Report SE134-01 Rev 02
November 2025

Exmouth Town Beach Coastal Hazard Management & Adaptation Management Plan

Seashore Engineering

CHRMAP

Shire of Exmouth

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

This Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) has been prepared for the Shire of Exmouth to provide a basis for active and ongoing management of coastal hazards. Evaluation has considered coastal hazards following the West Australian State Coastal Planning Policy SPP 2.6 [1] and associated CHRMAP Guidelines [2], including erosion, inundation and coastal landform mobility. In addition, there has been some consideration of runoff flooding, as this has been a significant factor in planning and development of Exmouth townsite.

The main area of interest for the CHRMAP extends for approximately 5km, from Exmouth golf course to the northern end of McLeod Street, including Exmouth Town Beach (Figure 1-1). Town Beach was previously identified as a coastal erosion hotspot, due to rapid erosion over 2007-2015 and proximity of public assets [3].

Overall, Exmouth CHRMAP aims to improve coastal planning and management within the Shire and better align the Shire's planning framework with State Planning Policy [1]. Assets considered through the CHRMAP process include:

- Natural Assets under direct management of the Shire.
- Existing Built Assets owned by the Shire or under direct management.
- Existing Built Assets owned or managed by the State Government.
- Existing Built Assets owned by private landowners, subject to Shire Planning and Development conditions.
- Areas designated for future development, subject to Shire Planning and Development conditions.

A key CHRMAP objective is to provide a strategic pathway for ongoing development of Exmouth foreshore, limiting risk to infrastructure, human safety, and other values, by:

- Determining where hazard is intolerable for Exmouth's assets and values.
- Identifying plausible pathways for hazard management for existing developments.
- Determining practical and economically viable mitigation measures to support greater coastal resilience.
- Identifying necessary refinements to local planning instruments.

The CHRMAP influences the:

- Shire's Local Planning Strategy [4] and Local Planning Policy [5] (Strategic Planning by Local Government)
- Local Planning Scheme [6] (Statutory Planning by Local Government)
- District/Local Structure Plans (Spatial Planning for District and Locality).

The CHRMAP approach involves consideration of alternative pathways for change and identifies where decisions may provide future constraints.

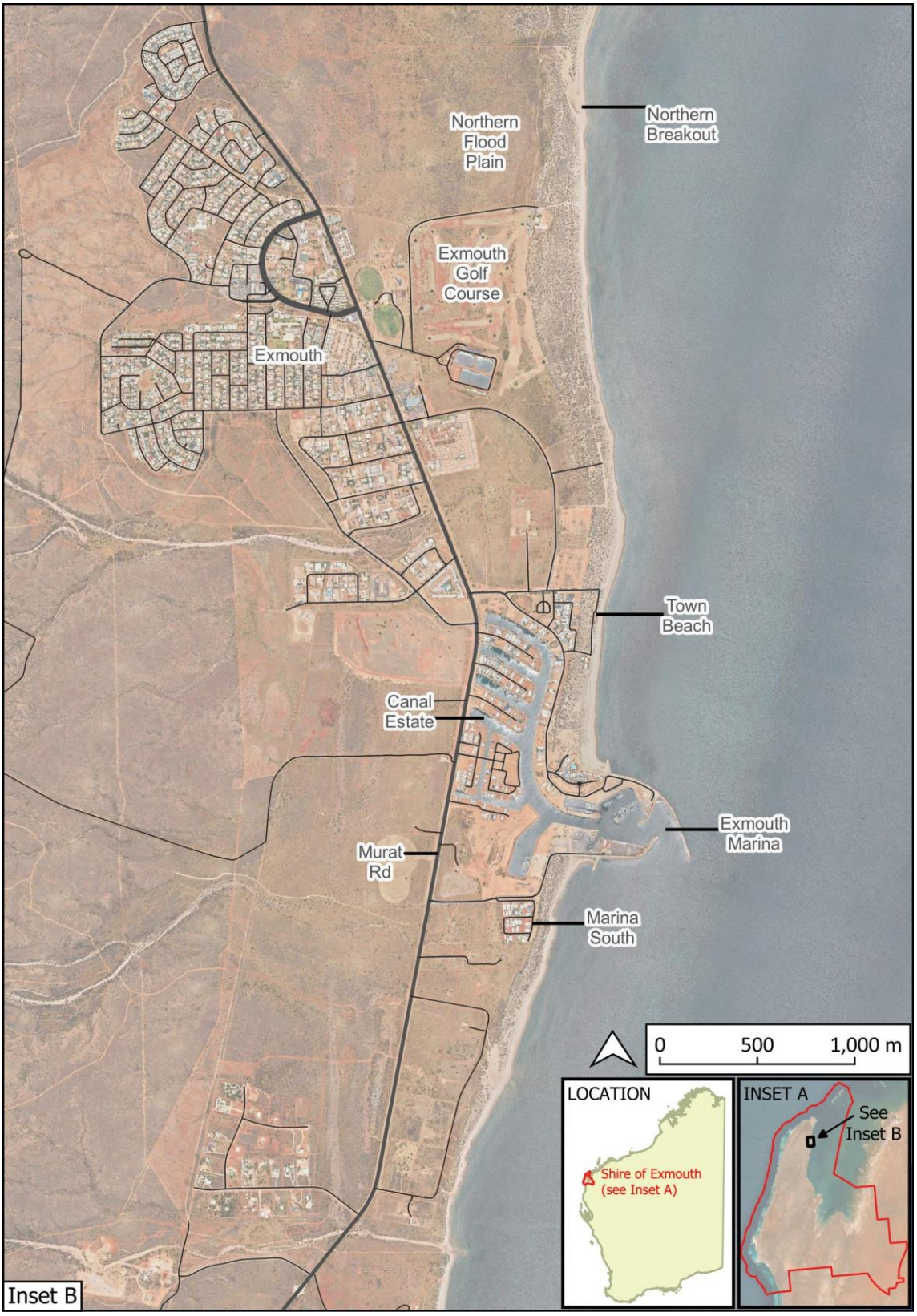


Figure 1-1: Location Diagram

Importantly, this CHRMAP does not resolve all coastal management issues or define a 'Masterplan' to guide long-term development – rather, it provides support to future decision-making by the Shire as its coastal planning and management objectives evolve. Furthermore, this CHRMAP should be actively maintained by the Shire, with review and revisions approximately every 5-10 years, to cater for changing conditions and townsite development. Recommended actions to facilitate future coastal planning and management are listed, including identified future investigations.

The potential for existing and planned land-uses along Exmouth coast to be affected by coastal processes within the next 100 years has been previously recognised through local development applications and studies [7,8,9]. The significance of this pressure was further highlighted by rapid erosion of Town Beach over 2007-2015, leading to its identification as a coastal erosion hotspot [3]. Consequently, the Shire chose to undertake a CHRMAP, supported by funding from the WAPC's Coastal Management Plan Assistance Program.

Work on Exmouth Town Beach CHRMAP was undertaken by Seashore Engineering and Land Insights project team. The project was established following the CHRMAP Guidelines [2] using a risk-based evaluation with 7 key stages (Figure 1-2). Previous reporting addressing Stages 1 and 2 includes:

Appendix A: Exmouth Town Beach CHRMAP: Establish the Context [10]

Appendix B: Exmouth Town Beach CHRMAP: Coastal Hazards [11]

Subsequent stages have used slightly different reporting titles due to the nature of Exmouth Town Beach and its management, with Steps 6 and 7 merged into one section. Key CHRMAP stages, associated actions and other related project deliverables are summarised in Table 1-1.

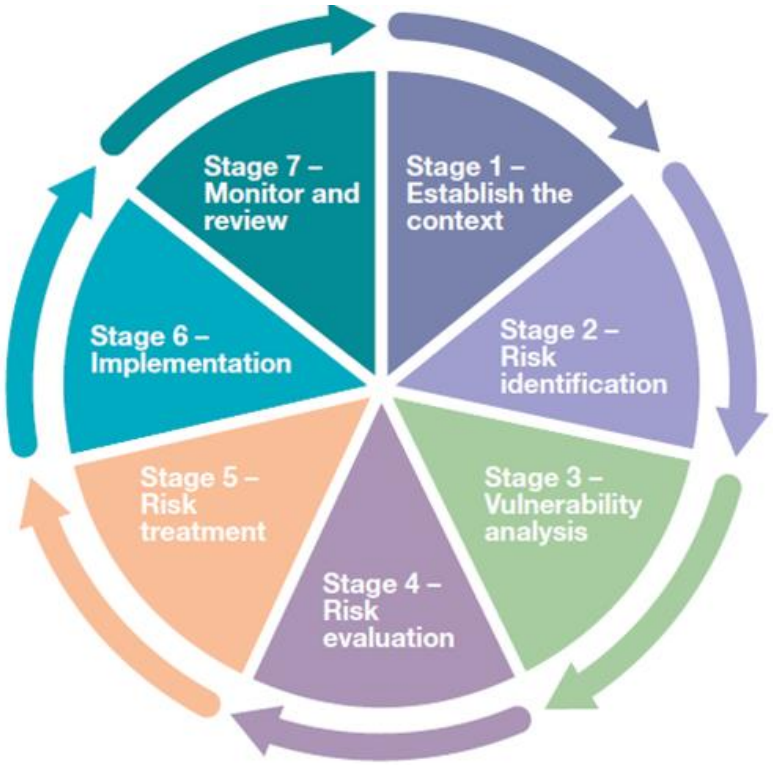


Figure 1-2: Stages in a CHRMAP Process following WAPC Guidelines

1.1. Exmouth CHRMAP Structure

Table 1-1: CHRMAP Stages and Project Deliverables

Assessment Phase	CHRMAP Stage	Details	Deliverable/Link to Section
1	Establish the Context	• Stakeholder and Community Engagement Plan • Identify community coastal values and aspirations	• Community Survey & Workshop 1 (see Figure 2-1) • Report 1: Establish the Context (Appendix AAPPENDIX A) • Adaptation Objectives & Success Criteria (Appendix A)
2 Hazard	Risk Identification	• Coastal hazard assessment and mapping for the selected planning timeframes • Detailed description of each asset/asset grouping	• Asset Register • Report 2: Coastal Hazards (Appendix B) • Workshop 2: Community Risk Assessment Workshop (Appendix C) • Workshop 3: Stakeholder Briefing Workshop (APPENDIX D)
3 Asset	Vulnerability Analysis	• Consequence and likelihood scales • Level of risk matrix and risk tolerance scale • Adaptive capacity of assets scale, vulnerability matrix, tolerance scales & vulnerability of assets at risk table	• Council Briefing Note • Council Briefing Session This Document
4 Risk Assessment & Priorities	Risk Evaluation	• Identification of existing controls that alter level of risk. • Reassessment of asset vulnerability considering existing controls • Assets requiring risk treatment as a priority	This Document
5 Adaptation Planning	Risk Treatment	• Identification of risk treatment options • Results of multi-criteria assessment (including community values and success criteria) • Cost benefit analysis of risk treatment options for short term, medium and long-term risk • Adaptation pathways or decision-making strategy with decision-points & management triggers for short, medium and long-term planning horizons	This Document
6 Implementation	Implementation Plan	• Land-use planning instrument requirements • Short-term implementation plan (present-25 years) • Medium and long-term strategic implementation plan (25-50 and 50-100 years)	This Document

1.2. Purpose of this Document

This document summarises risk assessment and adaptation planning components of Exmouth Town Beach CHRMAP, with due consideration of previously characterised coastal hazards [11] (see Appendix B). The CHRMAP aims to identify priority areas for management by the Shire, identifying adaptation options. This document has been designed to inform the Shire and its community when planning for potential coastal risk.

The assessment process has been guided by success criteria, identified by the Shire's community engagement process during **Phase 1: Establish the Context** (Section 2 & Appendix A and supplemented by coastal hazard assessment in **Phase 2: Risk Identification** (Section 3 & Appendix B). The assessment undertaken proceeded through key work phases that broadly align to stages in the CHRMAP process noted in the CHRMAP Guidelines [2].

At the outset of the study, the Project Team, in consultation with the Shire, considered the most appropriate way to apply the CHRMAP Guidelines in a fit-for-purpose assessment. Specifically, this aimed to account for local attributes of coastal hazards and address the Shire's key aims and objective for future coastal planning and management activities. Key points of interest in this respect are:

- The area of focal interest centres on a relatively small coastal strip where townsite development has occurred adjacent to the coast (Town Beach)
- Coastal management at Town Beach requires impacts from and to Exmouth marina and canals to be considered. This includes significant structural control due to the breakwaters and revetments, as well as active sediment management, with bypassing from south of the harbour and placement on Town Beach.
- Observations following sand management in 2022 included high erosion scarps and excessive presence of cobbles along Town Beach, affecting public access by 4WD, and limiting boat launching.
- Previous hydrological studies have flagged the role of the Northern Breakout to limit flooding affecting Exmouth town site, particularly the area of floodplain east of Murat Road from the Golf Course to Exmouth Marina.

The resulting approach was built on an understanding of these attributes and priorities for the Shire. The methodology employed adopted an asset exposure-value-sensitivity approach which largely aligns to WAPC CHRMAP Guidelines [2] stages (Figure 1-3), which parallels the hazard-asset-damage-mitigation elements identified in National disaster risk management [12]. Town Beach was a focus area for adaptation planning assessment as it is where most coastal assets are present, where existing management challenges require attention and potential for competing pressures is considered greatest.

Exmouth coast has been considered as four discrete management units (MU) intended to characterise areas where there is potential for synergistic or competing interests for assets. Erosion analysis is further conducted in eight sub-segments, (Figure 1-4), based on coastal change identified in the Coastal Hazards report (Appendix B).

