

Coastal Hazard Risk Management Adaption Plan

PREPARED FOR
Shire of Carnarvon

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1 Establishing the context

1.1 Introduction

Purpose

Local communities within the Western Australian coastal zone, including Carnarvon and Coral Bay, are drawn to the ocean interface for their livelihoods, with the coast central to their social and economic activities. Coastal settlement in these communities serves as a hub for recreation, tourism, and industry. The Coral Bay settlement and coastline, in particular, provides a major boost to regional tourism, while Carnarvon's coastal location supports its fishing industry and agricultural economy.

These social and economic activities often require significant investment in infrastructure and community improvements. The coastal landscape's natural beauty also provides important ecological services that are reflected in elevated real estate and commercial land values throughout the region.

Coastal management involves multiple authorities, each with distinct responsibilities based on land tenure, zoning, and management orders. In the context of climate variability, it is essential to bring all decision-makers together into an informed and collaborative planning process. The vulnerability of coastal assets to hazards such as erosion and inundation is expected to increase in the future, requiring coordinated adaptation strategies.

In response to these challenges, the Western Australian Planning Commission (WAPC) developed the Coastal Hazard Risk Management and Adaptation Planning (CHRMAP) framework and adopted State Planning Policy 2.6 – State Coastal Planning (SPP2.6), whose stated purpose 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.

State Planning Policy 2.6 requires local governments to undertake coastal hazard risk management and adaptation planning for areas at risk from changing coastal hazards. Completion of a CHRMAP is a prerequisite for local governments to access funding for coastal adaptation works. To meet this requirement, the Shire of Carnarvon has prepared this Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) for the Carnarvon and Coral Bay coastline.

This CHRMAP will identify where existing or proposed development and landholders are most exposed to changing coastal processes, assess the implications of these risks, and establish a framework for managing coastal hazards over the agreed planning timeframe. By analysing the vulnerability of specific assets, the CHRMAP will provide strategic guidance for the Shire to adopt a coordinated, integrated, and sustainable approach to land use planning and management decisions on behalf of the community.

The CHRMAP will also guide necessary updates to the Shire's Local Planning Strategy, Local Planning Scheme, and other relevant strategies and local planning policies. Through a structured process based on scientific

evidence and probability assessment, this plan will help the community identify priority coastal assets and determine how these will be protected and managed to address both immediate and future risks.

The CHRMAP adopts a risk management approach that directs how the Shire will address coastal hazard risks over time and assign priorities. This approach is designed to:

- Consider the risks arising from coastal hazards
- Identify risk management responses, and
- Prioritise and implement the risk management responses.

It considers '**who**' is responsible for managing the risk:

- **Private parties** are responsible for managing risks to their private assets and incomes. To manage these risks private parties, need to:
 - be aware of the risks and their responsibility for managing them
 - take steps to understand the magnitude and nature of the specific risks to their assets and activities
 - develop and implement strategies and actions to manage the risks.
- **Governments**, on behalf of the community, are primarily responsible for the oversight of planning and managing risk to public goods and public assets which they own and manage. Governments also seek to:
 - develop local policies and regulations consistent with State risk management approaches
 - facilitate by building resilience and adaptive capacity within the local community, including providing timely information about relevant known coastal hazards including erosion and inundation, and
 - building a workable partnership with the community to identify and manage risks.

The risk management process, adapted to the CHRMAP process, is in Figure 1.1.

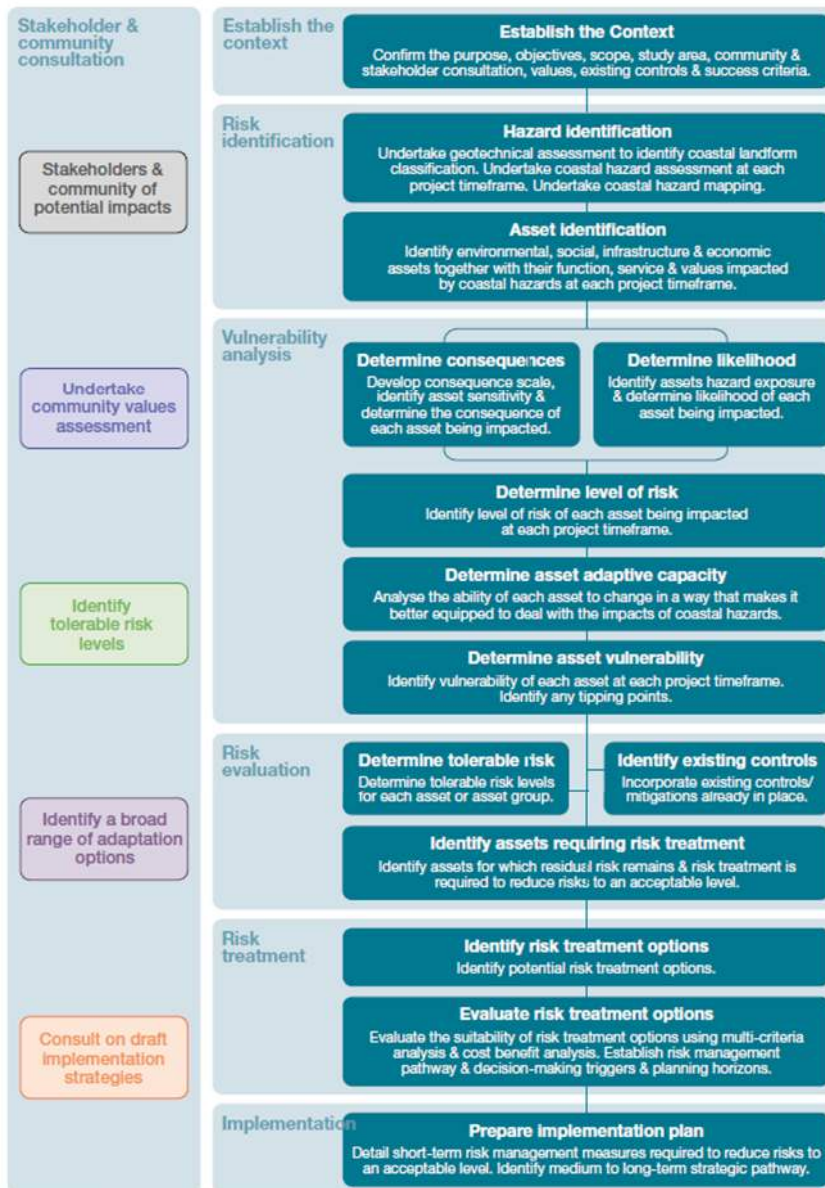


Figure 1.1– Risk management process flowchart adapted to coastal planning²

Preparing this CHRMAP

The CHRMAP has been prepared over a period of 18 months, following the seven stages outlined in Figure 1.2. For each stage of the project, a separate detailed technical report was prepared and provided to the Shire and Steering Group for review.

This document presents the consolidated outcomes of the CHRMAP process, drawing from the detailed technical assessments prepared at each stage:

- Establish the Context (September 2023)
- Hazard Assessment (October 2023)
- Vulnerability Analysis and Risk Evaluation (May 2024)
- Risk Treatment (December 2024)
- Implementation and Monitoring (May 2025)

These technical reports provide the evidence base for this plan and are available from the Shire of Carnarvon.

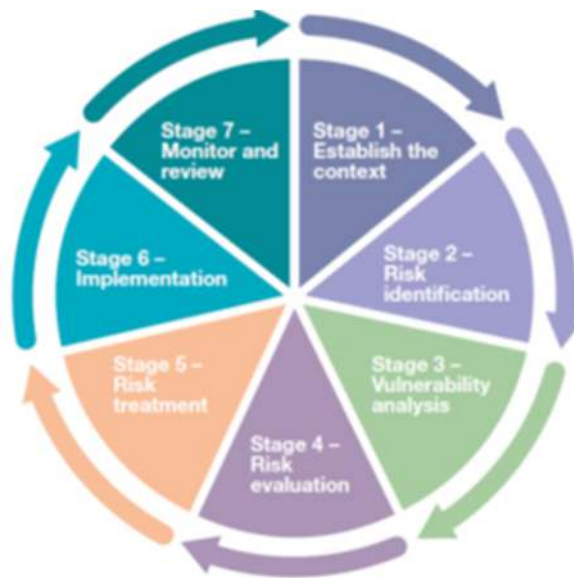


Figure 1.2 – CHRMAP preparation stages

CHRMAP Objectives

The objectives of the CHRMAP are set out within the guidelines provided by the Western Australian Planning Commission (WAPC) and are as follows:

- improve the understanding of coastal features, processes and hazards in the study area
- identify significant vulnerability trigger points and respective timeframes for the relevant coastal compartments to mark the need for immediate or medium-term risk management measures
- identify assets (natural and man-made) within the coastal zone and review the services and functions they provide
- review the identified assets vulnerability
- review the value of the vulnerable assets to adverse impacts from coastal hazards
- determine the consequence and likelihood of coastal hazards on the assets, and assign a level of risk
- identify possible (effective) risk management measures (or 'actions') and how these can be incorporated into short and longer-term decision-making
- engage stakeholders and the community in the planning and decision-making.

Preliminary Risk Identification

This CHRMAP focuses on assets within the study area that are likely to be exposed to coastal hazard processes. Each asset has been assessed against defined criteria to determine the level of risk over both short- and long-term timeframes. Based on these assessments, the plan identifies appropriate management responses, including physical protection works and strategic measures implemented through the Shire's planning scheme and related policy frameworks.

1.2 Study Areas

This CHRMAP focuses on the coastline between Massey Bay and the Gascoyne River mouth, and the settlement of Coral Bay. The importance of this coastline is heightened by the designation of the Ningaloo Coast as a UNESCO World Heritage area. The extent of the CHRMAP in each location is shown on Map 1.1 (Carnarvon) and Map 1.2 (Coral Bay).

Management and regulation of these coastal areas involves multiple authorities with distinct roles and responsibilities for different sections of the shoreline. This CHRMAP has been prepared in consultation with relevant authorities to ensure coordinated management approaches. The plan details the Shire's role in administering land use within these localities through its local planning framework, and provides general guidance on coastal hazard adaptation and risk management for the remainder of the Shire's coastal areas where appropriate.

Carnarvon

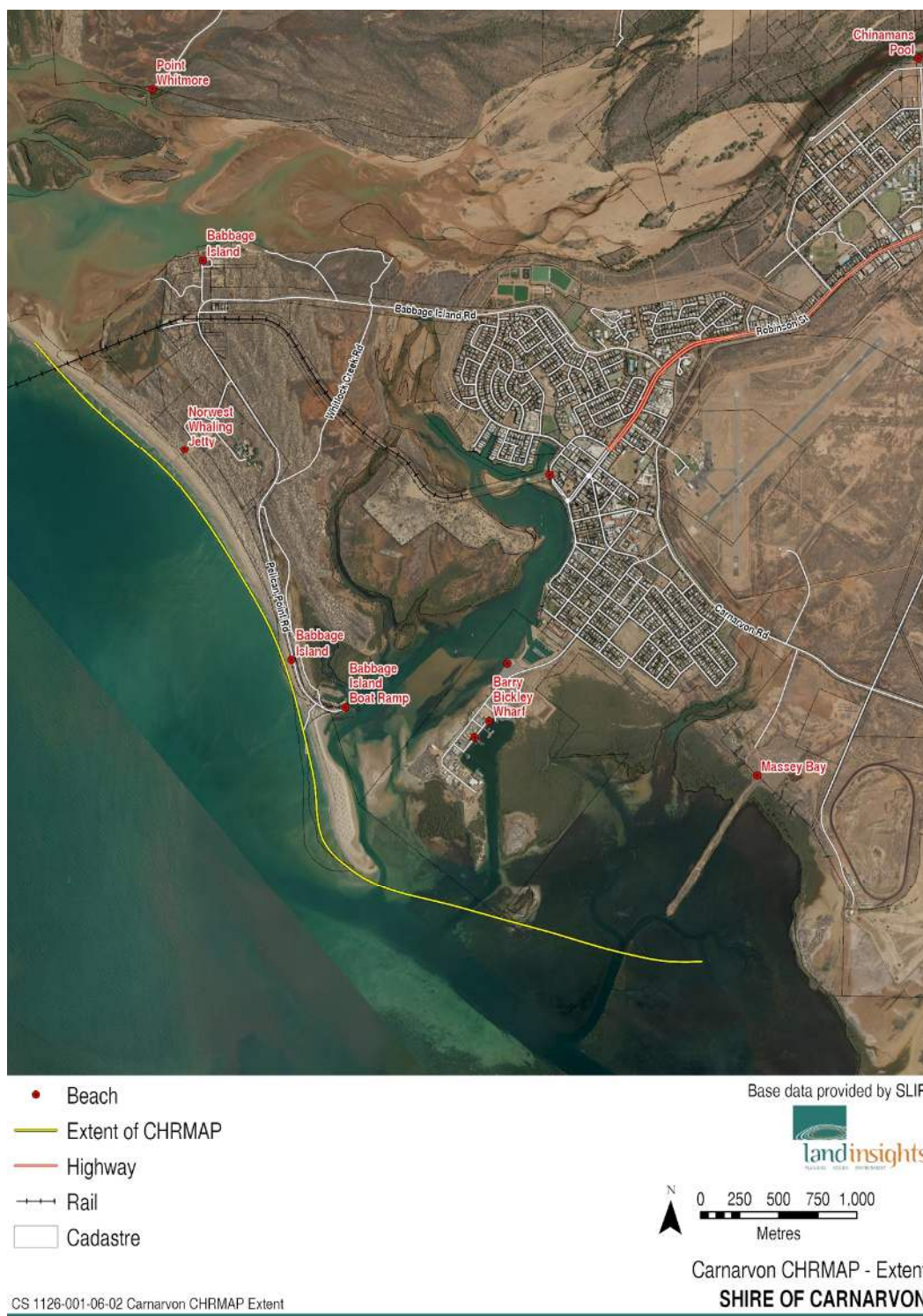
Carnarvon is situated at the delta of the Gascoyne River, resulting in a diverse land use pattern shaped by its coastal setting. The Gascoyne floodplain immediately upstream of the Indian Ocean is a food production area of State economic significance. Despite the town's long history of flooding, the Gascoyne River remains dry for much of the year.

The Shire's Local Planning Strategy identifies opportunities for expanding tourism and economic development to facilitate steady population growth within the townsite and its surrounds, while recognising the ongoing importance of pastoral activities in inland areas of the Shire.

Residential development is concentrated in close proximity to the town centre, with housing taking advantage of scenic coastal outlooks and beach access. Several areas within the Carnarvon townsite are covered by structure

plans including the Babbage Whitlock Structure Plan, Carnarvon Airport Structure Plan, Kingsford Structure Plan, and East Carnarvon Structure Plan. Within areas adjoining the coast and the Fascine, the strategy identifies opportunities for further intensification of tourism, residential, and community uses where appropriate.

The proximity of development to the coast means Carnarvon faces challenges from coastal hazards including erosion, sea-level rise, and storm surges. This CHRMAP will inform future planning decisions and guide updates to the Shire's planning scheme, strategy, and structure plans. It emphasises the implementation of adaptive management strategies such as prudent setback requirements, coastal buffers, and land-use zoning that anticipate future sea-level rise projections and more frequent extreme weather events.



Map 1.1 – CHRMAP Extent - Carnarvon

Coral Bay

Coral Bay is located 220 kilometres north of the Carnarvon townsite and is recognised as one of Australia's premier holiday destinations. It is situated adjacent to the UNESCO World Heritage-listed Ningaloo Reef, which is of international renown.

The settlement does not contain any residentially zoned land. The beach and coastal foreshore are designated as Foreshore Reserve under the Local Planning Scheme, while most development is located within the Tourist zone, with smaller areas allocated for workforce accommodation, holiday homes, and commercial uses. Development is positioned on the coast to take advantage of the scenic outlook; however, this proximity exposes existing infrastructure to potential coastal hazards.

The reliance on coastal tourism means that Coral Bay faces particular challenges from coastal hazards and requires proactive risk management. This CHRMAP identifies erosion and inundation through sea-level rise and storm and tidal surges as the primary coastal hazards affecting Coral Bay. Past impacts from marine infrastructure development have altered beach sand dynamics, demonstrating how modifications to the coastal system can increase exposure to climate-related impacts.

To mitigate these risks, the CHRMAP emphasises the implementation of adaptive management strategies including setback requirements, coastal buffers, and land-use zoning that anticipate future sea-level rise projections. Planning instruments such as an updated Coral Bay Settlement Structure Plan can guide development towards areas not subject to coastal hazards.



1.3 Existing Planning Controls

Planning in Western Australia is guided and regulated by the State Planning Framework, which ranges from overarching strategic planning strategies, to specific planning policies and supportive guidelines. Figure 1.3 explains the framework, which includes planning at the state, regional, and local levels and demonstrates how strategic planning is implemented through statutory planning controls (e.g., local planning schemes) and local planning policies. This Framework sits within the Planning and Development Act 2005. The relationships of the various policies are presented in Figure 1.4.

The planning documents within this Framework were reviewed to determine which are relevant to coastal hazard planning in the project area. This review helped to: assess the adequacy of the existing planning documents for addressing coastal hazards; identify gaps that needed to be addressed through the CHRMAP process (such as planning controls that are required, or need amending to enable implementation of CHRMAP recommendations); identify any potential planning issues that may constrain the CHRMAP process; and ensured that the adaptation plan aligns with state, regional and local planning frameworks.

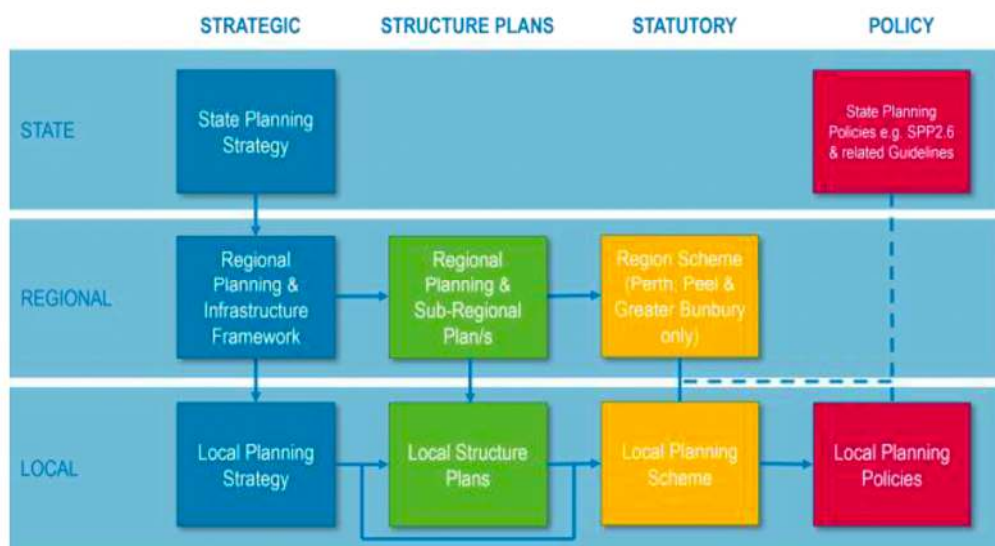


Figure 1.3 – Planning framework overview

1.4 State Planning Policies and Strategies

The following state documents have been reviewed. Information relevant to the CHRMAP has been included below:

- State Planning Strategy 2050
- WA Coastal Zone Strategy 2017
- State Planning Policy 2.6 – State Coastal Planning Policy (and Guidelines)
- State Planning Policy 2.9 – Water resources

- Coastal Hazard Risk Management and Adaptation Planning Guidelines 2019
- State Planning Policy 3.4 – Natural Hazards and Disasters

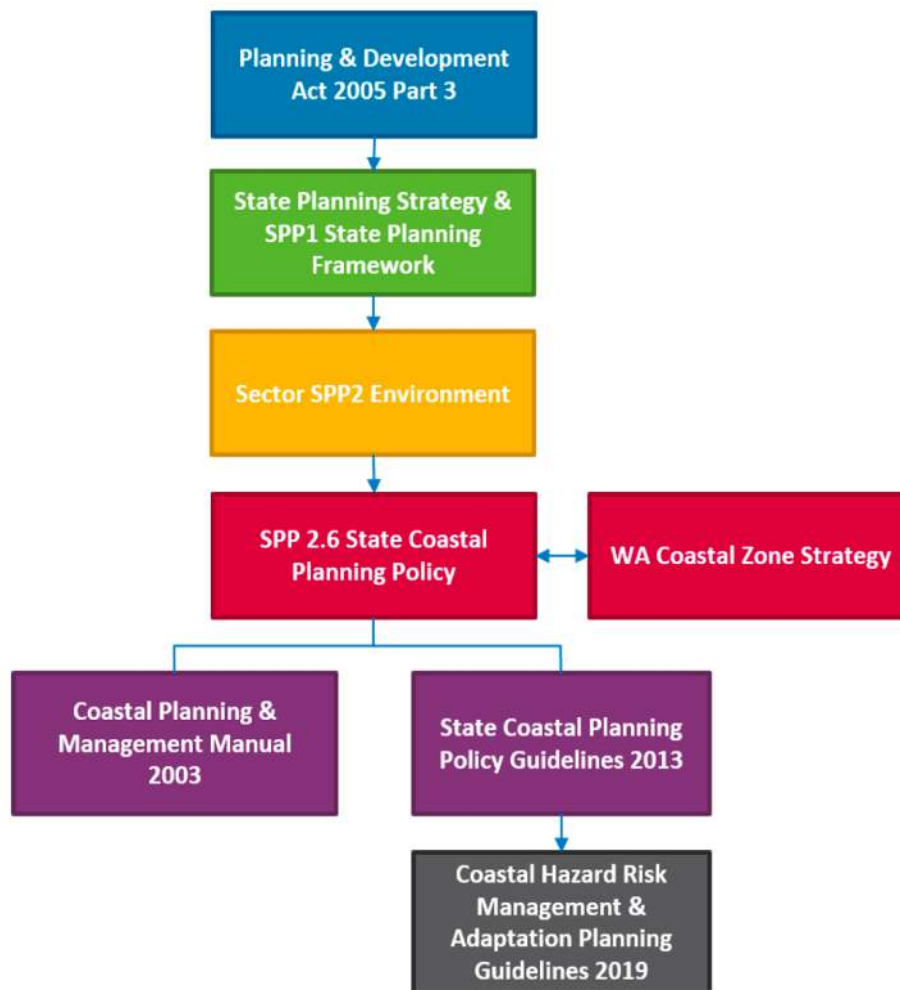


Figure 1.4 – Policy Relationships

A range of local planning documents were also reviewed, including:

- Shire of Carnarvon Strategic Community Plan 2022 – 2032
- Shire of Carnarvon Local Planning Strategy 2017 (LPS)
- Shire of Carnarvon Local Planning Scheme No.13 (LPS13)
- Babbage and Whitlock Islands Structure Plan (2014)
- Coral Bay Settlement Structure Plan (2014).

1.5 Community Engagement

Engagement Objectives

Engagement is undertaken to share information and to assist the community and stakeholders to contribute effectively to the preparation of the CHRMAP. As per the scope of work, the Stakeholder and Community Engagement Plan (SCEP) objectives include:

- the collection and collation of community and stakeholders' social, environment, infrastructure and economic values and aspirations for the coastal area; this information informed the remainder of the process, in particular the vulnerability analysis and multi-criteria assessment of adaptation options;
- an understanding of the level of tolerance and acceptability of specific risks within the community for specific assets, or groups of assets;
- involving the community in identifying suitable adaptation options;
- advising the community and stakeholders about the inclusion of a Benefit Distribution Analysis to assist with apportioning the costs (capital and recurrent) of chosen risk management measures, based on the beneficiary pays principle; and
- wide distribution of the draft CHRMAP to seek feedback on the proposed adaptation options, pathways and implementation plan.

Survey

A questionnaire was prepared to capture community opinion, test community values, knowledge and preconceptions about coastal change. This information is then used to gauge the level of support for different management options. Although only a limited number of responses were received; the survey responses have informed the outcome of the CHRMAP.

Stakeholder Meetings August 2023

Two days of interview were held with stakeholders who lived and worked in Carnarvon and Coral Bay, the conclusions of these interviews are outlined below.

Whilst Carnarvon and Coral Bay are situated on the same coast, they hold very different community dynamics, and the results indicate a variety of the values and expectations for the future roles and options in relation to coastal areas. Coral Bay is dominated by business interest whereas Carnarvon has this balanced by residents and other interest groups.

The Town of Carnarvon has since its founding borne the brunt of flooding and cyclones and therefore there is an acceptance that physical climate event risks are inevitable, likely and unable to be fully prevented or abated. Aboriginal knowledge about the place might shed a valuable insight into the history of Carnarvon as a delta and therefore a dynamic part of a high energy coastline in combination with a confluence with Gascoyne River.

Coral Bay is a more recent settlement and development – founded as a tourist hub in the 1980s. Unlike Carnarvon there is a focussed economic base of tourism, seasonal in nature, and the values are skewed towards ecoservice to tourist activities, access to the reef and beaches and the potential long-term impact of diminished 'Coral Bay nature experience' as witnessed when consulting the businesses which invested in tourism in the settlement.

This contrast is useful and further community benchmarking may explore the differences in the two communities, and identify the motivations of each to better control, manage or adapt to change.

1.6 Success Criteria

A preliminary consideration of success criteria was undertaken and is presented below. As the project progressed the criterion was modified and updated – particularly as community and stakeholder discussions were undertaken.

Risk Assessment and Mapping

- Completion of a comprehensive coastal risk assessment for Carnarvon (focus on inundation, delta processes, critical infrastructure) and Coral Bay (focus on dune erosion, tourism assets, beach access).
- Development of hazard maps for Carnarvon and Coral Bay, showing projected erosion/inundation extents for key planning horizons (e.g., 2035, 2050, 2125), with overlays of vulnerable assets and land use zones.

Community Engagement and Stakeholder Participation

- Conduct targeted engagement with Carnarvon residents, business owners, and Aboriginal groups to capture local knowledge of flooding, shoreline change, and asset priorities.
- Engage Coral Bay tourism operators, seasonal workers, and visitors to understand the economic and environmental values at risk, and preferences for managed retreat versus protection.
- Document and benchmark differences in community values and adaptation preferences between Carnarvon and Coral Bay.

Infrastructure Resilience

- For Carnarvon: Prioritise resilience upgrades for areas subject to inundation (e.g., Pelican Point Road), surge walls, and civic assets identified as high vulnerability in the CHRMAP.
- For Coral Bay: Focus on maintaining dune buffers, rationalising beach access, and planning for managed retreat of tourist infrastructure when triggers are reached.
- Develop asset-specific adaptation pathways and triggers for intervention, as detailed in the implementation plans.

Natural Buffer Restoration and Conservation

- In Carnarvon: Restore and maintain mangrove and dune systems, especially in areas identified as erosion/inundation hotspots (e.g., Babbage Island, South Carnarvon).
- In Coral Bay: Implement dune management plans, consolidate 4WD tracks, and prioritize revegetation in areas with high recreational use and erosion risk.
- Monitor buffer width and condition using aerial imagery and site surveys every 5 years.

Land Use Planning and Regulation

- Amend the Local Planning Scheme to introduce Special Control Areas (SCAs) for all land at risk by 2125 in Carnarvon and Coral Bay, with site-specific development controls and triggers for managed retreat.
- Require notifications on title for properties within SCAs and enforce minimum floor levels and setback requirements for new development.
- Review residential densities and lease arrangements in vulnerable areas, as recommended in the CHRMAP.

Funding and Resource Management

- Establish a coastal adaptation fund for the Shire, with contributions from rates, grants, and targeted levies for benefitting landowners.
- Prioritize funding for immediate actions in Carnarvon (e.g., surge wall upgrades, emergency management) and for technical studies and dune management in Coral Bay.
- Pursue external funding for significant mitigation works, as outlined in the implementation plan.

Education and Awareness

- Develop tailored education programs for Carnarvon (inundation risk, asset protection, emergency response) and Coral Bay (dune conservation, managed retreat, tourism impacts).
- Use local case studies and monitoring data to illustrate changing risks and adaptation successes.
- Survey community knowledge and perceptions every 5 years to inform future engagement.

Monitoring and Evaluation

- Implement long-term monitoring of shoreline position (HSD), dune condition, and asset vulnerability in both Carnarvon and Coral Bay, using aerial imagery and site surveys.
- Set clear triggers for review and update of the CHRMAP (e.g., after major storm events, every 5–10 years, or when new hazard data becomes available).
- Evaluate adaptation outcomes for each Management Unit and adjust pathways as needed.

2 Risk Identification

2.1 Introduction

The Carnarvon Townsite is subject to complex coastal and geomorphic processes influenced by tropical cyclones and river flooding, with natural and anthropogenic influences¹ in the area creating regions of erosion and inundation potential. As outlined in this chapter, Babbage and Whitlock islands are likely to be subject to future inundation risk, particularly during times of cyclonic activity.

One concern identified is that the risk of erosion south of Coral Bay may be intensified by the current lack of adequate foreshore reserve width in this area. This potential vulnerability is a key reason for including Coral Bay in the CHRMAP process, to assess whether broader reserves are necessary to better accommodate the possible landward movement of the shoreline in the future.

Historic variability in beach width and dune mobility, demonstrated through scarped dunes along the coast, indicates the potential for risk to the townsite and foreshore reserve from further erosion, and the lower lying parts of the Coral Bay Townsite and surrounds are at risk of inundation during the passage of tropical cyclones, a phenomenon which occurred several years ago.

Each of these potential risks will be exacerbated in terms of extent and frequency by the influence of climate change over the identified planning periods, most strongly felt via the impacts of sea level rise. Consideration has been made of this factor throughout this study.

¹ Examples might include:

- Coastal development: Construction of buildings, roads, and infrastructure close to the shoreline can alter natural sediment movement and contribute to erosion or reduced dune mobility.
- Seawalls and rock groynes: Installation of hard coastal defences may protect specific areas but often redirects wave and sediment energy, sometimes worsening erosion elsewhere.
- Sand mining and dredging: Removal of sand or sediments from beaches or river mouths for construction or navigation can deplete natural sediment supplies and impact beach stability.
- Recreational activities: Off-road vehicles, excessive foot traffic, and unmanaged tourist access can damage dune vegetation, reducing natural stability and increasing erosion risk.
- Altered river flows: Upstream water extraction, damming, or diversions can change the volume of freshwater and sediment reaching the coast, impacting delta and estuarine environments.
- Vegetation clearing: Removal of coastal vegetation for agriculture, development, or landscaping weakens natural dune and shoreline protection mechanisms.
- Stormwater and wastewater discharge: Increased runoff from urban areas can accelerate beach and foreshore erosion or alter local hydrological patterns.

Previous studies

The present study has reviewed historic reports to assist with the development of the CHRMAP, with a literature review of relevant previous studies presented in Section 2. The historical studies by Gems (2005) and Gems (2009) have been used to previously define coastal hazard in Carnarvon and Coral Bay.

2.2 Site Visit

Site visits for the Coral Bay and Carnarvon study locations were undertaken on the 13th and 14th June 2023. A brief summary of the observations captured in the field were presented in this section outlining the various areas throughout Carnarvon and Coral Bay.

2.3 Calculation of Coastal Processes Allowance – Carnarvon

A study was undertaken in relation to coastal process allowances for the study areas of Carnarvon and Coral Bay, in line with the procedures outlined in Schedule 1 of the State Coastal Planning Policy SPP2.6. The associated mapping providing an interpretation of areas potentially exposed to coastal processes over the applicable planning timeframe.

