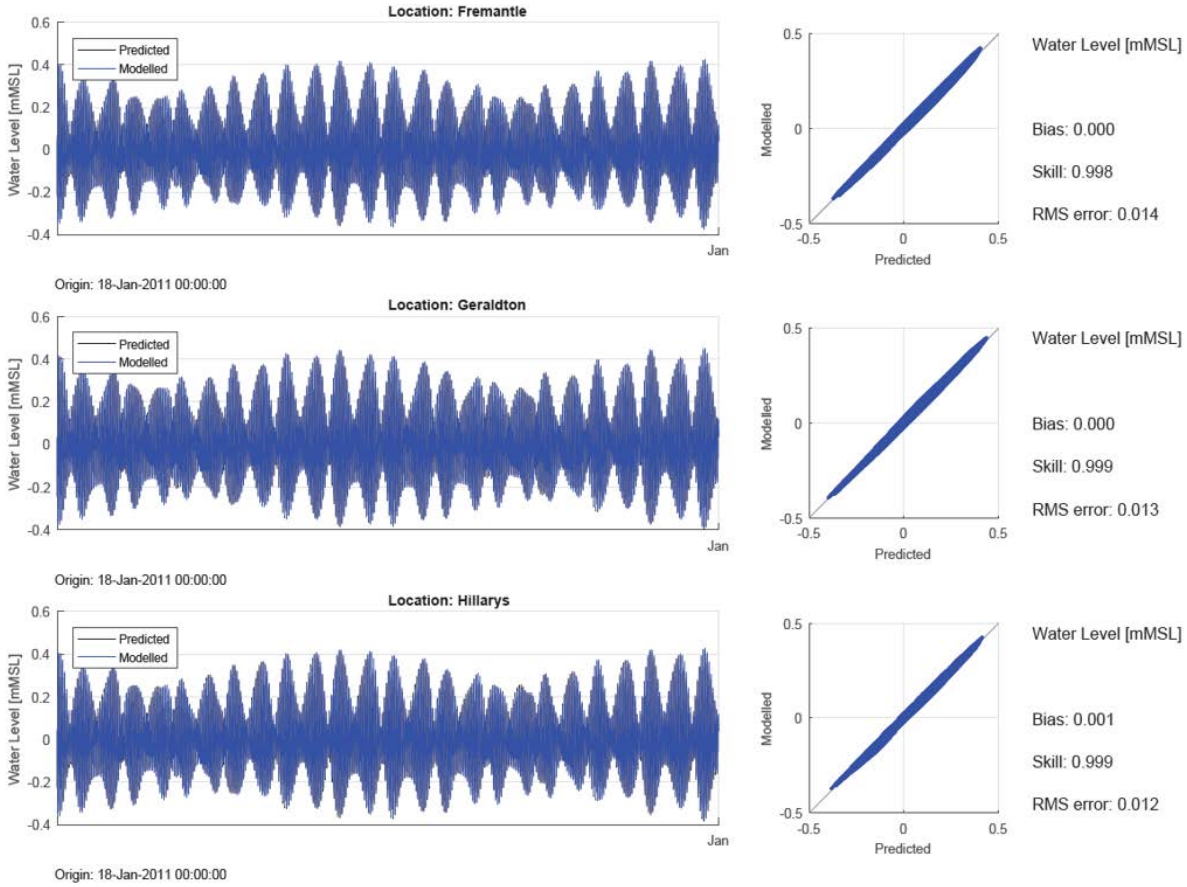


Figure 6: Time series comparisons of predicted (black), and simulated (blue) water levels for Fremantle, Geraldton, and Hillarys in 2011

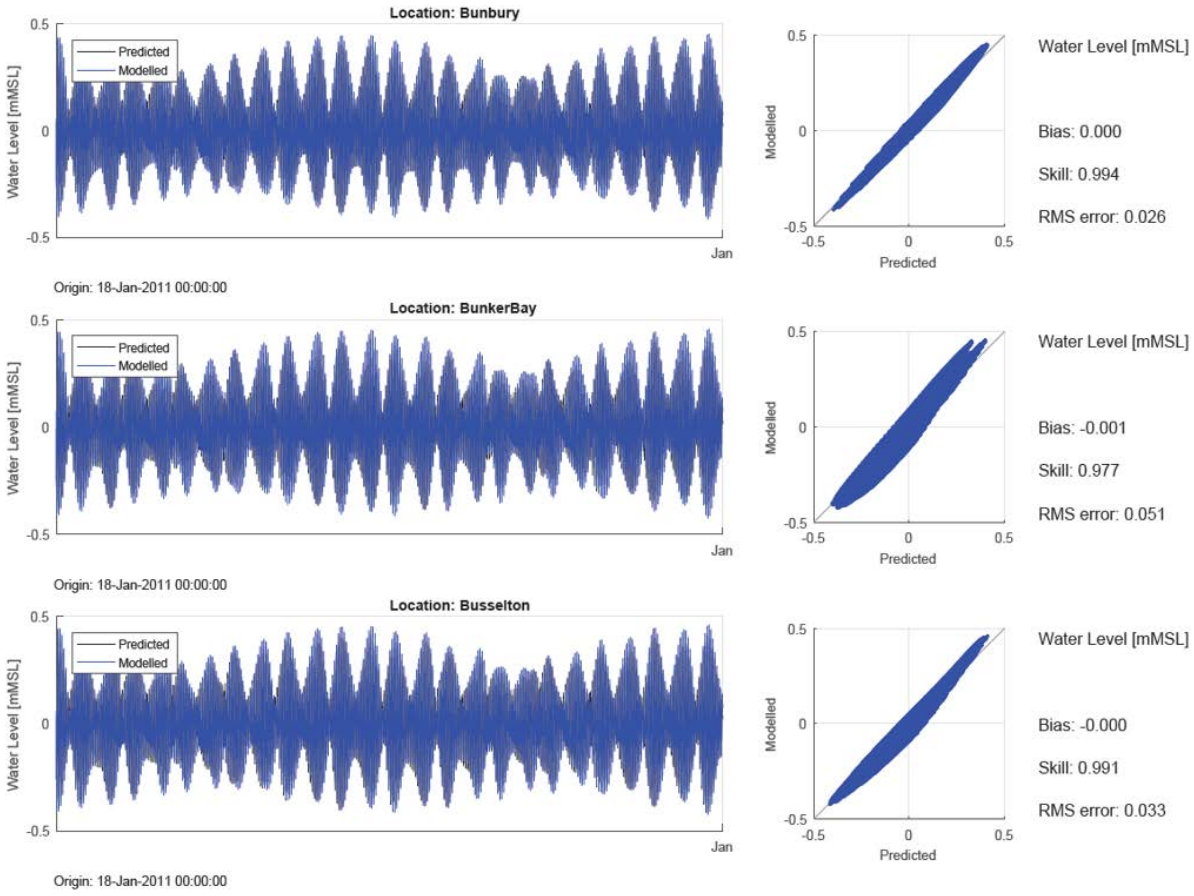


Figure 7: Time series comparisons of predicted (black), and simulated (blue) water levels for Bunbury, Bunker Bay, and Busselton in 2011.

Model Results

Model results were taken from just outside of Mandurah Channel and just outside of the Dawesville Cut, as seen in Figure 2. Results are presented from Figure 8 Figure 11, with the top panel showing the influence on water levels due to changes to water level (tide) only, as well as due to changes in wave conditions and the bottom panel showing the associated significant wave height.

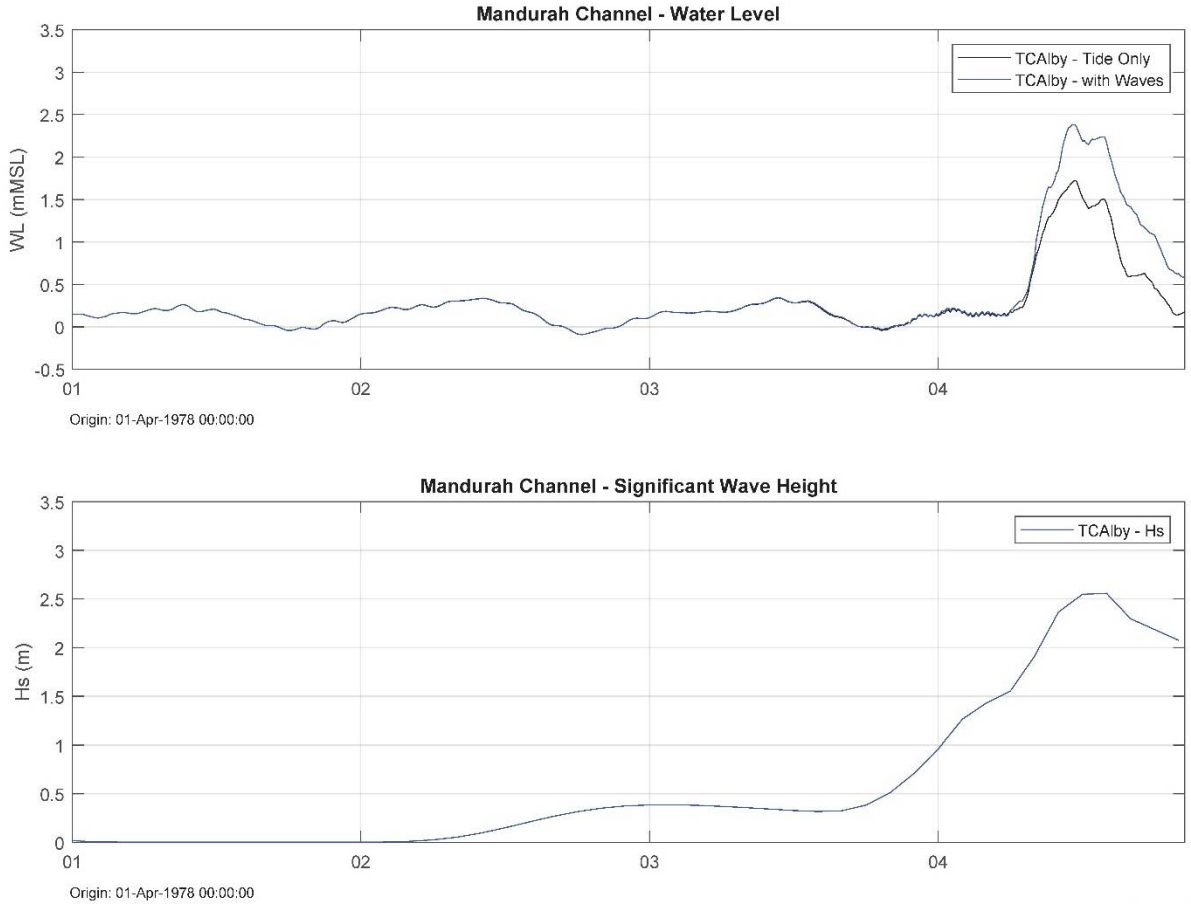


Figure 8: Water level and significant wave height modelled offshore of Mandurah Channel during a design storm based on Tropical Cyclone Alby

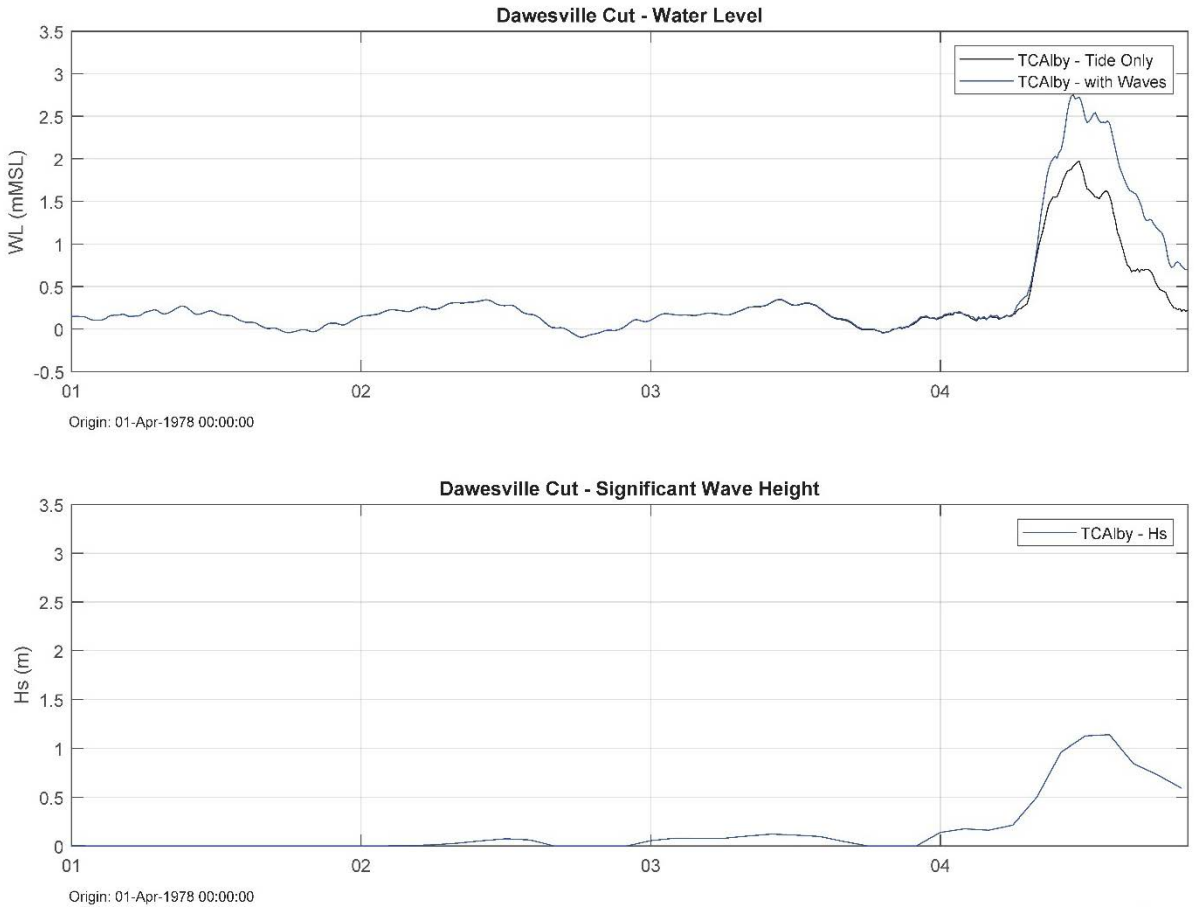


Figure 9: Water level and significant wave height modelled offshore of Dawesville Cut during a design storm based on Tropical Cyclone Alby

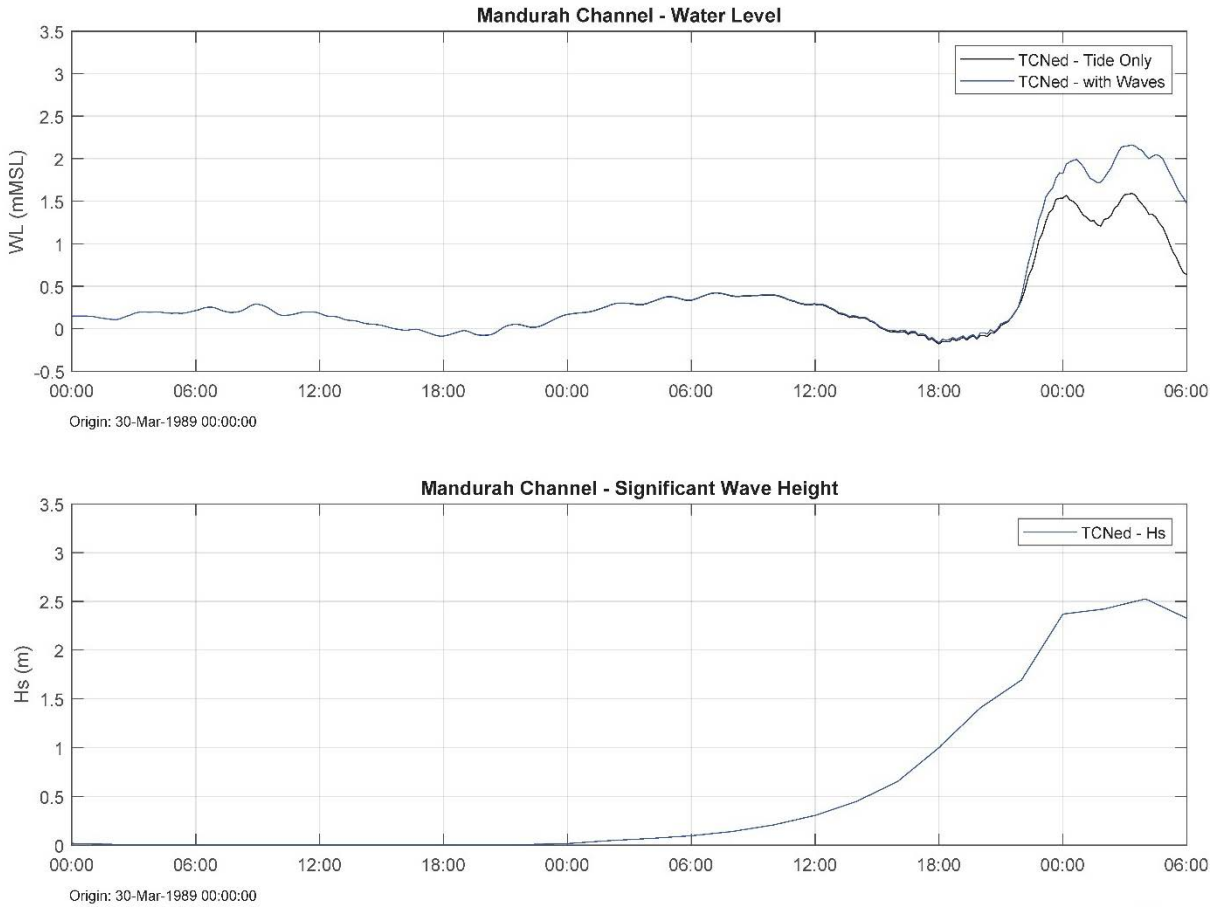


Figure 10: Water level and significant wave height modelled offshore of Mandurah Channel during a design storm based on Tropical Cyclone Ned

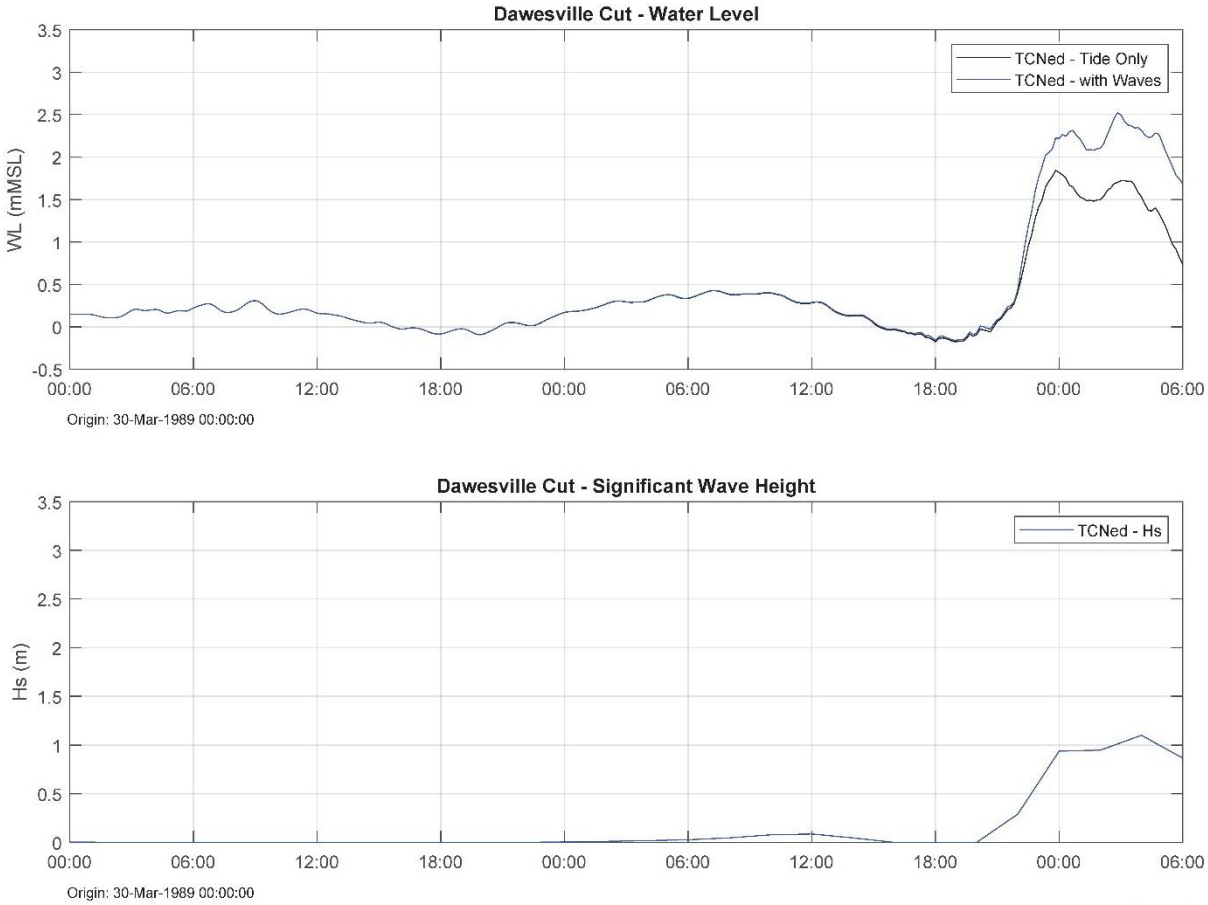


Figure 11: Water level and significant wave height modelled offshore of Dawesville Cut during a design storm based on Tropical Cyclone Ned

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C.2 Coastal Processes Allowance. Erosion Allowance for Peel-Harvey Shorelines

Baird.

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances (Erosion Setback)

Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

This map has been prepared by Baird Australia on behalf of the Shire of Murray as part of the Shire of Murray Coastal Hazard Risk Management and Adaptation Planning Project. The coastal setbacks have been adopted from the Coastal Hazard assessment completed for the Shire of Murray by Seashore (2021).

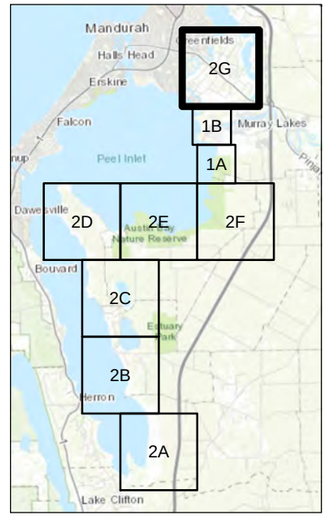
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

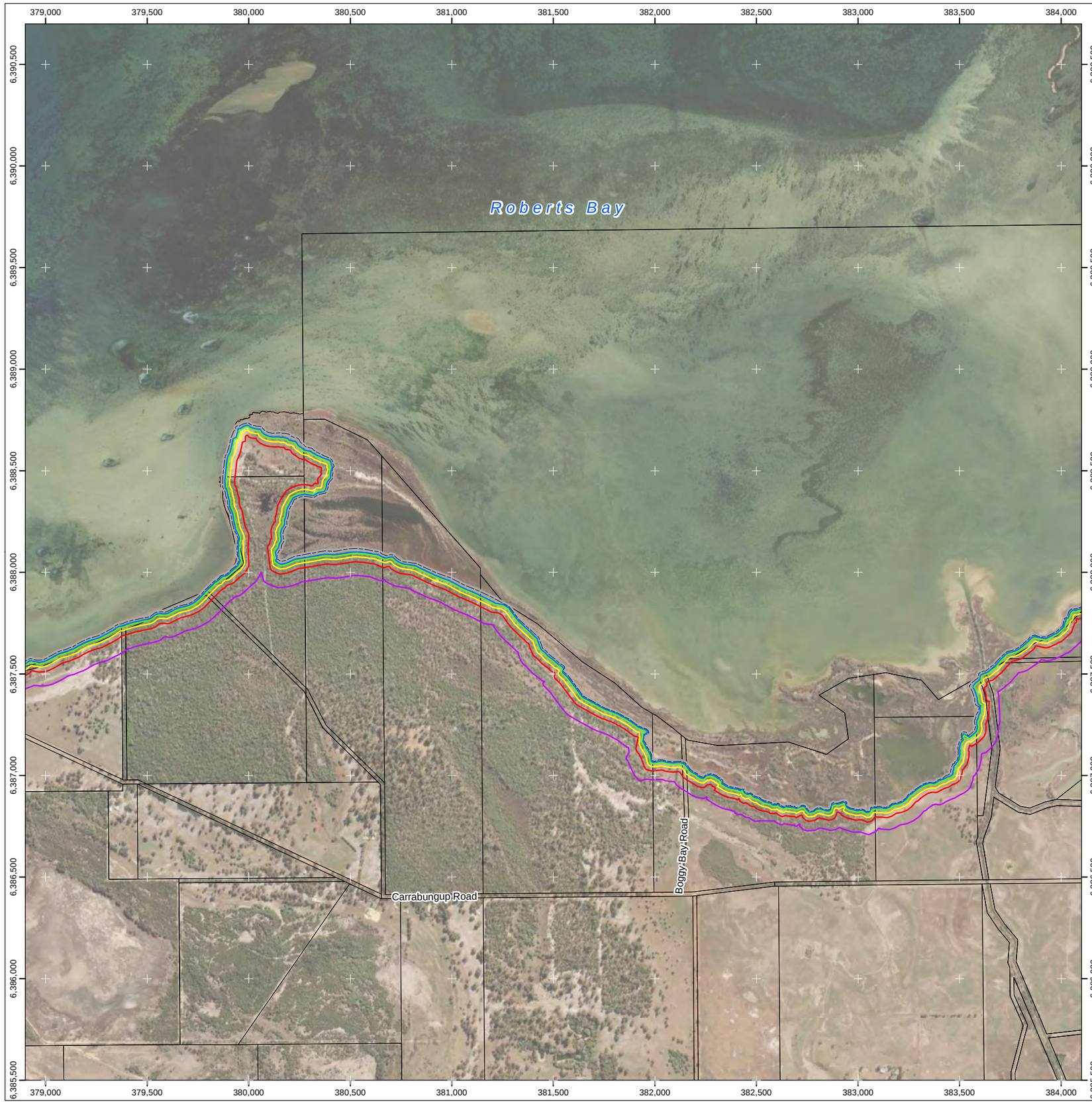
Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 2G

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances
(Erosion Setback)



Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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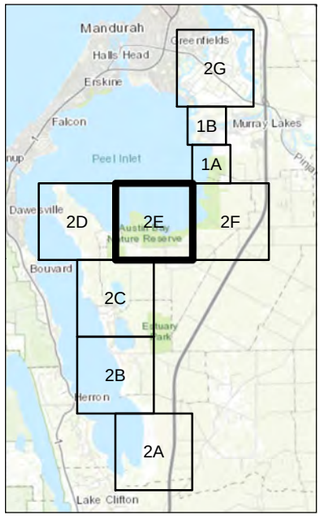
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 2E

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances
(Erosion Setback)



Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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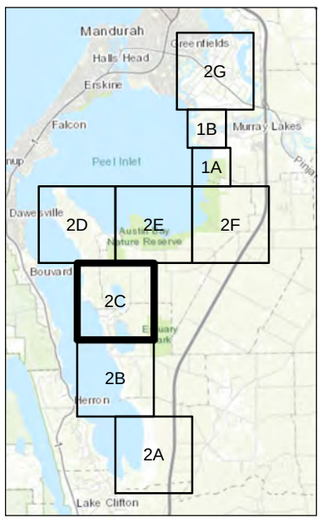
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 2C

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances
(Erosion Setback)



Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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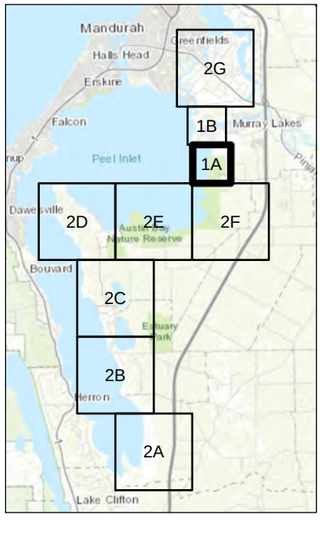
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 1A

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances
(Erosion Setback)



Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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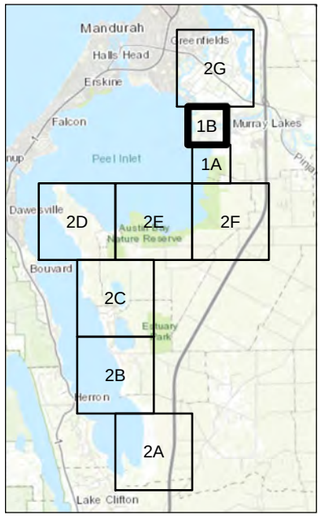
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 1B

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances
(Erosion Setback)

Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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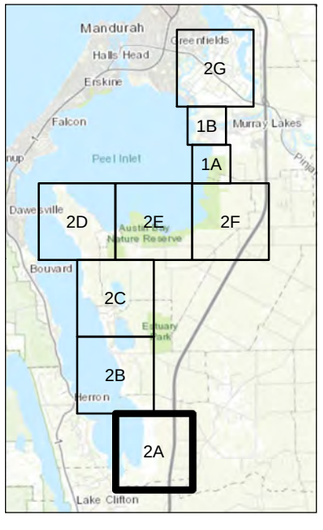
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 2A

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances (Erosion Setback)



Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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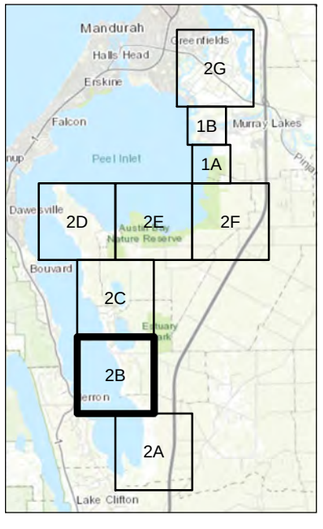
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Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 2B

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances
(Erosion Setback)

Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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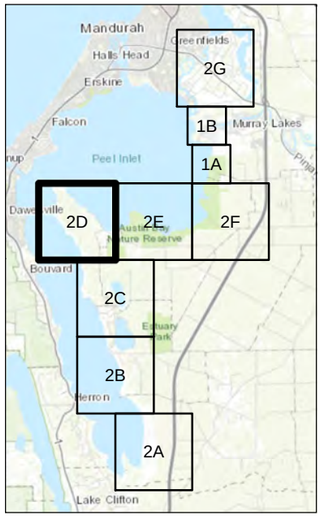
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 2D

Shire of Murray
Coastal Hazard Flood Mapping

Coastal Processes Allowances (Erosion Setback)

Horizontal Setback Datum

Setbacks

- 2020
- 2030
- 2050
- 2070
- 2120

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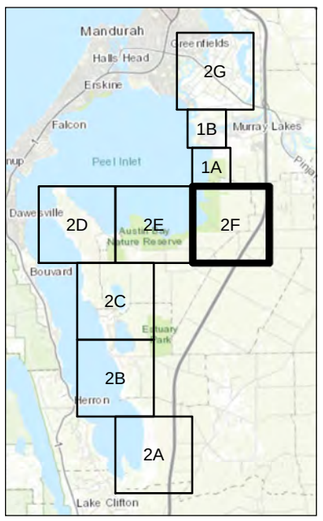
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2021.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



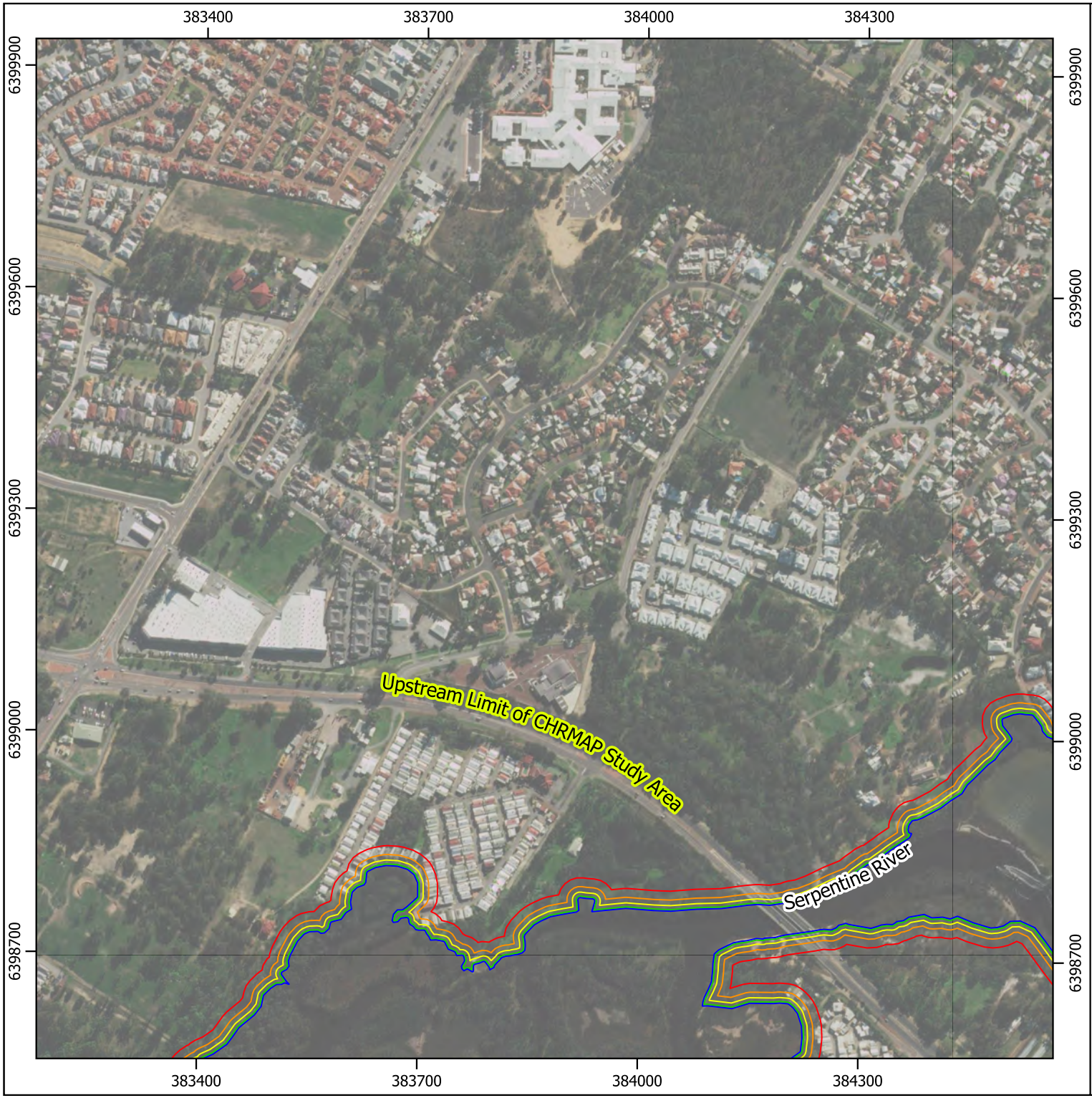
Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 20 Apr. 2021

Mapsheet: 2F

C.3 Erosion Hazard for Lower Murray and Serpentine Rivers



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

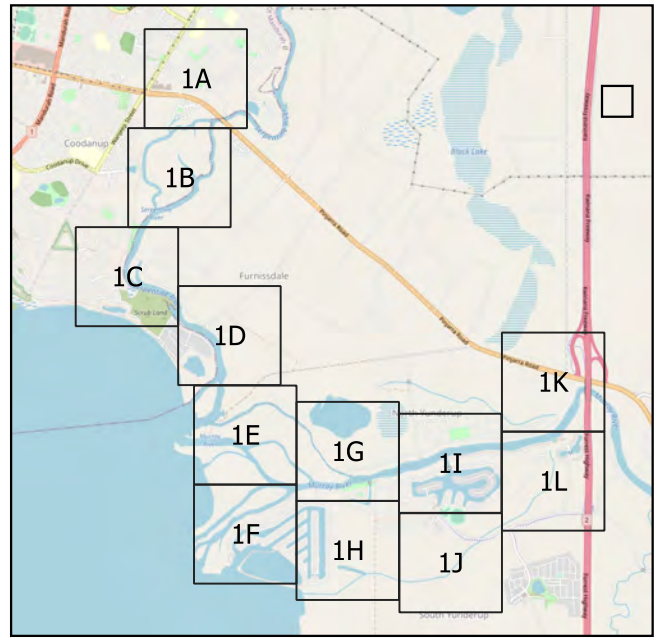
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

This map has been prepared by Baird Australia on behalf of the Shire of Murray as part of the Shire of Murray Coastal Hazard Risk Management and Adaptation Planning Project. The coastal setbacks used to create the erosion likelihoods have been adopted from the Coastal Hazard assessment completed for the Shire of Murray by Seashore (2021).

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Map 1A

Shire of Murray Baird.



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

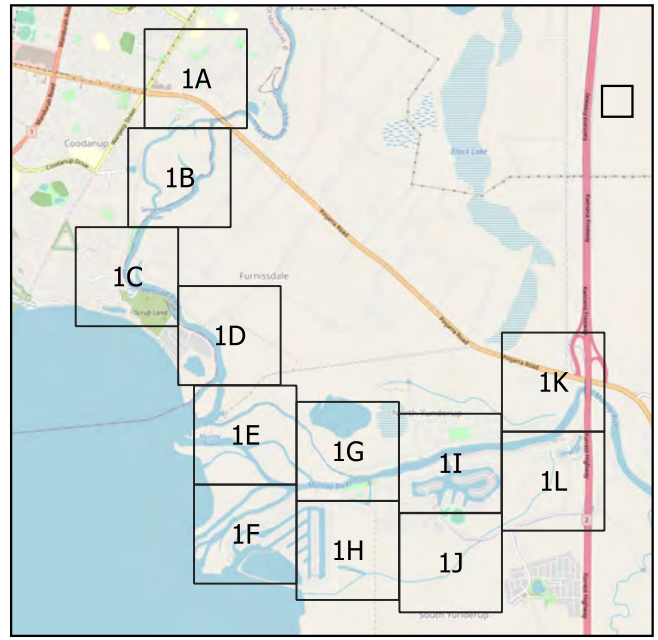
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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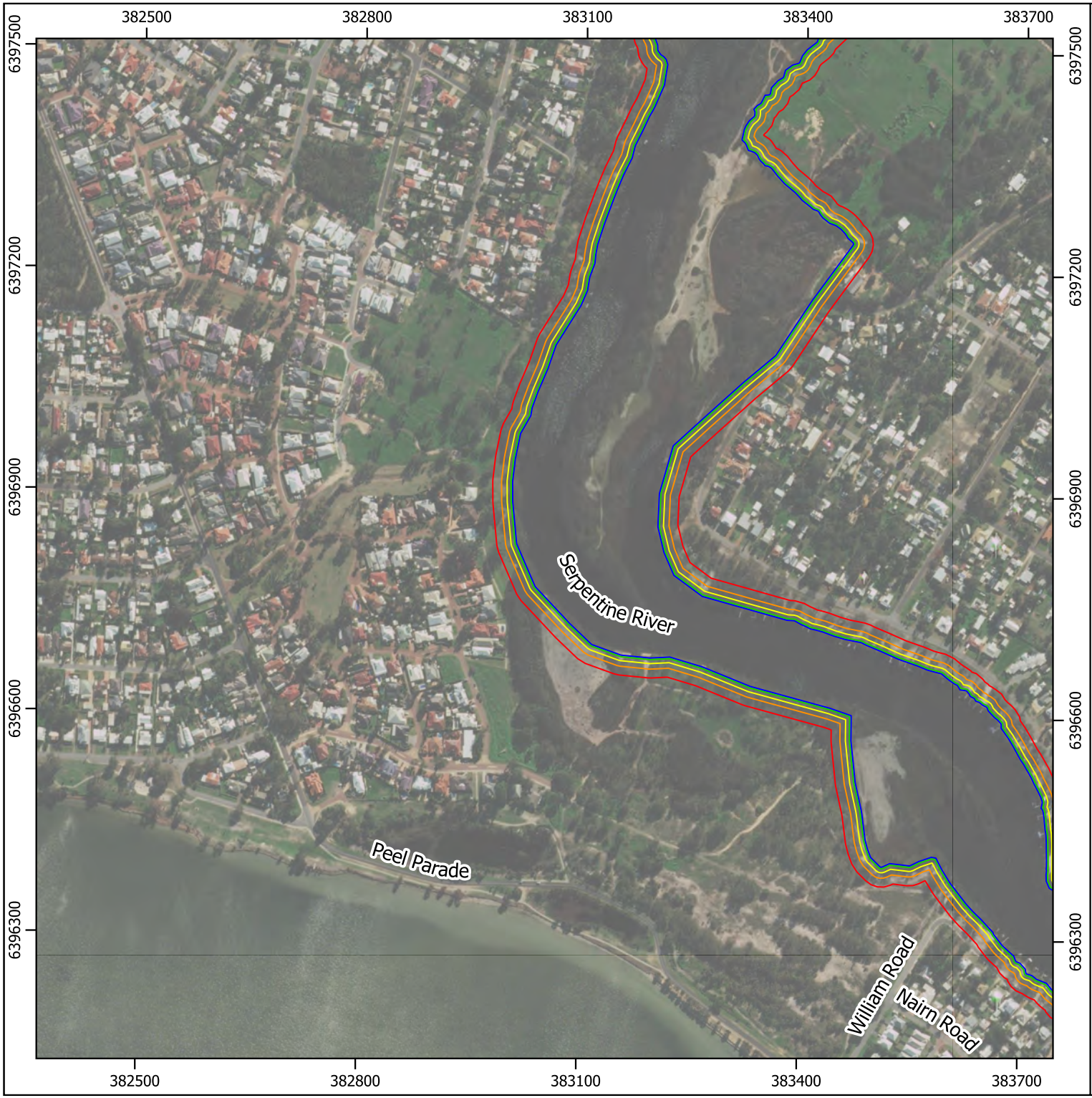
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Shire of Murray Baird.

Map 1B



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

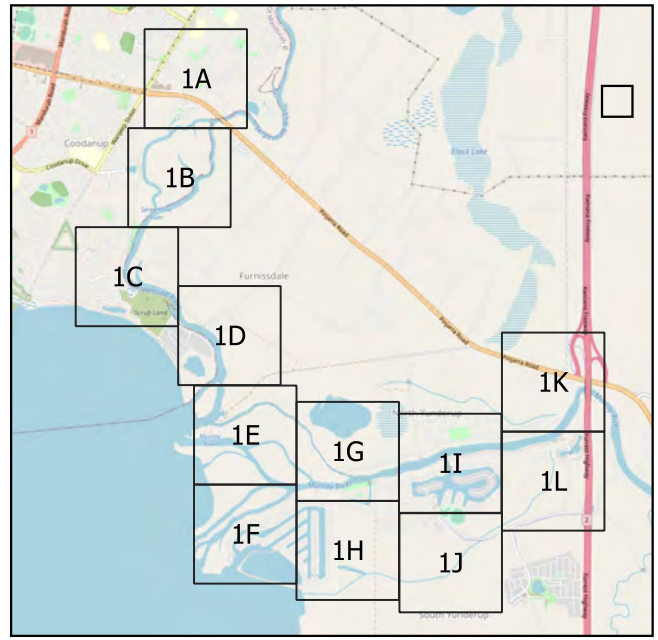
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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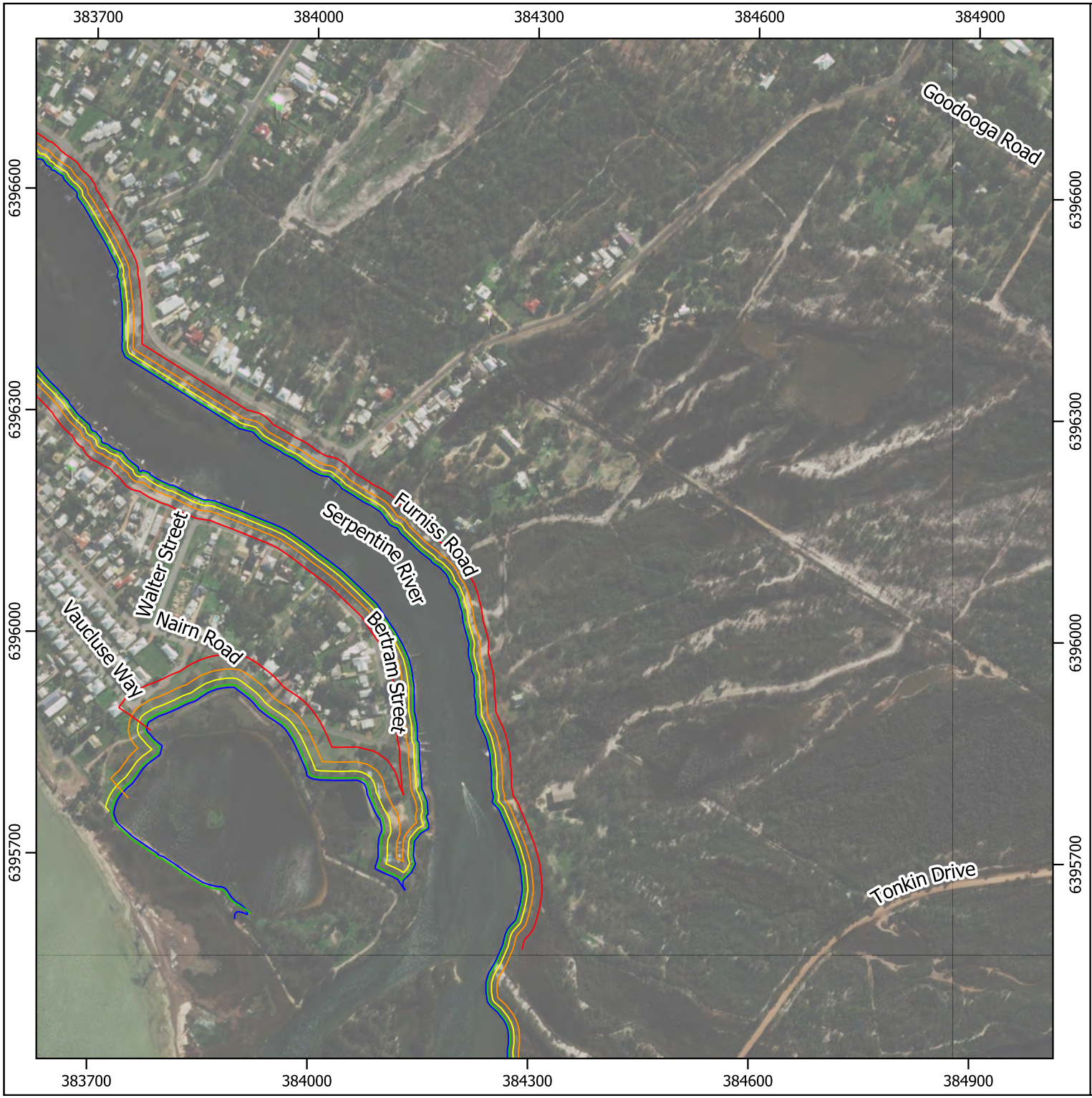
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Shire of Murray Baird.

Map 1C



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

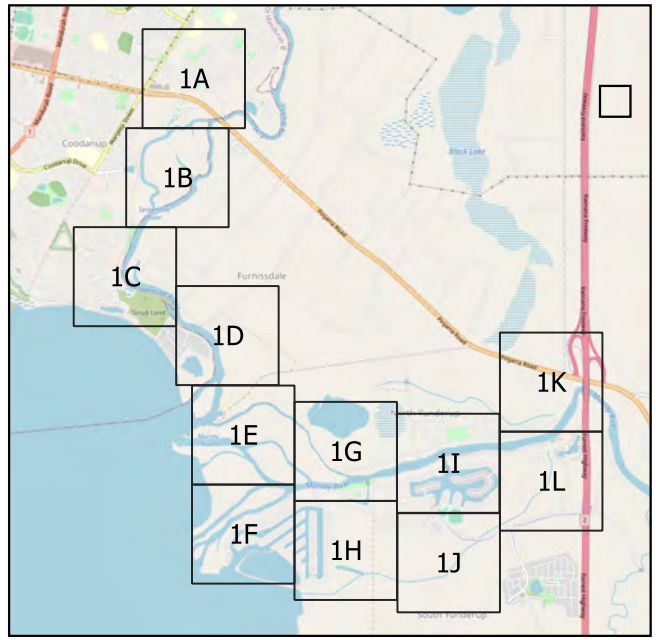
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

This map has been prepared by Baird Australia on behalf of the Shire of Murray as part of the Shire of Murray Coastal Hazard Risk Management and Adaptation Planning Project. The coastal setbacks used to create the erosion likelihoods have been adopted from the Coastal Hazard assessment completed for the Shire of Murray by Seashore (2021).

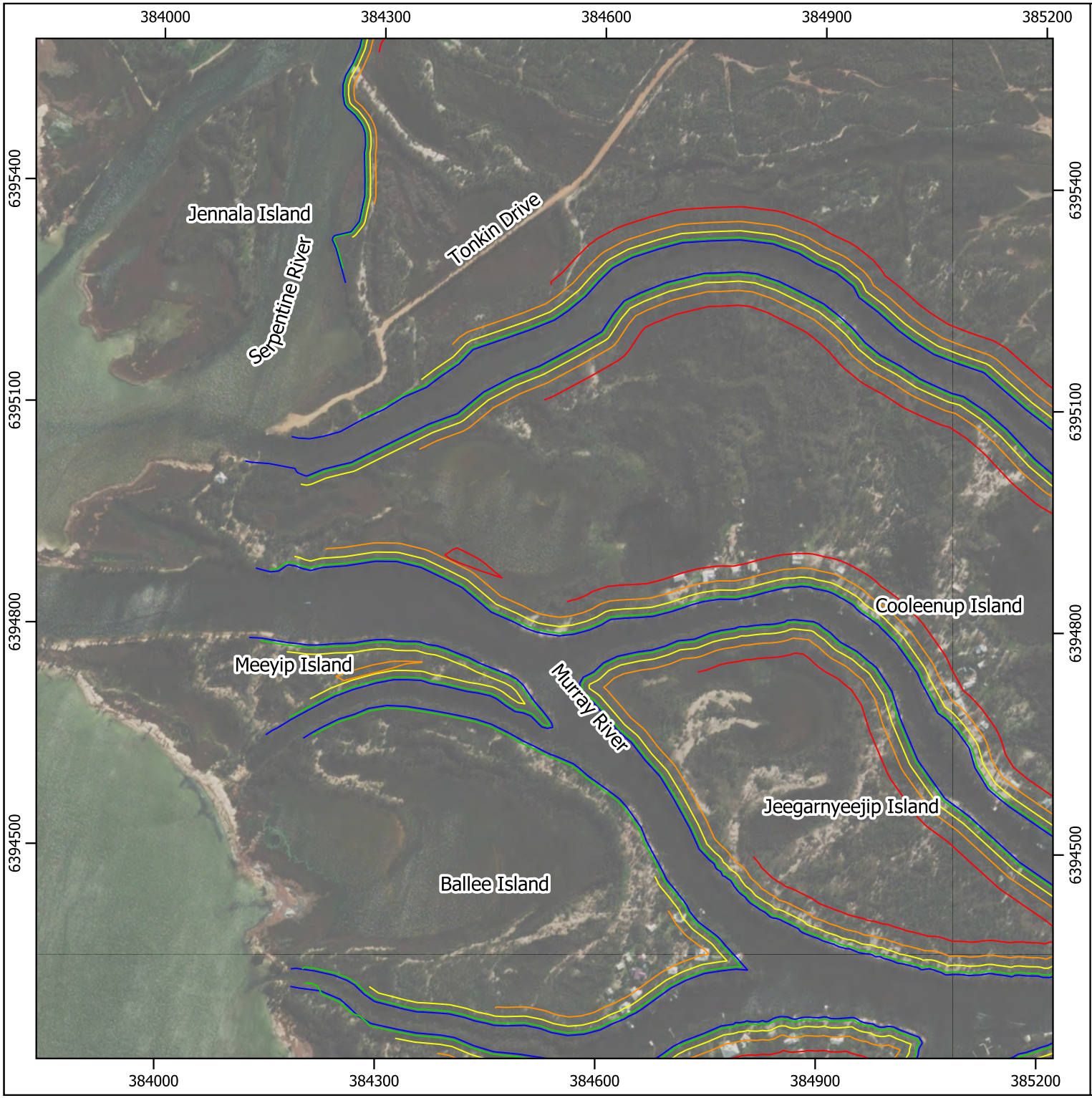
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Shire of Murray Baird.