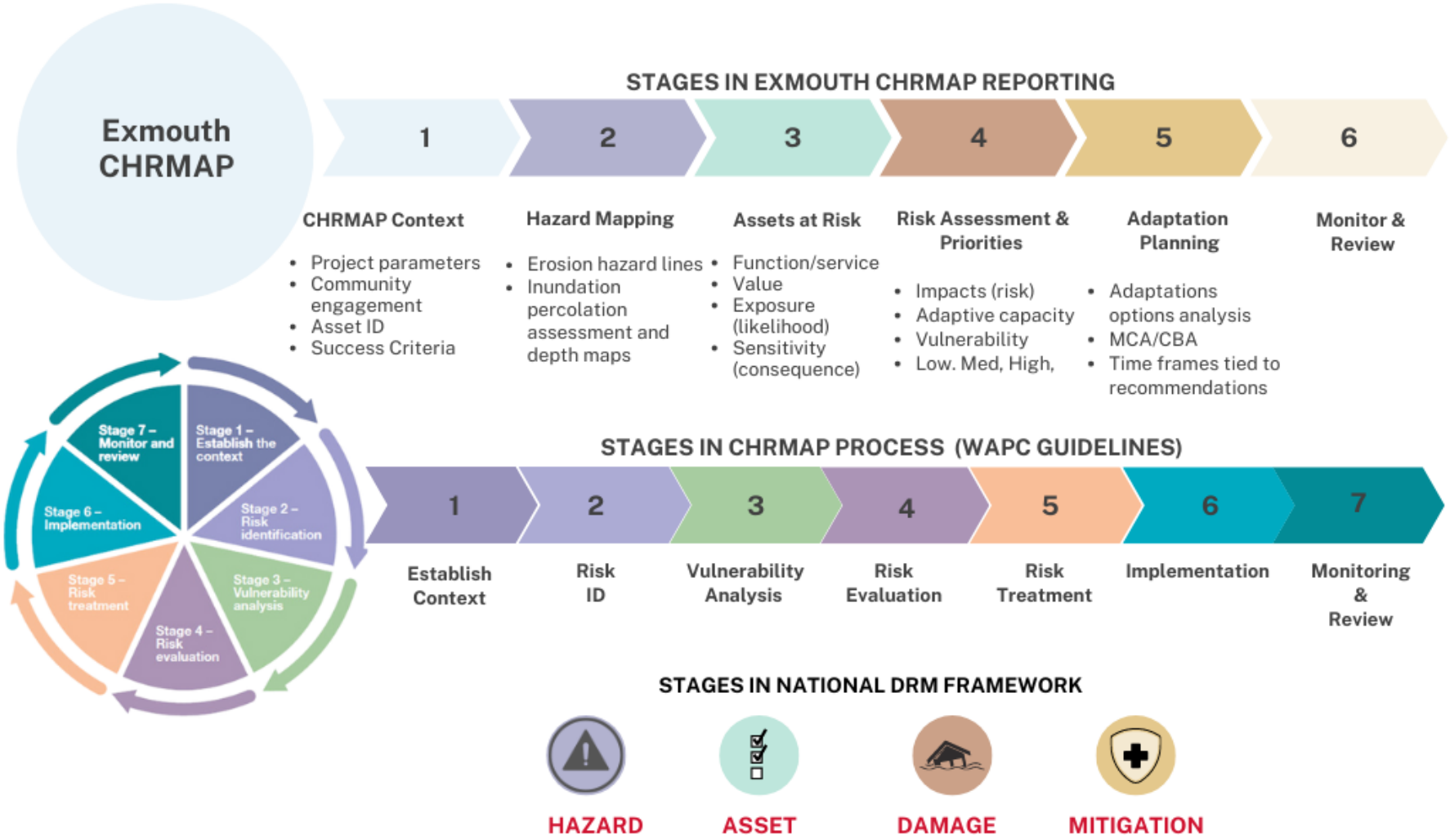


Figure 1-3: Exmouth CHRMAP Reporting Stages & Relationship to WAPC Guidelines

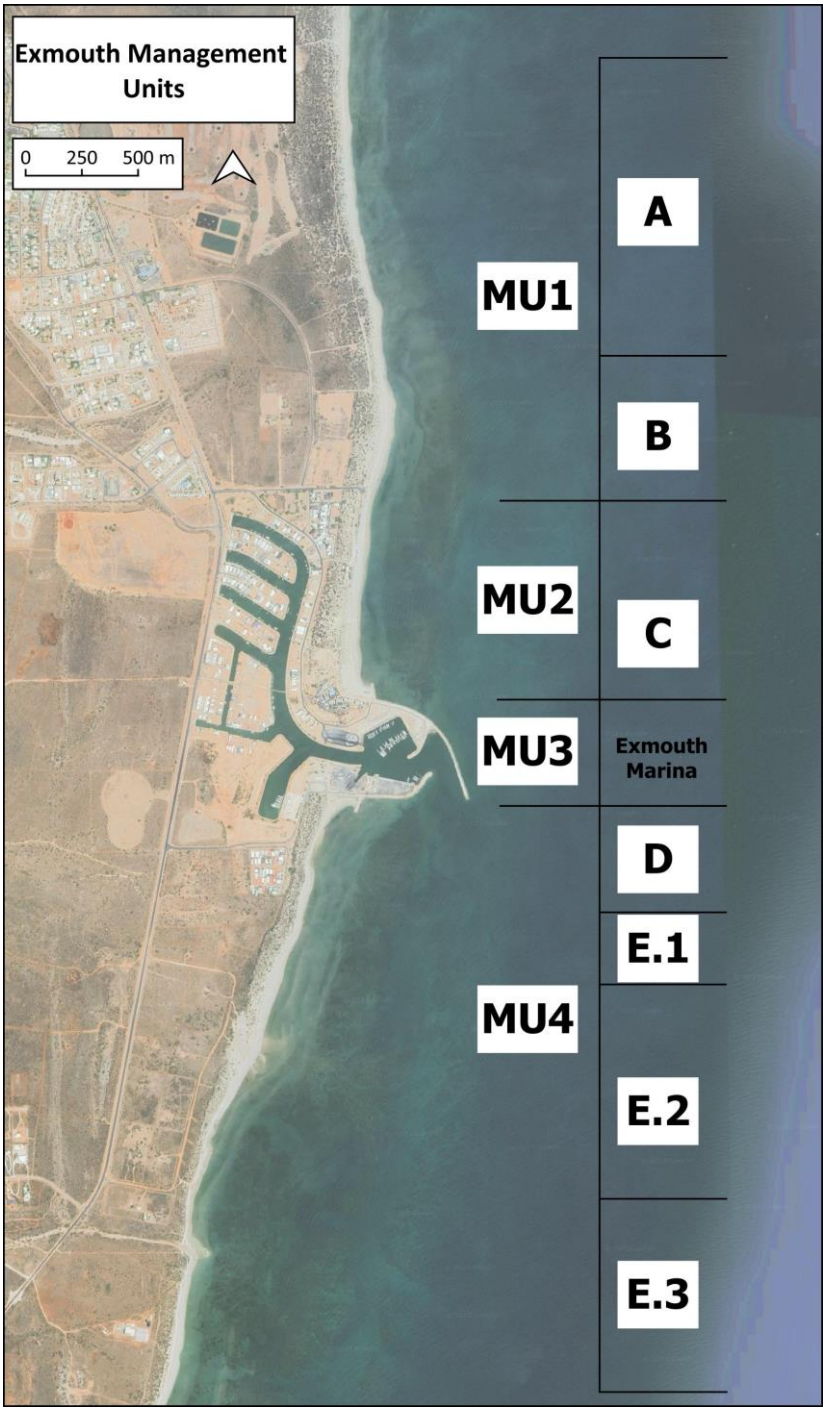


Figure 1-4: CHRMAP Management Units (MU) and analysis sub-segments

2. STEP 1: CHRMAP CONTEXT – OVERVIEW

Step 1: CHRMAP Context

- Community engagement
- Physical setting
- Project parameters & success criteria

2.1. Project Parameters & Priorities [a]

Indicative value of the coast to the local community was established as a basis for further investigation. The term 'value' is qualitative in this context and based on the environmental, social, and economic importance that the coastal area holds for the people that live, work and recreate there. The first stage of the **Community Values Assessment** carried out for the Shire of Exmouth CHRMAP was built around the following key questions:

Q1: Who are the stakeholders?
Q2: What are the existing management issues?
Q3: How are these likely to change into the future?
Q4: What assets are located within the coastal zone?
Q5: How do key stakeholders 'value' their coastal assets?

Work undertaken is described in ***Report 1: Establish the Context*** and summarised in Figure 2-1, which involved:

- Community survey
- Site visits & meetings
- Stakeholder 'values' workshop

Key findings from Phase 1 allowed identification of adaptation objectives (priorities) for the study area and definition of Success Criteria for the project.

See Boxes 1-4

[a] Q1-5 form the basis for Phase 1 reporting ***Report 1: Establish the Context*** (Appendix A). Key elements from Phase 1 relating to the risk assessment process are summarised in Boxes 1-4.

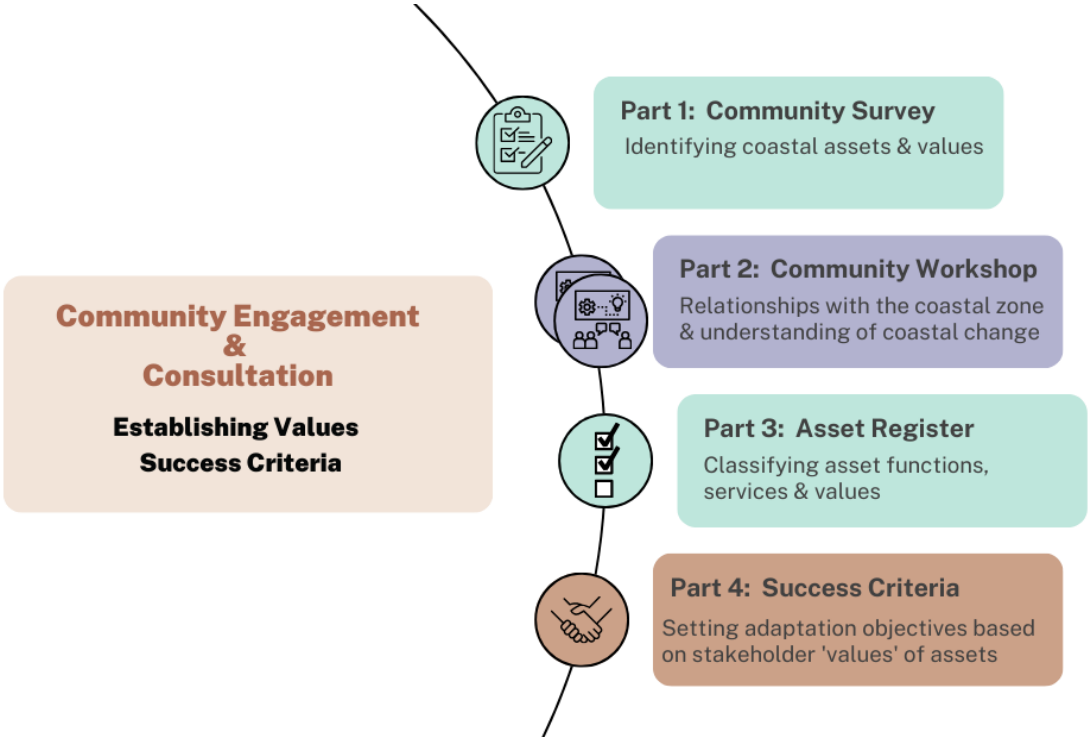


Figure 2-1: CHRMAP Context: Community Engagement & Consultation Process

2.2. Setting Adaptation Objectives through Community Engagement

Adaptation to climate change is heavily couched in a process of 'trade-offs' whereby the pros and cons of different decision-making pathways must be considered in the context of a desired future outcome. Identifying adaptation priorities or objectives for a coastal zone is therefore a key element in the decision making and strategic planning process of a CHRMAP. These priorities need to be identified early, through engagement and consensus building, to allow a shared understanding of the adaptation planning process built on local community values. The process for community engagement and consultation adopted for Exmouth CHRMAP is outlined in *Report 1: Establish the Context* (Appendix A). Through the Community Survey and Community Workshop, participants were prompted by Thought Starters (Figure 2-2).

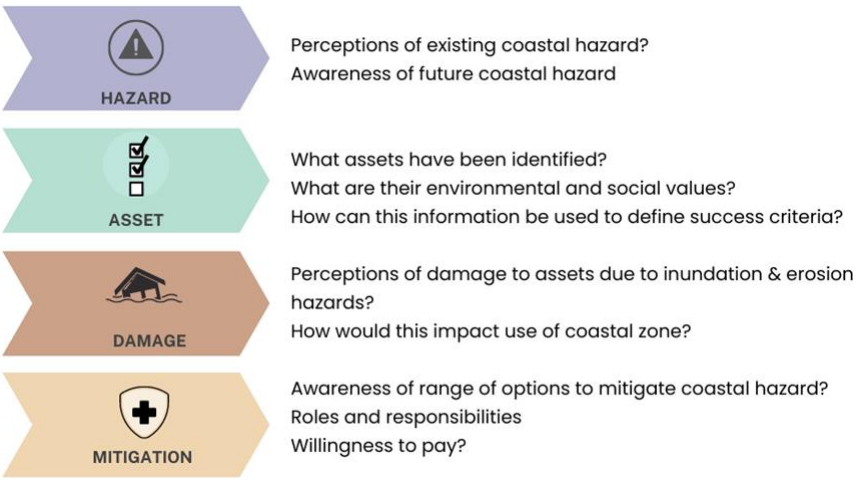


Figure 2-2: CHRMAP Context: Stakeholder Engagement Thought Starters

Box 1 and Box 2 summarise the Community Survey and Community Workshop respectively.

Part 1: Community Survey

Identifying coastal assets & values

97 submissions received over a one month period

- Over 90% of respondents identifying recreation on the coast is their main interest - boating, fishing, swimming, and snorkeling.
- Daily and weekly usage accounting for almost 90% of responses
- 60% of coastal users surveyed don't feel coastal erosion or inundation are a problem now or will be in the future.

- Environmental, social and economic assets ID for Town Beach
- Natural features (beach and dunes) more highly valued than coastal infrastructure (marina and the beach recreation facilities)

Use of and access to the beach as gateway to marine environment highly valued

Box 1: CHRMAP Context: Community Survey Summary

Part 2: Community Workshop, May 2022

Relationships with the coastal zone & understanding of coastal change

Summary:

- Town Beach is the focal point for community use of and access to the marine environment
- Natural areas are more highly valued than facilities which are not viewed as adding to natural function or 'experience'
- Ease of use and access are highly valued with only a limited interest in curbing this access to the benefit of conservation and management of natural areas.
- Aquatic recreation is more highly valued than terrestrial coastal experiences.
- Town beach is not seen as a highly commercial or tourist area but is valued by local people – residents and frequent visitors for its current intrinsic qualities.
- Diversity of understanding or acceptance that coastal environmental change implies corresponding human change.

Workshop findings reflect survey results: Use of and access to the beach a key priority; limited acknowledgement or awareness of existing or future coastal hazards.

Box 2: CHRMAP Context: Community Workshop Summary

2.3. Preliminary Asset Identification

Identifying and defining the value of assets within the study area through community engagement and maintaining a focus on these values through the CHRMAP process is a key part of the risk assessment process. A preliminary coastal asset register was established with information sourced through the Shire's asset register, supplemented with a site visit and interrogation of aerial photography. Reports have also been sourced from the Australian Exposure Information Platform (AEIP)[b] to provide an early indication of existing infrastructure asset financial values potentially at risk to erosion and inundation hazard. Where appropriate, assets were grouped into categories:

- **Residential:** private property adjacent to the ocean.
- **Transport infrastructure:** roads and access pathways.
- **Marine infrastructure:** harbour, jetties, boat ramps.
- **Utilities**: power, sewerage, and water.
- **Foreshore reserve**: including amenities within this area such as car parks, public ablutions, barbeque/picnic/shade areas, playground, and pedestrian access structures such as ramps, stairs and paths.
- **Commercial**: privately owned built infrastructure (cafes, shops, tourist accommodation).

Part 3: Asset Register

Classifying asset functions, services & values

A classification of the function/services provided by and value associated with coastal hazard for Exmouth.

- Asset ID - Shire asset register; aerial photography; community survey & workshop (**See Part 1 &2**)
- Function/Service - assets categorised as:
  - Residential
  - Commerical
  - Foreshore Reserve
  - Transport Infrastructure
  - Marine Infrastructure
- Value - qualitative assessment of environmental, social and economic values of assets to rate each asset as **LOW; MEDIUM; HIGH** value.

Value scores assigned to each asset identified based on a qualitative assessment of its service and function. This information is used to inform confirmation of SUCCESS CRITERIA (Part 4) and provide a consequence rating (sensitivity to impacts of coastal erosion and inundation) for each of the assets considered

Box 3: CHRMAP Context: Community Engagement & Consultation Process

2.4. Community Values and Success Criteria

Outcomes from the stakeholder engagement process acted as the basis for formulation of adaption objectives and success criteria. Key points from consultation with local community, business owners and Shire representatives can be summarised as:

[b] Australian Exposure Information Platform (ga.gov.au)

- Exmouth community expressed a strong sense of the "coast being part of their DNA". While Town Beach may not be as iconic as the nearby visitor 'hotspot' at Ningaloo, it is nevertheless the familiar exposure to coastal experience for local people and visitors (on a weekly and even daily basis).
- Natural areas are more highly valued than the built environment and associated facilities.
- Ease of use and access are highly valued with only a limited interest in curbing this ease of access to the benefit of conservation and management of natural areas.
- Aquatic recreation is more highly valued than terrestrial coastal experiences.
- The marina and harbour development does not have a high level of community affinity – it is accepted as being in-situ but is not connected with or associated with Town Beach or its use.
- Change is recognised as a challenge.
- Diversity of understanding or acceptance that coastal environmental change implies corresponding human change.

Consideration of outputs from the community survey, workshop and wider engagement process suggested the key adaptation objective for the Shire of Exmouth is to maintain access and utility of Town Beach and its associated facilities.

Success criteria aligning to this primary objective and guiding the process of rating 'consequences' of erosion and inundation coastal hazards to inform the vulnerability assessment in subsequent CHRMAP work phases are summarised as:

Part 4: Success Criteria

What does a good one look like?

Formulating **Adaptation Objectives** and **Success Criteria** for coastal hazard management and adaptation planning for Shire of Exmouth

- SC1: Preserve the function and opportunity for recreation activities along the coastline (such as walking/running, beach swimming 4WD) – primarily facilitated by access to and along the coast at Town Beach
- SC2: Preserve the access to and quality of the marine environment to facilite ongoing highly valued aquatic recreational activities (boating; fishing; diving)
- SC3: Retain and enhance areas of natural dunes and foreshore reserve.
- SC4: Maintain the services and function of the Town Beach foreshore area (financially, socially and built form)

Use of and access to the beach as gateway to marine environment most highly valued and continued access to Town Beach and the Marine Environment rated as a key adaptation objectives.