Coastal Classification

SPP2.6, requires the classification for coastal processes should be determined with regard to the physical and biological features of the coast. The coastal classification system in SPP2.6 denotes four general categories adopted in this assessment:

Sandy Coastlines

- Sandy coasts comprise unlithified/unconsolidated sediments, rock is either not present or not dominant. They typically feature gently to moderately sloping shores and are often backed by dunes or beach ridges, which may contain dune blowouts. The shoreline can quickly alternate between accretion and erosion but is likely to retreat as a result of sea level rise.
- Guidance in accordance with SPP2.6 specifies that the planning allowance for coastal erosion should be measured from the horizontal shoreline datum (HSD) and determined by calculating the cumulative impact of the following factors: short-term erosion (S1), historic shoreline movement (S2), and sea level rise allowance (S3), in addition to a contingency factor of 0.2 metres per year to account for uncertainty (U). This has been adopted in the CHRMAP and is outlined schematically in Figure 2.1.

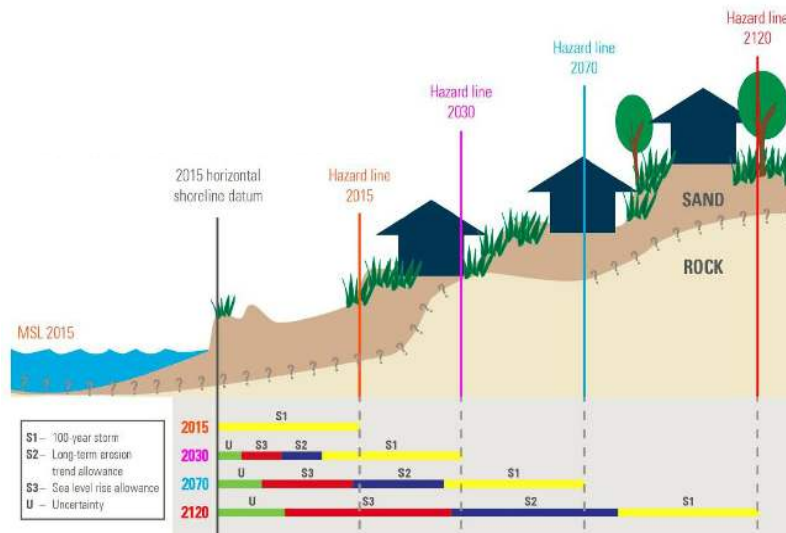


Figure 2.1 – Determining allowance for coastal erosion over time

Rocky Coasts

- Rocky coasts comprise a continuous rocky substrate which extends to an elevation above the active limit of the shoreline. In most instances this elevation should be defined at least one metre above the HSD.

Mixed Sandy and Rock Coasts

- These are classed as one of the three groups dependent on the location and continuity of the rock – fringing reef, rocky platforms or discontinuous rocky shorelines. These coasts may be sensitive to small variations in climatic conditions and often contain unstable/dynamic landforms.
- The allowance for erosion is generally determined using the methods specified for sandy coasts

Tidal Reaches of Inland Waters

- Tidal reaches of inland waters are inland water bodies which are predominantly controlled by coastal related processes, particularly tides and fluctuations in sea level. They include river mouths and estuaries and generally comprise flat to gently sloping shores often containing high percentages of finer sediments. These shorelines are strongly influenced by inundation and tidal processes.

Coastal Lowlands

- Coastal lowlands typically feature flat to gently sloping shores often containing high percentages of finer sediments. The near shore environment often comprises tidal flats, salt marshes or mangroves, with shorelines strongly influenced by inundation and tidal processes.

Islands

- For this assessment there are two Islands in the study area. For Babbage Island, the individual shorelines are treated in their respective category of sandy coast for the western facing open coast shoreline and as tidal reaches of inland waters for the inner Fascine shorelines. At Whitlock Island the

shorelines are protected from open ocean within the Fascine. There is a large area of reclaim on the Island which is treated as protected from coastal erosion in future planning periods.

The application of each of these coastal classifications is summarised for the study areas.

Sandy Coastlines

The areas assessed as sandy coastlines under SPP2.6 guidance are:

- the west facing shoreline of Babbage Island in Carnarvon
- the shorelines of Coral Bay other than those designated with rock in the foreshore (see below). Much of the shoreline is typically perched beaches, which align closest to the general category 'sandy and rocky coast'. In SPP2.6.

Tidal Reaches of Inland Waters

The areas assessed under this category are:

- Inner shorelines of Whitlock Island and Babbage Island within the Carnarvon Fascine.

These are predominantly mangrove fronted estuarine environments. The assessment technique recommended in SPP2.6 is for coastal erosion hazard distance based on sandy coasts, with SPP2.6 acknowledging the application is not well suited to these types of sheltered inland waters.

To overcome this limitation the treatment in this report is to adopt the HSD level at the 100-year level (1.92m AHD) and to adopt a S1 value of 10m coupled with allowance for sea level rise (S3) based on sandy coasts (105m over the 100-yr planning period). No historical shoreline erosion allowance (S2) is included. Uncertainty of 0.2m a year over the planning period is adopted. This approach is considered suitably conservative for the purpose of the CHA and the CHRMAP.

Coastal Lowlands

The areas assessed in this category are:

- tidal flats and mangrove fronted shoreline areas of Massey Bay in the southern shoreline of Carnarvon

These are mangrove fronted shoreline with fine sediments in the shoreline. Coastal erosion assessment is recommended to be based on 'sandy coasts' under SPP2.6, noting this approach is not ideally suited to assessment of these shorelines. In the assessment in this report the HSD is taken as the shoreline upper limit influenced by the regular tidal influence (HAT level of 1.1m AHD). The SBEACH model is not applicable for analysis of erosion for these shoreline areas due to the small sediment size. In the absence of modelling a minimum value of 40m has been adopted for cross-shore erosion (S1) with allowance for sea level rise (S3) based on sandy coasts (105m over the 100-yr planning period). No historical shoreline erosion allowance (S2) is included. Uncertainty of 0.2m a year over the planning period is adopted. This approach is considered suitably conservative for the purpose of the CHA and the CHRMAP.

Rocky Shorelines

The coastal classification 'Rocky Coasts' is adopted for three shoreline areas in Coral Bay. These are:

- Monck Head
- the section of shore around the boat ramp and immediately north

- the section north of Paradise Beach connecting to Coral Bay beach

For these sections, the assessment for coastal processes in future planning periods assumes no erosion will occur.

A summary of the coastal processes' allowances by location and respective shoreline section are present in the Table 2.1 & Table 2.2 for both Carnarvon and Coral Bay below.

Table 2.1 – Carnarvon Coastal Processes Allowances. Landward distance (m) from HSD by planning timeframe.

Coastal Processes Allowance (S1 + S2 + S3 + Uncertainty)					
Planning Year Section	2025 (S1)	2035	2050	2075	2125
Babbage Island CN1	18	30	43	78	143
Babbage Island CN2	18	30	43	78	143
Babbage Island CN3	7	19	32	67	132
Babbage Island CN4	11	29	51	101	196
Babbage Island CN5	18	38	63	118	223
Inner Fascine	10	22	35	70	135
Massey Bay	40	52	65	100	165

Table 2.2 – Coral Bay Coastal Processes Allowances. Landward distance (m) from HSD by planning timeframe.

Coastal Processes Allowance (S1 + S2 = S3 = Uncertainty)					
Planning Year Section	2025 (S1)	2035	2050	2075	2125
CB1	7	12	21	50	147
CB2	12	15	23	48	139
CB3 Rock Headland	0	0	0	0	0
CB4	9	15	27	60	166
CB5	6	9	16	41	131

Coastal Processes Allowance (S1 + S2 = S3 = Uncertainty)					
Planning Year Section	2025 (S1)	2035	2050	2075	2125
CB6 (Rock, Boat Ramp)	0	0	0	0	0
CB7	6	9	17	43	136
CB8 (Rock, Monk Head)	0	0	0	0	0

2.4 Mapping –Coastal Processes Allowance

There are the following sets of mapping included within the Chapter and include

1. Carnarvon Coastal Allowances with Structures in Place
2. Coral Bay Coastal Processes Allowances

For the mapping at point 1 it is assumed that the hard structures and flood walls in place currently in Carnarvon are maintained over the 100-year planning period and continue to protect the areas landward from erosion.



Map 2.1 – Coastal process allowance - Coral Bay.



Map 2.2 – Coastal process allowance - Carnarvon

2.5 Mapping – Inundation risk

Inundation risk mapping has been developed using the ground level defined in the LiDAR applying the design water level to determine depth. The mapping represents the peak water depth over the land surface in the design event and is a simple ‘bathtub flooding’ approach. It is noted that finished floor levels of properties in the coastal areas are not considered in the inundation mapping.

The LiDAR dataset used to inform the mapping was captured in July 2023 over the town areas of Carnarvon including Whitlock Island and Babbage Island. Land level in the tidal flats and region eastward of Massey Bay drive incorporating the Golf Club and Oyster Creek is described by survey data captured in 2014.

To improve the spatial mapping from a simple ‘bathtub’ flooding approach, all inundated areas have been incorporated a ‘hydro-connectivity’ algorithm. Hydro-connectivity ensures that the flooded inland areas connect to the offshore ocean region. This mechanism 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.

The flood mapping on Figures 2.3 to 2.10 show inundation levels for the 100 and 500-yr ARI event in the years 2025 and 2125 (100-yr planning period case). These scenarios have been included here to provide an indication of potential assets at risk. A range of other scenarios is provided in the detailed *Hazard Assessment Report*.



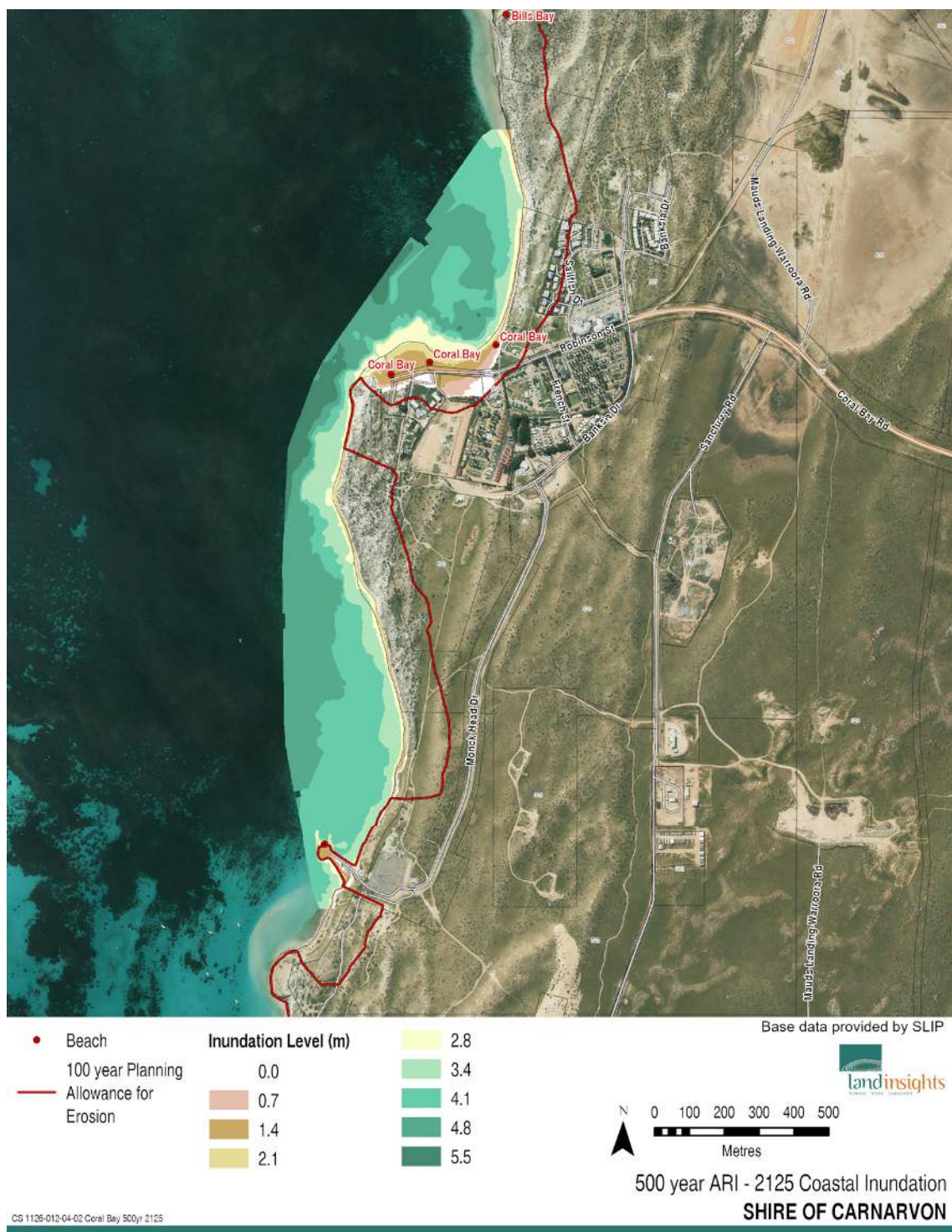
Map 2.3 – Coral Bay 100year ARI 2025



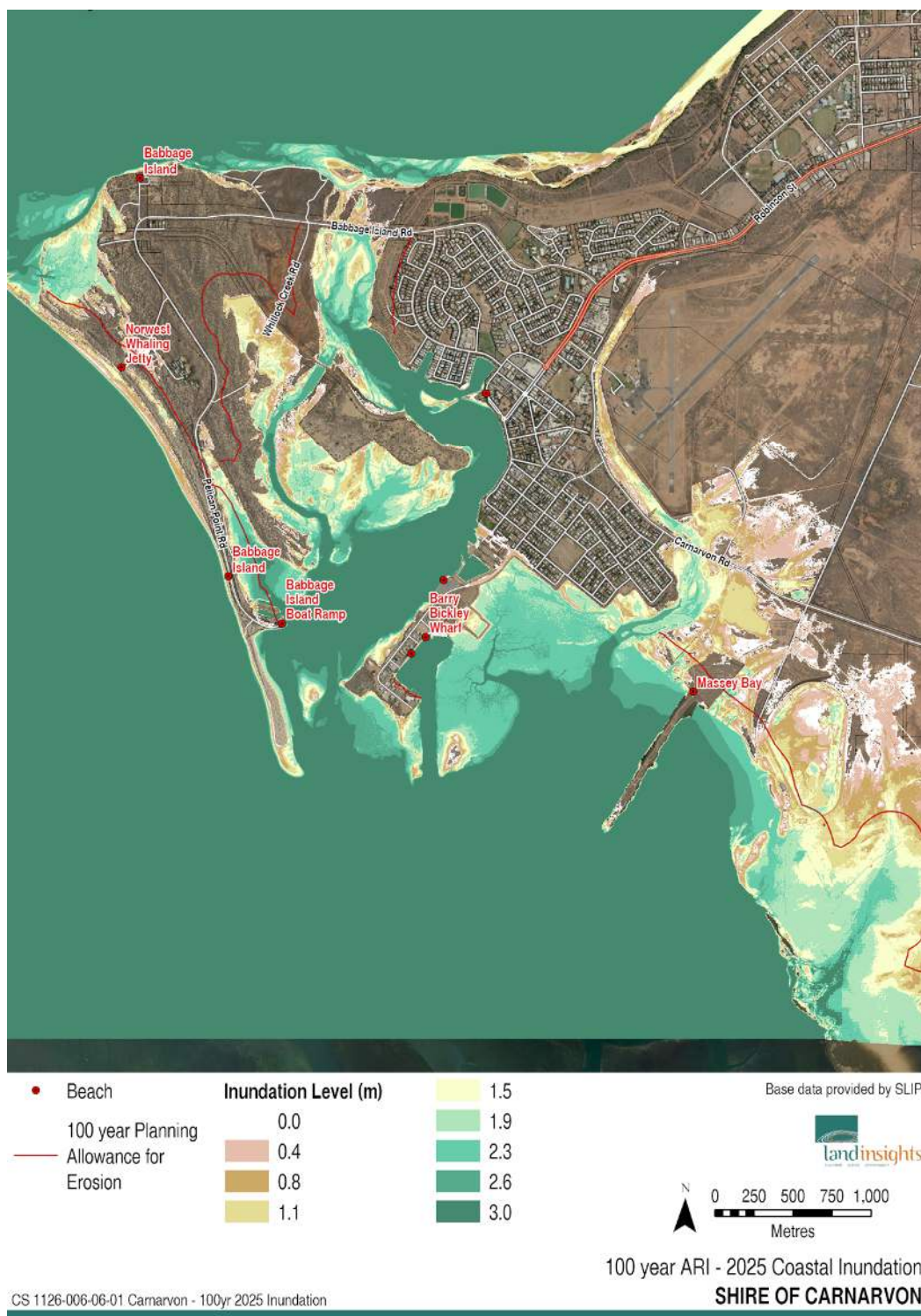
Map 2.4 – Coral Bay 100year ARI 2125



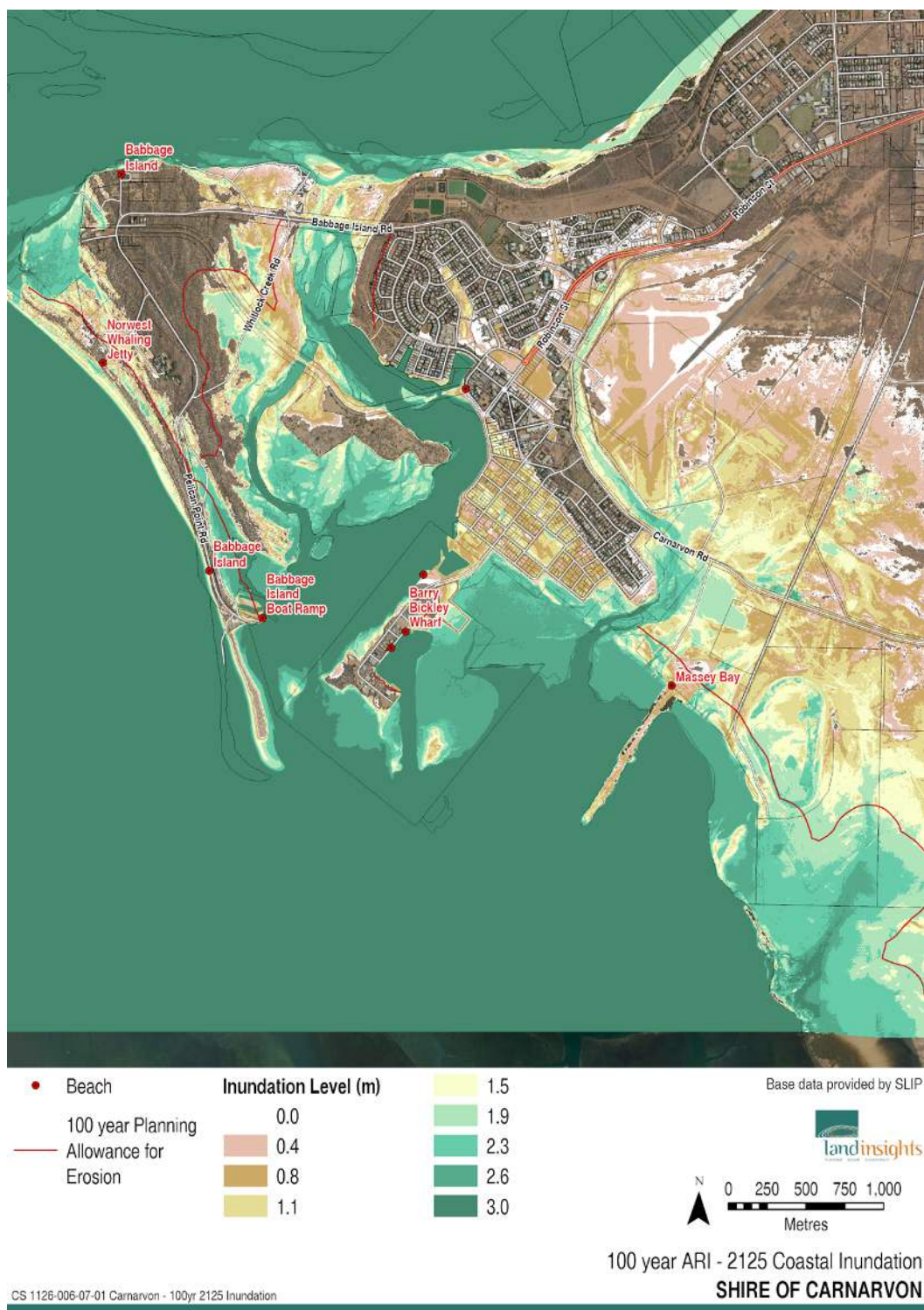
Map 2.5 – Coral Bay 500year ARI 2025



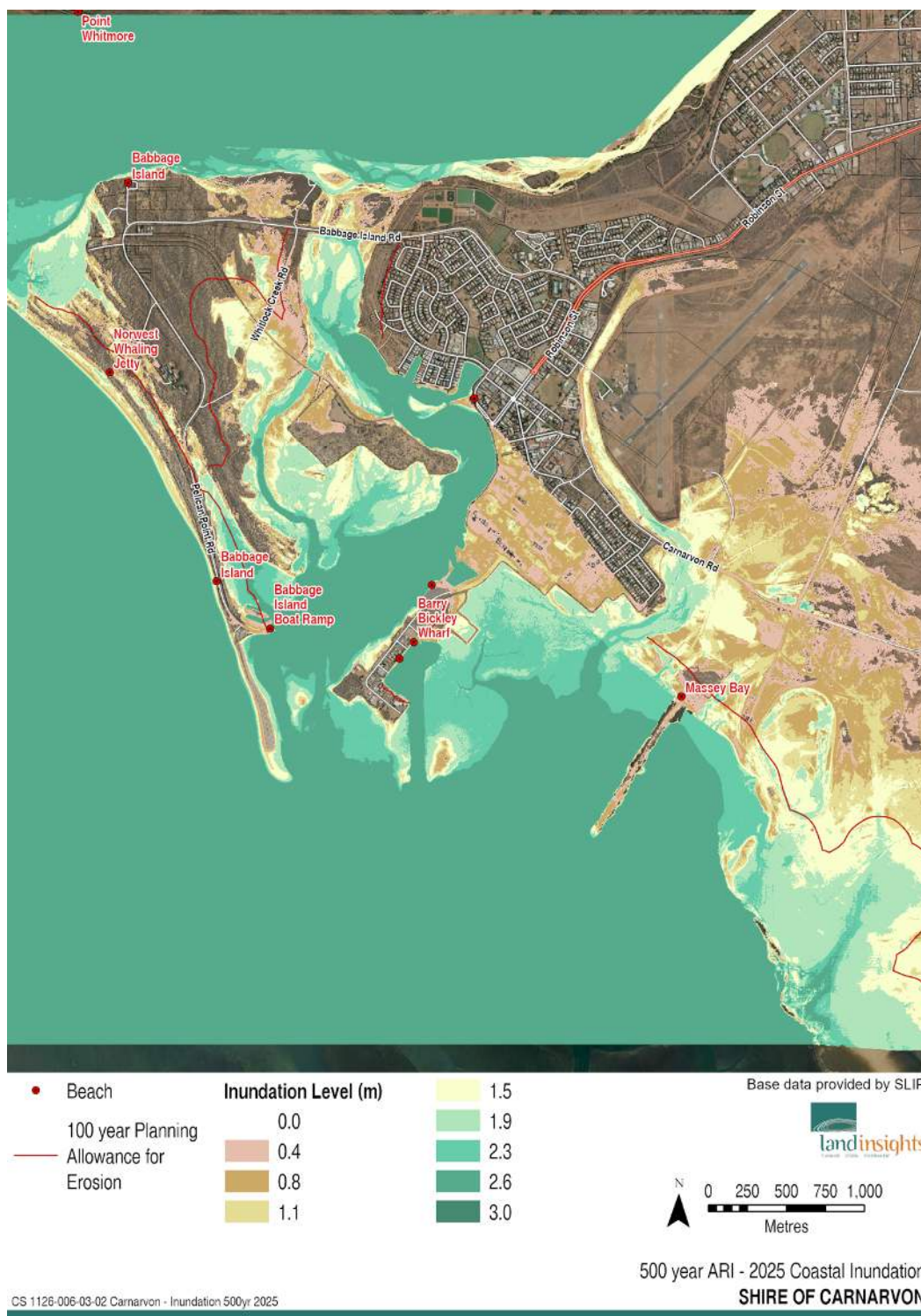
Map 2.6 – Coral Bay 500year ARI 2125



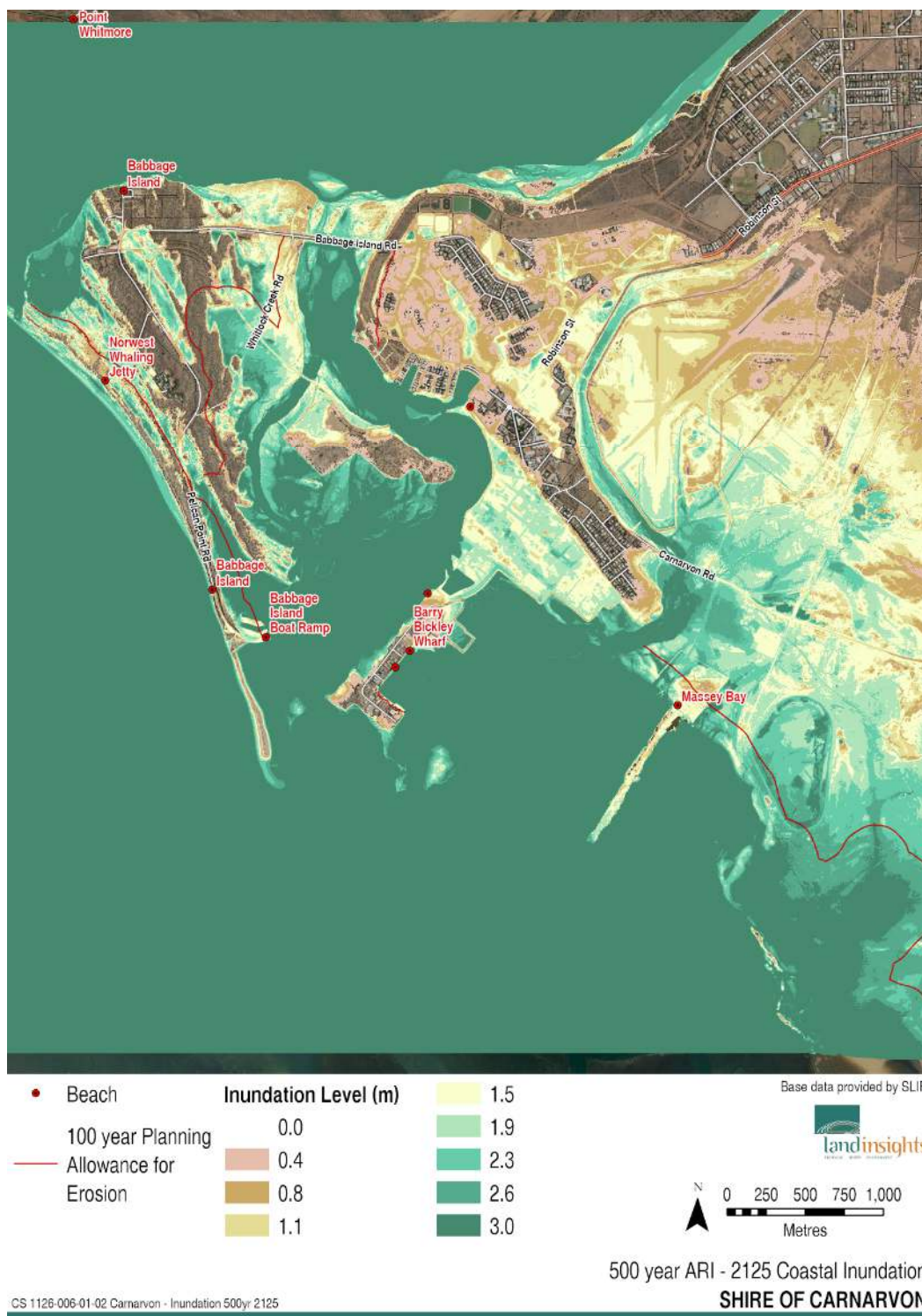
Map 2.7 – Carnarvon 100year ARI 2025



Map 2.8 – Carnarvon 100year ARI 2125



Map 2.9 – Carnarvon 500 year ARI 2025



Map 2.10 – Carnarvon 500year ARI 2125

Limitations

The accuracy of the LiDAR data on which the flood mapping is based is noted as follows.

- For Carnarvon the vertical accuracy of the July 2023 LiDAR data is stated as $\pm 0.07\text{m}$ (Woolpert 2023).
- For Coral Bay the accuracy of the landside survey data is assumed to be in the range $\pm 0.10\text{m}$.

3 Vulnerability Assessment & Risk Evaluation

A Vulnerability and Risk Evaluation Chapter Report was prepared which constitutes the second stage of the risk identification process. All identified risk assets within the identified study areas were assigned vulnerability ratings, according to the various scales. The vulnerability results are presented in full in the Vulnerability Analysis chapter report. A summary is presented below.

3.1 Asset Identification

Coastal Assets

For the purposes of this study, coastal assets were identified in the following ways:

- Asset information from the Shire
- Review of Local Planning Scheme and other planning documents (as outlined earlier in this document)
- Relevant data available via data.wa.gov.au
- The coastal values survey(s) and other engagement activities to identify additional assets of importance and value to the community
- Site visits to investigate locations and discussion with community members with local knowledge
- Identification of further assets from aerial photography (e.g., developed areas of foreshore reserve).

3.2 Asset Class

A range of coastal assets through the Shire that may be impacted by coastal processes in future planning periods broadly span the following categories:

- Roads
- Residential
- Commercial
- Public & Community
- Developed Foreshore Reserve
- Undeveloped Foreshore Reserve
- Environmental/ecosystem services
- Heritage.

Coastal Asset Functions, Services and Value

Coastal asset types through the Shire study area and specific management units and their functions, services and values are presented in Table 3.1 below adapted from (WAPC 2019) and is informed through community engagement and stakeholder views.

Table 3.1 - Overview of Coastal Asset functions, services, value based on (WAPC, 2019)

Asset Class	Function, Service, Value
Environment	

Asset Class	Function, Service, Value
Undeveloped foreshore reserve	Coastal access, recreation, and conservation; tourist drawcard; buffer to other 'higher value' assets. Local Planning Scheme zones/reserves: Foreshore
Environmental/ecosystem services	Habitat for flora and fauna (conservation value for rare and threatened species); recognised importance with RAMSAR; supports biodiversity and ecosystem integrity; ecosystem benefit. Local Planning Scheme zones/reserves: Environmental Conservation
Social	
Public and community	Provides recreation facilities Local Planning Scheme zones/reserves: Public Purpose; Strategic Infrastructure
Developed foreshore reserve	Ongoing access, community services, recreation and health benefits; lifestyle, social/family recreation. Local Planning Scheme zones/reserves: Public Open Space
Heritage	Significant site and place of historical importance; historical value, tourist attraction, culture. Local Planning Scheme zones/reserves: Heritage
Residential development	Provides housing for resident population and future population. Local Planning Scheme zones/reserves: Residential; Urban Development; Special Use
Economic	
Roads	Access (regular and emergency) Local Planning Scheme zones/reserves: Local Road; District Distributor Road
Commercial & Tourism	Provides employment and contributes to economy; provides jobs, serves community and visitors. Local Planning Scheme zones/reserves: Regional Centre; Tourism
Infrastructure	Industry and infrastructure base for the Shire; provides employment; major infrastructure. Local Planning Scheme zones/reserves: Strategic Infrastructure; Infrastructure Services; General Industry; Light Industry

3.3 Identified Coastal Assets

A coastal asset register has been established from existing data; the first site visit and via analysis of aerial photography. Reports from the *Australian Exposure Information Platform* (AEIP) provide an early indication of existing institution, infrastructure, and business assets, along with built form quantities and values.