Map 1D



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

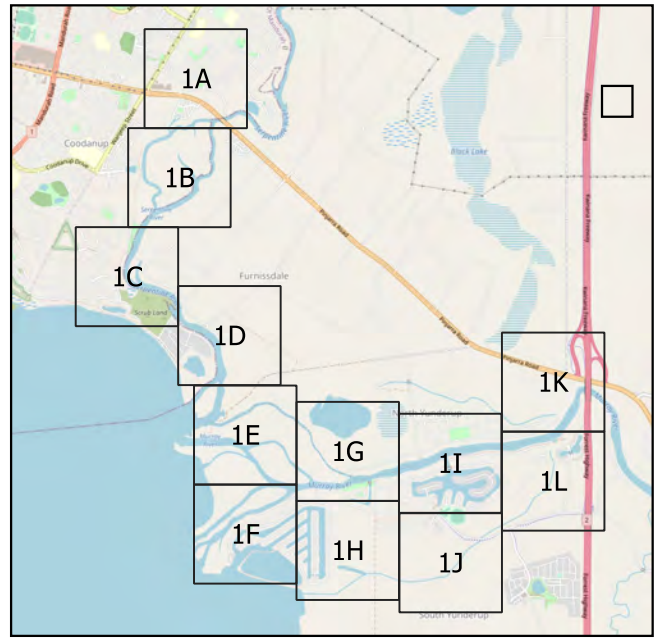
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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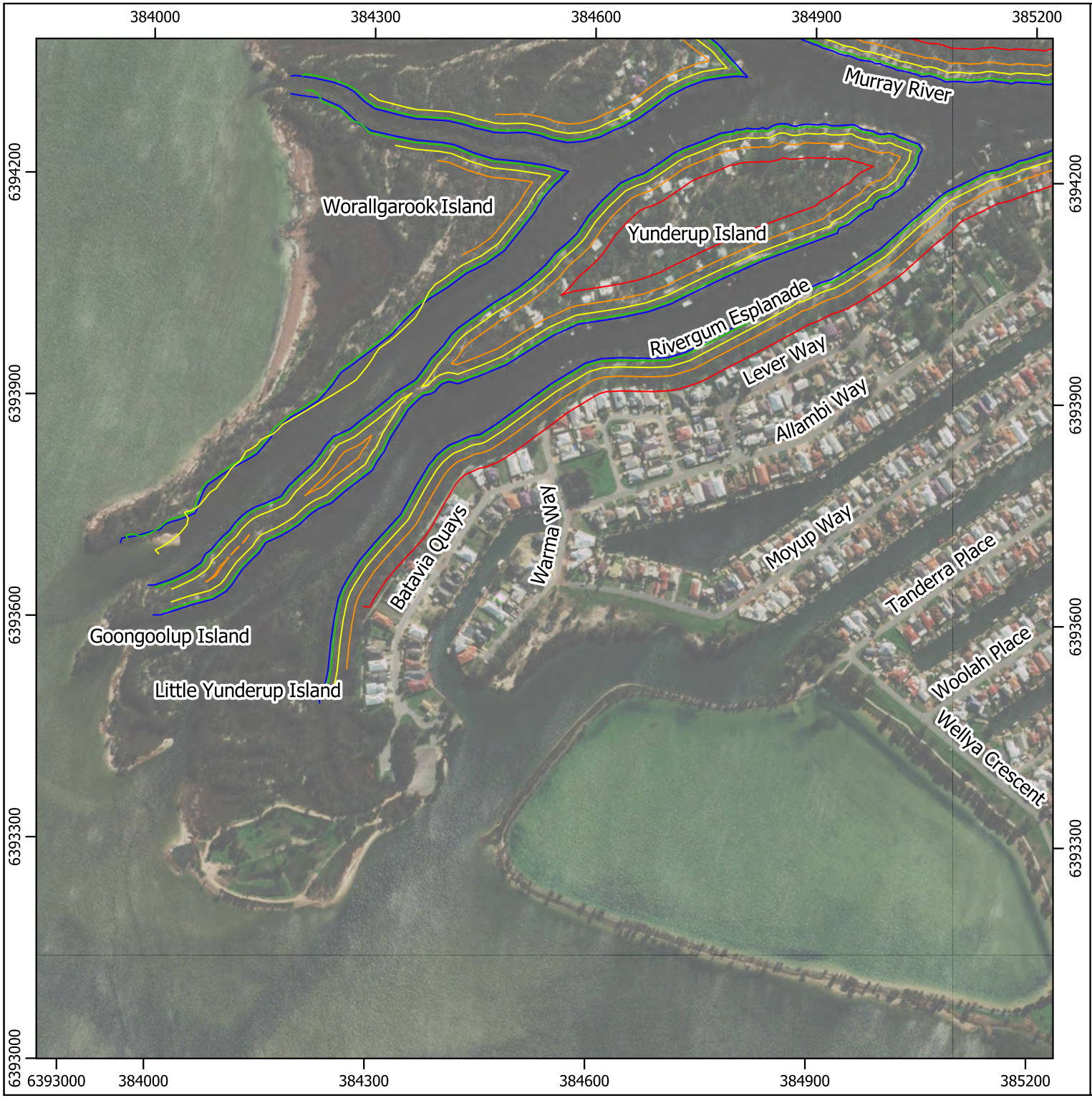
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Map 1E

Shire of Murray Baird.



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

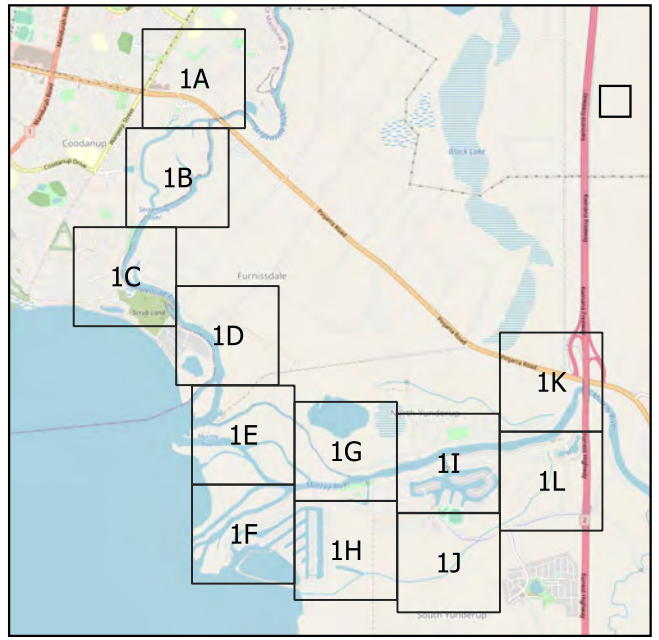
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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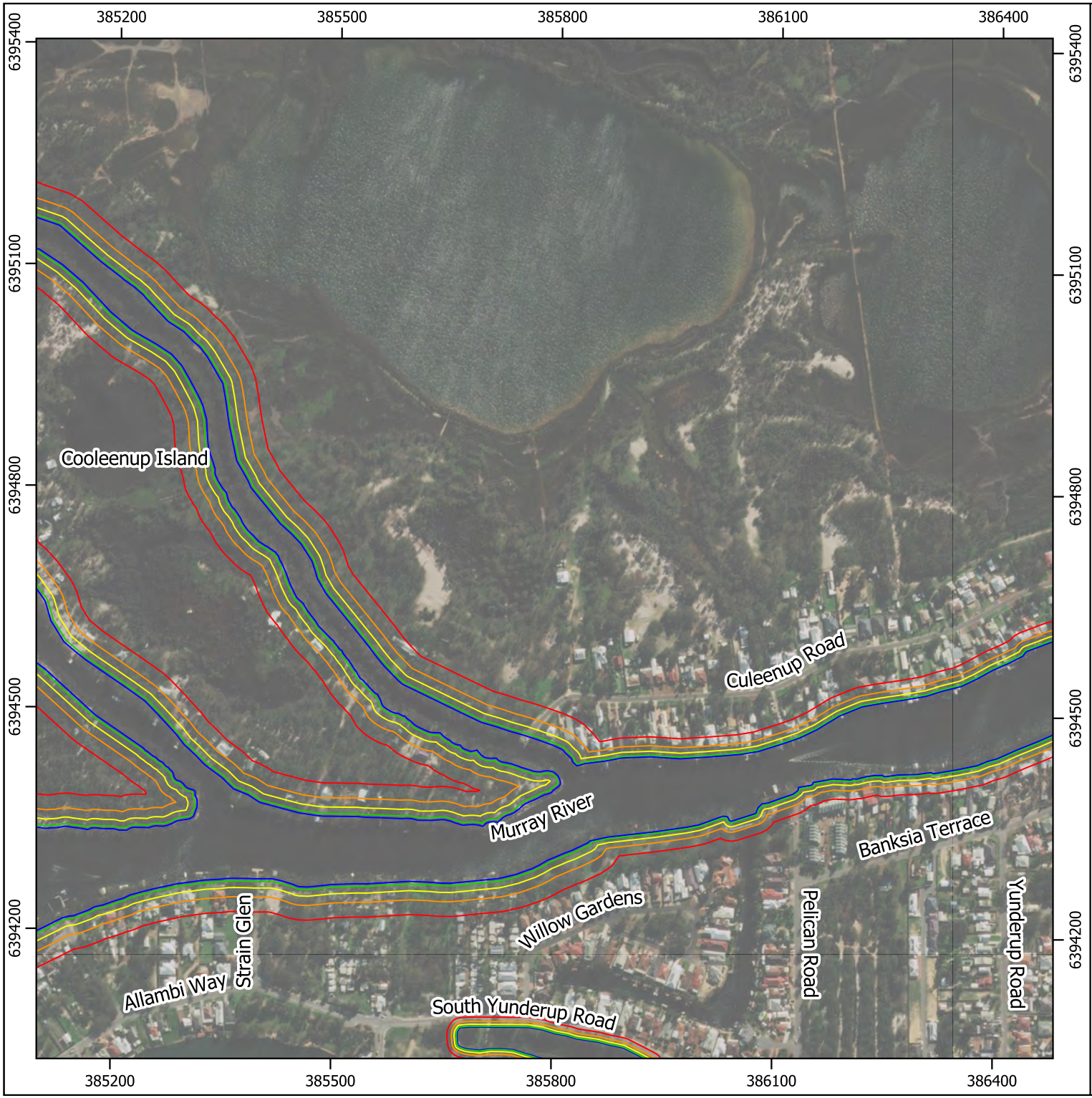
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Map 1F

Shire of Murray Baird.



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

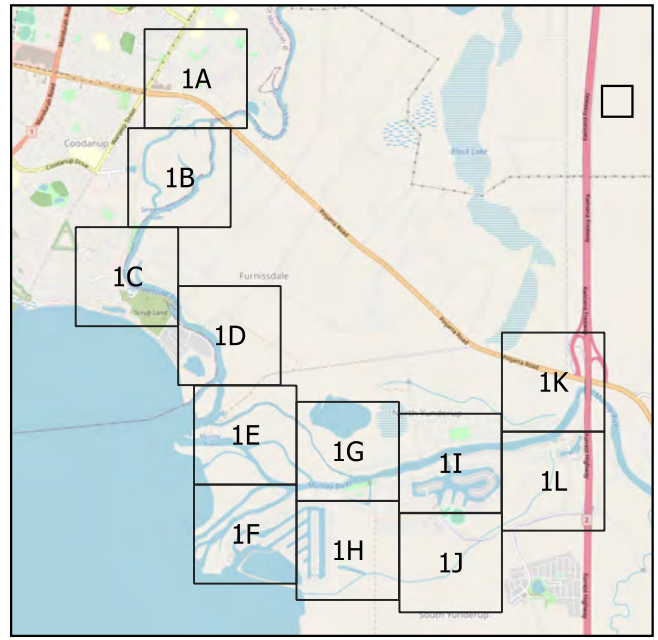
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

This map has been prepared by Baird Australia on behalf of the Shire of Murray as part of the Shire of Murray Coastal Hazard Risk Management and Adaptation Planning Project. The coastal setbacks used to create the erosion likelihoods have been adopted from the Coastal Hazard assessment completed for the Shire of Murray by Seashore (2021).

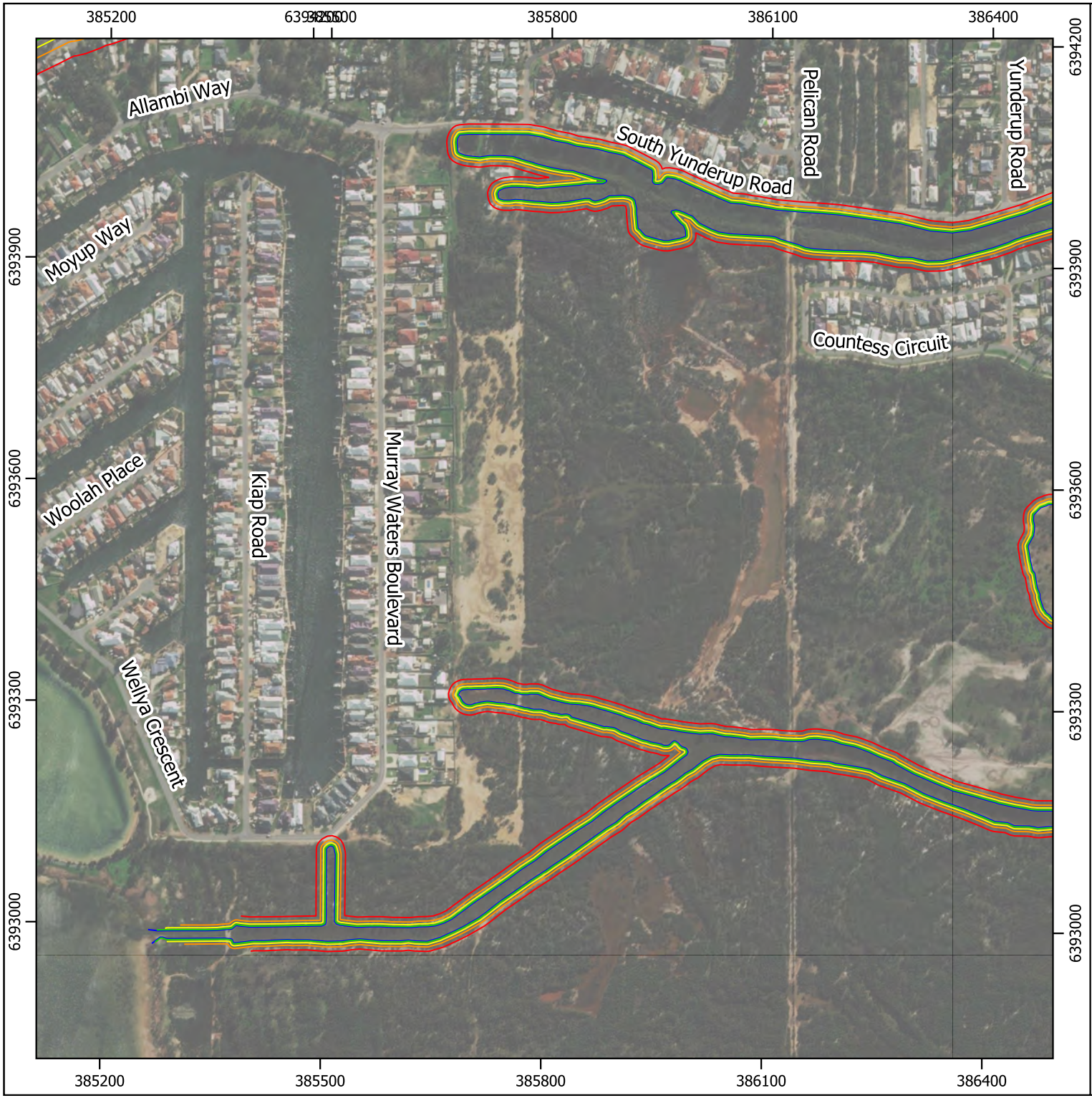
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Shire of Murray Baird.

Map 1G



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

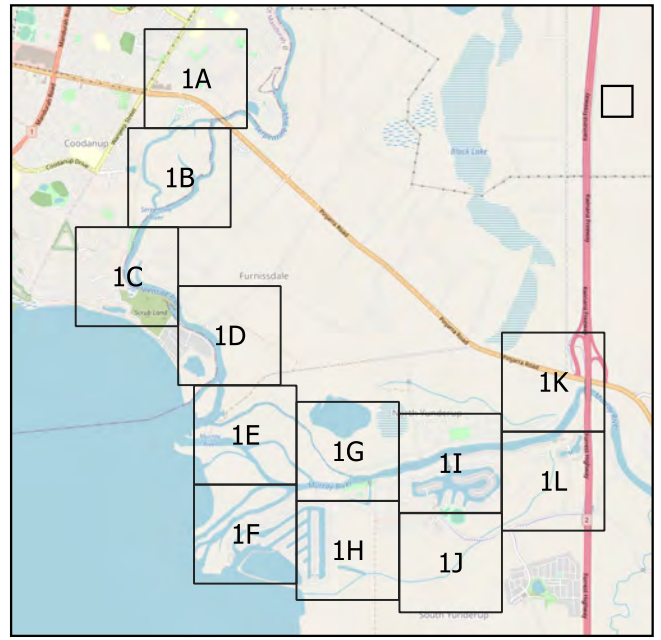
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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Map 1H

Shire of Murray Baird.



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

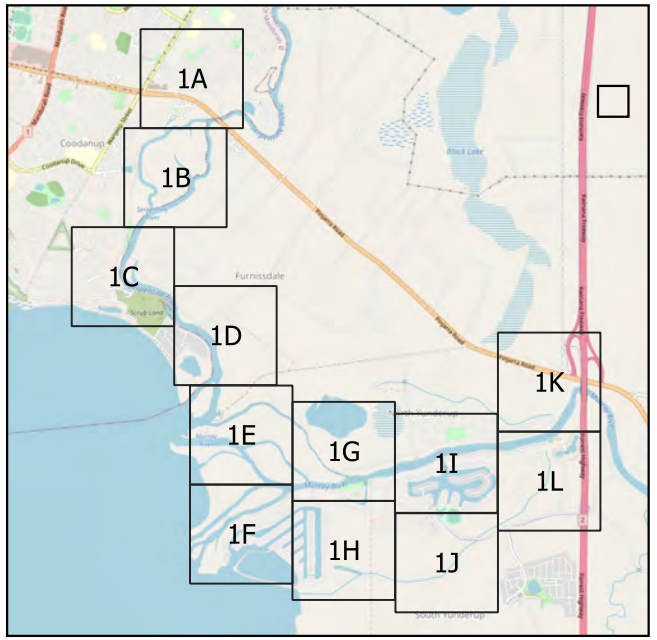
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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Shire of Murray Baird.

Map 1I



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

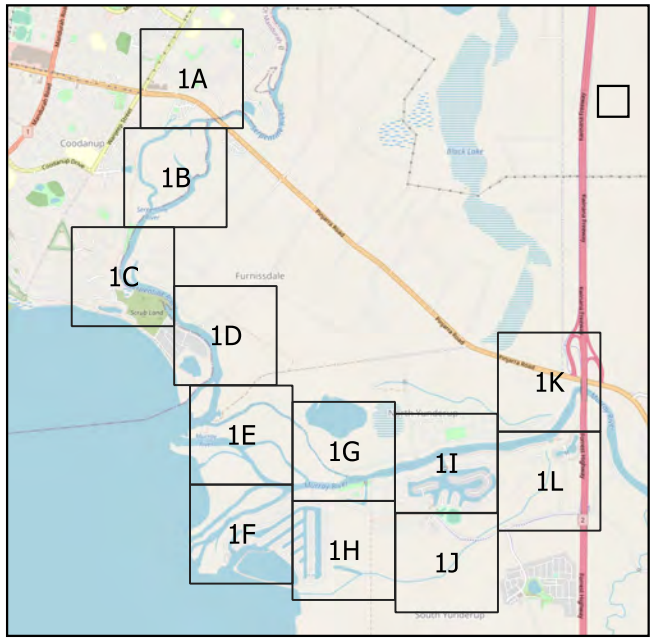
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
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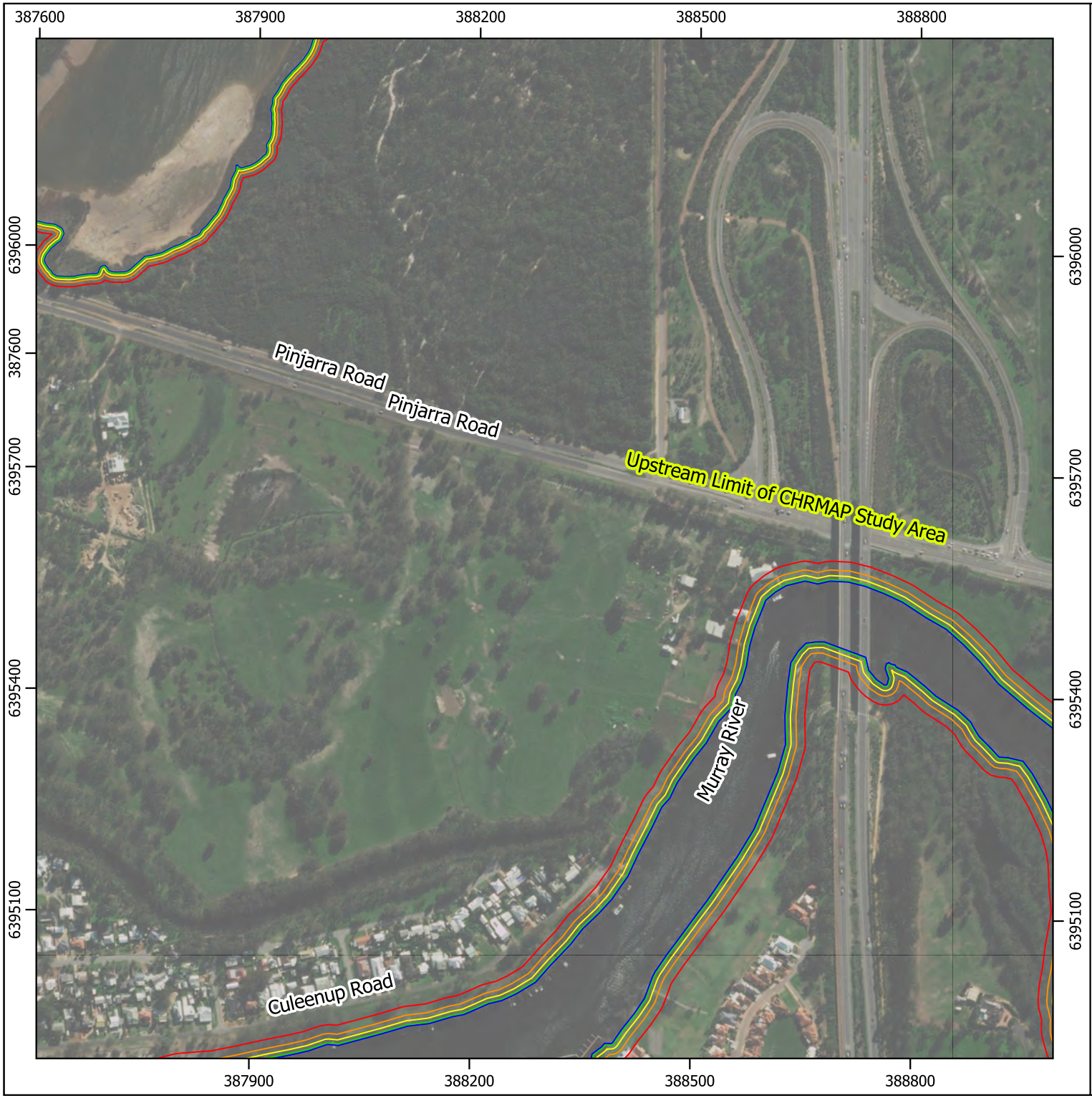
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Shire of Murray Baird.

Map 1J



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

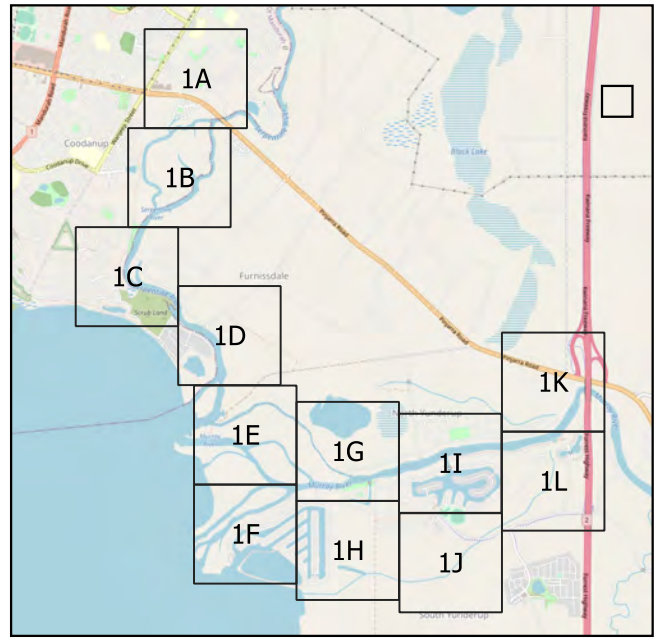
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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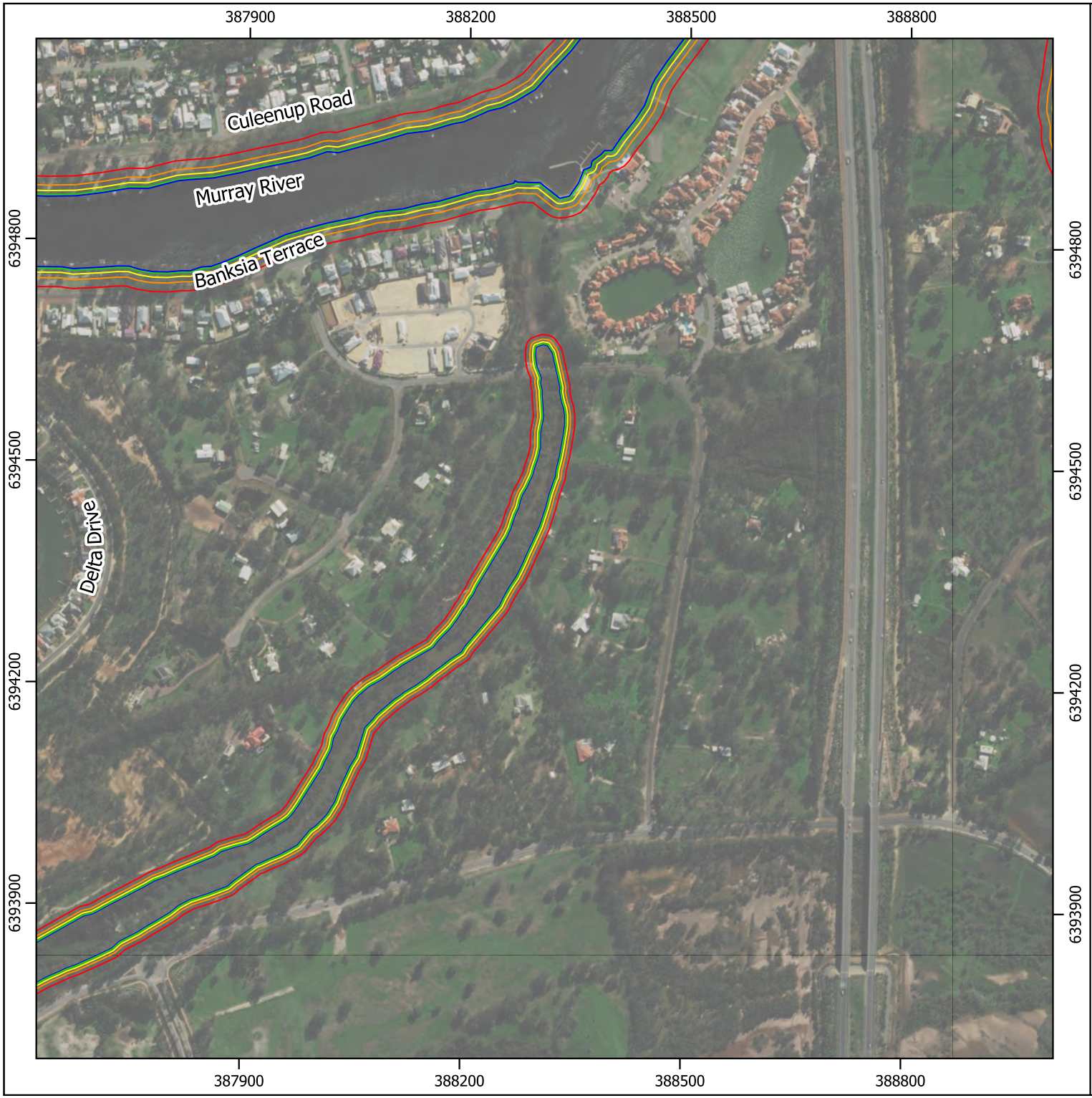
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Shire of Murray Baird.

Map 1K



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf



Shire of Murray

Coastal Processes Allowances
(Erosion Setback - Rivers)

Erosion Hazard

- 2120
- 2070
- 2050
- 2030
- 2020

N

0 100 200 300 m

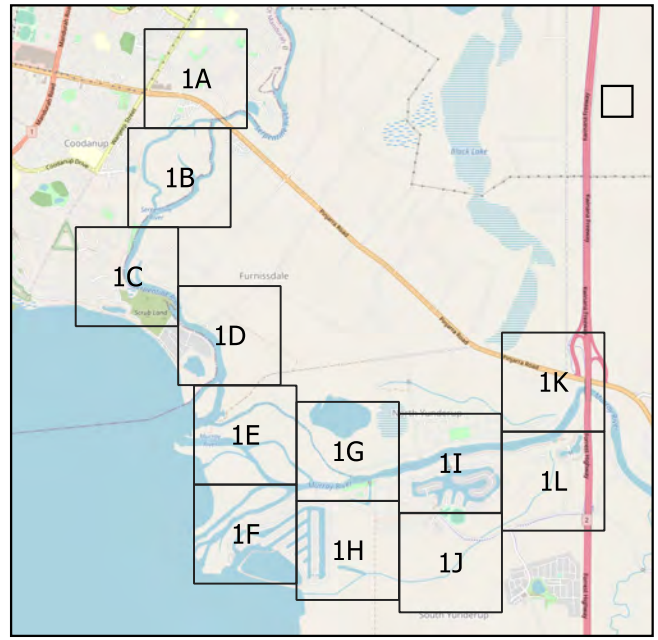
13064.101 | May-2021
Imagery: ESRI Basemap
Street Name Data: © OpenStreetMap contributors
Spatial Reference: GDA 2020 MGA Zone 50

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Shire of Murray Baird.

Map 1L



N:\Projects\13064.101_ShireMurrayCHRMAP\09_GIS\11_QGIS\Figures\ShireofMurray_RiverErosionHazard.pdf

C.4 Coastal Inundation Hazard

C.4.1 Coastal Inundation Hazard – 100yr ARI Scenario, Planning Year 2020 (No Sea Level Rise)

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

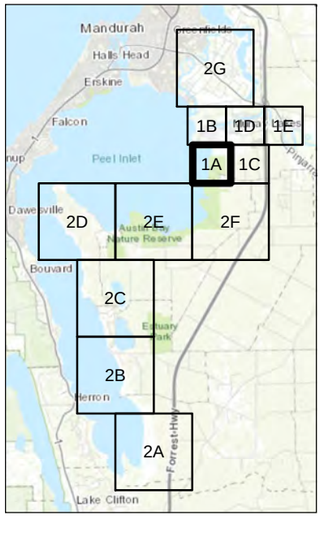
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1A

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)

Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

Source Data

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Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

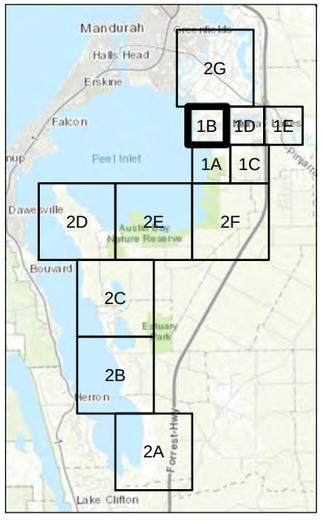
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1B

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

Source Data

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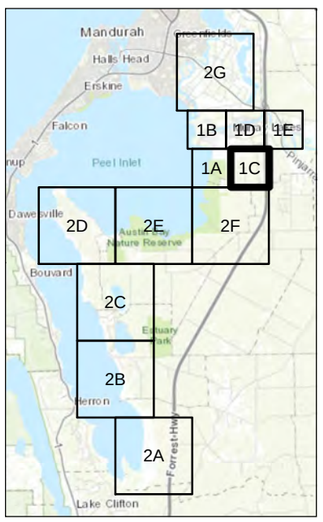
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1C

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

Source Data

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Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

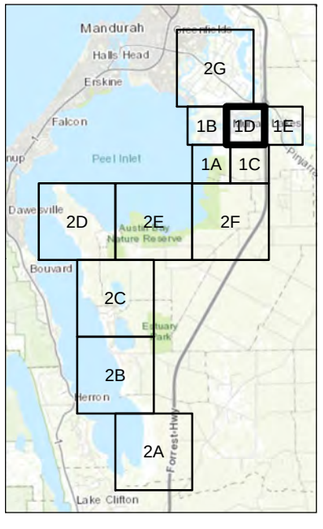
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
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https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1D

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

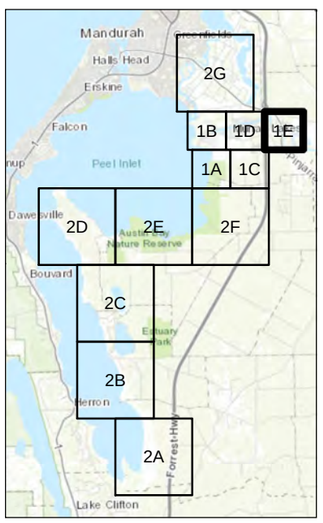
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
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Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

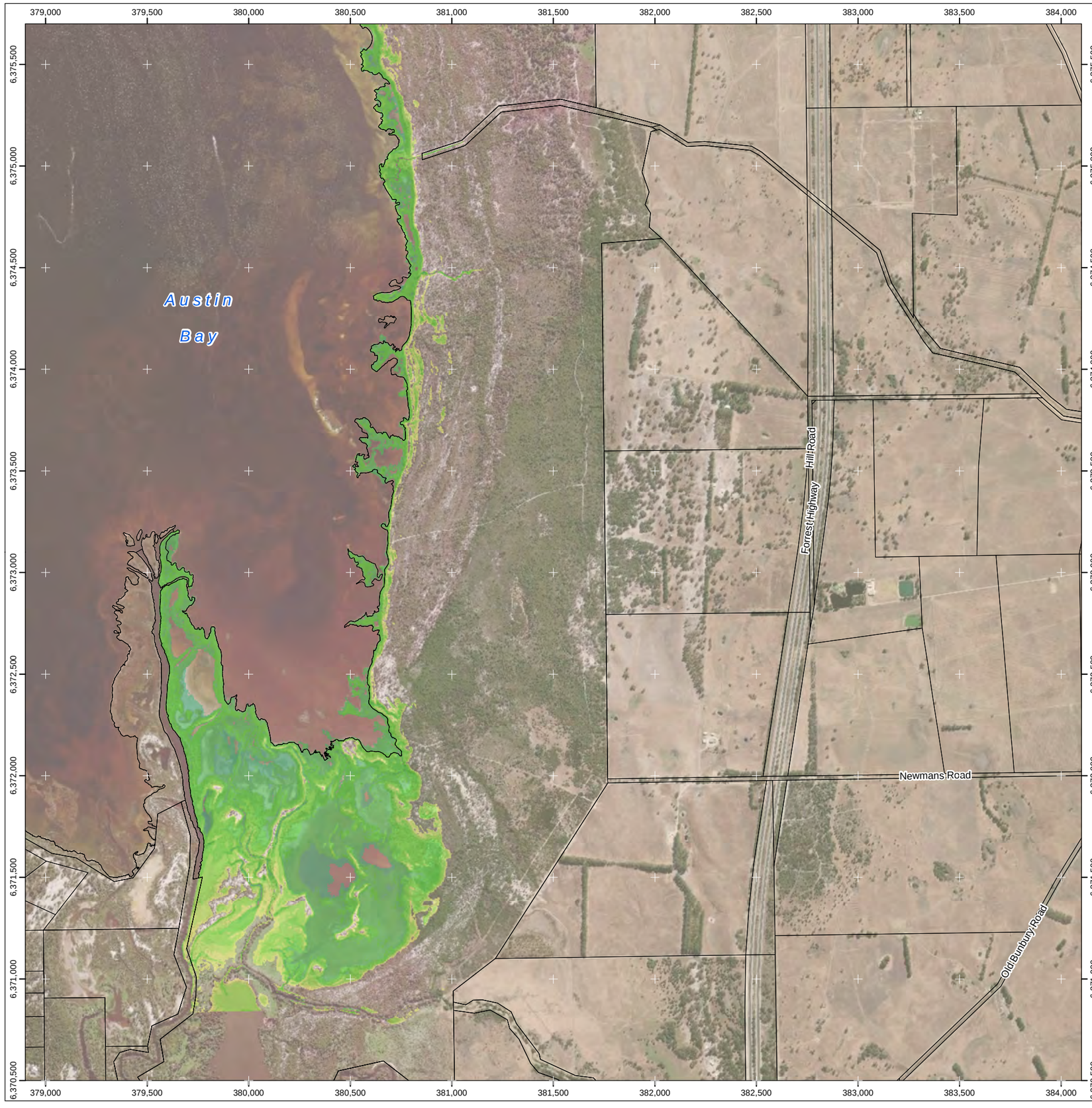
Map Published: 19 Nov. 2020

Mapsheet: 1E

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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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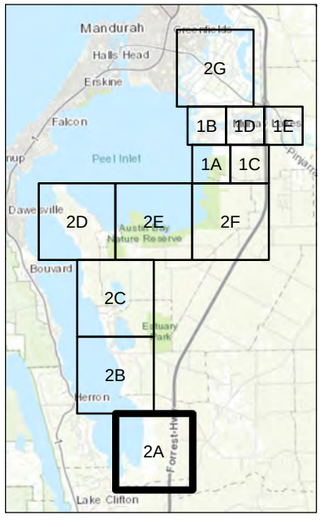
Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.

Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

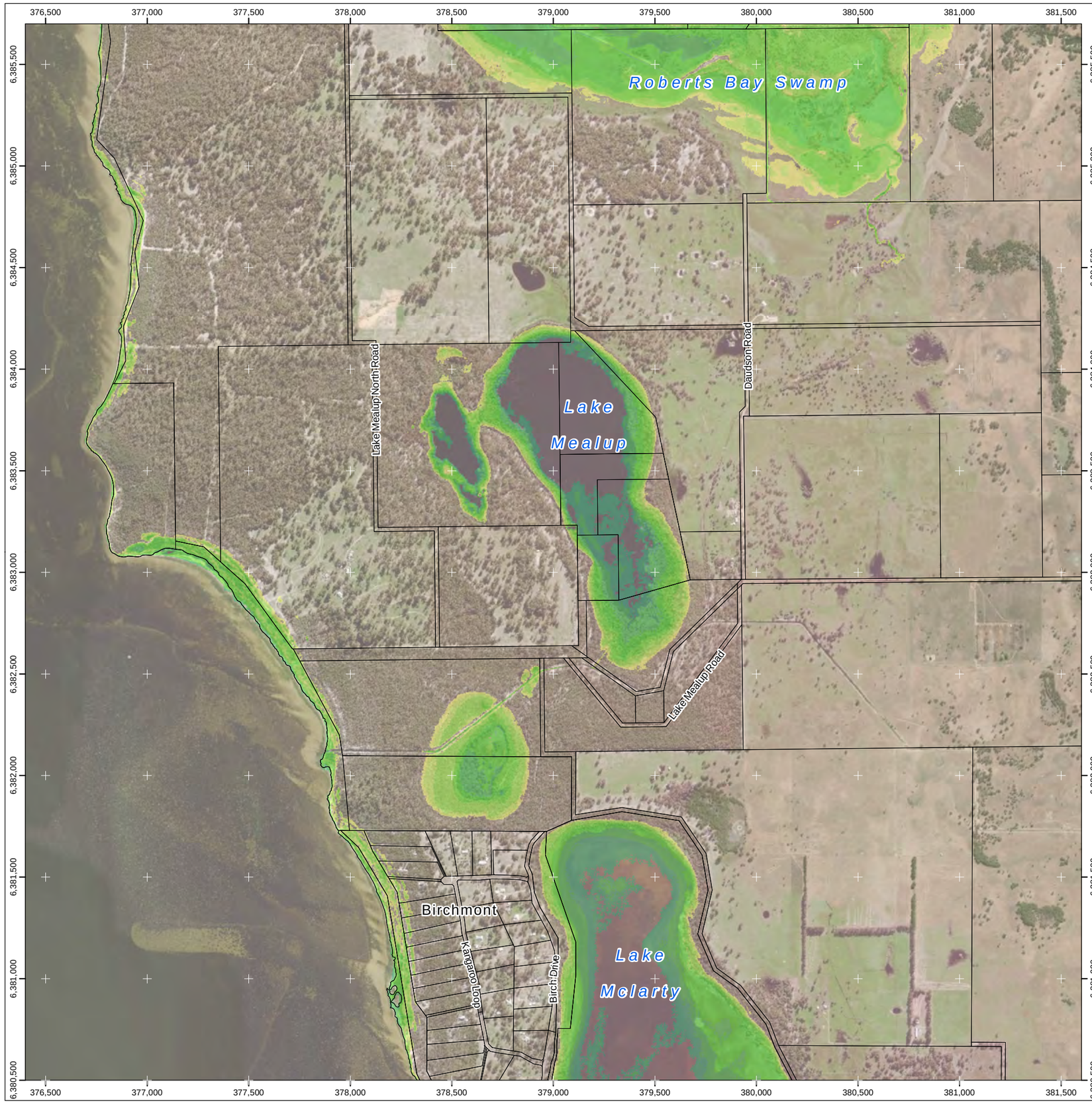
Map Published: 19 Nov. 2020

Mapsheet: 2A

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

Source Data

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Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

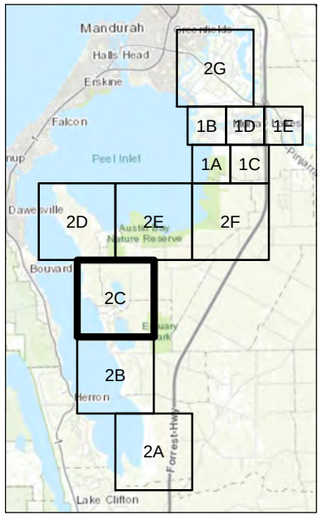
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2C

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

Source Data

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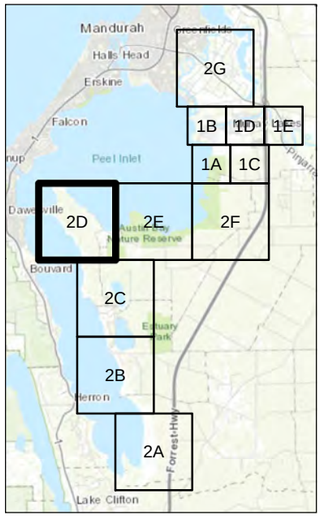
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

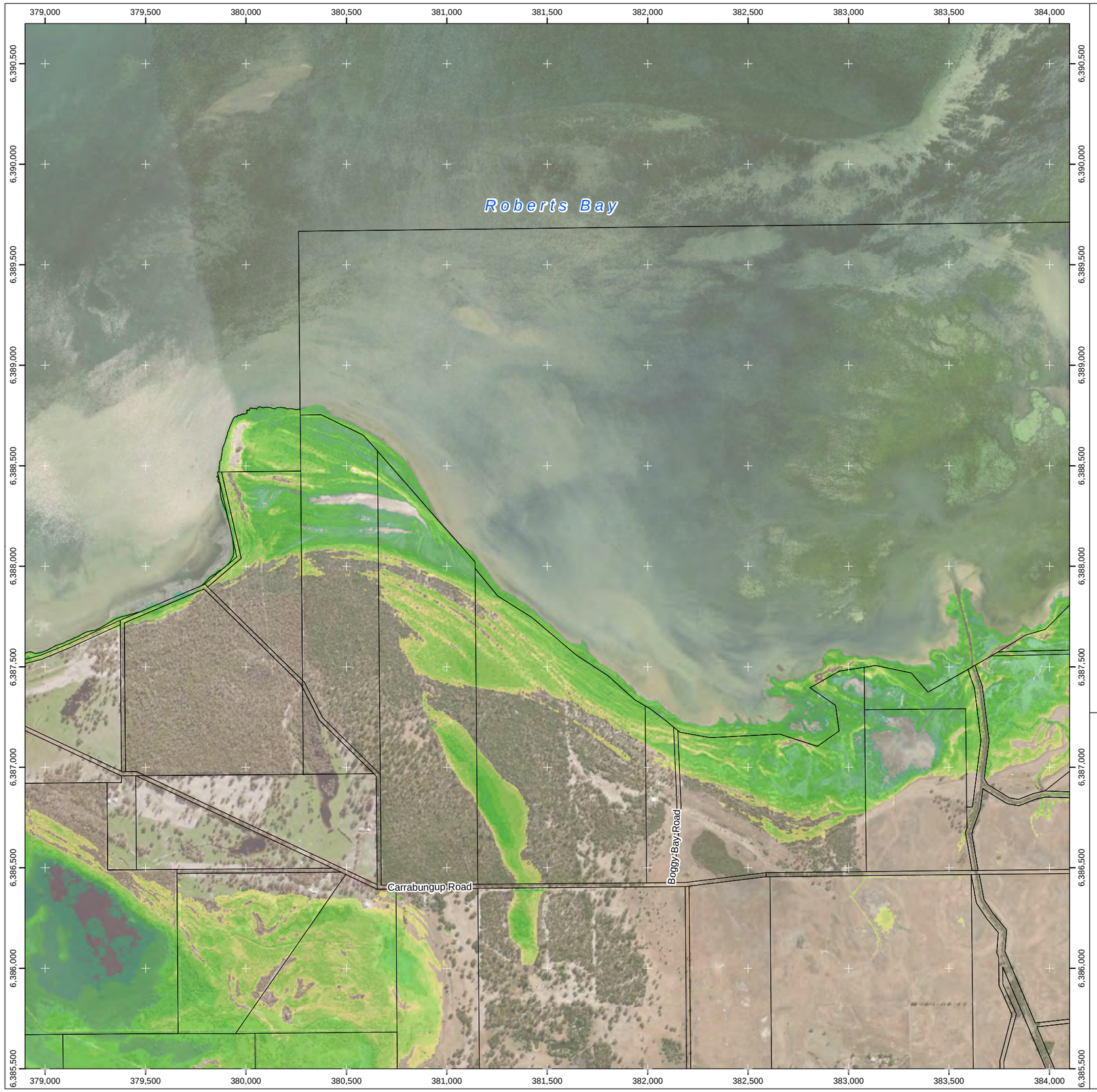
Map Published: 19 Nov. 2020

Mapsheet: 2D

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

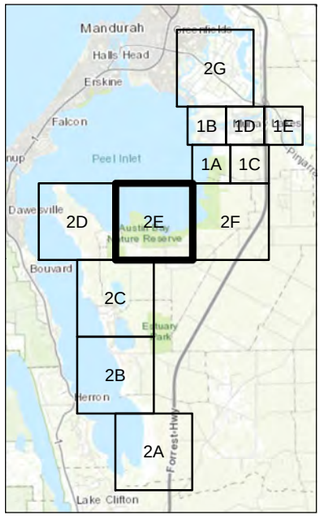
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2E

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)



Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

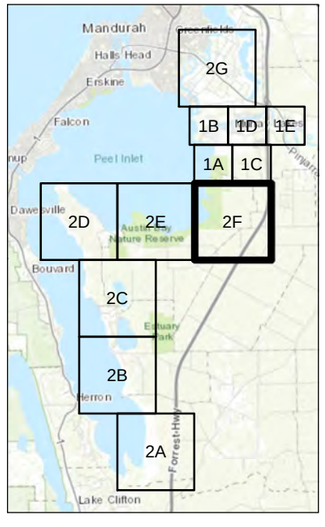
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2F

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.09m AHD (no Sea Level Rise)

Inundation Depth (m)

- > 1.0
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

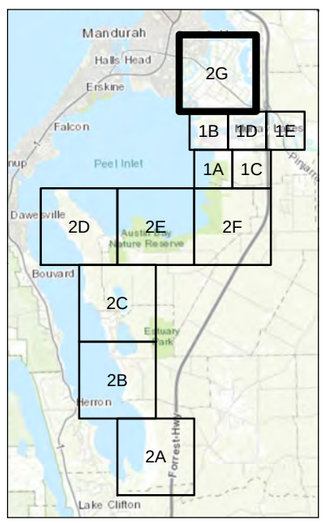
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2G

C.4.2 Coastal Inundation Hazard – 100yr ARI Scenario, Planning Year 2070 (Includes 0.4m Sea Level Rise)

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

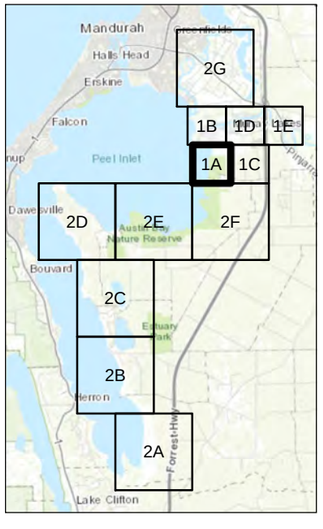
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1A

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)

Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

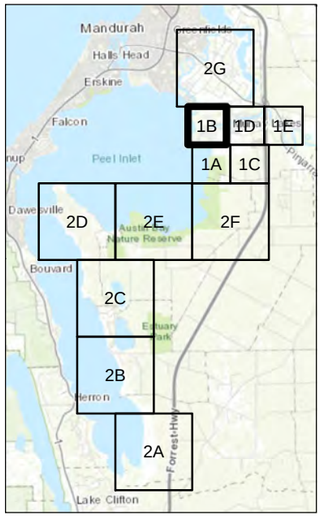
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1B

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

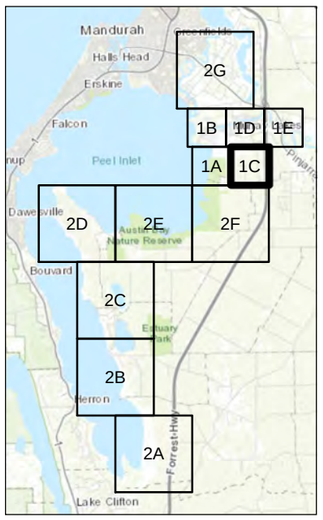
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1C

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)

Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

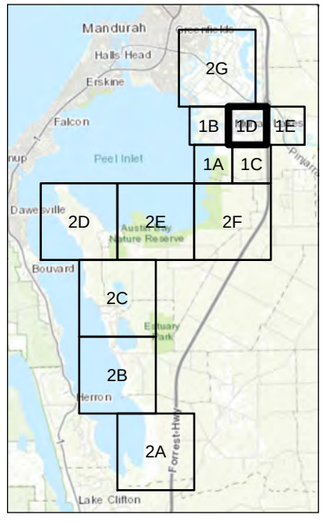
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Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1D

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

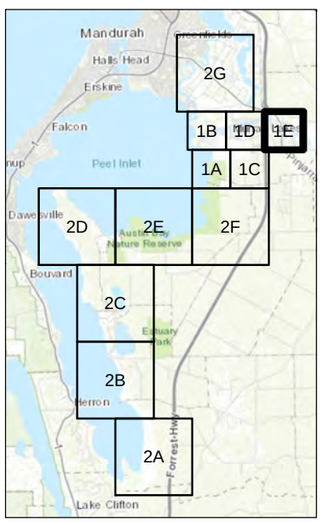
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

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Shire of Murray
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Mapping prepared by Baird.