Box 4: CHRMAP Context: Community Engagement & Consultation Process

Figure 2-3: Access along Town Beach: A key success criterion for Exmouth Community

2.5. Land-use Planning Instruments in the CHRMAP Context

Land-use planning instruments are important tools to reduce coastal risk to existing and future assets. Under the Western Australian Planning system, the approach to planning in relation to coastal hazards is guided by State Planning Policy 2.6: Coastal Planning [1] and the Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) Guidelines [2]. The guidelines refer to several planning instruments that can be implemented to manage hazards along the coast (Table 2-1).

Existing planning controls within each of the Management Units (MUs) for Exmouth Town Beach were considered at the outset of the CHRMAP. Existing tenure and planning arrangements for each MU are summarised in Appendix E: Existing Land-use Planning with an example for MU:1 Northern Flood basin presented (Table 2-2). This information provides context for subsequent assessment of residual risk (Section 5.2.1) to facilitate selection of appropriate adaptation options and actions to mitigate identified erosion or inundation hazards for the Shire.

Table 2-1: CHRMAP Context: Summary of Land-use Planning Instruments

SP	**Structure Plans (SP)** Developed and implemented where land is to be substantially developed. Applies to areas that have been identified by either the Local Government in their scheme or strategy or where required by the Western Australian Planning Commission. Should incorporate the findings and associated requirements of the CHRMAP in areas where there is potential for the further development, or the redevelopment of a site. Structure Plan development allows for the formation of a coastal foreshore reserve to manage current and future coastal erosion and possible inundation. Structure Plans do not have the force of the Local Planning Scheme, and act as guidance documents for future subdivision and development.
LPS	**Local Planning Scheme (LPS)** Amendments can be used to implement planning controls in relation to coastal management and can be used as a planning tool to identify risk and zone the land and apply provisions in relation to any development accordingly.
SCA	**Special Control Area (SCA)** can be declared through Local Planning Scheme over areas deemed significant in relation to coastal hazards & special provisions applied where necessary. Allows for specific planning mechanisms to be implemented where the highest coastal hazard has been identified through the CHRMAP process. Relate to a specific area and will have a set of specific development requirements and/or conditions that will relate specifically to the identified area. These will apply in addition to other local and state government planning frameworks applicable over the site.
CA	**Compulsory Aquisition (CA)** involves the taking of land where it has been deemed that risk to coastal hazard is likely to apply and hazards have advanced to a stage where land exceeds tolerable risk thresholds. This can be undertaken through 2 processes: Purchase of the land by the LG if the owner agrees to sell the parcel under Section 190 of the Planning and Development Act (2005). Compulsory acquisition by the LG without the agreement between parties under Section 191 of the Planning and Development Act coupled with the Land Administration Act (1997)
RL	**Reservation of Land (RL)** Land can be reserved for foreshore purposes and particularly applies to the management of public assets. The reservation of land would allow for improved asset management along the foreshore and for future planning of the foreshore reserve.
LPP	**Local Planning Policy (LPP)** Provides detail and guidance on acceptable development & assists in the decision-making process for development requiring discretion including design responses to constraints in relation to development proposals, introduction of relocatable buildings within areas such as tourism zone or coastal reserves, setbacks for development in relation to identified hazards, & floor levels for development. The LPP can also identify the requirement at development approval stage for notifications to be placed on any applicable titles.
NOT	**Notification on Title (NOT)** A Section 70A notification can be placed on a Title of land as a condition of planning approval. This can identify the identified hazard over the subject site. The notification can be either of a general nature in relation to the identified hazard or can be more specific and if required time-limited, for example where a temporary use may be allowed for a limited timeframe prior to an identified hazard occurring.

Table 2-2: Land-use Planning Context MU1: Northern Floodplain

<table>
<tr><td colspan="2">Assets

Golf Club: The Golf Club is part of a larger reserve encompassing sporting ovals on the western side of Willersdorf Road. The golf course, and the parcel of UCL, are reserved for Public Open Space

Beach: large parcel of land south of the golf course club house comprises Unallocated Crown Land. Within the scheme, the beach is reserved for Foreshore.

Wastewater Treatment Plant: Reserved for Public Purposes – Infrastructure Services. It is understood that that the Water Corporation is currently exploring options for the relocation of the plant.

Lots between Truscott Crescent and the Coast: Combination of Unallocated Crown Land, Reserve and freehold.</td><td> 
</td></tr>
<tr><td>Existing Situation</td><td colspan="2">• The Shire's Local Planning Scheme contains specific provisions for this special use (floodplain) zone SCA5.
• SCA5 does not extend over the dune systems or foreshore.
• Special Use land parcels (SU4) extend further east than the Tourism lot.
• These scheme reservations provide no specific existing development controls over any of these land parcels. The Shire, in receiving an application for development, would need to ensure that the objectives of the reserves are maintained, and that incompatible development is not permitted.
• Development of the Unallocated Crown Land would require management orders to be established, or other forms of tenure progressed over the relevant parcels.
• There are no specific controls related to coastal protection wtihin the Tourism zone.
• The Shire would need to rely on the broader provisions in SPP2.6 pertaining to the need for site-specific consideration of issues. There has been a foreshore (POS) reserve created on the seaward side of this land parcel that should provide some protection to any future tourist related uses.</td></tr>
<tr><td>Future Considerations</td><td colspan="2">• There is an opportunity to review tenure to create a wider foreshore reserve should the land parcels be modified in future.
• The intended future uses of the tourists lots are low-key recreational uses (Caravan Park and Camping Ground).
• While low key, these types of recreational facilities can represent significant investment by an operator over many years, and there will be a need for infrastructure to be placed appropriately.</td></tr>
</table>

Table 2-3: MU 1 Northern Floodplain. Existing Planning Controls

No	Description of Land	Special Use	Conditions
SU4	Lot 1 Truscott Crescent and Lots 969 and 1495 (Reserve 38701) Warne Street Lots 1403 and 1404 Truscott Crescent; and portion Reserve 27648, Lt 500 Nimitz Street, Exmouth Lot 198 Pace Retreat, Northwest Cape	As a 'P' use: • Caravan park. • Camping ground. As an 'A' use: • Telecommunications infrastructure As an 'I' use: • Ancillary dwelling. • Community purpose. • Convenience store. • Fast food outlet. • Motel. • Recreation - private. • Restaurant/café. • Single house (managers residence). • Shop.	Objectives of Special Use Zone 4 are as follows: 1. To cater for current and future supply of affordable tourist accommodation, principally in the form of caravan parks and camping grounds, to meet current and anticipated demand. 2. To control the location, form, character, and density of development to complement natural and built features within the locality. 3. To provide for high quality short-term accommodation and tourist facilities. 4. To protect potential and existing caravan and camping areas from the encroachment by other incompatible use or development. 5. Development shall not exceed 2 storeys in height above natural ground level, except where the local government considers that particular circumstances may warrant an exception and provided the objectives of the special use zone, and the Scheme are not compromised. 6. Landscaping shall be provided to integrate the development into the natural landscape and provide screening from visual and noise impacts of surrounding land uses. 7. A maximum of two ancillary dwellings and one single house (manager's residence) are permitted for permanent accommodation by staff employed by the Caravan Park and/or Camping Ground. 8. The combined gross floor area allocated for the commercial land uses listed in the 'Special Use' column shall not exceed 500m^2. 9. Fencing of individual caravan or camping sites is not permitted. 10. Freehold or Strata subdivision will not be supported. *Note: Development shall comply with all requirements of the Caravan Parks and Camping Grounds Regulations 1997 and/or shall be as determined by the local government.*

3. STEP 2: HAZARD MAPPING – OVERVIEW

Step 2: Hazard Mapping

- **Inundation Hazard Assessment**
- **Erosion Hazard Assessment**

3.1. Overview

Coastal hazards occur when processes at the interface between the ocean and the adjacent land can provide physical, environmental, or social loss. For the most part, this is commonly associated with movement of ocean waters (through waves, tides or storm surges) onto land area, particularly where it adversely affects land use. The two most investigated coastal processes are:

- Erosion, where oceans waters, including wave action, move sediment away from their existing position along the coast, removing a previous area of land.
- Coastal inundation, where land that was typically outside the influence of ocean waters, becomes submerged, typically for minutes to hours (i.e. typically excluding wave action).

For purposes of this study, erosion and inundation hazard were determined in line with State Coastal Planning Policy SPP 2.6 [1]. The capacity for coastal dynamics to interact with **stream runoff** has also been evaluated, as floodplain management has been a critical factor in Exmouth townsite layout, infrastructure, and future planning [4,7].

Details of the hazard assessment are in ***Report 2: Exmouth Town Beach CHRMAP: Coastal Hazards*** (Appendix B), which informed the risk assessment process reported herein. Hazard screening assessment at the outset of Stage 1 is summarised in Figure 3-1 and Figure 3-2. This is followed by a summary of asset identification and categorisation completed as part of this CHRMAP. An asset register is included in Appendix B.

2A: Erosion Hazard Assessment

Overview:

The approach to erosion hazard assessment is explained in the accompanying Hazard Assessment Report and followed the guidelines for a 100-year planning timeframe described by SPP 2.6 Schedule One. The sandy coast case has been adopted for Exmouth, with requires the following erosion setback allowances:

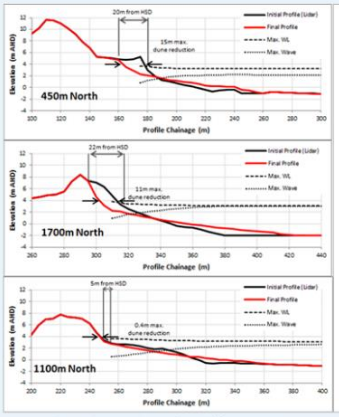
- HSD: Horizontal Setback Datum
- S1:Storm Erosion
- S2:Historic Shoreline Movement Trend
- S3:Sea Level Rise (following DoT, 2009)
- 0.2 m per year allowance for uncertainty

KEY MESSAGES

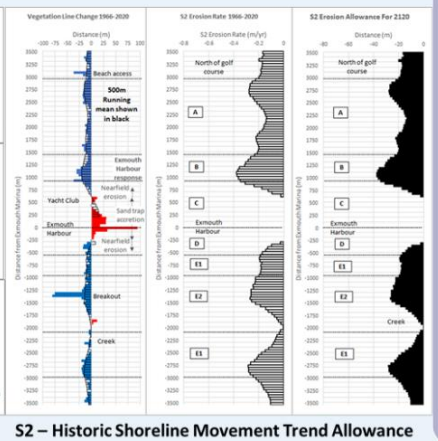
Coastal erosion hazard is most pronounced along the Town Beach foreshore area where coastal assets are situated with the present-day erosion buffer.

Elsewhere, the presence of coastal dunes mitigates present day impacts, but this will decrease into the future with projected sea level rise.

Underlying rock adjacent to the shoreline provides a potentially important element of erosion control for the Shires coastal assets. At present, the location and extent of rock is unknown.

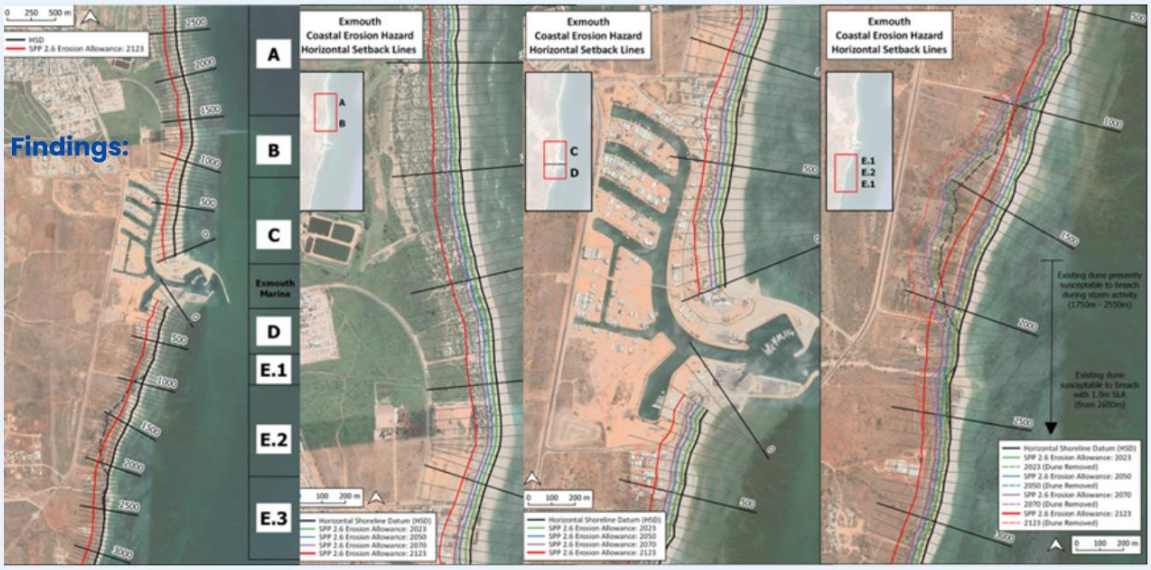


S1 – Storm Erosion Allowance



S2 – Historic Shoreline Movement Trend Allowance

Findings:



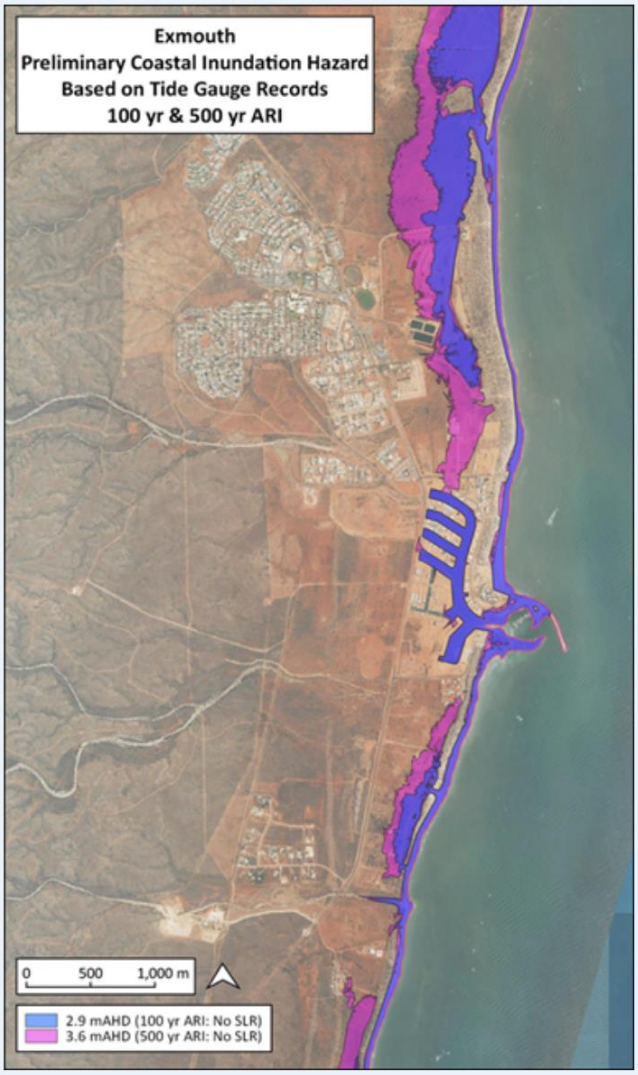
PROJECT OUTPUTS

Erosion hazard allowance for 7 segments across 3 Management Units (Harbour excluded) at the following timeframes: 2025; 2050; 2070; and 2125

Figure 3-1: Exmouth CHRMAP Erosion Hazard Assessment Summary

2B: Inundation Hazard Assessment

Overview:
Coastal inundation hazard was considered based upon previous work undertaken to determine design cyclones for the region as well as tide gauge records applicable to the study area. Flood mapping resulting from both approaches informed assessment of existing assets exposed to inundation hazard over a 100yr planning horizon. This was supplemented with stream flooding hazard and flood basin evaluation based on review and interpretation of work undertaken by SKM (2007).



Findings:
Coastal breakouts do not play a key role in management of stream flooding under prevailing conditions. Coastal inundation poses a limited threat, mostly within the area defined as streamflow flooding risk This implies that adaptation 'trade offs' associated with mitigation of runoff flooding versus limiting coastal inundation are likely to be more flexible than previously considered. That is, drainage of streamflow flooding is needed for health / land-use reasons, rather than flood risk to assets or safety.