Key assets under consideration are outlined in the tables below. Asset class is identified (as per Section 3.2), along with further relevant details. The location/extent of assets is shown in maps in this chapter.

Table 3.2 – Key assets at risk (erosion)

Locality	Asset Class	Asset Type	Facility Type	Description
Carnarvon	Commercial	Tourism	Accommodation	Carnarvon Beach Holiday Resort
Carnarvon	Developed Foreshore	Infrastructure	Toilet Block	Babbage Island Beach Toilets
Carnarvon	Undeveloped Foreshore	Recreation	Sandy Beach	Babbage Island Beach (extent)
Carnarvon	Road	Transport	Minor Road	Pelican Point Road
Carnarvon	Commercial	Industry	Processing Plant	NorWest Seafoods site
Carnarvon	Environment	Undisturbed Foreshore	Dunes	Babbage Island coastal dunes
Carnarvon	Environment	Undisturbed Foreshore	Dunes and intertidal area	Babbage/Whitlock Islands dunes and intertidal area
Carnarvon	Public Community	Recreation	Trail	Historic Tramway Reserve Trail
Carnarvon	Residential	Future Residential	Housing	Future Residential land (zoned)
Carnarvon	Residential	Future Residential	Housing	Future Residential land (development zone)
Carnarvon	Road	Transport	Important Road	Harbour Road
Carnarvon	Undeveloped Foreshore	Amenity	Dunes	Remnant dunes/Vegetation
Carnarvon	Commercial	Industry	Marine Services	Marine services adjacent to marina
Carnarvon	Commercial	Transport	Wharf Access	Wharf Access Road
Carnarvon	Commercial	Transport	Car Parks	Carparks adjacent Harbour Road
Carnarvon	Undeveloped Foreshore	Amenity	Sandy Foreshore	Sandy Foreshore adjacent Harbour Road
Carnarvon	Environment	Undisturbed Foreshore	Mangroves	Intertidal Mangroves
Carnarvon	Environment	Undisturbed Foreshore	Mangroves	Intertidal Mangroves
Carnarvon	Developed Foreshore	Recreation	Access	Massey Bay constructed access

Locality	Asset Class	Asset Type	Facility Type	Description
Carnarvon	Public Community	Recreation	Race Course	Race course and associated infrastructure (partial)
Carnarvon	Environment	Undisturbed Foreshore	Intertidal area	Intertidal area (extent)
Carnarvon	Infrastructure	Transport	Land-backed wharf	Wharf
Carnarvon	Infrastructure	Foreshore	Engineered walling	Fascine Wall
Carnarvon	Undeveloped Foreshore	Disturbed Foreshore	Constructed dunes	Sand Spit
Carnarvon	Infrastructure	Transport	Maritime	Babbage Island Boat Ramp
Carnarvon	Infrastructure	Transport	Maritime	Navigation Channel
Coral Bay	Environment	Undisturbed Foreshore	Dunes	Sandy coastal dunes
Coral Bay	Undeveloped Foreshore	Amenity	Dunes	Sandy dunes with informal beach access
Coral Bay	Commercial	Tourism	Accommodation	Chalets
Coral Bay	Road	Transport	Important Road	Robinson Street
Coral Bay	Developed Foreshore	Amenity	Toilet	Toilet Block
Coral Bay	Developed Foreshore	Amenity	Grass	Grassed Parkland
Coral Bay	Undeveloped Foreshore	Amenity	Sandy Beach	Coral Bay Beach
Coral Bay	Undeveloped Foreshore	Amenity	Heath	Coastal heath with constructed pedestrian access to beach
Coral Bay	Road	Transport	Car Park	Coral Bay public car park
Coral Bay	Commercial	Tourism	Accommodation	Caravan park; chalets, tourist accommodation along Robinson Street
Coral Bay	Environment	Undisturbed Dune	Dunes	Sandy dunes with limited beach access points
Coral Bay	Undeveloped Foreshore	Amenity	Dunes	Dunes with 4wd access

Locality	Asset Class	Asset Type	Facility Type	Description
Coral Bay	Developed Foreshore	Transport	Maritime	DOT-managed boat harbour



Map 3.1 – Carnarvon Erosion Planning Allowances with identified assets



Map 3.2 – Coral Bay Erosion Planning Allowances with identified assets

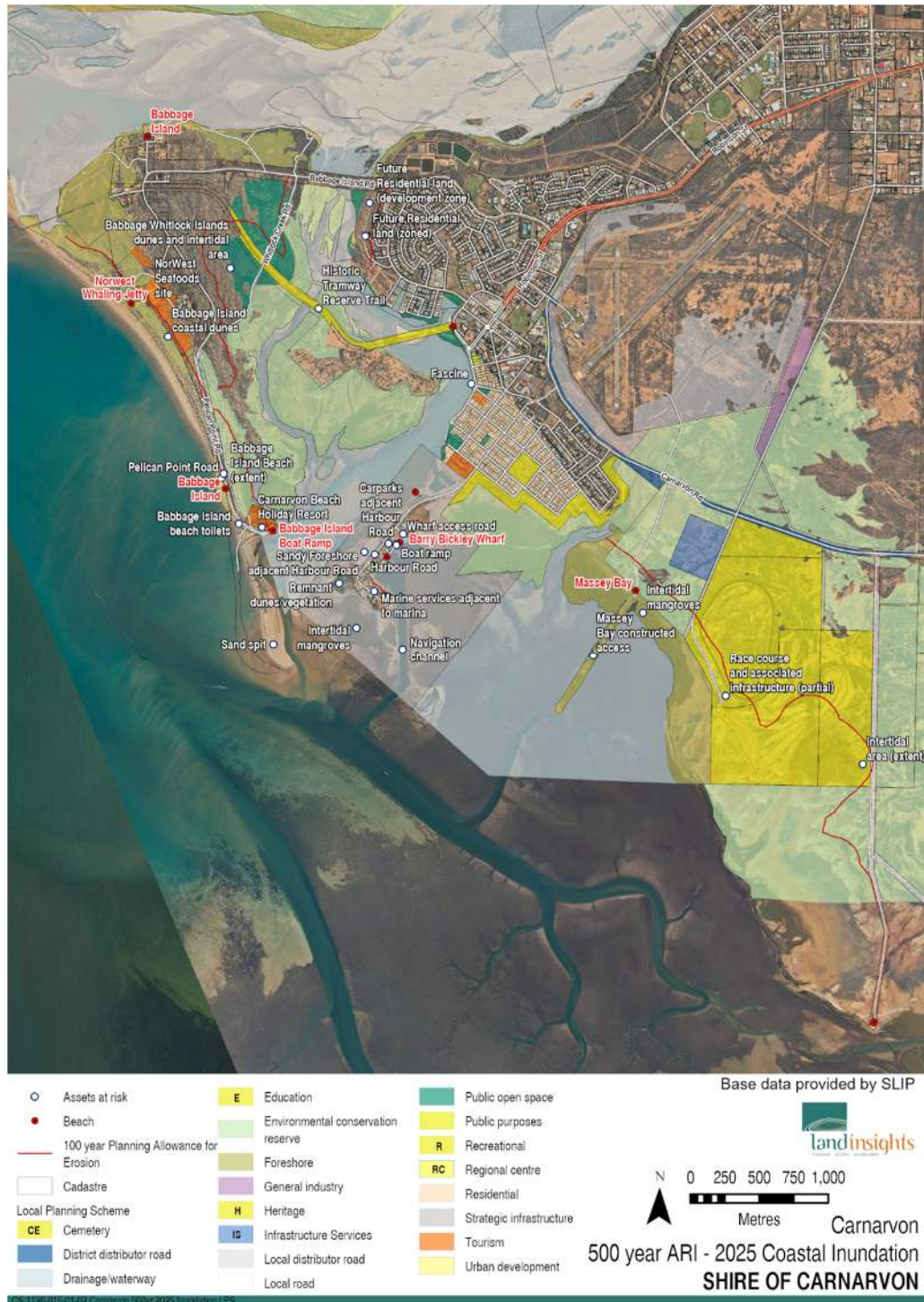
Table 3.3 – Local Planning Scheme zones and reserves impacted by inundation (500yr ARI) – Carnarvon

Zone/Reserve	Area (ha) 2025	Area (ha) 2125
Car Park	0	0.69
Cemetery	0	3.06
Civic and community	0	0.4
Commercial	0	0.66
Cultural Facilities	0	1.29
District distributor road	3.85	17.4
Drainage/waterway	817.84	817.84
Education	0	0.33
Environmental conservation reserve	1667.5	1813.36
Foreshore	151.63	191.47
General industry	0.56	16.16
Heritage	8.9	13.39
Infrastructure Services	9.99	12.04
Light industry	0	0.76
Local distributor road	4.05	15.6
Local road	21.47	69.31
Primary distributor road	0	7.91
Priority agriculture	0.31	0.42
Public open space	14.97	49.01
Public purposes	13.53	15.17
Recreational	179.64	215.13
Regional centre	0	8
Residential	3.46	63.41
Service commercial	0	0.39
Special use	0	2.09
Strategic infrastructure	159.71	358.08
Tourism	4.68	17.25
Urban Development	0	0.39

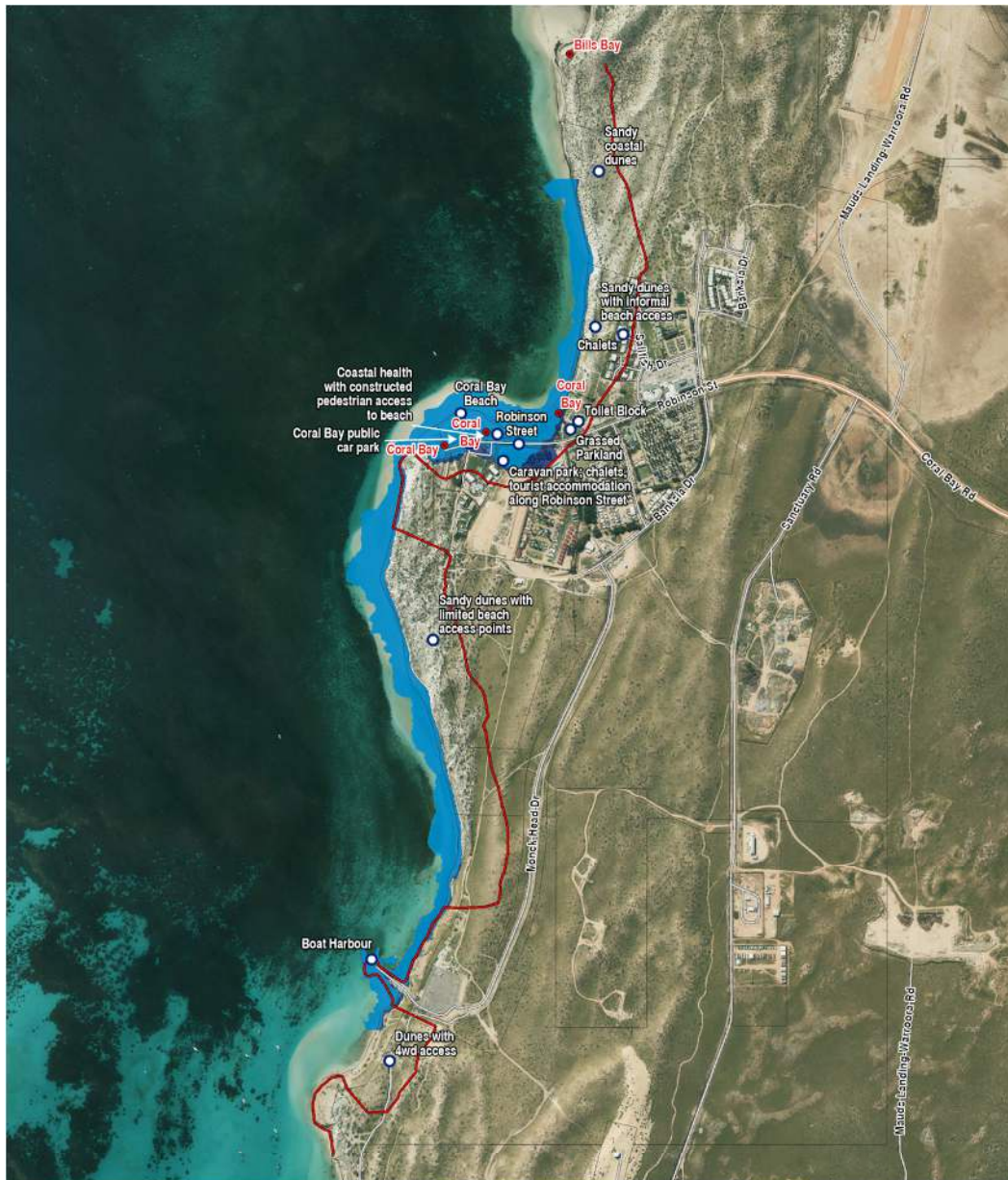
Table 3.4 – Local Planning Scheme zones and reserves impacted by inundation (500yr ARI) – Coral Bay

Zone/Reserve	Area (ha) 2025	Area (ha) 2125
Commercial	0	0.02
Foreshore	3.8	4.49
Local road	0.51	0.57
Tourism	0.44	0.95
Urban Development	0	0

The following plans indicate the possible extent of inundation for both 100- and 500-year events, for the present and projected 100 years into the future. The purpose of these plans is to show which assets, including physical infrastructure and zoning areas, may be affected during these periods. This information supports an assessment of asset vulnerability and informs the consideration of adaptation options.

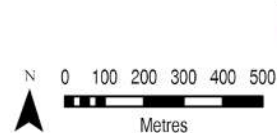


Map 3.4 - Carnarvon Inundation Risk 500yr ARI 2025 (Local Planning Scheme)



Base data provided by SLIP

- Assets at risk
- Beach
- 100 year Planning Allowance for Erosion
- 500 year ARI inundation - 2025
- 500 year ARI inundation - 2125



Coral Bay
500 year ARI - 2025 and 2125 Coastal Inundation
SHIRE OF CARNARVON

CS 1126-013-03-01 Coral Bay Inundation 2025 2125

Map 3.6 - Coral Bay Inundation Risk

An additional analysis of assets in the Shire of Carnarvon and Coral Bay was conducted using the Australian Exposure Information Platform (AEIP). The table below shows assets potentially at risk from a 500-year ARI inundation event, both now and in 100 years. This data details asset exposure within each land use zone or category for these extreme events.

Table 3.5 – Quantification of residential and commercial building assets affected by inundation

Category	Feature	500yr ARI 2025	500yr ARI 2125
Carnarvon			
Residential	Estimated Population affected	804	2762
	Dwelling Count	420	1406
	Building Count	359	1176
	Pre 1980 construction count	293	694
	Pre 1990 probable asbestos containing products	321	1035
	Reconstruction value	\$247,750,000	\$853,470,000
	Contents value	\$22,720,000	\$73,870,000
Commercial	Commercial building count	4	52
	Commercial Reconstruction Value	\$25,380,000	\$316,220,000
Institution – Education	School – Pre/Primary	0	1
	School - Secondary	0	1
	School – Other (Combined, Special)	1	1
Institution – Health & Welfare	Hospital – Public	0	
Institution – Emergency Services	Police Station	0	1
	SES Facility	0	
Institution – Government Facilities	Centrelink office	0	1
	Local Government Office	0	
Infrastructure – Transport	Airport – Major Areas	1	1

Category	Feature	500yr ARI 2025	500yr ARI 2125
	Road – Major (km)	0	4
	Road – Arterial and Sub-Arterial (km)	4	7
Agriculture - Avocados, Bananas, Broccoli, Capsicums, Grapes non wine production, Hay, Mandarins, Mangoes, Meat cattle, Melons, Nectarines, Oranges, Peaches, Pumpkins, Sheep and lambs, Tomatoes	Area	5ha	44ha
	Value	\$22 464	\$4,197,999

Coral Bay

Residential	Population estimate	0	0
	Dwelling count	0	0
	Building count	0	0
	Pre 1980 construction count	0	0
	Pre 1990 probable asbestos containing products **	0	0
	Reconstruction Value	0	0
	Contents Value	0	0
Commercial	Commercial building count	0	1
	Commercial Reconstruction value	0	\$17,170,000

Source: AEIP

3.4 Risk Assessment Framework

Approach to the risk assessment

A vulnerability assessment determines how coastal assets may be affected by change and events over the planning period. The factors influencing asset vulnerability include exposure, sensitivity, and adaptability. Exposure refers to the likelihood of an asset being affected by coastal change or hazards. Sensitivity relates to the potential damage or loss an asset might suffer, while adaptability reflects the assets capacity to adjust,

withstand, or cope with such hazards. This is displayed diagrammatically in Figure 3.1, with the input components displayed in blue.

In considering vulnerability in this report, inundation and erosion hazards are considered separately. Assets are grouped according to class for ease of interpretation and to facilitate potential economic impacts of asset vulnerability.

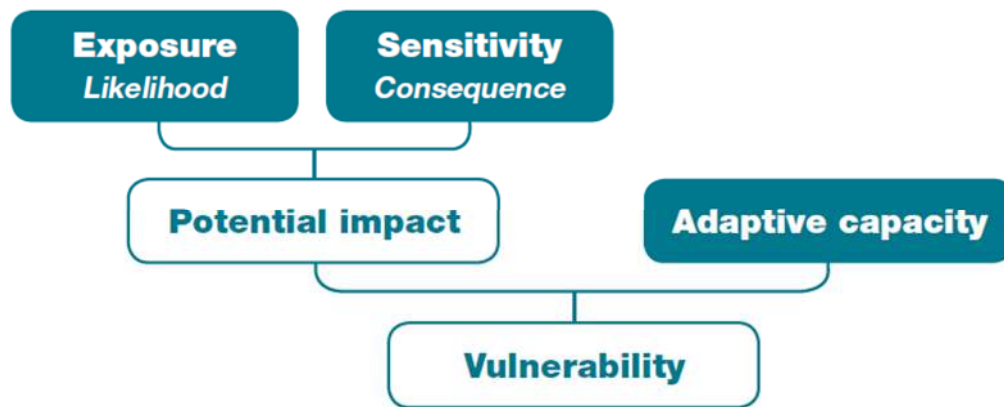


Figure 3.1 – Vulnerability assessment components (reproduced from (WAPC, 2019) – adapted from Allen Consulting, 2005)

Identifying the likelihood of an asset being affected

The exposure or likelihood of coastal assets to hazards directly corresponds to the probability of those hazards impacting an asset. In other words, it reflects the chance of erosion and/or storm surge inundation affecting both existing and future assets, along with their associated values (WAPC, 2019). The likelihood scale adopted for this study is presented in Table 3.6.

Table 3.6 – Exposure / Likelihood

Likelihood rating	Description	Annual Exceedance Probability
Almost Certain	Expected to occur in most circumstances	>90%
Likely	Impact to asset shoreline for a given planning timeframe is likely	50 – 90%
Possible	Impact to asset shoreline for a given planning timeframe is possible	10 – 50%
Unlikely	Impact to asset shoreline for a given planning timeframe is unlikely	1 – 10%
Rare	May occur in exceptional or unforeseen circumstances	<1%

What is the consequence of an asset being affected?

Within the context of this CHRMAP, *consequence* relates to the ability of an asset to respond to a coastal hazard. The response to the hazard could be a gradual response, or a stepped change in response to discrete events (WAPC 2019).

The consequence ranking presented in 3.11 outlines the physical impact that an event can have on an asset.

For each hazard, the consequence was assessed against the criteria and was based on the hazards and impacts of both coastal erosion and inundation. This assessment and the assignment of vulnerability identify areas that will require adaption and to prioritise areas that are vulnerable.

Table 3.7 – Consequence Rating

Likelihood rating	Physical, Financial	Environment	Community / Social & Cultural
Insignificant	No or minimal damage, perhaps requiring increased maintenance. Financial loss less than \$20,000	Negligible to no impact to the environment	Minimal short-term inconvenience to asset, services and function, <5% of community affected. Many alternatives exist.
Minor	Minor damage to assets resulting in restrictions in capability, financial loss of \$20,00 to \$200,000	Short term damage to environment. Recovery will be strong. Local or regional alternate habitat exists.	Isolated but noticeable (short term) decline or disruption to asset, services and function, <10% of community affected. No convenient alternative exists.
Moderate	Damage to assets resulting in isolated loss of capability, financial loss of \$200,000 to \$2 million	Medium term loss of environmental assets. Recovery is likely. Local or regional alternate habitats exist.	Moderate (short to medium term) decline or disruption to assets, services and function ,25% of community affected. No convenient alternative exists.
Major	Significant damage to many assets resulting in very limited capability, financial loss of \$2 million to \$5 million	Long term damage to assets. Limited chance of recovery. No alternate habitats exist.	Severe (medium-term) decline or disruption to asset, services and function, <50% of community affected. No convenient alternative exists.
Catastrophic	Significant damage to most assets resulting in loss of capability, financial loss of over \$5 million.	Permanent damage to environmental assets. No chance pf recovery. No alternate habitat(s) exist	Long term or permanent loss of asset, services and function >75% of community affected. No alternative exists.

Potential Impact – how to define risk?

The indicative level of risk or the potential impact in relation to coastal hazards is calculated by the product of exposure and sensitivity. It provides a classification of the potential impacts of coastal hazards on the identified assets within the Shire. These are to be determined and considered for each of the planning timeframes identified within the CHRMAP.

The evaluated level of risk in relation to hazards is influenced by the asset's tolerability (ie consequence). Definitions are provided in Table 3.8 & 3.9 below

Table 3.8 – Risk Level (Potential Impact) Matrix as Product of Sensitivity (Consequence) and Exposure (Likelihood)

Sensitivity/ Consequence	Exposure / Likelihood				
	Rare	Unlikely	Possible	Likely	Almost Certain
Catastrophic	Medium	High	Extreme	Extreme	Extreme
Major	Medium	Medium	High	Extreme	Extreme
Moderate	Low	Medium	Medium	High	High
Minor	Low	Low	Low	Medium	Medium
Insignificant	Low	Low	Low	Low	Low

Table 3.9 – Risk Profile Definition

Risk Profile	Definition ²
Low	Tolerable risk. A level of risk that is low and manageable without intervention outside routine asset maintenance.
Medium	A level of risk that may require intervention to mitigate, such as changes to design standards of asset maintenance. Short to medium term action required.
High	A level of risk requiring significant intervention to mitigate in the immediate to short term.
Extreme	Immediate action required to reduce the risk to acceptable levels.

3.5 Adaptive Capacity

The adaptive capacity of a coastal asset refers to its ability to adjust and respond effectively to the identified hazards of erosion and inundation. An asset with high adaptive capacity can readily adjust or it possesses inherent flexibility to respond to dynamic conditions. For instance, while built coastal structures and properties near the coast are constrained by their fixed nature, the mobile nature beach and dune systems may exhibit greater adaptability, often coping with change and minimising additional impacts.

² Note: Timeframes are aligned with the Coastal Hazard Assessment (CHA) planning periods. "Immediate to short term" corresponds to 2025–2035, "medium term" to 2050–2075, and "long term" to 2125. Hazards are assessed using 100-year ARI for erosion (S1) and inundation (S4) in the short and medium term, and 500-year ARI for extreme inundation in the long term.

The scale of adaptive capacity is provided in Table 3.10 below

Table 3.10 – Adaptive capacity scale

Adaptive Capacity	Description
No adaption required	Potential impact has insignificant effect on asset. Controls are re-established naturally or with ease before more damage would likely occur.
Very High	Good adaptive capacity. Functionally restored easily. Adaptive systems restored at a relatively low cost or naturally over time.
High	Decent adaptive capacity. Functionality can be restored, although additional adaptive measures should still be considered. Natural adaptive capacity restored slowly over time under average conditions.
Moderate	Small amount of adaptive capacity. Difficult but possible to restore functionality through repair and redesign.
Low	Little or no adaptive capacity. Potential impact would destroy all functionality. Redesign required.

Table 3.11 below outlines the assigned adaptive capacity for each asset category are presented in relation to both erosion and inundation combined. Ratings in relation to adaptive capacity is determined by the asset itself, groups of assets and then the opinions of the community and stakeholders.

Table 3.11 – Assigned adaptive capacity – erosion assets

Asset Category	Adaptive Capacity: Erosion
Roads	Moderate
Residential	Low
Commercial & Tourism	Low
Developed Foreshore Reserve	High
Undeveloped Foreshore Reserve	Moderate
Environment / Ecosystem Services	Moderate
Heritage	Low
Public / Community	Moderate
Infrastructure	Low

Table 3.12 – Assigned adaptive capacity – inundation assets (Local Planning Scheme)

Asset Category	Adaptive Capacity: Inundation
Car Park	Very High
Cemetery	Moderate
Civic and community	High
Commercial	High
Cultural Facilities	High
District distributor road	High
Drainage/waterway	High
Education	High
Environmental conservation reserve	High
Foreshore	High
General industry	Moderate
Heritage	Moderate
Infrastructure Services	Moderate
Light industry	Moderate
Local distributor road	High
Local road	High
Primary distributor road	High
Priority agriculture	High
Public open space	High
Public purposes	High
Recreational	High
Regional centre	Moderate
Residential	Moderate
Service commercial	Moderate
Special use	High
Strategic infrastructure	Moderate
Tourism	Moderate
Urban Development	High

3.6 Vulnerability scale

The vulnerability of an asset is determined by evaluating both the potential impact of coastal hazards (risk level) and the adaptive capacity of the identified asset. According to the CHRMAP Guidelines issued by the WAPC (2019), the study considers four vulnerability levels, which should be assessed for each of the specified timeframes within the CHRMAP. The diagram below illustrates the process of assessing vulnerability as part of the CHRMAP.



Figure 3.2 – Assessing vulnerability

Table 3.13 below is an example of the vulnerability matrix contained within the guidelines and will be used in the assessment against assets as part of the production of the CHRMAP.

Table 3.13 – Vulnerability Matrix

	Adaptive Capacity			
Potential Impact	Low	Moderate	High	Very High
Extreme	Very High	Very High	High	Medium
High	Very High	High	Medium	Medium
Medium	High	Medium	Medium	Low
Low	Medium	Medium	Low	Low

3.7 Vulnerability analysis

As illustrated in Table 3.13 above, vulnerability is a product of potential impact (risk) and adaptive capacity. To calculate vulnerability, each component of the formula has been considered, the results are presented in this section, along with brief analysis of key assets that are at risk. The CHRMAP adopts four levels of vulnerability, as outlined below:

- **Very high:** Asset has minimal to no ability to adapt to impacts of coastal hazards without additional support. Significant further adaptation is required to ensure the asset is not lost. Reconsideration of

design may be required if vulnerability cannot be reduced. Risk management measures will need to be a priority.

- **High:** Asset has limited ability to adapt to impacts of coastal hazards. Immediate to short term risk management measures are required.
- **Medium:** Asset has some ability to adapt to impacts of coastal hazards. Short term to medium term risk management measures are required.
- **Low:** Asset has high resilience and can adapt to impacts of coastal hazards without additional support. No immediate risk management measures are required other than monitoring.

Vulnerability to erosion

The outcomes of the vulnerability analysis for erosion across key assets, for coastal erosion, is provided in Table 3.14 below.

Table 3.14 – Erosion Vulnerability Ratings

		Vulnerability				
Asset Type	Description	2025	2035	2050	2075	2125
Carnarvon						
Commercial & Tourism	Carnarvon Beach Holiday Resort	Medium	Medium	Medium	Medium	Very High
Developed Foreshore	Babbage Island Beach Toilets	Medium	Medium	Medium	Medium	Medium
Undeveloped Foreshore	Babbage Island Beach (extent)	Medium	Medium	Medium	High	High
Road	Pelican Point Road	Medium	High	High	High	High
Commercial & Tourism	NorWest Seafoods site	Medium	Medium	Medium	Medium	Very High
Environment/ Ecosystem Services	Babbage Island coastal dunes	Medium	Medium	Medium	Medium	Medium
Environment/ Ecosystem Services	Babbage/Whitlock Islands dunes and intertidal area	Medium	Medium	Medium	Medium	Medium
Public community	Historic Tramway Reserve Trail	Medium	Medium	Medium	Medium	Medium
Residential Development	Future Residential land (zoned)	Medium	Medium	Very High	Very High	Very High
Residential Development	Future Residential land (development zone)	Medium	Medium	Very High	Very High	Very High
Road	Harbour Road	Medium	Medium	Medium	High	High
Undeveloped Foreshore	Remnant dunes/Vegetation	Medium	Medium	Medium	High	High

		Vulnerability				
Asset Type	Description	2025	2035	2050	2075	2125
Commercial & Tourism	Marine services adjacent to marina	Medium	Medium	Very High	Very High	Very High
Commercial & Tourism	Wharf Access Road	Medium	Medium	Very High	Very High	Very High
Commercial & Tourism	Carparks adjacent Harbour Road	Medium	Medium	Medium	Very High	Very High
Undeveloped Foreshore	Sandy Foreshore adjacent Harbour Road	Medium	Medium	High	High	High
Environment/ Ecosystem Services	Intertidal Mangroves	Medium	Medium	Medium	Medium	Medium
Environment/Ecosystem Services	Intertidal Mangroves	Medium	Medium	Medium	Medium	Medium
Developed Foreshore	Massey Bay constructed access	Medium	Medium	Medium	Medium	Medium
Public Community	Race course and associated infrastructure (partial)	Medium	Medium	Medium	Medium	Medium
Public Community	Race course and associated infrastructure (partial)	Medium	Medium	Medium	Medium	Medium
Undeveloped Foreshore	Intertidal area (extent)	Medium	Medium	Medium	Medium	Very High
Infrastructure	Wharf	Medium	Medium	Medium	Medium	Medium
Infrastructure	Fascine Wall	Medium	Medium	Medium	Medium	Medium
Undeveloped Foreshore	Sand Spit	Medium	Medium	Medium	High	High
Infrastructure	Babbage Island Boat Ramp	Medium	Medium	Medium	Medium	Medium
Infrastructure	Navigation Channel	Medium	Medium	Medium	Medium	Medium
Coral Bay						
Environment/ Ecosystem Services	Sandy coastal dunes	Medium	Medium	Medium	Medium	Medium
Undeveloped Foreshore	Sandy dunes with informal beach access	Medium	Medium	Medium	Medium	High
Commercial & Tourism	Chalets	Medium	Medium	Medium	Medium	Very High
Road	Robinson Street	Medium	Medium	High	High	High
Developed Foreshore	Toilet Block	Low	Low	Low	Low	Medium

Asset Type	Description	Vulnerability				
		2025	2035	2050	2075	2125
Developed Foreshore	Grassed Parkland	Low	Low	Low	Low	Medium
Undeveloped Foreshore	Coral Bay Beach	Medium	Medium	Medium	High	High
Undeveloped Foreshore	Coastal heath with constructed pedestrian access to beach	Medium	Medium	Medium	High	High
Road	Coral Bay public car park	Medium	Medium	Medium	Medium	Very High
Commercial & Tourism	Caravan park; chalets, tourist accommodation along Robinson Street	Medium	Medium	Medium	Medium	Very High
Environment/ Ecosystem Services	Sandy dunes with limited beach access points	Medium	Medium	Medium	Medium	Medium
Undeveloped Foreshore	Dunes with 4wd access	Medium	Medium	Medium	Medium	High
Infrastructure	Boat Launching Area (DOT)	Medium	Medium	Medium	Medium	Medium

The erosion vulnerability assessment demonstrates that both Carnarvon and Coral Bay face increasing risks to key coastal assets over the planning horizon. In Carnarvon, assets such as the Carnarvon Beach Holiday Resort, NorWest Seafoods site, and future residential development zones are projected to transition from “medium” vulnerability in the near term to “very high” vulnerability by 2125. Roads including Pelican Point Road and Harbour Road, as well as undeveloped foreshore and remnant dunes, also show a marked increase in vulnerability, reflecting the cumulative impacts of ongoing shoreline retreat, sea level rise, and limited adaptive capacity of fixed infrastructure and low-lying land. Notably, some assets, such as Babbage Island Beach Toilets and the Historic Tramway Reserve Trail, remain at “medium” vulnerability throughout, likely due to their location or construction.