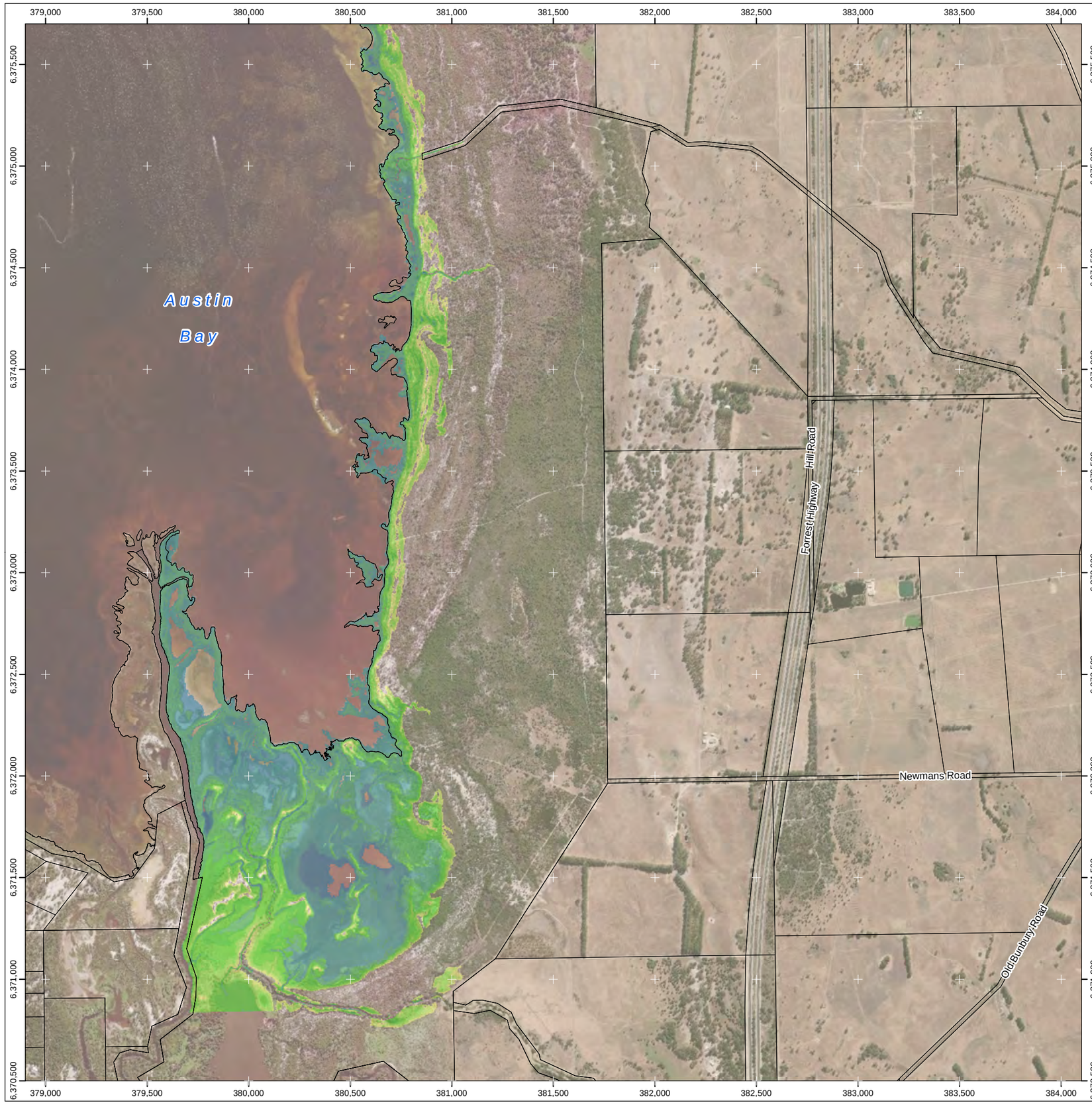
Map Published: 19 Nov. 2020

Mapsheet: 1E

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

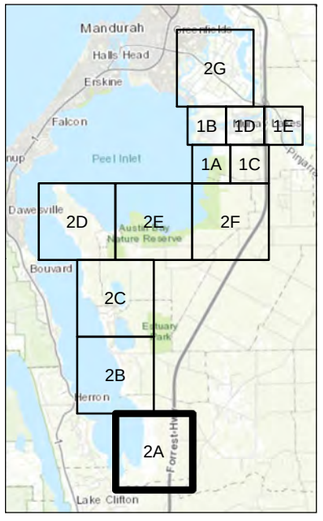
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

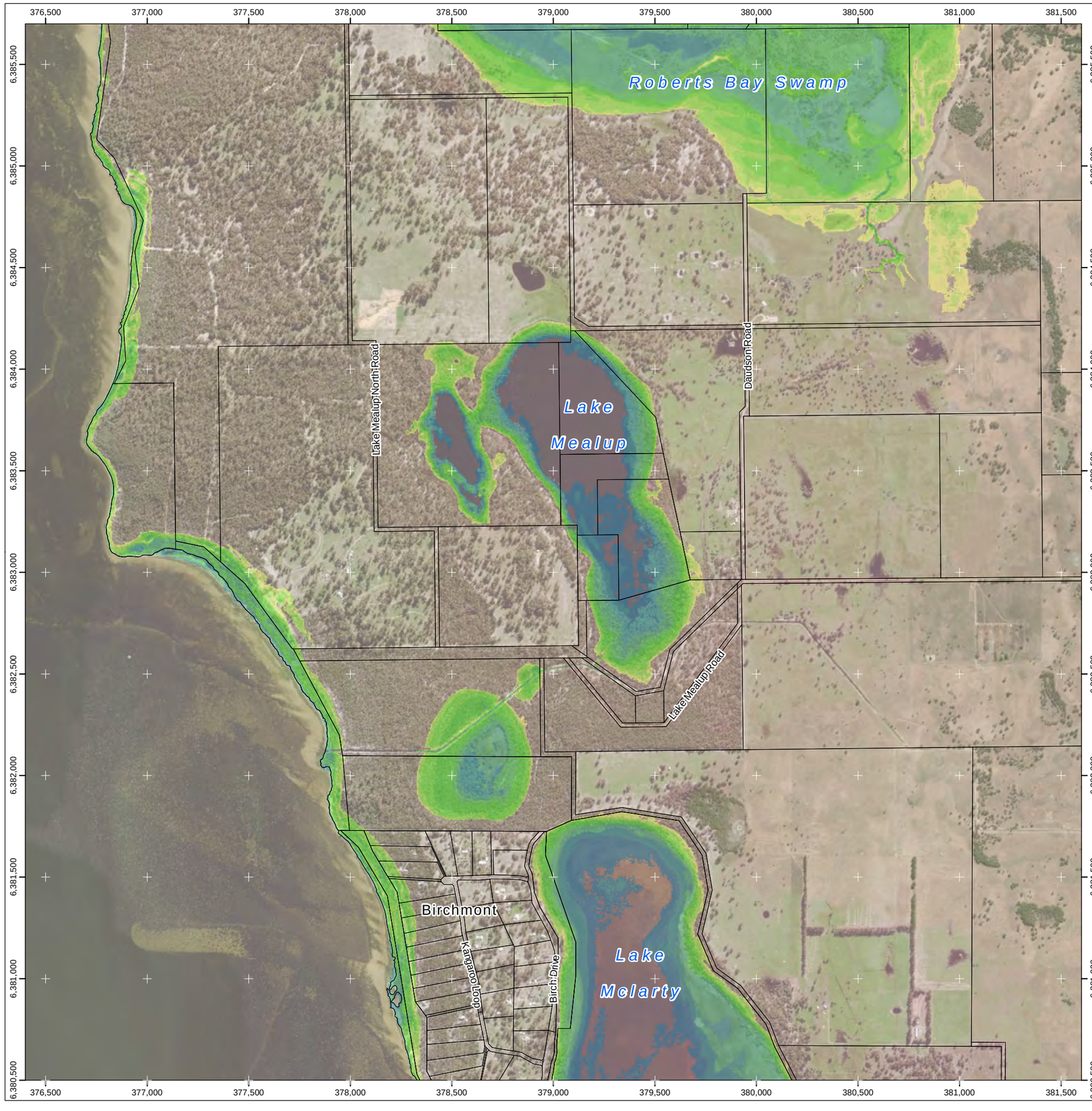
Map Published: 19 Nov. 2020

Mapsheet: 2A

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

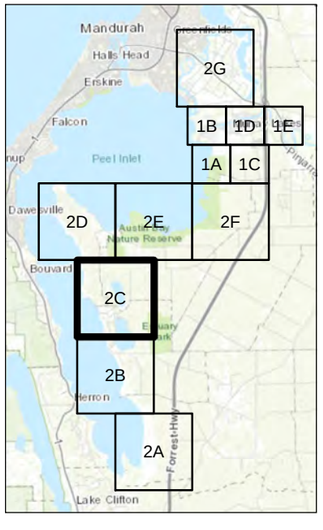
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2C

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

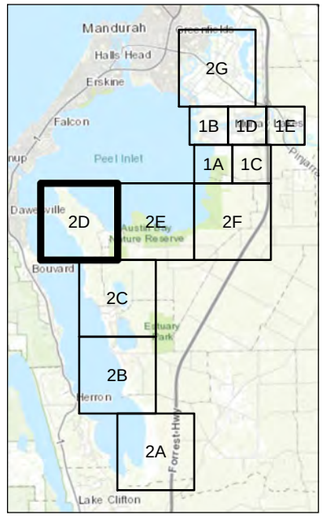
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0 200 400 600 800 1,000 m

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Shire of Murray
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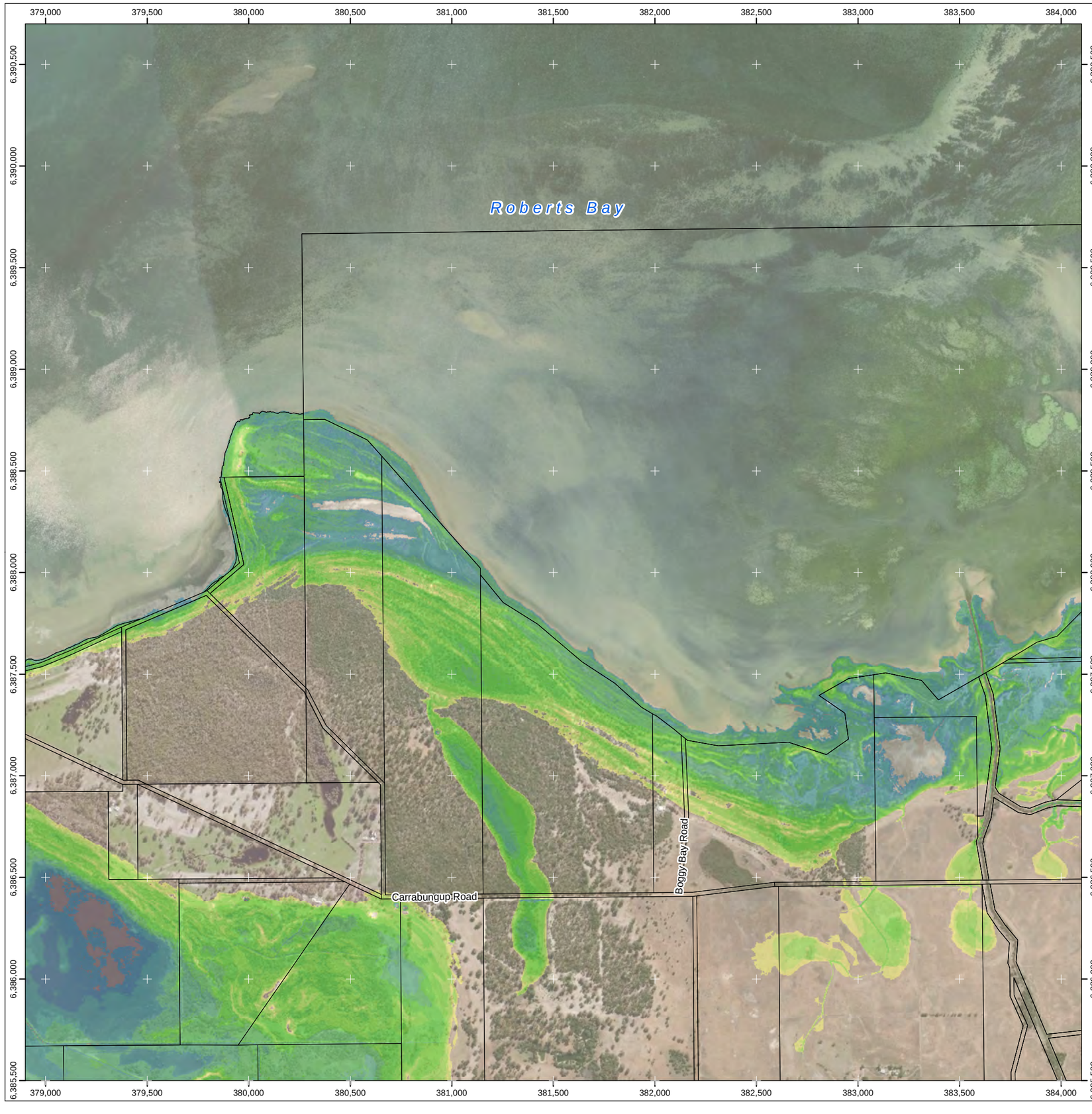
Map Published: 19 Nov. 2020

Mapsheet: 2D

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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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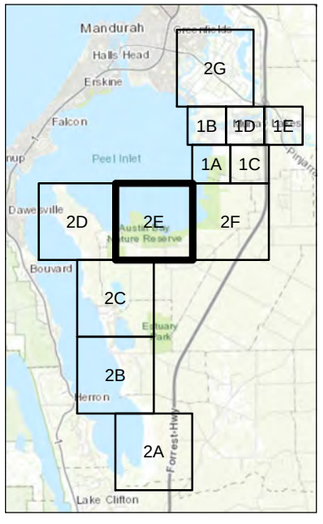
Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.

Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2E

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

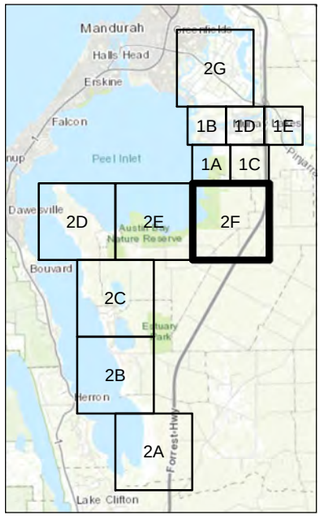
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2F

Shire of Murray
Coastal Hazard Flood Mapping

100yr ARI Design Storm
in Planning Year 2070

Inundation Depth Based on Peak Water level of 1.49m AHD (includes 0.4m Sea Level Rise)

Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

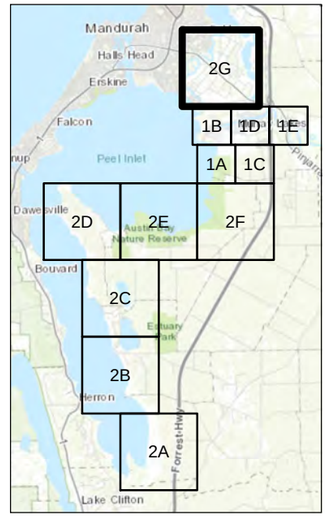
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2G

C.4.3 Coastal Inundation Hazard – 500yr ARI Scenario, Planning Year 2020 (No Sea Level Rise)

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

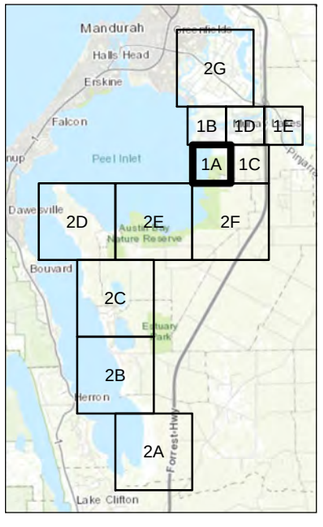
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
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https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1A

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)

Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

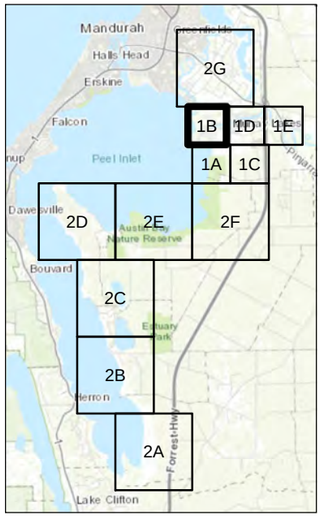
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1B

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

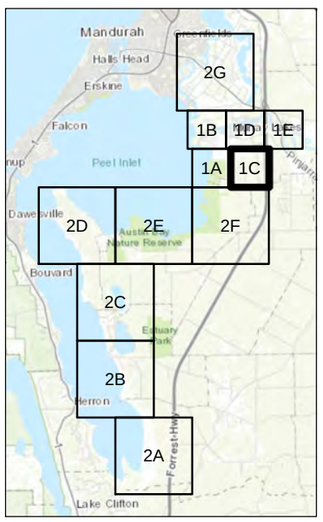
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1C

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)

Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

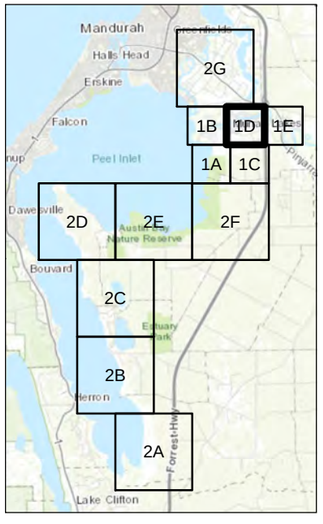
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 1D

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

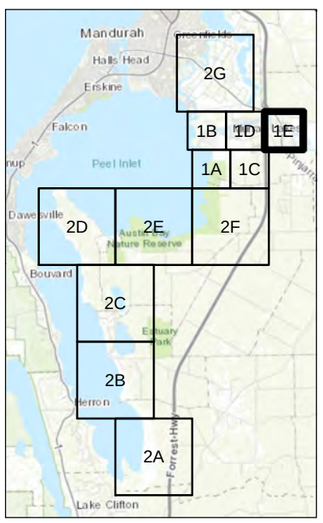
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Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

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Shire of Murray
1915 Pinjarra Rd
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Mapping prepared by Baird.

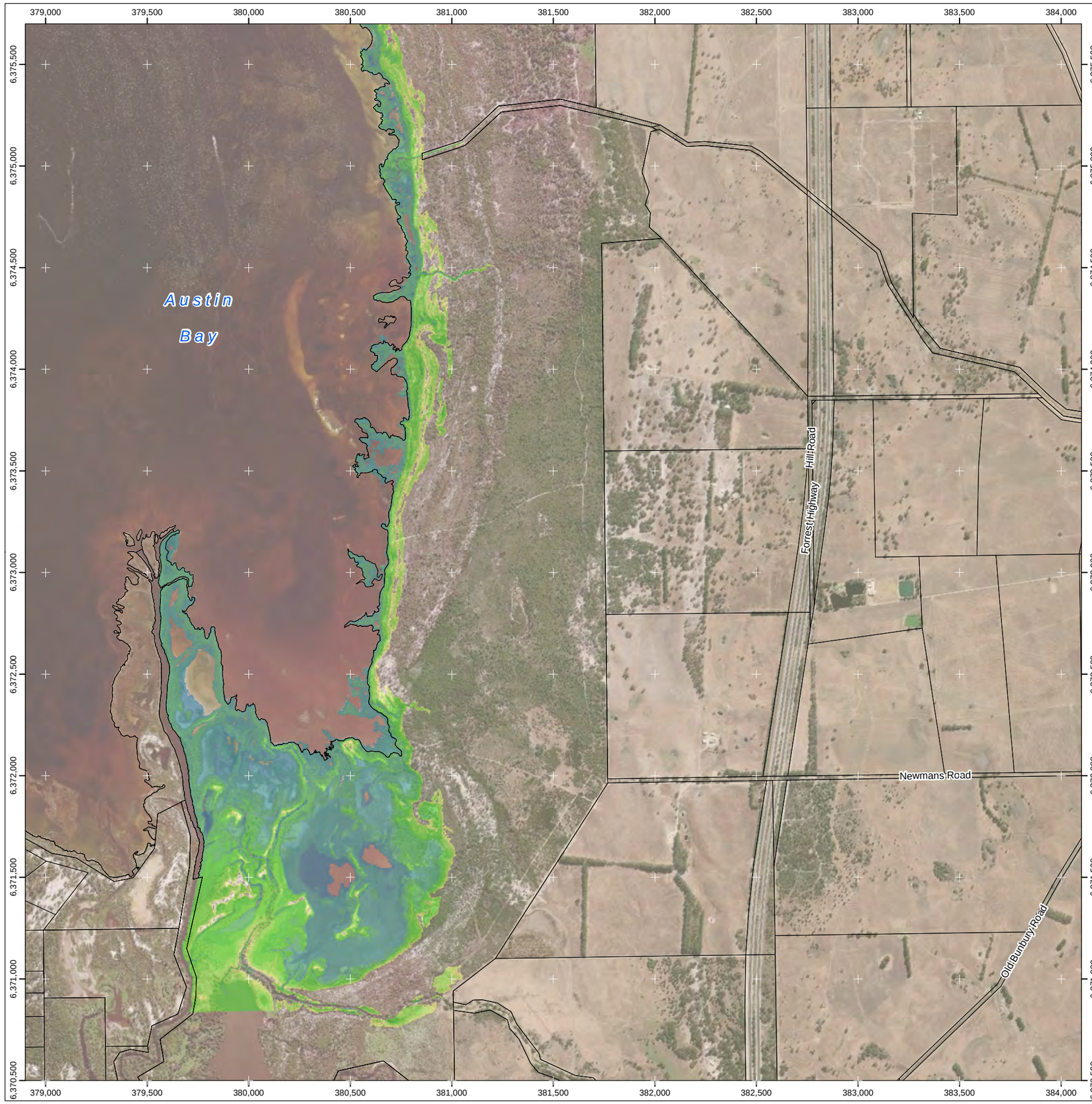
Map Published: 19 Nov. 2020

Mapsheet: 1E

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

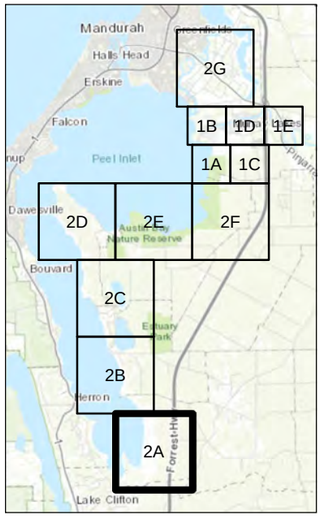
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2A

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)

Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
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- 0.41 - 0.6
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Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

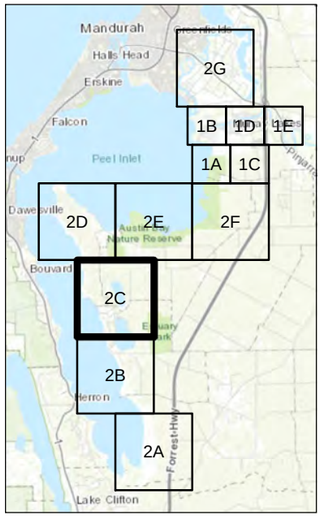
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Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

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Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2C

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
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Source Data

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Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

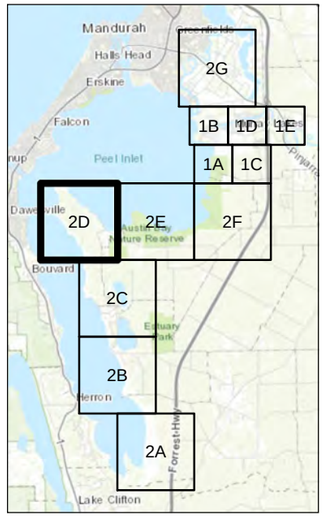
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0 200 400 600 800 1,000 m

1:20,000

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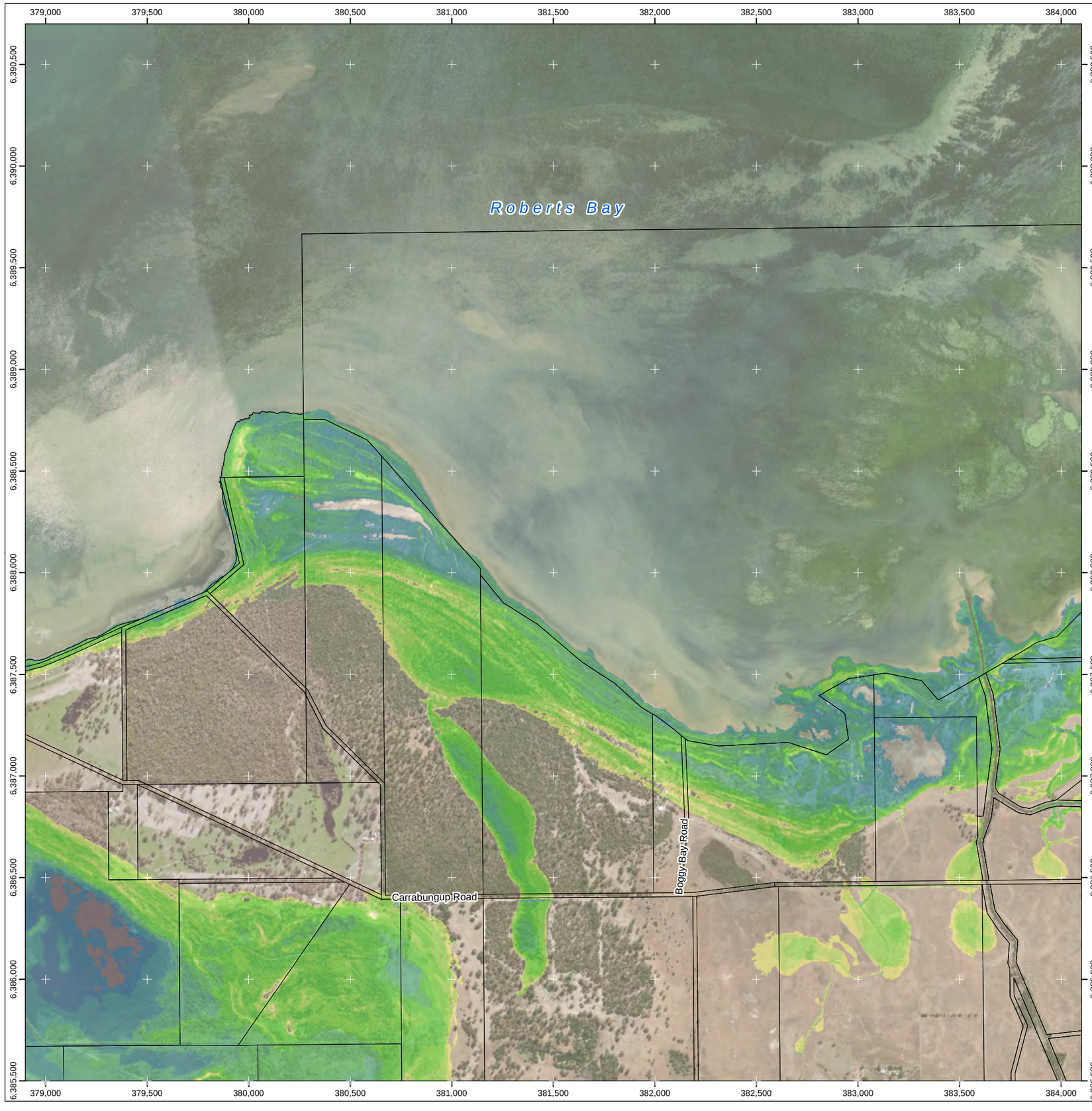
Map Published: 19 Nov. 2020

Mapsheet: 2D

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

Source Data

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Levels across Austin Lakes development based on construction drawings (2009) with minimum 2.9m AHD level across site.

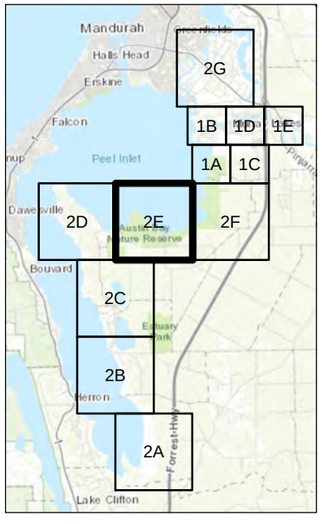
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Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

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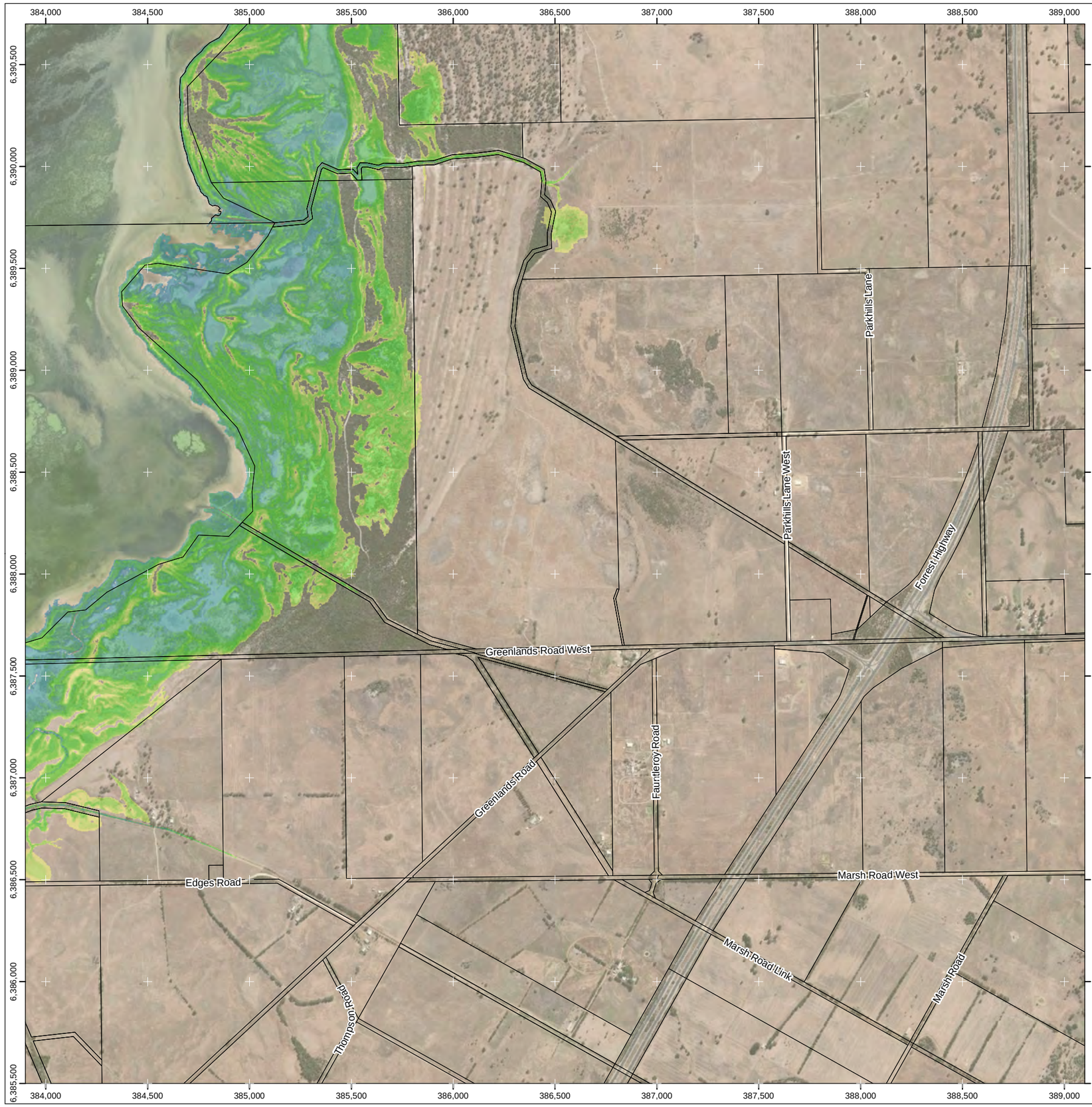
Map Published: 19 Nov. 2020

Mapsheet: 2E

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)



Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

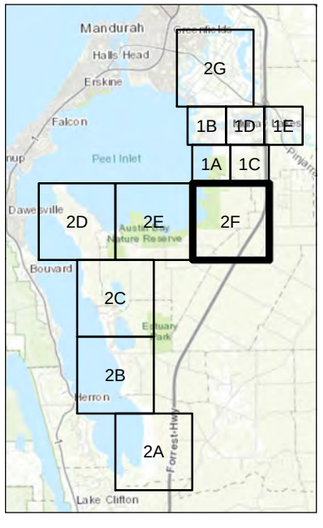
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

Mapsheet: 2F

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm
in Planning Year 2020

Inundation Depth Based on Peak Water level of 1.44m AHD (No Sea Level Rise)

Inundation Depth (m)

- > 1.4
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- 0 - 0.1

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.

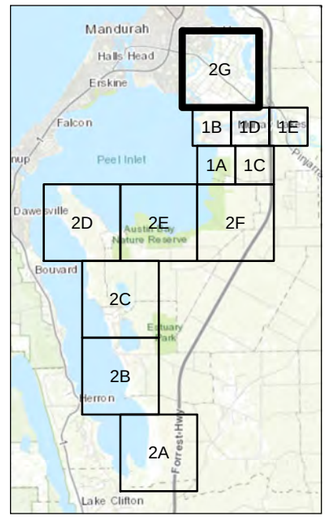
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 19 Nov. 2020

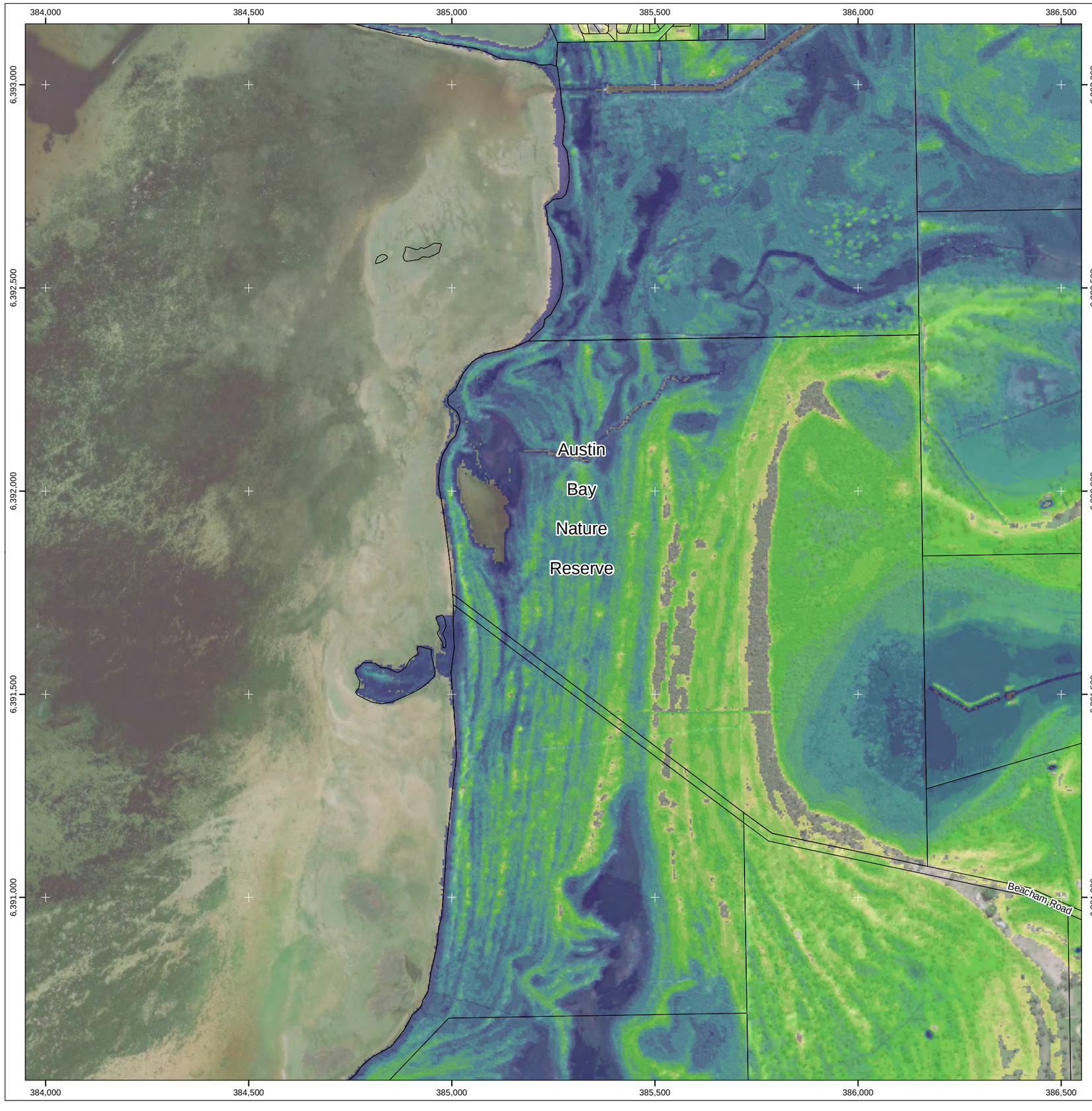
Mapsheet: 2G

C.4.4 Coastal Inundation Hazard – 500yr ARI Scenario, Planning Year 2120 (Includes 0.9m Sea Level Rise)

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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.

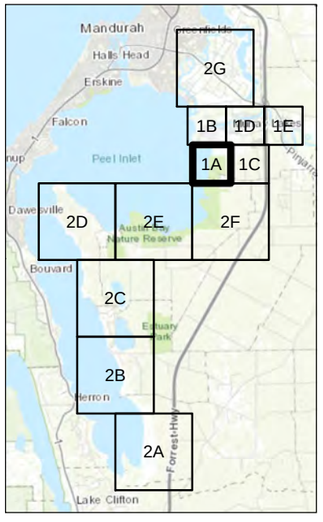
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 16 Nov. 2020

Mapsheet: 1A

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)

Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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.

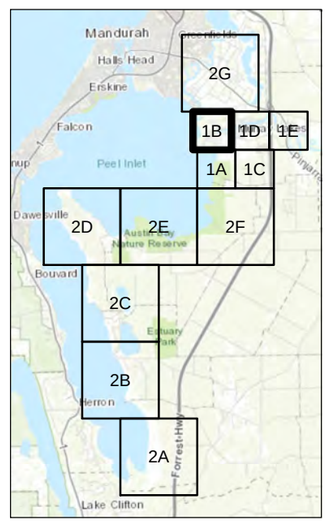
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Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

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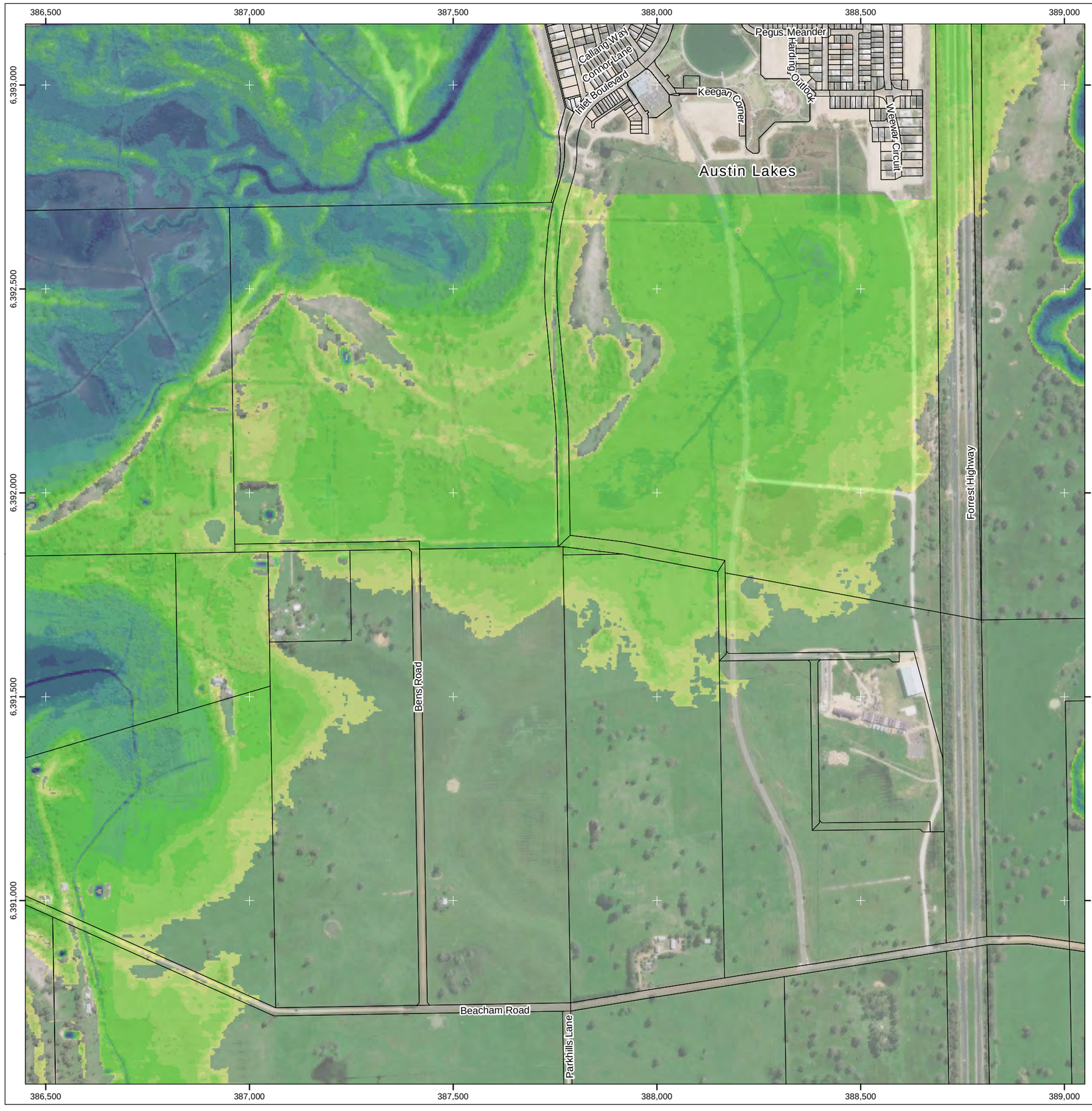
Map Published: 16 Nov. 2020

Mapsheet: 1B

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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.

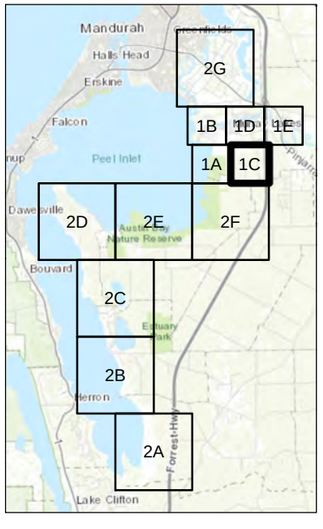
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0 100 200 300 400 500 m

1:10,000

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Mapping prepared by Baird.

Map Published: 16 Nov. 2020

Mapsheet: 1C

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)

Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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.

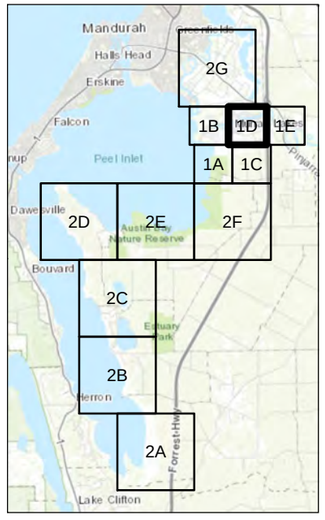
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 16 Nov. 2020

Mapsheet: 1D

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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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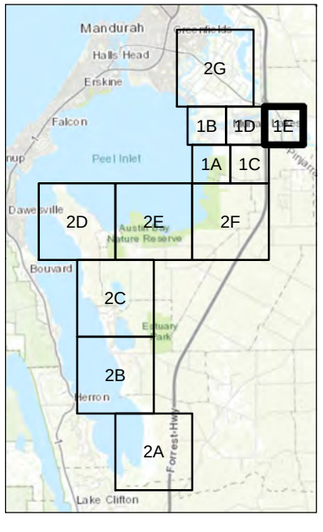
Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.

Spatial Reference: GDA 1994 MGA Zone 50

0 100 200 300 400 500 m

1:10,000

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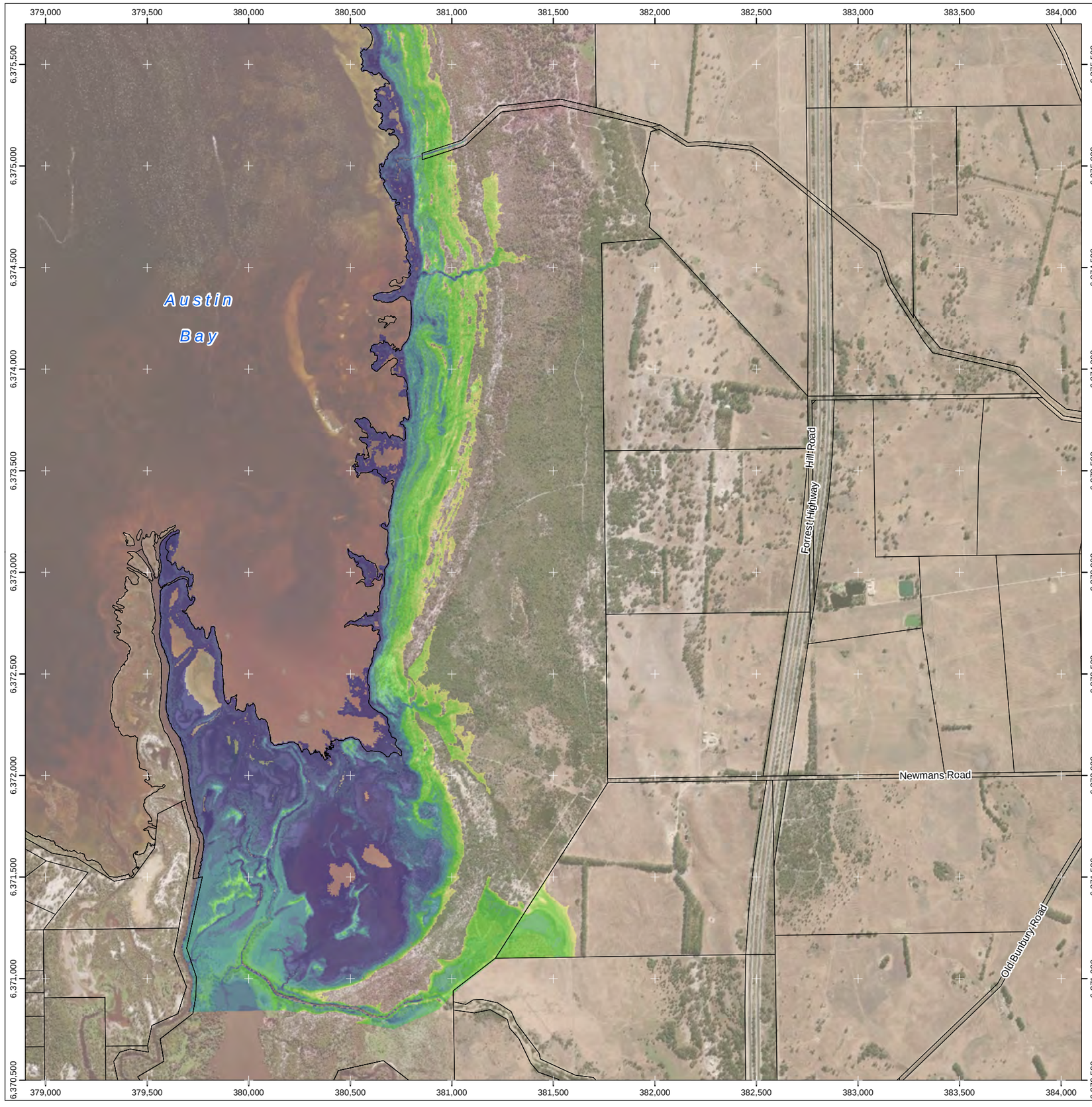
Map Published: 16 Nov. 2020

Mapsheet: 1E

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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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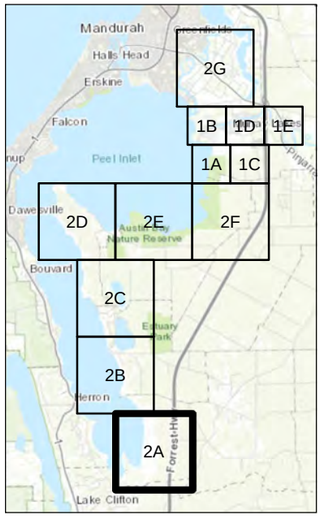
Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.

Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

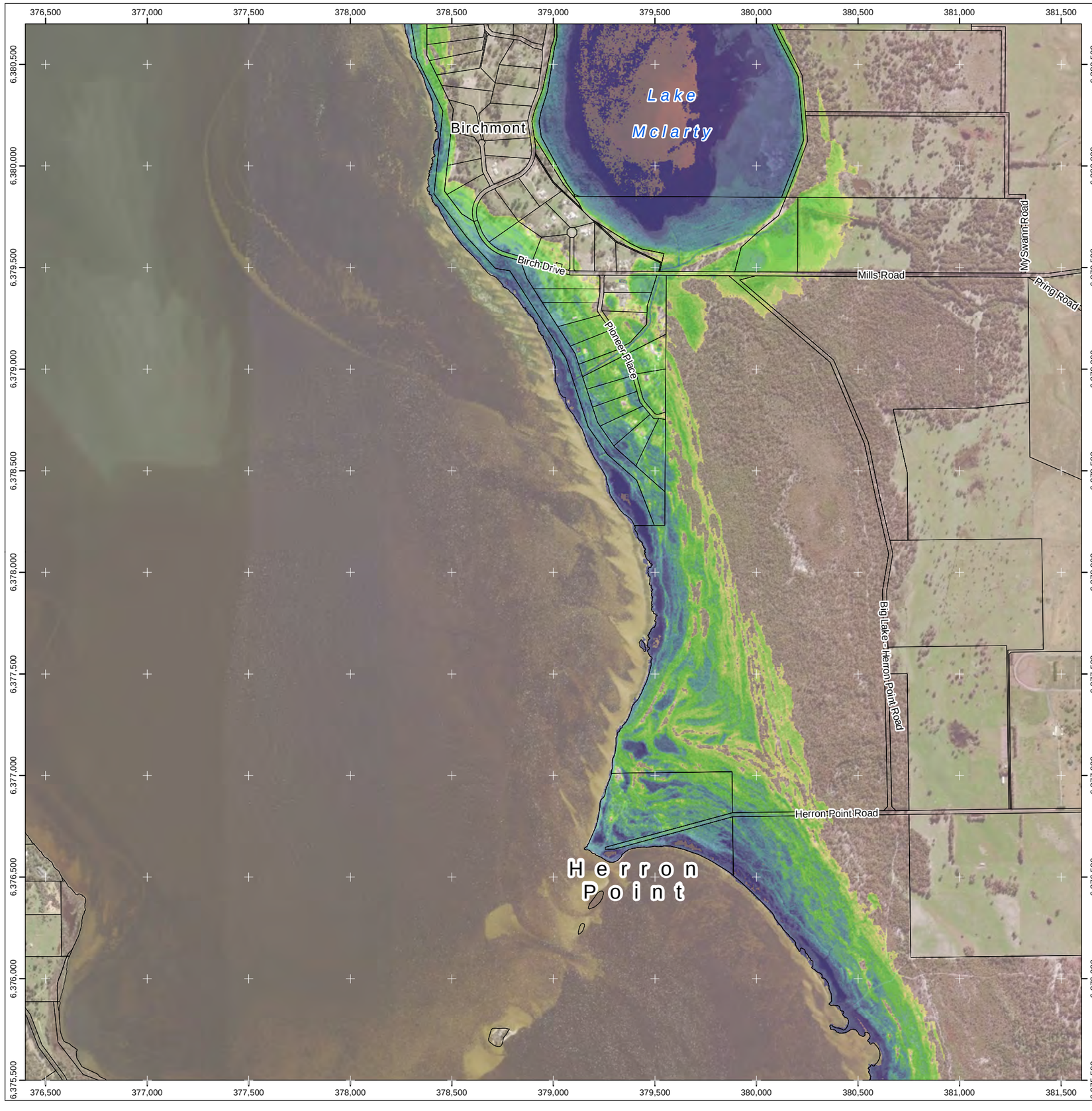
Map Published: 16 Nov. 2020

Mapsheet: 2A

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

N W E S

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.