KEY MESSAGES

Coastal Inundation Hazard is relatively mild for the Shire of Exmouth with the exception of the Exmouth Marina area where infrastructure assets and surrounding low lying land will likely be impacted.

Runoff flooding hazard has historically provided a focus for flood management, with coastal inundation identified as a secondary threat, typically occurring at lower elevations. Consequently, existing flood mitigation, through site identification, emergency management and minimum fill levels, provide effective controls to coastal inundation.

PROJECT OUTPUTS

Inundation hazard maps were produced for Northern Flood Basin; Town Beach; Exmouth Harbour and Canal; Harbour South showing the 100yr ARI; 100yr ARI + SLR; 500yr ARI and 500yr ARI plus SLR. Water level analysis was also interpreted to allow reporting against a SLR allowance for 2025 (0m); 2050 (+0.22m AHD); 2070 (0.42m AHD) and 2125 (+1m AHD)

Figure 3-2: Exmouth CHRMAP Inundation Hazard Assessment Summary

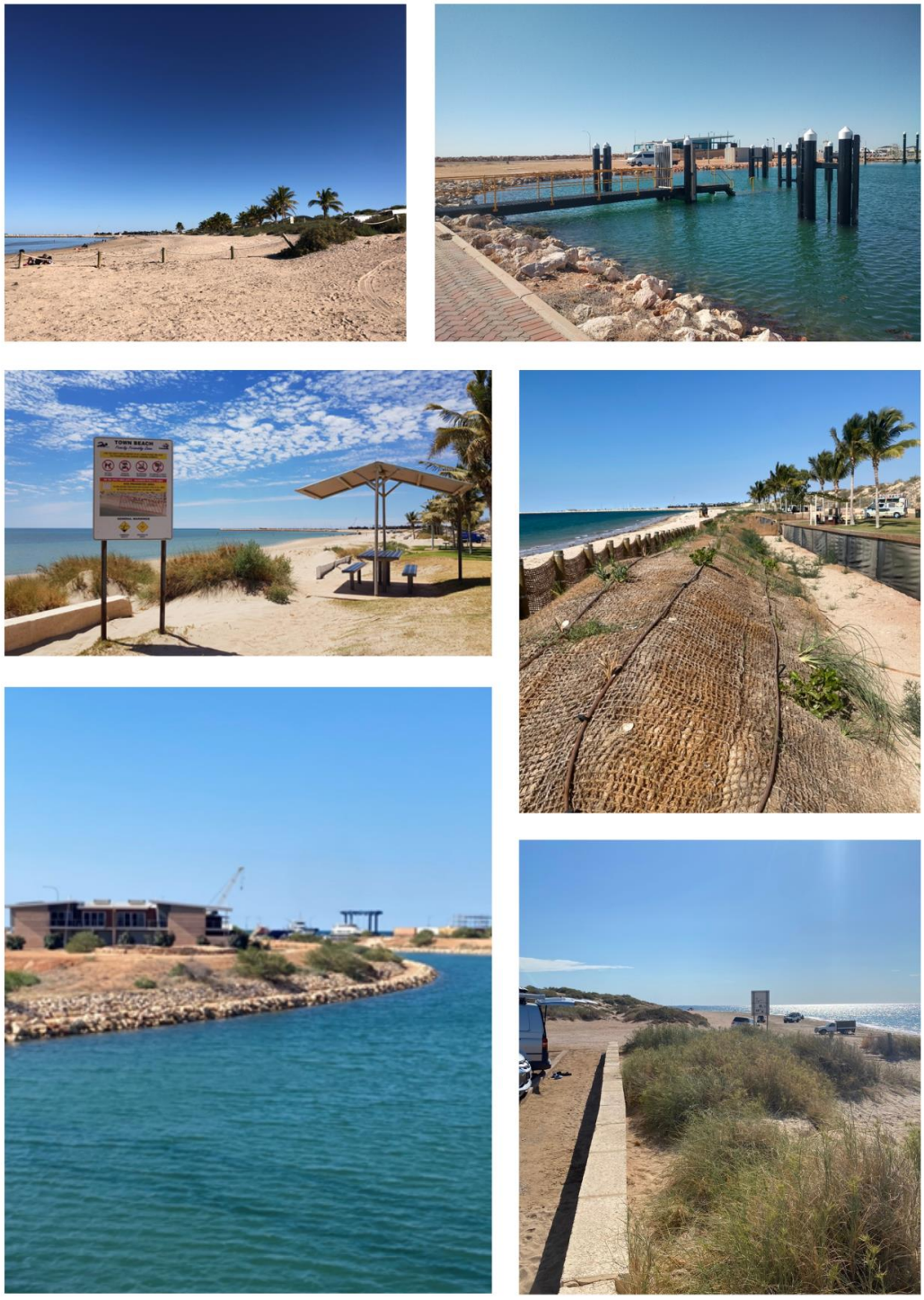


Figure 3-3: Coastal Assets: MU2 & MU3

3.2. Coastal Hazard Summary

Evaluation of coastal erosion [11] has indicated that accelerated erosion along Town Beach, which led to it being identified as a coastal erosion hotspot [3], was a result of sustained anomalous wind, combined with the presence of Exmouth Boat Harbour. Although the unusual wind conditions are likely to be impermanent, rapid local erosion observed along Town Beach is likely to recur, to some degree, whenever there is a switch in net transport direction (either way).

Coastal inundation provides a relatively limited hazard for Exmouth, with most areas exposed to coastal inundation already being identified as subject to runoff flooding, within Special Control Area 5 in the local planning scheme. However, relative frequency of coastal inundation will increase with projected sea level rise.

Consideration of inundation at this scale primarily facilitates decision making on constraints associated with of land release and the hazard mitigation decisions potentially associated with resilient future development. This information also provides a basis for prioritisation (of adaptation effort) provided in subsequent stages of this report (Section 6).

Since 2005, the northern breakout is the primary pathway for drainage, due to the as-built level of Madaffari Drive spillway. However, evaluation of runoff flood risk has indicated limited dependence of flood risk on the rate of drainage from the northern breakout, as the Northern Basin is sufficiently large to contain an extreme volume of floodwaters. This means that the breakout's drainage function is has low sensitivity to coastal change (expansion or partial closure of the breakout), provided a minimal pathway for runoff drainage is present.

Exmouth's coastal dunes provide an effective present-day barrier against wave action and a substantial barrier against erosion and inundation. The width and height of the dunes varies along the shore, with substantial dunes north of Exmouth Boat Harbour, able to withstand significant coastal recession without becoming susceptible to breaching. In contrast, dunes south of the Boat Harbour are lower, narrower and less continuous. These dunes may become susceptible to breaching under severe storm events following a limited amount of costal recession.

Opportunity to use active dune management or reinforcement to reduce future erosion hazard are considered within potential CHRMAP management options (Section 6). It is noted that if existing or proposed development encroaches on the dune reserve, loss of dune protection requires site-specific assessment of the dune reserve relative to the development. This includes presently vacant land on Truscott Crescent, zoned for tourism.

This information forms the basis of the risk assessment process detailed in following Sections.

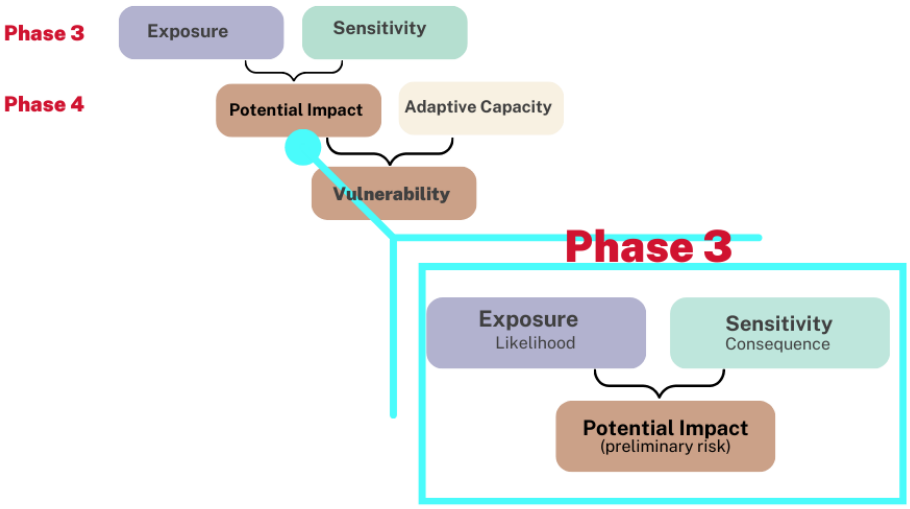
4. STEP 3: ASSETS AT RISK

Step 3: Asset Vulnerability

- Identify assets
- Determine exposure to erosion & inundation
- Evaluate sensitivity to erosion & inundation

4.1. Overview

Existing assets were identified through Phase 1 for the Exmouth Townsite. **Assets potentially impacted by coastal erosion and inundation hazards** were identified by comparing erosion hazard lines and inundation mapping against recent aerial imagery and cadastre of the Shire's coast. This defined a list of coastal assets identified in Phase 2 (Coastal Hazards Report [11] Appendix B). All assets lying seaward of the erosion and/or inundation hazard extent were recorded and identified within Management Unit (MU) and analysis sub-segments, based on coastal change linkages. Asset exposure rating and asset sensitivity ratings were derived for both erosion and inundation hazard to establish *Potential Impact* to coastal assets in Exmouth (i.e. preliminary risk, prior to mitigation actions).



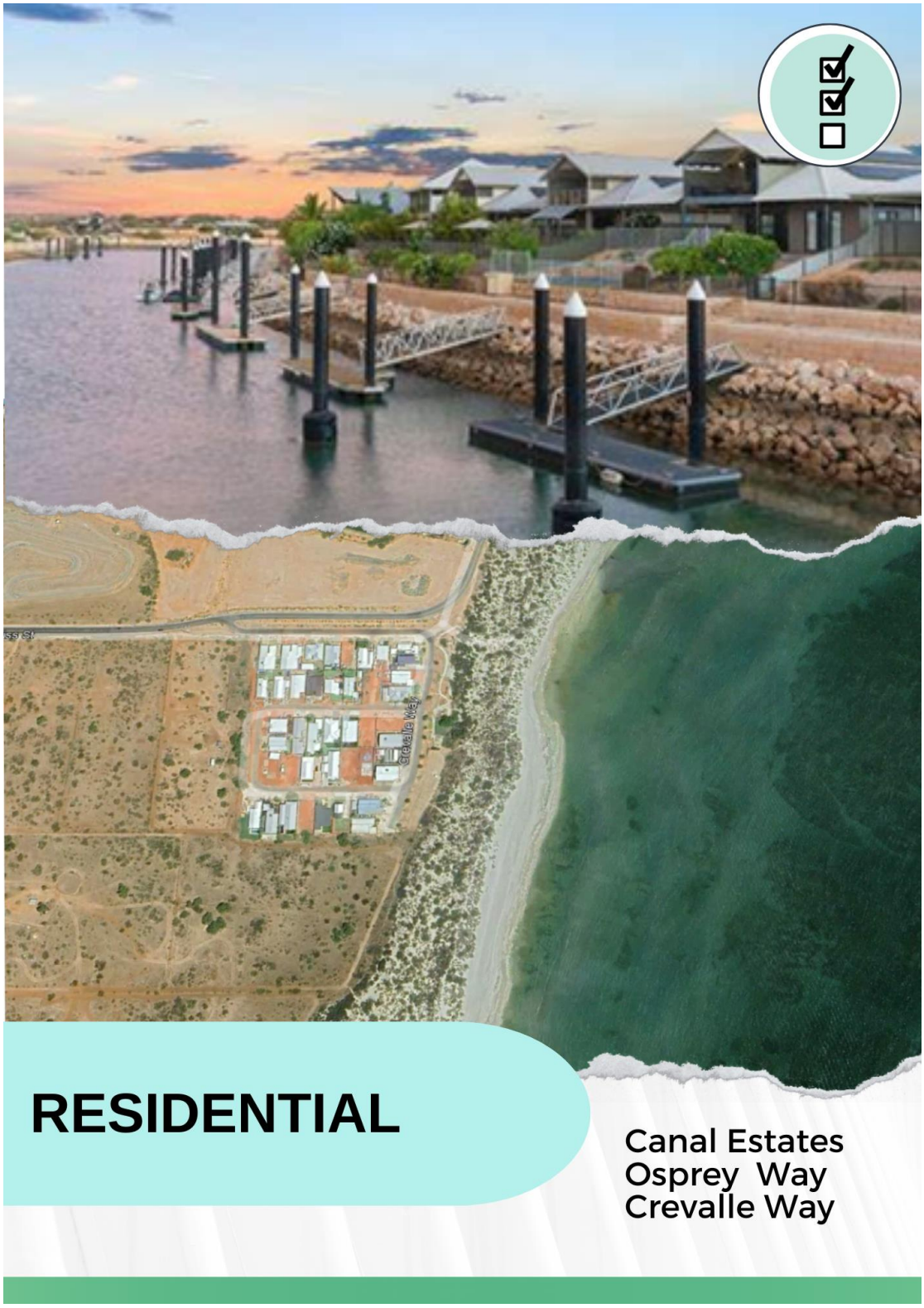
Key Commercial Assets in MU1 & MU2

Table 4-1: Summary of Asset Identification per Segment (A-E)

Management Unit & Sub-segment		#	Asset Areas
MU1	A	1	Low lying floodplain through northern breakout
		2	Reserve fronting golf course
		3	Exmouth golf course - lot with club buildings
		4	Willesdorf Road
		5	Exmouth Men's Shed
		6	Exmouth Oval
		7	Exmouth Community Garden
		8	Wastewater Treatment Facility lot
		9	RAC Exmouth Cape Holiday Park
		10	Two undeveloped lots on Truscott Crescent, zoned Special Use
	B	11	Two undeveloped lots on Truscott Crescent, zoned Tourism
MU2	C	12	Warne Street foreshore access and carpark
		13	Town Beach foreshore
		14	Warne Street to Friedman Way residential area
		15	Friedman Way foreshore access
		16	Exmouth Yacht Club
		17	Madaffari Drive
		18	Madaffari Drive canal lots
		19	Mantarays Ningaloo beach Resort
MU3		20	Exmouth Game Fishing Club Sports
		21	Exmouth Harbour walling
		22	Exmouth Harbour boat ramp & low-lying areas surrounding harbour
		23	Filled lot levels adjacent to Exmouth Marina
MU4	D	24	Neale Cove foreshore
		25	Maritime Facility on Neale Cove
		26	Crevalle Way foreshore
		27	Crevalle Way
		28	Crevalle Way residential area
	E1	29	Lot zoned special use north of McLeod Street
		30	Rural lots north of McLeod Street
	E2	31	McLeod Street
		32	Rural lots landward of McLeod Street
	E3	33	Rural lots south of McLeod Street

4.2. Asset Exposure Rating (Likelihood)

Likelihood is the probability of hazard impact (erosion or inundation) to existing and future assets and their values. Within the context of the vulnerability assessment, likelihood is used to consider the exposure of an asset to coastal hazards. Coastal hazard zone definition as per SPP2.6 Schedule One [1] only identifies a single level of coastal hazard recurrence, at the end of the projection period (by 2125). Consequently, to understand the emergence of hazard and the need to progressively adapt to increasing risk, changing likelihood of coastal hazards over time was projected. For both erosion and inundation hazards, likelihood is projected to progressively increase due to sea level rise and projected coastal recession (permanent erosion).



Residential Assets in MU3 & MU4

4.2.1. Erosion Likelihood

Erosion allowances were determined based on storm allowance, extrapolated historic change, and recession due to sea level rise following SPP 2.6 schedule one, for time frames of 2025, 2050, 2070 and 2125. As observed change was dominated by phases of beach rotation direct projection of historic change is not meaningful (i.e. the beach will not continue to rotate). Consequently, sub-segments were determined, within which coastal change showed connected behaviour.

Average erosion allowance was determined for each of the sub-segments along Exmouth foreshore (Table 4-2), to estimate available erosion buffers at each of the timeframes under consideration. Distinction was made between the allowance for short-term storm erosion, and the allowance for progressive change, termed recession, which results from net beach sediment loss as well as retreat due to sea level rise.