In Coral Bay, the vulnerability profile is similarly concerning for assets located on sandy dunes and low-lying foreshore areas. Sandy dunes with informal beach access, Coral Bay Beach, and the public car park are rated as “medium” vulnerability in the near term but increase to “high” or “very high” by 2125. Commercial and tourism assets, including chalets and caravan parks along Robinson Street, also shift from “medium” to “very high” vulnerability over time. Developed foreshore assets such as the toilet block and grassed parkland generally remain at “low” or “medium” vulnerability, reflecting their location or construction. These results highlight the importance of proactive dune management, planning controls, and managed retreat strategies to address the escalating erosion risk, particularly for assets with limited natural buffer or those situated close to the active shoreline.

Vulnerability to inundation

The outcome of the vulnerability for coastal inundation is provided in Table 3.15 below.

Table 3.15 – Inundation Vulnerability Ratings

Asset Type (Local Planning Scheme)	Vulnerability	
	2025 500YR ARI	2125 500YR ARI
Carnarvon		
Car Park	Low	Low
Cemetery	Medium	Medium
Civic and community	Low	Medium
Commercial	Low	Medium
Cultural Facilities	Low	Medium
District distributor road	Medium	Medium
Drainage/waterway	Low	Low
Education	Low	Medium
Environmental conservation reserve	Medium	Medium
Foreshore	Medium	Medium
General industry	Medium	Medium
Heritage	Medium	High
Infrastructure Services	Medium	High
Light industry	Medium	Medium
Local distributor road	Medium	Medium
Local road	Low	Medium
Primary distributor road	Medium	Medium
Priority agriculture	Low	Low
Public open space	Medium	Medium
Public purposes	Medium	Medium
Recreational	Low	Medium
Regional centre	Medium	High
Residential	High	High
Service commercial	Medium	High

Vulnerability		
Asset Type (Local Planning Scheme)	2025 500YR ARI	2125 500YR ARI
Special use	Low	Medium
Strategic infrastructure	High	Very High
Tourism	Medium	High
Urban Development	Low	Medium
Coral Bay		
Commercial	Low	Medium
Foreshore	Medium	Medium
Local road	Low	Medium
Tourism	Medium	High
Environmental conservation reserve	Low	Medium

The inundation vulnerability assessment in Table 3.15 shows that both Carnarvon and Coral Bay have a range of assets that are increasingly exposed to flood risk over the planning horizon, particularly under extreme events such as the 500-year ARI scenario. In Carnarvon, residential areas, strategic infrastructure, and service commercial zones are already rated as “high” vulnerability in the present day, with some assets (such as heritage and infrastructure services) escalating to “very high” vulnerability by 2125. Public open space, regional centres, and commercial areas also see their vulnerability increase from “medium” to “high” or “very high” over time, reflecting the cumulative impact of sea level rise and the limited adaptive capacity of low-lying land and critical infrastructure.

In Coral Bay, the vulnerability profile is similarly concerning for tourism assets and foreshore areas. Tourism zones, public car parks, and foreshore reserves are rated as “medium” or “high” vulnerability under current and future scenarios, with the risk intensifying by 2125. Environmental conservation reserves and local roads, while starting at “low” vulnerability, also increase to “medium” over time. These results highlight the importance of proactive adaptation measures, such as flood-proofing, planning controls, and emergency management, to address the growing risk of coastal inundation, especially for assets with limited elevation or those located close to the shoreline.

3.8 Existing Controls

Planning Controls

A summary of the current relevant planning controls applicable to the subject area are provided in Chapter 1 – Establish the Context of this report. A significant array of planning documentation applies to the subject area,

some of which already makes mention of coastal hazards, or values within the Shire that have provided input in the CHRMAP process.

Physical Controls

There are several existing physical controls that have been identified around Carnarvon. These structures have been considered in the assessment of shoreline erosion (Baird, 2023) and have been taken into account when considering the *likelihood* of an event occurring and thus flowing through to the likely risk and vulnerability of nearby assets.

The extent of physical structures is shown on Map 3.9 (overall) and 3.10 (detail).



Map 3.9 – Existing physical structures - Carnarvon



Map 3.10 – Existing physical structures – Carnarvon (detail)

3.9 Priorities for Risk Treatment

Identifying priorities for risk treatment is an important and somewhat subjective consideration of the vulnerability of key assets, coupled with the coastal values of the community that were gathered during the early stages of the project – as summarised in Table 3.16 below

Table 3.16 – Community consultation outcomes summary

Consideration	Carnarvon	Coral Bay
Environmental	Recognising the town is surrounded by natural places which can be impacted and changed by climate change. Biodiversity and ecology are likely to be impacted by climate. For example, rising sea levels and increased storm surges may lead to the loss of mangrove habitats and coastal dunes, while changes in rainfall and temperature could affect the health and distribution of native plant and animal species in the Gascoyne delta and surrounding wetlands.	Operators of tourism are aware of need to protect reefs and access to them for commercial business operations. Recognise visitors are recreational users (boats and beach focus) and are the settlement's key economic driver. Coral bleaching was seen as a crisis but overall, the reef is believed to be resilient. A defend approach to potential climate impacts is more evident than Carnarvon and there is resistance to the use of restrictive beach access as a management tool.
Culture	People have long witnessed changes and events due to natural forces and therefore more understanding of flooding high winds surges and erosion accretion. Carnarvon has a dynamic shoreline. There is a need to accept this fluidity and plan to be accommodating changes. Some focus on bridges, jetties and boating facilities – these were seen as very important for recreation and fishing tourism. Aboriginal knowledge of land and climate history is important, including their knowledge of past shorelines deltas and seasonal risks.	The sample is a small number of business proprietors, there are very few long-term residents who aren't operating businesses. Reliant entirely on inflow resources and businesses are not relocatable thus their willingness to defend and keep investing in maintaining the status of place and shoreline versus surrender or adaptive approaches.
Economy	Carnarvon needs to protect civic and business assets from impacts and design better. More attention to lifespan investment is required - for example boat ramps which are unusable after only a number of years. The CCI is interested in further dialogue - no set position of members yet but aware of sensitivities.	The Capped Population of Coral Bay and coastal nodes provide a false measure of security given the boom in pandemic demand which exceeded 3500 people. This placed a lot of pressure on utilities and natural areas and facilities beyond what was planned. It raised the impact of disconnected governance – with DBCA and Shire as well as different business interests working from own values. In the case of

Consideration	Carnarvon	Coral Bay
		previous 'economic' decisions they cited the boat ramp and marina as not successful due to scouring of Paradise Beach, EPA inattention to compliance, and resulting interruption of sand transport and impact on beach. Better governance of the place is needed. Shire has an extremely limited role and authority - which diminishes its ability to deliver the oversight needed to manage Coral Bay as a place. The present fragmentation of authority lacks consistency and security to deliver for continued business investment.

The risk management approach applied in this CHRMAP (likelihood, consequence, risk priorities) is combined with consultation outcomes and discussion with the Shire to agreed priorities which align with their organisational risk management framework.

In the process, the degree of tolerance and acceptability of coastal risk for key assets by the community has been determined using identified community values listed above, along with a review of existing planning controls.

This approach now forms a framework for future adaptation options to be considered in subsequent chapters. By incorporating existing controls and community values, the relative vulnerability is used to assess mitigation and adaptation priorities across different planning time frames. Prioritisation becomes critical to define trade-offs, including the physical transfer of erosion pressure or financial costs. This holistic approach better informs planning decisions about coastal and risk management.

Both Carnarvon and Coral Bay have assets at risk to an unacceptable level of vulnerability, at all planning timeframes, and as such all sites will require risk mitigation as part of their management regime. In summary, Carnarvon has a greater level of vulnerability to inundation compared to erosion. Coral Bay has comparatively smaller (but still significant in the longer-term), vulnerability to coastal change.

Table 3.17 – Priorities for risk treatment – Erosion

Asset Type	Description	Vulnerability	Planning Period
Carnarvon			
Commercial & Tourism	Carnarvon Beach Holiday Resort	Very High	100-yr
Undeveloped Foreshore	Babbage Island Beach (extent)	High	50-yr
Road	Pelican Point Road	High	10-yr
Residential Development	Future Residential land (zoned)	Very High	25-yr

Asset Type	Description	Vulnerability	Planning Period
Residential Development	Future Residential land (development zone)	Very High	25-yr
Road	Harbour Road	High	50-yr
Undeveloped Foreshore	Remnant dunes/Vegetation	High	50-yr
Commercial & Tourism	Marine services adjacent to marina	Very High	25-yr
Commercial & Tourism	Wharf Access Road	Very High	25-yr
Commercial & Tourism	Carparks adjacent Harbour Road	High	50-yr
Undeveloped Foreshore	Sandy Foreshore adjacent Harbour Road	High	25-yr
Undeveloped Foreshore	Intertidal area (extent)	Very High	100-yr
Coral Bay			
Undeveloped Foreshore	Sandy dunes with informal beach access	High	100-yr
Commercial & Tourism	Chalets	Very High	100-yr
Road	Robinson Street	High	25-yr
Undeveloped Foreshore	Coral Bay Beach	High	50-yr
Undeveloped Foreshore	Coastal heath with constructed pedestrian access to beach	High	50-yr
Road	Coral Bay public car park	Very High	100-yr
Undeveloped Foreshore	Dunes with 4wd access	High	100-yr

Table 3.18 – Priorities for risk treatment – Inundation

Local Planning Scheme Zone/Reserve	Vulnerability	Planning Period
Carnarvon		
Heritage	High	100-yr
Infrastructure Services	High	100-yr
Residential	High	Current
Service Commercial	High	100-yr
Strategic Infrastructure	High	Current
Coral Bay		
Tourism	High	100-yr

4 Risk Treatment

4.1 Risk treatment approach

Overview

The risk treatment and adaptation stage within the CHRMAP framework focuses on addressing residual risks to coastal assets. Its primary objective is to identify appropriate risk treatment responses that can effectively mitigate coastal hazard risks for the shoreline areas and coastal assets within the study area over the planning horizon. Additionally, these responses should allow for flexibility in future decision-making.

Key considerations include:

- **Current Vulnerability:** Presently, the level of coastal hazard vulnerability for coastal assets in the Shire is generally low/medium (refer tables 3.14 and 3.15). However, this risk is anticipated to escalate due to projected sea level rise in the coming years.
- **Sea Level Rise Scenarios:** The CHRMAP has examined various sea level rise scenarios consistent with SPP2.6. These scenarios assess how coastal assets may be affected by hazards in the future, considering events ranging from annual occurrences to extreme events (within the limits outlined in Section 1.3).
- **Uncertainty Acknowledgment:** Recognising the uncertainty associated with long-term predictions related to sea level rise and climate change, the risk treatment process incorporates this uncertainty into its considerations.
- **Risk Treatment Pathways:** The CHRMAP outlines risk treatment pathways that enable the management of coastal assets in the present while adjusting to changing risk profiles in the future. These pathways are designed to adapt over time, aligning with increasing risk levels due to sea level rise and climate change. Trigger points, rather than fixed time frames, guide adjustments.
- **Examples of Triggers:** Instances where a shift to a new level of risk management may be necessary include measured or actual changes in sea level or shoreline erosion near structures (e.g., houses).
- **Community Responsibility:** The ability of shorelines and riverine areas in the Shire to adapt and respond to changing conditions rests with the Shire and the community.

Decision-making context

Although the Shire is a manager of coastal areas and associated public assets, it is not the role nor remit of the Shire to protect or compensate for the loss of freehold property from damage caused by coastal processes. The CHRMAP process delivers a plan to assist the community to identify those most important assets along the coast, and to then consider how these will be protected and managed for immediate and future risk.

As such, the CHRMAP adopts a '**risk management**' approach to:

- Consider the risks arising from coastal hazards
- Identify risk management responses, and
- Prioritise and implement the risk management responses.

It considers '**who**' is responsible for managing the risk:

- **Private parties** are responsible for managing risks to their private assets and incomes. To manage these risks private parties, need to:
 - be aware of the risks and their responsibility for managing them
 - take steps to understand the magnitude and nature of the specific risks to their assets and activities
 - develop and implement strategies and actions to manage the risks.
- **Governments**, on behalf of the community, are primarily responsible for the oversight of planning and managing risk to public goods and public assets which they own and manage. Governments also seek to:
 - develop local policies and regulations consistent with State risk management approaches;
 - facilitate by building resilience and adaptive capacity within the local community, including providing timely information about relevant known coastal hazards including erosion and inundation; and
 - building a workable partnership with the community to identify and manage risks.

Adaption hierarchy

SPP 2.6 (Western Australian Planning Commission 2013) establishes a structured hierarchy of adaptation pathways designed to inform decision-making in coastal areas. These pathways serve as the framework for the Shire to evaluate adaptation strategies aimed at minimising risks associated with coastal hazards. The hierarchy of treatment options includes '**Avoid**,' '**Planned / Managed Retreat**,' '**Accommodate**,' and '**Protect**.' It is important to note that neither State nor Local Government are legally bound to safeguard private assets from coastal hazards. It is also noted that the CHRMAP process strongly discourages the long-term adoption of the 'Protect' pathway for adaptation.

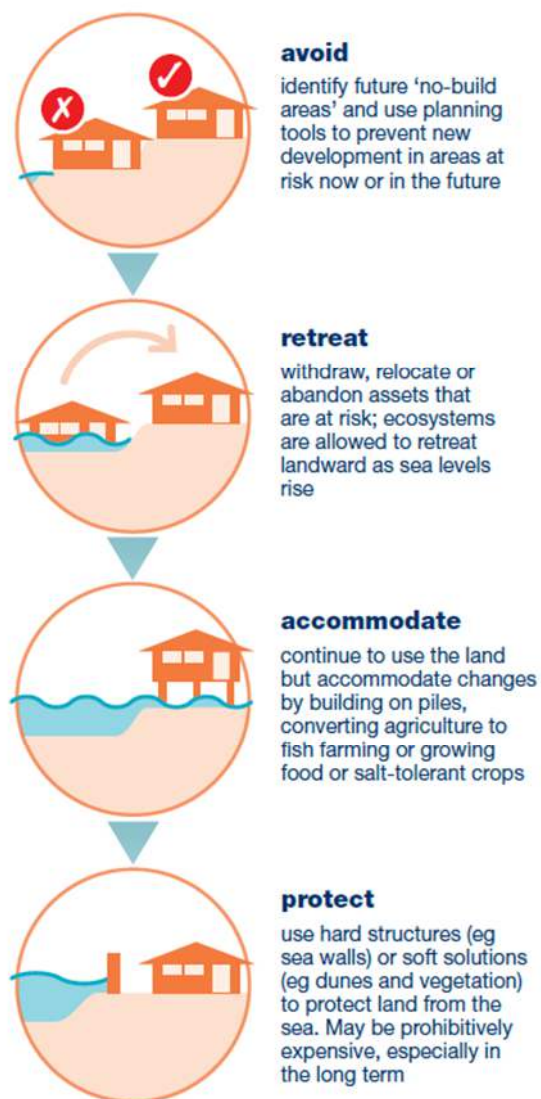


Figure 4.1 – Risk management and adaptation hierarchy (source: WAPC 2019)

The following table outlines the objectives of each of the treatment options.

Table 4.1 - Risk treatment options

Risk Treatment Option	Objectives
Avoid	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 Option	Objectives
	risk treatment options are the best form of risk management (mitigation) and where possible should be the risk treatment option of choice. Avoidance risk treatment options ensure that risk management measures that eliminate hazards, activities and exposures that can negatively affect an asset can be formulated and implemented. Avoidance is particularly applicable to all land use and development in greenfield locations.
Retreat	The planned or managed retreat risk treatment option aims to preserve beach and coastal foreshore assets, public access, recreation, conservation and coastal foreshore management. This risk treatment option allows coastal physical processes to occur with as little impediment from development as possible in the future, allowing natural dynamic movement and retreat in response to coastal physical processes, particularly sea level rise. 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 (discussed further in Section 5.4.1 Triggers). No new coastal structures would be constructed, and new development would be avoided or minimised within high-risk areas. Where possible and practical, dunes would be restored or enhanced 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), or if a trigger for removal is reached, they would be removed, including any associated coastal protection structures (e.g. temporary protection works that extended the life of the asset). If planned or managed retreat is the approach selected for implementation, it will need to be implemented through the planning framework and instruments within Western Australia.
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. These modified local planning frameworks should provide clear direction for decision-makers when assessing applications for new development, and to affected landholders. Planning frameworks might include a selection of the following instruments: clear development assessment criteria indicating what would be appropriate development; notifications on title, to inform current and future landholders of hazard; and planning approval conditions which allow the continued use of land until risks become intolerable. Accommodate risk treatment options can help to facilitate a switch to planned or managed retreat or protection risk treatment options later.

Risk Treatment Option	Objectives
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. Common hard protection structures include seawalls; groynes; offshore breakwaters and artificial headlands; and soft protection measures such as beach nourishment. Protection should be congruent with the coastal physical process and assets, amenity and value of any given location they are being imposed upon. When considering protection structures, it is important to understand they have off-site impacts, for example loss of beach in front and accelerated erosion at the edge of a seawall. Therefore, a protect decision must consider off-site impacts. In the event protection is selected for implementation, comprehensive analysis as part of the CHRMAP process should include the policy requirements of SPP 2.6 Cl. 5.7 Coastal protection works. Of importance to such analysis will be governance matters of ownership and funding arrangements for the construction and ongoing care, control and maintenance, in particular where protection of private property is considered. Risk management measures will need to ensure these requirements are implemented. Where public and private assets are proposed to be constructed inland of existing protection structures, such protection structures should only be considered as an interim risk management measure within the planning timeframes being considered in the CHRMAP. The design life of the protection structure should be a key factor in determining the appropriateness of the proposed asset or development. Decision-makers and landholders may need to consider the appropriateness of using interim protection structures 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.

Source: (Western Australian Planning Commission, 2019)

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

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 is incomplete.

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.

4.2 Adaption toolkit

Table 4.2 outlines a comprehensive list of adaptation options suitable for most coastal sites. These options address both short-term and long-term coastal hazard adaptation, extending beyond considerations solely related to climate change impacts. The right-hand columns provide insights into the suitability of each option for Coral Bay and Carnarvon.

While risks and corresponding adaptation strategies are evaluated independently, it's important to recognise that triggers for implementing these options can be adjusted to align with specific circumstances. For instance, if erosion or inundation risks escalate sooner than anticipated, a trigger may prompt an earlier adaptation response.

Table 4.2 - Adaptation toolkit

Category	Code	Name	Description	Possible actions	Comment / Suitability
AVOID	AV1	<i>Avoid development</i>	Avoiding new development within areas potentially impacted by coastal hazards (low, medium and high) and locating assets in areas that will not be vulnerable to coastal hazards.	1. Amend local planning scheme to include Special Control Area (SCA) which encompasses all areas affected by planning 10-, 20- and 100-year planning allowances (refer hazard assessment). 2. Establish planning-based controls that only allow development in the SCA that can address coastal hazard. 3. Reserve land in the Local Planning Scheme as required. 4. The Shire's Asset Management program to consider location for future public assets. 5. Amending the local planning framework to remove development potential on affected areas.	Financial resources will not be required to be spent on risk management. There are limited options to 'avoid' development within the CHRMAP study area where existing infrastructure is located, however can be implemented in undeveloped areas.
PLANNED OR MANAGED RETREAT	MR1	<i>Leave assets unprotected</i>	Accept functional loss of an asset following a coastal hazard event. Assets are not repaired to usable condition (only to ensure public safety is maintained).	6. Determine assets that are deemed sacrificial. 7. Monitoring (NR1) to identify when trigger is reached. 8. The Shire's Asset Management program to consider location for future public assets and update Council's Asset register to reflect likely timeframe for	Saves financial resources for alternative uses and allows for retreat that enables natural recession of the shoreline over the long-term.

Category	Code	Name	Description	Possible actions	Comment / Suitability
				impact to assist in prioritising asset relocation.	
	MR2	<i>Remove / Relocate</i>	Assets located in the hazard zone are permanently removed or relocated.	9. 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. 10. Monitoring (see NR1) to identify when trigger is reached for removal or relocation.	For residential and commercial property, this option may require voluntary or compulsory acquisition of land, transferrable development rights and land swaps. Enables the social and economic values of assets to be utilised until such time that the asset needs to be relocated. Can often coincide with asset replacement, and allows the cost of relocation to be shared with the cost of asset replacement.
	MR3	<i>Planning controls for managed retreat / Prohibit expanding existing use rights</i>	Use planning controls to allow continued use of the current infrastructure until such time that impacts arise, but restrict further or new development	11. Amend local planning scheme to include Special Control Area. 12. Notifications on title regarding the limits on expanding and/or modification of existing use rights.	This enables existing development and use rights to continue without increasing them, until such time that risk arising from coastal hazards is intolerable. Includes mechanisms for ensuring that the Shire, landowners and prospective buyers are made aware of the risk. Generally applicable where protection of assets is not viable. Works generally on zoned land (not local scheme reserves).
	MR4	<i>Voluntary acquisition</i>	Acquisition of affected properties on a voluntary basis.	13. Investigate/put in place funding for acquisition of priority properties. 14. Offer voluntary acquisitions reflecting asset value in light of hazard. 15. Reservation of land in a Local Planning Scheme.	This enables removal of private property(s) located within a land use that would otherwise be permitted, to ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation, and where alternative risk treatment options are not viable for the property and adjacent land. Early acquisition and leaseback could be used as an alternative to help reduce overall costs. Reservation of land in a local planning scheme signals the intent of the local government to acquire the land, and also activates provisions in the <i>Planning and Development Act 2005</i> regarding acquisition, resumption and compensation.

Category	Code	Name	Description	Possible actions	Comment / Suitability
ACCOMMODATE	AC1	<i>Design assets to withstand impacts</i>	Design of assets to withstand the impact of inundation, for example, building houses on stilts or raising building pads above the expected inundation levels	16. Planning response to stipulate building requirements. 17. Appropriate design requirements to be incorporated into the Shire's Asset Management Plan for public assets.	This is aimed at retaining existing assets in their current locations but reducing the consequences of the inundation hazard. It is often cheaper to mitigate the impacts with initial design outcomes as opposed to retrofitting (adapting) existing assets in the future.
	AC2	<i>Planning controls for accommodation</i>	Amend local planning frameworks to require assets to be designed to be able to accommodate hazards.	18. Amend local planning scheme to include a Special Control Area that identifies affected areas, requires any development to be approved by the Local Government, and outlines what requirements for accommodating the potential inundation risk need to be addressed. 19. Prepare local planning policy outlining relevant planning controls. This will generally be read in conjunction with the SCA. 20. Notifications on title when a development application is lodged/approved to advise of the potential risk.	Indicates to current and future landholders that an asset is at risk from coastal hazards over the planning timeframe, and that risk management and adaptation is likely to be required at some stage. Helps owners to make informed decisions about the level of risk they are willing to accept. This is a low-cost option that does not prohibit the use of other management options in the future. Limited application – would only apply where a Development Application is lodged with Council.
PROTECT	PR1	<i>Dune care/management</i>	Development of a long-term program for revegetation and rehabilitation of dune system.	21. Update existing Foreshore Management Plans to ensure that actions associated with dune management, within the context of coastal hazards, is adequately addressed.	Program needs to be considered in context of cost of replenishment and resources to undertake actions. Would require continued funding sources. This is a largely suitable option for the Shire's foreshore and is currently being implemented via existing Foreshore Management Plans.
	PR2	<i>Groyne</i>	Construct rock groynes along the beach approximately perpendicular to the shoreline to restrict longshore sediment movement and stabilise sections of shoreline. This option is often accompanied by beach nourishment.	22. Undertake a feasibility and design study to guide construction.	Hard protection can divert erosion issues elsewhere, such as to the down drift side of a groyne, and can have significant impact on coastal ecosystems when accompanied by beach nourishment. Groynes are not effective as a means of managing short-term storm erosion. Can be expensive and rock sources may not be readily available or affordable. Groynes change the nature and

Category	Code	Name	Description	Possible actions	Comment / Suitability
					appearance of the coast and can impact walking and beach use. Assessment of this option needs to consider long term maintenance, as this will extend the life of the groyne.
	PR3	Seawall	Construct seawall in front of assets or along length of coastline to protect them from coastal hazards.	23. Undertake a feasibility and design study to guide construction.	Hard protection can divert erosion issues elsewhere, such as to beaches either side of, and directly in front of, a seawall. They can also have significant impact on coastal ecosystems Seawalls are expensive and change the nature and appearance of the coast, typically resulting in long term loss of the beach in front. Rock sources may not be readily available or affordable. They need to be accompanied by beach nourishment/ replenishment, which adds to the cost of option. Assessment of this option needs to consider long term maintenance, as this will extend the life of the wall.
	PR4	Nearshore reef/ Breakwater/ Artificial Reef	Construct offshore reef(s)/breakwater(s) or raise existing natural nearshore reef structures to maintain level of protection as sea level rises.	24. Undertake a feasibility and design study to guide construction.	The impacts of these structures are relatively unknown, and untested in the local context. May have significant impact on coastal ecosystems in adjacent areas. Reefs are unlikely to be effective over time as sea levels rise, or the crest would need to be raised in height in response. Are very expensive to design, build and maintain and rock sources may not be readily available or affordable. Assessment of this option needs to consider long term maintenance, as this will extend the life of the structure.
	PR5	Beach (sand) nourishment	Addition of sand to the beach, dune and/or nearshore area to replace lost material and/or create additional buffer.	25. Undertake a feasibility and design study to guide construction.	This option is a temporary measure and can be more effective in association with other options. The sand may be from an external source or from a nearby part of that coastal area, as such availability of suitable sand sources may be an issue. Where suitable sources are not readily available or a considerable distance away, costs

Category	Code	Name	Description	Possible actions	Comment / Suitability
					are increased. If the nourishment sand is significantly finer than the existing beach sand the nourishment sand will be lost quickly.
NO REGRETS	NR1	Monitoring	Long term baseline monitoring and event-based monitoring following storm erosion events	26. Set up a baseline monitoring programme for long term trend and condition following major events. 27. Review results for particular asset triggers regularly. 28. 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).	Monitoring enables assessment of the frequency and severity of coastal hazard events (along with their impacts). This information is useful as part of an ongoing review process for the CHRMAP, and can be also useful in the identification of triggers that lead to particular management actions.
	NR2	Protection structure audit	Involves undertaking an audit of existing protection structures, to determine their current condition, effectiveness and future protection potential/adaptability.	29. Conduct audit of existing protection structures. 30. Update planning allowances lines where relevant to account for existing protection structures. 31. Update CHRMAP proposed actions to account for condition (life) of existing protection structures.	Depending upon the expected life and future protection from existing protection structures, there may be updates to the hazard estimates. This will flow on to affect other risk treatment options, including implementation of risk management measures. Limited applicability to Shire given limited existing structures.
	NR3	Notification on title	Using the Planning and Development Act 2005 and the Land Administration Act 1997 to place a notification on the titles of potentially affected properties.	32. Implement in accordance with the planning framework, and as conditions of approval for subdivision and development.	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. Allows vulnerability of asset to hazards to be conveyed to existing and future owners. One means of implementation that is low cost, is

Category	Code	Name	Description	Possible actions	Comment / Suitability
					through subdivision and development decision making
	NR4	Emergency evacuation plans	Establishing emergency evacuation management plans where existing assets may be affected by erosion and/ or inundation to manage the safety of community and stakeholders	33. Develop evacuation plans for each site considered by the CHRMAP. 34. Update evacuation plans with latest inundation mapping available or include coastal inundation area into existing evacuation plans.	This option is a low-cost option in addressing the consequences of erosion / inundation regarding safety to lives as the impact occurs.
DO NOTHING	DN	Do nothing	This is managed retreat at its most basic form. The asset will be lost after a hazard event. Repairs are carried out for public safety purposes only. Take no action. No limitations on development or implementation of adaptation planning. Accept risk	35. Take no action and accept risk.	Does not involve any new actions. Where existing levels of risk are low, accepting the risk may be appropriate. However, it may not be appropriate for high-risk locations/assets. The cost of Do Nothing may be substantially greater in the future than the current cost of implementing planning controls. This is because the value of land at risk continues to increase, as does the cost of mitigating recession impacts over time (such as retrofit, or even abandoning lost lands). Further, as the value of land at risk continues to increase over time, implementation of retreat risk treatment options in the future, to ensure land in the coastal zone is continuously provided for coastal foreshore management, public access, recreation and conservation, become increasingly desirable while more difficult to implement.

4.3 Multi-criterial assessment

MCA categories

A multi-criteria analysis (MCA) provides a qualitative framework to rank risk treatment options and has been completed to consider adaptation options for identified assets at Carnarvon and Coral Bay. The MCA is based on 6 broad categories as outlined in Table 4.2 below.

Table 4.3 - MCA criteria

Criteria	MCA considerations
Effectiveness	Ability for the option to mitigate the coastal hazard risk
Environmental Impact	Impact on existing native vegetation / dunes / coastal processes (including both construction and ongoing maintenance)
Social Impact	Impacts on amenity Potential impacts on Aboriginal and European heritage sites and values are considered in this criterion Public acceptability.
Landscape	Impacts on landscape Consideration of aesthetics associated within nearby areas
Cost	Upfront capital costs Ongoing maintenance costs Economic impacts – such as loss of businesses, income, value
Future adaptability	Whether the option is easily adaptable in future, such as for updated sea level rise levels If the option limits the feasibility of selecting other options in future

Assessment framework

To perform the MCA, each identified option was assessed against each of the criteria for each of the Management Units, this is shown within Table 3.2 of the Risk Assessment Chapter that forms part of the CHRMAP. The assessment criteria run across the top row whilst the ratings are shown below; each have a possible score from **-2 to +2**.