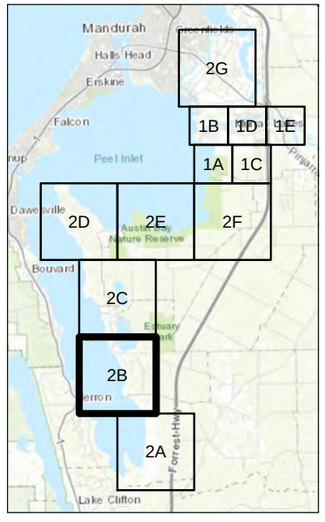
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

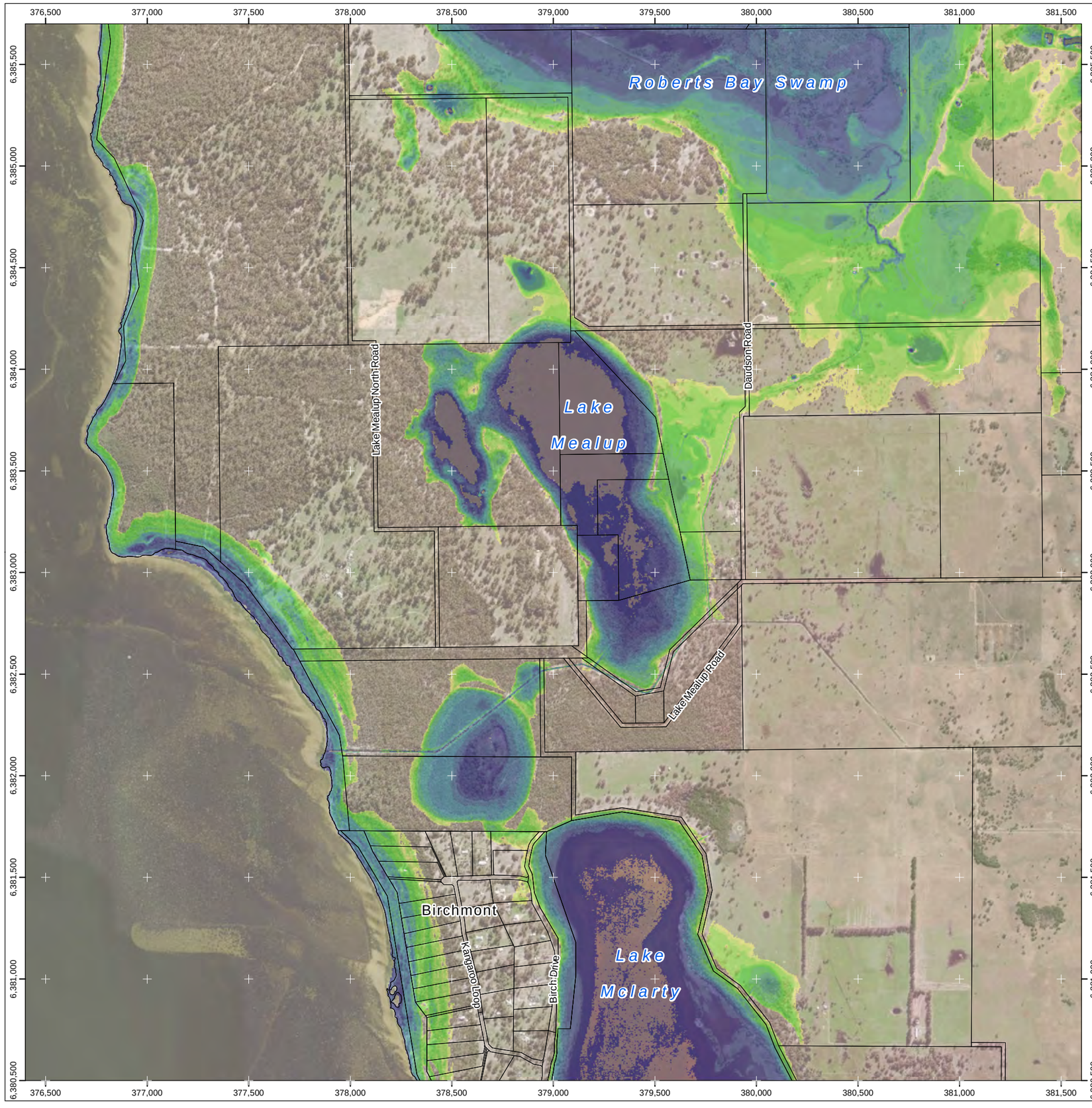
Map Published: 16 Nov. 2020

Mapsheet: 2B

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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.

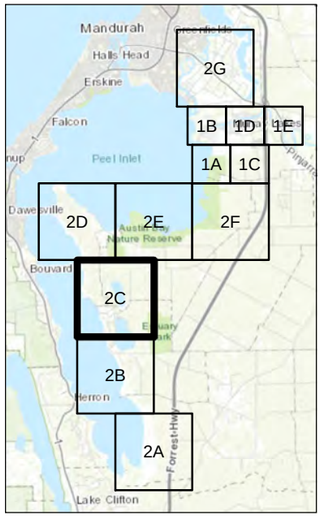
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 16 Nov. 2020

Mapsheet: 2C

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
- 0.21 - 0.4
- 0.11 - 0.2
- < 0.1

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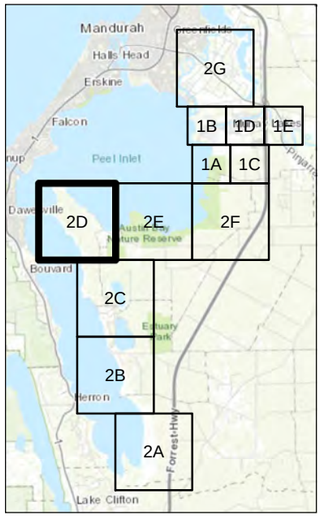
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0 200 400 600 800 1,000 m

1:20,000

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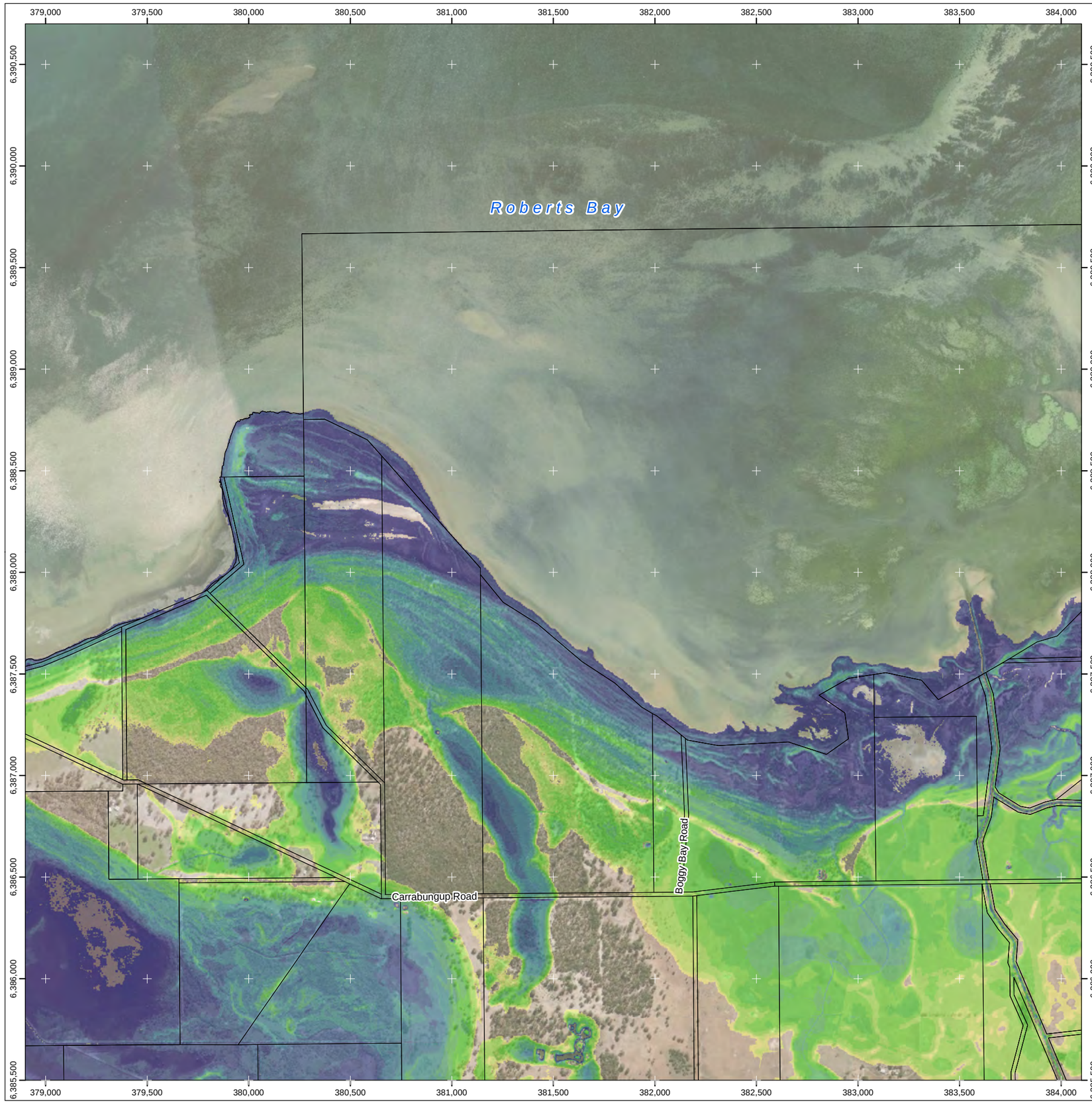
Map Published: 16 Nov. 2020

Mapsheet: 2D

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)



Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
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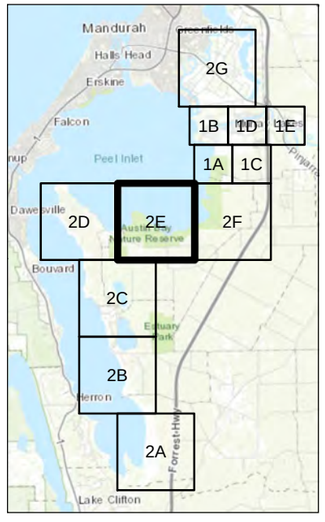
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Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

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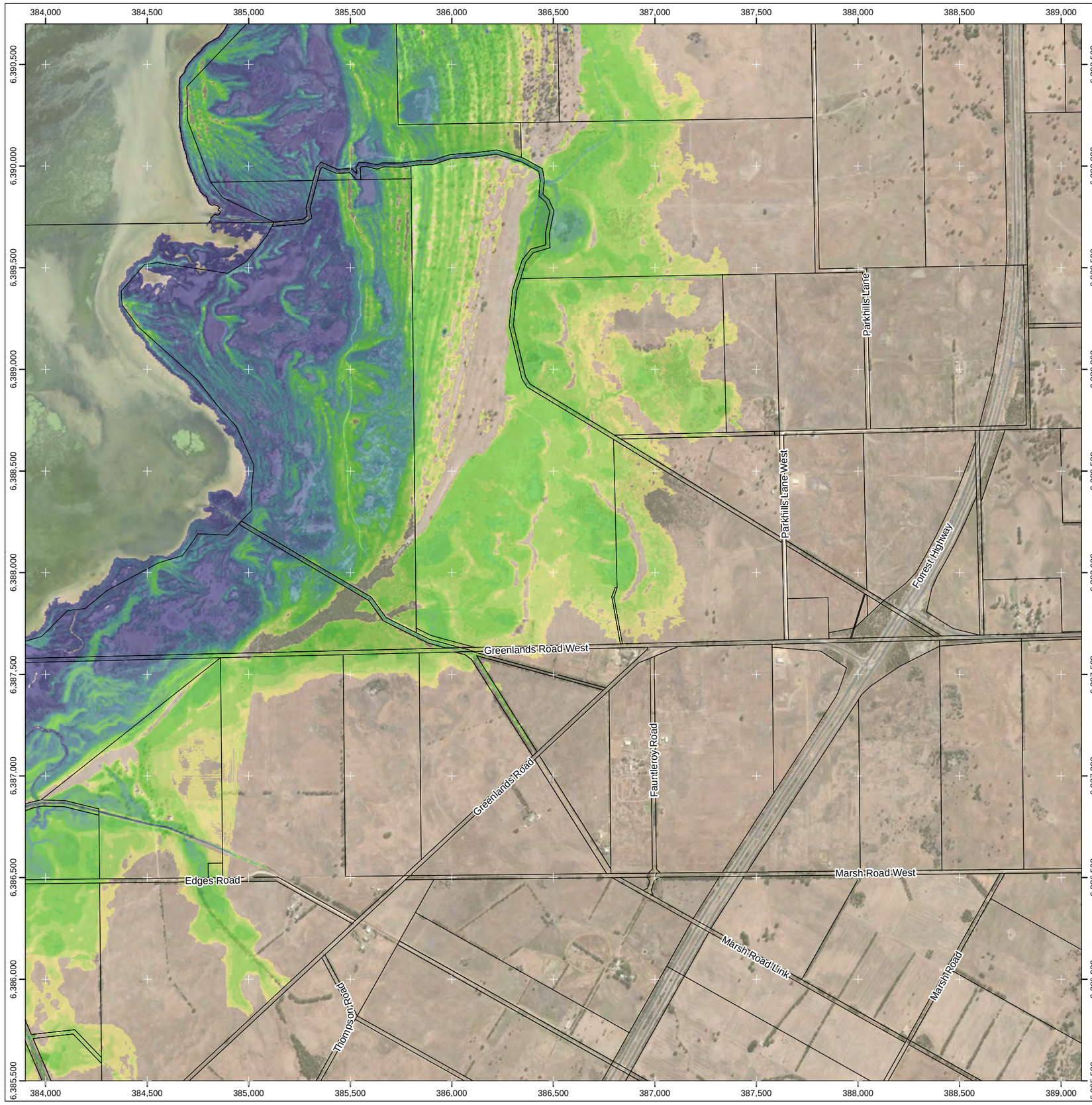
Map Published: 16 Nov. 2020

Mapsheet: 2E

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)



Inundation Depth (m)

- > 2.0
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- 1.21 - 1.4
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- 0.21 - 0.4
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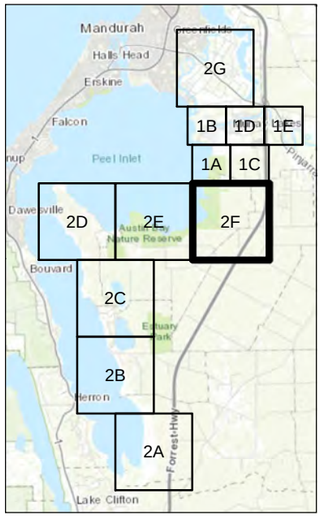
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Street name data © OpenStreetMap contributors.
Basemap Image: ESRI World Imagery © 2020.
Spatial Reference: GDA 1994 MGA Zone 50

0 200 400 600 800 1,000 m

1:20,000

Map scale representative fraction when printed on A3 page size (420x297 mm).



Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 16 Nov. 2020

Mapsheet: 2F

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)

Inundation Depth (m)

- > 2.0
- 1.81 - 2.0
- 1.61 - 1.8
- 1.41 - 1.6
- 1.21 - 1.4
- 1.01 - 1.2
- 0.81 - 1.0
- 0.61 - 0.8
- 0.41 - 0.6
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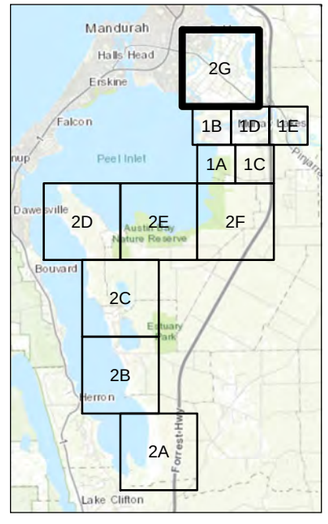
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Shire of Murray
1915 Pinjarra Rd
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https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 16 Nov. 2020

Mapsheet: 2G

Appendix D

Vulnerability Assessment by Shoreline Management Unit

Baird.

D.1 Vulnerability – Erosion

					Likelihood Category				Erosion Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
1	Beach areas	Environmental	Major	Average	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	H	H	VH	VH
1	Foreshore Nature Reserve	Environmental	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
1	Harvey Drain	Environmental	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
1	Kooljerrenup Nature Reserve	Environmental	Major	Average	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	H	H	VH	VH
1	Herron Point Camping Ground	Social	Moderate	Average	Rare	Unlikely	Possible	Almost Certain	L	M	M	H	L	M	M	H
1	Herron Point Foreshore	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
1	Coastal Pathways / Bridle Paths	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
1	Carpark at Herron Boat Ramp	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
1	Herron Point Boat Ramp	City Infrastructure	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
1	Herron Point Reserve Camping Ground Toilet / Showers	City Infrastructure	Minor	Poor	Rare	Rare	Unlikely	Possible	L	L	L	M	M	M	M	H
1	Infrastructure (Signage, shelters, fencing)	City Infrastructure	Insignificant	Good	Possible	Likely	Almost Certain	Almost Certain	L	L	M	M	L	L	L	L
1	Herron Point Road, Roads in Campground	City Infrastructure	Moderate	Poor	Rare	Unlikely	Possible	Likely	L	M	M	H	M	H	H	VH

					Likelihood Category				Erosion Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
2	Beach areas	Environmental	Major	Average	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	H	H	VH	VH
2	Foreshore Nature Reserve	Environmental	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
2	Lake McLarty and McLarty Nature Reserve	Environmental	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
2	Lake Mealup and Mealup Point Nature Reserve	Environmental	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
2	Foreshore Reserve at Birchmont Boat Ramp	Social	Moderate	Average	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	M	M	H	H
2	Coastal Pathways / Bridle Paths	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
2	Residential Properties	Private Asset	Major	Poor	Rare	Rare	Unlikely	Possible	L	L	M	H	M	M	H	VH
2	Carpark at Birchmont Boat Ramp	City Infrastructure	Moderate	Poor	Rare	Unlikely	Possible	Almost Certain	L	M	M	H	M	H	H	VH
2	Birchmont Boat Ramp	City Infrastructure	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
2	Infrastructure (signage, fencing, bus shelter)	City Infrastructure	Minor	Good	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	L	L	L
2	Drainage features (NOT Impacted by Erosion)	City Infrastructure	Moderate	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
2	Roads (Birch Drive, Mills Rd, Pioneer Place, Numbat Place, Kangaroo Loop)	City Infrastructure	Moderate	Poor	Rare	Rare	Unlikely	Possible	L	L	M	M	M	M	H	H

					Likelihood Category				Erosion Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
3	Beach area	Environmental	Major	Average	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	H	H	VH	VH
3	Foreshore Reserve	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
3	Austin Bay Nature Reserve	Environmental	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
3	Foreshore Reserve	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
3	Coastal Pathways / Bridle Paths	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
3	Residential Properties	Private Asset	Major	Poor	Rare	Rare	Unlikely	Possible	L	L	M	H	M	M	H	VH
3	Agricultural Properties	City Infrastructure	Moderate	Poor	Rare	Unlikely	Possible	Almost Certain	L	M	M	H	M	H	H	VH
3	Minor Infrastructure (signage, fencing)	City Infrastructure	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
3	Drainage features	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
3	Roads (Carabunga Road).	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH

					Likelihood Category				Erosion Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
4	Beach area - Peel Inlet facing beach Batavia Quays	Environmental	Major	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	E	E	E	H	VH	VH	VH
4	Riverbank - Murray River	Environmental	Major	Average	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	H	H	VH	VH
4	Austin Bay Nature Reserve	Environmental	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
4	Batavia Quays Wetland	Environmental	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
4	Batavia Quays Headland Feature - Acid Sulphate Soil Site	Environmental	Major	Poor	Likely	Almost Certain	Almost Certain	Almost Certain	H	E	E	E	VH	VH	VH	VH
4	South Yunderup Canal Bund - Water Quality Management	Environmental	Major	Poor	Rare	Rare	Unlikely	Possible	L	L	M	H	M	M	H	VH
4	Coastal Pathway - Bund in front of South Yunderup canals	City Infrastructure	Moderate	Average	Rare	Rare	Unlikely	Possible	L	L	M	M	L	L	M	M
4	Coastal Pathway - Wellya Crescent Park)	City Infrastructure	Moderate	Average	Rare	Rare	Unlikely	Possible	L	L	M	M	L	L	M	M
4	Foreshore Reserve (Tatham Rd, Rivergum Esplanade, Centenary Park)	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
4	Coastal Pathways Murray River (Tatham Rd, Rivergum Esplanade)	City Infrastructure	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
4	Coastal Pathways Batavia Quays Headland	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
4	Residential Properties South Yunderup Canal Estate	Private Asset	Major	Poor	Rare	Rare	Unlikely	Possible	L	L	M	H	M	M	H	VH
4	Residential Properties Placid Bend, Chipper Way, Countess Circuit	Private Asset	Major	Poor	Rare	Rare	Unlikely	Possible	L	L	M	H	M	M	H	VH
4	Residential Properties Batavia Quay	Private Asset	Major	Poor	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	VH	VH	VH	VH
4	Residential Properties Warma Way to Young Rd	Private Asset	Major	Poor	Rare	Rare	Unlikely	Possible	L	L	M	H	M	M	H	VH
4	Residential Properties Young Rd to Strain Glen	Private Asset	Major	Poor	Unlikely	Possible	Likely	Almost Certain	M	H	H	E	H	VH	VH	VH
4	Residential Properties Pelican Rd, Banksia Terrace	Private Asset	Major	Poor	Unlikely	Possible	Almost Certain	Almost Certain	M	H	E	E	H	VH	VH	VH
4	Tathams Caravan Park, Murray River Caravan Park	Private Asset	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
4	Jetties and Moorings along River Privately Held	Private Asset	Minor	Average	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	M	M	M	M
4	Minor Roads (Rivergum Esplanade, Young Rd, Strain Glen, Pelican Rd, Banksia Tce)	City Infrastructure	Moderate	Poor	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	H	H	VH	VH
4	Shire Jetties - Tatham Rd, Pelican Rd, Centenary Park	City Infrastructure	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
4	Boat Launch - Rivergum Esplanade Foreshore	City Infrastructure	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
4	Boat Launch - Batavia Quays Launch Facility	City Infrastructure	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
4	Batavia Quays Club Shed	City Infrastructure	Moderate	Poor	Rare	Rare	Unlikely	Possible	L	L	M	M	M	M	H	H
4	Toilets - Batavia Quays	City Infrastructure	Minor	Poor	Rare	Rare	Unlikely	Possible	L	L	L	M	M	M	M	H
4	Toilets - Pelican Road	City Infrastructure	Minor	Poor	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	M	H	H	H
4	Car Park - Batavia Quays	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
4	Car Park - Rivergum Esplanade Foreshore	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
4	Car Park - Centenary Park	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
4	Car Park - Pelican Road	City Infrastructure	Moderate	Poor	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	H	H	VH	VH
4	Park Furniture - Centenary Park	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
4	Playground Equipment - Centenary Park	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
4	Park Furniture- Wellya Crescent Park	City Infrastructure	Minor	Average	Rare	Rare	Unlikely	Possible	L	L	L	M	L	L	L	M
4	Playground Equipment - Wellya Crescent Park	City Infrastructure	Minor	Average	Rare	Rare	Unlikely	Possible	L	L	L	M	L	L	L	M
4	Park Furniture - Pelican Rd Park	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
4	Playground Equipment - Pelican Rd Park	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
4	Park Furniture- South Yunderup Foreshore	City Infrastructure	Minor	Average	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	M	M	M	M
4	Footpaths	City Infrastructure	Minor	Good	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	L	L	L
4	Minor Infrastructure (Signage, fencing, lighting, bus shelter)	City Infrastructure	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Drainage features (pits, pipes, culverts)	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
4	WaterCorp Infrastructure	Utilities	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH

					Likelihood Category				Erosion Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
5	Beach - Peel Inlet facing beaches on Cooleenup, Meeyip, Ballee, Woolgarook, Yunderup Islands	Environmental	Major	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	E	E	E	H	VH	VH	VH
5	Riverbank - Delta Islands and Murray River	Environmental	Major	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	E	E	E	H	VH	VH	VH
5	Nature Reserve, West end Yunderup Island	Environmental	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
5	Ballee Island Wetland	Environmental	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
5	Foreshore Pathway - Culeenup Rd east of Towerup St	City Infrastructure	Moderate	Average	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	M	M	H	H
5	Foreshore Reserve - Culeenup Rd east of Towerup St	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
5	Foreshore Reserve - Yunderup Island, Ballee Island, Cooleenup Island	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
5	Residential Properties North Yunderup, Culeenup Rd	Private Asset	Major	Poor	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	VH	VH	VH	VH
5	Residential Properties Thomasfield Pl, Ravenswood	Private Asset	Major	Poor	Rare	Unlikely	Possible	Likely	L	M	H	H	M	H	VH	VH
5	Residential Properties Yunderup Island	Private Asset	Major	Poor	Rare	Unlikely	Possible	Likely	L	M	H	H	M	H	VH	VH
5	Residential Properties Ballee Island	Private Asset	Major	Poor	Unlikely	Possible	Likely	Almost Certain	M	H	H	E	H	VH	VH	VH
5	Residential Properties Cooleenup Island	Private Asset	Major	Poor	Unlikely	Possible	Likely	Almost Certain	M	H	H	E	H	VH	VH	VH
5	Jetties and Moorings along River Privately Held	Private Asset	Minor	Average	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	M	M	M	M
5	Minor Roads (Culeenup Rd - Western end)	City Infrastructure	Moderate	Poor	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	H	H	VH	VH
5	Major Roads (Forrest Highway) No Erosion	City Infrastructure	Major	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
5	Shire Jetties - Culeenup Rd, Coopers Mill Precinct, North Yunderup Launch Facility. Swimming pontoon at swim beach	City Infrastructure	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
5	Boat Launch - North Yunderup Launch Facility	City Infrastructure	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
5	Toilets - Kingfisher Park (No Erosion Impact)	City Infrastructure	Minor	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
5	Toilets - Coopers Mill Precinct	City Infrastructure	Minor	Poor	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	H	H	H	H
5	Toilets - North Yunderup Launch Facility (No Erosion Impact)	City Infrastructure	Minor	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
5	Car Park - North Yunderup Launch Facility	City Infrastructure	Moderate	Poor	Rare	Unlikely	Possible	Likely	L	M	M	H	M	H	H	VH
5	Park Furniture - North Yunderup Foreshore Reserve	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
5	Park Furniture- North Yunderup Launch Facility	City Infrastructure	Minor	Average	Rare	Rare	Unlikely	Possible	L	L	L	M	L	L	L	M
5	Park Furniture - Coopers Mill Precinct	City Infrastructure	Minor	Average	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	M	M	M	M
5	Playground Equipment - Coopers Mill Precinct	City Infrastructure	Minor	Average	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	M	M	M	M
5	Park Furniture- Kingfisher Park (No Erosion Impact)	City Infrastructure	Minor	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
5	Playground Equipment - Kingfisher Park (No Erosion Impact)	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
5	Footpaths	City Infrastructure	Minor	Good	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	L	L	L
5	Minor Infrastructure (Signage, fencing, lighting, bus shelter)	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Drainage features (pits, pipes, culverts)	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
5	WaterCorp Infrastructure	Utilities	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
5	Coopers Mill	Cultural / Heritage	Major	Poor	Possible	Likely	Almost Certain	Almost Certain	H	H	E	E	VH	VH	VH	VH
5	Coopers Mill Caretakers House	Cultural / Heritage	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H

					Likelihood Category				Erosion Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
6	Riverbank - Serpentine River	Environmental	Major	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	E	E	E	H	VH	VH	VH
6	Foreshore Reserve - Furnissdale Foreshore	Social	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
6	Residential Properties Riverside Drive along Furnissdale Foreshore (No Erosion impacts)	Private Asset	Major	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
6	Residential Properties along Serpentine River, Tonkin Drive to Furnissdale Road	Private Asset	Major	Poor	Unlikely	Possible	Likely	Almost Certain	M	H	H	E	H	VH	VH	VH
6	Residential Properties Riverside Drive Smith St to Paull St	Private Asset	Major	Poor	Rare	Unlikely	Possible	Likely	L	M	H	H	M	H	VH	VH
6	Residential Properties Riverside Drive NE of Paull St	Private Asset	Major	Poor	Unlikely	Possible	Likely	Almost Certain	M	H	H	E	H	VH	VH	VH
6	Caravan Park (No Erosion Impact)	Private Asset	Moderate	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
6	Riverglades Resort	Private Asset	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
6	Jetties and Moorings along River - Privately Held	Private Asset	Minor	Average	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	M	M	M	M
6	Minor Roads (Riverside Drive Near Smith St)	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
6	Minor Roads (Furnissdale Rd, Ronlyn Rd) No Erosion Impacts	City Infrastructure	Moderate	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
6	Major Roads (Pinjarra Rd) No Erosion	City Infrastructure	Major	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
6	Shire Jetties - Furnissdale Launch Facility, Floating Jetty	City Infrastructure	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
6	Shire Jetties - Furnissdale Launch Facility, Timber Jetty	City Infrastructure	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
6	Shire Jetties - Tonkin Drive Foreshore Timber Jetty	City Infrastructure	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
6	Boat Ramp - Furnissdale Launch Facility	City Infrastructure	Moderate	Average	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	M	H	H	H
6	Toilets - York Road (No Erosion Impacts)	City Infrastructure	Minor	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M
6	Car Park - Furnissdale Launch Facility	City Infrastructure	Moderate	Poor	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	H	H	VH	VH
6	Car Park - Riverside Drive	City Infrastructure	Moderate	Poor	Rare	Rare	Unlikely	Possible	L	L	M	M	M	M	H	H
6	Car Park - Tonkin Drive Foreshore	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
6	Car Park - Furnissdale Bridge Foreshore	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
6	Park Furniture - Furnissdale Launch Facility Foreshore Reserve	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
6	Playground Equipment - Furnissdale Foreshore	City Infrastructure	Minor	Average	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	M	M	M
6	Park Furniture- York Road Park. No Erosion Impacts	City Infrastructure	Minor	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
6	Playground Equipment - York Road Park. No Erosion Impacts	City Infrastructure	Minor	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
6	Footpaths	City Infrastructure	Minor	Good	Rare	Rare	Unlikely	Possible	L	L	L	M	L	L	L	L
6	Minor Infrastructure (Signage, fencing, lighting, bus shelter)	City Infrastructure	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Drainage features (pits, pipes, culverts)	City Infrastructure	Moderate	Poor	Possible	Likely	Almost Certain	Almost Certain	M	H	H	H	H	VH	VH	VH
6	WaterCorp Infrastructure	Utilities	Moderate	Poor	Rare	Unlikely	Possible	Almost Certain	L	M	M	H	M	H	H	VH
6	York Road Clubrooms and Sports Courts (No Erosion)	City Infrastructure	Moderate	Poor	Rare	Rare	Rare	Rare	L	L	L	L	M	M	M	M

D.2 Vulnerability Assessment - Inundation

		m AHD				Likelihood Category				Inundation Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	Elevation	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
1	Beach areas	0.7	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
1	Foreshore Nature Reserve	1.2	Environmental	Minor	Good	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	L	L	L
1	Harvey Drain	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
1	Kooljerrenup Nature Reserve	1.2	Environmental	Major	Average	Unlikely	Possible	Likely	Almost Certain	M	H	H	E	M	H	H	VH
1	Herron Point Camping Ground	1.4	Social	Minor	Average	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	M	M
1	Herron Point Foreshore	1.1	Social	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
1	Coastal Pathways / Bridle Paths	1.2	Social	Minor	Good	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	L	L	L
1	Agricultural Properties	2.2	Private Asset	Minor	Good	Rare	Rare	Rare	Unlikely	L	L	L	L	L	L	L	L
1	Carpark at Herron Boat Ramp	0.95	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
1	Herron Point Boat Ramp	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
1	Herron Point Reserve Camping Ground Toilet / Showers	2.4	City Infrastructure	Minor	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
1	Infrastructure (Signage, shelters, fencing)	0.8	City Infrastructure	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
1	Roads in Campground	1.2	City Infrastructure	Moderate	Average	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	M	M	H	H
1	Herron Point Road	1.1	City Infrastructure	Moderate	Average	Possible	Possible	Almost Certain	Almost Certain	M	M	H	H	M	M	H	H

		m AHD				Inundation Likelihood				Inundation Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	Elevation	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
2	Beach areas	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
2	Foreshore Nature Reserve	1.2	Environmental	Minor	Good	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	L	L	L
2	Lake McLarty	1.5	Environmental	Major	Poor	Rare	Unlikely	Unlikely	Almost Certain	L	M	M	E	M	H	H	VH
2	Lake Mealup	1.5	Environmental	Major	Poor	Rare	Unlikely	Unlikely	Almost Certain	L	M	M	E	M	H	H	VH
2	Foreshore Reserve at Birchmont Boat Ramp	1.1	Social	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
2	Coastal Pathways / Bridle Paths	1.1	Social	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
2	Residential Properties	1.1	Private Asset	Moderate	Average	Possible	Possible	Almost Certain	Almost Certain	M	M	H	H	M	M	H	H
2	Carpark at Birchmont Boat Ramp	1.6	City Infrastructure	Minor	Good	Rare	Rare	Unlikely	Almost Certain	L	L	L	M	L	L	L	L
2	Birchmont Boat Ramp	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
2	Infrastructure (signage, fencing, bus shelter)	1.2	City Infrastructure	Insignificant	Good	Unlikely	Possible	Likely	Almost Certain	L	L	L	M	L	L	L	L
2	Drainage features	5	City Infrastructure	Moderate	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
2	Roads (Birch Drive, Mills Rd, Pioneer Place, Numbat Place, Kangaroo Loop)	1.5	City Infrastructure	Moderate	Average	Rare	Unlikely	Unlikely	Almost Certain	L	M	M	H	L	M	M	H

		m AHD				Likelihood Category				Inundation Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	Elevation	General Cat.	General	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
3	Beach area	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
3	Foreshore Reserve	0.7	Social	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
3	Austin Bay Nature Reserve	1.1	Environmental	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
3	Robert Bay Swamp	1.2	Environmental	Major	Poor	Unlikely	Possible	Likely	Almost Certain	M	H	H	E	H	VH	VH	VH
3	Coastal Pathways / Bridle Paths	0.8	Social	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
3	Agricultural Properties	2.2	Private Asset	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
3	Agricultural Land	1.4	Private Asset	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
3	Minor Infrastructure (signage, fencing)	0.6	City Infrastructure	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
3	Drainage features	0.6	City Infrastructure	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
3	Roads (Carabunga Road).	0.7	City Infrastructure	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H

		m AHD				Likelihood Category				Inundation Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	Elevation	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
4	Beach area - Peel Inlet facing beach Batavia Quays	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Riverbank - Murray River	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Austin Bay Nature Reserve	1.1	Environmental	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Batavia Quays Wetland	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Batavia Quays Headland Feature - Acid Sulphate Soil Site. Height of top of Revetment	2.4	Environmental	Catastrophic	Poor	Rare	Rare	Rare	Rare	M	M	M	M	H	H	H	H
4	South Yunderup Canal Bund - Water Quality Management	1.1	Environmental	Major	Average	Possible	Possible	Almost Certain	Almost Certain	H	H	E	E	H	H	VH	VH
4	Coastal Pathway - Bund in front of South Yunderup canals	1.1	City Infrastructure	Moderate	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	H	H	L	L	M	M
4	Coastal Pathway - Wellya Crescent Park)	1	City Infrastructure	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Foreshore Reserve (Tatham Rd, Rivergum Esplanade, Centenary Park)	0.9	Social	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Coastal Pathways Murray River (Tatham Rd, Rivergum Esplanade)	0.85	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Coastal Pathways Batavia Quays Headland	2.2	City Infrastructure	Minor	Good	Rare	Rare	Rare	Unlikely	L	L	L	L	L	L	L	L
4	Residential Properties South Yunderup Canal Estate	2.2	Private Asset	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
4	Residential Properties Placid Bend, Chipper Way, Countess Circuit	2.2	Private Asset	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
4	Residential Properties Batavia Quay	2.2	Private Asset	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
4	Residential Properties Warma Way to Young Rd	1.8	Private Asset	Moderate	Average	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	M
4	Residential Properties Young Rd to Strain Glen	1.7	Private Asset	Moderate	Average	Rare	Rare	Unlikely	Likely	L	L	M	H	L	L	M	H
4	Residential Properties Pelican Rd, Banksia Terrace	1.7	Private Asset	Moderate	Average	Rare	Rare	Unlikely	Likely	L	L	M	H	L	L	M	H
4	Residential Properties Murray River Drive, Leander Way, Pericho Close	1.8	Private Asset	Moderate	Average	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	M
4	Agricultural / Vacant Land - Beacheam Rd to Austin Cove	1.8	Private Asset	Moderate	Average	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	M
4	Tathams Caravan Park, Murray River Caravan Park	1.1	Private Asset	Moderate	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	H	H	L	L	M	M
4	Jetties and Moorings along River Privately Held	0.6	Private Asset	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Minor Roads (Rivergum Esplanade, Young Rd, Strain Glen, Pelican Rd, Banksia Tce)	1.3	City Infrastructure	Moderate	Average	Unlikely	Unlikely	Possible	Almost Certain	M	M	M	H	M	M	M	H
4	Major Roads (South Yunderup Road, Forrest Highway) No Erosion	1.5	City Infrastructure	Moderate	Average	Rare	Unlikely	Unlikely	Almost Certain	L	M	M	H	L	M	M	H
4	Canal Network (No Erosion)	0.5	City Infrastructure	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Shire Jetties - Tatham Rd, Pelican Rd, Centenary Park	0.7	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Boat Launch - Rivergum Esplanade Foreshore	0.6	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Boat Launch - Batavia Quays Launch Facility	0.6	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Batavia Quays Club Shed	1.6	City Infrastructure	Moderate	Good	Rare	Rare	Unlikely	Almost Certain	L	L	M	H	L	L	L	M
4	South Yunderup Fire Station (No Erosion Impact)	2.1	City Infrastructure	Major	Good	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	L
4	Toilets - Centenary Park (No Erosion Impact)	1.5	City Infrastructure	Minor	Average	Rare	Unlikely	Unlikely	Almost Certain	L	L	L	M	L	L	L	M
4	Toilets - Batavia Quays	1.6	City Infrastructure	Minor	Average	Rare	Rare	Unlikely	Almost Certain	L	L	L	M	L	L	L	M
4	Toilets - Pelican Road	2.5	City Infrastructure	Minor	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
4	Car Park - Batavia Quays	1.2	City Infrastructure	Minor	Good	Unlikely	Possible	Likely	Almost Certain	L	M	M	M	L	L	L	L
4	Car Park - Rivergum Esplanade Foreshore	1.1	City Infrastructure	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Car Park - Centenary Park	1.3	City Infrastructure	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
4	Car Park - Pelican Road	1.3	City Infrastructure	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
4	Car Park - Willow Gardens (No Erosion Impact)	1.8	City Infrastructure	Minor	Good	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	L
4	Car Park - Fire Station (No Erosion Impact)	1.8	City Infrastructure	Minor	Good	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	L
4	Park Furniture - Centenary Park	1.4	City Infrastructure	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
4	Playground Equipment - Centenary Park	1.4	City Infrastructure	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
4	Park Furniture- Wellya Crescent Park	1.4	City Infrastructure	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
4	Playground Equipment - Wellya Crescent Park	1.6	City Infrastructure	Minor	Good	Rare	Rare	Unlikely	Almost Certain	L	L	L	M	L	L	L	L
4	Park Furniture - Pelican Rd Park	1.7	City Infrastructure	Minor	Good	Rare	Rare	Unlikely	Likely	L	L	L	M	L	L	L	L
4	Playground Equipment - Pelican Rd Park	1.3	City Infrastructure	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
4	Park Furniture- Lucie Hunter Park (No Erosion Impact	0.9	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Park Furniture- South Yunderup Foreshore	0.9	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Footpaths	0.8	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Minor Infrastructure (Signage, fencing, lighting, bus shelter)	0.9	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
4	Drainage features (pits, pipes, culverts)	0.8	City Infrastructure	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
4	WaterCorp Infrastructure	0.9	Utilities	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H

NOTE: Residential Properties. LiDAR Level + 0.3m Freeboard

		m AHD				Likelihood Category				Inundation Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	Elevation	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
5	Beach - Peel Inlet facing beaches on Cooleenup, Meeyip, Ballee, Woolgarook, Yunderup Islands	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Riverbank - Delta Islands and Murray River	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Nature Reserve, West end Yunderup Island	0.9	Environmental	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Ballee Island Wetland	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Foreshore Reserve - Culeenup Rd east of Towerup St	0.9	Social	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Foreshore Reserve - Yunderup Island, Ballee Island, Cooleenup Island	0.9	Social	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Residential Properties North Yunderup, Culeenup Rd	1.8	Private Asset	Moderate	Average	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	M
5	Residential Properties Thomasfield Pl, Ravenswood	2.0	Private Asset	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
5	Rural Properties Pinjarra Rd, Tonkin Drv, Walter Rd	1.9	Private Asset	Moderate	Average	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	M
5	Residential Properties Thomasfield Pl, Ravenswood	2.0	Private Asset	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
5	Residential Properties Yunderup Island	1.0	Private Asset	Mod. / Maj [2]	Average / Low[2]	Possible	Likely	Almost Certain	Almost Certain	M	H	H	E	M	H	H	VH
5	Residential Properties Ballee Island	1.0	Private Asset	Mod. / Maj [2]	Average / Low[2]	Possible	Likely	Almost Certain	Almost Certain	M	H	H	E	M	H	H	VH
5	Residential Properties Cooleenup Island	0.9	Private Asset	Mod. / Maj [2]	Average / Low[2]	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	E	H	H	H	VH
5	Septic Sytems Yunderup Island	0.7	Private Asset	Major	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	E	E	E	E	H	H	H	H
5	Septic Sytems Ballee Island	0.7	Private Asset	Major	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	E	E	E	E	H	H	H	H
5	Septic Sytems Cooleenup Island	0.6	Private Asset	Major	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	E	E	E	E	H	H	H	H
5	Jetties and Moorings along River Privately Held	0.6	Private Asset	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Minor Roads (Culeenup Rd - Western end)	1.5	City Infrastructure	Moderate	Average	Rare	Unlikely	Unlikely	Almost Certain	L	M	M	H	L	M	M	H
5	Major Roads (Pinjarra Rd, Forrest Hwy)	2.2	City Infrastructure	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
5	Shire Jetties - Culeenup Rd, Coopers Mill Precinct, North Yunderup Launch Facility. Swimming pontoon at swim beach	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Boat Launch - North Yunderup Launch Facility	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Toilets - Kingfisher Park (No Erosion Impact)	2.3	City Infrastructure	Minor	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
5	Toilets - Coopers Mill Precinct	1.4	City Infrastructure	Minor	Average	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	M	M
5	Toilets - North Yunderup Launch Facility (No Erosion Impact)	1.8	City Infrastructure	Minor	Average	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	M
5	Car Park - North Yunderup Launch Facility	1.8	City Infrastructure	Minor	Good	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	L
5	Park Furniture - North Yunderup Foreshore Reserve	0.9	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Park Furniture- North Yunderup Launch Facility	1.8	City Infrastructure	Minor	Good	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	L
5	Park Furniture - Coopers Mill Precinct	0.9	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Playground Equipment - Coopers Mill Precinct	0.9	City Infrastructure	Minor	Good	Likely	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Park Furniture- Kingfisher Park (No Erosion Impact)	2.0	City Infrastructure	Minor	Good	Rare	Rare	Rare	Unlikely	L	L	L	L	L	L	L	L
5	Playground Equipment - Kingfisher Park (No Erosion Impact)	2.3	City Infrastructure	Minor	Good	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
5	Footpaths	1.0	City Infrastructure	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Minor Infrastructure (Signage, fencing, lighting, bus shelter)	0.8	City Infrastructure	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
5	Drainage features (pits, pipes, culverts)	0.8	City Infrastructure	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
5	WaterCorp Infrastructure	0.9	Utilities	Moderate	Average	Likely	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
5	Coopers Mill	0.7	Cultural / Heritage	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
5	Coopers Mill Caretakers House	1.4	Cultural / Heritage	Moderate	Average	Unlikely	Unlikely	Possible	Almost Certain	M	M	M	H	M	M	M	H

NOTE : for all Residential Properties the level is finished floor level = LiDAR Level + 0.3m Freeboard

2. For depth of flooding >1.0m over the Finished Floor level the consequence is Major and adaptive capacity is rated as low.

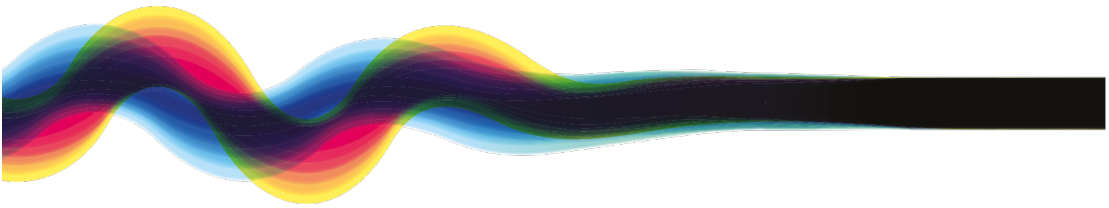
		m AHD				Likelihood Category				Inundation Risk Rating				Vulnerability - Incl. Adaptive Capacity			
SMU	Description	Elevation	General Cat.	Consequence	Adaptive Cap.	2030	2050	2070	2120	2030	2050	2070	2120	2030	2050	2070	2120
6	Riverbank - Serpentine River	0.5	Environmental	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Foreshore Reserve - Furnissdale Foreshore	0.7	Social	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Residential Properties Riverside Drive along Furnissdale Foreshore	1.4	Private Asset	Moderate	Average	Unlikely	Unlikely	Possible	Almost Certain	M	M	M	H	M	M	M	H
6	Residential Properties along Serpentine River, Tonkin Drive to Furnissdale Road	1.8	Private Asset	Moderate	Average	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	M
6	Residential Properties Riverside Drive Smith St to Paull St	1.5	Private Asset	Moderate	Average	Rare	Unlikely	Unlikely	Almost Certain	L	M	M	H	L	M	M	H
6	Residential Properties Riverside Drive NE of Paull St	1.5	Private Asset	Moderate	Average	Rare	Unlikely	Unlikely	Almost Certain	L	M	M	H	L	M	M	H
6	Rural Properties Pinjarra Rd to Goodooga Rd	2	Private Asset	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M
6	Caravan Park	1.7	Private Asset	Minor	Good	Rare	Rare	Unlikely	Likely	L	L	L	M	L	L	L	L
6	Riverglades Resort	2.5	Private Asset	Moderate	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
6	Jetties and Moorings along River - Privately Held	0.5	Private Asset	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Minor Roads (Riverside Drive Near Smith St)	0.7	City Infrastructure	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
6	Minor Roads (Riverside Drive foreshore, Furnissdale Rd, Ronlyn Rd)	1.2	City Infrastructure	Moderate	Average	Unlikely	Possible	Likely	Almost Certain	M	M	H	H	M	M	H	H
6	Major Roads (Pinjarra Rd)	3	City Infrastructure	Moderate	Average	Rare	Rare	Rare	Rare	L	L	L	L	L	L	L	L
6	Shire Jetties - Furnissdale Launch Facility, Floating Jetty	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Shire Jetties - Furnissdale Launch Facility, Timber Jetty	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Shire Jetties - Tonkin Drive Foreshore Timber Jetty	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Boat Ramp - Furnissdale Launch Facility	0.5	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Toilets - York Road	2	City Infrastructure	Minor	Average	Rare	Rare	Rare	Unlikely	L	L	L	L	L	L	L	L
6	Car Park - Furnissdale Launch Facility	1.3	City Infrastructure	Minor	Good	Unlikely	Unlikely	Possible	Almost Certain	L	L	M	M	L	L	L	L
6	Car Park - Riverside Drive	0.7	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Car Park - Tonkin Drive Foreshore	1	City Infrastructure	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Car Park - Furnissdale Bridge Foreshore	1	City Infrastructure	Minor	Good	Possible	Likely	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Park Furniture - Furnissdale Launch Facility Foreshore Reserve	1.1	City Infrastructure	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Playground Equipment - Furnissdale Foreshore	1.1	City Infrastructure	Minor	Good	Possible	Possible	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Park Furniture- York Road Park.	1.8	City Infrastructure	Minor	Good	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	L
6	Playground Equipment - York Road Park.	1.8	City Infrastructure	Minor	Good	Rare	Rare	Rare	Possible	L	L	L	M	L	L	L	L
6	Footpaths	0.7	City Infrastructure	Minor	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Minor Infrastructure (Signage, fencing, lighting, bus shelter)	0.7	City Infrastructure	Insignificant	Good	Almost Certain	Almost Certain	Almost Certain	Almost Certain	M	M	M	M	L	L	L	L
6	Drainage features (pits, pipes, culverts)	0.8	City Infrastructure	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
6	WaterCorp Infrastructure	0.7	Utilities	Moderate	Average	Almost Certain	Almost Certain	Almost Certain	Almost Certain	H	H	H	H	H	H	H	H
6	York Road Clubrooms and Sports Courts	2.1	City Infrastructure	Moderate	Average	Rare	Rare	Rare	Unlikely	L	L	L	M	L	L	L	M

NOTE: Residential Properties. LiDAR Level + 0.3m Freeboard

Appendix E

Planning Instruments Review

E.1 Review of Planning Instruments



element.

Shire of Murray

Coastal Hazard Risk Management Adaptation Plan

December 2020

Document ID:					
Issue	Date	Status	Prepared by	Approved by	
			Name	Name	Signature
V1	27/10/20	Draft	Mike Davis	Draft	
V2	14/12/20	Final	Mike Davis	MD	

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Contents

1. Community Profile Overview 1
2. Existing Planning Framework 2
2.1 Corporate Governance Framework 3
2.1.1 Murray 2030 Strategic Community Plan 3
2.1.2 Corporate Business Plan 2020 – 2024 3
2.1.3 Emergency Risk Management Report 2013 3
2.2 Relevant Legislation 4
2.2.1 Planning and Development (Local Planning Schemes) Regulations 2015 4
2.3 State Planning Framework 6
2.3.1 Perth and Peel @ 3.5 Million and Sub-regional Planning Framework 6
2.3.2 Peel Region Scheme 6
2.3.3 State Planning 2.1: Peel-Harvey Coastal Plain Catchment 6
2.3.4 State Planning Policy 2.6: State Coastal Planning 6
2.3.5 State Coastal Planning Policy No. 2.6: State Coastal Planning Policy Guidelines 6
2.3.6 Planned or Managed Retreat Guidelines 7
2.3.7 State Planning Policy 3.4: Natural Hazards and Disasters 8
2.3.8 Development Control Policy 1.8: Canal Estates and Artificial Waterway Development 8
2.4 Local Planning Framework 9
2.4.1 Local Planning Scheme No. 4 9
2.4.2 Boating Facilities and Moorings Local Planning Policy 9
2.4.3 General Development Requirements for Properties Abutting an Artificial Canal Waterway 9
2.4.4 Canal Walls – Yunderup Stage One Canals, Local Planning Policy 9
2.4.5 Lot 803 North Yunderup Road Structure Plan Map 10
2.4.6 Lots 1, 2 and 49 Banksia Terrace, South Yunderup Structure Plan 10
2.4.7 Murray River Foreshore Masterplan 10
2.5 Summary of Existing Controls 11
2.5.1 Summary of options 11

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1. Community Profile Overview

The Shire of Murray is located within the Peel region approximately 80 kilometres south of the Perth City Centre. The Shire includes the Harvey Estuary and is located adjacent to the Peel Inlet. The Murray River and Serpentine River both flow into the estuary.

The original inhabitants of the Murray area are the Binjareb Aboriginal people.

The Shire recorded a population of 17,911 people in 2019 (ABS, 2019). The Shire is predominantly zoned for rural purposes however includes the main township of Pinjarra and other settlements of Ravenswood, Dwellingup, North Dandalup and other smaller settlements. A number of canal developments have been built on the Murray River and Estuary.

Notable transport routes that run through the Shire include the Kwinana Freeway, Forrest Highway, the Southern Western Highway and the Perth-Bunbury railway line. It is noted that the Forrest Highway traverses the Murray River near the intersection with Pinjarra Road.

According to Population.ID, the Shire's population has grown from 12,522 in 2006 to 17,911 in 2019, representing an average growth rate of 1.43% during this period (Population.Id, 2020).

Approximately 89% of the Shire's population lived in a separate (single) dwelling as at 2016 (Population.Id, 2020).

It is noted that there are approximately 5,368 jobs generated within the Shire, of which, 2,351 employed persons (43.8%) also live in the Shire (Population.Id, 2020).

2. Existing Planning Framework

This section outlines the existing planning controls applicable to land use and development within the Shire with a particular focus on coastal planning and management to inform the identification of issues relating to the preparation of this CHRMAP. The following documents are included in this review.

Table 1 – Relevant Planning Framework

Corporation Strategic Planning • Murray 2030 Strategic Community Plan • Corporate Business Plan 2020 - 2024 • Emergency Risk Management Report 2013
Relevant Legislation • Planning and Development (Local Planning Schemes) Regulations 2015
State Planning Framework • Perth and Peel @ 3.5 Million • Peel Region Scheme • State Planning 2.1: Peel-Harvey coastal plain catchment • State Planning Policy 2.6: State Coastal Planning • State Planning Policy 2.6: State Coastal Planning Policy Guidelines • Coastal hazard risk management and adaptation planning guidelines • State Planning Policy 3.4: Natural Hazards and Disasters • Development Control Policy 1.8: Canal Estates and Artificial Waterway Development
Local Planning Framework • Shire of Murray Local Planning Scheme No. 4 • Boating Facilities and Moorings Local Planning Policy • General Development Requirements for Properties Abutting an Artificial Canal Waterway • Canal Walls – Yunderup State One Canals, Local Planning Policy <u>Structure Plans</u> • Lot 803 North Yunderup Road Structure Plan Map • Lots 1, 2 and 49 Banksia Terrace, South Yunderup <u>Masterplans</u> • Murray River Foreshore Masterplan

2.1 Corporate Governance Framework

2.1.1 Murray 2030 Strategic Community Plan

The Shire of Murray 2030 Strategic Community Plan (SCP) is the overarching strategy which guides the future governance of the local government over the next 10 years. The SCP establishes the following vision for the Shire:

"By 2030, the Shire of Murray will be a place where business thrives, we protect our environment, and all people enjoy an outstanding quality of life".