Table 4-2: Erosion allowances per study segment

Sub-Segment		2025	2050*			2070*			2125*		
			Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
1500-3000m N	**A**	20	52	55	54	78	85	82	153	167	160
950-1500m N	**B**	20	48	53	50	72	82	75	140	160	147
0-950m N	**C**	20	48	57	50	72	88	75	140	173	146
Harbour Area	Excluded from erosion analysis due to presence of structures										
0-550m S	**D**	20	48	53	50	72	81	75	140	158	146
550-950m S	**E1**	20	53	53	53	80	81	81	157	159	158
950-2100m S**	**E2**	20	48	55	52	72	85	79	140	166	155
2100-300m S	**E3**	20	49	56	53	74	85	80	143	167	157

Minimum, maximum and average erosion allowances are defined across each sub-segment

* Erosion is weakly tied to projected time frames. These effectively represent recession scenarios.

** Erosion allowances in E2 do not include allowance for potential dune instability in severe storms.

The minimum distance of each asset from the horizonal setback datum (HSD) was considered relative to the recession distance to estimate an available erosion buffer at each timeframe, to rate its exposure to erosion hazard.

Figure 4-1: Town Beach foreshore assets located within the erosion hazard zone.

Foreshore Reserve Assets in MU2 Town Beach

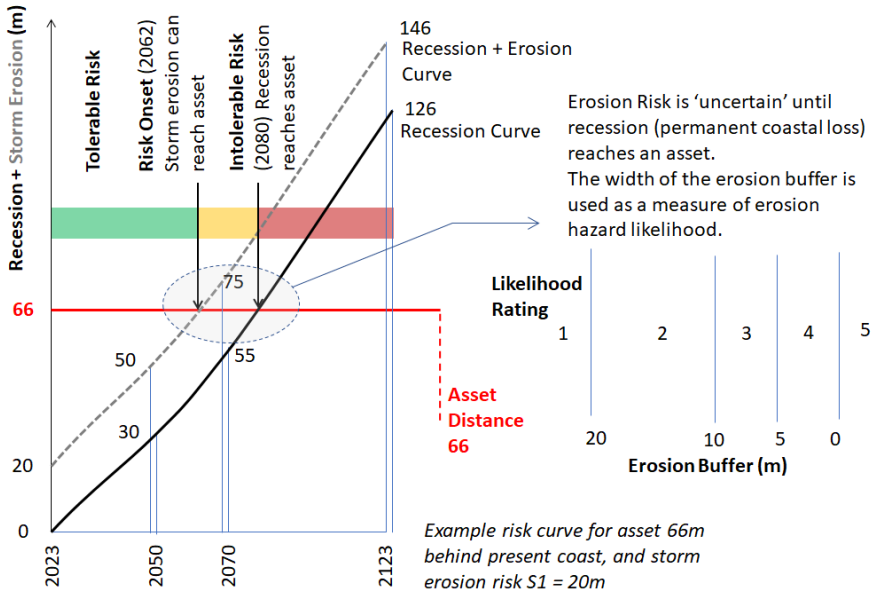


Figure 4-2: Erosion Likelihood Rating

An exposure rating of low, medium, high or very high (1 to 4) was assigned to each asset (Table 4-3), based on projected recession at each time scale. As presented in the Coastal Hazards report [11] (Appendix B) there is a significant change to erosion hazard associated with longer time frames (2070 or 2125) due to a weak link between forecast time, sea level rise and coastal recession. Due to uncertainty associated with relating sea level rise to recession, these longer-term ratings effectively represent recession scenarios, rather than forecasting coastal position at these time frames. The longer time frames are scenarios for primary dune loss, or dune field loss respectively.

Table 4-3: Erosion Likelihood Rating

Buffer Width	Exposure Rating
>20m	Low (L)
10-20m	Medium (M)
0-10m	High (H)
<0m	Extreme (E)

For example, Exmouth Golf Course is in subsegment A in MU 1 (Northern Flood Basin). The average erosion allowance for this subsegment in 2025 is 20m, in 2050 is 54m, in 2070 is 82m and in 2125 is 160m. The Golf Course infrastructure is located at a minimum distance of 130m landward of the Horizontal Setback Datum. The erosion buffer available to the golf course provides low erosion risk for the time frames of 2025, 2050 & 2070 but would shift to extreme risk by 2125.

Table 4-4: Erosion Likelihood Rating for Golf Course Assets

	2025	2050	2070	2125
Av. Erosion Allowance	20m	54m	82m	160m
Distance to HSD	130m	130m	130m	130m
Recession	0m	34m	62m	140m
Buffer	130m	96m	68m	-10m
Exposure Rating	L	L	L	E

Table 4-5: Asset Exposure (Likelihood) to EROSION for Exmouth Townsite

Management Unit	Segment	Asset	Category	Min. Dist HSD (m)	Exposure Rating (Likelihood) for EROSION			
					2025	2050	2070	2125
MU1	A	Reserve fronting golf course	Foreshore Reserve	25	L	E	E	E
		Exmouth golf course - lot with club buildings	Recreation	130	L	L	L	E
		Two undeveloped lots on Truscott Crescent, zoned Special Use	Undeveloped Lot	24	L	E	E	E
	B	Two undeveloped lots on Truscott Crescent, zoned Tourism	Undeveloped Lot	86	L	L	L	E
MU2	C	Warne Street foreshore access and carpark	Foreshore	0	E	E	E	E
		Town Beach foreshore	Foreshore	0	E	E	E	E
		Warne Street to Friedman Way residential area	Residential	66	L	L	M	E
		Friedman Way foreshore access	Foreshore	0	E	E	E	E
		Exmouth Yacht Club	Recreation	0	E	E	E	E
		Madaffari Drive	Transport	107	L	L	L	E
		Madaffari Drive canal lots	Residential	125	L	L	L	E
		Mantarays Ningaloo Beach Resort	Commercial	20	M	E	E	E
MU4	D	Neale Cove	Transport	73	L	L	M	E
		Maritime Facility on Neale Cove	Marine	92	L	L	L	E
		Crevalle Way foreshore	Foreshore	54	L	L	E	E
		Crevalle Way	Transport	74	L	L	M	E
		Crevalle Way residential area	Residential	90	L	L	L	E
	E1	Lot zoned Special use north of McLeod Street	Reserve	14	M	E	E	E
		Rural lots North of McLeod Street	Undeveloped Lot	90	L	L	L	E
	E2	McLeod Street	Transport	55	L	L	E	E
		Rual lots landward of McLeod Street	Undeveloped Lot	75	L	L	M	E
	E3	Rural lots south of McLeod Street	Undeveloped Lot	55	L	L	E	E

Overall, assets most exposed to erosion hazard are located within MU 2 sub-segment C, along Town Beach foreshore area with Warne Street carpark, Exmouth Yacht Club and Friedman Way all currently falling within the present-day erosion hazard zone (i.e. there is no present-day erosion buffer, with existing extreme erosion exposure.

With 50-60m average recession for the 2050 scenario, the Golf Club reserve and Special Use lots at Truscott Street (MU1 sub-segment A) are rated as extreme exposure with the addition of Mantarays (in MU2 sub-segment C) and the Special Use zone north of McLeod Street (in MU4 E1).

With ~80m average recession for the 2070 scenario, Crevalle Way foreshore in sub-segment D and both McLeod Street (in MU4 E2) and rural lots to the south (in MU4 E3) have extreme erosion risk.

With ~160m average recession for the 2125 scenario, all assets identified along the study area are rated as extremely exposed to erosion based on existing erosion buffers.

4.2.2. Inundation Likelihood

The minimum ground elevation adjacent to each asset was determined using the available 2006 LiDAR dataset. Exposure of existing assets to coastal inundation has been considered via a 'percolation' assessment approximating inundation extent up to +6.8m AHD (i.e. including very extreme events). All existing assets potentially impacted by flood events up to +6.2m AHD were identified as subject to potential inundation hazard (in Coastal Hazard report, Appendix B). The lowest level at which wetting of the asset was identified was used to define inundation exposure.

It is noted that differences between the level when initial wetting commences and the minimum ground level adjacent to the asset indicate protection by a natural or man-made barrier. This may potentially affect initial flood warning time, speed of inundation and post-flood drainage.

Inundation likelihood was related to an inundation-frequency curve, derived from tide gauge analysis. This was presented as either the number of days per year, based on daily maximum water level, or the average number of years between events above the level. The inundation-frequency curve was shifted upward for future time scenarios, based on projected sea level rise. For assets above 6.2mAHD, coastal inundation hazard is deemed to be avoided. It is clarified that inundation levels do not include effects of nearshore waves (e.g. wave runup), which need to be included for the design of assets immediately adjacent to the coast.

Inundation likelihood classes were developed based on relative recurrence of inundation events, at each time frame (i.e. incorporating sea level rise). This is illustrated graphically in Figure 4-3, with the classes representing different types of inundation event (Table 4-6). Allowance for "unsteady" processes (e.g. surge pulses or long waves) are only included in the most severe inundation category (500^{+} yr ARI) as these are not captured in the tide gauge record, and their influence is dissipated by distance landward from the coast.

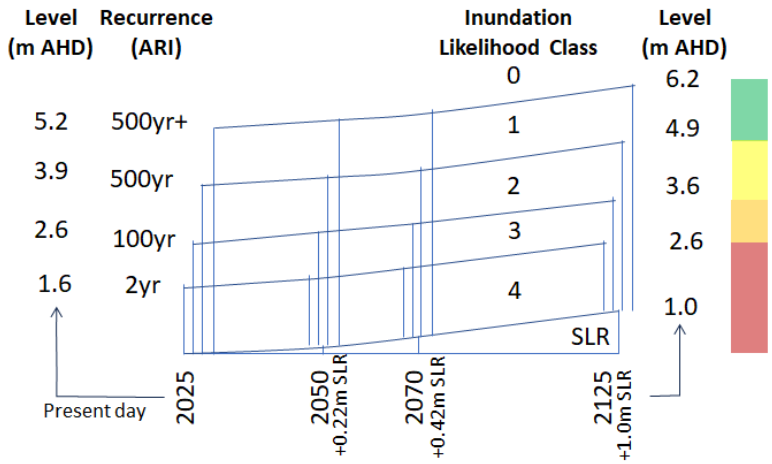


Figure 4-3: Inundation Likelihood Classes

Information was used to rate each assets exposure to Inundation hazard as negligible, low, medium, high, or extreme:

Table 4-6: Inundation Exposure Rating

Rating	Exposure	Recurrence	Comment
0	Negligible	>500⁺yr ARI	Above severe storm effects
1	Low (L)	500yr-500⁺yr ARI	Severe storm + unsteady effects
2	Medium (M)	100-500yr ARI	Severe storm inundation
3	High (H)	2-100yr ARI	Storm inundation
4	Extreme (E)	<2yr ARI	Inundated without storms

Overall, exposure to inundation hazard is relatively low for most areas at the present time with extreme exposure only on the floodplain adjacent to the northern breakout (MU1 A) and low-lying parts of Exmouth Boat Harbour (MU3). High exposure has been identified for Exmouth Golf course (MU1 A), parts of Truscott Crescent area (MU1 B) and rural lots south of McLeod Street (MU4 E1).

Under sea level rise scenarios, exposure across all areas increases. Areas transitioning from medium to high inundation exposure include the Wastewater Treatment Plant lot (MU1 A), Truscott Crecent (MU1 A), Town Beach foreshore area (MU2 C), Murat Rd near Gnulli Court (MU2 C) and residential lots near Crevalle Way (MU4 D).

Table 4-7: Asset Exposure (Likelihood) to INUNDATION for Exmouth Townsite

MU	Sub-segment	Asset Inundation Description	Minimum Level (m AHD)	Exposure Rating (Likelihood) for INUNDATION			
				2025 0m SLR	2050 0.22m SLR	2070 0.42m SLR	2125 1m SLR
1	A	Low lying floodplain through northern breakout	+1.4	E	E	E	E
		Golf Course	+2.1	H	H	H	E
		Exmouth Men's Shed	+4.8	L	L	L	M
		West section of Willesdorf Road	+4.6	L	L	L	M
		Exmouth oval	+5.6	–	–	–	L
		Exmouth Community Garden	+5.5	–	–	L	L
		Wastewater Treatment Facility	+3.0	M	M	M	H
		RAC Exmouth Cape Holiday Park	+4.1	L	M	M	M
		Truscott Crescent 700m north of Warne Street	+2.9	M	M	H	H
	B	Small northeast parcel of lots zoned for Tourism on Truscott Crescent	+2.4	H	H	H	E
2	C	Town Beach foreshore area	+3.0	M	M	M	H
		Yacht Club buildings	+4.7	L	L	L	M
		Ningaloo Resort overtopped. (Front row of villas)	+4.2	L	L	M	M
		Murat Road near Gnulli Court	+3.4	M	M	M	H
		Madaffari Drive over spillway ** based on site assessment	+4.0	L	M	M	M
3	Harbour	Exmouth Game Fishing Club Sports	+3.6	M	M	M	M
		Exmouth Harbour walling (tidal inundation)	+1.4	E	E	E	E
		Exmouth Harbour boat ramp	+1.6	H	E	E	E
		Majority of Exmouth Harbour surrounds	+1.4	E	E	E	E
		Filled lot levels adjacent to Exmouth Marina	+5.2	–	L	L	L
4	D	Residential lots adjacent to Crevalle Way **	+3.4	M	M	M	H
	E1	Murat Road south of McLeod Street	+5.3	–	L	L	L
		Rural lots south of McLeod Street through dune breakouts	+2.1	H	H	H	E

** Only applicable to a portion of the asset

Marine Infrastructure in MU3

4.3. Asset Sensitivity Rating (Consequence)

Asset sensitivity describes the consequences of an asset being exposed to coastal hazards. A qualitative value for each asset was established through stakeholder consultation considering social, environmental, and economic benefits and services it provides to the Exmouth coastal community:

1. **Social** – support quality of life, health and wellbeing of the community and include social benefits and services provided by environmental or infrastructure assets or land. Examples include beaches and foreshore reserves, car parking, and formal access paths (public infrastructure) to them.
2. **Environmental** – support coastal habitats for their geologic, geomorphic, biodiversity and landscape and ecosystem services such as those provided by dune habitats for local flora and fauna, trapping of and storing sand, and providing a source of sand to replenish beaches following erosion events.
3. **Economic** – values of the assets identified that support industry, tourism, employment or relate to matters that have an economic implication.

Attributes 1-3 were rated as Low, Medium or High in terms of their perceived sensitivity to erosion and inundation hazard, with ratings aggregated to give an overall consequence rating per asset.

Low = no loss of social, environmental, economic function or service due to projected inundation/erosion.

Medium = some loss of social, environmental, economic function or service.

High = significant impact to social, environmental, economic function or service.

The only area that was considered highly sensitive to potential erosion hazards across the length of the study area was Town Beach Foreshore (MU2 C). That is, the services, functions and values of the environmental, social and economic assets in this area were considered most significantly impacted by erosion along its reaches (Table 4-8).

Similarly, most assets considered for Exmouth were given a low or medium consequence rating to inundation (Table 4-9) across all segments except for the Wastewater Treatment Plant lot (MU1 A) and Town Beach Foreshore (MU2 C).