The ratings will provide a priority for adaptation options to be subject to CBA. At the completion of this process a clear direction for adaptation will be identified and incorporated into an Implementation Plan. It is acknowledged that that more than one adaptation option may be required across varying timeframes.

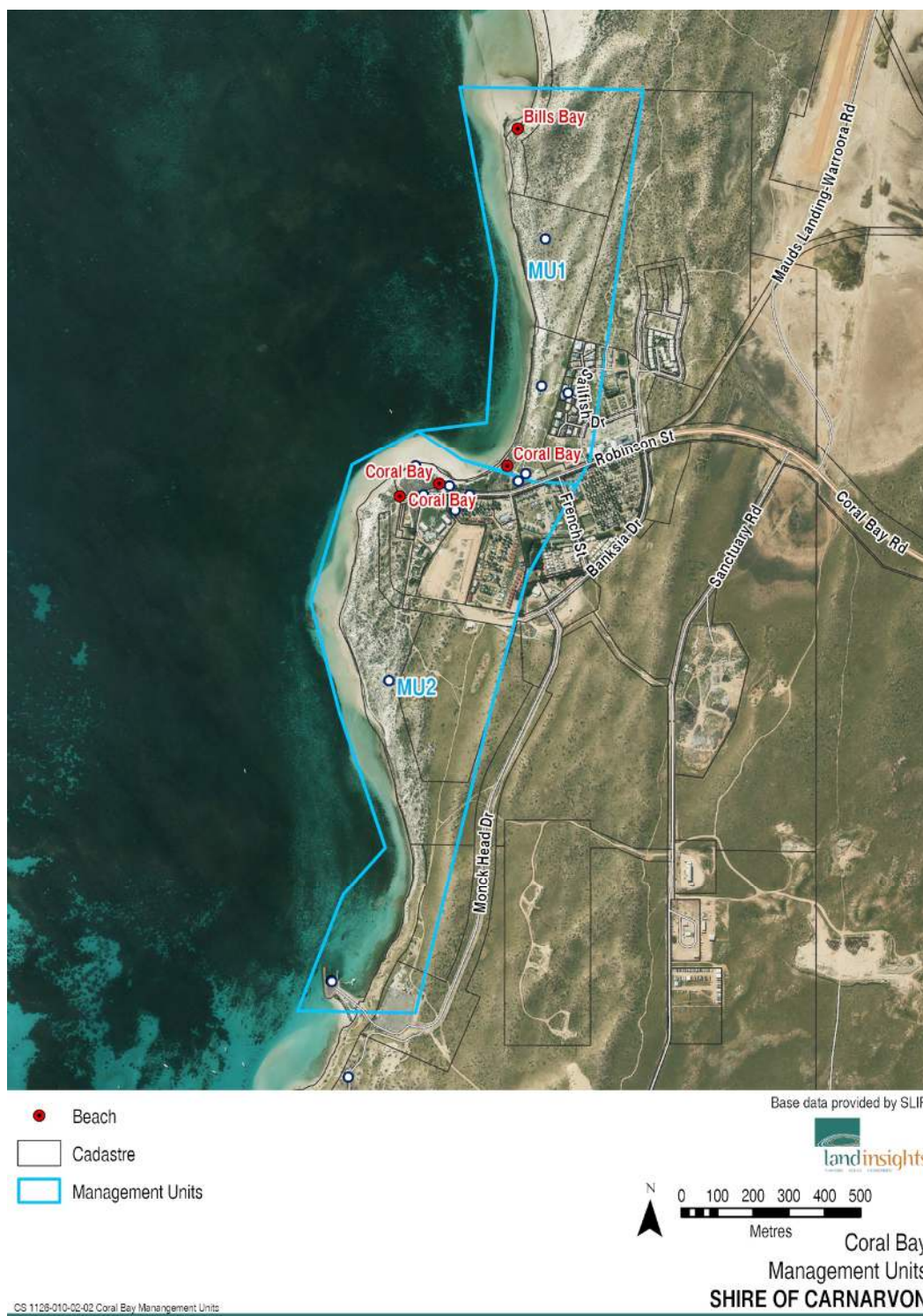
It is also important to note that the rating/score is subjective, based on knowledge of local condition by the project team, stakeholder knowledge and feedback, and Shire input. The weightings applied reflect the outcomes of previous consultation in both locations, resulting in an increased importance placed on the effectiveness and cost of adaptation options with Carnarvon, compared to the greater focus on environmental, aesthetic and social considerations in Coral Bay.

4.4 Management units

To assist with refining the MCA, both Carnarvon and Coral Bay have been divided into separate sectors. Sectors have been identified based on land use, coastal characteristics and topography. The extent of sectors across both settlements is provided in Figures 4.1 and 4.2 below.



Map 4.1 – Management Units (Carnarvon)



Map 4.2 – Management Units (Coral Bay)

4.5 MCA Outcomes – Carnarvon

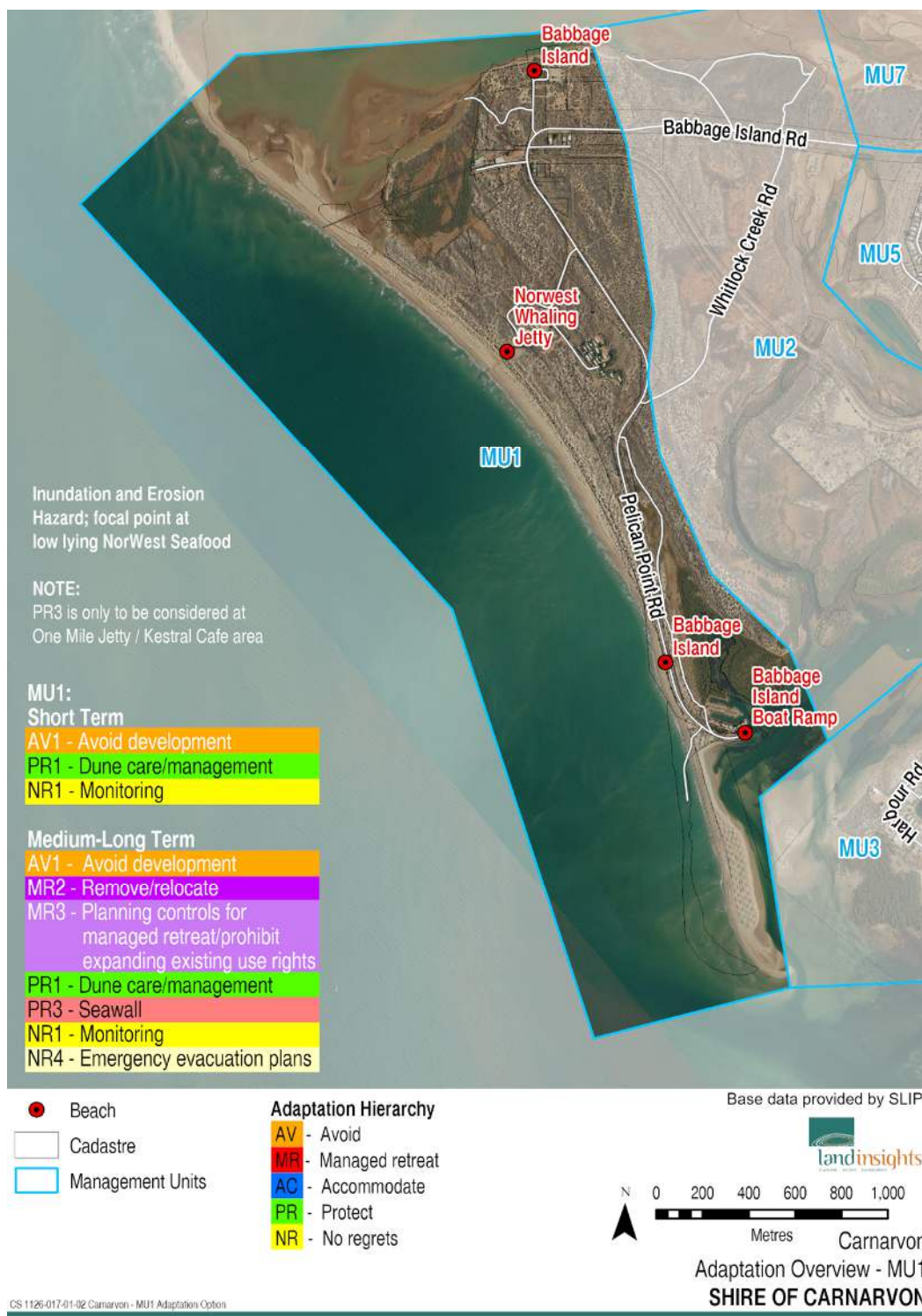
MU1: Babbage Island Coastal

Boundary Definition

The Babbage Island Coastal Management Unit (MU1) is characterised by its open ocean exposure, which includes wave run-up. The landward boundary of this unit is defined by a high dune ridge that is positioned well landward to account for coastal erosion allowances. This area is susceptible to both inundation and erosion.

Preliminary Adaptation Considerations

- The Carnarvon Beach Holiday Resort and the Babbage Island boat ramp area are situated at extremely low land levels, with some areas reaching as low as 1.6 metres. Any future breaches in the spit could create new channels near Pelican Point, which may necessitate relocation in the long term.
- Erosion buffers are available throughout much of the area, facilitating a sequence of strategies: initially adopting an Avoid approach, followed by Accommodate through dune management, and eventually Retreat, which involves either relocating landward or opting for protective measures.
- The land surrounding the NorWest Seafood Site is at 1 to 2 metres AHD. Mitigation measures are required, including raising or removing the access pathway through the frontal dune. In the longer term, relocation to higher land may become necessary.
- For the One-Mile Jetty/heritage precinct, accommodating development can be considered – this will be achieved by maintaining the mangroves for erosion protection. In the longer term, retreat/relocation, or protection, can be considered.



Map 4.3 – Adaptation Overview MU1 (Carnarvon)

MU2: Babbage Island Fascine

Boundary Definition

Management Unit MU2 encompasses the area defined by the landward side of a high dune ridge. There are pathways for inundation through both the Gascoyne River and the Fascine.

Preliminary Adaptation Considerations

There are three primary adaptation considerations for Management Unit MU2, Babbage Island Fascine: Avoid, Accommodate, and Protect. Detailed considerations for each strategy are provided below.

Avoid:

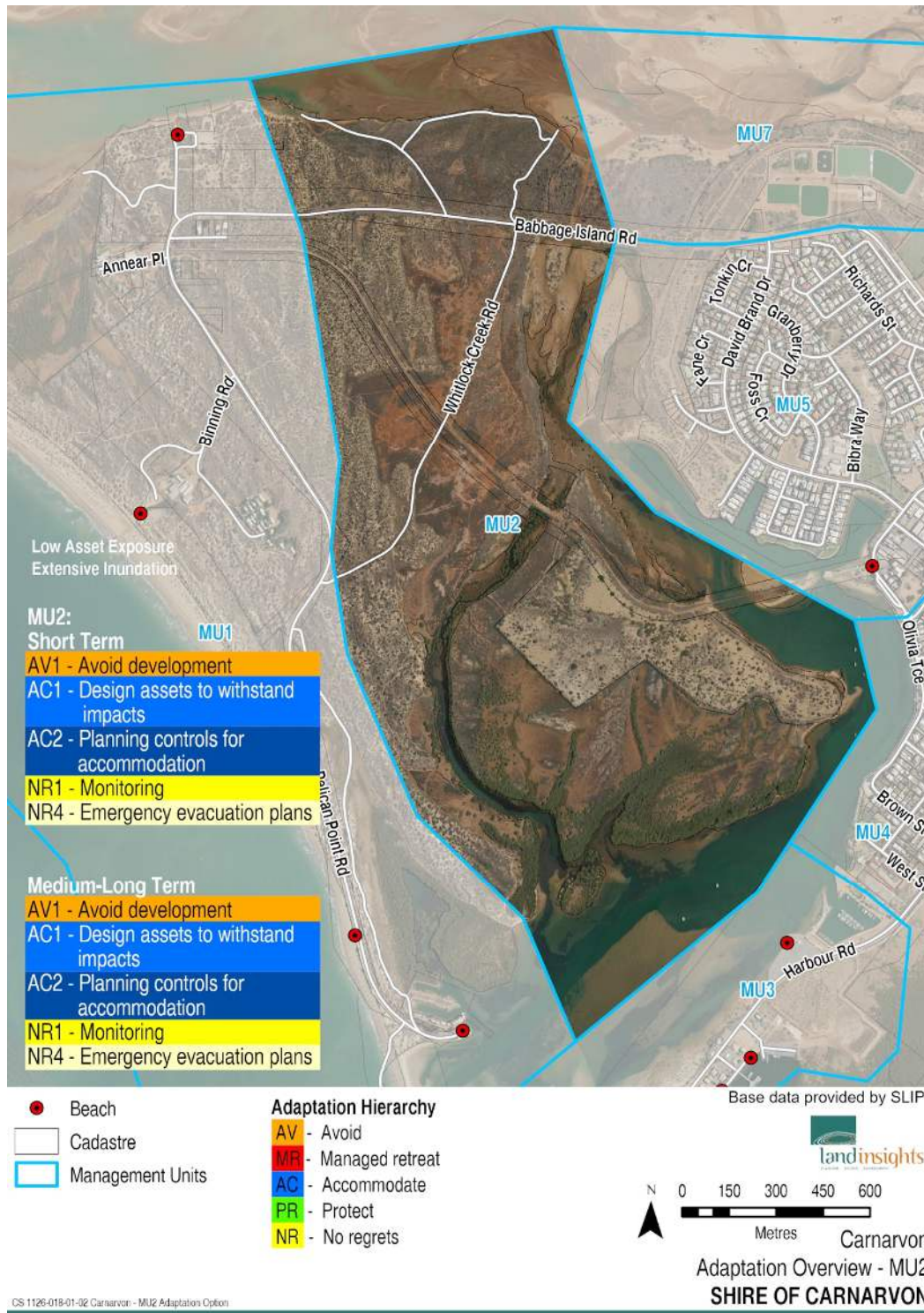
- There are limited assets in this Management Unit, but potential inundation is extensive.
- Avoidance of development in low-lying areas is recommended to minimise risk.

Accommodate:

- Historic Tramway Reserve Trail: Impacts are expected around +2.4m AHD.
- The future golf course grassed areas should be set above 2.5m AHD, which corresponds to the 10-year Annual Recurrence Interval (ARI) flood level of +1.05m.
- The golf course clubhouse should be constructed above 3.5m AHD to ensure resilience against flooding.

Protect:

- Conduct a structure audit and upgrade: Small rock structures at the Tramway bridge abutment should be enhanced, with the height raised to +2.7 AHD.



Map 4.4 – Adaptation Overview MU2 (Carnarvon)

MU3: Fascine Maritime Facilities

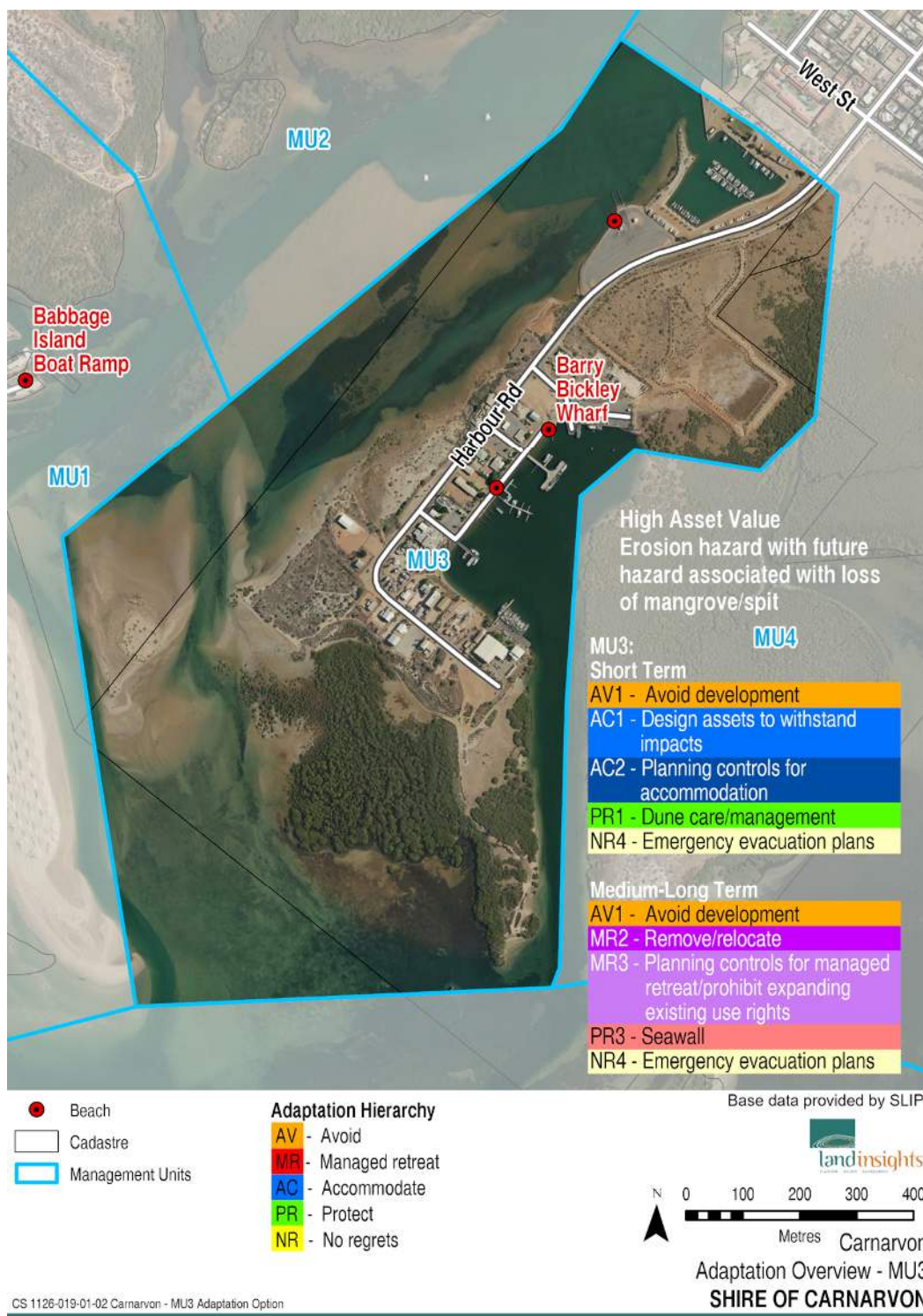
Boundary Definition

MU3 encompasses the Fascine Maritime Facilities, including the Pickles Point marine and industrial area, which is situated approximately 3 meters above the Australian Height Datum (AHD). Harbour Road, which features erosion protection around the boat harbour, also falls within this unit, with the remaining area positioned at around 3.5 meters AHD. The dune and adjacent sandy areas along Harbour Road are low-lying and require consideration for potential wave run-up, especially with the risk of spit breaching. The wharf access road, which declines from 3.5 meters to 1.55 meters at the wharf, is another critical component. Additionally, the intertidal mangrove area in this region plays a significant protective role for the landward assets.

Preliminary Adaptation Considerations

The following preliminary adaptation considerations have been identified for the Fascine Maritime Facilities management unit. These points aim to address the potential risks and enhance the resilience of the area in response to environmental changes and hazards.

- Harbour Road requires an emergency management plan, along with dune management and protection measures.
- Future development should be avoided on the undeveloped foreshore to minimise environmental impact.
- Marine services adjacent to the marina must have an Emergency Management Plan and be flood-proofed and protected.
- The Wharf Access Road should be elevated and safeguarded in conjunction with any wharf upgrades.
- Harbour Road carpark can tolerate infrequent inundation, thus may not require significant alterations.
- It is essential to retain, and possible extend, mangroves and plan for potential spit breaches and increased wave impacts. Any wave exposure could result in sediment redistribution and erosion, affecting nearby assets.



Map 4.5 – Adaptation Overview MU3 (Carnarvon)

MU4: South Carnarvon

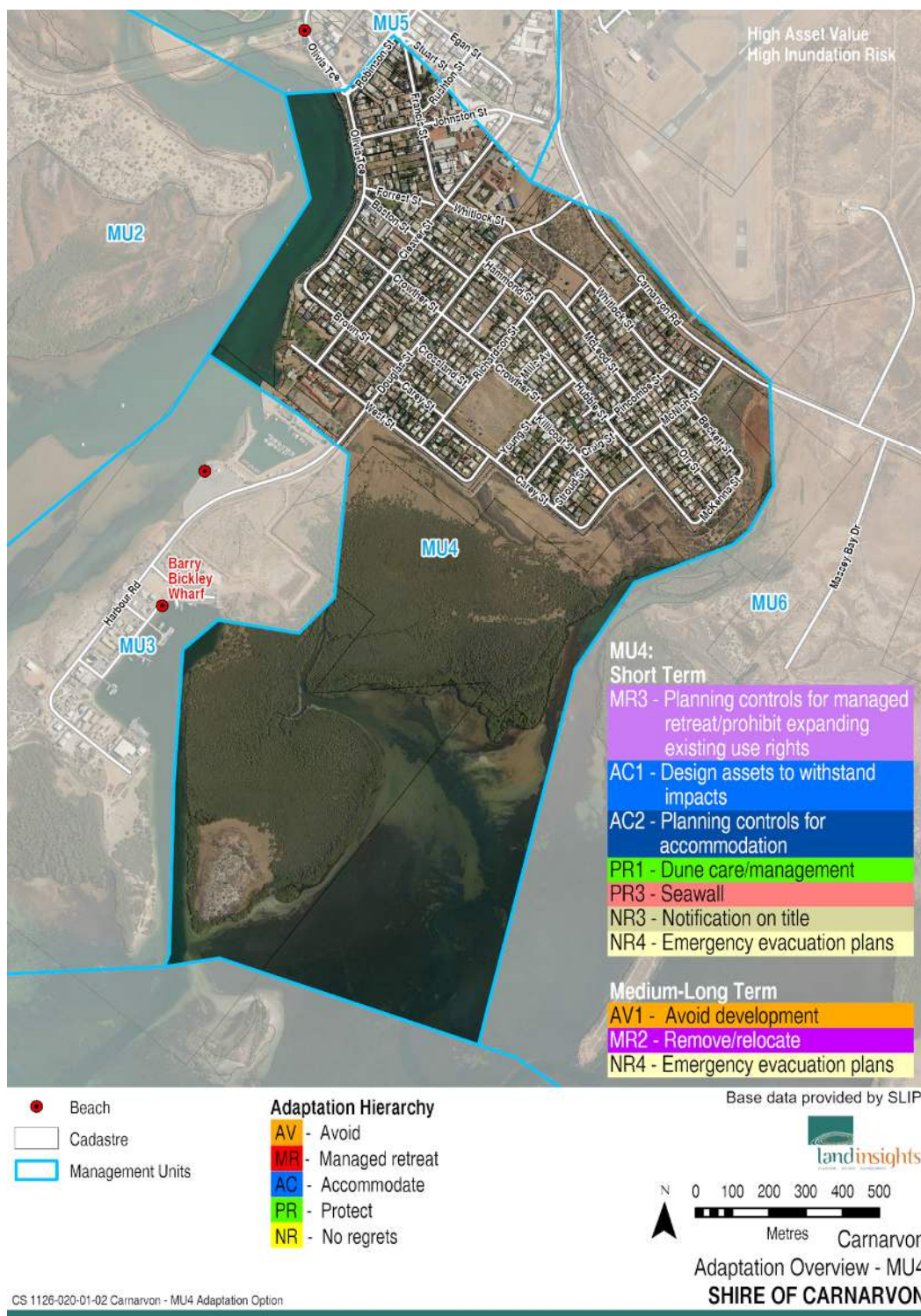
Boundary Definition

MU4, encompasses a basin of extremely low-lying residential areas. The region is particularly vulnerable as road levels range between +1.4 to +1.6 meters AHD, which will be below the Highest Astronomical Tide with a 0.5-meter sea level rise.

Preliminary Adaptation Considerations

The following preliminary adaptation considerations have been identified for the Fascine Maritime Facilities management unit.

- **Inundation Protection:** The existing South Carnarvon Surge Wall offers protection along the southern perimeter of the residential area, with a current capacity of approximately +2.1 to +2.2 meters AHD (100-year ARI).
- **Ingress Points:** Inundation ingress can initially occur through the Carnarvon Yacht Club, reaching West Street at +1.4 meters AHD (~6-year ARI) and causing widespread inundation at +1.6 meters AHD (~20-year ARI).
- **Foreshore Levees:** There is an opportunity to mitigate inundation by using foreshore levees along the Carnarvon Fascine, particularly adjacent to the Yacht Club and Olivia Terrace. This is practical up to +2.1 meters AHD, corresponding to a 500-year ARI.
- **Relocation Considerations:** Given the low road network for evacuation and the impracticality of property fill levels above +2.5 meters AHD, relocation may be a necessary consideration for long-term adaptation.



Map 4.6 – Adaptation Overview MU4 (Carnarvon)

MU5: Carnarvon/Brockman

Boundary Definition

This section covers a basin of relatively low-lying residential area within Brockman. Two key pathways for inundation are identified: one through the Fascine and another around the back near James St/Marr Place.

Preliminary Adaptation Considerations

Preliminary adaptation considerations for the Carnarvon/Brockman precinct are outlined below. These measures aim to address key pathways for inundation and provide effective protection for the residential areas within this basin.

Both Brockman/Carnarvon Areas

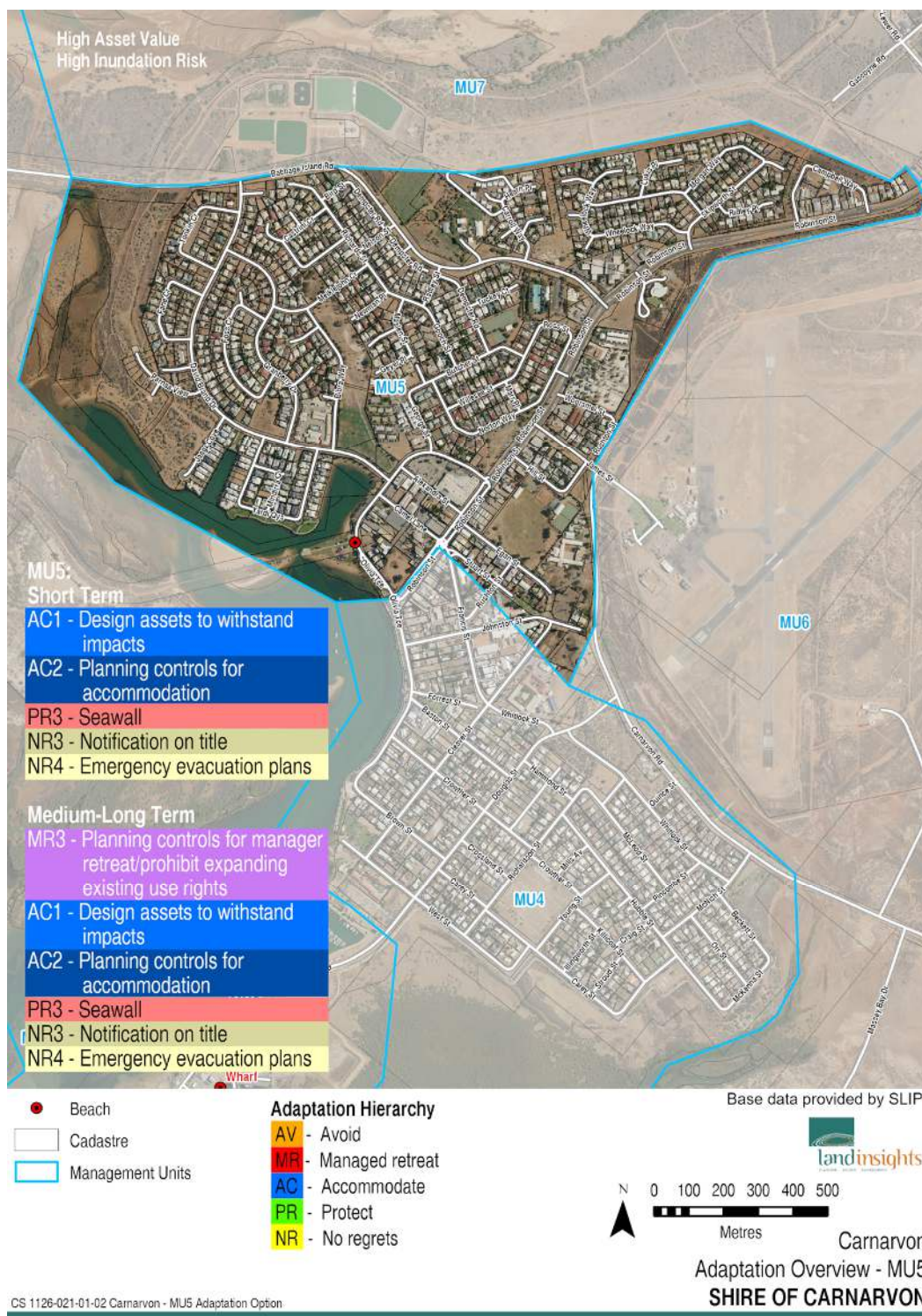
- **Protect:** A raised barrier could be used at the back, approximately 0-1.5 meters above existing levels, running parallel with Dempster Road and Marr Place. This pathway reaches as low as +2.0 meters AHD but is likely to experience estuarine dampening.
- Sub-arterial roads are generally as low as +2.3 meters AHD, potentially requiring modified levels for high sea level rise scenarios, especially for excavation purposes.
- Property levels are generally slightly higher than +2.6 meters AHD, which should provide for adequate property level protection.

Brockman Only:

- Property levels in Carnarvon are generally slightly higher than 2.6 meters AHD, providing adequate **protection** at the property level.
- It is recommended to raise the low section of Babbage Island Road near the David Brand Drive intersection.
- On the Fascine:
 - Levees are generally sufficient north of the Marina Precinct.
 - In the Marina Precinct, roads should be modified to be at least 2.6 meters AHD, with property fill adjustments for high sea level scenarios.
 - A localised levee structure adjacent to David Brand Drive should connect to higher land on Camel Lane and integrate with decision-making for the Marina Precinct.

Carnarvon Only:

- Property levels are generally slightly higher >2.6m AHD, which allow for property level **protection**.