The SCP establishes a range of strategies to address facets of community, the environment, the economy and governance, with the following strategies relevant to planning for coastal processes"

- Ensure the safety of our community;
- Connect the natural assets, waterways, parks and reserves to the community;
- Upgrade the amenity of the Murray River Square, foreshore reserve and Glebe Land;
- Ensure Town Planning Scheme and Local Planning Strategy facilitates quality and diverse planning outcomes;
- Continually review and enhance public boating facilities and environmental sustainability within our waterways; and
- Undertake a risk assessment of the impact of climate change.

These strategies inform the Shire's Corporate Business Plan and expenditure on programs relevant to foreshore and coastal planning.

2.1.2 Corporate Business Plan 2020 – 2024

The Corporate Business Plan (CBP) is the Shire's four year business plan which informs the Shire's annual budget to deliver the priorities of the community. The CBP identifies a range of projects and actions, of which, the following are relevant to the preparation of this CHRMAP:

- Progressively improve and activate family friendly foreshore reserves;
- Progressively implement the Murray River Foreshore Masterplan;
- Review and implement the Sandy Cover South Yunderup Reserve Masterplan;
- Prepare and implement the Shire of Murray Reserve Management Plans;
- Implement the Herron Point Management Plan;
- Implement Waterways Management Plans;
- Progress the development of recreational boating facilities to meet community needs;
- Undertake a feasibility study for boat launching improvements at Batavia Quays; and
- Complete the Coastal Hazard Risk Management and Adaptation Planning Strategy and consider outcomes within the planning framework.

2.1.3 Emergency Risk Management Report 2013

The Shire has prepared an Emergency Risk Management Report which identifies the effects of storm surge and flooding as a risk that is present within the Shire. The document incorporates a Community Emergency Risk Assessment tool which can be used to correlate the likelihood and consequence to identify a risk rating similar to what is required as part of the CHRMAP process.

2.2 Relevant Legislation

2.2.1 Planning and Development (Local Planning Schemes) Regulations 2015

The *Planning and Development (Local Planning Schemes) Regulations 2015* (the regulations) were introduced by the State government to ensure a consistent structure, format and approach to local planning schemes across the state of Western Australia.

The regulations have recently been amended to introduce additional measures in response to the COVID-19 pandemic. These additional measures and exemptions to certain development and land use are temporary in nature and do not have any specific relevance to this study.

The State government is currently progressing further amendments to the Regulations which may amend the terminology and planning instruments referenced below.

The regulations contain 'deemed provisions' being Schedule 2 of the Regulations and these provisions automatically apply to all local government planning schemes throughout the state and supersede corresponding provisions of these schemes.

Schedule 2 of the Regulations contain provisions relating to various planning mechanisms which have varying degrees of application to implementing adaptation approaches for coastal processes. The planning mechanisms available in the Regulations are examined below.

Local Planning Policy

Part 2: Division 2 of the deemed provisions relates to the preparation of local planning policies. A local planning policy may apply generally to the Scheme area or deal with a specific class or classes of matters.

In making a determination under the scheme, the authority responsible for determining a planning application must have due regard to each relevant local planning policy, to the extent that the policy is consistent with the scheme. In addition to introducing new policy measures, a local planning policy may also vary existing deemed-to-comply provisions of the Residential Design Codes, where it is considered appropriate. In the context of coastal hazard and risk planning, a local planning policy could introduce additional design requirements for development, such as elevated habitable floor levels, additional required setback requirements and other relevant matters to ensure coastal hazard issues are appropriately responded to within the planning framework.

Structure Plans and Activity Centre Plans

Part 4 of the deemed provisions relates to the preparation of structure plans while Part 5 relates to the preparation of Activity Centre Plans. A structure plan (or Activity Centre Pan) may be prepared for a specific area if:

(a) The area is:

  i. All or part within a zone that is identified by the scheme as being suitable for urban or industrial development; and

  ii. Identified in this scheme as an area requiring a structure plan to be prepared before any future subdivision or development is undertaken; or

(b) A State Planning Policy requires a structure plan to be prepared for the area; or

(c) The Commission considers that a structure plan for the area is required for the purposes of orderly and proper planning.

The relevant decision maker of subdivision and development applications within a structure plan area must have due regard to but is not bound by a structure plan. A structure plan therefore does not have the full force and effect of the scheme. Once adopted, a structure plan which identifies zoning and land use permissibility, would need to be normalised within a scheme by way of a scheme amendment, if the zoning and land use permissibility is to have statutory weight.

It is noted that this section of the deemed provisions is currently the subject of a proposed amendment to the Regulations, whereby it is proposed to delete reference to 'Activity Centre Plans' in favour of 'Structure Plans' and 'Precinct Structure Plans'.

Local Development Plans

Part 6 of the Regulations provides for the preparation of local development plans (LDP), which states:

'A local development plan in respect of an area of land in the Scheme area may be prepared if –

(a) The Commission has identified the preparation of a local development plan as a condition of approval of a plan of subdivision of the area; or

(b) A structure plan requires a local development plan to be prepared for the area; or

(c) An activity centre plan requires a local development plan to be prepared for the area; or

(d) The Commission and the local government considers that a local development plan is required for the purposes of orderly and proper planning.'

It is considered that the LDP as a statutory instrument will have limited application within the Shire for responding to coastal hazards and processes and that there are more appropriate mechanisms (i.e. Scheme provisions and/or local planning policy) to address such matters.

Special Control Areas

Special Control Areas (SCA) may be established as set out within Part 5 of the model scheme provisions (Schedule 1 of the Regulations). SCAs are typically put in place to establish special provisions to target a single issue or related set of issues often overlapping zone and reserve boundaries. The provisions of an SCA would establish the purposes and objectives of the SCA, specific development requirements and, if applicable, referral requirements to relevant agencies. A SCA could therefore be established within a scheme to comprehensively address the specific development issues associated with land prone to coastal hazard and risk issues.

A SCA would be delineated on the scheme maps by way of line work, which could follow the extent of mapped areas known to be prone to storm surge and or coastal physical processes (erosion, sea level rise allowance).

General Development Provisions

Part 4 (Clause 32) of the model scheme has provisions for the establishment of additional site and development requirements in addition to those set out in the R-Codes, activity centre/structure plans, local development plans or State and local planning policies. General development provisions could technically set out general development requirements relating to areas subject to coastal flooding and / or coastal processes. However, it is considered that given the specific nature of coastal issues, including the varied locational extent to which it may affect land within a district, specific development requirements would more appropriately be established within a Special Control Area as opposed to general provisions within the scheme.

Supplemental Provisions

The Regulations provide for local planning schemes to establish provisions that supplement the provisions set out in Schedule 1 and 2 of the Regulations, or provisions that vary a provision established in Schedule 1. Such supplemental provisions are typically contained within a Schedule within the scheme. This section could be used to introduce additional provisions and requirements in relation to coastal planning matters.

Exemptions from planning approval

Regulation 61 of the deemed provisions specifies works and land uses that are exempt from the requirement to obtain development approval.

This is an important consideration of the CHRMAP process, as the specified exemptions may provide for certain situations where certain development may be established within an area affected by storm surge or coastal processes without the requirement to obtain planning approval. However, there are ways of addressing this issue. For instance, a local planning policy or local development plan could vary the deemed-to-comply requirements of the R-Codes to put in place additional design requirements that may trigger the requirement for planning approval. Secondly, a Special Control Area could be established over land affected by coastal processes or storm surge, which

would trigger the requirement for the prior planning approval to be obtained from the responsible authority, including the requirement for the prior planning approval to be obtained for exempted development.

2.3 State Planning Framework

2.3.1 Perth and Peel @ 3.5 Million and Sub-regional Planning Framework

Perth and Peel @ 3.5 Million was released by the State government 2018 and provides the overarching framework to deliver four sub-regional strategies to guide future growth and development across the Perth and Peel metropolitan area through to the year 2050.

The Shire of Murray is located within the South Metropolitan Peel sub-regional area. The document plans for the provision of an additional 302,180 dwellings within this sub-region by 2050.

It is noted that the South Metropolitan Peel Sub-regional Planning Framework identifies a Planning Investigation Area around the Ravenswood settlement in proximity to the Murray River. Planning Investigation Areas are areas that may be suitable for rezoning and development subject to further detailed investigations. The Ravenswood Planning Investigation Area is subject to a number of investigations, including the need to understand inundation and flood management implications.

2.3.2 Peel Region Scheme

The Peel Region Scheme (PRS) is the principal region scheme which applies to the study area and zones and reserves land. The PRS reserves a majority of the coastal and river foreshores within the study area as 'Parks and Recreation' however there are some areas, such as the existing canal developments, which are zoned 'Urban'.

2.3.3 State Planning 2.1: Peel-Harvey Coastal Plain Catchment

State Planning Policy 2.1: Peel-Harvey Coastal Plain Catchment (SPP 2.1) establishes land use and development requirements for land contained within the Peel-Harvey coastal plain catchment area. A primary objectives of SPP 2.1 is to prevent land uses that are likely to result in excessive nutrient export into the Peel-Harvey system. This policy does not have any direct implications for this CHRMAP.

2.3.4 State Planning Policy 2.6: State Coastal Planning

State Planning Policy 2.6: State Coastal Planning Policy (SPP 2.6) and associated guidelines have been prepared to guide decision making policy in relation to planning along the state's coastline.

SPP2.6 provides policy on the determination of an appropriate foreshore reserve, which acts as a coastal buffer to accommodate coastal processes as a result of coastal erosion and risk or storm surge inundation in future planning periods.

SPP2.6 seeks to ensure coastal hazard risk management and adaptation planning is established to guide the location and form of development along the coast. The policy establishes a hierarchy for undertaking coastal hazard and risk adaptation planning. The adaptation measures of Avoid, Planned or Managed Retreat, Accommodate and Protect are to operate on a sequential and preferential basis starting with avoid as part of the coastal hazard risk management adaptation planning process.

This CHRMAP has been prepared to respond to the requirements of SPP 2.6.

2.3.5 State Coastal Planning Policy No. 2.6: State Coastal Planning Policy Guidelines

The State Coastal Planning Policy guidelines were introduced to provide guidance on the application of SPP 2.6. These guidelines identify a range of ongoing risk management and adaptation planning measures that may be considered in the assessment of development proposals located within an area known to be subject to storm surge risk or coastal erosion hazard. The guidelines establish a process for undertaking CHRMAP, as follows:

1. Establish a context;

2. Undertake a risk vulnerability assessment;
3. Determine the likelihood of the hazard occurring;
4. Determine the consequences;
5. Evaluate the risks;
6. Set in place adaptation management measures; and
7. Undertake monitoring and review.

This CHRMAP has generally been prepared in accordance with the above defined process.

Adaptation planning may be implemented through a range of mechanisms including decision-making on zoning, structure plans, subdivision and development applications.

2.3.6 Planned or Managed Retreat Guidelines

The Planned or Management Retreat Guidelines form an attachment the CHRMAP Guidelines and provide guidance on how to implement a policy of planned or managed retreat, and is applicable to 'Brownfield' and 'Infill' development, as it is these locations that are currently, and increasingly, vulnerable to coastal hazards with limited opportunities to introduce less vulnerable forms of use or development through planning control. The policy is based on principles of social, environmental and economic sustainability and adheres to objectives set out in State Planning Policy No. 2.6: State Coastal Planning Policy (discussed above). The approach ensures ongoing protection and provision of a coastal foreshore reserve and beach amenity and continuing undiminished public access to beaches. The policy directly references the completion of a comprehensive CHRMAP process, in order to outline necessary guidelines.

Key principles identified are as follows:

- To ensure land in the coastal zone is continuously provided for coastal foreshore management public access, recreation and conservation;
- To ensure public safety and reduce risk associated with coastal erosion and inundation;
- To avoid inappropriate land use and development of land at risk from coastal erosion and inundation; and
- To ensure land use and development does not accelerate coastal erosion or inundation risks; or have a detrimental impact on the functions of public reserves.

The guidelines outline the approach for implementing the Planned or Managed Retreat Policy, outlining planning mechanisms and their associated levels. Structure planning, local planning scheme amendment and taking of land is the first, second and third (respectively) planning mechanism for the policy.

<u>Structure Planning:</u>

Structure planning is identified as the first mechanism, requiring the consideration of risks identified in the CHRMAP process to feed into subdivision conditions of coastal areas where some degree of comprehensive redevelopment of land remains an option.

<u>Local Planning Scheme Amendment:</u>

A local planning scheme amendment is the second mechanism and is required to give statutory weight to the proposed Planned or Management Retreat Policy.

A scheme amendment is to be informed by SPP2.6 and such an amendment should classify areas vulnerable to coastal processes within a Special Control Area (SCA). An SCA may establish specific land use and development controls which may include preventing certain land use and development in areas at risk of coastal processes, incorporating adaptation development requirements (i.e. building above the known storm surge level) or requiring development to retreat from the risk at specific trigger points.

Taking of Land:

Taking of land is the third planning mechanism and occurs when it is assumed that land has not been transferred or committed to the public realm through structure planning processes, and that coastal processes have advanced to the point where there is no further economic or social utility in land due to coastal changes.

Where land is reserved under the relevant planning scheme, options to move this land from private to the public realm include:

- Purchase of the land by the responsible authority if the owner is willing to sell it by ordinary sale pursuant to s 190 of the PD Act; or
- Compulsory taking by the responsible authority without agreement pursuant to s 191 of the PD Act.

If land cannot be acquired under the above options (land not reserved under local planning scheme), in order to move this land from the private to public realm, it can be argued that the land is acquired for a 'public work' (that is, for the protection of foreshores). Options available for acquiring land for a 'public work' include:

- Taking by agreement under the *Land Administrative Act 1997* (LA Act); or
- Compulsory acquisition by the Minister for Lands for the purpose of a 'public work' under the LA Act.

It is the preferred approach that the land be purchased by the responsible authority by agreement under the relevant acts above.

2.3.7 State Planning Policy 3.4: Natural Hazards and Disasters

State Planning Policy 3.4: Natural Hazards and Disasters (SPP 3.4) was prepared to ensure that land use planning appropriately considers the risk of natural hazards and disasters. It addresses storm surge as well as a range of other hazards, including overland flooding. With respect to overland flooding events, SPP 3.4 requires that the 100-year average recurrence interval overland flood event by used as the defined flood event in relation to the assessment of proposals.

While SPP 3.4 identifies a 100-year ARI (average recurrence interval) event for storm surge, the policy also references SPP 2.6, which requires regard to be given to a 500 year ARI storm surge event.

With respect to storm surge, SPP 3.4 further states with respect to cyclonic activity and storm surge:

- Where storm surge studies have been undertaken and show inundation may occur, new permanent buildings should be constructed to take account of the effects of storm surge (including wind and wave set up).
- In areas where storm surge studies have not been undertaken, but evidence is available to demonstrate vulnerability to inundation, any development proposals should be supported by studies that demonstrate inundation will not occur.

2.3.8 Development Control Policy 1.8: Canal Estates and Artificial Waterway Development

Development Control Policy 1.8: Canal Estates and Artificial Waterway Development establishes development requirements for canal estates and other artificial waterway development. This policy requires decision making to have regard to State Planning Policy 2.6 as well as sea level rise and tidal and storm surge levels.

2.4 Local Planning Framework

2.4.1 Local Planning Scheme No. 4

The Shire's Local Planning Scheme No. 4 (LPS4) is the principal statutory planning document which applies land use and development controls within the Shire at a local level.

A specific objective of LPS4 is to 'preserve the special environment associated with the lakes and waterways within the Scheme Area'.

While a majority of the estuary and Murry River foreshore are reserved for Parks and Recreation under the PRS, there are also substantial private landholdings zoned for various purposes including land zoned 'Rural', 'Residential', 'Canal Development' and other purposes.

Also of particular note to this study are the following specific localities:

- Murray Delta Island Development: Zoned 'Canal Development', 'Residential' and located within the 'Floodprone Special Control Area'.
- Point Grey: Zoned 'Special Development' with a marina proposal previously lodged but refused by the Shire with the Shire's decision upheld by the State Administrative Tribunal.

Part XII of LPS4 establishes requirements for land located within river flood plains. Amongst these requirements are the following:

- A plan of subdivision shall not be approved for land within a flood fringe in the Residential or Canal Development zones unless that part of the land behind the minimum setbacks from street and rear boundaries is not less than 300mm above the flood level.
- A plan of subdivision shall not be approved for land within a flood fringe in the Special Rural zone unless part of the land in each lot has an area of not less than 2,000sqm at or above the flood level and is suitable for the erection of a dwelling in accordance with the provisions of this Scheme.
- Building levels within flood fringe land shall be a minimum of 150mm above the 1 in 100 year flood level for all existing subdivisions and for new subdivisions 500mm above the 1 in 100 year flood level.

2.4.2 Boating Facilities and Moorings Local Planning Policy

This Local Planning Policy establishes requirements for boating facilities within the Shire's artificial canal waterways. It establishes requirements in relation to visual amenity, setback requirements, clearance of navigation channels and interface with public areas and public access to canal waterways.

The policy does not establish requirements in relation to sea level rise or coastal processes and could perhaps benefit from a review following the completion of this CHRMAP.

2.4.3 General Development Requirements for Properties Abutting an Artificial Canal Waterway

This Local Planning Policy establishes objectives and requirements for various types of development that interface with the canal frontage area to ensure visual amenity along the canal waterways is maintained. Specifically, the policy relates to the construction of a dwelling, patio, verandah, shade sail structure, deck, retaining wall or outbuilding on property that abuts an artificial canal waterway.

The policy does not consider the implications of sea level rise or coastal processes.

2.4.4 Canal Walls – Yunderup Stage One Canals, Local Planning Policy

This Local Planning Policy has been prepared in response to the issue of overtopping of local tidal events over the original canal walls constructed in stage 1 of the Yunderup Canals estate. The policy

notes that the sea level is projected to rise 0.15m in the coming 25 to 30 years, thus further exacerbating the issue.

This policy requires that all proposed canal wall replacements and modifications require the planning approval of the Shire. The principal objective of the policy is to ensure that replacement canal walls are replaced to a height that is above the current local tidal range to reduce the frequency of overtopping caused by storm surge and sea level rise.

The policy requires that the canal wall replacement shall have a top of wall height of 0.7m AHD.

It is recommended that this policy be reviewed following the findings of this CHRMAP.

2.4.5 Lot 803 North Yunderup Road Structure Plan Map

The Lot 803 North Yunderup Road Structure Plan proposes residential (R20-R40) on vacant land adjacent to Regional Open Space associated with the Wilgie Creek foreshore just north of the intersection of North Yunderup Road and Deering Drive. Due to the proximity to Wilgie Creek, there is the potential that the land may be subject to coastal inundation processes.

2.4.6 Lots 1, 2 and 49 Banksia Terrace, South Yunderup Structure Plan

The Structure Plan relating to Lots 1, 2 and 49 Banksia Terrace provides for the further subdivision of the subject lots which are located adjacent to the artificial canal waterway. The land is currently vacant and the structure plan provides for a 3m setback to the foreshore reserve within the private lots.

2.4.7 Murray River Foreshore Masterplan

The Murray River Foreshore Masterplan seeks to create an attractive and sustainable foreshore precinct which is centred around the Murray River Square. The masterplan identifies a number of foreshore improvements including an upgraded path network, landscaping and informal amphitheatre, a formal town square and event space and upgrades to the existing Exchange Hotel.

2.5 Summary of Existing Controls

2.5.1 Summary of options

The statutory planning mechanisms that may be available to address coastal hazards within the Shire of Murray are considered in the following table which outlines the advantages and disadvantages of each option.

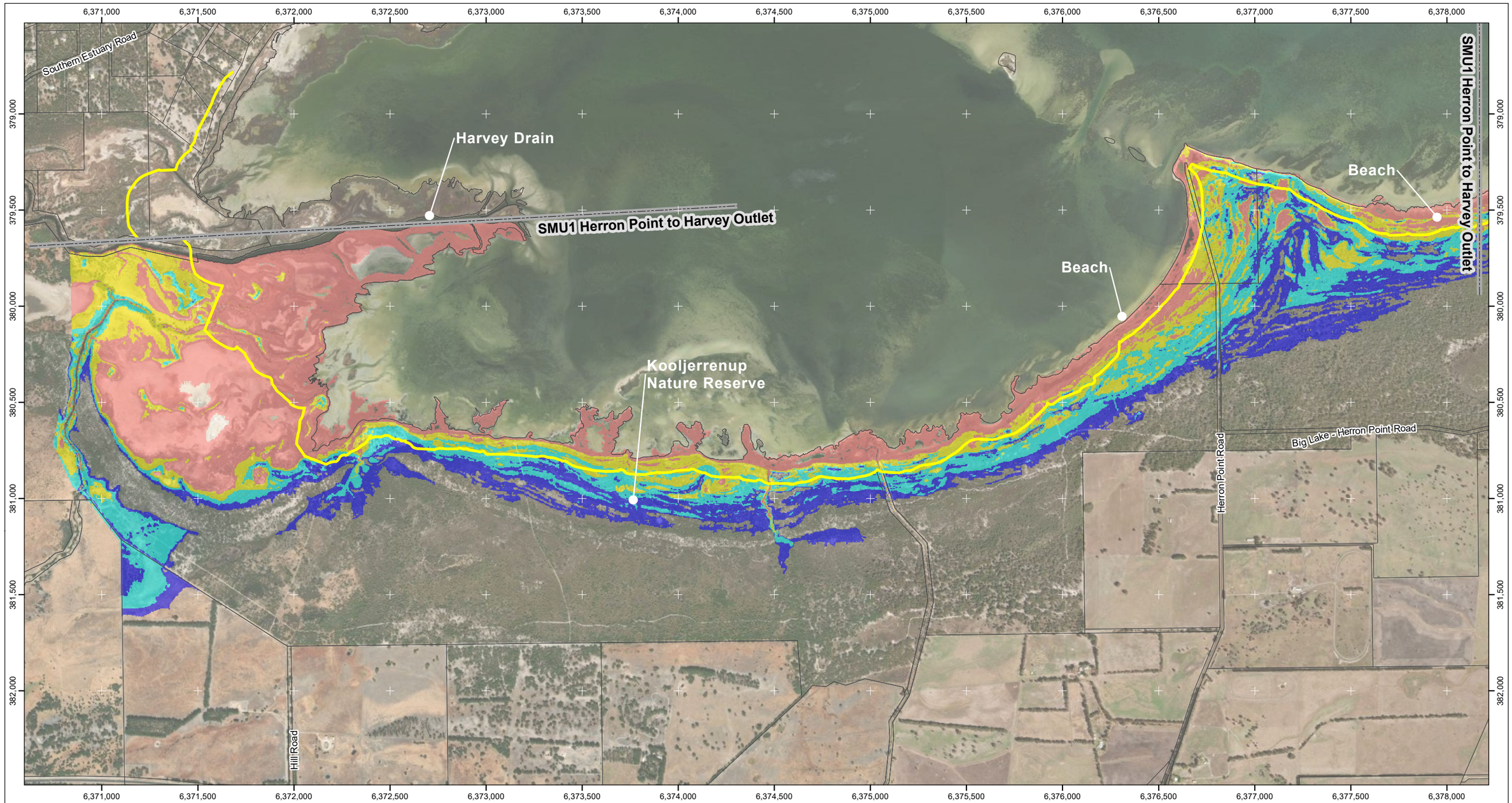
Statutory Measure	Advantages	Disadvantages
Structure Plan / Activity Centre Plan	Can address location specific issues i.e. identification of coastal physical setbacks and areas affected by storm surge.	Does not have the force and effect of the Scheme. Decision makers to have due regard only. Structure Plan cannot specify / enforce built form requirements. Location specific only and therefore cannot address coastal hazard issues on a broad scale. Generally, requires the land to be appropriately zoned to require the preparation of a structure plan.
Local Development Plan	Can specify built form requirements to address location specific coastal hazard issues i.e. increased setbacks, minimum habitable floor levels etc. Has statutory weight of the local planning scheme. Can vary 'deemed-to-comply' development requirements.	Location specific only and therefore cannot address coastal hazard issues on a broad scale.
Local Planning Policy	Can address coastal hazard and risk issues at a district (broad) level and/or at a location specific level. Can include mapping of coastal hazard issues with flexibility to update mapping as and when amendments are required to be undertaken.	Is only a 'due regard' document and does not have the full force and effect as provisions contained in a local planning scheme

	Can vary 'deemed-to-comply' development requirements. Can be amended relatively quickly (compared to local planning scheme amendment as new coastal studies are completed.	
Special Control Area	SCAs may establish specific provisions to address a specific issue such as storm surge and or coastal processes. SCAs can broadly address unique issues that extend across multiple zones and/ or reserves. SCAs can be used to require development approval for otherwise normally 'exempted' development. In this regard, SCAs are the preferred mechanism to identify where and what type of development requires development approval to allow for appropriate consideration of the risk of coastal processes.	A scheme amendment would potentially need to be progressed every time mapping of the coastal issue is amended and/or updated. This may be avoided if the Special Control Area refers to a separate Local Planning Policy which may contain reference to mapping of coastal hazards.
General Development Provisions (Part 4; Clause 32 of the model scheme provisions)	Can establish provisions which broadly address coastal hazards. Can introduce provisions which relate to a local planning policy addressing coastal hazards and which may contain coastal hazard mapping.	Given the specific nature of coastal issues, including the varied locational extent to which it may affect land within a district, specific development requirements would more appropriately be established within a Special Control Area as opposed to general provisions within the scheme.
Supplemental Provisions to Schedule 1 and 2 of the Regulations	May be used to supplement the standard scheme provisions set out in Schedule 1 and 2 of the Regulations to address specific coastal process issues.	Given the specific nature of coastal issues, including the varied locational extent to which it may affect land within a district, specific development requirements would more appropriately be established within a Special Control Area as opposed to the supplemental provisions of a scheme.

Appendix F

Asset Mapping and Coastal Hazard Area

Baird.



Legend

Water Depth (m)

- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5
- 2120 Coastal Processes Line

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.

Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

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 1 - Herron Point to Harvey Outlet

Shire of Murray
Coastal Hazard Flood Mapping

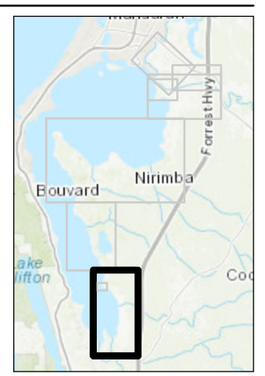
500yr ARI Design Storm in Planning year 2120

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: 10 Nov. 2021



379,000
379,500
6,377,000
6,376,500

Beach
Camp Area
Shelter
Beach Access
Toilet Block
Camp Ground Road
Wetland
Herron Point
Boat Ramp
Car Park
Wetland
Herron Point Rd
Beach
Herron Point Road

Legend

Water Depth (m)
- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5
- 2120 Coastal Processes Line

N W E S

0 200 metres

Source Data
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SMU 1 – Herron Point

Shire of Murray
Coastal Hazard Flood Mapping

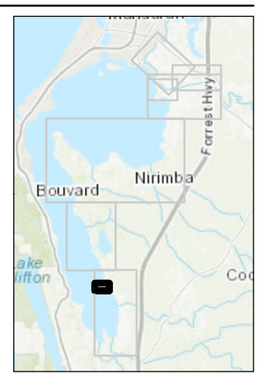
500yr ARI Design Storm in Planning year 2120

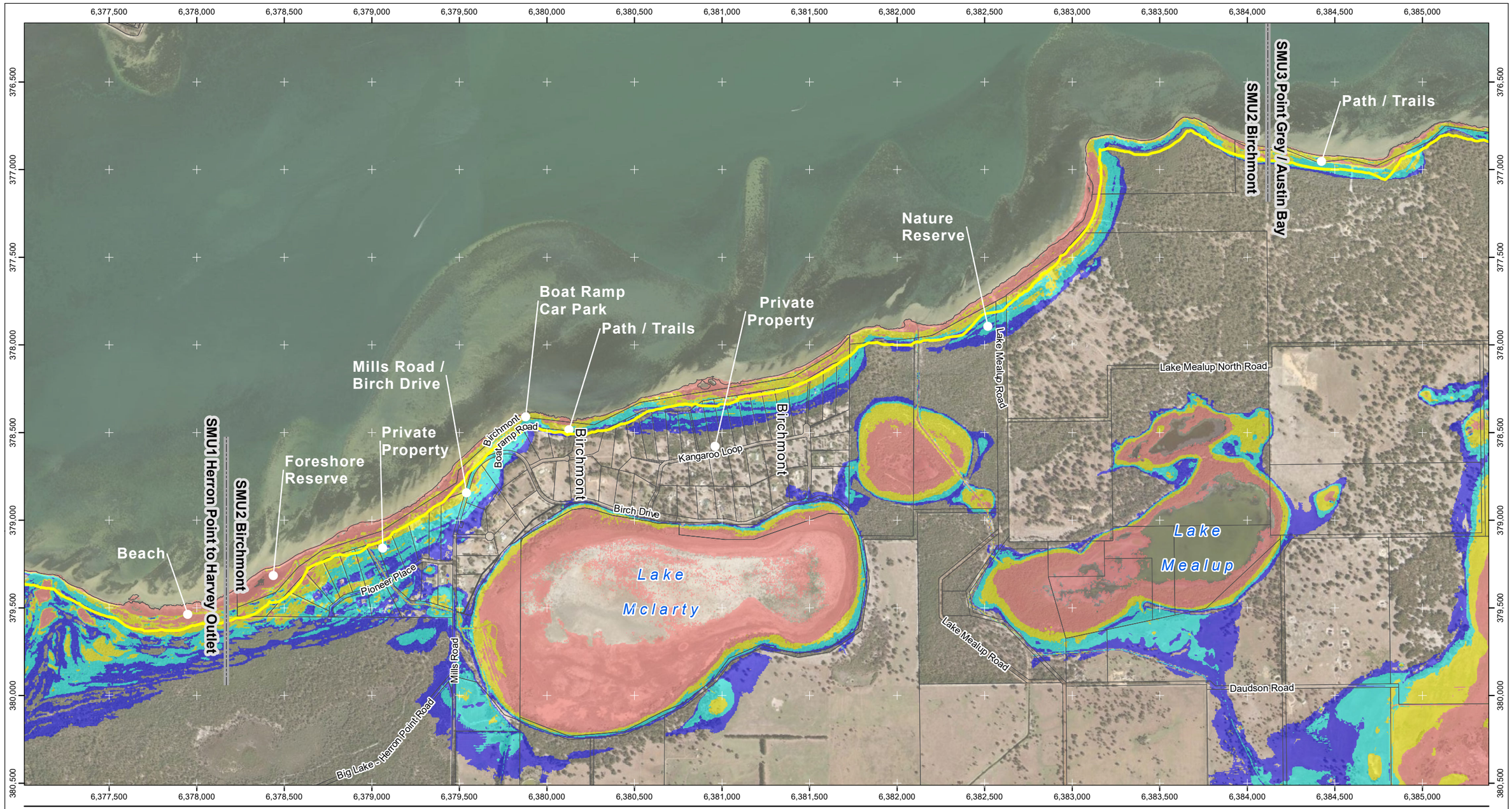
Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

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Legend

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- 0 - 0.5
- 2120 Coastal Processes Line

0 200 metres

Source Data
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SMU 2 – Birchmont

Shire of Murray
Coastal Hazard Flood Mapping

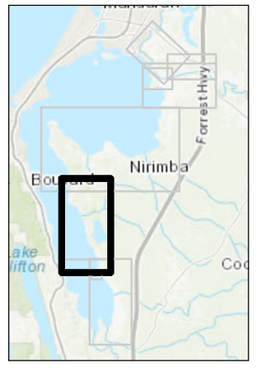
500yr ARI Design Storm in Planning year 2120

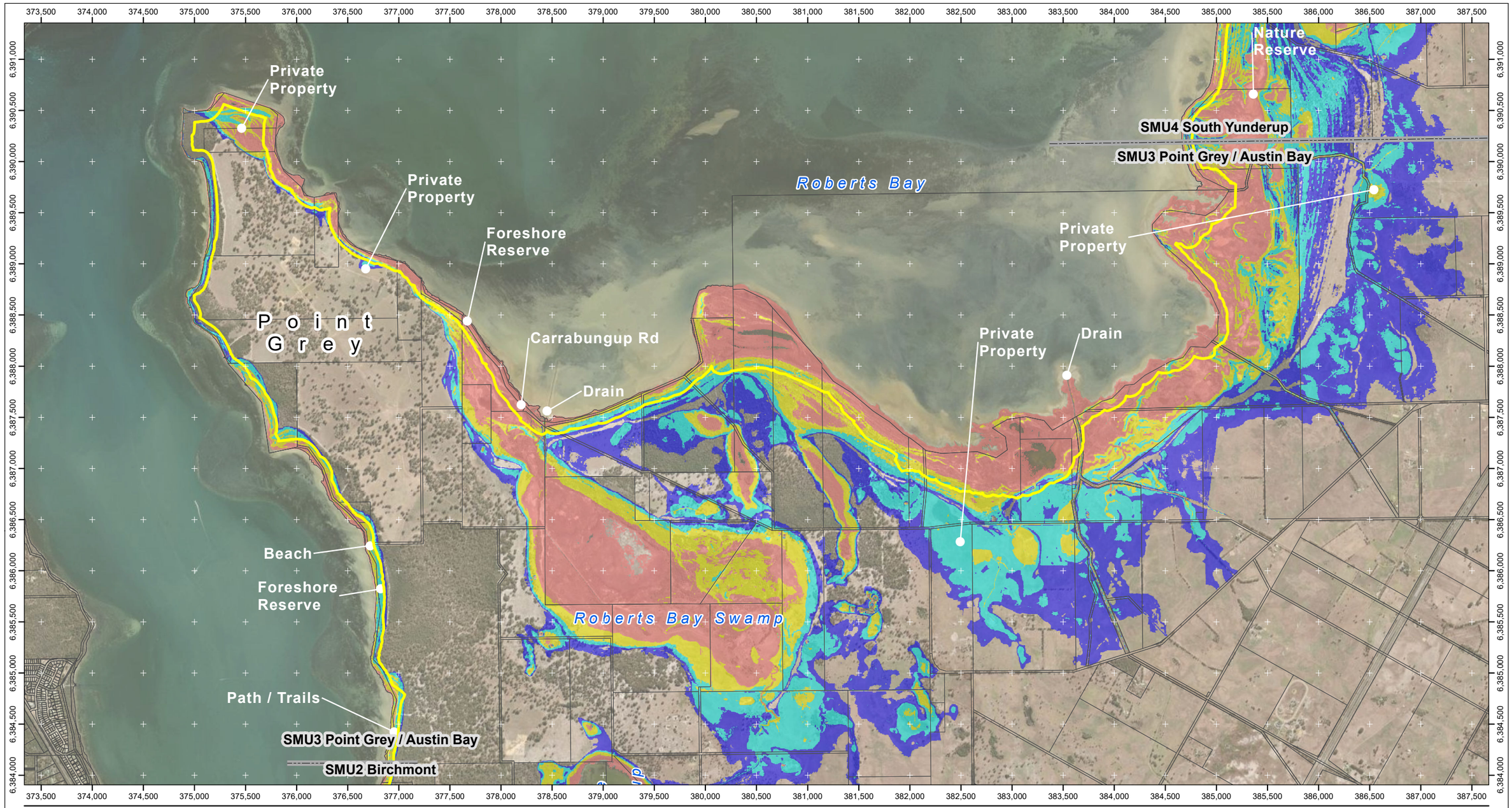
Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

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Legend

Water Depth (m)

- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5

2120 Coastal Processes Line

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.

Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

Disclaimer

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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

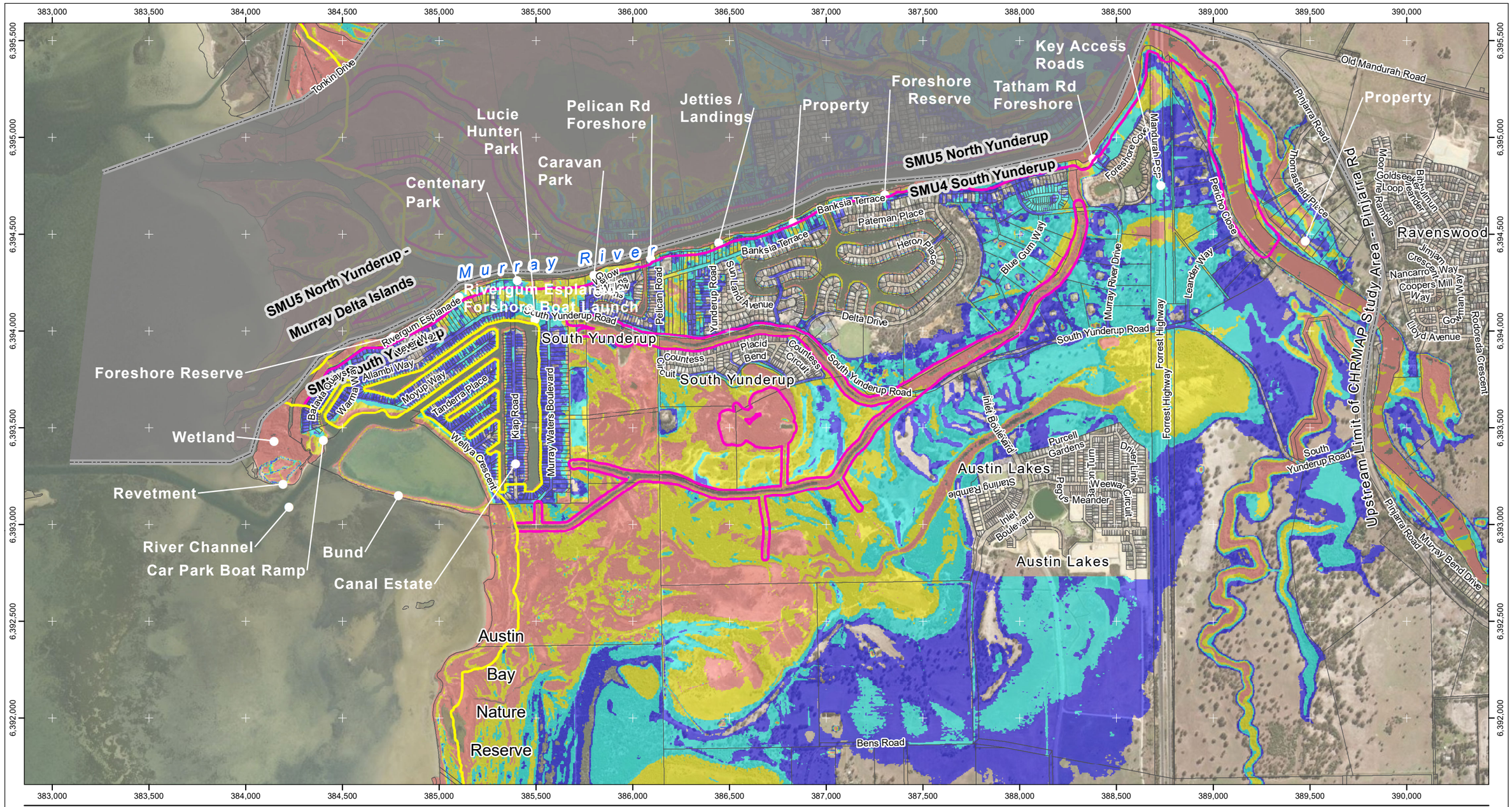
Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 10 Nov. 2021





Legend

Water Depth (m)

- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5

2120 Coastal Processes Line

2120 Erosion River Banks

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 4 – South Yunderup

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm in Planning year 2120

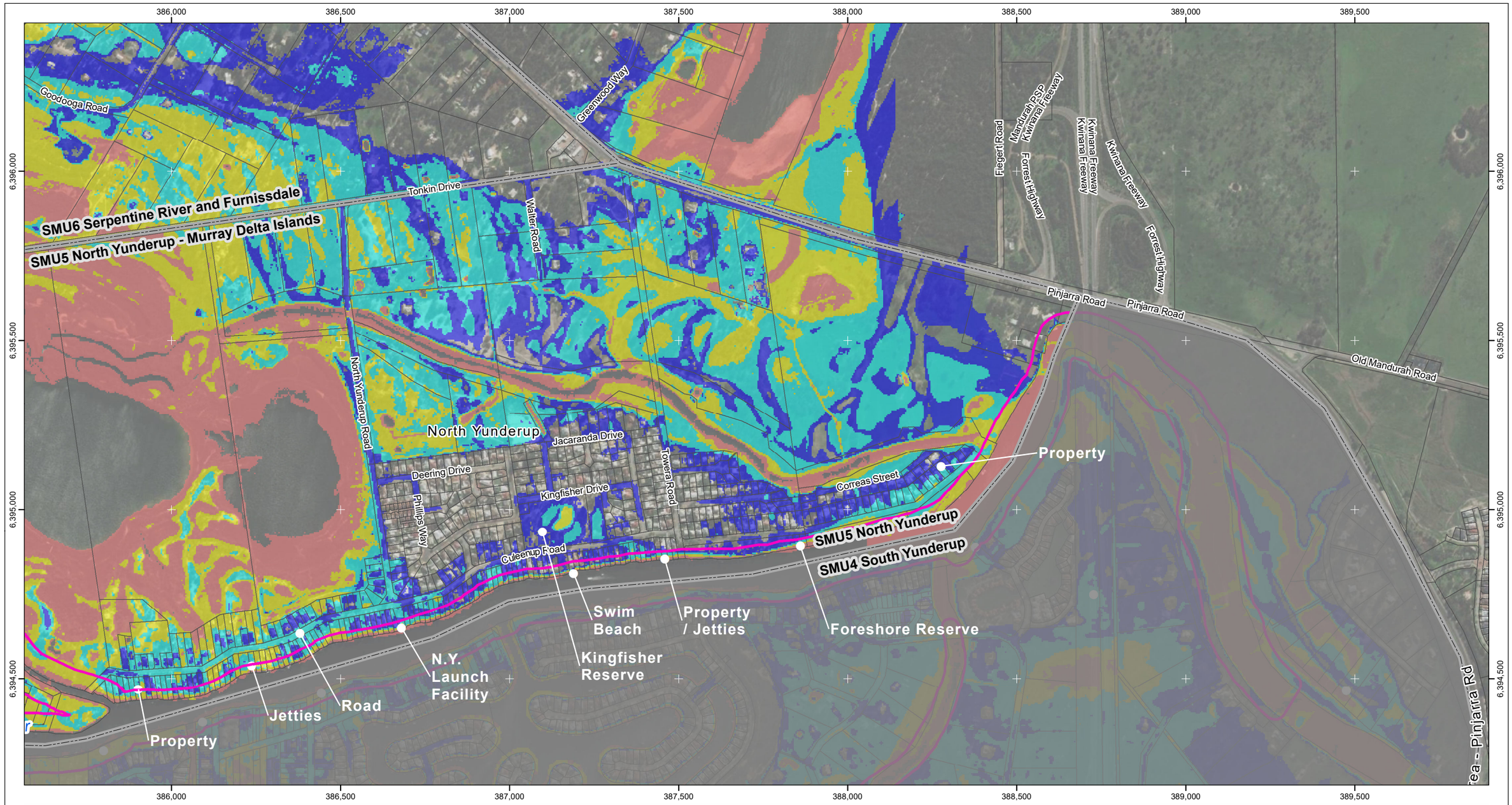
Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 10 Nov. 2021





Legend

Water Depth (m)

- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5

2120 Coastal Processes Line

2120 Erosion River Banks

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

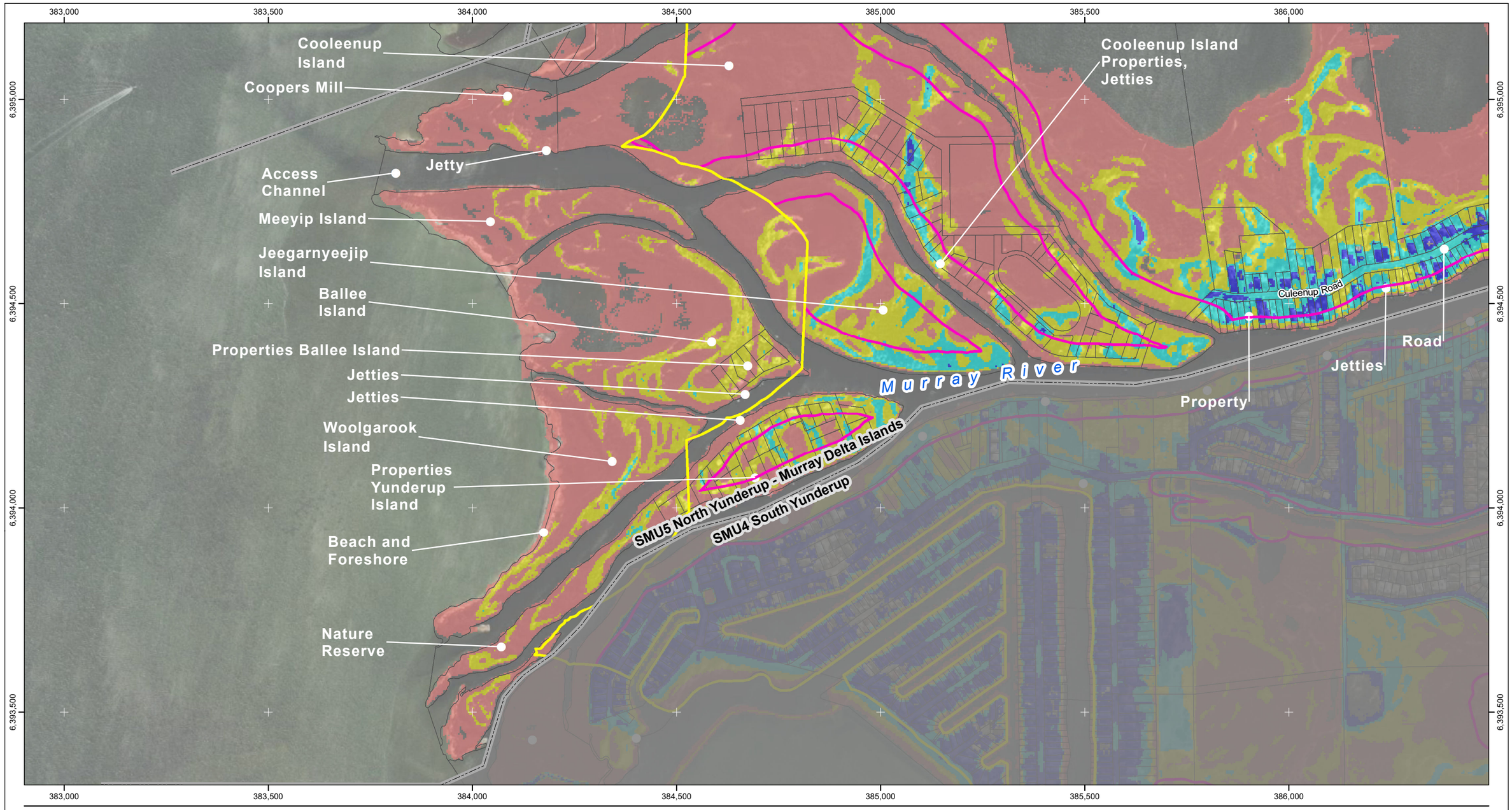
Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 10 Nov. 2021





Legend

Water Depth (m)

- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5

- 2120 Coastal Processes Line
- 2120 Erosion River Banks

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 – Murray Delta Islands

Shire of Murray
Coastal Hazard Flood Mapping

500yr ARI Design Storm in Planning year 2120

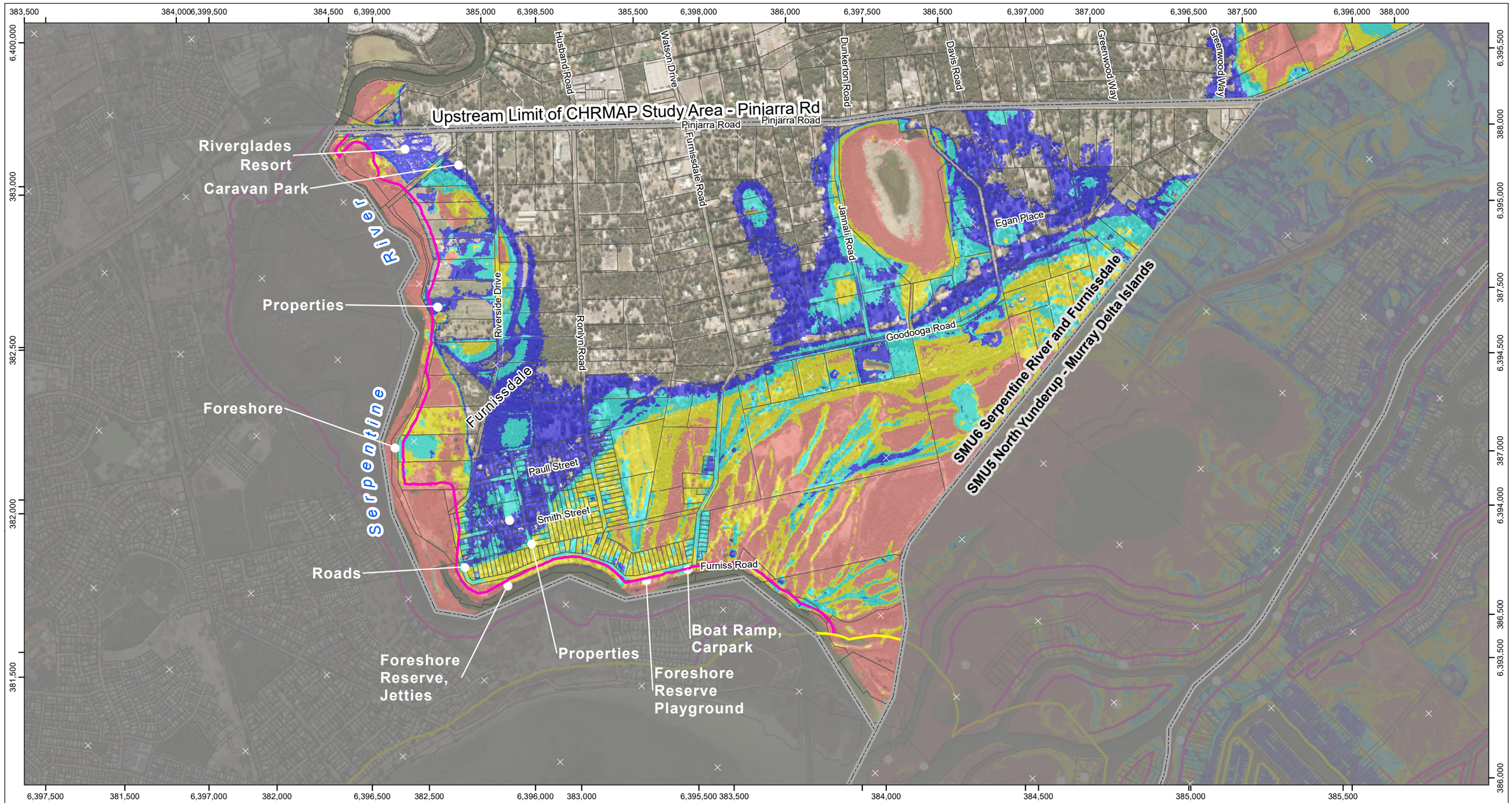
Inundation Depth Based on Peak Water level of 2.34m AHD (includes 0.9m Sea Level Rise)

Shire of Murray
1915 Pinjarra Rd
Pinjarra WA 6208
https://www.murray.wa.gov.au/

Mapping prepared by Baird.

Map Published: 11 Nov. 2021





Legend

Water Depth (m)

- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5
- 2120 Coastal Processes Line
- 2120 Erosion River Banks

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.
Cadastral data supplied by Landgate. This product is for information purposes only and is not guaranteed. The information may be out of date and should not be relied upon without further verification from the original documents. Where the information is being used for legal purposes then the original documents must be searched for all legal requirements.

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 6 – Serpentine River and Furnissdale

Shire of Murray
Coastal Hazard Flood Mapping

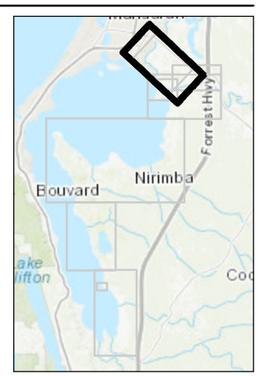
500yr ARI Design Storm in Planning year 2120

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: 11 Nov. 2021



Appendix G

Adaptations Option Workshop Summary

Baird.