Table 4-8: Asset Sensitivity Rating (Consequence) EROSION for Exmouth Townsite

Sub-segment	Asset	Category	Min. Dist HSD (m)	Consequence Rating
A	Reserve fronting golf course	Land	25	M
	Exmouth golf course - lot with club buildings	Recreation	130	M
	Lots on Truscott Crescent, zoned Special Use	Land	24	M
B	Lots on Truscott Crescent, zoned Tourism	Land	86	M
C	Warne Street foreshore access and carpark	Foreshore	0	M
	Town Beach foreshore	Foreshore	0	H
	Warne Street to Friedman Way residences	Residential	66	L
	Friedman Way foreshore access	Foreshore	0	M
	Exmouth Yacht Club	Recreation	0	M
	Madaffari Drive	Road	107	L
	Madaffari Drive canal lots	Residential	125	L
	Mantarays Ningaloo beach Resort	Resort	20	M
D	Neale Cove	Road	73	M
	Maritime Facility on Neale Cove	Marine	92	L
	Crevalle Way foreshore	Foreshore	54	M
	Crevalle Way	Road	74	L
	Crevalle Way residential area	Residential	90	L
E1	Lot zoned Special use north of McLeod Street	Rural	14	M
	Rural lots North of McLeod Street	Rural	90	M
E2	McLeod Street	Rural	55	M
	Rural lots landward of McLeod Street	Road	75	M
E3	Rural lots south of McLeod Street	Rural	55	M

Table 4-9: Asset Sensitivity Rating (Consequence) INUNDATION for Exmouth Townsite

MU	Segment	Initial Wetting (m AHD)	Asset Description	Consequence Rating
1	A	2.0	Low lying floodplain through northern breakout	M
		3.4	Golf Course	M
		4.8	Exmouth Men's Shed	L
		4.8	West section of Willesdorf Road	M
		5.8	Exmouth oval	M
		5.6	Exmouth Community Garden	L
		3.4	Wastewater Treatment Facility	H
		4.4	RAC Exmouth Cape Holiday Park	M
		3.0	Truscott Crescent 700m north of Warne Street	L
	B	3.2	Lots zoned for Tourism on Truscott Crescent	L
2	C	3.2	Town Beach foreshore area	H
		4.8	Yacht Club buildings	M
		4.6	Ningaloo Resort overtopped. (Front row of villas)	M
		3.6	Murat Road near Gnulli Court	L
		4.0	Madaffari Drive over spillway	L
3	Harbour	3.6	Exmouth Game Fishing Club Sports	M
		1.5	Exmouth Harbour walling (tidal inundation)	M
		1.6	Exmouth Harbour boat ramp	M
		2.5	Majority of Exmouth Harbour surrounds	M
		5.25	Filled lot levels adjacent to Exmouth Marina	M
4	D	3.6	Residential lots adjacent to Crevalle Way	M
	E1	5.6	Murat Road south of McLeod Street	L
		2.6	Rural lots south of McLeod Street through dunes	M

Figure 4-4: 4WD Access on Town Beach, North of Warne Street Carpark

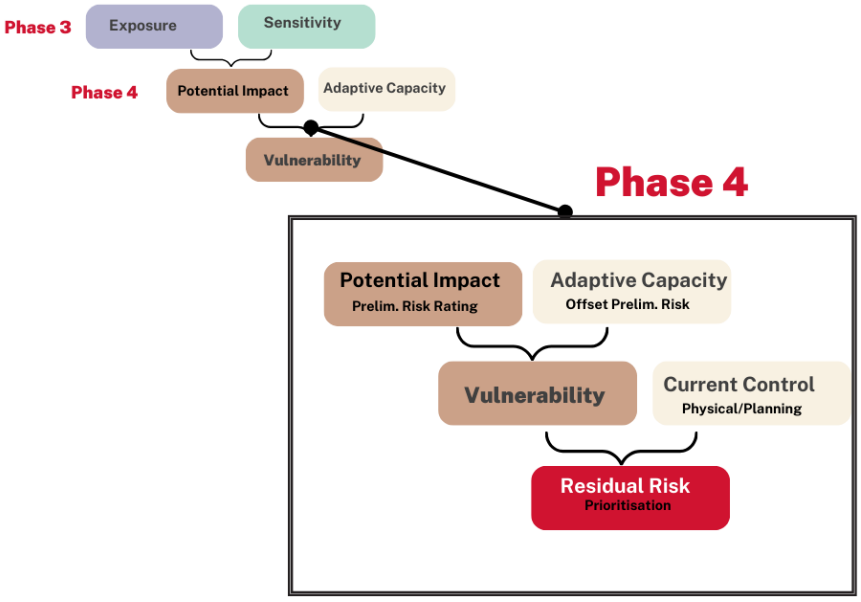
5. STEP 4: RISK ASSESSMENT & PRIORITIES

Step 4: Risk Evaluation

- Risk rating by asset
- Adaptive capacity by asset
- Vulnerability by asset

5.1. Overview

Phase 4 established a risk rating per asset (likelihood + consequence) to determine potential impacts of erosion and inundation. An evaluation of adaptive capacity then allowed determination of overall asset vulnerability, which was examined in the context of existing controls as a basis for elucidating residual risk. Risk ratings per management unit were evaluated to prioritise assets and discrete areas requiring further treatment. Overall, only assets deemed to have 'high' or 'extreme' risk to erosion or inundation hazard were considered for further analysis in Phase 5.



5.2. Risk Ratings & Matrices

Risk ratings for each asset were generated by combining likelihood (exposure) and consequence (sensitivity) scales (Table 5-1). These matrices defined four levels of risk:

Table 5-1: Risk Rating Matrix (Initial)

		Exposure			
		L	M	H	E
Sensitivity	L	Negligible	Low	Medium	High
	M	Low	Medium	High	Extreme
	H	Medium	High	Extreme	Extreme

The **adaptive capacity** of each asset is its capacity to be modified in a way that makes it better equipped to deal with negative impacts arising from coastal hazards effects. However, adaptive capacity does not consider planned risk management measures. It identifies an asset's ability to reduce intolerable risk arising from coastal hazards. The adaptive capacity scale takes into consideration design and function or form of the asset and was assessed as high, medium or low. In general terms, adaptive capacity was rated by hazard type:

- Inundation adaptive capacity was low for residential buildings, medium for roads, and high for landscaped foreshore assets.
- Erosion adaptive capacity low for residential buildings, medium for roads or landscaped assets, and high for the Men's Shed (relocatable) or the floodplain area (naturally dynamic).

Table 5-2: Adaptive Capacity Rating Scales

Adaptive Capacity	Description	Rating
High	Good adaptive capacity. Functionality restored easily. Adaptive systems restored at a relatively low cost or naturally over time.	3
Medium	Difficult but possible to restore functionality through repair and redesign.	2
Low	Little or no adaptive capacity. Potential impact would destroy all functionality. Redesign required	1

The adaptive capacity rating for each asset was subsequently considered in conjunction with its preliminary risk rating (potential impact) for erosion and inundation hazard to establish an overall asset vulnerability* rating (Table 5-3).

Table 5-3: Vulnerability Rating Derivation

		Adaptive Capacity		
		L	**M**	**H**
Risk Rating	**L**	Medium	Low	Low
	M	High	Medium	Low
	H	Extreme	High	Medium
	E	Extreme	Extreme	High

* Note the term "vulnerability" is used here specifically for consistency with the CHRMAP Guidelines [2]. However, it is noted that inclusion of sensitivity and adaptive capacity obscures physical risk to the asset – for example, existing access at Friedman Way foreshore would be lost with a small amount of coastal erosion. The high adaptive capacity for this asset implies that the foreshore access can be easily rebuilt, although it should be acknowledged that this will need to be progressively moved landward with erosion.

Table 5-4: Asset Vulnerability Rating EROSION for Exmouth Townsite

Management Unit	Segment	Asset	Category	Min. Dist HSD (m)	Vulnerability Rating – EROSION 0m 2025	55m 2050	80m 2070	160m 2125
MU1	A	Reserve fronting golf course	Foreshore Reserve	25	L	H	H	H
		Exmouth golf course - lot with club buildings	Recreation	130	M	M	M	E
		Two undeveloped lots on Truscott Crescent, zoned Special Use	Undeveloped Lot	24	L	E	E	E
	B	Two undeveloped lots on Truscott Crescent, zoned Tourism	Undeveloped Lot	86	L	L	L	E
MU2	C	Warne Street foreshore access and carpark	Foreshore	0	H	H	H	H
		Town Beach foreshore	Foreshore	0	E	E	E	E
		Warne Street to Friedman Way residential area	Residential	66	L	L	M	E
		Friedman Way foreshore access	Foreshore	0	H	H	H	H
		Exmouth Yacht Club	Recreation	0	E	E	E	E
		Madaffari Drive	Transport	107	L	L	L	H
		Madaffari Drive canal lots	Residential	125	L	L	L	E
		Mantarays Ningaloo Beach Resort	Commercial	20	H	E	E	E
MU4	D	Neale Cove	Transport	73	L	L	M	E
		Maritime Facility on Neale Cove	Marine	92	L	L	L	E
		Crevalle Way foreshore	Foreshore	54	L	L	H	H
		Crevalle Way	Transport	74	L	L	L	H
		Crevalle Way residential area	Residential	90	L	L	L	E
	E1	Lot zoned Special use north of McLeod Street	Reserve	14	M	E	E	E
		Rural lots North of McLeod Street	Undeveloped Lot	90	L	L	L	E
	E2	McLeod Street	Transport	55	L	L	E	E
		Rual lots landward of McLeod Street	Undeveloped Lot	75	L	L	M	E
	E3	Rural lots south of McLeod Street	Undeveloped Lot	55	L	L	E	E

Table 5-5: Asset Vulnerability Ratings INUNDATION for Exmouth Townsite

MU	Segment	Initial Wetting (m AHD)	Asset Inundation Description	Vulnerability Rating – INUNDATION 2025 0m SLR	2050 0.22m SLR	2070 0.42m SLR	2125 1m SLR
1	A	2	Low lying floodplain through northern breakout	H	H	H	H
		3.4	50% of golf course inundation	H	H	H	E
		4.8	Exmouth Mens Shed	L	L	L	L
		4.8	West section of Willesdorf Road	L	L	L	M
		5.8	Exmouth oval	L	L	L	L
		5.6	Exmouth Community Garden	L	L	L	L
		3.4	Wastewater Treatment Facility lot	H	H	H	E
		4.4	Eastern margin of RAC Exmouth Cape Holiday Park **	M	H	H	H
		3	Crosses Truscott Crescent 700m north of Warne Street	L	L	M	M
	B	3.2	Small northeast parcel of lots zoned for Tourism on Truscott Crescent **	M	M	M	H
2	C	3.2	Town Beach foreshore area	H	H	H	E
		4.8	Yacht Club buildings	M	M	M	H
		4.6	Walling fronting Ningaloo Resort overtopped. Front row of villas **	M	M	H	H
		3.6	Crosses Murat Road near Gnulli Court	L	L	L	M
		4	Madaffari Drive over spillway ** based on site assessment, constructed after 2006 lidar	L	L	L	L
3	Harbour	3.6	Exmouth Game Fishing Club Sports**	H	H	H	H
		1.5	Exmouth Harbour walling locally overtopped	E	E	E	E
		1.6	Exmouth Harbour boat ramp & low-lying walling locally overtopped	H	E	E	E
		2.5	Majority of Exmouth Harbour surrounds	E	E	E	E
		5.25	Filled canal lot levels adjacent to Exmouth Marina	L	M	M	M
4	D	3.6	Residential lots adjacent to Crevalle Way **	H	H	H	E
	E1	5.6	Crosses Murat Road south of McLeod Street	L	L	L	L
		2.6	Rural lots south of McLeod Street through dune breakouts	H	H	H	E

**Level indicates when inundation exposure occurs. This will only affect a part of the assets.

Vulnerability that would be deemed acceptable, tolerable, or intolerable was defined, where intolerable vulnerability requires risk management measures as a priority. Tolerance levels were set in consultation with Shire representatives and with reference to information gathered through the consultation process with community and stakeholders.

Vulnerability rated 'low' or 'medium' under present conditions can be viewed as acceptable, requiring no additional risk management measures other than monitoring. However, if the risk is identified as currently being high or extreme, or can reach these levels before the end of the CHRMAP planning timeframes, these risks require more short-term or immediate risk management measures to reduce the risk back to tolerable or acceptable levels. The tolerance level adopted for this study was used to identify which risk, locations and assets require risk management measures as a priority.

Table 5-6: Vulnerability Scale

Vuln. level	Description and level of Action required	Tolerance
E	Asset has minimal ability to cope with the impacts of coastal hazards without additional support. Adaptation will need to be considered as a priority	INTOLERABLE
H	Asset has limited ability to cope with the impacts of coastal hazards. Immediate to short-term adaptation is likely to be required to reduce risk to acceptable levels.	TOLERABLE
M	Asset has some ability to cope with the impacts of coastal hazards. However short to medium term actions are likely to be required to reduce risk to acceptable levels.	TOLERABLE/ ACCEPTABLE
L	Asset has high resilience; it can cope with the impacts of coastal hazards without additional support. No immediate action required	ACCEPTABLE

5.3. Existing Controls

The Risk Evaluation carried out in Phase 4 was used to prioritise risk management measures for the study area. Assets with vulnerability rated high or extreme were examined in greater detail. The risk evaluation considers if there are already risk management measures in place or **existing controls** that can be taken into consideration to reduce the risk rating determined through the vulnerability assessment (Section 5.2).

Existing controls and risk management measures already in place in the Shire of Exmouth study area have the potential to reduce the consequences and/or likelihood of coastal hazard. Controls can be in physical, natural, or planning/management controls (Table 5-7). A consideration of the influence of the existing controls on mitigating risk was determined to produce a final rating of residual risk for assets in each MU.

The process adopted was to take the high or extreme erosion and inundation vulnerability ratings for each asset and adjust these ratings in the context of the effectiveness of existing controls over study timeframes: 2025, 2050, 2070 or 2125. A rating of '0' denoted no reduction in risk offered by the existing control while a rating of '3' indicated a wholly effective risk mitigation, up to the limit of evaluation. Control ratings were subtracted from vulnerability ratings to get a rating of residual risk for each timeframe:

0 = no residual risk
1 = low residual risk
2 = medium residual risk
3= high residual risk
4 = extreme residual risk

Controls that influence inundation hazard (MU1) are primarily land use planning, insurance and drainage with some reduction in risk also provided by dunes to the North (MU1) and the South (MU4) and the breakwater at the harbour and the canal walls within Exmouth Marina (MU3). In terms of erosion hazard, dunes provide natural control in MU1 and MU4 while structural control is dominant in MU2 and MU3. Setbacks for existing development are not classed as effective controls, as the setback has already been incorporated into the evaluation of erosion likelihood. Where an area is presently undeveloped, the capacity to provide additional erosion buffer through setback on the lots has been treated as partial control, ineffective to somewhat effective (0-2) based on lot width.

Table 5-7: Existing Controls to Mitigate Erosion (E) or Inundation (I)

Control	Details	Example	Application
Physical	Shoreline protection structures or seawalls	Breakwater Canal Walls Revetement Drainage and spillways Sand management	E, I E, I E I E
Natural	Shoreline topography features	Dunes Rock may be present, but the elevation and extent is unknown.	E, I E
Planning	Controls on land use and management	Setback* Flood management: • Land-use control • Elevation • whether in or out of the floodplain area) Insurance Finished Floor Levels	E, I I I I I E, I I

Overall Risk Rating is subsequently developed by applying consequences (Table 4-8 and Table 4-9) to Residual Risk ratings.