Map 4.7 – Adaptation Overview MU5 (Carnarvon)

MU6: Rural – Southside of Carnarvon

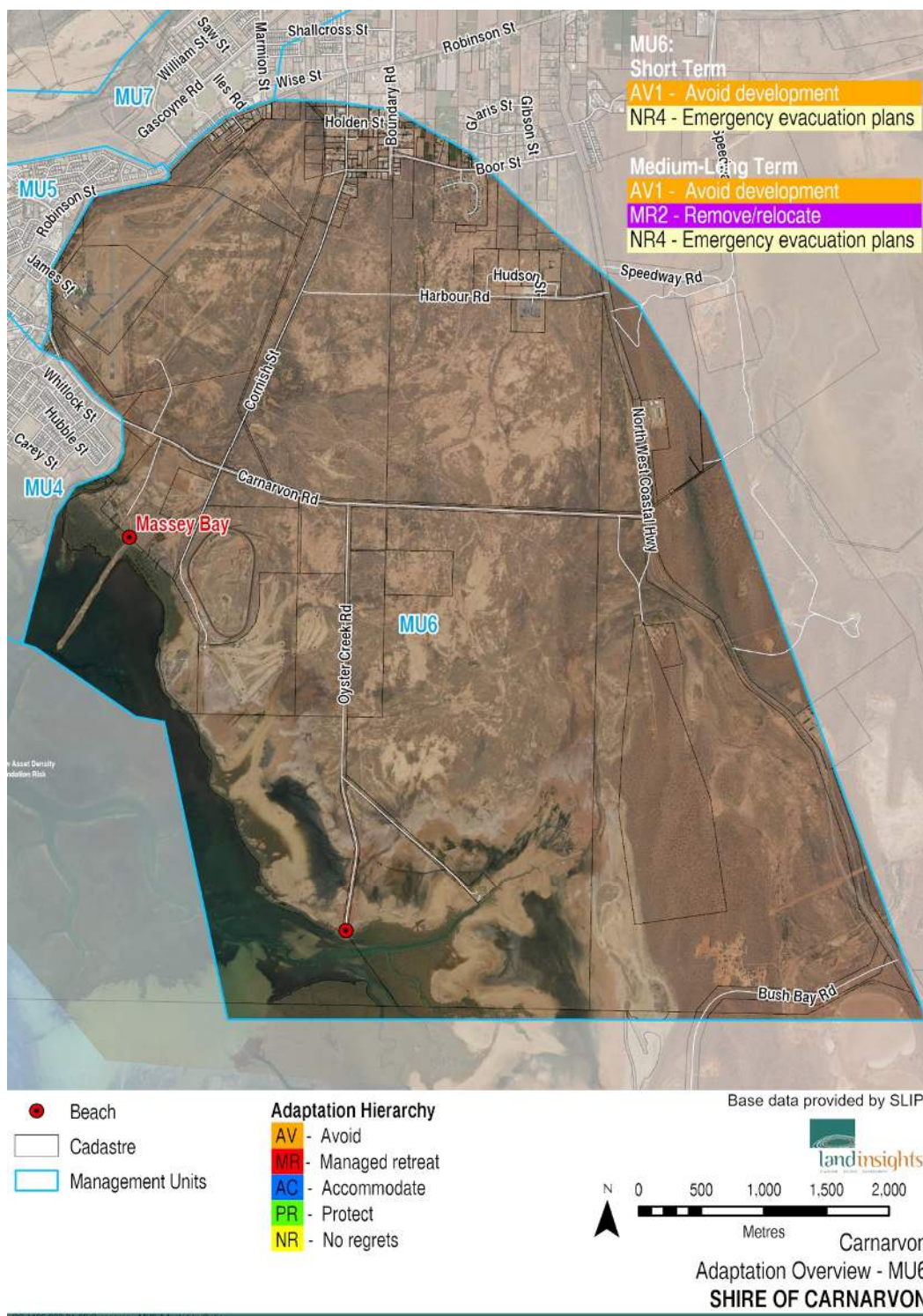
Boundary Definition

The MU6 management unit, encompassing the rural southside of Carnarvon, is defined by its regional area, with inundation ingress through Massey Bay and the creek system.

Preliminary Adaptation Considerations

The following are the preliminary adaptation considerations for the MU6 management unit, encompassing the rural southside of Carnarvon:

- Development should be **avoided** in low-lying areas.
- Adaptation at the asset level is recommended for airport facilities, as there is ample space to raise the runway and facilities. Additionally, possible long-term relocation is planned.



Map 4.8 – Adaptation Overview MU6 (Carnarvon)

MU7: Gascoyne River

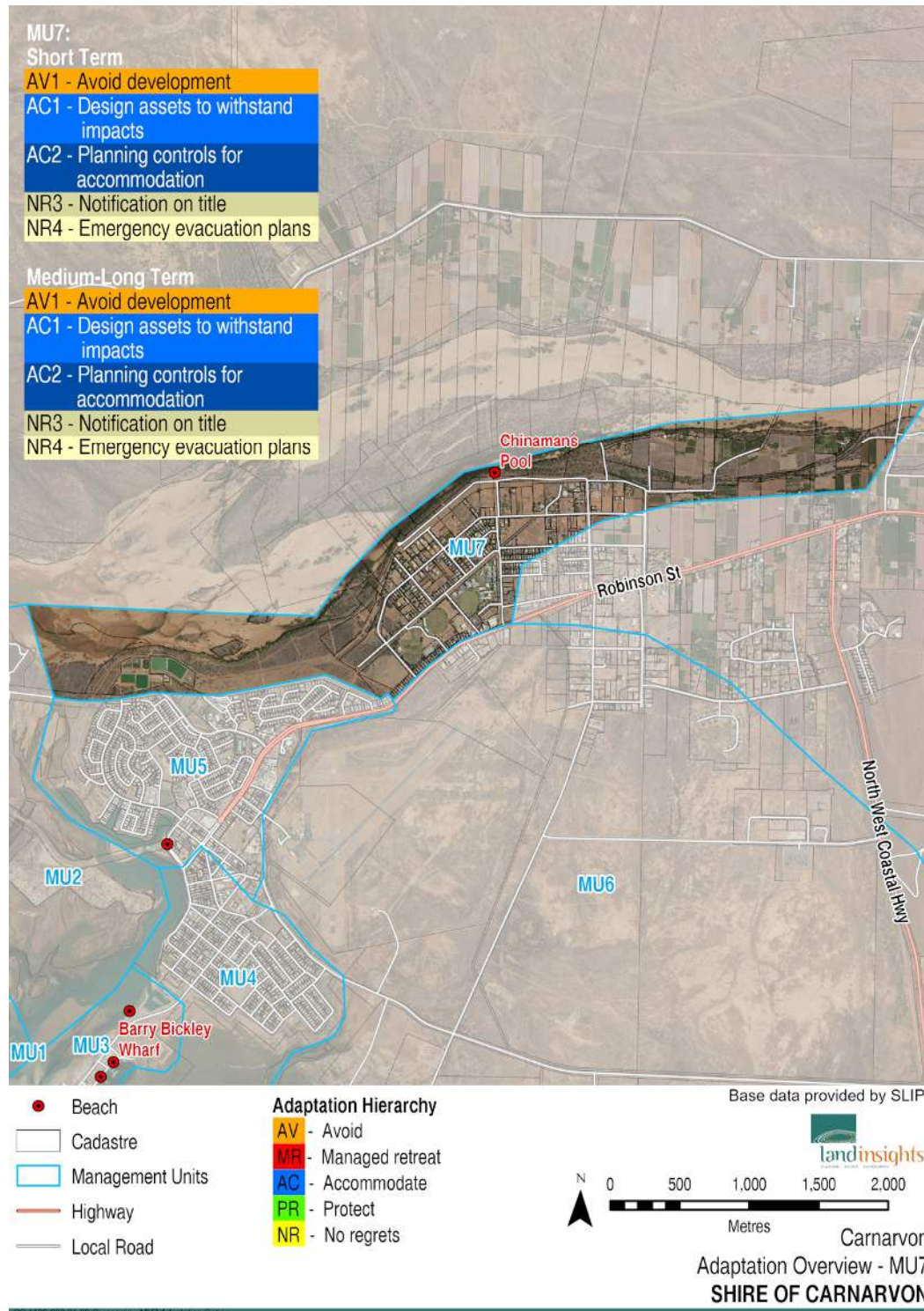
Boundary Definition

MU7 encompasses the Gascoyne River area, which is subject to potential river flooding.

Preliminary Adaptation Considerations

Preliminary adaptation considerations for MU7 include:

- **Avoid:** Any new development should be avoided. Existing development is set above the hazard zone and is therefore unlikely to be impacted in the future.
- Raise low section of Babbage Island Road, near David Brand Drive intersection for inundation protection to Waste Water Treatment and MU5. This is at +2.9m AHD, so only applicable for high sea level rise scenarios.



Map 4.9 – Adaptation Overview MU7 (Carnarvon)

4.6 MCA Outcomes – Coral Bay

Low intervention, non-structural solutions are most appropriate options for further investigation, given strong preference for preservation of environmental values in Coral Bay, in particular, access and amenity to the beach and nearshore area and conservation of marine habitat.

Overall, where avoiding hazard is not possible, managed retreat is the preferred option to treat identified erosion and inundation hazards due to the presence of relatively wide coastal buffer and availability of potentially suitable relocation sites to the landward.

Likely impacts at Coral Bay will be inundation of the low-lying areas around Robinson Road in the settlement with associated impacts on the adjacent beach and dunes. Existing infrastructure is largely camping and tourist accommodation with a small commercial zone impacted by inundation.

A brief discussion of hazards and preferred treatment options per Management Unit is provided below.

MU1: Bills Bay to Coral Bay

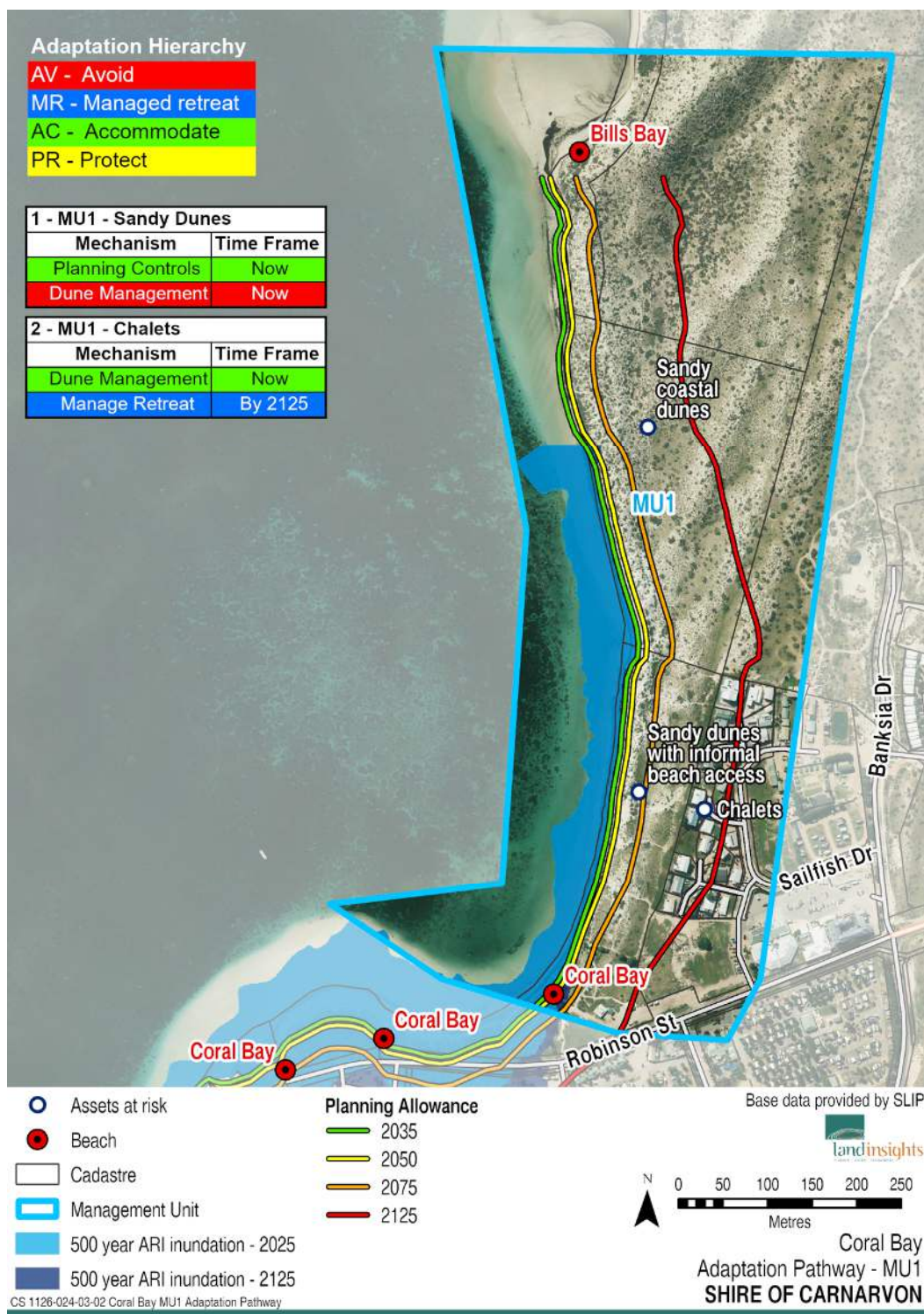
Boundary Definition

Management Unit 1 (MU1) encompasses the stretch from Bills Bay to Coral Bay Beach. This area features sandy dunes with informal beach access to the north and chalets set back approximately 75 meters from the High-Storm-Dune (HSD) line, situated landward of the erosion hazard line, which is projected to be about 25 metres by 2125. The southern portion of this unit includes significant beach infrastructure such as shelters, access points, toilets, foreshore amenities, and an information centre. Towards the northeast of Robinson Street, the low dunes provide a critical natural barrier, essential for maintaining the integrity and accessibility of Coral Bay Beach.

Preliminary Adaptation Considerations

Preliminary adaptation options for Management Unit 1 (MU1) have been developed to balance environmental preservation with community and infrastructure needs.

- **Avoid** future hazard by preventing new developments in vulnerable areas.
- Manage the existing dune area to maintain its protective function against erosion and inundation.
- Instigate a program of **managed retreat** for the chalets when specific decision triggers are reached, which will be detailed in the implementation plan.



Map 4.10 – Adaptation Overview MU1 (Coral Bay)

MU2: Settlement to Boat Harbour

Boundary Definition

Settlement (MU2 North)

The low-lying area adjacent to Robinson Street, with its narrow coastal buffer, is susceptible to erosion and inundation. This vulnerability impacts beach access, the foreshore, the low dunes, and nearby infrastructure. Specifically, erosion is projected to affect Robinson Street by 2035, the Robinson Street carpark and campsite by 2075, and the Ningaloo Reef Resort by 2125.

South (MU2 South)

Largely undeveloped foreshore, valued highly for its environmental and pedestrian access, and the dune area immediately south of the harbour, which is used for 4WD activities, face significant challenges. By 2125, the shoreline is expected to retreat by over 150 meters, resulting in the loss of beach and dune habitats and narrowing the coastal buffer seaward of Monck Head Drive by approximately 50 meters. This retreat will intersect Banksia Drive to the south by 2075. Additionally, current impacts on the boat ramp facilities to the south require sediment bypassing to address the buildup on the southern side of the causeway.

Preliminary Adaption Considerations

MU2 North

To mitigate the high erosion and inundation hazards in the low-lying area with narrow coastal buffers, the preferred strategy includes:

- Dune management to reinforce natural barriers.
- Managed retreat by relocating the carpark, rerouting Robinson Road, and moving campgrounds to higher ground.

In the short term, an emergency management plan should be developed for the campground area.

An alternative approach involves:

- Beach renourishment to preserve beach value and protect infrastructure, with initial allowances up to 1,000 m³ in the first decade, exponentially increasing to 70,000 m³ per decade to align with sea level rise projections.

While constructing a seawall could potentially mitigate sea level rise impacts, it was excluded from the Cost-Benefit Analysis (CBA) based on the Multi-Criteria Analysis (MCA) results. This exclusion was due to:

- The misalignment of hard protection structures with the site-specific adaptation objectives.
- The substantial size required for effective protection (over 400 meters), which would also necessitate beach renourishment to maintain beach value.

MU 2 South

The following preliminary adaptation options for this management unit include:

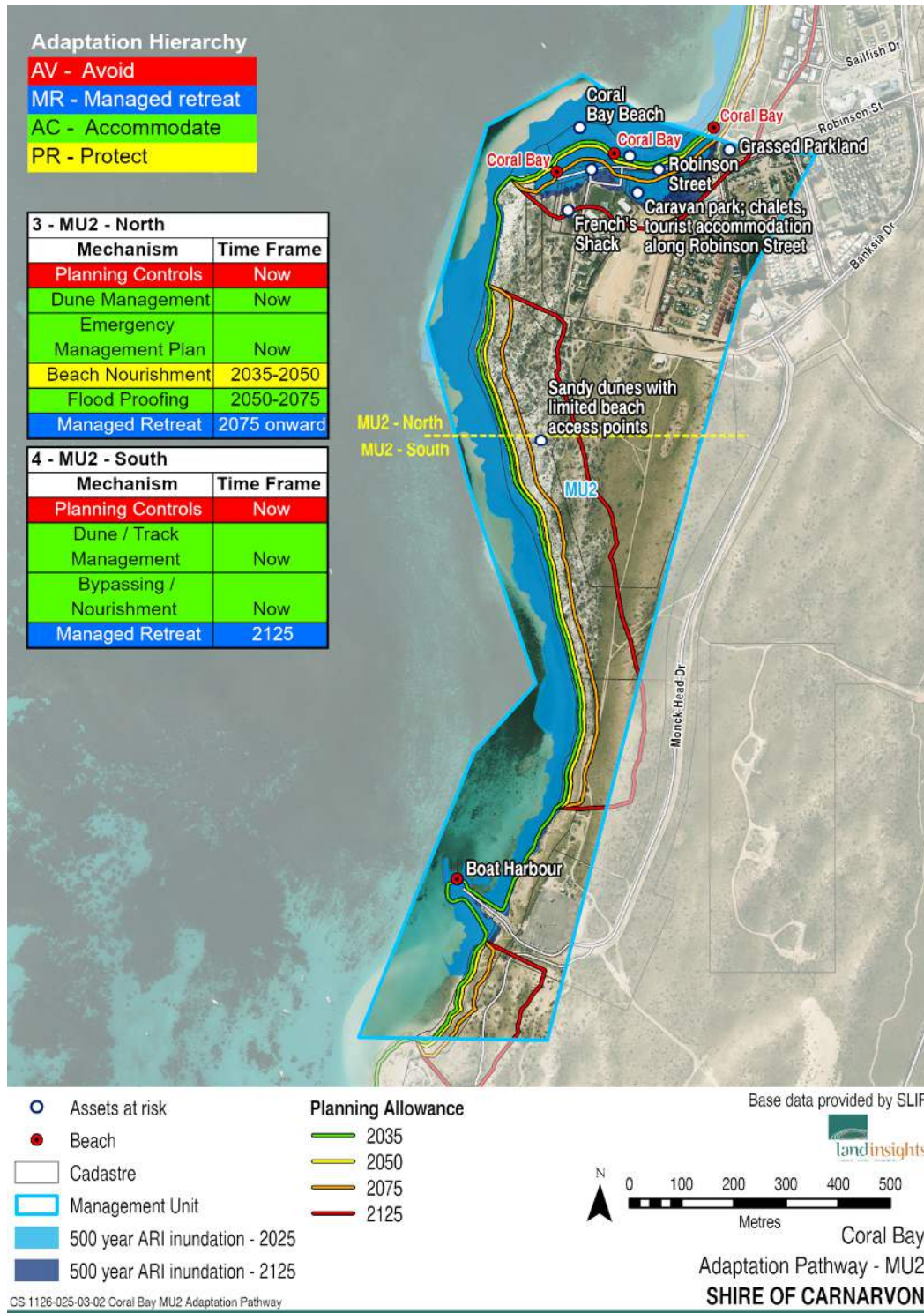
- Avoid establishing beach access tracks in areas with rocks, cliffs, narrow beaches, and those directly oriented toward prevailing winds. These conditions contribute to dune mobility and may cause access restrictions due to soft, boggy sand at the dune-beach interface.
- Tracks in dunes immediately to the south of the townsite should be avoided or rationalised due to potential dune mobility.
- Reestablishing littoral drift by bypassing at the causeway and marine facility could be considered, with potential placement at Paradise Beach.



Coral bay beach looking landward to Robinson Road area adjacent to caravan park. Coastal buffer is narrow here and area to landward is relatively low-lying. Assets along this stretch of the coastline are exposed to erosion hazard and inundation hazard at the present time with erosion hazard lines extending landward as far as Ningaloo resort by 2125 and inundation.



Low Lying area at Coral Bay Beach adjacent to Robinson Road.



Map 4.11 – Adaptation Overview MU2 (Coral Bay)

4.7 Potential Responses

Table 4.4 – Potential planning responses

Planning response	Description	Comment / Suitability
<i>Structure Plan / Precinct Structure Plan</i>	<i>These plans can address location-specific issues, such as the identification of coastal physical setbacks and areas affected by storm surge. However, they do not have the force and effect of the Scheme, meaning decision-makers only need to have due regard for them. Structure plans cannot specify or enforce built form requirements. They are location-specific and therefore cannot address coastal hazard issues on a broad scale. Generally, the land needs to be appropriately zoned to require the preparation of a structure plan.</i>	<i>A structure plan can be used to coordinate the response to inundation risk, such as identifying floor levels for new development over a relatively large area. However, it has limited effect on existing development.</i>
<i>Local Development Plan</i>	<i>These plans can specify built form requirements to address location-specific coastal hazard issues, such as increased setbacks and minimum habitable floor levels. They hold the statutory weight of the local planning scheme and can vary 'deemed-to-comply' development requirements. However, they are also location-specific and cannot address coastal hazard issues on a broad scale.</i>	<i>LDPs have a refined scope of matters when compared to a structure plan. They are normally made over relatively small areas comprising one or more lots that have a common level of development capability. As they tend to be used for smaller areas, and LDPs will not be as effective as other planning responses, particularly where a neighbourhood or locality response is needed.</i>
<i>Local Planning Policy</i>	<i>Local planning policies can address coastal hazard and risk issues at both a district (broad) level and a location-specific level. They can include mapping of coastal hazard issues with the flexibility to update mapping as amendments are required. However, they are only 'due regard' documents and do not have the full force and effect of provisions contained in a local planning scheme. These policies can vary 'deemed-to-comply' development requirements and can be amended relatively quickly compared to a local planning scheme amendment, as new coastal studies are completed.</i>	<i>Local planning policies are likely to be effective in the short term, or until the risk increases to a point that requires a more coordinated response between land use and infrastructure planning. Any policies will need to consider whether support is required to ensure development that is normally exempt from development approval is captured by the policy. This support can be provided through the application of a special control area that triggers development approval, with the policy providing the development settings.</i>
<i>Special Control Area</i>	<i>Special Control Areas (SCAs) may establish specific provisions to address</i>	<i>The special control area will work most effectively with a supporting local planning</i>

<i>Planning response</i>	<i>Description</i>	<i>Comment / Suitability</i>
	issues such as storm surge and coastal processes. They can broadly address unique issues that extend across multiple zones and reserves. SCAs can be used to require development approval for developments that are otherwise normally 'exempted'. This makes SCAs the preferred mechanism to identify where and what type of development requires 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 or updated. This may be avoided if the SCA refers to a separate Local Planning Policy that contains references to mapping coastal hazards.	policy that sets out the development requirements and also to ensure the mapping of coastal hazards is updated in the planning framework as required.
General Development Provisions (Part 4; Clause 32 of the model scheme provisions)	These provisions can broadly address coastal hazards and introduce provisions related to a local planning policy addressing coastal hazards, which may contain coastal hazard mapping. Given the specific nature of coastal issues and the varied locational extent to which they 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.	Clause 32 could be employed should it be considered necessary to incorporate development provisions into the Scheme. This will provide the greatest statutory weight when compared to a local planning policy or supplemental provisions. However, it will be static and difficult to change over time as coastal hazard mapping matures.
Supplemental Provisions to Schedule 1 and 2 of the Regulations	These provisions 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 and the varied locational extent to which they 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.	Supplemental provisions are unlikely to provide any greater effect when compared to clause 32 development provisions or special control area.
Improvement Plan and Scheme	An Improvement Scheme is a strategic planning tool used to facilitate the development and use of land in areas	An improvement plan and scheme would be most effective in this CHRMAP where there is a need to coordinate with

<i>Planning response</i>	<i>Description</i>	<i>Comment / Suitability</i>
	identified as requiring special planning. It replaces the local planning scheme for the area it covers, allowing for more targeted and comprehensive planning efforts. Improvement schemes are based on improvement plans, which outline the specific objectives and guidelines for the development of the land. The Western Australian Planning Commission (WAPC) administers these schemes and is guided in decision-making by the improvement plan. An improvement plan and scheme will be more effective than a structure plan only where there is agreement between state and local governments that a coordinated planning and infrastructure response is required. In most cases, other planning responses will be likely to be more appropriate, particularly in the short-medium term.	infrastructure works and the future development or redevelopment of an area prone to inundation.

Planned or managed retreat policy

One probable adaptation method for the Shire is managed retreat, and planning for this should begin soon for vulnerable assets. The WAPC CHRMAP guidelines offer advice on the Planned and Managed Retreat approach for assets facing erosion and inundation, serving as a basis for policy development.

Foreshore management plan

Foreshore management plans can implement the CHRMAP's recommendations for specific foreshore reserves, especially when dune management is advised. These plans address dune management, infrastructure, sand renourishment, and other protection adaptations. They also serve as a vital tool for community communication and planning for public spaces and facilities.

Emergency response plan

In accordance with the Emergency Management Act 2005, the Shire is responsible for helping the community prepare for, prevent, respond to, and recover from various emergencies. Accordingly, the Shire has established a *Local Emergency Management Plan* that considers a range of potential emergencies within the Shire, including flooding. The plan is managed by the Community Emergency Services Manager employed by the Shire.

It is advised that the LEMP be reviewed together with this CHRMAP to ensure that areas identified as at risk have appropriate measures for emergency response and recovery.

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 adaptation options in this task focuses on conducting a Cost Benefit Analysis (CBA) as part of the risk treatment process.

At this stage of the project, a Cost-Benefit Analysis (CBA) is useful in the context of coastal hazard risk management and adaptation planning for several reasons:

- **Determining Economic Value:** It helps to determine the economic value of assets at risk due to coastal hazards.
- **Cost of Hazards:** It assesses the current and future annual costs that hazards pose to susceptible assets.
- **Mitigation Costs:** It evaluates the costs associated with different options to mitigate coastal hazards.
- **Economic Evaluation:** It provides an economic evaluation of the reduction in costs of hazards to susceptible assets as a result of mitigation options.
- **Decision-Making:** It supports decision-making by comparing the benefits of an adaptation action against its costs, ensuring that resources are used efficiently and effectively.
- **Prioritisation:** It aids in prioritising adaptation options based on their cost-effectiveness.

4.8 Cost benefit analysis

Context for Multi-Criteria Assessment (MCA) and Coastal Adaptation Options

The Cost Benefit Analysis (CBA) for the Carnarvon and Coral Bay Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) has been prepared to provide an evaluation of the economic implications of various coastal adaptation options. This analysis is based on the Multi-Criteria Assessment (MCA) ratings and priority list of adaptation options subsequently considered. The adaptation options considered include:

- Avoid
- Managed Retreat
- Accommodate
- Protect
- No Regrets.

The MCA framework evaluates these options based on six criteria:

- Effectiveness
- Environmental Impact
- Social Impact
- Landscape
- Cost
- Future Adaptability.

Each criterion is rated on a scale from Positive 2 (very effective) to Negative 2 (very ineffective), with Zero as the midpoint. The analysis covers nine Management Units (MUs) across Coral Bay and Carnarvon, assessing the risk treatment options for each asset through community engagement and subsequent financial and economic cost assignments.

The CBA involves assigning financial and economic costs and benefits to the adaptation options over four planning periods: 2035, 2050, 2075, and 2125. The preferred adaptation options are presented in tables, including the 'do-nothing' base case and, where applicable, a 'Protect' option based on indicative coastal engineering costs and estimated benefits.

Social and Environmental Costs and Benefits

The analysis includes additional coastal amenity benefits arising from both use (access, recreation, environmental health, heritage) and non-use (existence, bequest, option) values of the coastal zone. These values are based on previous studies of beach and foreshore reserves, adjusted for inflation. The estimates consider the extent of coastal development, with higher values assigned to highly developed urban coastlines compared to less developed areas.

It is important to note that there are limitations to these estimates, as they largely depend on the beach type and frequency of use. The extent of coastal development in the form of residential and commercial land also significantly affects beach values. For instance, highly developed urban coastlines, such as the Sunshine Coast in Queensland and the Surf Coast in Victoria, have substantially higher values compared to less developed areas like the Clarence Valley or Augusta-Margaret River.

Financial and Economic Costs and Benefits

The financial and economic costs are based on the replacement cost of Shire assets and the Gross Rental Values (GRVs) of private properties within the Management Units. The analysis also considers the potential damage costs from coastal inundation, particularly in areas like South Carnarvon, where a breach in the surge wall could lead to significant annual damage costs. According to the WA Coastal Inundation Assessment – Phase 2 Report, South Carnarvon has the largest average annual damage cost from inundation up to extreme levels, estimated at \$1.2 million per year. This cost assumes no foreshore levees are installed. However, the use of foreshore levees to finished floor level to +2.5m AHD can reduce the present-day average annual damage cost for the entire Carnarvon Fascine segment from \$1.15 million per year down to \$510,000 per year (source: WA Coastal Inundation Assessment – Phase 2 Report).

Assumptions

Several assumptions underpin the analysis, including the perspective of public costs and benefits from the Shire of Carnarvon, the impact of private costs on private property, and the use of replacement costs for calculating

public economic costs. The recreational value of beaches and foreshore reserves is also considered, along with the Shire's rates revenue as the primary economic benefit for cost-benefit ratio estimation. The replacement cost of roads is assumed to be \$116 per square metre, based on Australis (2023). Future CPI would impact equally on the value of benefits (rate revenue) as well as costs (replacement cost and property values).

Cost Benefit Analysis

The initial coastal engineering costs for the potentially impacted MUs are detailed, with costs included in the CBA if the MCA recommends coastal protection as the preferred response option. The analysis presents benefit-cost ratios for each MU and planning period, comparing the 'do-nothing' option with specific risk treatment options. The ratios indicate the economic viability of each option, guiding future decision-making and funding allocation for coastal adaptation projects.

The Benefit Distribution Analysis will form part of the upcoming implementation plan.

Important Considerations

1. **Beach Valuation Estimates:** The estimates of use and non-use benefits are based on the benefits transfer method, which relies on studies of comparable sites across Australia. This approach, while sufficient for informing and prioritising coastal management and adaptation options, has limitations. The valuation of beaches and foreshore reserves can vary significantly based on the type of beach and frequency of use. Further primary data collection from users in Coral Bay and Carnarvon could provide more accurate valuations.
2. **Impact of Coastal Development:** The extent of coastal development in the form of residential and commercial land significantly affects beach values. Highly developed urban coastlines have substantially higher values compared to less developed areas. This factor should be considered in future analyses to ensure accurate valuations and effective adaptation strategies.
3. **Damage Costs from Coastal Inundation:** The potential damage costs from coastal inundation, particularly in areas like South Carnarvon, are significant. The analysis assumes no foreshore levees are installed. However, the use of foreshore levees can substantially reduce these costs. Further investigation into the feasibility and cost-effectiveness of installing foreshore levees in vulnerable areas is recommended.
4. **Assumptions and Future CPI Impact:** The analysis is based on several assumptions, including the perspective of public costs and benefits from the Shire of Carnarvon and the impact of private costs on private property. The replacement cost of roads and future CPI impacts are also considered. These assumptions should be periodically reviewed and updated to ensure the accuracy and relevance of the analysis.

4.9 Pathways

Risk management approach

Effective risk management pathways assist in prioritising adaptation responses. These pathways provide a structured approach to decision-making, incorporating a sequence of decision points over time. This ensures that

responses are adaptive and appropriate as circumstances evolve, avoiding premature commitments to specific risk treatment options that may not be suitable in the long term.