G.1 Summary Slides Presented in the Workshop

Shire of Murray CHRMAP

- Examines the processes of erosion and inundation within the study area to understand coastal hazard risk affecting the shoreline areas today and the forecast impacts over the next 100 years (to 2120) associated with projected climate change and sea level rise.
- Developed in consultation with SoM, the local community, and a range of stakeholders in accordance with local and national guidelines. Delivered through a multi-discipline approach incorporating science, engineering, community engagement, land use planning and economic expertise.
- Aims to improve the understanding of coastal hazard risk for the community and stakeholders and to develop coastal adaptation approaches and pathways which can mitigate risk over the short to medium term (next 10-20 years) and provide management and adaptation strategies to mitigate hazard in future planning periods (next 100 years).

Rhelm

Workshop Overview

- A number of options identified to deal with several key issues
  - Erosion / Inundation of Nature Reserves
  - Inundation of Island Properties
  - Erosion of Islands/ River Banks
  - Septic Tanks
- Seeking input from key stakeholders
- The outcomes of this workshop will then provide input to further evaluation and assessment by the team for the preparation of the CHRMAP

Rhelm

Agenda

- Introductions
- Overview of MCA process
- Erosion – Nature Reserves
- Inundation – Island Properties
- Erosion – Islands and Riverbanks
- Septic Tanks
- Workshop Wrap-up

Multi-Criteria Assessment (MCA)

- An MCA is a tool to compare various alternatives or options
  - Provides a structured way to compare and contrast options
  - Uses a number of criteria, and scoring of those criteria, to compare options
  - Criteria are assigned a “score” based on the expected performance against those criteria
- Three key categories adopted for Shire of Murray
  - Technical
  - Social
  - Environmental
- These are then compared against the cost score for the option

Rhelm

MCA Categories and Criteria

- **Technical**
  - Feasibility – the feasibility of designing and implementing the option
  - Effectiveness – how effective the option is at achieving the outcome
  - Climate Change Adaptation – how adaptable the option is to meet the likely changes due to climate change
  - Construction and Maintenance – ease of construction and associated maintenance
- **Social**
  - Community – impacts on the community
  - Public Amenity – impacts on the recreational use of areas, access to areas etc
- **Environmental**
  - Natural Environment – impacts on the natural environment
  - Visual Amenity – visual impacts associated with the option

Rheim

MCA Scoring

Score	Technical	Social and Environmental
-2	Very Poor Performance	High negative impact
-1	Poor Performance	Medium Negative Impact
0		Low to no impact
1	Good Performance	Medium positive impact
2	Very Good Performance	High positive impact

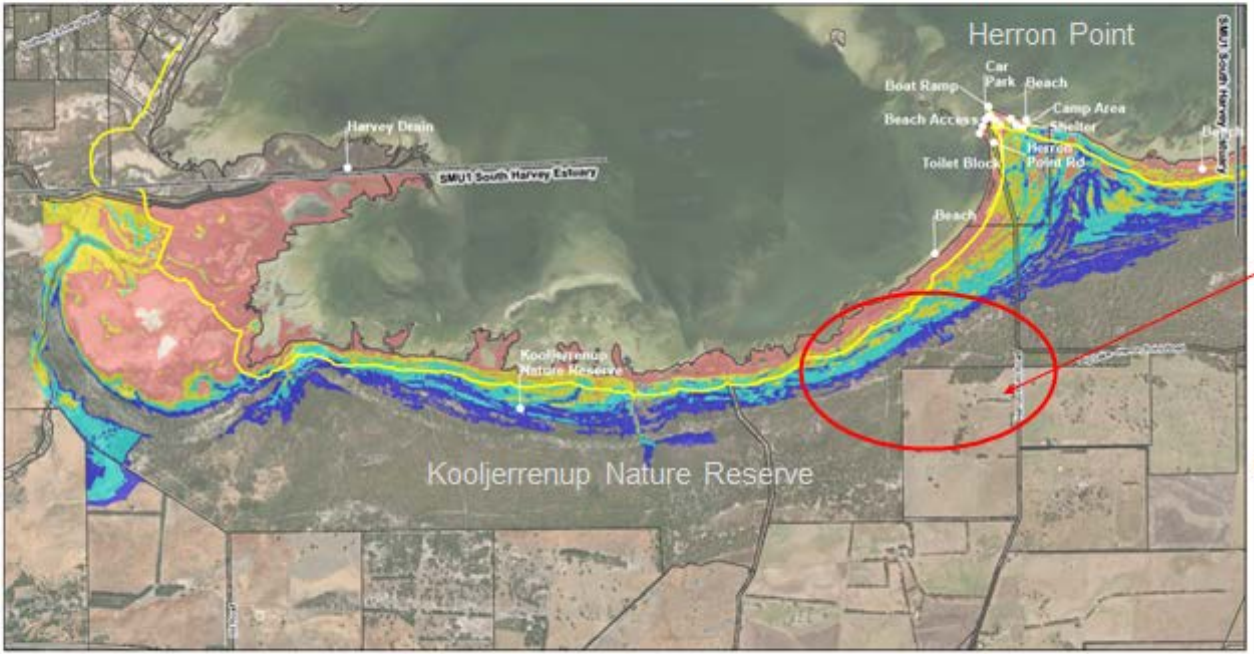
Score	Cost
1	Most Expensive
2	
3	
4	
5	Least Expensive

costs to include private costs as well

Structure of Discussion

- Overview of the issue
- Options identified to mitigate the issue
- Scoring of the options
  - Discussion amongst the group

Erosion / Inundation Nature Reserve





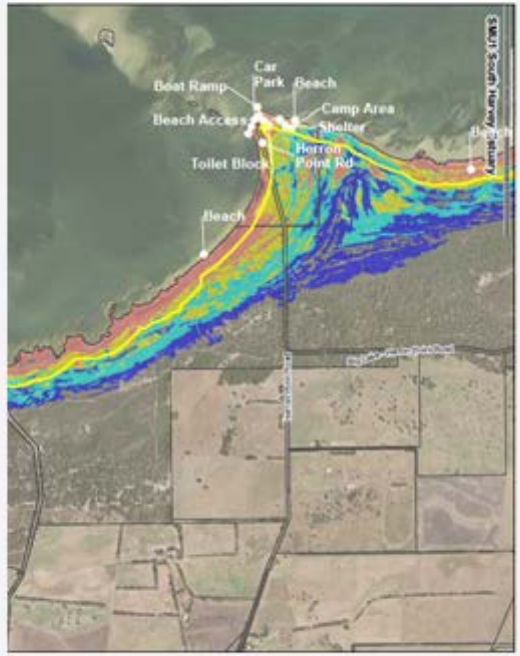
- Loss of width
- Potential for retreat into the landside area in future ?

Inundation – 2120, ARI500yr

Water Depth (m)
- 1.6 - 2
- 1.1 - 1.5
- 0.6 - 1
- 0 - 0.5
- 2120 Coastal Processes Line

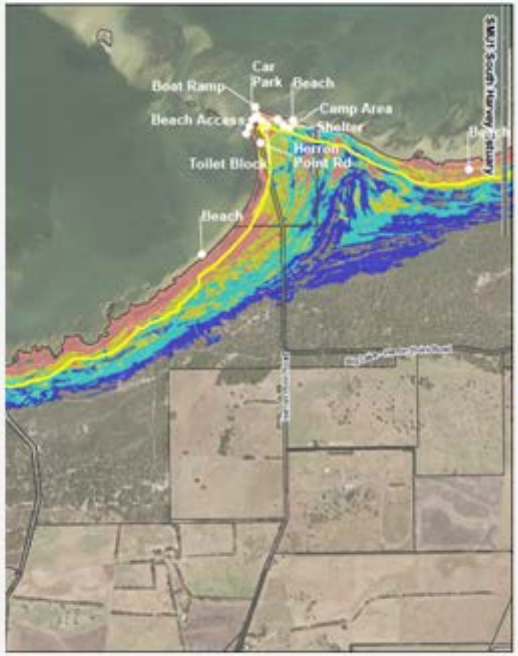
Erosion / Inundation Nature Reserve

- Overview of the issue
  - Erosion potential. Future coastal processes allowance of 150m - 200m inland
  - With sea level rise and extreme events the inundation area extends ~500m inland
  - Loss of Habitat for water birds / shore birds
  - Modification of coastal saltmarsh area
- Options identified to mitigate the issue
  1. Do nothing (annual monitoring)
  2. Managed Retreat
  3. Protect

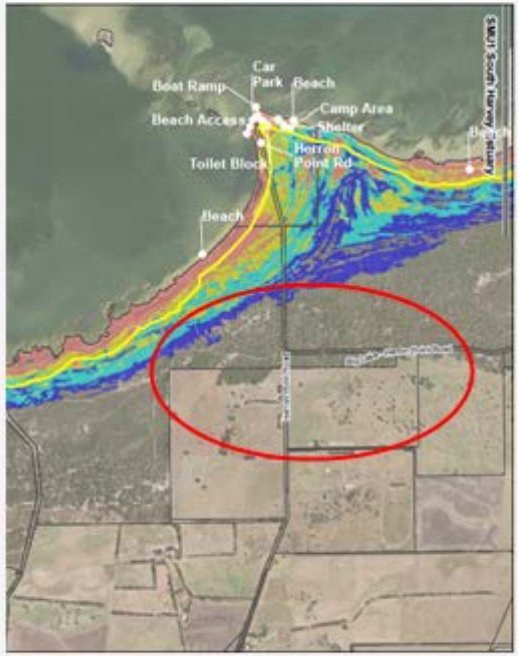


Erosion / Inundation Nature Reserve

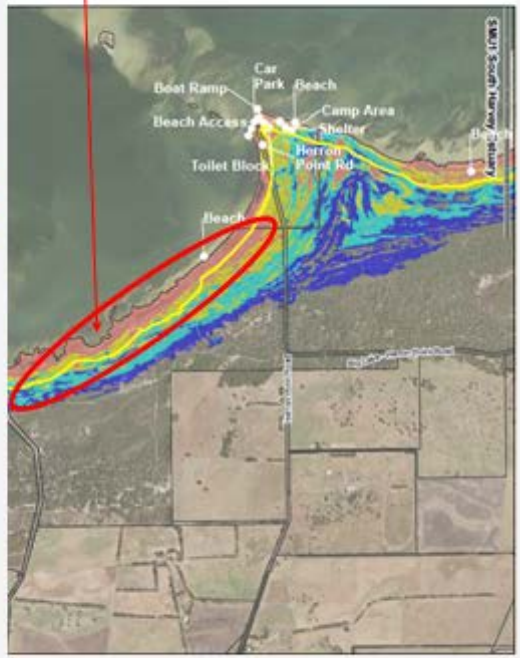
Nature Based Solutions
to protect shoreline areas



Do Nothing / Monitor



Managed Retreat



Protect

Rhelm

MCA Scoring

	Technical				
Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction & Maintenance	**Technical Score**
1. Managed Retreat - do nothing	2	-2	2	2	**4**
2. Managed Retreat - purchase Farm Areas Landward for future expansion	0	1	1	-1	**1**
3. Protection - nature based approaches	-1	2	1	-1	1

challenges in acquisition of land

establishment of vegetation - challenges over the timeframes

nature based - oyster reefs/ submerged reefs etc

B. — 19 81

Rhelm

MCA Scoring

	Social		
Option	Community	Public Amenity	**Social Score**
1. Managed Retreat - do nothing	-2	-1	**-4**
2. Managed Retreat - purchase Farm	1	1	**4**
3. Protection - nature based approaches	2	1	**6**

issues with landowners

Rhelm

MCA Scoring

	Environment		
Option	Natural Environment	Visual Amenity	**Environmental Score**
1. Managed Retreat - do nothing	-2	-1	-6
2. Managed Retreat - purchase Farm Areas Landward for future expansion	1	1	**4**
3. Protection - nature based approaches	2	1	6

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MCA Scoring

Option	Cost Score
1. Managed Retreat - do nothing	5
2. Managed Retreat - purchase Farm Areas Landward for future expansion	2
3. Protection - nature based approaches	3

only buying enough to provide buffer

Rhelm

Option	Technical	Social	Environment	Total Performance Score	Cost Score
Weighting	50%	25%	25%		
1. Managed Retreat - do nothing	4	-6	-6	**-1**	**5**
2. Managed Retreat - purchase Farm Areas Landward for future expansion	1	4	4	**2.5**	**2**
3. Protection - nature based approaches	1	6	6	**3.5**	**3**

Option	Technical	Social	Environment	Total Performance Score	Cost Score
Weighting	33%	33%	33%		
1. Managed Retreat - do nothing	4	-6	-6	**-2.64**	**5**
2. Managed Retreat - purchase Farm Areas Landward for future expansion	1	4	4	**2.97**	**2**
3. Protection - nature based approaches	1	6	6	**4.29**	**3**

legal - built into feasibility and constructability

Inundation of Properties

- Overview of the issue
  - Under projected sea level rise there is increased risk of inundation for properties in low lying areas
  - Areas of Interest - Murray Delta Islands, North / South Yunderup, Furnissdale
  - 2000 properties are within the 2120 coastal inundation hazard extent under a projected sea level rise of 0.9m in 100 years



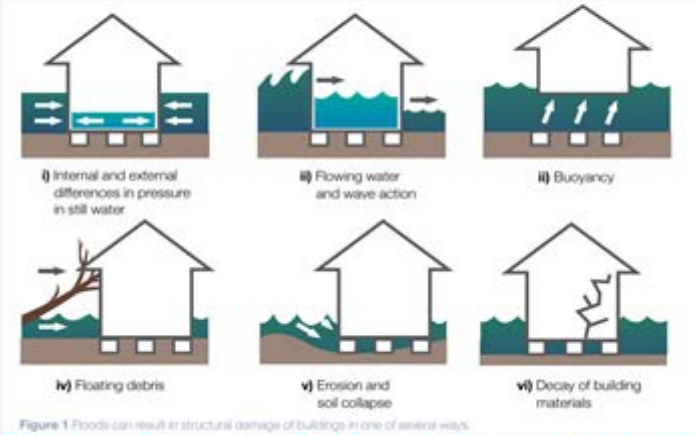


Figure 1 Floods can result in structural damage of buildings in one of several ways.

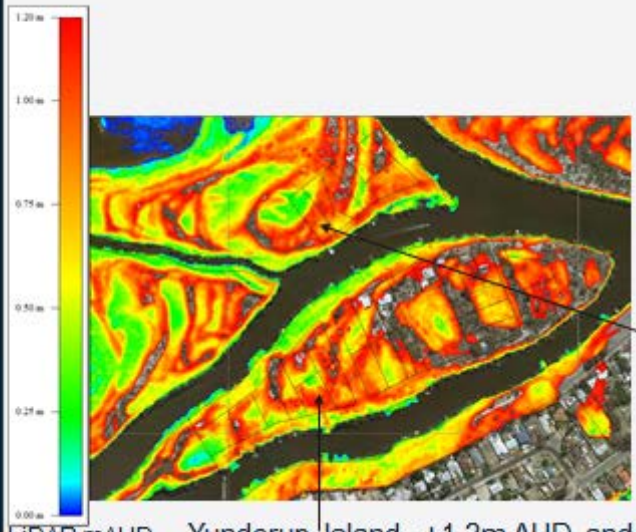
Structural Damage to Buildings in Floods - NCCARF

Inundation of Properties

Overview – Water Level

- General Tide Range +0.3m AHD (0.9mCD)
- Winter Storms +0.8m AHD (1.4mCD)
- Largest Measured +1.0mAHD (1.6mCD)





LiDAR mAHD

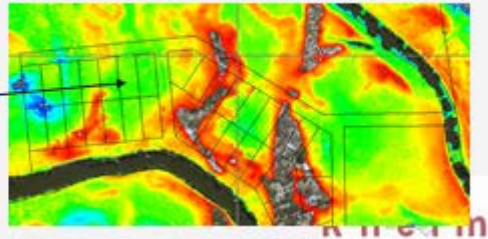
Yunderup Island +1.2m AHD and above

Land Elevation – Murray Delta Islands

Ballee Island +1.2m AHD

NW Cooleenup Island +0.3m AHD

Mid /Lower Cooleenup Is +1.2m AHD and above



Inundation Properties

- Options identified
  1. Housing Design - Raise Floor Level
  2. Housing Design - Use Fill to raise development pad
  3. Temporary Flood Barrier
  4. Permanent Flood Barrier
  5. Storm Surge Barrier at Dawesville Cut
  6. Voluntary Acquisition / Managed Retreat



Op1 Raise Floor Level



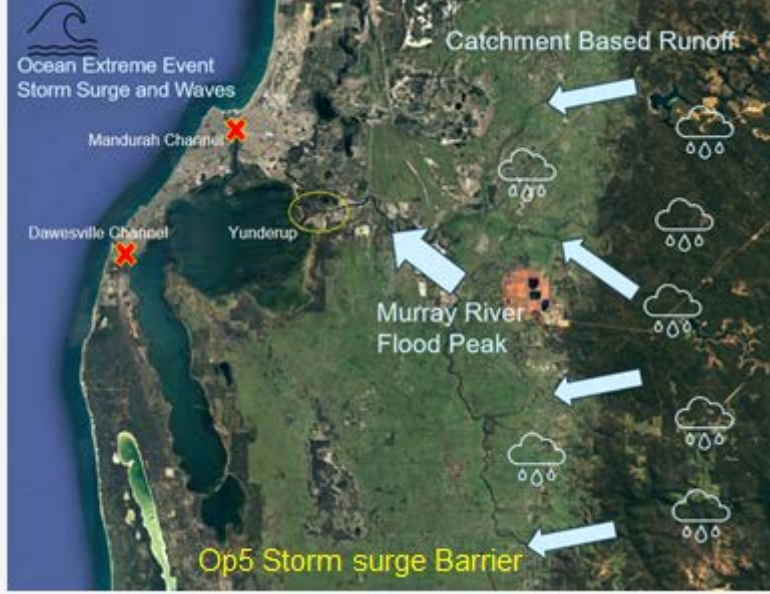
Rhelm

Inundation Properties





Op4 Levee





MCA Scoring

	Technical				
Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction & Maintenance	Technical Score
1. Planning Based Approaches for Housing Design - Raise Floor Levels and improve foundation design to withstand flood conditions (as redev.)	2	1	1	2	**6**
2. Planning Based Approached for Housing Design. Fill Properties to Design Level (as redev.)	1	1	-1	1	2
3. Temporary Flood Barriers at the edge of the 3 Islands that can be erected to protect from inundation ahead of the event	-2	-1	1	-2	-4
4. Permanent Flood Barriers at the edge of the 3 Islands that can be built and maintained at a level above the design flood	1	1	1	-1	**2**
5. Build Flood Barrier at the Dawesville Cut	-2	2	1	-2	**-1**
6. Managed Retreat. Islands returned to Nature	-1	2	2	-1	2

consider not having slab on ground

could be for a property only

property level protection?

flood barrage needs to consider the wider area (not just shire)

B. — 19 81

Rhelm

MCA Scoring

	Social		
Option	Community	Public Amenity	Social Score
1. Planning Based Approaches for Housing Design - Raise Floor Levels and improve foundation design to withstand flood conditions (as redev.)	2	0	**4**
2. Planning Based Approached for Housing Design . Fill Properties to Design Level (as redev.)	2	1	6
3. Temporary Flood Barriers at the edge of the 3 Islands that can be erected to protect from inundation ahead of the event	1	0	**2**
4. Permanent Flood Barriers at the edge of the 3 Islands that can be built and maintained at a level above the design flood	1	-1	**0**
5. Build Flood Barrier at the Dawesville Cut	2	0	**4**
6. Managed Retreat. Islands returned to Nature	-2	1	**-2**

with fill - opportunity to est. vegetation

can have natural features in the permanent barrier

barriers can be at property or island edge

B. — 19 81

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MCA Scoring

	Environment		
Option	Natural Environment	Visual Amenity	Environmental Score
1. Planning Based Approaches for Housing Design - Raise Floor Levels and improve foundation design to withstand flood conditions (as redev.)	0	0	0
2. Planning Based Approached for Housing Design . Fill Properties to Design Level (as redev.)	-1	-1	**-4**
3. Temporary Flood Barriers at the edge of the 3 Islands that can be erected to protect from inundation ahead of the event	0	0	**0**
4. Permanent Flood Barriers at the edge of the 3 Islands that can be built and maintained at a level above the design flood	-1	0	-2
5. Build Flood Barrier at the Dawesville Cut	0	-1	-2
6. Managed Retreat. Islands returned to Nature	2	1	**6**

barrage potential benefits for SLR for enviro

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MCA Scoring

Option	Cost Score
1. Planning Based Approaches for Housing Design - Raise Floor Levels and improve foundation design to withstand flood conditions (as redev.)	5
2. Planning Based Approached for Housing Design . Fill Properties to Design Level (as redev.)	5
3. Temporary Flood Barriers at the edge of the 3 Islands that can be erected to protect from inundation ahead of the event	3
4. Permanent Flood Barriers at the edge of the 3 Islands that can be built and maintained at a level above the design flood	2
5. Build Flood Barrier at the Dawesville Cut	1
6. Managed Retreat. Islands returned to Nature	2

private based costs

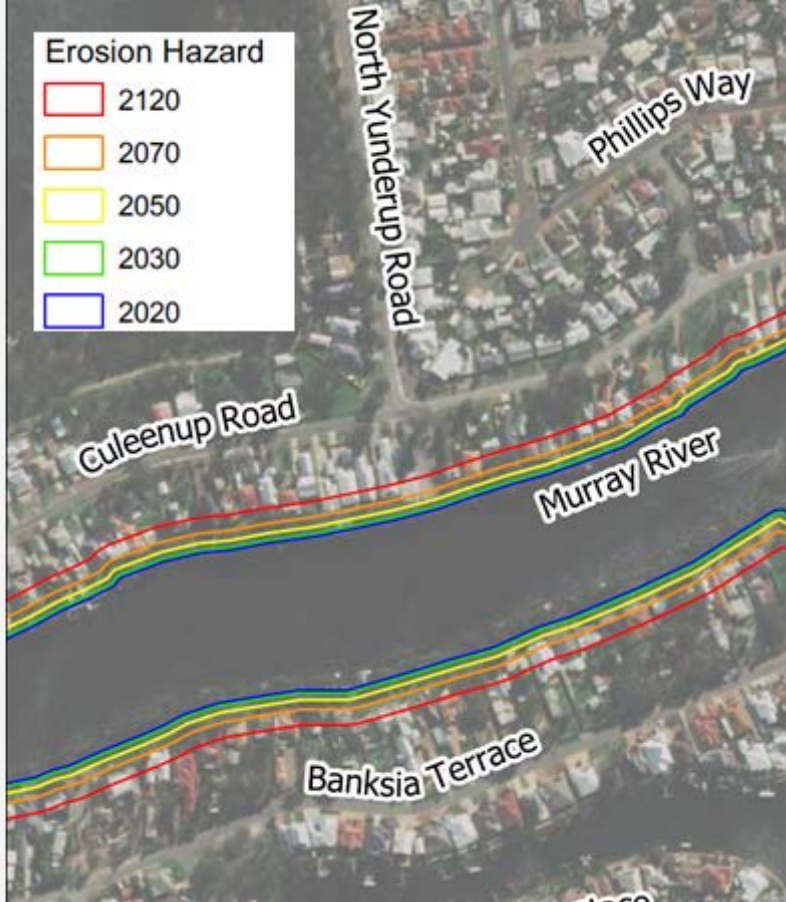
Rhelm

Option	Technical	Social	Environment	Total Performance	Cost Score
Weighting	33%	33%	33%		
1. Planning Based Approaches for Housing Design - Raise Floor Levels and improve foundation design to withstand flood conditions (as redev.)	6	4	0	**3.3**	**5**
2. Planning Based Approached for Housing Design . Fill Properties to Design Level (as redev.)	2	6	-4	**1.32**	**5**
3. Temporary Flood Barriers at the edge of the 3 Islands that can be erected to protect from inundation ahead of the event	-4	2	0	**-0.66**	**3**
4. Permanent Flood Barriers at the edge of the 3 Islands that can be built and maintained at a level above the design flood	2	0	-2	**0**	**2**
5. Build Flood Barrier at the Dawesville Cut	-1	4	-2	**0.33**	**1**
6. Managed Retreat. Islands returned to Nature	2	-2	6	**1.98**	**2**

Erosion of Riverbanks

- Overview of the issue
  - Erosion of Murray and Serpentine Shorelines
  - Threat to property and assets landward
  - Affects North / South Yunderup, Murray Delta Islands, Furnissdale
- Options identified to mitigate issue
  1. Do nothing (annual monitoring)
  2. Managed Retreat
  3. Protection – Hard engineered walls
  4. Protection through Nature Based Solutions
  5. Reduce Vessel Speed (*** Implement)

vessel type rather than just speed



MCA Scoring

	Technical				
Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction & Maintenance	**Technical Score**
Do Nothing	2	-2	2	2	**4**
Hard Engineering Solutions	1	2	-1	-1	**1**
Soft Edge Treatments	1	1	1	1	**4**
Managed Retreat	-1	2	2	-1	**4**

Rhelm

MCA Scoring

	Social		
Option	Community	Public Amenity	**Social Score**
Do Nothing	-2	-2	**-8**
Hard Engineering Solutions	0	1	**2**
Soft Edge Treatments	1	2	**6**
Managed Retreat	-2	1	**-2**

potential for properties with no public land - hard engineering may be better

managed retreat - empty blocks over time an issue (visual etc)

MCA Scoring

	Environment		
Option	Natural Environment	Visual Amenity	**Environmental Score**
Do Nothing	-1	-1	**-4**
Hard Engineering Solutions	-1	-1	**-4**
Soft Edge Treatments	1	2	**6**
Managed Retreat	2	1	**6**

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MCA Scoring

Option	Cost Score
Do Nothing	5
Hard Engineering Solutions	2
Soft Edge Treatments	3
Managed Retreat	1

hard engineering could be more expensive

Rhelm

Option	Technical	Social	Environment	Total Performance Score	Cost Score
Weighting	33%	33%	33%		
Do Nothing	4	-8	-4	**-2.64**	**5**
Hard Engineering Solutions	1	2	-4	**-0.33**	**2**
Soft Edge Treatments	4	6	6	**5.28**	**3**
Managed Retreat	2	-2	6	**1.98**	**1**

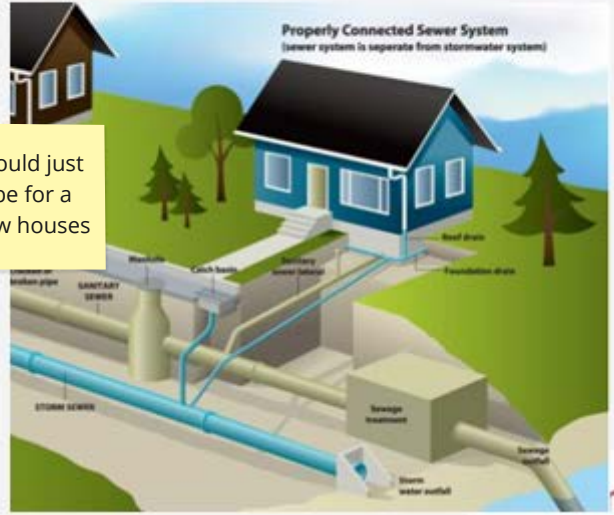
Septic Systems

- Overview of the issue
  - The septic systems on Murray Delta Islands pose a risk to River Water Quality in Future under sea level rise scenarios
  - An extreme inundation event could flood the septic and release faecal material into the Murray
- Options identified to mitigate the issue
  1. Upgrade all systems on each island to one centralised unit (ATU) above hazard level
  2. Connect to mains (WaterCorp)
  3. Managed Retreat of all houses

note that there are other places as well



Could just be for a few houses



MCA Scoring

	Technical				
Option	Feasibility	Effectiveness	Climate Change Adaptation	Construction & Maintenance	**Technical Score**
1. Managed Retreat - all properties	-1	2	2	-1	2
2. Upgrade Island septic to be on one central system located and maintained above the flodd level	1	1	2	-1	3
3. Connect the Islands to Main Sewage (WaterCorp). This would require pipe network and pumps under the river onto the islands.	-1	2	1	-2	0

several sub-options could be possible

Rhelm

MCA Scoring

	Social		
Option	Community	Public Amenity	Social Score
1. Managed Retreat - all properties	-2	1	-2
2. Upgrade Island septic to be on one central system located and maintained above the flodd level	2	1	6
3. Connect the Islands to Main Sewage (WaterCorp). This would require pipe network and pumps under the river onto the islands.	2	1	6

Rhelm

MCA Scoring

	Environment		
Option	Natural Environment	Visual Amenity	**Environmental Score**
1. Managed Retreat - all properties	2	2	**8**
2. Upgrade Island septic to be on one central system located and maintained above the flodd level	1	1	4
3. Connect the Islands to Main Sewage (WaterCorp). This would require pipe network and pumps under the river onto the islands.	2	1	6

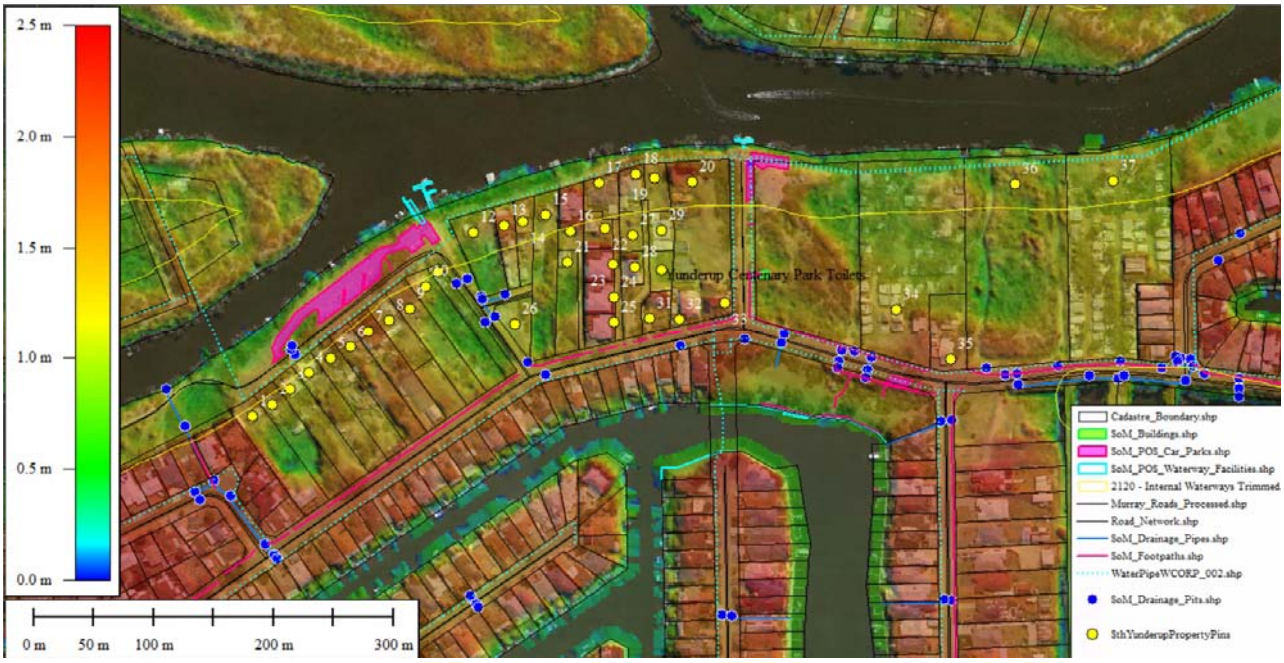
Appendix H

Hazard Impact Regions

Baird.

H.1 Hazard Region Calculated for Inundation and Erosion

South Yunderup






0 m
50 m
100 m
150 m
200 m
250 m


50 m
150 m
250 m
350 m

Depth of Overfloor Inundation Calculated for South Yunderup Properties

ASSUMPTIONS

ARI Considered: 1yr, 2yr, 5yr, 10yr, 20yr, 50yr, 100yr, 500yr

Planning Periods and Sea Level Rise

Planning Periods	2020	2030	2050	2070	2120
Sea Level Rise (m)	0	0.1	0.2	0.4	0.9
Assumed Freeboard of Houses			0.3	m	

Elevation Calculated from LiDAr Data

Depth of Overfloor Inundation (m) for each property. Calculated for 8 ARI inundation levels across the 5 Respective Planning Periods

Location	Property Pin	East	North	House=H Undeveloped = U	Elevation (mAHD)	Floor Level with Freeboard Allowance	2020 (Present Day) No SLR								2030 (+0.1m SLR)								2050 (+0.2m SLR)								2070 (+0.4m SLR)								2120 (+0.9m SLR)							
	Return Period						1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr
	Peak Inundation Level (m AHD)						0.60	0.78	0.87	0.91	0.96	1.04	1.09	1.44	0.70	0.88	0.97	1.01	1.06	1.14	1.19	1.54	0.80	0.98	1.07	1.11	1.16	1.24	1.29	1.64	1.00	1.18	1.27	1.31	1.36	1.44	1.49	1.84	1.50	1.68	1.77	1.81	1.86	1.94	1.99	2.34
South Yunderup Properties	1	384989.6	6394044	H	1.56	1.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.08	0.13	0.48
	2	385005.6	6394055	H	1.34	1.64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	0.21	-	-	-	-	-	-	-	0.05	0.14	0.18	0.23	0.31	0.36	0.71
	3	385020.7	6394068	H	1.31	1.61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	0.23	-	-	-	-	-	-	-	0.07	0.16	0.20	0.25	0.33	0.38	0.73
	4	385036.1	6394082	H	1.28	1.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-	-	0.26	-	-	-	-	-	-	-	0.10	0.19	0.23	0.28	0.36	0.41	0.76
	5	385054	6394094	H	1.56	1.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.13	0.48
	6	385070.5	6394104	H	1.57	1.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	0.12	0.47
	7	385085.9	6394117	H	1.95	2.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09
	8	385103.2	6394127	H	1.54	1.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	-	-	-	0.02	0.10	0.15	0.50
	9	385120.8	6394137	H	1.61	1.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.08	0.43
	10	385133.2	6394156	H	1.19	1.49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.15	-	-	-	-	-	-	-	0.35	0.01	0.19	0.28	0.32	0.37	0.45	0.50	0.85	0.16	0.34	0.43	0.47	0.52	0.60	0.65	1.00
	11	385143.2	6394168	H	1.04	1.34	-	-	-	-	-	-	-	0.10	-	-	-	-	-	-	0.20	0.30	-	-	-	-	-	-	-	0.50	0.16	0.34	0.43	0.47	0.52	0.60	0.65	1.00								
	12	385172.9	6394202	H	1.28	1.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-	-	0.26	-	0.10	0.19	0.23	0.28	0.36	0.41	0.76								
	13	385198.7	6394208	H	1.85	2.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.19
	14	*385214*	*6394211*	H	*1.53*	1.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	-	-	0.03	0.11	0.16	0.51
	15	385233.1	6394217	H	1.41	1.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	-	-	-	0.06	0.10	0.15	0.23	0.28	0.63							
	16	385253.9	6394203	H	1.32	1.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	0.22	-	0.06	0.15	0.19	0.24	0.32	0.37	0.72							
	17	385277.9	6394244	H	1.84	2.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20
	18	385308.2	6394252	H	1.89	2.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15
	19	385324.3	6394249	H	1.54	1.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.10	0.15	0.50
	20	385355.8	6394245	H	1.71	2.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33
	21	385251.2	6394177	H	1.21	1.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.14	-	-	-	-	-	-	-	0.34	-	0.18	0.27	0.31	0.36	0.44	0.49	0.84								
	22	385282.8	6394205	H	1.62	1.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.08	0.43
	23	385289.4	6394175	H	1.88	2.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.16
	24	385290.1	6394147	H	2.01	2.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
	25	385290.7	6394126	H	1.89	2.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15
	26	*385208*	*6394124*	H	*1.12*	1.42	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	0.12	-	-	-	-	-	-	-	0.22	-	-	-	-	-	0.02	0.07	0.42	0.08	0.26	0.35	0.39	0.44	0.52	0.57	0.92
	27	*385306*	*6394200*	H	*1.40*	1.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14	-	-	-	-	-	-	-	-	-	-	0.07	0.11	0.16	0.24	0.29	0.64
	28	385307.9	6394172	H	1.83	2.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.21
	29	385329.9	6394204	H	1.23	1.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.11	-	-	-	-	-	-	-	0.31	-	0.15	0.24	0.28	0.33	0.41	0.46	0.81								
	30	385330.1	6394170	H	1.18	1.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	0.17	-	-	-	-	-	-	-	0.37	0.02	0.21	0.30	0.34	0.39	0.47	0.52	0.87								
	31	*385320*	*6394129*	H	*1.51*	1.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	-	-	-	-	0.05	0.13	0.18	0.53								
	32	385344.5	6394128	H	1.91	2.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13
	33	385382.7	6394142	H	1.88	2.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.16
	34	385525.2	6394136	H	1.46	1.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	0.01	0.05	0.10	0.18	0.23	0.58								
	35	385570.6	6394094	H	1.99	2.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05
	36	*385624*	*6394243*	H	*1.25*	1.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	-	0.29	-	0.13	0.22	0.26	0.31	0.39	0.44	0.79								
	37	385705.9	6394246	H	1.13	1.43	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	0.11	0.21	-	-	-	-	-	-	-	0.41	0.07	0.25	0.34	0.38	0.43	0.51	0.56	0.91								
	38	*386268*	*6394385*	H	*1.47*	1.77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	-	0.04	0.09	0.17	0.57								
	39	*386292*	*6394353*	H	*1.86*	2.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.18
	40	*386311*	*6394388*	H	*1.09*	1.39	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	0.15	0.25	-	-	-	-	-	-	-	0.45	0.11	0.29	0.38	0.42	0.47	0.55	0.60	0.95								
	41	*386331*	*6394387*	H	*1.36*	1.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.02	0.11	0.15	0.20	0.28	0.33	0.68								
	42	*386350*	*6394386*	H	*1.82*	2.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.22
	43	*386369*	*6394385*	H	*1.55*	1.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.09	0.14	0.49
	44	*386391*	*6394404*	H	*1.42*	1.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.12	-	-	0.05	0.09	0.14	0.22	0.27	0.62								
	45	386391.5	6394374	H	1.53	1.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	0.03	0.11	0.16	0.51								
	46	386431.7	6394398	H	1.68	1.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.36
	47	386470.6	6394444	H	1.58	1.88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	0.11	0.46
	48	386488.9	6394416	H	1.39	1.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15	-	-	-	0.08	0.12	0.17	0.25	0.30	0.65							
	49	386512.7	6394435	H	1.33	1.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	-	0.21	-	0.05	0.14	0.18	0.23	0.31	0.36	0.71								
	50	3865.30	6394449	H	1.60	1.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.09	0.44
	51	386548.7	6394461	H	1.54	1.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	0.02	0.10	0.15	0.50							
	52	386570.6	6394457	H	1.83	2.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.21
	53	386595.2	6394465	H	1.90	2.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15
	54	386617.2	6394462	H	1.34	1.64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	0.20	-	0.04	0.13	0.17	0.22	0.30	0.35	0.70								
	55	386661.2	6394438	H	1.94	2.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
	56	386685.8	6394462	H	1.61	1.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.08	0.43
	57	386704.2	6394470	H	2.03	2.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
	58	*386725*	*6394474*	H	*1.76*	2.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.28
	59	386742.3	6394491	H	1.90	2.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
	60	386748.9	6394523	H	1.65	1.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.39
	61	386768.2	6394531	H	2.05	2.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	62	386786.3	6394539	H	1.65	1.95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.39
	63	386804.9	6394546	H	1.68	1.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.36
	64	386823.4	6394552	H	1.60	1.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.09	0.44
	65	386843	6394562	H	2.03	2.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
	66	*386859*	*6394569*	H	*1.68*	1.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.36
	67	*386877*	*6394576*	H	*2.03*	2.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
	68	386892.2	6394582	H	2.03	2.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
	69	386901.5	6394585	H	2.16	2.46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	70	386915.9	6394590	H	1.64	1.94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.05	0.40
	71	*386936*	*6394594*	H	*2.25*	2.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	72	*386950*	*6394614*	H	*1.42*	1.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.12	-	-	0.05	0.09	0.14	0.22	0.27	0.62								
	73	386968.4	6394564	H	1.83	2.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.21
	74	386173	6394370	H	2.50	2.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	75	386209	6394380	H	2.15	2.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	76	*386227*	*6394391*	H	*1.95*	2.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09
	77	386245.6	6394392	H	1.79	2.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.26
	78	386254.1	6394392	H	1.85	2.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.19
	79	387592.1	6394685	H	2.12	2.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	80	*387609*	*6394681*	H	2.50	2.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	81	*387630*	*6394681*	H	*2.15*	2.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	82	*387658*	*6394689*	H	*1.99*	2.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05
	83	*387677*	*6394691*	H	*2.00*	2.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04
	84	*387696*	*6394691*	H	*2.00*	2.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04
	85	*387718*	*6394685*	H	*2.31*	2.61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	86	*387741*	*6394678*	H	*2.34*	2.64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	87	*387761*	*6394676*	H	*2.39*	2.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	88	*387777*	*6394689*	H	*1.73*	2.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.31
	89	387797.3	6394695	H	1.94	2.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
	90	387820	6394687	H	2.13	2.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	91	387836.9	6394682	H	1.96	2.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08
	92	387869.5	6394675	H	2.23	2.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	93	387888.4	6394693	H	2.45	2.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	94	387906	6394700	H	2.43	2.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	95	387926.9	6394706	H	2.30	2.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	96	387944.8	6394710	H	2.13	2.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	97	387966.1	6394712	H	2.06	2.36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	98	387998.6	6394743	H	1.97	2.27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07
	99	388016.2	6394749	H	2.02	2.32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
	100	388035.3	6394754	H	2.14	2.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	101	388051.4	6394760	H	2.29	2.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	102	387823.6	6394616	H	2.01	2.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
	103	387847.6	6394528	H	1.80	2.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.24
	104	387926.7	6394609	H	1.93	2.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11
	105	387989.7	6394576	H	1.91	2.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
	106	387993.6	6394504	H	1.56	1.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	0.13	0.48
	107	387951.8	6394393	H	1.61	1.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.08	0.43
	108	387905.6	6394359	H	1.78	2.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.26

| | | |

Calculated Erosion Areas for South Yunderup RiverFront Properties

ASSUMPTIONS

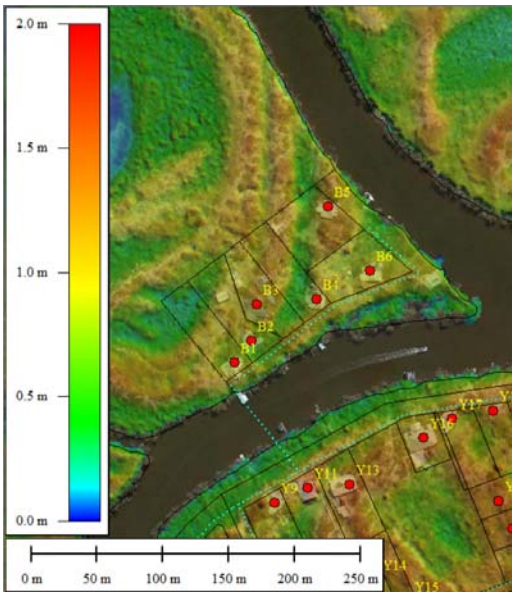
Estimate of the lot area

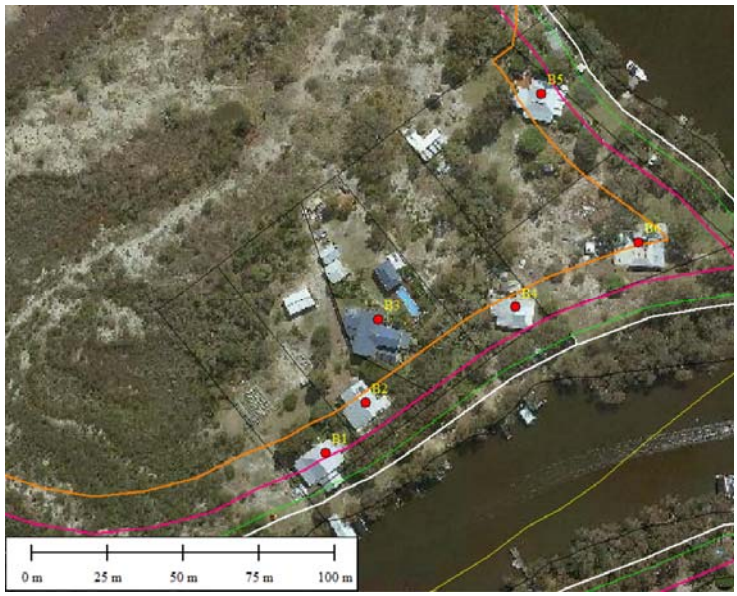
Erosion areas do not consider erosion of house a total loss of area (approach adopted at the Islands)

Elevation Calculated from LiDAr Data			Area of the Lot Which is lost to Erosion (m2)					% of the Total Lot Which is lost to Erosion				
Location	Property Pin	Lot Size (m2)	2120	2130	2150	2170	2120	2120	2130	2150	2170	2120
South Yunderup Riverfront Properties	1	2627	0	0	0	0	160	0%	0%	0%	0%	6%
	2	2198	0	0	0	0	160	0%	0%	0%	0%	7%
	3	2225	0	0	0	0	155	0%	0%	0%	0%	7%
	4	2249	0	0	0	0	145	0%	0%	0%	0%	6%
	5	2300	0	0	0	0	165	0%	0%	0%	0%	7%
	6	2225	0	0	0	0	160	0%	0%	0%	0%	7%
	7	2326	0	0	0	0	155	0%	0%	0%	0%	7%
	8	1351	0	0	0	0	155	0%	0%	0%	0%	11%
	9	2376	0	0	0	0	155	0%	0%	0%	0%	7%
	10	2359	0	0	0	0	166	0%	0%	0%	0%	7%
	11	1191	0	0	0	0	72	0%	0%	0%	0%	6%
	12	2096	0	0	230	630	1230	0%	0%	11%	30%	59%
	13	1007	0	0	60	260	580	0%	0%	6%	26%	58%
	14	1005	0	0	60	260	580	0%	0%	6%	26%	58%
	15	2943	0	0	44	314	772	0%	0%	1%	11%	26%
	16	1599	0	0	40	270	780	0%	0%	3%	17%	49%
	17	973	0	0	112	337	973	0%	0%	12%	35%	100%
	18	786	0	0	160	390	786	0%	0%	20%	50%	100%
	19	793	0	0	80	370	793	0%	0%	10%	47%	100%
	20	6759	0	0	370	1024	2061	0%	0%	5%	15%	30%
	21											
	22											
	23											
	24											
	25											
	26											
	27											
	28											
	29											
	30											
	31											
	32											
	33											
	34	13270	0	295	1060	2117	3800	0%	2%	8%	16%	29%
	35											
	36	15273	0	295	1060	2117	3800	0%	2%	7%	14%	25%
	37	13724	0	295	1060	2117	3800	0%	2%	8%	15%	28%
	38	1869	0	0	0	150	390	0%	0%	0%	8%	21%
	39	1763	0	0	0	140	370	0%	0%	0%	8%	21%
	40	1656	0	0	0	120	340	0%	0%	0%	7%	21%
	41	1550	0	0	0	110	335	0%	0%	0%	7%	22%
	42	1495	0	0	0	105	360	0%	0%	0%	7%	24%
	43	1495	0	0	0	105	340	0%	0%	0%	7%	23%
	44	748	0	0	0	110	340	0%	0%	0%	15%	45%
	45											
	46	3018	0	0	0	140	600	0%	0%	0%	5%	20%
	47	1549	0	0	0	69	300	0%	0%	0%	4%	19%
	48	1567	0	0	0	70	310	0%	0%	0%	4%	20%
	49	1585	0	0	0	75	290	0%	0%	0%	5%	18%
	50	1524	0	0	0	70	300	0%	0%	0%	5%	20%
	51	1386	0	0	0	75	305	0%	0%	0%	5%	22%
	52	1248	0	0	0	54	300	0%	0%	0%	4%	24%
	53	1532	0	0	0	30	300	0%	0%	0%	2%	20%
	54	1651	0	0	0	0	300	0%	0%	0%	0%	18%
	55	3389	0	0	0	70	310	0%	0%	0%	2%	9%
	56	1616	0	0	0	20	240	0%	0%	0%	1%	15%
	57	1616	0	0	0	65	240	0%	0%	0%	4%	15%
	58	1617	0	0	0	70	240	0%	0%	0%	4%	15%
	59	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	60	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	61	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	62	1617	0	0	0	145	375	0%	0%	0%	9%	23%

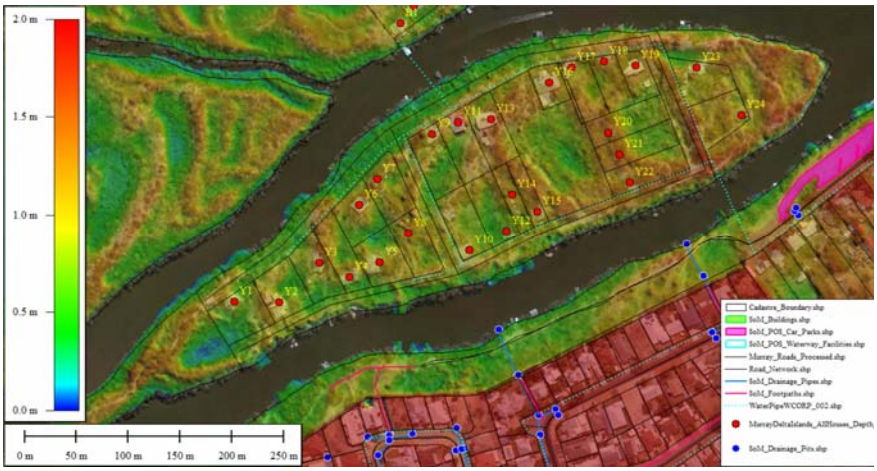
	63	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	64	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	65	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	66	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	67	1617	0	0	0	145	375	0%	0%	0%	9%	23%
	68	808	0	0	0	55	90	0%	0%	0%	7%	11%
	69	808	0	0	0	55	90	0%	0%	0%	7%	11%
	70	1681	0	0	0	90	315	0%	0%	0%	5%	19%
	71	1732	0	0	0	90	315	0%	0%	0%	5%	18%
	72	933	0	0	0	80	320	0%	0%	0%	9%	34%
	73											
	74	5763	0	0	0	0	225	0%	0%	0%	0%	4%
	75	2263	0	0	0	101	315	0%	0%	0%	4%	14%
	76	1828	0	0	0	180	470	0%	0%	0%	10%	26%
	77	1013	0	0	0	75	190	0%	0%	0%	7%	19%
	78	1013	0	0	0	75	190	0%	0%	0%	7%	19%

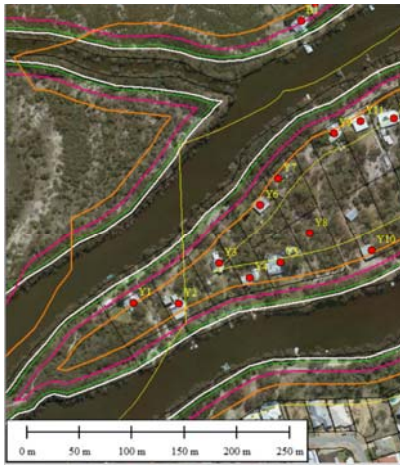
Ballee Island



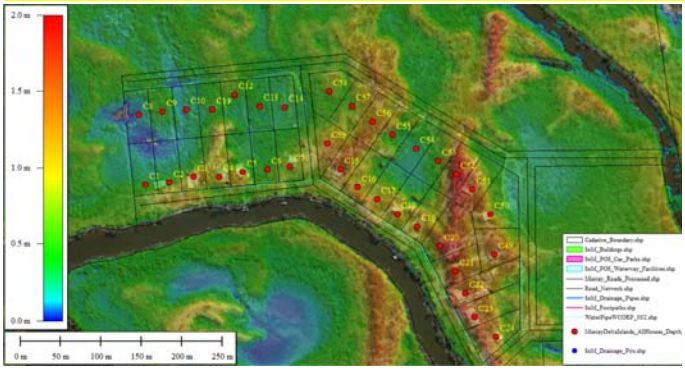


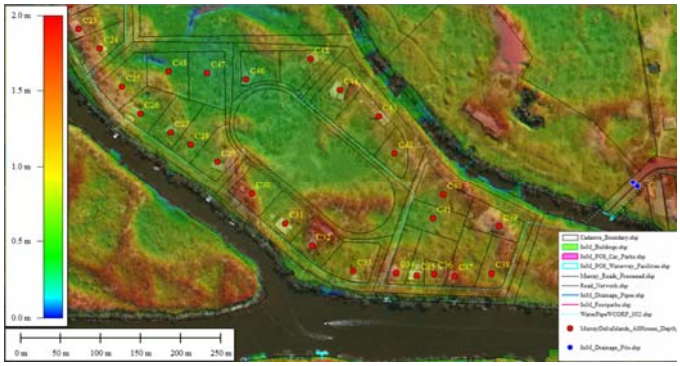
Yunderup Island





Coolenup Island





Depth of Overfloor Inundation Calculated for the Murray Delta Island Properties

ASSUMPTIONS

ARI Considered: 1yr, 2yr, 5yr, 10yr, 20yr, 50yr, 100yr, 500yr

Planning Periods and Sea Level Rise

Planning Periods	2020	2030	2050	2070	2120
Sea Level Rise (m)	0	0.1	0.2	0.4	0.9

Assumed Freeboard of Houses: 0.3 m

Elevation Calculated from LiDAr Data

Depth of Overfloor Inundation (m) for each property. Calculated for 8 ARI inundation levels across the 5 Respective Planning Periods