Table 5-8: Residual & Overall Risk Ratings EROSION for Exmouth Townsite

Management Unit	Segment	Asset	Residual Risk Rating – EROSION				Overall Risk Rating – EROSION			
			0m 2025	55m 2050	80m 2070	160m 2125	0m 2025	55m 2050	80m 2070	160m 2125
MU1	A	Reserve fronting golf course	L	M	M	M	L	M	M	M
		Exmouth golf course - lot with club buildings	L	L	L	M	L	L	L	M
		Two undeveloped lots on Truscott Crescent, zoned Special Use	L	H	H	H	L	H	H	H
	B	Two undeveloped lots on Truscott Crescent, zoned Tourism	L	L	L	M	L	L	L	M
MU2	C	Warne Street foreshore access and carpark	L	L	M	M	L	L	M	M
		Town Beach foreshore	L	M	H	H	M	E	E	E
		Warne Street to Friedman Way residential area	L	L	L	M	L	L	L	L
		Friedman Way foreshore access	M	M	M	M	M	M	M	M
		Exmouth Yacht Club	L	H	E	E	L	H	E	E
		Madaffari Drive	L	L	L	L	L	L	L	L
		Madaffari Drive canal lots	L	L	L	L	L	L	L	L
		Mantarays Ningaloo Beach Resort	L	L	M	H	L	L	M	H
MU4	D	Neale Cove	L	L	L	H	L	L	L	H
		Maritime Facility on Neale Cove	L	L	L	H	L	L	L	L
		Crevalle Way foreshore	L	L	M	M	L	L	M	M
		Crevalle Way	L	L	L	M	L	L	L	L
		Crevalle Way residential area	L	L	L	H	L	L	L	L
	E1	Lot zoned Special use north of McLeod Street	L	M	H	H	L	M	H	H
		Rural lots North of McLeod Street	L	L	L	H	L	L	L	H
	E2	McLeod Street	L	L	H	H	L	L	H	H
		Rual lots landward of McLeod Street	L	L	L	H	L	L	L	H
	E3	Rural lots south of McLeod Street	L	L	H	H	L	L	H	H

Table 5-9: Asset Vulnerability Ratings INUNDATION for Exmouth Townsite

MU	Segment	Initial Wetting m AHD	Asset Inundation Description	Residual Risk Rating – INUNDATION 2025 0m	2050 +0.2m	2070 +0.4m	2125 +1.0m	Overall Risk Rating – INUNDATION 2025 0m	2050 +0.2m	2070 +0.4m	2125 +1.0m
MU1	A	2	Low lying floodplain through northern breakout	M	H	H	H	M	H	H	H
		3.4	50% of golf course inundation	L	L	M	E	L	L	M	E
		4.8	Exmouth Mens Shed	L	L	L	L	L	L	L	L
		4.8	West section of Willesdorf Road	L	L	L	M	L	L	L	M
		5.8	Exmouth oval	L	L	L	L	L	L	L	L
		5.6	Exmouth Community Garden	L	L	L	L	L	L	L	L
		3.4	Wastewater Treatment Facility lot	L	L	M	E	H	H	E	E
		4.4	Eastern margin of RAC Exmouth Cape Holiday Park **	L	L	M	H	L	L	M	H
		3	Crosses Truscott Crescent 700m north of Warne Street	L	L	L	M	L	L	L	L
	B	3.2	Small northeast parcel of lots zoned for Tourism on Truscott Cres **	L	M	M	H	L	L	L	L
MU2	C	3.2	Town Beach foreshore area	L	M	H	E	H	E	E	E
		4.8	Yacht Club buildings	L	L	M	H	L	L	M	H
		4.6	Walling fronting Ningaloo Resort overtopped. Front row of villas **	L	L	M	H	L	L	M	H
		3.6	Crosses Murat Road near Gnulli Court	L	L	L	M	L	L	L	L
		4	Madaffari Drive over spillway ** based on site assessment	L	L	L	L	L	L	L	L
MU3	Harbour	3.6	Exmouth Game Fishing Club Sports**	H	H	H	H	H	H	H	H
		1.5	Exmouth Harbour walling locally overtopped	L	M	H	E	L	M	H	E
		1.6	Exmouth Harbour boat ramp & low-lying walling locally overtopped	H	E	E	E	H	E	E	E
		2.5	Majority of Exmouth Harbour surrounds	M	H	E	E	M	H	E	E
		5.25	Filled canal lot levels adjacent to Exmouth Marina	L	M	M	M	L	M	M	M
MU4	D	3.6	Residential lots adjacent to Crevalle Way **	H	H	H	E	H	H	H	E
	E1	5.6	Crosses Murat Road south of McLeod Street	L	L	L	L	L	L	L	L
		2.6	Rural lots south of McLeod Street through dune breakouts	L	L	M	E	L	L	M	E

** Level of initial wetting only affects a small part of the asset

Residual and overall risk ratings display progressively increasing risk to assets over the forecast scenarios, corresponding to increasing sea level rise associated coastal recession. In the present day, the only assets with overall erosion risk above low (L) are Town Beach Foreshore and Friedman Way beach access, both in MU2. Present-day inundation risk is more active, with:

- MU1 has high (H) overall inundation risk for the wastewater treatment facility and medium (M) for the floodplain area.
- In MU2, Town Beach access has high (H) overall inundation risk.
- For MU3, the game fishing club and boat ramp areas have high (H) overall risk and the general hardstand around the harbour has medium (M) overall risk.
- Within MU4, residential lots next to Crevalle Way have medium (M) overall inundation risk.

For the most extreme scenario, represented by 2125, potential coastal risk increases significantly. Overall inundation risk rations for each management unit are:

- MU1 has high (H) erosion risk rating for Truscott Ave Special use lots and medium (M) rating for all other coastal assets.
- MU2 has extreme (E) overall erosion risk rating for Town Beach foreshore and the Yacht Club, with high (H) for Mantarays and medium (M) for Warne Street and Friedman Way access points.
- MU4 has high (H) for Neale Cove foreshore, and all coastal assets adjacent to McLeod Street. Crevalle Way foreshore has medium (M) overall erosion risk rating.

Equivalently, there is significant increase of overall inundation risk ratings:

- MU1 has extreme (E) overall inundation risk rating for the golf course and wastewater treatment plant. The floodplain and RAC caravan park have high (H) overall inundation risk and there is medium (M) overall inundation risk for part of Willesdorf Road.
- MU2 has extreme (E) overall inundation risk for Town Beach, with high (H) risk for the Yacht Club and Mantarays.
- MU3 has extreme (E) overall inundation risk for all assets within the harbour except the game fishing club, which has high (H) risk. There is medium (M) overall inundation risk for the lots adjacent to the canals.
- MU4 has extreme (E) overall inundation risk for lots adjacent to Crevalle Way and south of McLeod Street.

Risk has been characterized by ratings and time frames:

- Present-day risk management or mitigation is considered appropriate for assets with overall risk rating of medium (M) or above.
- Projected risk has been identified to require management where risk rating of high (H) or above occurs from 2050. These cases are considered to require present-day adaptive management (i.e. mitigation works need not be constructed, but budgeting for mitigation should commence, and monitoring against a trigger for action).
- Emerging risk has been identified based on risk rating of high (H) or above from 2070. This does not presently require adaptive management, but the risk is expected to develop over the next 50-100 years and needs to be incorporated into planning.
- Possible risk has been identified based on risk rating of high (H) or above from 2125. This represents extreme scenarios of coastal change, and therefore requires consideration for planning, but may not be realized within the next 100 years.

Table 5-10: Assets deemed to require Hazard Management

	Erosion Hazard	Inundation Hazard
Present-day Risk *Requires mitigation now*	MU2 Town Beach Foreshore MU4 Friedman Way Foreshore Access	MU1 Floodplain area MU1 Wastewater Treatment Plant MU2 Town Beach Foreshore MU3 Exmouth Game Fishing Club MU3 Exmouth Harbour MU4 Lots Adjacent to Crevalle Way
Projected Risk *Requires adaptation plan now*	MU1 Truscott Special Use Lots MU2 Exmouth Yacht Club MU4 McLeod St Special Use Lots	
Emerging Risk *Integrate into planning*	MU4 McLeod Street MU4 Rural Lots South of McLeod St	
Possible Risk *Consider long-term management*	MU2 Mantarays MU3 Neale Cove Foreshore MU4 Rural Lots N & W of McLeod St	MU1 Golf Course MU1 RAC Holiday Park MU2 Exmouth Yacht Club MU2 Mantarays MU4 Lots S of McLeod St

Overall EROSION risk that would otherwise require management is mitigated by dunes for the Golf Course. Erosion risk is mitigated or deferred by protective structures for Warne Street, Town Beach, Exmouth Yacht Club and Mantarays. Future maintenance and upgrading will be required to continue this level of hazard mitigation.

Overall INUNDATION risk that would otherwise require management is deferred by dunes for the Golf Course, RAC Holiday Park and rural lots south of McLeod Street. Protective structures defer inundation hazard management for Exmouth Yacht Club, Mantarays and Exmouth Boat Harbour. Future maintenance and upgrading will be required to continue this level of hazard mitigation.

Adaptation pathways to treat hazards deemed to require hazard management (Table 5-10) are discussed per Management Unit (MU) in Section 6. Direction setting guidance is aligned to the stakeholder adaptation priorities identified for each MU, which were driven by community led CHRMAP success criteria.

6. STEP 5: ADAPTATION PLANNING

Step 5: Adaptation Planning

- Adaptation hierarchy
- Options analysis for Town Beach
- MCA / CBA
- Adaptation Timeframes & pathways

6.1. Overview

Successful risk management and adaptation planning requires identification and assessment of options to determine viable strategies. Options should mitigate risk to an acceptable level whilst maintaining values important to stakeholders. The risk prioritisation undertaken through this CHRMAP has identified key assets and areas susceptible to potential impacts of coastal erosion and inundation, both now and into the future.

Overall, Exmouth's large and wide dune system gives substantial protection from coastal inundation and provides a large buffer to storm erosion and coastal recession. Present-day hazards are largely associated with coastal development in front of the dune system, including **Town Beach foreshore** and **Exmouth Boat Harbour**, both of which have protective works. However, in the longer-term, erosion and inundation pressures are expected to increase, requiring a focused risk treatment effort.

This Section outlines Step 5 of the CHRMAP process, which undertakes an **Adaptation Options Analysis** to identify preferred strategies for 'risk treatment'. This prioritises options for coastal hazard mitigation and is aligned to Succes Criteria determined by the Shire and its' stakeholders.

A 'report card' for each MU has been produced to guide adaptation decision making for the Shire with summaries presented and extended discussion in associated Appendices.

Adaptive Pathways are presented for MU1, MU3 and MU4, where characteristics of assets for each management unit determine limited options for hazard mitigation.

A more detailed **Adaptation Options Analysis** is presented for Town Beach to explore the viability of alternative management pathways. This analysis included:

- Multi Criteria Analysis – to establish the suitability of potential adaptation options to treat the identified risks.
- Cost Benefit Analysis – to provide insight into economic utility of suitable options.
- Project team Council briefing – to gain input on Shire preferences and delineate decision making pathways moving forward.

6.2. Adaptation Planning Overview

Adaptation planning fosters preparedness to manage risks and impacts of changes to our coast, by planning for the most appropriate decisions and options to implement over time. It requires a decision-making framework that enables the right decision to be made at the right time, in the context of identified erosion and inundation hazard, and reflecting the community-defined social, environmental, and economic value of the coast.

In this respect, 'good' practice in adaptation planning requires flexibility – the ability to make appropriate decisions on available options to meet the changing needs of communities and coastal areas through time as risks to assets change from tolerable to intolerable. The CHRMAP Guidelines [2] outline over-arching strategies that may be employed in adaptation planning, following a hierarchy of avoid, retreat, accommodate or protect (**Figure 6-1**).

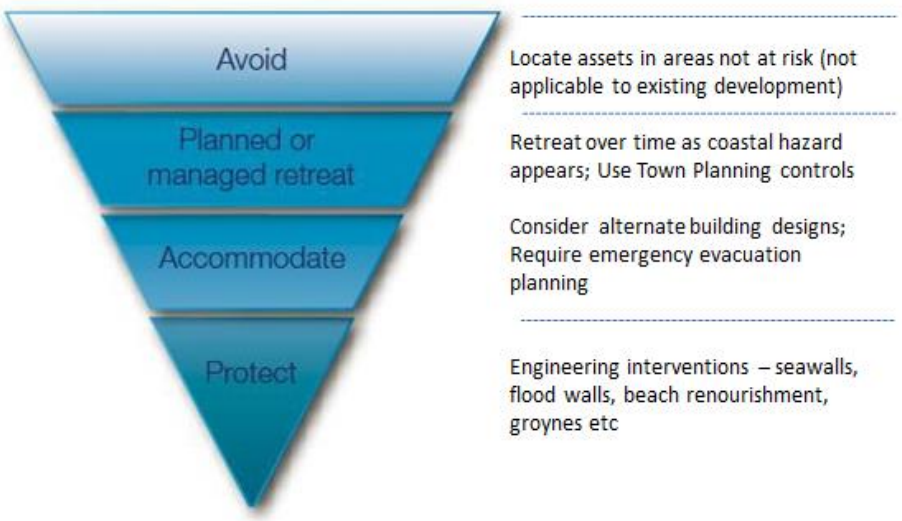


Figure 6-1: Adaptation Hierarchy for Mitigating Hazards

Applicability of any mitigation is determined by the nature of asset being considered, the level of risk, and the agreed adaptation objectives or priorities established by the community and stakeholders in that coastal area.

- **Avoid:** *new* development in areas at risk.
- **Planned or Managed Retreat:** of *existing* development in the face of intolerable risk.
- **Accommodate:** through design or management measures to limit impacts of hazard exposure.
- **Protect:** assets from exposure through structural interventions.

Table 6-1: Adaptation Strategies and Associated Options
Adapted from WAPC (2019) CHRMAP Guidelines [2]

Strategy	Options
Avoid	Development planning approvals take into consideration: • Coastal Erosion setbacks. • Inundation extents. Changes to the Local Planning framework: • Local Planning Strategy. • Local Planning Scheme. • Local Planning Policy. • Development Control.
Managed Retreat	Retreat over time as coastal hazard appears. Considerations could include: • Development control on further development. • Consideration of time-based structures (e.g. limited life span). • Notifications on title to prevent new/replacement of existing structures on land.
Accommodate	• Consider alternate building designs. • Require emergency evacuation planning. • Set minimum floor levels based on structure. • Locate development on least hazardous portion of site. • Use building materials that are flood resistant and/or designed to withstand forces. • Modify building design to allow for future relocation.
Protect	**Beach Nourishment** Place sediment to offset beach erosion. Requires integration with primary and secondary dunes. Typically used on high use beaches or foreshore reserves where retreat is not viable. **Benefit:** • Maintains beach amenity. • Mitigates further erosion. **Limitation:** • Requires sediment source. • Temporary or short-term measure, which can smother adjacent areas. • Relative high cost and ongoing expense.
	Groynes **Benefit:** • Retain beach access and function. • Reduces sensitivity of sand transport to fluctuations of wave direction. **Limitation:** • Can enhance coastal volatility and may create an area of local erosion pressure. • Transfer erosion pressure.
	Seawall Often an expensive option. Likely to lead to reduction or loss of usable sandy beach. Likely more tolerable than other protection options because familiar (already being used).
	Artificial reef Difficult to design submerged structures to work effectively, and costly to build and maintain.
	Breakwaters: Social concerns about ocean views. Concerns could be offset by designing shore-attached structures.

For Exmouth townsite, applicability of these adaptation measures has been considered at a strategic level to provide recommendations for adaptative action across each management unit (Table 6-2). This is explored further in 'Report Cards' for each Management Unit (MU).

Table 6-2: Strategies for adaptive action across Exmouth Townsite MUs
"X" indicates strategy generally considered viable, "x" indicates there may be some constraints to implementation, and blank indicates the strategy is not considered viable.

Management Unit	Avoid	Retreat	Accomm-odate	Protect	Preferred Measure
MU 1: Northern Flood Basin	X	x	X		Avoid Accommodate
MU 2: Town Beach		X		X	Protect Retreat
MU 3: Exmouth Boat Harbour			x	X	Protect
MU 4: South of Harbour	x	X	X		Accommodate Retreat

Discrete options associated with each of these adaptation strategies are explored for prioritised risks identified through CHRMAP Step 4 (Section 5, Table 5-10). Asset level adaptation pathways are aligned to adaptation objectives and success criteria. In areas where existing assets have been deemed to require hazard management, a decision to retreat, accommodate or protect depends on:

- Consequences of taking no action.
- Feasibility and social, environmental or economic costs associated with actions (e.g. relocation) or structural interventions (to accommodate or protect) compared with the residual value and life of the asset.
- Disruption and costs involved with actions.

6.3. MU1: Northern Flood Basin

The Northern Flood Basin (MU1) has limited built form, with a significant, wide coastal dune barrier providing protection against erosion and inundation (Table 6-3, Figure 6-2, Figure 6-3b). Immediate needs for hazard management or adaptation relate to inundation risk to the floodplain area (including the wastewater treatment plant) and erosion risk to Truscott Crescent Special Use Lots, which have a narrow coastal setback. In the long term, there is potential for coastal inundation hazard to affect the Golf Course and RAC Holiday Park.

Table 6-3: Assets deemed to require Hazard Management in MU1

	Erosion Hazard	Inundation Hazard
Present-day Risk *Requires mitigation now*		Floodplain area Wastewater Treatment Plant
Projected Risk *Requires adaptation plan now*	Truscott Cres Special Use Lots	
Emerging Risk *Integrate into planning*		
Possible Risk *Consider long-term management*		Golf Course RAC Holiday Park

A key factor for this area is the ability to develop land zoned for tourism and the overall ability of the flood basin to play an effective role for runoff flood risk mitigation into the future. Maximising longer-term dune protection from inundation and erosion is considered to require dune management, with early action being most cost-effective.

6.3.1. Coastal Risk Management for Northern Flood Basin (MU1)

Coastal inundation risk management for the Northern Flood Basin is intertwined with runoff flood risk management, with extreme runoff levels being above coastal inundation levels for general flood avoidance criteria (around 1% AEP), even with +1.0m sea level rise. Consequently, ongoing review and update of Exmouth Floodplain Management Strategy [13] is expected to provide guidelines for development within the floodplain (Special Control Area SCA 5), including identification of required finished floor levels and evacuation planning. One important distinction between coastal inundation and runoff flooding hazards is that insurance will not cover 'Actions of the Sea', unless parametric insurance is sought.