By establishing these clear risk management pathways, the Shire can plan, prioritise, and prepare for future actions even if all decisions cannot be made today. This approach emphasises responsiveness to changing conditions while maintaining flexibility in selecting the most suitable risk treatment options from the risk management hierarchy outlined in the CHRMAP.

The pathways approach also highlights the importance of trigger points, which are specific conditions or thresholds that signal the need for action. These trigger points are integral to the dynamic nature of the risk management process, allowing for timely and efficient implementation of risk management measures as coastal hazards and associated risks manifest over time.

This section outlines the pathways and triggers for action for each of the key locations.

Triggers

There are four trigger points considered by this CHRMAP:

1. **Proximity trigger:** when the most landward portion of an erosion scar threatens ground stability, or when long-term erosion trends, as evidenced by monitoring, indicate an insufficient erosion buffer for the upcoming winter season.
2. **Replacement trigger:** When an asset being accommodated reaches the end of its useful life and needs replacement.
3. **Damage trigger:** when any property within a designated hazard zone or Special Control Area sustains irreparable damage.
4. **Access trigger:** When a public road or accessway can no longer provide legal access to a property or townsite.

5 Implementation Plan – Coral Bay

A strong community preference for preservation of environmental value requires that risk mitigation in Coral Bay should involve low intervention, nonstructural solutions as far as possible. The community has identified particular interest in providing access and amenity to the beach and nearshore area, with conservation of marine habitat. Overall, where avoiding hazard is not possible, **MANAGED RETREAT** is the preferred option to treat identified erosion and inundation hazards due to the presence of a relatively wide coastal buffer and availability of potentially suitable relocation sites to landward.

Likely impacts at Coral Bay will be inundation of low-lying areas around Robinson Road in the settlement with associated impacts on the adjacent beach and dunes. Existing infrastructure is largely camping and tourist accommodation with a small area zoned as commercial potentially impacted by inundation.

A brief discussion of preferred treatment options per Management Unit is provided with a tabulated summary of positively rated MCA results. The cost-benefit of potential options was considered to inform a preferred adaptation pathway per MU. The set of actions associated with preferred pathways are provided as a short-term implementation plan for Coral Bay MU 1; MU2 (North) and MU2 (South) in the Sections that follow.

5.1 Coral Bay MU 1: Bills Bay to Coral Bay Beach

There is limited inundation and erosion hazard at present due to a wide coastal buffer and high backing dunes. The large dune ridge increases in size to the north and is generally above 10m. Tourist chalets are presently set back approximately 75m from the Horizontal Shoreline Datum (HSD). Future erosion will impact beach infrastructure to the South (shelters, access, toilets, foreshore amenities, information center) with tourist chalets landward of the 2125 mapped erosion hazard allowance by ~25m. The preferred pathway for this Management Unit is **MANAGED RETREAT** over the 100-year planning horizon with dune and track management recommended for the short term in conjunction with planning controls to avoid further exposure of assets.



Bills Bay to Coral Bay Beach: high dunes & wide buffer with fragmented access

Table 5.1: Coral Bay MU1: Preferred Adaptation Pathways

MU1: Sandy Dunes with informal beach access • Provide buffer to tourist accommodation to landward (~75m) • Large dune ridge increasing in size to north, but generally 10m and reaching >13m • Wave exposure low in Coral Bay (e.g. run-up), but higher to north and south.			
Accommodate (now)	Planning Controls	Avoid/ Accommodate; allow expansion of facilities, but subject to planning controls (e.g. low value/temporary managed retreat)	Now
Avoid (future)	Dune Management	Revegetation to encourage dune building. Rationalise beach access.	Now
PATHWAY: Avoid Development in Erosion Hazard Area; amend local planning scheme to include Special Control Area which encompasses all areas affected by erosion hazard over the 100-year planning period. Establish planning-based controls that only allow SCA development where hazards are otherwise mitigated. TRIGGER: beach and foreshore reserve become highly or very highly vulnerable to impacts in next planning timeframe (next ~10 years). MONITORING: Long term baseline monitoring (beach width; HSD; dune condition) and event-based monitoring following storm erosion events. Monitor movement of the HSD line every 5 to 10-years as part of CHRMAP update. Determine HSD from examination of vegetation lines in latest available aerial image.			
MU1: Chalets - North High elevation on dunes (>10m AHD) with reasonable setback allowance. No inundation risk			
Accommodate (short term)	Dune Management	Revegetation of dune buffer to encourage dune building and delay managed retreat. Rationalise beach access	Now
Retreat (long term)	Managed Retreat	Plan for managed retreat of chalets by 2125	By 2125
PATHWAY: Leave unprotected and review the site under a managed retreat approach. Carry out dune management/track management and plan for managed retreat when triggers are reached (likely by ~2075). Remove and relocate the assets a distance appropriate for the asset design life / lifecycle (by ~2125). TRIGGER: The Horizontal Shoreline Datum (HSD) is within the S1 (12m) distance of asset's seaward extent. MONITORING: Long term baseline monitoring (beach width; HSD; dune condition) and event-based monitoring following storm erosion events.			

Table 5.2: Coral Bay MU1: Action List

Option	Type	Actions	Timeframe	Cost	Responsibility
Planning	CMP	Avoid expansion of high value fixed infrastructure facilities into dune area	Now	Neg.	Shire
	CMP	Allow expansion of low value/temporary infrastructure subject to planning controls (managed retreat)	Now	Neg.	Shire
	SP	Define Special Control Area	By 2050	\$5k	Shire
	BDG	Prepare guidance regarding flood proofing	By 2050	\$10k	State Govt / Shire
	BDG	Flood proof chalets during renewal	by 2075	***	Property owners
Technical Studies	CMA	Dune Management Plan (including access/track management)	Now	\$15k	Shire
Monitoring	CMA	Beach Width	Annual	\$5k	Shire
	CMA	Dune Condition Assessment (%veg cover; blow outs)	~5 yearly	\$5-10k	Shire
Relocate	SP	Relocate chalets When distance from to HSD is within S1 and/or assets are damaged	By 2125	TBD	External

5.2 Coral Bay MU 2 (North): Coral Bay Townsite

MU2 (North) is adjacent to the Coral Bay town settlement and encompasses the western edge of its commercial area, Robinson Street and its adjacent carpark, a campsite landward of Robinson Street and Ningaloo Reef Resort, which is landward of the long-term erosion hazard line (~2125 planning timeframe). The low-lying area adjacent to Robinson Street has a narrow coastal buffer and is exposed to erosion and inundation. Coastal hazards can impact on beach access, environmental condition of the foreshore and low dunes, and infrastructure to landward.



Coral Bay beach, landward to Robinson Road area adjacent to caravan park.



Low Lying area at Coral Bay Beach adjacent to Robinson Road.

The coastal buffer adjacent to Robinson Road is narrow and the area to landward is relatively low-lying. Assets along this stretch of coast are exposed to erosion hazard and inundation hazard at the present time with 2125 erosion hazard lines extending landward as far as Ningaloo Resort. The preferred pathway to mitigate impacts is (a) **dune management**; (b) **managed retreat** involving relocating the carpark, rerouting

Robinson Street and moving campgrounds to higher ground. In the short term, an emergency management plan should be prepared for the campground area.

An alternate pathway would involve renourishment for beach value and protection of the carpark and road (nominal allowances of up to 10,000 m³ in first 10 years and increasing exponentially up to 70,000 m³ per decade towards long-term scenarios for beach area to keep pace with sea level rise). Results of the Cost Benefit Analysis (CBA) undertaken indicated that renourishment only rates positively up until 2050. However, any renourishment undertaken at this location should be carefully considered (due to potential flow on effects for the highly valued marine environment) and include an Environmental Impact Assessment as well as identification of a suitable sand source.

While a seawall would potentially reduce sea level rise impacts in this area, it was not an alternative not included in recommendations for a CBA due to the outcomes of the MCA analysis, largely due to:

- a. Hard protection of the beach does not align to site specific adaptation objectives
- b. Effective protection at this site would require a 400m+ long structure and would also require associated nourishment to retain beach value.

Table 5.3: Coral Bay MU2 (North): Preferred Adaptation Pathways

Coral Bay MU2 (North): Narrow coastal dunes with informal beach access; Robinson Street Carpark and Adjacent Campground; western edge of commercial precinct - Dunes provide buffer to Robinson Road (<30m in places) - Multiple shore perpendicular access paths - Low lying foreshore backed by road/carpark with limited opportunity for natural realignment - Very High Inundation Risk - Low lying road impacted by erosion by ~2035; carpark and campsite by ~2075			
Avoid	Planning Controls	Avoid placing facilities in fragile dune area (now) and plan for managed retreat (2035; or when triggers are reached)	Now
Accommodate	Dune Management	Sand back passing, beach scraping and dune placement to enhance resilience. Requires revegetation; Rationalise beach access.	Now
	Emergency Management Plan	With evacuation planning for campground area	Now
Protect	Beach Nourishment	Potentially viable up to 2050 but with EIA and ID of appropriate sediment source	2035-2050
Accommodate	Flood Proofing	Commercial/tourist infrastructure with renewal	2050-2075
Retreat	Managed Retreat	Plan for managed retreat/realignment of road and carpark and potential relocation of camping facilities	2075 onwards

PATHWAY: Avoid Development in Erosion and Inundation Hazard Area; amend local planning scheme to include Special Control Area which encompasses all areas affected by hazard over the 100-year planning period.

Commence a dune management program (access consolidation and revegetation) to improve protective function to landward road, carpark and tourist infrastructure. Investigate the feasibility of localised beach nourishment (up to ~2050 only) and plan for flood proofing of landward infrastructure (by ~2075 or when triggers are reached) and eventual rerouting of road and relocation of campground.

TRIGGER: General dune management to commence now with targeted interventions required if the Horizontal Shoreline Datum (HSD) is within the S1 (7m) of Robinson Road. Inundation hazard to the campground is considered tolerable for the campground, with an evacuation plan in place, if there is <20m of dune (alongshore) below 2.9m AHD, but would require mitigation when SLR +0.4m (~2075) if the dune is not providing effective protection.

MONITORING: Long term baseline monitoring (beach width; HSD; dune condition) and event-based monitoring following storm erosion events. Monitor the movement of the HSD line every 5-years as part of the CHRMAP review. Determine HSD from examination of vegetation lines in latest available aerial image.

Table 5.4: Coral Bay MU2 (North): Action List

Option	Type	Actions	Time frame	Resources	Responsibility
Planning	EMP	Emergency Management Plan (including consideration of alternative access with impacts to road)	Now	\$15k	Shire
	CMAp	Dune and Access Management Plan	Now	\$15k	Shire
	SP	Define special control area	Now	\$5k	Shire
	SP	Avoid expansion (only removable infrastructure on beach)	Now	Neg	Shire
Technical Studies	CM	Beach Nourishment: EIA and Sediment Source ID	0-5 years	\$30-50k	Shire
	CM	Sand Drift Management Plan Robinson Road	0-5 years	\$15k	Shire
Monitoring	CMAp	Dune Condition (including veg. and track/access assessment)	Annual	\$5k	Shire
	CMAp	Monitor Buffer (HSD)	~5 yearly	\$5-10k	Shire
Protect	CM	Potential short-term nourishment to defer relocation	2035	\$2M	Shire/State Govt.
Relocate	SP	Raise/re-route Road and relocate carpark landward (pending outcome of technical study)	50-75yrs	TBD	Shire
	SP	Relocate low campground	75-100yrs	TBD	Property Owner

5.3 Coral Bay MU 2 (South): Settlement to Boat Ramp

The area south of the settlement extending towards the boat ramp is a largely undeveloped foreshore with environmental value and pedestrian access highly rated by the community. An area of dunes immediately south of the ramp is used for recreational 4WD activities. Shoreline retreat of 150m+ has been projected by 2125 with loss of beach and dune habitat and constriction of the coastal buffer seaward of Monck Head Drive (~50m by 2125); intersecting Banksia Drive to the South by ~2075.



Monck Head Boat Ramp

Accretion observed to the south, with erosion to the North at Paradise Beach

Table 5.5: Coral Bay MU2 (South): Preferred Adaptation Pathways

MU2 South: Undeveloped foreshore; rocky shoreline/perched beach backed by dunes Relatively wide buffer between shoreline and Monck Head Drive Sand drift issues to south of Boat Ramp; erosion to the north at Paradise Beach 4WD and pedestrian access paths Erosion hazard potential near boat ramp is high by ~2075			
Avoid	Planning Controls	Avoid placing any further tracks/access between Monck Head Drive and the coast	Now
Accommodate	Dune/Track Management	Revegetation of dunes; Rationalise beach access; consolidate 4WD track access	Now
Accommodate/Project	Bypassing/Nourishment	South of Causeway/Paradise Beach	Now
Retreat	Managed Retreat	Plan for managed retreat/realignment of road and carpark	2125
PATHWAY: The recommended pathway for this MU is managed retreat by 2125 with short term actions that avoid any further beach access tracks due to presence of rock (including cliffs), narrow beaches, and orientation directly toward prevailing winds (i.e. for dune mobility, and access restriction (soft boggy sand at dune beach interface). It is recommended that existing tracks in the dunes are rationalised immediately south of the townsite due to potential dune mobility. Buildup of sediment on the southern side of the boat ramp causeway has been observed and likely requires a bypassing regime to address sand drift issues around the boat ramp facilities with potential placement to the north at Paradise Beach to address erosion (cited in the community consultation; Risk Evaluation Report). TRIGGER: Banksia Drive (unsealed) should be relocated if the upper limit of coastal erosion (i.e. scarp crest) is within 6m of the unsealed road (S1 allowance). MONITORING: Long term baseline monitoring (beach width; HSD; dune condition) and event-based monitoring following storm erosion events. Monitor the movement of the HSD line every 5-years as part of the CHRMAP review. Determine HSD from examination of vegetation lines in latest available aerial image.			

Table 5.6: Coral Bay MU2 (South): Action List

Option	Type	Actions	Time frame	Resources	Responsibility
Planning	CMP	Dune and Access Management Plan	Now	\$15k	Shire
	SC	Avoid expansion (only removable infrastructure on beach)	Now	Neg.	Shire
Technical Studies	CM	Bypassing feasibility study	Now	\$30-50k	State Govt.
	RBFS	Drift Management Plan (Boat Ramp)	Now	\$30k	State Govt.
Monitoring	CMP	Dune Condition (including veg. and track/access assessment)	Annual	\$5k	Shire
	CMP	Monitor Buffer (HSD)	~5 yearly	\$5-10k	Shire
Protect	CM	Potential short-term by-passing/ nourishment- Boat ramp and marine/Paradise Beach	1-5yrs	TBD	State Govt.
Relocate	SP	Banksia Drive	50yrs	TBD	Shire
	SP	Raise/re-route Monck Head Drive (pending outcome of technical study)	75-100yrs	TBD	State Govt.

6 Implementation Plan – Carnarvon

The focus of the Carnarvon CHRMAP is the coastline between Massey Bay and Gascoyne River mouth. Most sites considered in Carnarvon CHRMAP have a relatively narrow coastal buffer, high development density and high proportion of built assets vulnerable to inundation impacts with erosion impacts to a lesser degree. Stakeholder consultation for Carnarvon confirmed the high value placed on coastal infrastructure, for example, bridges, jetties and boating facilities, which are viewed as very important for recreation and fishing tourism. Key adaptation objectives for Carnarvon are increasing the resilience of civic and business assets through 'protection and better design'. Potential adaptation strategies to treat identified 'high' and 'very high' risk to assets per MU are summarised here with a summary of options selected through the MCU and subject to subsequent Cost Benefit Analysis. Adaptation actions associated with preferred pathways are provided with timeframes and indicative costs for implementation.

6.1 Carnarvon MU 1: Babbage Island

This MU is located to the North of the settlement, with ocean exposure, including wave run-up. Land surrounding Nor West Seafoods site is extremely low at 1-2m AHD and will require mitigation, with a pathway through the frontal dune access point. Initial management should focus on raising/removing the access pathway with possible flood proofing requirements and relocation to higher land when triggers are reached. Erosion and inundation hazard was rated 'very high' for the Pelican Point Waterfront Resort and Babbage Island boat ramp area both with extremely low land levels (~1.6m AHD). The stability of the MU is directly related to the continuity of Babbage Island spit (if spit breaching occurs, erosion and inundation hazard will increase).

Pelican Point Road has high erosion risk within the short-term (~10 year) planning timeframe. Adaptation of this asset also requires consideration of preferred adaptation approaches to emerging high risks identified beyond 25 years to Babbage Island beach (~50 years) and Carnarvon Beach Holiday Resort (~100 years). Location of these assets on a dynamic spit feature provides reduced confidence in projection timeframes, as erosion and spit rotation can accelerate rapidly, potentially shortening effective planning timeframes.

Since completion of Carnarvon and Coral Bay Coastal Hazard Report (Baird 2023), further erosion has occurred adjacent to the Pelican Point Access Road, resulting in the complete loss of the dune in front of the ablation block and further reduction in remaining dune buffer along the road's extent immediately to the north. The erosion is subsequently deemed to present an immediate risk to the Shire, requiring mitigation in the short-term. The road provides the sole access to key assets, including the Carnarvon Beach Resort and Babbage Island Beach, with the value of each asset requiring consideration in both short- and long-term adaptation measures. The preferred adaptation pathway for Pelican Point Road (Pelican Point Waterfront Resort) is **MANAGED RETREAT**. The managed retreat pathway includes the downgrade and then relocation of the road with eventual removal of the road and Caravan Park likely to be required (indicatively after 2075). A protect pathway involving use of a seawall as protection, with size and extent progressively extended with increasing erosion risk. However, the cost/benefit ratio of this option for the Shire was low and therefore it was not further considered as a recommended option.

It is noted that other forms of protection, such as groynes, were not deemed appropriate solutions, with greater interruption of sediment transport likely to contribute to destabilisation of the spit which is providing a role in navigation to Carnarvon Fascine.

Interpretation of the Cost-Benefit Analysis suggests that as well as the managed retreat³ pathway for the area around Pelican Point Road/Pelican Point Waterfront resort, **AVOID/ACCOMMODATE** options should be employed for the beach area extending northwest from Pelican Point, including the Nor West Seafoods site⁴.



Pelican Point Waterfront Resort

Low lying infrastructure exposed to overtopping and increased erosion hazard if spit breaching occurs.

³ Protection of assets for this area was cost prohibitive. For example, rerouting the full length of Pelican Point Road would cost approximately \$2.3M, gaining ~30m of additional buffer. Given the highly dynamic nature of this area, relocation would be viable for a 25-year timeframe at best and would provide negligible benefit for the Shire (ramp use and vehicle access to the Spit). Similarly, while dune management along the 500m strip adjacent to the road may provide interim protection for the short to medium term, the required investment required for an 'effective' outcome is in the order of \$25,000/annum. Use of hard coastal engineering measures would cost \$2.5M for short to medium term protection, but will act to transfer erosion pressure, potentially acting to destabilise the Spit, which would significantly affect MU3 and MU4.

⁴ Nor West Seafoods site was not rated as 'high risk' but is likely to be vulnerable to inundation given a) it's low-lying nature and b) a flood pathway through the dunes. It is recommended that owners of the facility do a structure audit, flood proof with renewal and consider managed retreat to a landward site when triggers are reached (HSD being <18m from assets and/or >20m of dune, measured alongshore, below 3.0m AHD). Without the dune providing effective protection from inundation, inundation risk to this site is intolerable.

Table 6.1: Carnarvon MU1: Preferred Adaptation Pathways

Carnarvon MU 1: Carnarvon beach holiday resort and Pelican Point Road; Babbage Island Beach - Part of a dynamic river delta system, and influenced by spit evolution (e.g. rotation/breaching) - Most existing facilities set around +2.0 to +2.1m AHD - Erosion lines impact holiday park by 2075, but subject to spit dynamics - Road is an erosion hazard at the present time with limited space to the landward for rerouting			
AVOID/ Accommodate	Planning Controls	Pelican Point: Avoid expansion of fixed infrastructure facilities, especially in low lying areas due to inundation impact and uncertainty of spit evolution; Plan for managed retreat when triggers are reached. Beach: Limit fixed infrastructure on coast (carparks, toilets), and select appropriate setbacks based on expected design life; low value infrastructure only within erosion hazard area (e.g. picnic tables, bbqs)	Now-2035
ACCOMMODATE	Dune Management	Pelican Point: Revegetation to maintain dune buffer for wave run-up and access road. Very limited capacity for dune management for mitigation, with sustained erosion trend established as the spit has rotated. Beach: Manage existing dunes (revegetation, pathway consolidation) up to 30m from HSD. When trigger is reached, consider cost benefit of dune building in line with CHRMAP review.	Now
	Structure Audit	Canals/Boat Ramp Pelican Point Road	Now
	Emergency Management	Holiday Resort including evacuation plan Pelican Point Road	Now
	Damage response plan	Holiday Resort, Boat ramp, canals; Pelican Point Road	Now
RETREAT	Relocate/Remove	Pelican Point Road: relocation not feasible due to limited landward buffer; downgrade and ultimately remove	2035-2050
	Managed Retreat	Holiday Resort: plan for and remove facility when triggers are reached (S1 allowance = 4m); spit breaching; road downgrade/loss)	By 2075
PATHWAY: The recommended pathway for this MU is managed retreat by 2075 with short term actions that avoid any further exposure and include an emergency management plan. The Pelican Point Road requires immediate attention, with plans for downgrade (next 10 years) and relocation. TRIGGER: Plan for road downgrading⁵ and rerouting when Pelican Point Road is within the S1 allowance of the HSD (18m) and/or overtopping causes damage to more than 20% of the road. Plan for managed retreat of the Holiday Resort when infrastructure is (a) subject to overtopping that causes damage to more than 20% of assets, (b) HSD is within 4m of			

⁵ Subject to findings of technical studies recommended in Action List (Table 3-2)

infrastructure⁶, (c) spit is breached, or (d) damage to the access road preventing two-way traffic; dune management until the HSD is within 30m of dune buffer, at the S1 allowance (18m) plan for relocation of any beach infrastructure.

MONITORING: Long term baseline monitoring (beach width; HSD; dune condition) and event-based monitoring following storm erosion events (distance from road to HSD). Monitor the movement of the HSD line every 5-years as part of the CHRMAP review. Determine HSD from examination of vegetation lines in latest available aerial image.

Table 6.2: Carnarvon MU1: Action List

Option	Type	Actions	Time frame	Resources	Funding
Planning	EMP	Emergency Management Plan (including consideration of alternative access)	Now	\$15k	Shire
	EMP	Emergency Recovery Management Plan	Now	\$10k	Shire
	BDG	Flood Proofing with renewal (Nor West Seafoods only)	With Renewal	***	Private
	SP	Avoid expansion (only removable infrastructure on beach)	Now	\$5k	Shire
Accommodate	CMA	Dune Management – restoration over 500m @ ~\$15k/year until <30m dune remaining ⁷	Annually	\$15k	Shire
Technical Studies	SP	Road downgrade and relocation feasibility study	2035-2050	\$30-50k	Shire
	CMA	Sand Drift Management Plan (Pelican Point Road)	Now	\$15k	Shire
Monitoring	CMA	Dune Condition (including veg. and track/access assessment)	Annual	\$5k	Shire
	CMA	Monitor Buffer (5yr HSD; 10yr HSD)	~5 yearly	\$5-10k	Shire
Relocate	SP	Downgrade and relocate road to landward (pending outcome of technical study)	20-50yr	\$200-500k	Shire/State Govt.

⁶ This trigger has now been reached (as of early 2025) and while retreat is the preferred pathway according to the strategic planning process embedded within the CHRMAP, it is acknowledged that this decision requires further targeted discussion at a council level and in consultation with impacted stakeholders.

⁷ The buffer across most of the road is presently <30m; Therefore, site specific assessment/consideration is required – to include scoping of potential dune condition assessment, sand drift management plan and any related dune management/restoration - as part of an integrated adaptive pathway across the MU. This should flow on from the aforementioned targeted discussions at Council level, including key stakeholders, to decide on a preferred pathway for the MU.

	SP	Relocate and remove Holiday Park	50-75yr	TBD	Shire/State Govt./ Private
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6.2 Carnarvon MU 3: Maritime Facility

Carnarvon MU3 includes Pickles Point marine and industrial area with land set ~3m AHD. The Harbour Road has erosion protection around the boat harbour, but the remainder is unprotected and lying at ~3.5m AHD. The Wharf access road falls from +3.5m to +1.55m at the wharf itself. A low-lying area of remnant vegetation is located adjacent to the sandy area along harbour road which will require consideration of potential wave runup with spit breaching. An intertidal mangrove area provides important protective function for assets to the landward.

Overall, a **PROTECT** pathway is recommended for this site over the planning period with a focus on a seawall to protect low-lying harbour road. An emergency management plan/evacuation plan should be put in place at the present time as well as management of remnant vegetation and intertidal mangrove areas to retain their protective function for assets to the landward and planning controls to limit development on the currently vacant sandy lot.

Table 6.3: Carnarvon MU3: Preferred Adaptation Pathways

Carnarvon MU3: Remnant Vegetation & Undeveloped Sandy Foreshore			
Dune areas – Already low +2.5m AHD			
- Sandy area – Too Low 0.9-1.0m AHD rising to above 3m - Highly susceptible to change in spit character and loss of weak mangrove controls			
AVOID	Planning Controls	Uncertain exposure due to location in lee of dynamic spit, and requirement for space to mitigate wave run-up for Marine Services. Avoid any new development in the sandy lot at the southwest corner of the Maritime Facility.	Now
Marine Services Adjacent to Marina			
- Access road generally above +3.5m AHD; Land set as low as 3m AHD - Erosion depends on spit dynamics			
AVOID	Emergency Management Plan	Land set as low as 3m AHD, requiring implementation with high SLR Scenario. Access road generally above +3.5m AHD except near south Carnarvon (see Harbour Road)	Now
	Foreshore Management	Retain western foreshore buffer for mitigation of wave run-up with loss of spit length	Now
	Flood Proofing	Raise floor levels for new development	With renewal
Wharf Access Road - Falls from +3.5m to +1.55m at Wharf			

PROTECT	Raise	Raise low section to at least +3.5m AHD, with Wharf level based on land-marine connection. For +1.55m, this is <10yr ARI with 0.2m SLR and <1yr ARI with 0.4m SLR.	2035
	Protect	Upgrade Wharf	2075

Harbour Road

- Low Section around +1.4 to +1.5m extending 400m from South Carnarvon. Existing erosion protection due to boat harbour.
- Remainder is +3.5m AHD but no erosion protection

ACCOMMODATE	Emergency Management Plan	Currently at less than a 10yr ARI (1.2m) and requires an emergency management plan/evacuation plan	Now
	Vegetation Management	Retain western foreshore buffer for mitigation of wave run-up with loss of spit length	Now
PROTECT	Raise	Raise low area at South Carnarvon section to at least +3.5m AHD (400m)	2035
	Seawall	Commence along Perimeter extending ~1000m (recognising this would be earlier if spit was lost)	2050

PATHWAY: The recommended pathway for this MU is raising the road (~2035) and providing protection via a seawall (~2050 onward) with short term actions that limit any further development on undeveloped lots, instigate emergency management/evacuation planning and manage areas of mangrove and remnant vegetation to retain their protective function. Flood proofing should be considered with renewal of infrastructure.

TRIGGER: Overtopping that causes damage to the road triggers road raising; When HSD is within 10m of the road for more than 20% of its length, planning for the seawall should commence.

MONITORING: Long term baseline monitoring (distance from road to HSD; mangrove condition) and event-based monitoring following storm erosion events. Monitor the movement of the HSD line every 5-years as part of the CHRMAP review. Determine HSD from examination of vegetation lines in latest available aerial image. Structural conditions assessment/damage assessment.

Table 6.4: Carnarvon MU3: Action List

Option	Type	Actions	Timeframe	Resources	Funding
Planning	EMP	Emergency Management Plan	Now	\$15k	Shire
	CM	Mangrove Management Plan	Now	\$10k	Shire
	SP	Limit Development on Sandy Lot	Now	Neg.	Shire
	SP	Define Special Control Area	Now	\$10k	Shire
	SP	Notifications on Title	Now	0	Shire
	BDG	Flood Proofing marine services	25yr	TBC	State Govt.
Monitoring	CMAF	Vegetation Condition	Annual	\$5k	Shire
	CMAF	Monitor Buffer (HSD)	~5 yearly	\$5-10k	Shire
Protection	SP	Raise Road	20-50yr	\$200-500k	Shire
	CP	Build Seawall	50-75yr	TBD	Shire/State Govt.

6.3 Carnarvon MU 4: South Carnarvon

The South Carnarvon area is largely occupied by a residential area located in an extremely low-lying basin. Road levels are between +1.4-1.6m AHD and will be below Highest Astronomical Tide with 0.5m Sea level Rise (SLR). South Carnarvon Surge Wall was construction in 2004 and presently provides inundation protection along the southern perimeter of South Carnarvon residential area. The Surge Wall was built with incomplete encirclement around the entire perimeter of South Carnarvon, with a gap in inundation protection structure presently existing near Carnarvon Yacht Club (GEMS 2008).

Inundation through the protection gap near the Yacht Club begins to impact West Street at a still water level of 1.3 to 1.4m AHD (~6-year ARI), with widespread flooding of residential areas likely to occur at +1.6 to 1.7m AHD (~20-65 year ARI). In comparison, the existing Surge Wall and Fascine Walling provide protection up to +2.3m AHD, which corresponds to a 300-400 year ARI *still water level*, due to inclusion of freeboard to account for wave action.

Despite this exposure, the area has fortunately been exposed to little inundation, with a series of three events in the 1970s reaching just below the level causing widespread inundation. TC Glynis (Feb 1970 reached 1.64m AHD, with TC Hazel (Mar-1979) and TC Vanessa (Jan-1976) both reaching 1.60m AHD. It is further acknowledged that a large proportion of property has floor levels already set above ground levels, which provides mitigation to modest inundation events.

However, overall, the existing situation poses a significant risk to human safety and damage to property, which will increase substantially with sea level rise.

Managed retreat is not a feasible option here due to associated loss of land value and the implication of displacement of people. The preferred adaptation pathway for South Carnarvon is therefore **PROTECT**. The recommended pathway would include an infill levee and a staged approach to raising the surge wall. A starting point for design options is given by the original South Carnarvon Surge Wall assessment, which identified three alternatives, noting that these are no longer directly valid following foreshore works completed since 2003. Therefore, an immediate step will be investigation of appropriate specifications for surge wall improvements in South Carnarvon as a key outcome of the CHRMAP implementation plan for this MU.

An important consideration for design shall be the capacity to ultimately raise all protection structures to above the Surge Wall of +2.3m AHD, in the context of longer-term planning for a protection strategy that accommodates projected sea level rise. This option would require: A site/condition assessment; and Review of existing drainage capacity and evaluation of an adaptation pathway to manage sea level rise impacts, as existing low-lying land within South Carnarvon is below 1 year ARI/HAT for sea level rise scenarios above 0.6m.