ISLAND	Property Pin	East	North	House=H Undeveloped = U	Elevation (mAHD)	Floor Level with Freeboard Allowance	2020 (Present Day) No SLR								2030 (+0.1m SLR)							
						Return Period	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr
						Peak Inundation Level (m AHD)	0.60	0.78	0.87	0.91	0.96	1.04	1.09	1.44	0.70	0.88	0.97	1.01	1.06	1.14	1.19	1.54
Ballee Island	B1	384640.7	6394288	H	0.88	1.18	-	-	-	-	-	-	-	0.26	-	-	-	-	-	-	0.01	0.36
	B2	384654	6394305	H	0.71	1.01	-	-	-	-	-	0.03	0.08	0.43	-	-	-	0.00	0.05	0.13	0.18	0.53
	B3	384657.9	6394333	H	1.19	1.49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05
	B4	384703.3	6394337	H	1.02	1.32	-	-	-	-	-	-	-	0.12	-	-	-	-	-	-	-	0.22
	B5	384711.9	6394410	H	1.11	1.41	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	0.13
	B6	384744	6394360	H	0.88	1.18	-	-	-	-	-	-	-	0.26	-	-	-	-	-	-	0.01	0.36
Turnbirup Island	Y1	384480.8	6394011	H	0.95	1.25	-	-	-	-	-	-	-	0.19	-	-	-	-	-	-	-	0.29
	Y2	384524.2	6394010	H	1.01	1.31	-	-	-	-	-	-	-	0.13	-	-	-	-	-	-	-	0.23
	Y3	384562.8	6394049	H	1.16	1.46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08
	Y4	384591.7	6394035	H	0.96	1.26	-	-	-	-	-	-	-	0.18	-	-	-	-	-	-	-	0.28
	Y5	384620.6	6394050	H	1.11	1.41	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	0.13
	Y6	384601.3	6394107	H	1.26	1.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y7	384618.7	6394133	H	1.34	1.64	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y8	*384649*	*6394079*	*U*	*1.22*	*1.52*	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	0.15
	Y9	384671.7	6394178	H	1.09	1.39	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	-	0.23
	Y10	384707.4	6394062	H	1.01	1.31	-	-	-	-	-	-	-	0.13	-	-	-	-	-	-	-	0.23
	Y11	384696.8	6394189	H	1.38	1.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y12	384743	6394081	H	0.72	1.02	-	-	-	-	-	0.02	0.07	0.42	-	-	-	-	0.04	0.12	0.17	0.52
	Y13	384728.6	6394192	H	1.41	1.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y14	384748.5	6394118	H	1.14	1.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
	Y15	384773.3	6394101	H	1.16	1.46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08
	Y16	384784.5	6394229	H	1.28	1.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y17	384806.3	6394244	H	1.22	1.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
	Y18	384837.6	6394250	H	1.28	1.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y19	384867.6	6394246	H	1.14	1.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
	Y20	*384841*	*6394179*	*U*	*1.48*	*1.78*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y21	*384852*	*6394158*	*U*	*1.42*	*1.72*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y22	384862.4	6394130	H	1.37	1.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Y23	384926.3	6394244	H	1.04	1.34	-	-	-	-	-	-	-	0.10	-	-	-	-	-	-	-	0.20
	Y24	384970	6394197	H	1.13	1.43	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	0.11
Cookernup Island	*C1*	*384687*	*6394864*	*U*	*0.33*	*0.63*	-	0.15	0.24	0.28	0.33	0.41	0.46	0.81	0.07	0.25	0.34	0.38	0.43	0.51	0.56	0.91
	C2	384716.6	6394867	H	0.89	1.19	-	-	-	-	-	-	-	0.25	-	-	-	-	-	-	0.00	0.35
	C3	384746.5	6394875	H	1.08	1.38	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-	-	0.16
	C4	384778.3	6394875	H	0.88	1.18	-	-	-	-	-	-	-	0.26	-	-	-	-	-	-	0.01	0.36
	C5	384807.2	6394881	H	0.79	1.09	-	-	-	-	-	-	-	0.35	-	-	-	-	-	0.05	0.10	0.45
	C6	*384838*	*6394885*	*U*	*0.43*	*0.73*	-	0.05	0.14	0.18	0.23	0.31	0.36	0.71	-	0.15	0.24	0.28	0.33	0.41	0.46	0.81
	C7	384866	6394888	H	0.67	0.97	-	-	-	-	-	0.07	0.12	0.47	-	-	-	-	0.04	0.09	0.17	0.22
	C8	384679	6394914	*U*	*0.12*	*0.42*	0.18	0.36	0.45	0.49	0.54	0.62	0.67	1.02	0.28	0.46	0.55	0.59	0.64	0.72	0.77	1.12
	C9	*384708*	*6394958*	*U*	*0.39*	*0.69*	-	0.09	0.18	0.22	0.27	0.35	0.40	0.75	0.01	0.19	0.28	0.32	0.37	0.45	0.50	0.85
	C10	*384738*	*6394961*	*U*	*0.40*	*0.70*	-	0.08	0.17	0.21	0.26	0.34	0.39	0.74	0.00	0.18	0.27	0.31	0.36	0.44	0.49	0.84
	C11	*384770*	*6394961*	*U*	*0.40*	*0.70*	-	0.08	0.17	0.21	0.26	0.34	0.39	0.74	-	0.18	0.27	0.31	0.36	0.44	0.49	0.84
	C12	*384798*	*6394979*	*U*	*0.51*	*0.81*	-	-	0.06	0.10	0.15	0.23	0.28	0.63	-	0.07	0.16	0.20	0.25	0.33	0.38	0.73
	C13	*384828*	*6394963*	*U*	*0.36*	*0.66*	-	0.13	0.22	0.26	0.31	0.39	0.44	0.79	0.04	0.23	0.32	0.36	0.41	0.49	0.54	0.89
	C14	*384859*	*6394964*	*U*	*0.30*	*0.60*	0.01	0.19	0.28	0.32	0.37	0.45	0.50	0.85	0.11	0.29	0.38	0.42	0.47	0.55	0.60	0.95
	C15	384928.7	6394885	H	1.27	1.57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C16	384949.9	6394862	H	0.95	1.25	-	-	-	-	-	-	-	0.19	-	-	-	-	-	-	-	0.29
	C17	384974	6394846	H	1.03	1.33	-	-	-	-	-	-	-	0.12	-	-	-	-	-	-	-	0.22
	C18	384999.1	6394827	H	1.10	1.40	-	-	-	-	-	-	-	0.04	-	-	-	-	-	-	-	0.15
	C19	385023.2	6394811	H	1.18	1.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06
	C20	385052.1	6394786	U	1.64	1.94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C21	385070.4	6394755	U	1.66	1.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C22	385082.9	6394728	H	1.47	1.77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C23	385094.5	6394697	H	1.39	1.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C24	385120.5	6394672	H	1.27	1.57	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C25	385148.5	6394623	U	1.02	1.32	-	-	-	-	-	-	-	0.12	-	-	-	-	-	-	-	0.22
	C26	385171.6	6394589	H	0.58	0.88	-	-	-	0.03	0.08	0.16	0.21	0.56	-	-	0.09	0.13	0.18	0.26	0.31	0.66
	C27	385209.2	6394565	H	0.63	0.93	-	-	-	-	0.03	0.11	0.16	0.51	-	-	0.04	0.08	0.13	0.21	0.26	0.61
	C28	*385235*	*6394549*	*U*	*0.61*	*0.91*	-	-	-	-	0.05	0.13	0.18	0.53	-	-	0.06	0.10	0.15	0.23	0.28	0.63
	C29	385267.5	6394527	H	0.76	1.06	-	-	-	-	-	-	0.04	0.39	-	-	-	-	0.01	0.09	0.14	0.49
	C30	385310.9	6394484	H	1.32	1.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C31	385352.3	6394446	H	0.95	1.25	-	-	-	-	-	-	-	0.19	-	-	-	-	-	-	-	0.29
	C32	385386.1	6394418	H	1.53	1.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C33	385437.2	6394385	H	1.11	1.41	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	-	0.13
	C34	385491.1	6394383	H	1.42	1.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C35	385516.3	6394380	H	0.85	1.15	-	-	-	-	-	-	-	0.29	-	-	-	-	-	-	-	0.04
	C36	*385539*	*6394382*	*U*	*1.13*	*1.43*	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	0.11
	C37	*385564*	*6394378*	*U*	*1.61*	*1.91*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C38	385609.7	6394382	H	1.13	1.43	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	0.11
	C39	385619.6	6394442	H	1.57	1.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C40	385549.7	6394483	U	1.15	1.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09
	C41	*385537*	*6394453*	*U*	*0.68*	*0.98*	-	-	-	-	-	0.06	0.11	0.46	-	-	-	-	0.03	0.08	0.16	0.21
	C42	*385489*	*6394537*	*U*	*0.92*	*1.22*	-	-	-	-	-	-	-	0.22	-	-	-	-	-	-	-	0.32
	C43	385469.1	6394585	H	1.15	1.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09
	C44	385420.2	6394618	H	0.85	1.15	-	-	-	-	-	-	-	0.29	-	-	-	-	-	-	0.04	0.39
	C45	385384.3	6394659	H	0.81	1.11	-	-	-	-	-	-	-	0.33	-	-	-	-	-	0.03	0.08	0.43
	C46	385303	6394612	U	*0.32*	*0.62*	-	0.17	0.26	0.30	0.35	0.43	0.48	0.83	0.09	0.27	0.36	0.40	0.45	0.53	0.58	0.93
	C47	385254.4	6394640	H	0.34	0.64	-	0.14	0.23	0.27	0.32	0.40	0.45	0.80	0.06	0.24	0.33	0.37	0.42	0.50	0.55	0.90
	C48	385206.9	6394642	H	0.41	0.71	-	0.07	0.16	0.20	0.25	0.33	0.38	0.73	-	0.17	0.26	0.30	0.35	0.43	0.48	0.83
	C49	385118.5	6394776	H	1.39	1.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C50	385113.7	6394827	H	1.13	1.43	-	-	-	-	-	-	-	0.01	-	-	-	-	-	-	-	0.12
	C51	*385092*	*6394859*	*U*	*1.61*	*1.91*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C52	*385072*	*6394878*	*U*	*2.35*	*2.65*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C53	*385049*	*6394895*	*U*	*0.48*	*0.78*	-	-	0.09	0.13	0.18	0.26	0.31	0.66	-	0.10	0.19	0.23	0.28	0.36	0.41	0.76
	C54	*385022*	*6394912*	*U*	*0.27*	*0.57*	0.03	0.21	0.30	0.34	0.39	0.47	0.52	0.87	0.13	0.31	0.40	0.44	0.49	0.57	0.62	0.97
	C55	*384993*	*6394928*	*U*	*0.38*	*0.68*	-	0.10	0.19	0.23	0.28	0.36	0.41	0.76	0.02	0.20	0.29	0.33	0.38	0.46	0.51	0.86
	C56	*384968*	*6394946*	*U*	*1.22*	*1.52*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
	C57	*384943*	*6394965*	*U*	*0.63*	*0.93*	-	-	-	-	0.03	0.11	0.16	0.51	-	-	0.04	0.08	0.13	0.21	0.26	0.61
	C58	*384914*	*6394983*	*U*	*0.65*	*0.95*	-	-	-	-	0.01	0.09	0.14	0.49	-	-	0.02	0.06	0.11	0.19	0.24	0.59
	C59	384912.3	6394918	H	1.23	1.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
	Mill Cott	384090.3	6395002	H	0.85	1.15	-	-	-	-	-	-	-	0.29	-	-	-	-	-	-	0.04	0.39
	Mill	384121.2	6395021	U	0.50	0.80	-	-	0.07	0.11	0.16	0.24	0.29	0.64	-	0.08	0.17	0.21	0.26	0.34	0.39	0.74

ISLAND	Property Pin	2050 (+0.2m SLR)								2070 (+0.4m SLR)								2120 (+0.9m SLR)							
		1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr
		0.80	0.98	1.07	1.11	1.16	1.24	1.29	1.64	1.00	1.18	1.27	1.31	1.36	1.44	1.49	1.84	1.50	1.68	1.77	1.81	1.86	1.94	1.99	2.34
Ballee Island	B1	-	-	-	-	-	0.06	0.11	0.46	-	-	0.09	0.13	0.18	0.26	0.31	0.66	0.32	0.50	0.59	0.63	0.68	0.76	0.81	1.16
	B2	-	-	0.06	0.10	0.15	0.23	0.28	0.63	-	0.17	0.26	0.30	0.35	0.43	0.48	0.83	0.49	0.67	0.76	0.80	0.85	0.93	0.98	1.33
	B3	-	-	-	-	-	-	-	0.15	-	-	-	-	-	-	0.00	0.35	0.01	0.19	0.28	0.32	0.37	0.45	0.50	0.85
	B4	-	-	-	-	-	-	-	0.32	-	-	-	0.04	0.12	0.17	0.52	0.18	0.36	0.45	0.49	0.54	0.62	0.67	1.02	
	B5	-	-	-	-	-	-	-	0.23	-	-	-	-	-	0.03	0.08	0.43	0.09	0.27	0.36	0.40	0.45	0.53	0.58	0.93
	B6	-	-	-	-	-	0.06	0.11	0.46	-	-	0.09	0.13	0.18	0.26	0.31	0.66	0.32	0.50	0.59	0.63	0.68	0.76	0.81	1.16
Turnbirup Island	Y1	-	-	-	-	-	-	-	0.39	-	-	0.02	0.06	0.11	0.19	0.24	0.59	0.25	0.43	0.52	0.56	0.61	0.69	0.74	1.09
	Y2	-	-	-	-	-	-	-	0.33	-	-	-	-	0.05	0.13	0.18	0.53	0.19	0.37	0.46	0.50	0.55	0.63	0.68	1.03
	Y3	-	-	-	-	-	-	-	0.18	-	-	-	-	-	-	0.03	0.38	0.04	0.22	0.31	0.35	0.40	0.48	0.53	0.88
	Y4	-	-	-	-	-	0.03	0.08	0.38	-	-	0.01	0.05	0.10	0.18	0.23	0.58	0.24	0.42	0.51	0.55	0.60	0.68	0.73	1.08
	Y5	-	-	-	-	-	-	-	0.23	-	-	-	-	-	0.03	0.08	0.43	0.09	0.27	0.36	0.40	0.45	0.53	0.58	0.93
	Y6	-	-	-	-	-	-	-	0.08	-	-	-	-	-	-	-	0.28	-	0.12	0.21	0.25	0.30	0.38	0.43	0.78
	Y7	-	-	-	-	-	-	-	0.20	-	-	-	-	-	-	-	0.20	-	0.04	0.13	0.17	0.22	0.30	0.35	0.70
	Y8	-	-	-	-	-	-	-	0.12	-	-	-	-	-	-	-	0.32	-	0.16	0.25	0.29	0.34	0.42	0.47	0.82
	Y9	-	-	-	-	-	0.05	0.10	0.45	-	-	-	-	-	0.05	0.10	0.45	0.11	0.29	0.38	0.42	0.47	0.55	0.60	0.95
	Y10	-	-	-	-	-	0.05	0.13	0.18	0.53	-	-	-	-	0.05	0.13	0.18	0.53	0.19	0.37	0.46	0.50	0.55	0.63	0.68	1.03
	Y11	-	-	-	-	-	-	-	0.16	-	-	-	-	-	-	-	-	-	-	0.09	0.13	0.18	0.26	0.31	0.66
	Y12	0.05	0.09	0.14	0.22	0.27	0.62	0.48	0.66	0.75	0.79	0.84	0.92	0.97	1.32										
	Y13	-	-	-	-	-	-	-	0.13	-	-	-	-	-	-	0.06	0.10	0.15	0.23	0.28	0.63				
	Y14	-	-	-	-	-	-	-	0.20	-	-	-	-	-	0.05	0.40	0.06	0.24	0.33	0.37	0.42	0.50	0.55	0.90	
	Y15	-	-	-	-	-	-	-	0.18	-	-	-	-	-	0.03	0.38	0.04	0.22	0.31	0.35	0.40	0.48	0.53	0.88	
	Y16	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-	0.26	-	-	0.10	0.19	0.23	0.28	0.36	0.41	0.76	
	Y17	-	-	-	-	-	-	-	0.12	-	-	-	-	-	-	0.32	-	-	0.16	0.25	0.29	0.34	0.42	0.47	0.82	
	Y18	-	-	-	-	-	-	-	0.06	-	-	-	-	-	-	0.26	-	-	0.10	0.19	0.23	0.28	0.36	0.41	0.76	
	Y19	-	-	-	-	-	-	-	0.20	-	-	-	-	-	0.05	0.40	0.06	0.24	0.33	0.37	0.42	0.50	0.55	0.90	
	Y20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	-	0.03	0.08	0.16	0.21	0.56
	Y21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.12	-	-	-	0.05	0.09	0.14	0.22	0.27	0.62
	Y22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.17	-	-	0.01	0.10	0.14	0.19	0.27	0.32	0.67
	Y23	-	-	-	-	-	0.02	0.10	0.15	0.50	-	-	-	-	0.02	0.10	0.15	0.50	0.16	0.34	0.43	0.47	0.52	0.60	0.65	1.00
	Y24	-	-	-	-	-	-	0.01	0.06	0.41	0.07	0.25	0.34	0.38	0.43	0.51	0.56	0.91								
Cookernup Island	*C1*	0.17	0.35	0.44	0.48	0.53	0.61	0.66	1.01	0.37	0.55	0.64	0.68	0.73	0.81	0.86	1.21	0.87	1.05	1.14	1.18	1.23	1.31	1.36	1.71
	C2	-	-	-	-	-	0.05	0.10	0.45	-	-	0.08	0.12	0.17	0.25	0.30	0.65	0.31	0.49	0.58	0.62	0.67	0.75	0.80	1.15
	C3	-	-	-	-	-	-	-	0.26	-	-	-	-	-	0.06	0.11	0.46	0.12	0.30	0.39	0.43	0.48	0.56	0.61	0.96
	C4	-	-	-	-	-	0.06	0.11	0.46	-	-	0.09	0.13	0.18	0.26	0.31	0.66	0.32	0.50	0.59	0.63	0.68	0.76	0.81	1.16
	C5	0.02	0.07	0.15	0.20	0.25	0.55	0.41	0.59	0.68	0.72	0.77	0.85	0.90	1.25										
	C6	0.07	0.25	0.34	0.38	0.43	0.51	0.56	0.91	0.27	0.45	0.54	0.58	0.63	0.71	0.76	1.11	0.77	0.95	1.04	1.08	1.13	1.21	1.26	1.61
	C7	-	0.01	0.10	0.14	0.19	0.27	0.32	0.67	0.03	0.21	0.30	0.34	0.39	0.47	0.52	0.87	0.53	0.71	0.80	0.84	0.89	0.97	1.02	1.37
	C8	0.38	0.56	0.65	0.69	0.74	0.82	0.87	1.22	0.58	0.76	0.85	0.89	0.94	1.02	1.07	1.42	1.08	1.26	1.35	1.39	1.44	1.52	1.57	1.92
	C9	0.11	0.29	0.38	0.42	0.47	0.55	0.60	0.95	0.31	0.49	0.58	0.62	0.67	0.75	0.80	1.15	0.81	0.99	1.08	1.12	1.17	1.25	1.30	1.65
	C10	0.10	0.28	0.37	0.41	0.46	0.54	0.59	0.94	0.30	0.48	0.57	0.61	0.66	0.74	0.79	1.14	0.80	0.98	1.07	1.11	1.16	1.24	1.29	1.64
	C11	0.10	0.28	0.37	0.41	0.46	0.54	0.59	0.94	0.30	0.48	0.57	0.61	0.66	0.74	0.79	1.14	0.80	0.98	1.07	1.11	1.16	1.24	1.29	1.64
	C12	-	0.17	0.26	0.30	0.35	0.43	0.48	0.83	0.19	0.37	0.46	0.50	0.55	0.63	0.68	1.03	0.69	0.87	0.96	1.00	1.05	1.13	1.18	1.53
	C13	0.15	0.33	0.42	0.46	0.51	0.59	0.64	0.99	0.35	0.53	0.62	0.66	0.71	0.79	0.84	1.19	0.85	1.03	1.12	1.16	1.21	1.29	1.34	1.69
	C14	0.21	0.39	0.48	0.52	0.57	0.65	0.70	1.05	0.41	0.59	0.68	0.72	0.77	0.85	0.90	1.25	0.91	1.09	1.18	1.22	1.27	1.35	1.40	1.75
	C15	-	-	-	-	-	-	-	0.07	-	-	-	-	-	-	-	0.27	-	0.11	0.20	0.24	0.29	0.37	0.42	0.77
	C16	-	-	-	-	-	0.04	0.09	0.39	-	-	0.02	0.06	0.11	0.19	0.24	0.59	0.25	0.43	0.52	0.56	0.61	0.69	0.74	1.09
	C17	-	-	-	-	-	-	-	0.32	-	-	-	-	0.03	0.12	0.17	0.52	0.18	0.36	0.45	0.49	0.54	0.62	0.67	1.02
	C18	-	-	-	-	-	-	-	0.25	-	-	-	-	-	0.04	0.10	0.45	0.11	0.29	0.38	0.42	0.47	0.55	0.60	0.95
	C19	-	-	-	-	-	-	-	0.16	-	-	-	-	-	-	0.01	0.36	0.02	0.20	0.29	0.33	0.38	0.46	0.51	0.86
	C20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.40
	C21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.38
	C22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	-	0.00	0.04	0.09	0.18	0.23	0.58
	C23	-	-	-	-	-	-	-	0.15	-	-	-	-	-	-	-	0.15	-	-	0.08	0.12	0.17	0.25	0.30	0.65
	C24	-	-	-	-	-	-	-	0.27	-	-	-	-	-	-	-	0.27	-	0.11	0.20	0.24	0.29	0.37	0.42	0.77
	C25	-	-	-	-	-	-	-	0.32	-	-	-	-	0.04	0.12	0.17	0.52	0.18	0.36	0.45	0.49	0.54	0.62	0.67	1.02
	C26	0.12	0.30	0.39	0.43	0.48	0.56	0.61	0.96	0.62	0.80	0.89	0.93	0.98	1.06	1.11	1.46								
	C27	0.07	0.25	0.34	0.38	0.43	0.51	0.56	0.91	0.57	0.75	0.84	0.88	0.93	1.01	1.06	1.41								
	C28	0.09	0.27	0.36	0.40	0.45	0.53	0.58	0.93	0.59	0.77	0.86	0.90	0.95	1.03	1.08	1.43								
	C29	0.13	0.22	0.26	0.31	0.39	0.44	0.79	0.45	0.63	0.72	0.76	0.81	0.89	0.94	1.29									
	C30	-	-	-	-	-	-	-	0.22	-	-	0.06	0.15	0.19	0.24	0.32	0.37	0.72								
	C31	-	-	-	-	-	0.04	0.09	0.39	0.25	0.43	0.52	0.56	0.61	0.69	0.74	1.09									
	C32	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.11	0.16	0.51								
	C33	-	-	-	-	-	-	-	0.23	-	-	-	-	0.03	0.08	0.43	0.09	0.27	0.36	0.40	0.45	0.53	0.58	0.93	
	C34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.12	-	-	-	0.05	0.09	0.14	0.22	0.27	0.62
	C35	0.01	0.09	0.14	0.49	-	0.03	0.12	0.16	0.21	0.29	0.34	0.69	0.35	0.53	0.62	0.66	0.71	0.79	0.84	1.19				
	C36	-	-	-	-	-	-	-	0.21	-	-	-	-	0.01	0.06	0.41	0.07	0.25	0.34	0.38	0.43	0.51	0.56	0.91	
	C37	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.08	0.43								
	C38	-	-	-	-	-	-	-	0.21	-	-	-	-

Calculated Erosion Areas for Murray Delta Islands

ASSUMPTIONS

Estimate of the lot area / % lost to erosion over 5 planning periods

Once the Erosion Setback line hits the house assume all is lost. Shows as **100%**

Elevation Calculated from LiDAr Data

Location	Property Pin	East	North	House=H Undeveloped = U	Elevation (mAHD)	Lot Size (m2)	Area of the Lot Which is lost to Erosion					% of the Total Lot Which is lost to Erosion				
							2120	2130	2150	2170	2120	2120	2130	2150	2170	2120
Murray Delta Islands	B1	384640.7	6394288	H	1.52	2022	0	0	100	2022	2022	0%	0%	5%	100%	100%
	B2	384654	6394305	H	1.56	2022	0	0	120	2022	2022	0%	0%	6%	100%	100%
	B3	384657.9	6394333	H	1.77	2023	0	0	100	370	2023	0%	0%	5%	18%	100%
	B4	384703.3	6394337	H	1.58	2022	0	0	50	2022	2022	0%	0%	2%	100%	100%
	B5	384711.9	6394410	H	1.54	2564	0	0	50	2564	2564	0%	0%	2%	100%	100%
	B6	384744	6394360	H	1.63	2319	0	0	70	2319	2319	0%	0%	3%	100%	100%
	Y1	384480.8	6394011	H	1.55	2240	0	0	0	2240	2240	0%	0%	0%	100%	100%
	Y2	384524.2	6394010	H	2.10	2104	0	0	0	2104	2104	0%	0%	0%	100%	100%
	Y3	384562.8	6394049	H	2.09	2035	0	0	0	600	2035	0%	0%	0%	29%	100%
	Y4	384591.7	6394035	H	2.18	1967	0	0	0	211	1967	0%	0%	0%	11%	100%
	Y5	384620.6	6394050	H	1.75	2084	0	0	0	266	2084	0%	0%	0%	13%	100%
	Y6	384601.3	6394107	H	1.55	1966	0	0	0	467	1966	0%	0%	0%	24%	100%
	Y7	384618.7	6394133	H	2.13	2003	0	0	0	300	2003	0%	0%	0%	15%	100%
	Y8	*384649*	*6394079*	*U*	*1.96*	1962	0	0	0	158	770	0%	0%	0%	8%	39%
	Y9	384671.7	6394178	H	1.90	2102	0	0	0	128	2102	0%	0%	0%	6%	100%
	Y10	384707.4	6394062	H	2.20	2109	0	0	0	132	2109	0%	0%	0%	6%	100%
	Y11	384696.8	6394189	H	1.94	2058	0	0	0	135	2058	0%	0%	0%	7%	100%
	Y12	384743	6394081	H	1.82	2075	0	0	0	145	2075	0%	0%	0%	7%	100%
	Y13	384728.6	6394192	H	1.88	2089	0	0	0	100	2089	0%	0%	0%	5%	100%
	Y14	384748.5	6394118	H	1.25	1063	0	0	0	68	1063	0%	0%	0%	6%	100%
	Y15	384773.3	6394101	H	1.30	1063	0	0	0	68	1063	0%	0%	0%	6%	100%
	Y16	384784.5	6394229	H	1.43	1200	0	0	0	222	1200	0%	0%	0%	19%	100%
	Y17	384806.3	6394244	H	2.10	1595	0	0	0	70	1595	0%	0%	0%	4%	100%
	Y18	384837.6	6394250	H	1.99	1446	0	0	0	70	1446	0%	0%	0%	5%	100%
	Y19	384867.6	6394246	H	1.26	1283	0	0	0	70	1283	0%	0%	0%	5%	100%
	Y20	*384841*	*6394179*	*U*	*1.68*	2050	0	0	0	0	0	0%	0%	0%	0%	0%
	Y21	*384852*	*6394158*	*U*	*1.87*	2050	0	0	0	0	0	0%	0%	0%	0%	0%
	Y22	384862.4	6394130	H	1.29	2063	0	0	0	171	2063	0%	0%	0%	8%	100%
	Y23	384926.3	6394244	H	0.99	2022	0	0	0	64	2022	0%	0%	0%	3%	100%
	Y24	384970	6394197	H	1.00	2022	0	0	0	2022	2022	0%	0%	0%	100%	100%
	C1	*384687*	*6394864*	*U*	*1.01*	2022	0	0	0	0	2022	0%	0%	0%	0%	100%
	C2	384716.6	6394867	H	2.42	2022	0	0	0	35	2022	0%	0%	0%	2%	100%
	C3	384746.5	6394875	H	1.82	2022	0	0	0	70	2022	0%	0%	0%	3%	100%
	C4	384778.3	6394875	H	1.45	2022	0	0	0	70	2022	0%	0%	0%	3%	100%
	C5	384807.2	6394881	H	2.04	2022	0	0	0	235	2022	0%	0%	0%	12%	100%
	C6	*384838*	*6394885*	*U*	*2.19*	2022	0	0	0	333	951	0%	0%	0%	16%	47%
	C7	384866	6394888	H	1.57	2022	0	0	0	408	2022	0%	0%	0%	20%	100%
	C8	*384679*	*6394954*	*U*	*1.48*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C9	*384708*	*6394958*	*U*	*1.36*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C10	*384738*	*6394961*	*U*	*1.61*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C11	*384770*	*6394961*	*U*	*1.55*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C12	*384798*	*6394979*	*U*	*1.43*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C13	*384828*	*6394965*	*U*	*1.10*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C14	*384859*	*6394964*	*U*	*1.29*	2022	0	0	0	0	0	0%	0%	5%	0%	0%
	C15	384928.7	6394885	H	1.77	2022	0	0	100	345	2022	0%	0%	2%	17%	100%
	C16	384949.9	6394862	H	1.93	2022	0	0	50	350	1000	0%	0%	1%	17%	49%
	C17	384974	6394846	H	2.14	2022	0	0	20	360	1000	0%	0%	0%	18%	49%
	C18	384999.1	6394827	H	1.77	2022	0	0	0	350	2022	0%	0%	0%	17%	100%
	C19	385023.2	6394811	H	1.83	2022	0	0	0	175	2022	0%	0%	0%	9%	100%
	C20	385052.1	6394786	U	2.02	3143	0	0	0	82	825	0%	0%	0%	3%	26%
	C21	385070.4	6394755	U	2.32	2019	0	0	0	250	2019	0%	0%	0%	12%	100%
	C22	385082.9	6394728	H	2.15	2730	0	0	0	254	2730	0%	0%	0%	9%	100%
	C23	385094.5	6394697	H	1.95	2481	0	0	0	2481	2481	0%	0%	2%	100%	100%
	C24	385120.5	6394672	H	2.03	2306	0	0	55	990	2306	0%	0%	5%	43%	100%
	C25	385148.5	6394623	U	1.67	2611	0	75	107	620	1460	0%	3%	4%	24%	56%
	C26	385171.6	6394589	H	2.24	2200	0	0	110	600	2200	0%	0%	5%	27%	100%
	C27	385209.2	6394565	H	2.01	2407	0	0	120	590	2407	0%	0%	5%	25%	100%
	C28	*385235*	*6394549*	*U*	*2.23*	2369	0	0	130	580	1115	0%	0%	5%	24%	47%
	C29	385267.5	6394527	H	2.14	2295	0	0	130	2295	2295	0%	0%	0%	100%	100%
	C30	385310.9	6394484	H	1.71	2320	0	0	0	380	2320	0%	0%	0%	16%	100%
	C31	385352.3	6394446	H	1.81	2320	0	0	0	330	2320	0%	0%	0%	14%	100%
	C32	385386.1	6394418	H	2.09	2320	0	0	10	420	2320	0%	0%	2%	18%	100%
	C33	385437.2	6394385	H	2.25	2670	0	0	40	2670	2670	0%	0%	0%	100%	100%
	C34	385491.1	6394383	H	2.30	1760	0	0	0	1760	1760	0%	0%	0%	100%	100%
	C35	385516.3	6394380	H	2.37	2291	0	0	2	2291	2291	0%	0%	0%	100%	100%
	C36	*385539*	*6394382*	*U*	*2.23*	825	0	0	10	825	825	0%	0%	2%	100%	100%
	C37	*385564*	*6394379*	*U*	*2.29*	2810	0	0	20	2810	2810	0%	0%	1%	100%	100%
	C38	385609.7	6394382	H	1.90	2132	0	0	25	460	1120	0%	0%	3%	22%	53%
	C39	385619.6	6394442	H	2.09	2364	0	0	55	880	2364	0%	0%	0%	37%	100%
	C40	385549.7	6394483	U	2.23	2509	0	0	5	780	2260	0%	0%	0%	31%	90%
	C41	*385537*	*6394453*	*U*	*1.63*	2406	0	0	0	0	170	0%	0%	0%	0%	7%
	C42	*385489*	*6394537*	*U*	*1.52*	1615	0	0	0	70	920	0%	0%	0%	4%	57%
	C43	385469.1	6394585	H	1.67	3422	0	0	0	3422	3422	0%	0%	0%	100%	100%
	C44	385420.2	6394618	H	2.06	2368	0	0	0	340	2368	0%	0%	0%	14%	100%
	C45	385384.3	6394659	H	2.14	2200	0	0	0	210	210	0%	0%	0%	10%	10%
	C46	*385303*	*6394632*	*U*	*2.21*	1990	0	0	0	0	0	0%	0%	0%	0%	0%
	C47	385254.4	6394640	H	2.14	3080	0	0	0	0	0	0%	0%	0%	0%	0%
	C48	385206.9	6394642	H	2.28	2721	0	0	0	0	0	0%	0%	0%	0%	0%
	C49	385118.5	6394776	H	2.50	2384	0	0	0	0	0	0%	0%	0%	0%	0%
	C50	385113.7	6394827	H	2.33	3291	0	0	0	0	0	0%	0%	0%	0%	0%
	C51	*385092*	*6394859*	*U*	*2.49*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C52	*385072*	*6394878*	*U*	*2.32*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C53	*385049*	*6394895*	*U*	*2.45*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C54	*385022*	*6394911*	*U*	*2.47*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C55	*384993*	*6394928*	*U*	*2.37*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C56	*384968*	*6394946*	*U*	*2.40*	2022	0	0	0	0	0	0%	0%	0%	0%	0%
	C57	*384943*	*6394965*	*U*	*2.31*	2044	0	0	0	0	0	0%	0%	0%	0%	0%
	C58	*384914*	*6394983*	*U*	*2.01*	2336	0	0	0	0	0	0%	0%	0%	0%	0%
	C59	384912.3	6394918	H	2.18	1835	0	0	0	15	270	0%	0%	0%	1%	15%
	Mill Cott	384090.3	6395002	H	2.13											
	Mill	384121.2	6395021	U	2.26											

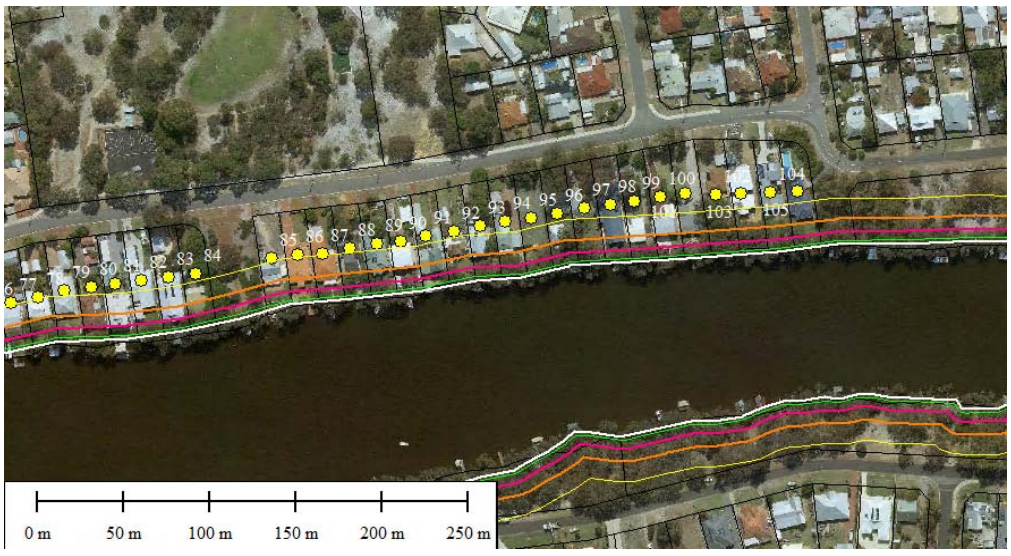
North Yunderup








ucture.shp [88 Features]
0 m
50 m
100 m
150 m
200 m
250 m


0 m
50 m
100 m
150 m
200 m
250 m

Depth of Overfloor Inundation Calculated for North Yunderup Properties

ASSUMPTIONS

ARI Considered: 1yr, 2yr, 5yr, 10yr, 20yr, 50yr, 100yr, 500yr

Planning Periods and Sea Level Rise

Planning Periods	2020	2030	2050	2070	2120
Sea Level Rise (m)	0	0.1	0.2	0.4	0.9
Assumed Freeboard of Houses			0.3	m	

Elevation Calculated from LiDAr Data

Depth of Overfloor Inundation (m) for each property. Calculated for 8 ARI inundation levels across the 5 Respective Planning Periods

Location	Property Pin	East	North	House=H Undeveloped = U	Elevation (mAHD)	Floor Level with Freeboard Allowance	2020 (Present Day) No SLR								2030 (+0.1m SLR)								2050 (+0.2m SLR)								2070 (+0.4m SLR)								2120 (+0.9m SLR)							
					Return Period		1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr
					Peak Inundation Level (m AHD)		0.60	0.78	0.87	0.91	0.96	1.04	1.09	1.44	0.70	0.88	0.97	1.01	1.06	1.14	1.19	1.54	0.80	0.98	1.07	1.11	1.16	1.24	1.29	1.64	1.00	1.18	1.27	1.31	1.36	1.44	1.49	1.84	1.50	1.68	1.77	1.81	1.86	1.94	1.99	2.34
North Yunderup Properties	1	385819.3	6394469	H	1.52	1.82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.04	0.12	0.17	0.52
	2	385835.2	6394464	H	1.56	1.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	0.08	0.13	0.48
	3	385854.1	6394454	H	1.77	2.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27
	4	385870.7	6394455	H	1.58	1.88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	0.11	0.46
	5	385883.7	6394474	H	1.54	1.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.10	0.15	0.50
	6	385899	6394480	H	1.63	1.93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.06	0.41
	7	385917.6	6394464	H	1.55	1.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.09	0.14	0.49
	8	385933.3	6394469	H	2.10	2.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	385949.3	6394470	H	2.09	2.39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10	385964.3	6394469	H	2.18	2.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	385977.6	6394482	H	1.75	2.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.29
	12	385996.4	6394464	H	1.55	1.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.09	0.14	0.49
	13	386010.1	6394479	H	2.13	2.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	14	*386028*	*6394471*	H	*1.96*	2.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08
	15	386041.8	6394481	H	1.90	2.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
	16	386056.9	6394481	H	2.20	2.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	17	386072.1	6394482	H	1.94	2.24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.10
	18	386088.6	6394482	H	1.82	2.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.23
	19	386103.6	6394487	H	1.88	2.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.16
	20	386117.2	6394492	H	1.25	1.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	-	-	-	-	-	-	0.29	-	0.13	0.22	0.26	0.31	0.39	0.44	0.79
	21	386136.7	6394493	H	1.30	1.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	-	-	-	-	-	-	0.24	-	0.08	0.17	0.21	0.26	0.34	0.39	0.74
	22	386150.2	6394507	H	1.43	1.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11	-	-	0.04	0.08	0.13	0.21	0.26	0.61
	23	386163	6394526	H	2.10	2.40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	24	386177.8	6394537	H	1.99	2.29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05
	25	386193.7	6394546	H	1.26	1.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	-	-	-	-	-	-	0.28	-	0.12	0.21	0.25	0.30	0.38	0.43	0.78
	26	*386216*	*6394547*	H	*1.68*	1.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.36
	27	*386239*	*6394549*	H	*1.87*	2.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.17
	28	386255.4	6394549	H	1.29	1.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	0.25	-	0.09	0.18	0.22	0.27	0.35	0.40	0.75
	29	386271.6	6394552	H	0.99	1.29	-	-	-	-	-	-	-	0.15	-	-	-	-	-	-	-	0.25	-	-	-	-	-	-	-	0.35	-	-	-	0.02	0.07	0.15	0.20	0.55	0.21	0.39	0.48	0.52	0.57	0.65	0.70	1.05
	30	386288.1	6394555	H	1.00	1.30	-	-	-	-	-	-	-	0.14	-	-	-	-	-	-	-	0.24	-	-	-	-	-	-	-	0.34	-	-	-	0.01	0.06	0.14	0.19	0.54	0.20	0.38	0.47	0.51	0.56	0.64	0.69	1.04
	31	*386303*	*6394560*	H	*1.01*	1.31	-	-	-	-	-	-	-	0.14	-	-	-	-	-	-	-	0.24	-	-	-	-	-	-	-	0.34	-	-	-	0.01	0.05	0.14	0.19	0.54	0.20	0.38	0.47	0.51	0.56	0.64	0.69	1.04
	32	386319	6394564	H	2.42	2.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	33	386334.1	6394570	H	1.82	2.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.22
	34	386346.5	6394575	H	1.45	1.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	-	-	0.02	0.06	0.11	0.19	0.24	0.59
	35	386363	6394581	H	2.04	2.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	36	*386375*	*6394585*	H	*2.19*	2.49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	37	386389.4	6394592	H	1.57	1.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07	0.12	0.47
	38	*386404*	*6394601*	H	*1.48*	1.78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.06	-	-	-	0.03	0.08	0.16	0.21	0.56
	39	*386415*	*6394607*	H	*1.36*	1.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.18	-	0.02	0.11	0.15	0.20	0.28	0.33	0.68
	40	*386431*	*6394613*	H	*1.61*	1.91	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.09	0.44
	41	*386444*	*6394622*	H	*1.55*	1.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.09	0.14	0.49
	42	*386459*	*6394634*	H	*1.43*	1.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11	-	-	0.04	0.08	0.13	0.21	0.26	0.61
	43	*386483*	*6394643*	H	*1.10*	1.40	-	-	-	-	-	-	-	0.04	-	-	-	-	-	-	0.14	-	-	-	-	-	-	-	0.24	-	-	-	-	0.04	0.09	0.44	0.10	0.28	0.37	0.41	0.46	0.54	0.59	0.94
	44	*386507*	*6394648*	H	*1.29*	1.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	0.25	-	0.09	0.18	0.22	0.27	0.35	0.40	0.75
	45	386523	6394651	H	1.77	2.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27
	46	386536.8	6394653	H	1.93	2.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11
	47	386553.5	6394655	H	2.14	2.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	48	386569.3	6394659	H	1.77	2.07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.28
	49	386584.5	6394662	H	1.83	2.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.21
	50	386599.4	6394664	H	2.02	2.32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.07
	51	386613.8	6394666	H	2.32	2.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	52	386627.4	6394670	H	2.15	2.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	53	386644.3	6394673	H	1.95	2.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09
	54	386660	6394677	H	2.03	2.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01
	55	386693.7	6394687	H	1.67	1.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.37
	56	386711.3	6394689	H	2.24	2.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	57	386724.9	6394694	H	2.01	2.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
	58	*386739*	*6394697*	H	*2.23*	2.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	59	386754.8	6394701	H	2.14	2.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	60	386769.2	6394703	H	1.71	2.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33
	61	386784.7	6394708	H	1.81	2.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.23
	62	386798.3	6394711	H	2.09	2.39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	63	386813.7	6394717	H	2.25	2.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	64	386828	6394724	H	2.30	2.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	65	386846.3	6394738	H	2.37	2.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	66	*386870*	*6394754*	H	*2.23*	2.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	67	*386885*	*6394764*	H	*2.29*	2.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	68	386898.2	6394772	H	1.90	2.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
	69	386913.2	6394782	H	2.09	2.39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	70	386926.4	6394790	H	2.23	2.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	71	*386940*	*6394796*	H	*1.63*	1.93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.06	0.41
	72	*386954*	*6394801*	H	*1.52*	1.82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	0.04	0.12	0.17	0.52
	73	386969.1	6394806	H	1.67	1.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	0.37
	74	386984	6394811	H	2.06	2.36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	75	387000.4	6394815	H	2.14	2.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	76	*387015*	*6394819*	H	*2.21*	2.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	77	387029.9	6394822	H	2.14	2.44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	78	387045.3	6394825	H	2.28	2.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	79	387060.5	6394829	H	2.50	2.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	80	*387076*	6394831	H	2.33	2.63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	81	*387090*	*6394832*	H	*2.49*	2.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	82	*387105*	*6394835*	H	*2.32*	2.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	83	*387121*	*6394837*	H	*2.45*	2.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	84	*387137*	*6394839*	H	*2.47*	2.77	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	85	*387181*	*6394848*	H	*2.37*	2.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	86	*387196*	*6394850*	H	*2.40*	2.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	87	*387210*	*6394851*	H	*2.31*	2.61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	88	*387226*	*6394854*	H	*2.01*	2.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.03
	89	387241.7	6394856	H	2.18	2.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	90	387255.6	6394857	H	2.13	2.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	91	387270.3	6394861	H	2.26	2.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	92	387286.5	6394864	H	2.23	2.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	93	387301.3	6394867	H	2.21	2.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	94	387315.8	6394869	H	2.26	2.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	95	387331.4	6394872	H	2.12	2.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	96	387346	6394874	H	2.04	2.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
	97	387361.7	6394877	H	1.29	1.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-	-	-	-	-	0.25	-	0.09	0.18	0.22	0.27	0.35	0.40	0.75
	98	387376.9	6394879	H	1.96	2.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08
	99	387390.9	6394881	H	1.60	1.90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04	0.09	0.44
	100	387406	6394884	H	1.84	2.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20
	101	387420.6	6394886	H	1.91	2.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14
	102	387438.3	6394885	H	2.36	2.66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	103	387452.5	6394886	H	2.12	2.42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	104	387469.9	6394887	H	2.50	2.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	105	387485.2	6394887	H	2.50	2.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	106	385835	6394564	H	1.11	1.41	-	-	-	-	-	-	-	0.03	-	-	-	-	-	-	0.13	-	-	-	-	-	-	-	0.23	-	-	-	-	0.03	0.08	0.43	0.09	0.27	0.36	0.40	0.45	0.53	0.58	0.93
	107	385863.9	6394551	H	2.00	2.30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.04
	108	385884.2	6394551	H	1.63	1.93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.06	0.41

| | | |

Calculated Erosion Areas for North Yunderup RiverFront Properties

ASSUMPTIONS

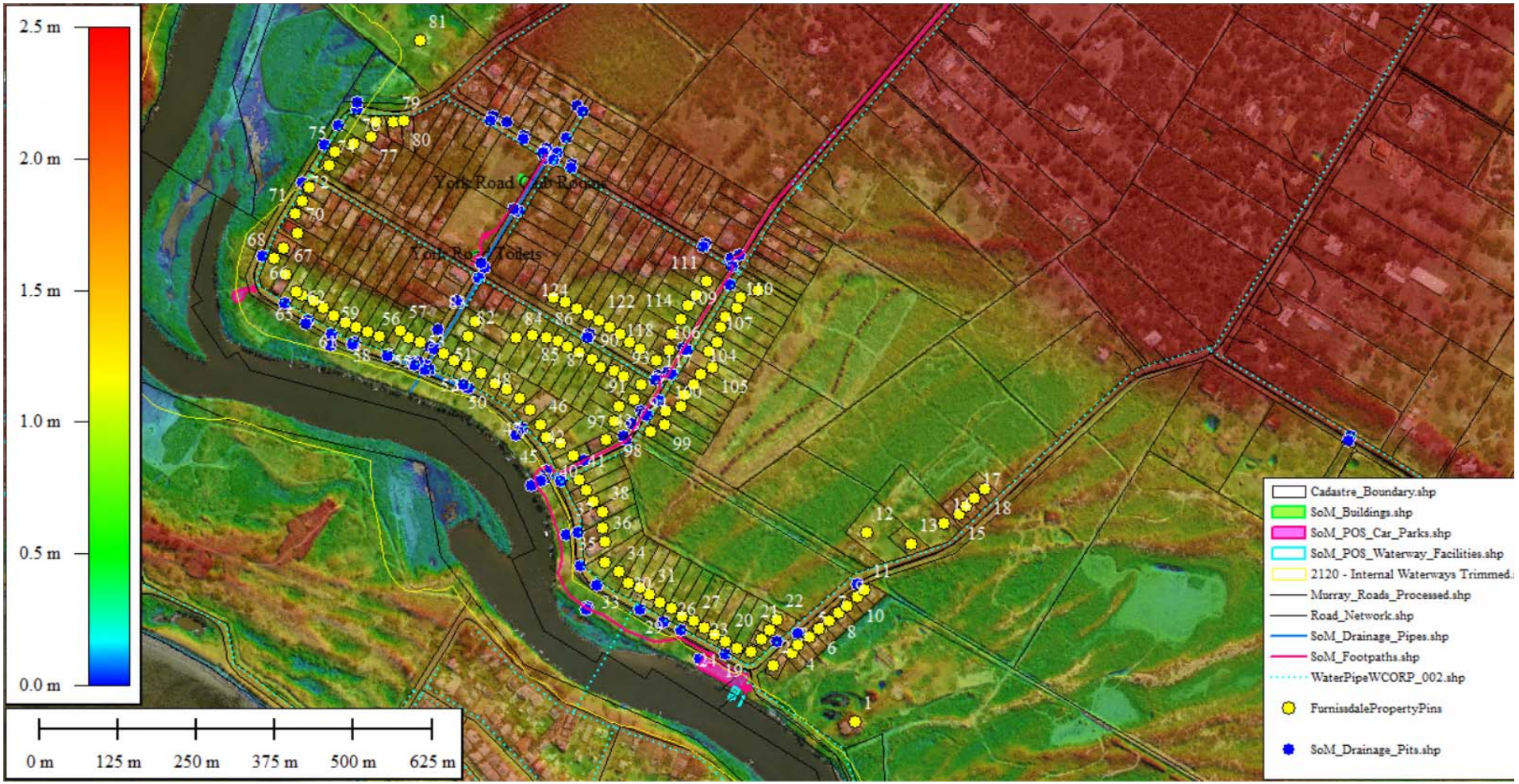
Estimate of the lot area / % lost to erosion over 5 planning periods

Erosion areas do not consider erosion of house a total loss of area (approach adopted at the Islands)

Elevation Calculated from LiDAr Data

Location	Property Pin	East	North	House=H Undeveloped = U	Elevation (mAHD)	Lot Size (m2)	Area of the Lot Which is lost to Erosion					% of the Total Lot Which is lost to Erosion				
							2120	2130	2150	2170	2120	2120	2130	2150	2170	2120
North Yunderup Riverfront Properties	1	385819.3	6394469	H	1.52	1368	40	80	160	285	1075	3%	6%	12%	21%	79%
	2	385835.2	6394464	H	1.56	1406	40	80	160	285	970	3%	6%	11%	20%	69%
	3	385854.1	6394454	H	1.77	1319	40	80	160	285	700	3%	6%	12%	22%	53%
	4	385870.7	6394455	H	1.58	1151	40	80	160	285	450	3%	7%	14%	25%	39%
	5	385883.7	6394474	H	1.54	1104	40	80	160	285	420	4%	7%	14%	26%	38%
	6	385899	6394480	H	1.63	1100	40	80	160	285	420	4%	7%	15%	26%	38%
	7	385917.6	6394464	H	1.55	1184	40	80	160	285	420	3%	7%	14%	24%	35%
	8	385933.3	6394469	H	2.10	1091	20	40	140	285	420	2%	4%	13%	26%	38%
	9	385949.3	6394470	H	2.09	1143	20	40	140	285	420	2%	3%	12%	25%	37%
	10	385964.3	6394469	H	2.18	981	20	40	140	285	420	2%	4%	14%	29%	43%
	11	385977.6	6394482	H	1.75	1099	20	40	140	285	420	2%	4%	13%	26%	38%
	12	385996.4	6394464	H	1.55	1151	20	40	140	285	420	2%	3%	12%	25%	36%
	13	386010.1	6394479	H	2.13	1174	20	40	140	285	420	2%	3%	12%	24%	36%
	14	*386028*	*6394471*	H	*1.96*	1094	20	40	140	285	420	2%	4%	13%	26%	38%
	15	386041.8	6394481	H	1.90	1158	20	40	140	285	420	2%	3%	12%	25%	36%
	16	386056.9	6394481	H	2.20	1123	20	40	140	285	420	2%	4%	12%	25%	37%
	17	386072.1	6394482	H	1.94	1125	20	40	140	285	420	2%	4%	12%	25%	37%
	18	386088.6	6394482	H	1.82	1113	20	40	140	285	420	2%	4%	13%	26%	38%
	19	386103.6	6394487	H	1.88	1097	20	40	140	285	420	2%	4%	13%	26%	38%
	20	386117.2	6394492	H	1.25	1058	20	40	140	285	420	2%	4%	13%	27%	40%
	21	386136.7	6394493	H	1.30	1160	20	40	140	285	420	2%	3%	12%	25%	36%
	22	386150.2	6394507	H	1.43	1101	20	40	140	285	420	2%	4%	13%	26%	38%
	23	386163	6394526	H	2.10	1137	20	40	140	285	420	2%	4%	12%	25%	37%
	24	386177.8	6394537	H	1.99	1139	0	0	140	285	420	0%	0%	12%	25%	37%
	25	386193.7	6394546	H	1.26	1153	0	0	160	340	380	0%	0%	14%	29%	33%
	26	*386216*	*6394547*	H	*1.68*	1822	0	0	120	220	730	0%	0%	7%	12%	40%
	27	*386239*	*6394549*	H	*1.87*	1073	0	0	140	220	400	0%	0%	13%	21%	37%
	28	386255.4	6394549	H	1.29	1008	20	40	150	220	410	2%	4%	15%	22%	41%
	29	386271.6	6394552	H	0.99	1005	20	40	160	220	410	2%	4%	16%	22%	41%
	30	386288.1	6394555	H	1.00	1003	20	40	120	220	410	2%	4%	12%	22%	41%
	31	*386303*	*6394560*	H	*1.01*	1006	0	0	110	220	410	0%	0%	11%	22%	41%
	32	386319	6394564	H	2.42	1046	20	40	115	220	410	2%	4%	11%	21%	39%
	33	386334.1	6394570	H	1.82	1078	0	0	120	220	410	0%	0%	12%	20%	38%
	34	386346.5	6394575	H	1.45	1102	0	0	125	220	410	0%	0%	13%	20%	37%
	35	386363	6394581	H	2.04	1037	20	40	140	220	410	2%	4%	8%	21%	40%
	36	*386375*	*6394585*	H	*2.19*	888	20	40	80	220	410	2%	5%	9%	25%	46%
	37	386389.4	6394592	H	1.57	984	20	40	80	220	410	2%	4%	8%	22%	42%
	38	*386404*	*6394601*	H	*1.48*	979	20	40	80	220	410	2%	4%	13%	22%	42%
	39	*386415*	*6394607*	H	*1.36*	970	0	0	130	220	410	0%	0%	13%	23%	42%
	40	*386431*	*6394613*	H	*1.61*	969	0	0	125	220	410	0%	0%	12%	23%	42%
	41	*386444*	*6394622*	H	*1.55*	1550	0	0	120	220	410	0%	0%	7%	14%	26%
	42	*386459*	*6394634*	H	*1.43*	951	0	0	110	200	410	0%	0%	19%	21%	43%
	43	*386483*	*6394643*	H	*1.10*	1040	0	0	180	380	710	0%	0%	6%	37%	68%
	44	*386507*	*6394648*	H	*1.29*	1070	0	0	60	180	410	0%	0%	5%	17%	38%
	45	386523	6394651	H	1.77	1038	0	0	55	180	410	0%	0%	6%	17%	39%
	46	386536.8	6394653	H	1.93	1898	0	0	60	180	410	0%	0%	3%	9%	22%
	47	386553.5	6394655	H	2.14	1014	0	0	55	180	410	0%	0%	6%	18%	40%
	48	386569.3	6394659	H	1.77	1049	0	0	60	180	410	0%	0%	6%	17%	39%
	49	386584.5	6394662	H	1.83	1056	0	0	60	180	410	0%	0%	1%	17%	39%
	50	386599.4	6394664	H	2.02	1007	0	0	6	180	410	0%	0%	5%	18%	41%
	51	386613.8	6394666	H	2.32	1037	0	0	55	180	410	0%	0%	6%	17%	40%
	52	386627.4	6394670	H	2.15	1037	0	0	60	180	410	0%	0%	6%	17%	40%
	53	386644.3	6394673	H	1.95	1016	0	0	60	180	410	0%	0%	6%	18%	40%
	54	386660	6394677	H	2.03	893	0	0	60	180	410	0%	0%	2%	20%	46%
	55	386693.7	6394687	H	1.67	898	0	0	20	280	450	0%	0%	9%	31%	50%
	56	386711.3	6394689	H	2.24	921	0	0	80	280	450	0%	0%	12%	30%	49%
	57	386724.9	6394694	H	2.01	996	0	0	110	280	450	0%	0%	15%	28%	45%
	58	*386739*	*6394697*	H	*2.23*	919	0	0	150	280	450	0%	0%	16%	30%	49%
	59	386754.8	6394701	H	2.14	994	50	100	150	280	450	5%	10%	17%	28%	45%
	60	386769.2	6394703	H	1.71	964	50	100	165	280	450	5%	10%	17%	29%	47%
	61	386784.7	6394708	H	1.81	964	50	100	160	280	450	5%	10%	15%	29%	47%
	62	386798.3	6394711	H	2.09	935	50	100	140	280	450	5%	11%	16%	30%	48%
	63	386813.7	6394717	H	2.25	941	50	100	145	280	450	5%	11%	9%	30%	48%
	64	386828	6394724	H	2.30	916	20	40	80	280	450	2%	4%	29%	31%	49%
	65	386846.3	6394738	H	2.37	1963	25	50	265	605	450	1%	3%	8%	31%	23%
	66	*386870*	*6394754*	H	*2.23*	1066	40	80	150	280	450	4%	8%	15%	26%	42%
	67	*386885*	*6394764*	H	*2.29*	1086	40	80	160	280	450	4%	7%	15%	26%	41%
	68	386898.2	6394772	H	1.90	1033	40	80	160	280	450	4%	8%	15%	27%	44%
	69	386913.2	6394782	H	2.09	979	40	80	160	280	450	4%	8%	16%	29%	46%
	70	386926.4	6394790	H	2.23	1050	40	80	160	280	460	4%	8%	15%	27%	44%
	71	*386940*	*6394796*	H	*1.63*	1011	40	80	160	280	460	4%	8%	16%	28%	45%
	72	*386954*	*6394801*	H	*1.52*	898	40	80	160	280	460	4%	9%	18%	31%	51%
	73	386969.1	6394806	H	1.67	924	40	80	160	280	460	4%	9%	18%	30%	50%
	74	386984	6394811	H	2.06	915	30	60	170	280	460	3%	7%	19%	31%	50%
	75	387000.4	6394815	H	2.14	893	30	60	170	280	460	3%	7%	19%	31%	52%
	76	*387015*	*6394819*	H	*2.21*	926	30	60	170	280	460	3%	6%	18%	30%	50%
	77	387029.9	6394822	H	2.14	1007	30	60	170	270	460	3%	6%	17%	27%	46%
	78	387045.3	6394825	H	2.28	991	30	60	170	270	460	3%	6%	17%	27%	46%
	79	387060.5	6394829	H	2.50	957	30	60	170	270	460	3%	6%	18%	28%	48%
	80	387076	6394831	H	2.33	938	30	60	170	270	460	3%	6%	19%	29%	49%
	81	*387090*	*6394832*	H	*2.49*	961	35	70	180	270	460	4%	7%	19%	28%	48%
	82	*387105*	*6394835*	H	*2.32*	1014	35	70	180	270	460	3%	7%	17%	27%	45%
	83	*387121*	*6394837*	H	*2.45*	1000	25	50	175	270	460	3%	5%	17%	27%	46%
	84	*387137*	*6394839*	H	*2.47*	972	25	50	170	270	460	3%	5%	18%	28%	47%
	85	*387181*	*6394848*	H	*2.37*	847	5	10	175	270	460	1%	1%	17%	32%	54%
	86	*387196*	*6394850*	H	*2.40*	878	10	20	140	270	460	1%	2%	16%	31%	52%
	87	*387210*	*6394851*	H	*2.31*	891	10	20	140	270	460	1%	2%	16%	30%	52%
	88	*387226*	*6394854*	H	*2.01*	861	10	20	140	270	460	1%	2%	16%	31%	53%
	89	387241.7	6394856	H	2.18	879	10	20	140	270	460	1%	2%	16%	31%	52%
	90	387255.6	6394857	H	2.13	871	10	20	140	270	460	1%	2%	16%	31%	53%
	91	387270.3	6394861	H	2.26	883	10	20	140	270	460	1%	2%	16%	31%	52%
	92	387286.5	6394864	H	2.23	854	10	20	140	270	460	1%	2%	16%	32%	54%
	93	387301.3	6394867	H	2.21	899	10	20	140	270	460	1%	2%	16%	30%	51%
	94	387315.8	6394869	H	2.26	871	10	20	140	240	460	1%	2%	14%	28%	53%
	95	387331.4	6394872	H	2.12	941	10	20	120	240	460	1%	2%	13%	26%	49%
	96	387346	6394874	H	2.04	898	10	20	120	240	460	1%	2%	13%	27%	51%
	97	387361.7	6394877	H	1.29	1001	10	20	120	240	460	1%	2%	12%	24%	46%
	98	387376.9	6394879	H	1.96	1007	10	20	120	240	460	1%	2%	12%	24%	46%
	99	387390.9	6394881	H	1.60	906	10	20	120	240	460	1%	2%	13%	26%	51%
	100	387406	6394884	H	1.84	967	10	20	120	240	460	1%	2%	12%	25%	48%
	101	387420.6	6394886	H	1.91	1121	10	20	120	240	460	1%	2%	11%	21%	41%
	102	387438.3	6394885	H	2.36	1015	10	20	120	220	460	1%	2%	12%	22%	45%
	103	387452.5	6394886	H	2.12	1030	10	20	120	220	460	1%	2%	12%	21%	45%
	104	387469.9	6394887	H	2.50	1084	10	20	120	220	460	1%	2%	11%	20%	42%
	105	387485.2	6394887	H	2.50	960	10	20	120	220	460	1%	2%	0%	23%	48%

Furnissdale



Depth of Overfloor Inundation Calculated for Furnissdale Properties

ASSUMPTIONS

ARI Considered: 1yr, 2yr, 5yr, 10yr, 20yr, 50yr, 100yr, 500yr

Planning Periods and Sea Level Rise

Planning Periods	2020	2030	2050	2070	2120
Sea Level Rise (m)	0	0.1	0.2	0.4	0.9
Assumed Freeboard of Houses			0.3	m	

Elevation Calculated from LiDAr Data

Depth of Overfloor Inundation (m) for each property. Calculated for 8 ARI inundation levels across the 5 Respective Planning Periods

Location	Property Pin	East	North	House=H Undeveloped = U	Elevation (mAHD)	Floor Level with Freeboard Allowance	2020 (Present Day) No SLR								2030 (+0.1m SLR)								2050 (+0.2m SLR)								2070 (+0.4m SLR)								2120 (+0.9m SLR)							
					Return Period		1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr
					Peak Inundation Level (m AHD)		0.60	0.78	0.87	0.91	0.96	1.04	1.09	1.44	0.70	0.88	0.97	1.01	1.06	1.14	1.19	1.54	0.80	0.98	1.07	1.11	1.16	1.24	1.29	1.64	1.00	1.18	1.27	1.31	1.36	1.44	1.49	1.84	1.50	1.68	1.77	1.81	1.86	1.94	1.99	2.34
Furnissdale Properties	1	384215	6396161	H	1.89	2.19																																									0.15
	2	384085	6396251	H	1.87	2.17																																									0.17
	3	384113.4	6396271	H	1.74	2.04																																									0.30
	4	384124.1	6396284	H	1.62	1.92																																								0.02	0.07	0.42
	5	384141	6396296	H	1.63	1.93																																								0.01	0.06	0.41
	6	384156.4	6396309	H	1.67	1.97																																									0.02	0.37
	7	384172.8	6396323	H	1.58	1.88																																								0.06	0.12	0.47
	8	384187.5	6396337	H	1.77	2.07																																										0.27
	9	384201.4	6396348	H	1.44	1.74																																							0.03	0.07	0.12	0.20	0.25	0.60
	10	384217.3	6396362	H	1.55	1.85																																								0.01	0.09	0.14	0.49
	11	384229.8	6396372	H	1.51	1.81																																								0.05	0.13	0.18	0.53
	12	384232.3	6396446	H	1.54	1.84																																								0.02	0.11	0.16	0.51
	13	384303.4	6396447	H	1.60	1.90																																								0.04	0.09	0.44
	14	*384355*	*6396481*	H	*1.73*	2.03																																											0.31
	15	384379.3	6396496	H	1.83	2.13																																											0.21
	16	384390.3	6396509	H	1.90	2.20																																											0.14
	17	384404.2	6396522	H	2.05	2.35																																											-
	18	384419.6	6396536	H	1.95	2.25																																											0.09
	19	384049.3	6396274	H	1.26	1.56																																											0.08								0.28																		

| | | |

Appendix I

Economic Report (Rhelm)

I.1 Economic Analysis - Technical Report



engineering | environmental | economics | engagement

Shire of Murray: Coastal Hazard Risk Management and Adaptation Planning

Economic Assessment

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Prepared for: **Baird**

February 2022

Contact Information

Rhelm Pty Ltd
ABN : 55 616 964 517
Level 1, 50 Yeo Street
Neutral Bay NSW 2089
Australia

Lead Author:
Rhys Thomson
contact@rhelm.com.au

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Cover Image: *Properties on Ballee Island (CNES / Airbus Maxar Technologies, Google Maps, 2022)*

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Executive Summary

Overview

The community of the Shire of Murray (SoM) are facing the adverse impacts of coastal erosion and inundation on their coastlines. The vulnerability of land use and development within the estuarine and tidally influenced riverine zone from physical process hazards is expected to increase in the future with the impacts of climate change. The shoreline areas in the SoM are currently impacted by erosion and inundation processes with loss of nature reserves, foreshore parkland and residential properties.

Objectives & Methodology

In order to ensure that the coastal hazard is factored into decision-making for future planning requirements, a Coastal Hazard Risk Management and Adaptation Planning (CHRMAP) is being undertaken. The CHRMAP process is a risk-based approach to ensure that the coastal hazard is factored into decision-making for future planning requirements. The overall objective of the study is to forecast inundation and erosion paths between 2020 to 2120, in order to cost estimate necessary actions by council or other government bodies to protect both public and private assets.

The assessment has been undertaken for erosion and inundation across five timeline scenarios associated with sea level rise (SLR):

- 2020: no SLR
- 2030: +0.1m SLR
- 2050: +0.2m SLR
- 2070: +0.4m SLR
- 2120: +0.9m SLR.

The assessment has focused on a part of the overall Shire of Murray CHRMAP study area, being:

- North Yunderup
- South Yunderup
- Murray Delta Islands
- Kooljerrenup Nature Reserve

Assessment Scenarios

The economic cost benefit analysis (CBA) assesses various scenarios against a “base case” scenario. In this case, a “do-minimum” scenario was adopted for the base case condition. Under this scenario, no mitigation is undertaken to protect foreshore areas or property, and erosion and inundation will continue to worsen and impact the study area.

Mitigation options are then compared with the base case scenario, to determine the overall economic viability of implementing these mitigation measures. Two key types of mitigation measures were assessed:

- Hard engineering option, which would include typical foreshore treatments like revetments;
- Nature based solutions, which include a combination of vegetation and softer engineering solutions to provide protection.

A separate option was considered for Kooljerrenup Nature Reserve as a part of the CHRMAP. Under this option, an adaption strategy of purchasing land on the eastern side of the reserve is considered, to

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mitigate the loss of land due to erosion on the shoreline side. This option has not been explicitly assessed as a part of the CBA, but the base case economic loss of land has been estimated to assist in informing this option.

Further discussion on these is provided in the overall CHRMAP report.

Costs estimates for these mitigation options were provided by Baird and include both the capital costs and maintenance costs.

Base Case Economic Impacts

Under the base case, economic impacts from both erosion and inundation were considered. A summary of these various impacts is provided in Table i.

Table i. Base Case Impacts

Location	Mitigation Option	Inundation	Erosion
Yunderup Island	Hard	$510,258	$65,782
	Nature Based	$510,258	$65,782
Ballee Island	Hard	$400,968	$89,853
	Nature Based	$400,968	$89,853
Coolenup Island	Hard	$2,108,132	$154,764
	Nature Based	$2,108,132	$154,764
Nth Yunderup Shoreline	Hard	$102,238	$5,181,221
	Nature Based	$102,238	$5,181,221
South Yunderup	Hard	$110,807	$1,624,422
	Nature Based	$110,807	$1,624,422
Kooljerrenup Nature Reserve		$0	$5,091,392

Cost Benefit Analysis

The benefits for the mitigation options were considered in terms of the protection provided for both erosion, as well as inundation of properties. Economic values were estimated for both the base case condition, as well as the mitigation option, to determine an overall net benefit. These were compared against the estimated costs for the project. A summary of the economic results is shown in Table ii.

Climate change results in a non-stationary environment, where risks and impacts on the community are expected to change over time. For inundation and erosion, with sea level rise these are anticipated to worsen. From an economic viewpoint, while a project may not be viable to implement today, it may be viable in the future as climate change continues to worsen. Understanding when this will occur can assist in SoM planning into the future. A summary of an estimate of when this would occur, based on the sea level rise projections, is provided in Table ii.

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Table ii. Summary of Economic Results

Location	Mitigation Option	Total Costs	Total Benefits	NPV[1]	BCR	Timeframe for Viability[2]
Yunderup Island	Hard	4.16	0.58	-3.58	0.14	30 – 50 years
	Nature Based	0.47	0.04	-0.43	0.08	30 – 50 years
Ballee Island	Hard	1.72	0.49	-1.23	0.29	20 – 40 years
	Nature Based	0.09	0.05	-0.03	0.61	10 – 20 years
Coolenup Island	Hard	12.81	2.26	-10.55	0.18	>50 years
	Nature Based	0.66	0.09	-0.57	0.14	20 – 40 years
Nth Yunderup Shoreline	Hard	5.69	5.28	-0.40	0.93	5 – 10 years
	Nature Based	0.64	3.11	2.46	4.82	current
Sth Yunderup Shoreline	Hard	5.45	1.74	-3.72	0.32	10 – 30 years
	Nature Based	0.62	0.97	0.36	1.74	current

A distributional analysis is a useful tool for understanding the key beneficiaries for a mitigation option. It is undertaking by assessing the beneficiaries for each of the net benefits identified. For the Shire of Murray, the key beneficiaries are private landowners, as well as the Shire of Murray (though the public assets such as reserves). A summary of the distributional analysis is provided in Table iii.

Table iii. Distributional Analysis

Location	Mitigation Option	Private Landowners	Shire of Murray
Yunderup Island	Hard	100%	0%
	Nature Based	100%	0%
Ballee Island	Hard	100%	0%
	Nature Based	100%	0%
Coolenup Island	Hard	100%	0%
	Nature Based	100%	0%
Nth Yunderup Shoreline	Hard	100%	0%
	Nature Based	100%	0%
Sth Yunderup Shoreline	Hard	90%	10%
	Nature Based	88%	12%

[1] Net Present Value (the difference between the net benefits and net costs)
[2] Indicative timeframe at which the project may have a BCR > 1 in the future.

DRAFT

Table of Contents

Executive Summary ..... **ii**

Overview ii

Objectives & Methodology ii

Assessment Scenarios ii

Base Case Economic Impacts iii

Cost Benefit Analysis iii

1 Introduction **1**

2 Economic Assessment **4**

2.1 Assumptions 4

2.2 Scenarios 4

2.2.1 The Base Case 4

2.2.2 Mitigation Options 4

3 Base Case **6**

3.1 Erosion 6

3.1.1 Private Land 6

3.1.2 Private Houses 7

3.1.3 Public Assets 7

3.1.4 Kooljerrenup Nature Reserve 8

3.2 Flood Inundation and Damages 9

3.3 Other Considerations 11

4 Mitigation Options **12**

4.1 Option Performance 12

4.2 Mitigation Option Costs 12

5 Economic Results **13**

5.1 Benefit Summary 13

5.2 Cost Benefit Analysis 14

5.3 Distributional Analysis 15

5.4 Sensitivity Analysis 15

6 References **17**

DRAFT

Figures

Figure 1-1. Locality 2
Figure 1-2. Key Areas of Investigation 2
Figure 1-3. Kooljerrenup Nature Reserve 3
Figure 2-1. Example of "Hard" Engineering Solution (left) and Nature Based Solution (right) 5
Figure 3-1 Kooljerrenup Nature Reserve forecast erosion 9
Figure 3-2 Water levels (m AHD) for each ARI in each modelled year (SLR scenario) 10
Figure 3-3 Residential damage curve adopted for the analysis 11

Tables

Table 3-1 Kooljerrenup Nature Reserve: forecast land lost to erosion 8
Table 3-2 Water levels (m AHD) for each ARI in each modelled year (SLR scenario) 9
Table 3-3 Flood damage estimation tool: user inputs 10
Table 4-1 Mitigation Option Protection Levels 12
Table 4-2. Summary of Mitigation Option Costs 12
Table 5-1. Benefit Summary (present values based on discount rate of 7%pa) 13
Table 5-2 Economic assessment results: individual projects ($M, present value at 7% p.a.) 14
Table 5-3. Distributional Analysis 15
Table 5-4. Sensitivity Analysis - BCR 16

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Acronyms

AAD	Annual Average Damage
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AWE	Average Weekly Earnings
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CHRMAP	Coastal Hazard Risk Management and Adaptation Planning
CMU	Coastal Management Units
FYRR	First Year Rate of Return
IA	Infrastructure Australia
IRR	Internal Rate of Return
LGA	Local Government Area
NPV	Net Present Value
NPVI	Net Present Value per Dollar of Capital Investment
NSW	New South Wales
PV	Present Value
SoM	Shire of Murray
SLR	Sea Level Rise

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1 Introduction

The community of the Shire of Murray (SoM) are facing the adverse impacts of coastal erosion and inundation on their coastlines. The vulnerability of land use and development within the estuarine and tidally influenced riverine zone from physical process hazards is expected to increase in the future with the impacts of climate change. The shoreline areas in the SoM are currently impacted by erosion and inundation processes with loss of fringing vegetation in some areas of the Peel Harvey Estuary, the Murray and Serpentine River entrances experiencing erosion events and the delta islands being periodically affected by high water levels and erosive conditions. The influence of climate change and sea level rise is anticipated to exacerbate the erosion and high-water levels.

The Shire of Murray is located 80km South of Perth in Western Australia with a population of approximately 18,000. An overview of the locality is shown in Figure 1-1. The focus of this economic assessment is on four key areas within the study area, namely North Yunderup, South Yunderup, the Yunderup delta islands, and Koolijerrenup Nature Reserve (Figure 1-2 and Figure 1-3). These four areas were selected through the CHRMAP process, due to their vulnerability to both erosion and inundation events in the future and their containment of highly valued or protected lands.

The economic assessment undertaken as part of this report refines the evaluation of a number of options by quantifying the economic value of the various adaptation options considered to mitigate against hazards associated with coastal erosion. The Cost Benefit Analysis (CBA) was performed to consider the economic costs and benefits of the protection options, along with the implications of the Base Case for the study areas.

As part of this CHRMAP economic assessment, five sea level rise (SLR) scenarios were modelled:

- 2020: no SLR
- 2030: +0.1m SLR
- 2050: +0.2m SLR
- 2070: +0.4m SLR
- 2120: +0.9m SLR.

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Figure 1-1. Locality

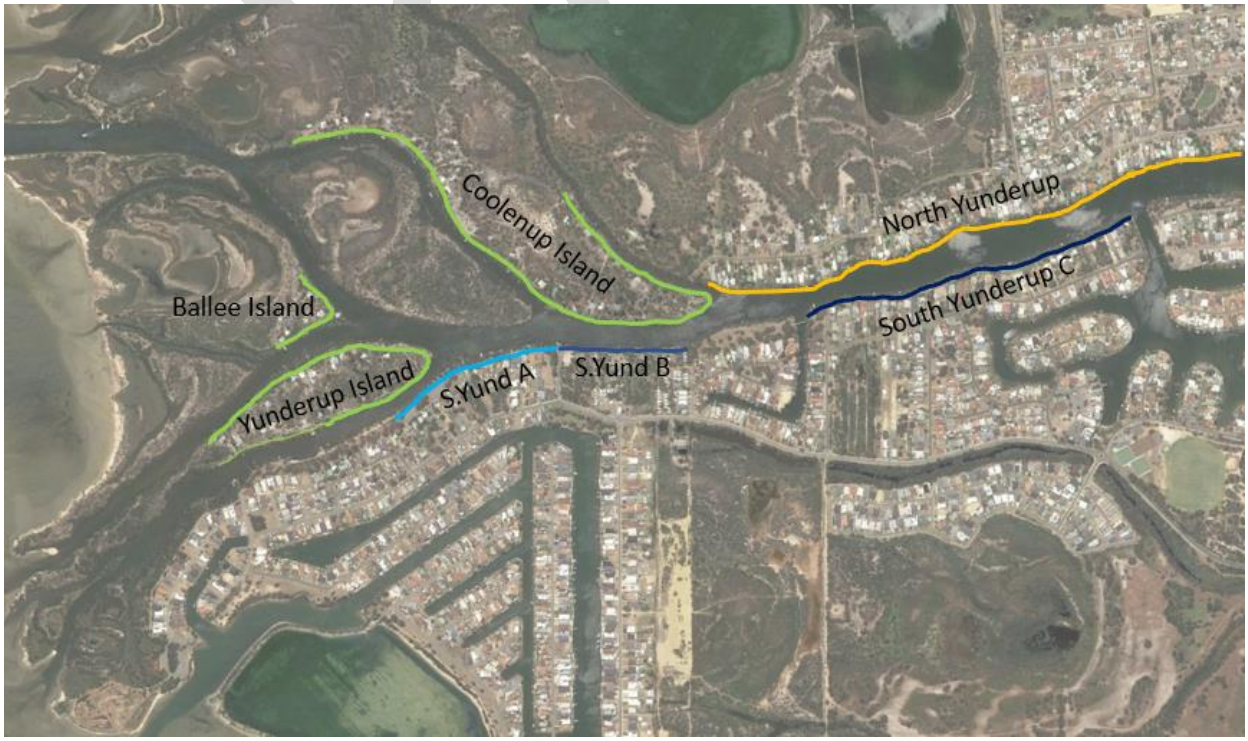


Figure 1-2. Key Areas of Investigation

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Figure 1-3. Kooljerrenup Nature Reserve

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2 Economic Assessment

The economic assessment considers the comparative costs and benefits of the proposed mitigation options against a base case scenario.

The economic merit of the individual projects was determined by comparing the present value (PV) of the change in net economic benefits (compared with the Do-Minimum base case) less the change in capital and maintenance costs. The key benefits incorporated within this Cost Benefit Analysis (CBA) assessment were in the form of savings in inundation damages and erosion loss.

Standard evaluation metrics of Net Present Value (NPV), Net Present Value of Investment (NPVI), and Internal Rate of Return (IRR), have been determined to support the assessment of viability.

2.1 Assumptions

For the purposes of this assessment, a number of assumptions have been made to facilitate estimation of economic values. These include:

- 2021/22 was utilised as the base year of assessment
- 2026 is the 'year of opening', i.e. the commencement of project benefits
- Capital expenditure costs for each project were deemed to be expended in 2025, and include the works associated with upgrading and maintaining public assets
- The length of the economic assessment period is 50 years (i.e. 2026 to 2075)
- A primary discount rate of 7% p.a. has been applied and sensitivities of 4% and 10% p.a. have also been calculated.

Realistically, if multiple options were implemented, these would likely be staggered over a number of years. However, the same 'year of opening' of the various options considered was adopted to provide a consistent base against which to compare the various options.

Where other alternative parameters or other assumptions were used in the identification and evaluation of relevant costs and benefits, these are documented in the following subsections.

2.2 Scenarios

A cost benefit analysis compares mitigation options against a base case. The definition of these scenarios is outlined below.

2.2.1 The Base Case

In the absence of the project, it is assumed that a 'do-minimum' approach would be adopted. The Council would be assumed to take no action to mitigate against the forecast inundation and erosion and a planned retreat approach would be adopted. This scenario and the assessment has been further discussed in Section 3.

2.2.2 Mitigation Options

The overall CHRMAP has considered a number of options to mitigate the effects of erosion and inundation, as well as climate change. This long list of options was then evaluated through a Multi-Criteria Assessment (MCA), and shortlisted options were identified for further assessment. The details of these option are discussed in the CHRMAP report.

Of the short-listed options, the following options have been assessed as part of this economic assessment:

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- "Hard" engineering solution – this involves the construction of a revetment/ seawall on the foreshore, to provide protection to properties and land against erosion. By raising the crest of the revetment, these solutions also provide protection against inundation as well.
- Nature based solutions – similar to above, these use vegetation and "softer" engineering approaches to provide protection against erosion. These options are not considered to provide significant benefits for inundation.

Examples of these solutions are shown in Figure 2-1.



Figure 2-1. Example of "Hard" Engineering Solution (left)[3] and Nature Based Solution (right)[4]

A separate option was considered for Kooljerrenup Nature Reserve as a part of the CHRMAP. Under this option, an adaption strategy of purchasing land on the eastern side of the reserve is considered, to mitigate the loss of land due to erosion on the shoreline side. This option has not been explicitly assessed as a part of the CBA, but the base case economic loss of land has been estimated to assist in informing this option.

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[3] https://cirtexcivil.co.nz/case-studies/tauranga-sea-wall-rock-revetment-terratex-k-geotextile/
[4] Syrinx Environmental (2018), Lower Murray River, Foreshore Stabilisation Guidelines. Prepared for the Shire of Murray, November 2018.

3 Base Case

The base case scenario considers an assessment of the impacts of inundation and erosion under current conditions as well as under the forecast impacts due to climate change.

3.1 Erosion

The erosion assessment under the base case assumes that no mitigating actions are undertaken to limit the erosion. The economic loss associated with the erosion includes:

- Loss of Private Land;
- Loss of Public Reserves and Nature Reserves;
- Loss of Public Assets (such as roads, parking areas etc).

The economic loss was quantified through the loss of land area or asset over time. Spatial analysis provided by Baird, predicts the percentage of land lost for each property lot and reserve within the CHRMAP study area for the five representative periods in time – 2020, 2030, 2050, 2070 and 2120.

3.1.1 Private Land

The valuation of properties was based on an assessment of the current property market conditions and the sales in the market across the previous decade. Land values were estimated based on property sale prices and deducting an estimate of the value of the house on the structure. This analysis was undertaken for 20 representative properties in the study area.

The intention is to derive a representative average land value for each of the key parts of the study area. It is not intended to be a precise property by property estimate, but rather than overall average to provide an indication of the economic loss.

The analysis estimated:

- North Yunderup foreshore properties have a value of $600 per square metre;
- South Yunderup foreshore properties have a value of $350 per square metre;

The Murray delta islands provided additional challenges in estimating land values. There was significant variation in property sale prices across the islands. Property sale prices ranged from $50,000 to over $800,000. Further, as the assessment areas adopted for each of the islands only have a few properties, the influence of land value can have a significant effect on the economic assessment.

Reviewing the sale values suggest that some of the higher prices may be associated with the infrastructure (house and other infrastructure) on the property, as much as the land value itself. Reviewing the various sales, an estimated land value of $80,000 per property was adopted. However, a sensitivity analysis was undertaken on this value to understand its influence on the results.

Using the above values, the loss of land was estimated at each snapshot period in time from the erosion estimates from Baird. A linear loss rate was assumed between these periods.

A further assumption was included in the analysis, where the property area falls below 500 square metres. At this point, it was assumed that the lot was no longer viable, and therefore the property would be completely lost. At this lot size, while it would be possible to reconstruct a house on the lot, the continual erosion would make that reconstruction not feasible. When this occurred on the property, the remainder of the property value is assumed as a loss.

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3.1.2 Private Houses

In addition to the loss of land, as erosion continues it can result in a loss of the house as well. When the erosion reaches the house, a loss of the asset is assumed (and the house is assumed to be reconstructed on the remainder of the residential lot).

The following was assumed for the building values:

- Murray Delta Islands: $198,000
- North Yunderup: $330,000
- South Yunderup: $330,000.

The cost for North Yunderup and South Yunderup has been derived from *Rawlinsons Construction Cost Guide 2019*. It is recognised that there is significant variance in building types within these areas, but these were adopted to provide a representative average.

The types of houses on the Murray delta islands are highly variable, with relatively modest structures to large houses. In general, the houses are of a smaller and or/ simpler construction type. In the absence of more precise valuations, an estimate of 60% of the North and South Yunderup was assumed.

3.1.3 Public Assets

The foreshore and parkland areas within the Yunderup and Murray Delta Islands study area, incurred erosion damages to not only private land areas, but also to public assets. Public assets were inclusive, but not limited to; boat ramps, bollards, carparks, footpaths, park utilities, reserves and signage.

The value for most assets were based on Shire of Murray Asset Database and were assigned to each component. Baird provided estimates of the periods of time when each of these assets would be lost to erosion.

The economic value of the reserves includes both the benefit that it provides to the community through their use of the asset, together with a "non-use" value, which is the amenity that is gained from the existence of the asset. The key public reserve areas are in South Yunderup and include foreshore sections of land as well as some parks.

Pascoe et al (2017) provides non-market values for a number of coastal areas but does not include estimates for parkland or bushland. While there are some similar studies on parkland values, most require some estimate of the usage of the parkland. Anecdotal information suggests a relatively low usage of the reserve assets, and therefore this was not included in the overall estimate. This will provide a lower bound estimate of the economic value.

Hence, for the purposes of this study, a non-use value per square metre was derived from a scaled value of Pascoe's shrubland valuation for the Byron Bay area in northern NSW. The shrubland valuation for Byron Bay was chosen as a basis due to the similarities to Yunderup's environmental and geographical characteristics, being both regional and coastal locations. Moreover, through research using *.id* (Informed Decisions) and the Australian Bureau of Statistics (ABS), it was found that both areas showed similar socio-economic characteristics with almost identical weekly household incomes and mortgage repayments. Hence, with such similarities, Pascoe's initial valuation of $73 per square metre was able to be scaled down to $24.41 per square metre through the weighting of the population of Byron Bay (9,246) and Yunderup (3,092).

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3.1.4 Kooljerrenup Nature Reserve

The reserve is listed as a strictly protected nature reserve under the International Union for Conservation of Nature (IUCN) since 1975 in the 1a category. This categorisation allows the Western Australia Department of Biodiversity, Conservation and Attractions to protect biodiversity and geomorphic features through strict controls and limitation of human visitation and use.

Without undertaking more complex willingness-to-pay or other detailed economic assessments, it is difficult to provide an economic value for these types of natural assets. However, there are a number of studies that investigate the value of environmental assets, and some of these can be translated to the local area to provide an indication of the value. However, it is recognised that there are a number of local factors and community values that can result in an alternative valuation. Therefore, any estimates provided in this report should be considered indicative.

The valuation for Kooljerrenup Nature Reserve has been derived from weighted adaptation of Pascoe et al (2017) non-market values for Scrubland, Marshlands and Estuaries. An estimate of $68.30 per square metre. Although this valuation derives from literature relating to coastal assets, it is argued that the reserve provides benefits for biodiversity and the conservation of geological structures which have a high value.

Baird provided estimates of the land area loss under the different time horizons is shown Table 3-1 and in Figure 3-1.

Table 3-1 Kooljerrenup Nature Reserve: forecast land lost to erosion

Year	SLR (m)	Total Area Lost (m^2)
2020	-	0
2030	+ 0.1	61,786
2050	+ 0.2	196,525
2070	+ 0.4	338,138
2120	+ 0.9	665,712

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Figure 3-1 Kooljerrenup Nature Reserve forecast erosion

3.2 Flood Inundation and Damages

The depth of inundation at properties across the study area was modelled for the five SLR scenarios listed in Section 1. The water level in each of these scenarios is presented in Table 3-2 and illustrated in Figure 3-2.

Table 3-2 Water levels (m AHD) for each ARI in each modelled year (SLR scenario)

Year	SLR (m)	1yr	2yr	5yr	10yr	20yr	50yr	100yr	500yr
2020	-	0.60	0.78	0.87	0.91	0.96	1.04	1.09	1.44
2030	+ 0.1	0.70	0.88	0.97	1.01	1.06	1.14	1.19	1.54
2050	+ 0.2	0.80	0.98	1.07	1.11	1.16	1.24	1.29	1.64
2070	+ 0.4	1.00	1.18	1.27	1.31	1.36	1.44	1.49	1.84
2120	+ 0.9	1.50	1.68	1.77	1.81	1.86	1.94	1.99	2.34

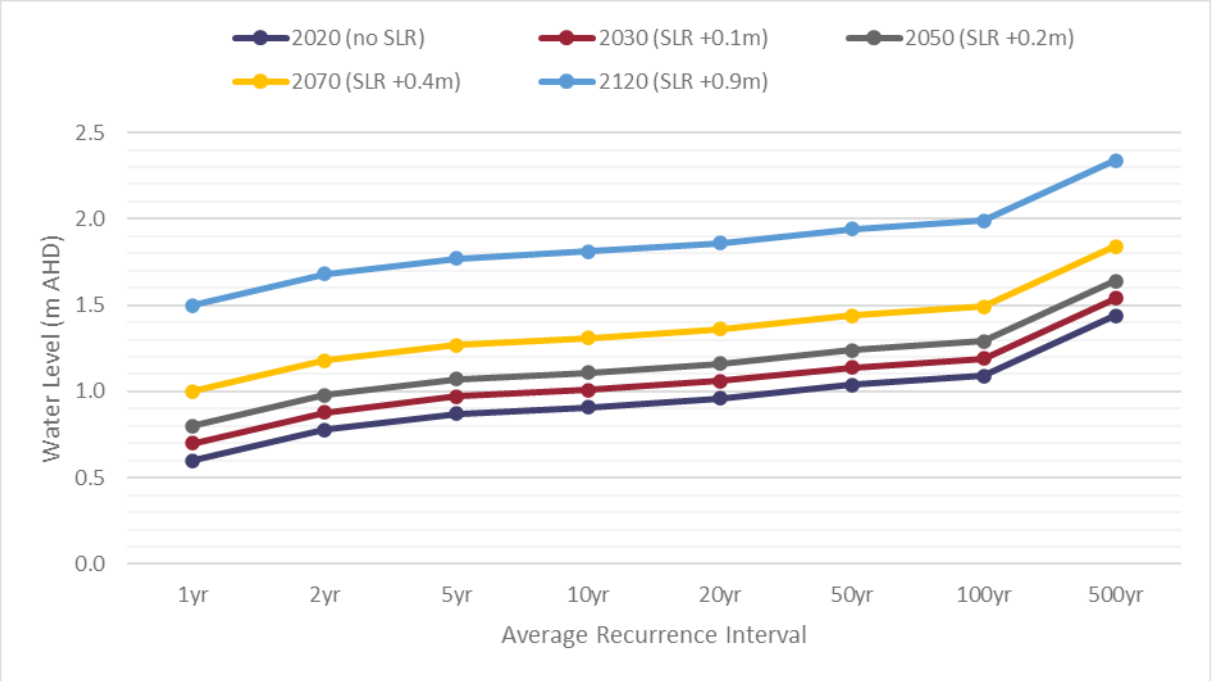


Figure 3-2 Water levels (m AHD) for each ARI in each modelled year (SLR scenario)

Baird provided information for the properties in the study area include:

- Estimated ground level at the house;
- Estimated floor level of the house, based on an assumed 0.3 metres above ground;
- The over floor flooding depth for different AEP events and under the different SLR scenarios.

Flood damages were calculated using the *Flood Damage Estimation Tool FD01* (DPE, 2022), which forms part of the NSW Floodplain Development Manual Update. This tool represents the culmination of the most recent research in flood damages in both Australian and Internationally. It is not specifically focused on NSW and can be adapted to other states in Australia. The tool facilitates the calculation of structural, internal (contents) and external damages for each property, as a function of the depth of inundation in each AEP event. In the absence of detailed property data, it was assumed that the majority of residential properties were single storey with a floor area of 240 square metres (categorised as 'large'). Some properties on some of the Murray Delta Islands were re-classified as small or medium based on an inspection of the aerial imagery.

A summary of the key model inputs is described in Table 3-3.

Table 3-3 Flood damage estimation tool: user inputs

Input	Value	Justification / Threshold
Replacement value	$2,000 per m^2	Default recommendation
Average value of contents	$490 per m^2	Default recommendation
External damages	$15,000 per property	If overfloor flooding is present
Clean-up costs	$4,000 per property	If overfloor flooding is present
Actual-to-potential ratio	0.9	Default recommendation

The base year of dollar values within the tool is 2019. As a result, in line with DPE guidance, Average Weekly Earnings (AWE)[5] has been used to inflate values to present day – the second quarter of the 2021/22 financial year – by a rate of 4.75%.

External damages were only incorporated when overfloor flooding occurred.

The residential damage curve used in the analysis, based on the above inputs, is displayed in Figure 3-3. It is noted that it is inclusive of structural, internal and external damages at a given overfloor flood depth.

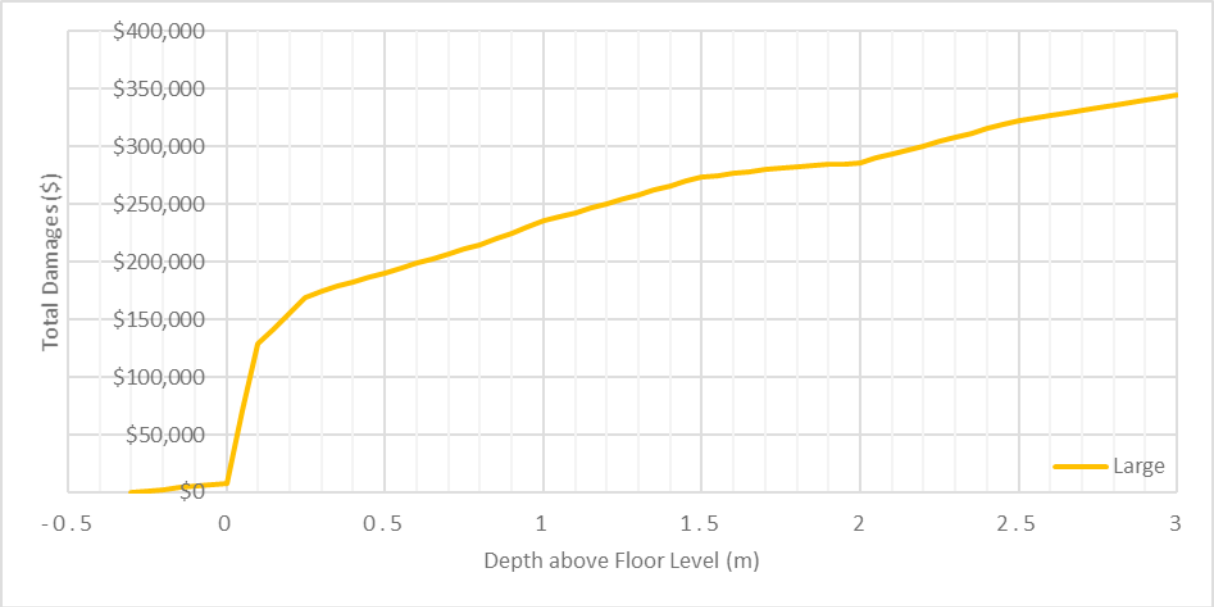


Figure 3-3 Residential damage curve adopted for the analysis

3.3 Other Considerations

The economic analysis focuses on the erosion and inundation impacts. However, there are a number of other considerations that are not directly included within this analysis:

- Tidal inundation – under sea level rise, tidal levels will increase, which will result in inundation of areas that were previously above the normal tidal limit. Regular tidal inundation of a residential property limits its potential viability, and may lead to a property needing to be abandoned if no mitigating actions are undertaken. A preliminary assessment was undertaken which suggests that the impact of this on properties was less than the influence of erosion, and therefore this was conservatively not included within the analysis.
- Groundwater Impacts – Increases in sea level rise will influence groundwater levels, particularly in the delta islands. This can result in impacts in building foundations, services etc.

[5] ABS Series ID - A85002148L

4 Mitigation Options

As identified in Section 2.2.2, two key options were considered; a hard engineering option and a nature-based option.

4.1 Option Performance

Following discussion with Baird, the following as assumed in terms of the performance of these options in terms of erosion and flood inundation protection. The assumed protection (and hence reduction in loss) under the different options is shown in Table 4-1

Table 4-1 Mitigation Option Protection Levels

Project	Inundation	Erosion
Hard Engineering	100%	100%
Nature Based Solution	0%	60%

4.2 Mitigation Option Costs

Capital and maintenance costs were provided by Baird for both option types, and for the different parts of the study area. Baird provided a low range and high range estimate for the capital costs. Based on these, a middle range estimate was adopted for the economics.

The annual maintenance cost of all projects is estimated to be 2% of the undiscounted capital cost for the life of the project, based on information provided by Baird. A summary of the capital and maintenance costs, together with the present value equivalent, is shown in Table 4-2.

Table 4-2. Summary of Mitigation Option Costs

Area	Mitigation Option	Maintenance Costs		Capital Costs	
		Annual	PV (7% p.a.)	Cost	PV (7% p.a.)
Yunderup Island	Hard	$79,800	$898,988	$3,990,000	$3,257,029
	Nature Based	$9,044	$101,885	$452,200	$369,130
Ballee Island	Hard	$33,000	$371,762	$1,650,000	$1,346,891
	Nature Based	$1,700	$19,151	$85,000	$69,385
Coolenup Island	Hard	$246,000	$2,771,318	$12,300,000	$10,040,464
	Nature Based	$12,648	$142,486	$632,400	$516,227
Nth Yunderup	Hard	$109,200	$1,230,195	$5,460,000	$4,456,986
	Nature Based	$12,376	$139,422	$618,800	$505,125
Sth Yunderup	Hard	*$104,700*	*$1,179,500*	*$5,235,000*	*$4,273,319*
	Nature Based	$11,866	$133,677	$593,300	$484,310

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5 Economic Results

5.1 Benefit Summary

A summary of the base case impacts to the study area, both in terms of inundation and erosion, are summarised in Table 5-1. The mitigation works target a reduction in these costs. Table 5-1 provides a summary of the mitigation residual cost under the mitigation scenario (for erosion and inundation) and the associated net benefit.

There are several key points to note from the estimated benefits:

- The inundation damages for Coolenup Island are high. This is a function of the number of residential properties on this island together with the low-lying nature of the terrain. However, as no floor level information was available, it is possible that the floor levels are higher than the assumed 0.3m above ground. If the floor levels are higher, then this would result in a different outcome. This is a similar outcome for the remainder of the Murray Delta Islands. The economic estimate could be refined with floor levels survey and more detailed information on each of the properties.
- Erosion damages for North Yunderup are relatively high. This is reflective of the higher density development in this area, the proximity of both the properties and the houses to the river edge and the higher value of land. By comparison, South Yunderup is lower as it has greater buffer in front of most properties as well as larger residential lots and generally a lower value.
- Based on the estimates provided here, an estimated erosion loss of around $5.1M for the Kooljerrenup Reserve is estimated.

Table 5-1. Benefit Summary (present values based on discount rate of 7%pa)

Location	Mitigation Option	Inundation Damages			Erosion Damages		
		Base Case	Project Case	Difference	Base Case	Project Case	Difference
Yunderup Island	Hard	$510,258	$0	$510,258	$65,782	$0	$65,782
	Nature Based	$510,258	$510,258	$0	$65,782	$26,313	$39,469
Ballee Island	Hard	$400,968	$0	$400,968	$89,853	$0	$89,853
	Nature Based	$400,968	$400,968	$0	$89,853	$35,941	$53,912
Coolenup Island	Hard	$2,108,132	$0	$2,108,132	$154,764	$0	$154,764
	Nature Based	$2,108,132	$2,108,132	$0	$154,764	$61,905	$92,858
Nth Yunderup Shoreline	Hard	$102,238	$0	$102,238	$5,181,221	$0	$5,181,221
	Nature Based	$102,238	$102,238	$0	$5,181,221	$2,072,488	$3,108,733
South Yunderup	Hard	$110,807	$0	$110,807	$1,624,422	$0	$1,624,422
	Nature Based	$110,807	$110,807	$0	$1,624,422	$649,769	$974,653
Kooljerrenup Nature Reserve		$0	N/A	N/A	$5,091,392	N/A	N/A

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5.2 Cost Benefit Analysis

The relative costs and benefits of the Project Case in comparison to the Base Case were compared through a Cost Benefit Analysis (CBA). The results of the CBA are summarised in Table 5-2. A positive NPV and BCR greater than one support a claim for the project to be considered as economically feasible.

Climate change results in a non-stationary environment, where risks and impacts on the community are expected to change over time. For inundation and erosion, with sea level rise these are anticipated to worsen. From an economic viewpoint, while a project may not be viable to implement today, it may be viable in the future as climate change continues to worsen.

An economic analysis was undertaken by "shifting" the start of the assessment forward in time to the point at which the BCR reaches 1. This represents the time at which the project is likely to be economically viable. This can provide useful information from a planning perspective, to allow for SoM to plan for future mitigation that might be required.

The time periods indicated here are based on the sea level rise rates that have been adopted in the study. A variation in those rates will result in a change to these timeframes. Therefore, these should be considered to be indicative.

A summary of the periods where each of the mitigation options and associated study areas will become viable is shown in Table 5-2.

For the Murray Delta Islands, the mitigation options have a BCR less than 1, suggesting that the options are presently not economically viable. This is a function of the low density of development on the islands and the large lots leading to relatively high mitigation option costing relative to the benefit. While that is the case at present, nature-based solutions on Ballee Island would become viable in the next 10 – 20 years based on current SLR projections. This is largely due to the larger erosion risk on this island and the relatively small area for the number of houses protected.

For North Yunderup, the nature-based solutions perform well, with a BCR of 4.8. This is due to the density of properties in this area and their proximity to the river. However, there may be practical challenges in implementing nature-based solutions within the available space in this area. A hard engineering solution, while having a BCR less than 1, is expected to be viable within 5 – 10 years, and therefore could also be considered given the likely planning horizons.

South Yunderup performs well with nature-based solutions. These solutions may also suit this area given that there is generally greater land buffer in this location compared with the northern side.

Table 5-2 Economic assessment results: individual projects ($M, present value at 7% p.a.)

Location	Mitigation Option	Total Costs	Total Benefits	NPV[6]	BCR	Timeframe for Viability[7]
Yunderup Island	Hard	4.16	0.58	-3.58	0.14	30 – 50 years
	Nature Based	0.47	0.04	-0.43	0.08	30 – 50 years
Ballee Island	Hard	1.72	0.49	-1.23	0.29	20 – 40 years
	Nature Based	0.09	0.05	-0.03	0.61	10 – 20 years

[6] Net Present Value (the difference between the net benefits and net costs)
[7] Indicative timeframe at which the project may have a BCR > 1 in the future.

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Coolenup Island	Hard	12.81	2.26	-10.55	0.18	>50 years
	Nature Based	0.66	0.09	-0.57	0.14	20 – 40 years
Nth Yunderup Shoreline	Hard	5.69	5.28	-0.40	0.93	5 – 10 years
	Nature Based	0.64	3.11	2.46	4.82	current
Sth Yunderup Shoreline	Hard	5.45	1.74	-3.72	0.32	10 – 30 years
	Nature Based	0.62	0.97	0.36	1.74	current

5.3 Distributional Analysis

A distributional analysis is a useful tool for understanding the key beneficiaries for a mitigation option. It is undertaking by assessing the beneficiaries for each of the net benefits identified.

For the Shire of Murray, the key beneficiaries are private landowners, as well as the Shire of Murray (though the public assets such as reserves). A summary of the distributional analysis is provided in Table 5-3.

Table 5-3. Distributional Analysis

Location	Mitigation Option	Private Landowners	Shire of Murray
Yunderup Island	Hard	100%	0%
	Nature Based	100%	0%
Ballee Island	Hard	100%	0%
	Nature Based	100%	0%
Coolenup Island	Hard	100%	0%
	Nature Based	100%	0%
Nth Yunderup Shoreline	Hard	100%	0%
	Nature Based	100%	0%
Sth Yunderup Shoreline	Hard	90%	10%
	Nature Based	88%	12%

5.4 Sensitivity Analysis

A sensitivity analysis was undertaken to understand the relative robustness of the economic outcomes for a selection of the locations and mitigation scenarios. A sensitivity analysis was undertaken on the cost estimate, together with the discount rate, to understand the relative sensitivity of the options. This is summarised in Table 5-4.

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Table 5-4. Sensitivity Analysis - BCR

Location	Mitigation Option	Base	Upper Range Cost Estimates	4% Discount Rate	10% Discount Rate
Yunderup Island	Hard	0.14	0.09	0.28	0.08
	Nature Based	0.08	0.05	0.22	0.03
Ballee Island	Hard	0.29	0.19	0.54	0.17
	Nature Based	0.61	0.35	1.56	0.24
Nth Yunderup Shoreline	Hard	0.93	0.63	1.76	0.56
	Nature Based	4.82	2.75	9.13	2.91

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Rhelm Pty Ltd

ABN 55 616 964 517

ACN 616 964 517

Head Office

Level 1, 50 Yeo Street

Neutral Bay NSW 2089

contact@rhelm.com.au

+61 2 9098 6998

www.rhelm.com.au