Table 6.5 - Carnarvon MU4: Preferred Adaptation Pathways

Carnarvon MU4: South Carnarvon Residential Area			
• Lowest levels of road +1.4-1.6m AHD			
AVOID	Planning Controls	Policy amendment for flood proofing and limit new development	Now
AVOID	Emergency Management Plan	Emergency response and damage management planning required for roads and residences	Now

PROTECT	Drainage Review	Review of drainage functionality and capacity including efficiency/condition of flood gates; investigate opportunities for and potential effectiveness of one-way valve system to deal with overtopping when levee installed	Now
	Flood Proofing	Raise floor levels for new development	With renewal
	Infill Levee	Local raising to 2.3m AHD along 400m	Now
	Raise Surge Wall 1	Phase 1 – raise surge wall	2035
	Raise Surge Wall 2	Phase 2 – secondary raise of surge wall	2075-2125

PATHWAY: Begin protection works in the short term (infill levee) in conjunction with emergency response and damage management planning; structure condition assessment and drainage capacity/efficiency review as well as policy controls to limit new development and allow for flood proofing (property raising) as appropriate with renewal. In the medium term, the surge wall should be raised (with an associated study to determine most appropriate options) in conjunction with ongoing drainage management. In the medium to long term, further raising of the surge wall will be required (or increased property levels/raising of roads and reserve for human safety and access in the absence of this).

TRIGGER: Initial trigger for levee construction and emergency response planning/damage planning already reached (Road levels are between +1.4-1.6m AHD and will be below Highest Astronomical Tide with a 0.5m Sea level Rise (SLR). Inundation near the Yacht Club to West Street with widespread flooding of residential areas; subsequent triggers: inundation events damage road and/or cause road closures more twice or more in one year; drainage system damaged/becomes ineffective; road no longer functional

MONITORING: Inundation extent and levels associated with high water level events; condition/damage assessment of infrastructure – existing walling; drainage.

Table 6.6: Carnarvon MU4: Action List

Option	Type	Actions	Timeframe	Resources	Funding
Planning	EMP	Emergency Management Plan	Now	\$15k	Shire
	CM	Mangrove Management Plan	Now	\$10k	Shire
	TS	Drainage Efficiency Review (including Flood Gate condition assessment)	Now	\$30k	Shire
	SP	Define Special Control Area	Now	\$10k	Shire
	SP	Policy Amendments for Flood Management	Now	\$40k	Shire
	SP	Raised Property Levels During Renewal	Now	***	Property Owners
Technical Studies	CP	Surge protection brought to standard protection level	Now	\$50k	Shire/State Govt.
Monitoring	CMAF	Vegetation Condition	Annual	\$5k	Shire

	CMAP	Monitor Buffer (HSD)	~5 yearly	\$5-10k	Shire
Protection	CP	Infill Levee (400m)	Now	\$2M	Shire/State Govt.
	CP	Levee Maintenance	Annual	\$20k	Shire
	CP	Raise surge wall (potential; to be determined pending outcome of technical study)	10-25yr	TBD	Shire/State Govt.

6.4 Carnarvon MU 5: Brockman

Brockman MU is a largely residential area situated in a relatively low-lying basin with two key inundation pathways through the Fascine and around the back near James St/Marr place. Along Dempster Rd and Marr place, the inundation pathway is as low as +2.0m AHD, but likely to experience estuarine dampening. Sub-arterial roads are generally as low as +2.3m AHD, potentially requiring modified levels for high SLR scenario for excavation. The preferred adaptation pathway for Brockman is **PROTECT** with emergency management planning in the short term. Property levels in the Brockman area are generally slightly higher >2.6m AHD, which should allow for property level protection in the medium to long term planning horizon.

Table 6.7: Carnarvon MU5: Preferred Adaptation Pathways

Carnarvon MU5: Brockman Residential Area			
	Planning Control	Floor levels/Floodproofing for any land <3.5	Now
	Emergency Management	i.e. inundation <500yr event. Road networks mostly support effective evacuation for up to 1.05m SLR	Now
	Damage response plan	i.e. inundation <500yr event	Now
	Protect – Levee 1	Raised local barrier to treat pathway near back of suburb, near Dempster Rd and Marr place. This pathway activates at +2.6m AHD; small intervention to lower impacts of extreme events	Within 0.1m SLR 2035
	Protect – Levee 2	Foreshore Levee system along Fascine foreshore or roads. Requires drainage consideration.	TBA subject to risk

Table 6.8: Carnarvon MU5: Action List

Option	Type	Actions	Timeframe	Resources	Funding
Planning	EMP	Emergency Management Plan	2075 onwards	\$15k	Shire / State Govt.
	EMP	Emergency Recovery Plan	2075 onwards	\$15k	Shire / State Govt.
	SP	Define Special Control Area	By 2050	\$10k	Shire
	BDG	Building requirements for flood proofing (any land <3m)	2050-2075	\$10k	Shire / State Govt.
Technical Studies	TS	Drainage Efficiency Review & feasibility study for foreshore levee system	2050-2075	\$50k	Shire

Monitoring	CMP	Monitor Buffer (HSD)	~\$5 yearly	\$5-10k	Shire
Protection	CP	Levee system across foreshore or roads with drain considerations	2075 onwards	TBD	Shire / State Govt.

7 Land use planning response

7.1 Local Planning Strategy

The Shire of Carnarvon is currently preparing an updated Local Planning Strategy. CHRMAP outcomes should be addressed whilst the Strategy is prepared, or as a minor amendment to it once endorsed. It is recommended that residential densities in vulnerable areas be reviewed in the light of coastal hazard risk. Reference should be made to the requirements of SPP2.6 as they pertain to proposed development subject to coastal hazard risk, including the requirements for adequate coastal foreshore reserves.

7.2 Local Planning Scheme

The Local Planning Scheme should be amended to reflect changes in the Local Planning Strategy. The provisions of a Special Control Area should be implemented over residential and regional centre zones.

Special Control Area

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.

To implement the SCA, the Shire should initiate an amendment to Local Planning Scheme No. 13 to insert a new SCA12 in Schedule 7 – Special Control Areas as follows:

Table 7.1 – Special Control Area 12: Coastal Hazard

Purpose	Objectives	Additional Provisions
The Shire of Carnarvon has prepared and adopted a <i>Coastal Hazard Risk Management and Adaptation Plan</i> (CHRMAP) that identifies land potentially at risk of coastal erosion or inundation. This Special Control Area provides guidance for land use and development within these areas.	- To identify land within Carnarvon and Coral Bay at risk of erosion and inundation by coastal processes by 2125. - To ensure public health and safety and reduce risk associated with coastal erosion and inundation. - To protect new development from the impacts of coastal erosion and inundation. - To avoid inappropriate land use and development of land at risk of coastal erosion and inundation.	- Notwithstanding any other provision of the Scheme, all proposed development within SCA12 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. - In considering any application for development approval, or its advice in relation to a proposed

Purpose	Objectives	Additional Provisions
	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 impact on the functions of public reserves. 7. To ensure coastal process considerations are taken into account in preparing strategic planning proposals and in assessing subdivision and development applications.	structure plan, or application for subdivision of land within SCA12, the local government is to have particular regard to: - The <i>Shire of Carnarvon Coastal Hazard Risk Management and Adaptation Plan</i> (CHRMAP); - State Planning Policy 2.6 – <i>State Coastal Planning Policy</i>; - The Shire of Carnarvon <i>Coastal Hazard Local Planning Policy</i>; - The likely effect on public safety and the risk associated with coastal inundation and erosion; - The existing and likely future effect of coastal erosion or inundation on the land; - The vulnerability of any roads providing access to the land and any public utility infrastructure servicing the land; - The continued suitability of servicing the land with an onsite effluent disposal system, where reticulated sewer is not available; - The impact that any proposed earthworks, retaining walls or other protective measures will have on the amenity of the locality and water flows; and - The adequacy of the coastal foreshore reserve to provide for continued coastal foreshore management, public access, recreation, conservation and landscape amenity. 3. An application for development approval for development proposed within SCA12 may be referred to any statutory, public or planning authority for advice and

Purpose	Objectives	Additional Provisions
		recommendations before being considered by the local government. 4. Where the local government decides to approve an application for development approval it may impose conditions so as to: 5. constrain the location of development; 6. control the form of construction, including foundations and associated works; 7. determine the form, location and construction of access; 8. require a minimum floor level for development; 9. limit the term of the approval; 10. 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 11. require the registration of a notification under section 70A of the <i>Transfer of Land Act 1893</i> on the Certificate of Title of the subject land at the cost of the landowner advising: 12. that the lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years; 13. of any limited term of a development approval; and 14. 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

Purpose	Objectives	Additional Provisions
		government upon a trigger event occurring. 15. Where an application for subdivision of land within SCA12 is referred to the local government, it may recommend that the Commission applies conditions requiring: 16. the finished surface level of the land, or the level of public roads providing access to the land are raised sufficiently to reduce the risk of coastal inundation; 17. building envelope/s, where applicable, provide a specified area of land that is located above the coastal inundation level; 18. 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.

As part of the introduction of SCA12 into the Scheme, the extents of the special control area will need to be shown on the Scheme Maps for Carnarvon (MU3 Maritime Facilities and MU4 South Carnarvon) and for Coral Bay (MU2 North). The extents of the SCA are to contain all areas that are subject to erosion or inundation by 2125.

7.3 Local Planning Policy

To provide context for, and guidance on the operation of Special Control Area 12 (SCA12), it is recommended that the Shire of Carnarvon prepare a Local Planning Policy for Coastal Hazard. The Local Planning Policy should address matters such as:

- Requirements for Development Applications in areas affected by SCA12;
- Guidelines for exempted development; and
- Guidance for the shire when considering strategic planning proposals, subdivision referrals and development applications.

Requirements for Development Applications

The standard requirements for the information to accompany a development application is outlined at clause 63 of the deemed provisions for local planning schemes contained in the *Planning and*

Development (Local Planning Schemes) Regulations 2015 (deemed provisions). Sub-clause (d) allows for a local government to require reasonable additional information. It is recommended that a future local planning policy outlines the nature of the additional information required to accompany development applications on land subject to coastal hazard.

Exempted Development

It is recommended that the following development be exempted from the SCA12 requirement for development approval:

- temporary or non-permanent structures not used for human habitation;
- extensions to an existing single, grouped or multiple dwelling where the net floor area of the proposed extensions is no more than 50m²; and
- a change of use where no new structures are proposed.

Guidance to Local Government

The Policy will provide a series of guidance statements to the Shire to assist in the decision-making process for strategic proposals, subdivision referrals and development applications.

In relation to strategic proposals, the policy will trigger coastal hazard to be a “matter to be considered” when assessing or providing comment on strategic proposals, such as structure plans, scheme amendments, or similar. The Policy will similarly outline the considerations required for the Shire when providing a referral response to the WAPC on subdivision applications. In relation to development applications, the Policy will provide additional guidance to the Shire when considering a development application against SCA12 and the matters outlined in clause 67(2) of the deemed provisions.

7.4 Foreshore Management Plan

It is recommended that the Department of Biodiversity, Conservation and Attractions (DBCA) prepare a framework for coastal management for Coral Bay. In relation to Carnarvon, it is recommended that the Shire prepare a coastal management plan. The framework / plan will address immediate management issues including access, environmental management, dune management, community use and provision of facilities.

8 Funding considerations

Estimates to undertake actions appropriate for coastal hazard management have been provided for each of the Management Units. It is noted that these costs represent consideration of tight scoping, and efficiency developed through combining actions (e.g. HSD mapping should be done for each townsite, rather than as a separate task for each MU). It should be recognised that realised costs for each action may vary substantially, particularly if loose scoping or a higher standard of performance is required (e.g. a drone survey gives much greater information than measuring beach width).

Implementation of the actions listed for each MU would result in Shire expenses of \$300-400 k within the next 0-5 years, ongoing expense of around \$60-75 k per annum, and around \$10-12 M worth of significant hazard mitigations (

Table 8.1), which would contribute an average of ~\$200 k per annum, if distributed over the next 50 years.

Table 8.1 - Summary of Costs for Action Lists per Townsite

Location	First 0-5 Years	Ongoing	Deferred	Significant Items
Coral Bay	\$110-130 k	\$20-25 k/yr	\$15 k	MU2 (N) Beach Nourishment
Carnarvon	\$210 k	\$40-50 k/yr	\$530-1150 k	MU1 Resort Relocation MU3 Pickles Point Seawall MU4 Infill Levee MU4 Raise Surge Wall MU5 Brockman Levee

External funding is considered valuable for establishing the set of management plans and studies which are the main immediate activities (years 0-5). However, external funding is essential if the Shire of Carnarvon is to achieve significant coastal hazard mitigation works.

A range of funding options will need to be considered for both short-term and longer-term actions, and in some instances, broader or 'all of Government' approaches may be required. For example, funding for economically important assets could be sourced through regional economic development grants, and environmentally important assets funded through conservation grant programs. To support the consideration of external funding sources, types of action have been identified, which can be related to potential funding (Table 8.2), typically based on shared LG & Agency funding.

Table 8.2 - Potential Funding sources, by Action Type

Action Type	Potential External Funding Sources
BDG – Building Design Guidelines	
CM – Coastal Management	Coastwest (DPLH)
CMA – Coastal Monitoring & Action Plan	Coastal Adaptation & Protection Grants (DOT)
CMP – Coastal Management Plan	CMPAP Funding (DPLH)

Action Type	Potential External Funding Sources
CP – Coastal Protection	Coastal Adaptation & Protection Grants (DOT) Disaster Ready Fund (NEMA)
EMP – Emergency Management Plan	Disaster Resilience & Recovery Funding (DFES)
RBFS – Recreational Boating Facility	RBFS Funding (DOT)
SP – Structure Plan	CMPAP Funding (DPLH)
TS – Technical Study	

The WAPC (2003) *Coastal Planning & Management Manual* provides a valuable resource to support initial development of Coastal Management Plans and Dune Management Plans.

A preliminary priority ranking for the significant items has been developed based on immediacy, economics (from B-C ratios) and equity, with the latter based on the proportion of public to private benefit (Table 8.3). However, it is acknowledged that priority is more likely to be determined by the order with which urgent pressure is experienced.

Table 8.3 - Preliminary Prioritisation of Significant Items

Location	Significant Items	Immediacy	Economics	Equity	TOTAL
Coral Bay	MU2 (N) Beach Nourishment	5	4	1	3
Carnarvon	MU1 Resort Relocation	2	6	6	5
	MU3 Pickles Point Seawall	4	2	3	2
	MU4 Infill Levee	1	1	3	1
	MU4 Raise Surge Wall	3	3	5	4
	MU5 Brockman Levee	6	5	4	6

Note: 1 indicates highest priority and 6 indicates lowest priority

The relative capacity to use different financial mechanisms to raise internal funding differs between the six significant items:

- Beach nourishment provides general amenity, and therefore is suited to general rates levy, or visitor contribution.
- Pickles Point seawall would service a discrete set of government and private agencies, whose commercial operations would be affected by erosion hazard if it is left unmitigated. This situation supports use of a contributory fund.
- The proposed structures for South Carnarvon and Brockman provide mitigation for defined areas, largely occupied by private residences. This suggests use of differential rates, although use of a general rates levy may be appropriate given the landowners, particularly in South Carnarvon, are likely to experience falling land values with sea level rise, even if mitigation is put in place.

- It is challenging to use typical funding mechanisms for relocation of the resort from Pelican Point, as there is a single private beneficiary.

9 Monitoring and review

Monitoring and review activities related to preferred adaptation pathways were identified for each MU and summarised in the foregoing Sections. These activities were largely related to monitoring required to trigger the next level of management action. They are supplementary to sustained long-term coastal monitoring activities, specifically including:

- Measurement of sea levels at Department of Transport's Carnarvon tide gauge.
- Measurement of atmospheric conditions at the Bureau of Meteorology's Automatic Weather Station 006011 at Carnarvon Airport
- Capture of high-resolution aerial imagery, coordinated by Landgate, typically in 5-10 year intervals. Some imagery may be available via organisations such as Google Earth.
- Low-resolution evaluation of 'detected shorelines' from satellite imagery. Geoscience Australia provide a free product suitable for characterisation of long-term trends.

Monitoring activities common through the MUs include HSD measurement and dune (vegetation) condition assessment. These can be undertaken with different levels of cost and complexity, acknowledging the need to transition towards more detailed methods if refined decision-making is required (Table 9.1). In general, low-cost monitoring is considered viable for Coral Bay and Carnarvon, potentially using moderate or high-cost monitoring at baseline and every 5-10 years, to provide a framework for lower resolution assessment.

Table 9.1 - Alternative Monitoring Levels

	HSD Measurement	Dune Condition
Low Cost	Beach Width	Site Photos & Review of Landgate imagery
Moderate Cost	RTK Beach Scarp	Transects with Species ID
High Cost	Topographic survey	Drone Survey & Multispectral

The CHRMAP process is designed to be ongoing, with regular updates associated with the emergence and collection of new information, such as new legislation, identification of climatic changes, or any new information that becomes available and significantly modifies the understanding of coastal hazards. This is typically anticipated to require CHRMAP update every 5-10 years. As such, actions recommended here should be subject to review and revision as appropriate, incorporating results from recommended further studies. This includes scoping potential protection enhancement for South Carnarvon and ongoing evolution of Babbage Island Spit.

10 APPENDIX A - Strategic Adaptation Approaches (adapted from WAPC, 2021)

Approach	Description	Triggers	Actions & Considerations
Avoid	No new residential or commercial development in areas identified for managed retreat	Undeveloped land lies within the hazard extent	Implement planning controls to avoid inappropriate development of the land Continue to update hazard extent mapping as required relative to new information
Accommodate	Emergency Response Plan Drift Management Plan	The shoreline (HSD) is within the S1 distance of most seaward asset	Prepare response plans for infrastructure that could be impacted
Managed retreat All landward assets eventually retreated through land acquisition to ensure a foreshore reserve is retained	Planning controls for managed retreat	Residential or commercial property lies seaward of the 100-year coastal hazard erosion line.	• Include all affected land in a Special Control Area and ensure the hazard information is incorporated in structure planning • Provide notification of potential hazards on certificates of title where possible or by direct contact with landowners • Appropriate where cost of protection prohibitive (environmental, social, economic) • Not implemented until triggers are reached likely beyond 2070. • The Shire would not acquire private property for transfer to the public realm unless there was sufficient funding for compensation, with contributions from the state and federal government. • Revised relative to new information when the CHRMAP is reviewed
	Minor Infrastructure (short-medium term) Manage impacts to minor public or drainage infrastructure	Damage to asset that results in it being damaged, destroyed or becoming unsafe	Repair and maintain infrastructure in the short term to extend short term life and function but leave unprotected; and/or remove and relocated to a less vulnerable area.
	Major Infrastructure (long term) Instigate managed retreat in areas where triggers are reached	The shoreline (HSD) is within the S1 An asset is damaged, destroyed or becomes unsafe due to coastal erosion or inundation impacts;	• Ensure mechanisms for compensation of landowners • Realign public roads

Approach	Description	Triggers	Actions & Considerations
		Water, sewerage or electricity to a lot is no longer available. A public road is no longer available or able to provide legal access to a property.	
Protect	Interim soft protection (up to 2035)	Beach and coastal foreshore reserve is significantly diminished with respect to its original state and function (ecosystems, amenity, economic value impacted along more than 50% of area) Shoreline (HSD) is within the S1 distance (see CHRMAP Hazard Assessment) of most seaward asset.	Dune rehabilitation undertaken to increase natural protective function. Dune management should only be instigated in areas with >30m area between the shoreline and the HSD; investment of approximately \$30/m Sand renourishment pending identification of a suitable source and EIA (identify potential impacts on marine habitat)
	Long term hard protection in key areas when triggers are reached (post 2050) Increased development density may be permitted where long term protection is identified and there is an overwhelming planning justification New development in these areas may be required to contribute to the ongoing maintenance of the protection	Shoreline (HSD) is within the S1 distance of most seaward asset; A specific coastal management technique (i.e. soft protection) is forecast to no longer be economically or physically feasible within 10 years; Beach and coastal foreshore reserve is significantly diminished with respect to its	Construct hard protection structures based on detailed analysis of feasible options (i.e. groynes, seawalls, breakwaters) where: - Erosion and/or inundation impacts a large proportion of residents (cost/benefit of costly protection) - Areas of key community attraction and commercial activity. - Significant infrastructure without clear alternative locations to perform the required function - If hard structures are installed to protect landward assets, this will significantly impact beach amenity (where applicable) in the long term. - The type and suitability of structures to be installed will require further modelling and detailed analysis. - The need for protection in will be revised relative to new information when the CHRMAP is reviewed in 10 years

Approach	Description	Triggers	Actions & Considerations
		original state and function	

11 Appendix B – Implementation Plan overview

Element	Attribute	Action	Considerations
Funding	Costs	Conduct a detailed economic assessment to establish the economic value/contribution of natural assets in key vulnerable areas	- Direct and indirect economic benefits provided by beaches and the coastal foreshore reserve (including parks) are not well understood at present and should be further elucidated given the primary focus on 'beach value' for the Coral Bay site. - The assessment should focus on Coral Bay Beach and Babbage Island Beach areas, where the highest vulnerability is present in the short term. - This information would also be useful in informing a more comprehensive benefit distribution to guide detailed options assessment and inform the next CHRMAP review and could also have implications for a specified area rate to apportion funding contributions, aligning them with the level of benefit that certain rate payers will receive as a result of management
	Sources	Establish a cash reserve for coastal adaptation through existing budgeting Pursue Part funding through Federal & State Government Investigate new funding mechanisms through a Coastal Hazard Management and Adaptation fund	- Annual inputs allocated into a cash reserve for coastal adaptation through existing budgeting processes, relative to other priorities. - Future costs will be considerably greater than current expenditure on coastal management and will require part funding from the Federal and State Governments (e.g. through Disaster Resilience Funding) - The Shire could establish a fund for management of coastal hazards directed towards a combination of interim protection and compensation for affected landholders to implement managed retreat - This would involve targeted revenue raising mechanisms and preparation of a Coastal Adaptation Costing Plan to inform potential rate increases (e.g through % increase to all rates; differential area rate based on land use and zoning; developer contributions; 'user pays' revenue from boat ramps, parking etc)
Land Use Planning	Structure Plans	Update Structure Planning	All structure planning should account for the hazards identified in this CHRMAP and the requirements of SPP2.6. The primary mechanism for achieving this through structure planning will be the allocation of a suitable portion of land as coastal foreshore reserve. This foreshore reserve should be of adequate width to account for the 2125 coastal erosion hazard line, and ensure a functional foreshore area will remain should this hazard extent be realised in the future
	SCAs	Amendment of TPS to create SCAs	The SCA should be based on the 2125 hazard extent, plus an additional allowance for future foreshore amenity.

Element	Attribute	Action	Considerations
		The Shire will notify owners of land situated within the mapped 100-year erosion and inundation extents directly, via mail or email. There are also mechanisms to apply notification of the potential hazards to Certificates of Title and these should be implemented where possible.	• The SCA should establish the intent to eventually retreat from the identified area, where this is identified as the priority long term pathway. • SCA's should require that all development in the area requires approval, allowing control of development and ensure it aligns with the long-term pathways for the area. • SCA's should not extend over areas zoned such that development is already prohibited, such as Parks and Recreation Reserve. It is important that the Shire notify the community and potentially affected landholders and stakeholders of the results of the CHRMAP and the extents of potential coastal hazards.
	Leases	Review Leases Where the Shire leases facilities on land vulnerable to coastal hazards	Short term measures could include: • Notifying all affected leases of potential coastal hazards • Reviewing the suitability of lease arrangements relative to the CHRMAP at such time that new leases are applied for or existing leases are due for renewal • If leases are in an area identified for protection or with hazards not likely to be realised until 2070, then renewing for a term up to 20 years may be appropriate If leases are in an area likely to be vulnerable in the short term, consider not leasing, or leasing with a reduced term or event-limited arrangement. The suitability of leases in the future would need to be investigated relative to the findings of future CHRMAPs and long term adapt

Element	Attribute	Action	Considerations
Hot Spot Management	Sediment Management	Initiate/continue targeted beach/foreshore/dune management in vulnerable areas.	In the short term, beach nourishment could be employed to manage coastal hazards at Coral Bay MU2 (North) due to vulnerability of landward assets, the potential for event-based erosion and the opportunity to improve beach amenity (in the short term) and potential by-passing could be appropriate at the Coral Bay boat ramp Coral Bay MU2 (South) but would require a site-specific assessment to establish sediment source and ecosystems services trade-offs taking account of: • Appropriate location for placement. • Most effective placement volume, footprint and profile. • Appropriate sand in terms of grain size and colour. • Timing nourishment for greatest effect. Dune management is potentially appropriate at a number of MUs including Coral Bay and at Babbage Island in Carnarvon MU1 but should only be carried out where: Appropriate management plan is first in place to ensure targeted planting in conjunction with watering, signage, track management and other measures to potentially build site-specific dune resilience The existing area of dune between the shoreline and HSD is >30m Management occurs in conjunction with appropriate monitoring (post storm and annually) A management budget of ~\$30/linear metre of dune is available to ensure efforts are robust and 'fit for purpose'
	Detailed options assessment	Undertake a detailed assessment for management of coastal vulnerability related to: Inundation of residential area in Carnarvon MU4 South Carnarvon	With a particular focus on inundation through pathways that occur at 'gaps' to existing surge wall Potential options for different protection measures (e.g levee; staged approach to surge wall works)
		Undertake a detailed assessment for management of coastal vulnerability related to: Erosion of Pelican Point Road Carnarvon MU 1 Babbage Island	Options for relocation of Pelican Point Road and Waterfront Resort facilities – cost benefit of rerouting road (short term) versus downgrade and relocation

Element	Attribute	Action	Considerations
		Undertake a detailed assessment for management of coastal vulnerability related to breaching of Babbage Island Spit (Carnarvon MU1; MU3; MU4)	Loss of protective function and enhanced erosion at maritime facility Implications for navigation channel Infrastructure impacts – Pelican Point
	Emergency Response	Update the existing asset inventory to identify vulnerable assets and prepare an emergency/ damage response plan to respond to potential coastal impacts.	- Use the hazard extents derived through the CHRMAP, for the present day and 2035 planning timeframes, to create an inventory of assets that could be impacted, further to the existing asset database. Assess potential risks to public safety (flooding, unsafe/unstable infrastructure etc.). - Develop a plan to respond to hazardous events, and the asset damage and scenarios that could be associated with them. - This plan might involve the rapid installation of signage and access prevention, the timely removal of damaged assets and response plans for emergency situations. Focus Areas: - Robinson Road, carpark and campsite (Coral Bay MU2 North) - Pelican Point Road and Pelican Point Water Front Resort (Carnarvon MU1) - Nor West Seafoods Site (Carnarvon MU1) - Maritime Facilities/Harbour Road (Carnarvon MU3) - South Carnarvon (Carnarvon MU4)

Element	Attribute	Action	Considerations
Monitoring	Long Term Monitoring	Initiate a long-term coastal monitoring program, incorporating ad hoc storm and metocean monitoring, and coastal asset condition assessments	Long term estimates of recession using historic high resolution aerial imagery (ongoing shoreline change analysis) and current position of the HSD established through regular monitoring, in addition to analysis of collected aerial imagery. At areas where most pronounced change is likely a monitoring program should include: • Regular analysis (annually) of aerial images, to identify planform change as well as shoreline change (and erosion rates) for other vulnerable areas and creation of GIS layers to describe them. • Baseline profile monitoring to establish beach width/dune buffer measurement points. • 6 monthly buffer width monitoring at set transect locations (to be determined on a site-specific basis relative to length and width (height) of available buffer. • The surveying should prioritise areas with the highest vulnerability at present (Babbage Island: Pelican Point Area; Babbage Island Spit; Robinson Road; Remnant vegetation at Maritime facility in MU3 should have surveying commence as soon as possible, to ensure the longest dataset possible is available to inform future management). • Ongoing surveys should occur in conjunction with the buffer width measurements for 'hotspot' sites timed at intervals between the seasonal summer and winter (approximately April and October/November, respectively).

Element	Attribute	Action	Considerations
	Storm Response Monitoring	The collection of data to inform storm-based erosion and inundation understanding.	Data can be used to validate modelled erosion and inundation extents and inform the design of coastal structures. These extents are used as a trigger distance to initiate a change in the management pathway, such as a shift to managed retreat. As such, the Shire should seek to incorporate ad hoc storm monitoring in key vulnerable areas into the recommended long-term coastal monitoring program including: • Post storm beach width (at a minimum) and profiles (if possible), targeting vulnerable sections of coastline at Robinson Road; Pelican Point, Babbage Island Spit; remnant vegetation at maritime facility. Sampling should target the most severe storm events, or those with the greatest potential to lead to shoreline impact. • Inundation extents associated with high water level events should be chosen where the peak of the storm is predicted to occur at high tide, ideally during spring tides. Extent of inundation should be recorded (depth where possible); recovery time and associated damage to assets if applicable. Frequency of inundation and damage are used as triggers for key assets at Robinson Road (Coral Bay MU 2 Coral Bay) and Harbour Road (Carnarvon MU 3) as well as South Carnarvon (Carnarvon MU4). • Photo monitoring pre/post storm at fixed located locations (see photo monitoring guidance appendix)

Element	Attribute	Action	Considerations
	Existing Coastal Infrastructure - Condition Assessment	These assets include boat ramps, jetties, groynes, seawalls, breakwaters and associated access infrastructure, like carparks and access ways which are generally designed to be sufficiently strong to withstand coastal hazards (often accompanied by protection)	More regular condition assessment of coastal infrastructure should be undertaken by the Shire and where relevant, State Government: - Assets like boat ramps, protection structures and access-ways subject to altered functionality as conditions change. - Existing coastal asset may have been under-designed for present and/or future coastal conditions - For significant infrastructure, assessments should be carried out by an experienced coastal or maritime structural engineer. - Formal inspection frequency should be approximately every 5 to 10 years, but this should be flexible based on the outcomes of previous assessments and observations from informal assessments. - There should also be the capacity to inspect infrastructure after major storm events, to identify any critical damage. Carnarvon MU 1 Babbage Island; MU 3 Maritime Facility; MU 4 South Carnarvon.
Further Investigations	Geophysical Assessment	Geophysical investigations to ID depth of erodible material below the ground surface.	- Noting that managed retreat is a potential adaptation option in the future, geophysical investigations may be beneficial prior to major built infrastructure being removed. The geophysical investigation would inform the managed retreat decision, ensuring assets are not removed unnecessarily – e.g Coral Bay MU 1 chalets. - ID if there is a continuous, alongshore rock barrier located below the ground surface (e.g. within a sand dune), that has sufficient strength and height to prevent coastal hazards impacting assets on its landward side. - Such investigations are carried out by geologists using specialised equipment.

Element	Attribute	Action	Considerations
	Drainage Management and Maintenance	Asset Management Plan and Drainage Maintenance Program	- Conduct an asset condition assessment to inform update of the Shire's Asset Management Plan and Drainage Maintenance Program - Develop a priority matrix to ensure drainage assets are performing as expected. - Consider critical failure mode analysis and timeframes for upgrade or renewal in context of preferred adaptation pathways (protection v managed retreat) to determine maintenance program and associated financing to be included in the Infrastructure Asset Management Plan and the Shires 10 Year Business Plan. - Stormwater and drainage system be reviewed for functional capacity should issues be reported.
Review	Review	Future document review	Undertake a full revision of the Shire's hazard extents and CHRMAP identifying and incorporating relevant new information. The key changes to any future revisions of the CHRMAP should include an update of hazard estimates using more recent information, the findings of specialist investigations undertaken, changes to projected sea level rise, climate change effects and any changes to the use of the foreshore. The CHRMAP will be reviewed in 10 years or when SPP 2.6 is reviewed, whichever comes first.