Maintenance of the northern breakout (Figure 6-3a) as a flow outlet, and longer-term potential for modification of Madaffari Drive spillway should be incorporated in the updated floodplain management strategy, with coastal change considered as a management issue. Preliminary flood risk evaluation for the Coastal Hazard Assessment (Appendix B) suggests the northern flood basin has a large enough volume that runoff flooding risk is likely to remain tolerable unless the breakout closes over substantially. The breakout is located within land managed by the Department of Defence [14] (refer to Local Planning Policy 6).

With sea level rise, increased tidal inflow will convert a portion of the floodplain into a tidal basin. This will kill existing vegetation and convert it to swamp habitat, gradually increasing in area. This change was considered tolerable by the community and stakeholders.

The Wastewater Treatment Plant has previously been identified as a constraint to townsite development, and subject to runoff flood hazard. Water Corporation have advised that relocation of the plant is planned within 0-5 years, which will address the longer-term inundation risk.

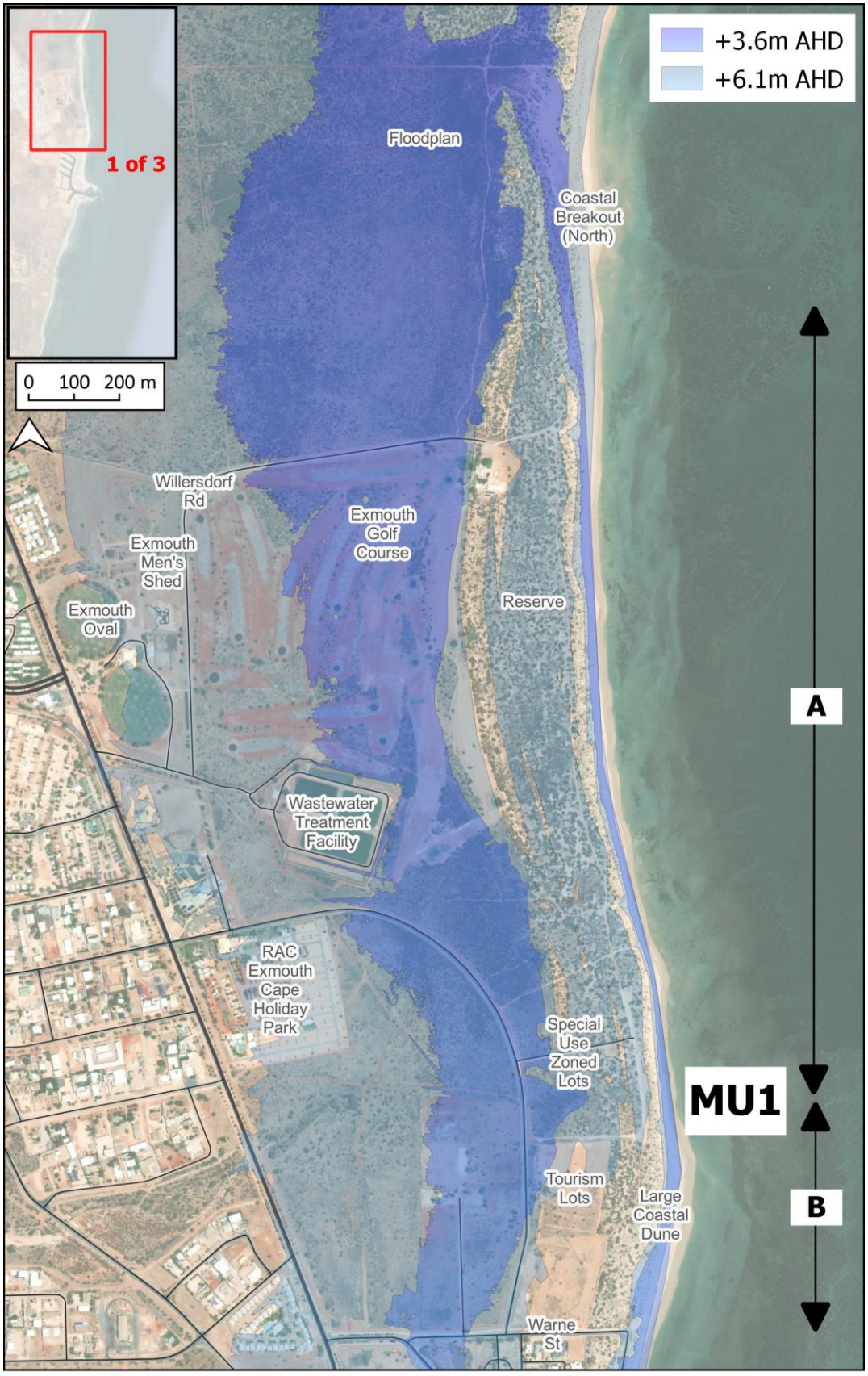


Figure 6-2: MU1 Northern Flood Basin, including segments A & B
Shaded areas show best estimate of 500-yr ARI inundation (darker) & upper limit estimate +1m SLR (lighter).

On Truscott Crescent Special Use Lots, the existing setback to the lot boundary is 24m. This is considered adequate in the present-day to provide protection against acute storm response but provides negligible tolerance to coastal recession. Adoption of the avoid-retreat-accommodate-protect hierarchy suggests these lots should be subject to time-limited use (e.g. 21-year lease), with a local monitoring and adaptation plan developed prior to building. Longer leasehold could be considered based on internal building footprints within the lot boundary, or an appropriate plan for relocation of assets when hazard is deemed intolerable.

a)

b)

Figure 6-3: MU1 a) Northern Breakout at north end, and b) Extensive Coastal Dune

MU 1: NORTHERN FLOOD PLAIN Report Card	
MU1: Segment A&B	**Reserve fronting Golf Course to Truscott Crescent**
Use and 'value'	Tourist Zoned lots; Golf Course; Access and utility of foreshore Land reserved for Department of Defence north of golf course includes northern breakout.
Adaptation Objective:	Focus on inundation management, practices to protect existing dunes and **facilitate opening and development of new land.**
Hazard 	**Erosion: Segment A** is subject to relatively low erosion hazard, with large reserves providing setback for future development. Although the 2125 erosion allowance encroaches on golf club lot boundaries, existing building are positioned futher landward. Development on vacant lots presently zoned for Tourism in **Segment B** requires consideration of erosion hazard for the seaward portion of lots by 2070. **Inundation:** Present day events above 10yr ARI causes inundation of flood basin through the northern breakout. Elsewhere, inundation is a minor present-day hazard, with hazard increasing with sea level rise at some locations, eventually require hazard recognition and management.
Assets 	Golf course; Caravan Park; Ovals; Wastewater treatment plant; Exmouth Escape; Tourism zoned lots
Damage 	• Potential salinisation of northern flood basin with vegetation change (0.4m SLR) • Golf course – tolerable damage to low lying area requires consideration (0.4m SLR) • Access to tourism lots zoned at Truscott Cresent – implications for lot development and land value (1m SLR) • Wastewater Treatment Plant – the face of the protective bunds can be reached by a severe inundation event under 0.2m SLR. Overtopping or damage to the bunds requires higher inundation.
Mitigation 	• Coastal flooding poses a limited threat, mostly within the area defined as floodplain risk (Special Control Area SCA 5) • This implies adaptation 'trade-offs' associated with mitigation of runoff flooding versus limiting coastal inundation are likely to be more flexible than previously considered. That is, drainage of streamflow flooding is needed for health / land-use reasons, rather than flood risk to assets or safety.

Summary:

Exposure to inundation hazard risk is generally mild overall with hazard for built-form infrastructure for the most part minimal. Therefore, the focus moving forward will generally be on inundation management practices to facilitate opening and development of new land.

- Stream flooding Special Control Area SCA5 covers most of potential area of coastal inundation hazard.
- 'Adaptation' largely involves incorporation of coastal inundation into existing management plans.
- Following suggestion of DWER, coordinate review and update of Exmouth hydrological assessment
- Wastewater treatment plant bunds are exposed to infrequent flooding from runoff and coastal inundation. It is understood there are plans to relocate the WTP. However, longer-term use of the WTP increases inundation frequency with SLR may require bund reconfiguration to limit scour & undermining risk.
- Dunes provide significant erosion buffer and inundation barrier – dune management recommended as cost-effective approach to preserve the protection provided.
- Undertake geophysical & geotechnical assessment of rock along dunes (lower priority than narrow dunes).
- Undertake a topographic survey and assess road structure adjacent to Exmouth Marina Village northern spillway. This should be used to evaluate the viability of installing pipes or culverts at a lower level under the road to the northern spillway – reducing reliance on the northern breakout for drainage.

AVOID and **ACCOMODATE** are preferred strategies to deliver adaptation objective of retaining land utility and opening new land for development.

Figure 6-4: Madaffari Drive Spillway in action

6.3.2. Adaptive Pathways for Northern Flood Basin (MU1)

Actions to mitigate erosion and inundation risk are limited at an asset level:

- Water Corporation plans to relocate the Wastewater Treatment Plant are underway. These should be supported.
- Most built assets are within Special Control Area 5 (Floodplain) in the local planning scheme LPS4, with greater recurrence of runoff flooding than coastal inundation. Consideration of coastal inundation in revision of the floodplain management strategy will facilitate effective management of inundation risk.
- Salinisation of the floodplain has been identified as a tolerable impact by the community and stakeholders.
- Due to absence of development on Truscott Crescent Special Use lots, the limited available erosion buffer can be effectively managed through time-limited use (e.g. 21 year lease). Guidance regarding requirements for conditional approval or time limited approval should be established through a coastal SCA, consistent with WAPC CHRMAP Guidelines [2] Appendix 4.

Coastal inundation management is strongly related to runoff inundation management, with the northern flood basin providing a critical storage area for floodwaters, reducing hazard to the town. Review and refinement of the floodplain management strategy is recommended, clearly defining floodplain development protocols, with acknowledgement of the secondary hazard of coastal inundation, and consideration of coastal process dynamics impact on hydraulic capacity of the northern breakout. Potential management options include:

1. Maintaining the northern breakout to ensure a target hydraulic capacity, that will reduce the extent of runoff flooding (i.e. potentially allowing land development).
2. Maintaining the northern breakout with minimal hydraulic capacity, so that it will open during flood events.
3. Enhancing alternative flow paths from the northern floodplain to Exmouth Gulf, e.g. putting lower level culverts on Madaffari Drive spillway. This also may require modification of Murat Road reserve, to enhance flow paths leading to the spillway.
4. Determining flood extent if the northern breakout were to close over due to dune instability. This potentially increases runoff flooding hazard across the floodplain.

These options are all dependent on floodplain management, with coastal inundation a secondary consideration. Any management of the northern breakout is contingent on its role as part of land reserved for the Department of Defence.

Existing dunes provide a significant erosion buffer and inundation barrier, except at the northern breakout. Pedestrian and vehicle traffic have denuded areas of dune and created areas of mobile dune face, which is subject to sand drift landward and along shore (northward). Management options include:

1. Allowing the dunes to continue to degrade – this will accelerate erosion and reduce coastal protection provided by the dunes.
2. Undertaking low-cost measures to limit dune impacts (e.g. signage, controlled access)
3. Undertake moderate-cost measures to preserve dune protection function (e.g. replanting, drift fencing).

Given the substantial dune system along most of MU1, use of low-cost measures is considered the most cost-effective level of management east of the golf course, potentially with moderate-cost measures adjacent to the tourist zone and special use lots. It is recommended a dune management plan be developed and implemented.

Shore stabilisation measures to the South, particularly structural interventions along Town Beach and the Yacht Club area (in MU2), have the capacity to transfer erosion pressure to the MU1 (Northern Flood Basin) coast. This should be evaluated within design of any stabilization structures, and a coastal adaptation response identified to mitigate impacts to MU1.

A recommended pathway for risk treatment in MU1 is:

Table 6-4: Recommended Actions for MU1

Issue	Required Timeframe	Recommendation
Runoff flooding	Immediate	Liaise with DWER to develop revised Floodplain Management Strategy. This should consider coastal dynamics and instability of northern breakout.
Breakout instability	Immediate	Study to identify minimum channel area required for drainage (may be part of Floodplain Management Strategy)
Dune management	Immediate	Develop and implement a dune management plan, to reduce dune destabilization through traffic.
Development in floodplain	5-10 years	Prepare and implement guidelines for development within the floodplain SCA 5, including identification of required finished floor levels and evacuation planning.
Development in coastal risk areas	5-10 years	Development of Coastal SCA, incorporating requirements for conditional approval and time-limit approval.
Limited erosion buffer	10-30 years	Apply time-limited leasehold to Truscott Crescent Special Use lots, with conditions outlined by coastal SCA..
Transferred erosion stress	Subject to MU2 management	Undertake coastal monitoring. Identify coastal adaptation response as part of stabilization design for MU2.
Floodplain salinisation	20-50 years	No action presently deemed necessary.
Wastewater treatment plant	40-60 years *	Mitigate inundation hazard to WTP
Coastal inundation hazard	40-60 years *	Amend SCA 5 wording. Advise occupants regarding limitations of insurance.
* These actions are unlikely to become critical without SLR ~0.4m. However, early action is considered highly beneficial.		

6.4. MU2: Town Beach

Town Beach (MU2) is the most highly used part of Exmouth foreshore. It serves as a focal point connecting Exmouth community to the Gulf, with two foreshore access points and extensive public use of the beach area. Landscaping infrastructure has been incorporated to enhance beach amenity including a car park and a grassed foreshore recreational area with BBQ facilities, partly protected by an artificial foredune and low rock revetment (Figure 6-6).

Built infrastructure includes Exmouth Yacht Club building, located adjacent to Friedman Way access, with Mantarays Resort being 450m further south, tucked against Exmouth Boat Harbour, behind a substantial revetment. Residential properties have been developed along Madaffari Drive and Osprey Way, set back at least 70m from the coast, with the foreshore reserve occupied by a large dune buffer.

The location of beach access, landscaping infrastructure and the nearshore built assets (Exmouth Yacht Club and Mantarays) determines they are exposed to present day erosion and inundation hazard. The dune buffer to landward, combined with foreshore protection works, are deemed to provide effective protection to residential properties behind the dune (Table 6-5). In the long term, there is potential for coastal hazards to affect Mantarays Resort and for inundation hazard to reach Exmouth Yacht Club.

Table 6-5: Assets deemed to require Hazard Management in MU2

	Erosion Hazard	Inundation Hazard
Present-day Risk *Requires mitigation now*	Town Beach Foreshore Friedman Way Access	Town Beach Foreshore
Projected Risk *Requires adaptation plan now*	Exmouth Yacht Club	
Emerging Risk *Integrate into planning*		
Possible Risk *Consider long-term management*	Mantarays	Exmouth Yacht Club Mantarays

6.4.1. Coastal Risk Management for Town Beach

The key objective for Town Beach is to provide management which supports ongoing beach amenity (Figure 6-5). This has led to installation of infrastructure to enhance beach use, rather than having intrinsic infrastructure value, except perhaps for Mantarays Resort, although its value is also substantially linked to beach amenity. This perspective is reflected in the type of coastal defence systems and the value of protected infrastructure:

- Light defences along northern Town Beach (Figure 6-11) are adequate for short-term erosion pressure but would likely fail under direct hit from a tropical cyclone.
- Protected assets are largely landscaping elements, or low investment development such as the Yacht Club building.

Combining low-cost infrastructure and low-cost defence uses the ‘accommodate’ strategy for coastal risk mitigation (Section 6.2). Its economic viability relies on an effective ceiling to investment, balanced against the risk of damage (with costs of replacement and recovery). This risk will change over time.

Figure 6-5: Coastal Assets and Amenity along Town Beach foreshore

An aspirational vision for Town Beach is to provide beach facilities along the shore from Warne Street towards Mantarays. This has resulted in dispersed assets, presently with a long gap between Mantarays and Exmouth Yacht Club (Figure 6-6). This gap was originally provided with recognition that flanking erosion may occur due to disruption of alongshore sediment transport by Exmouth Boat Harbour breakwaters, partly mitigated through a sand management program by the Department of Transport and Major Infrastructure (see Section 7.3).

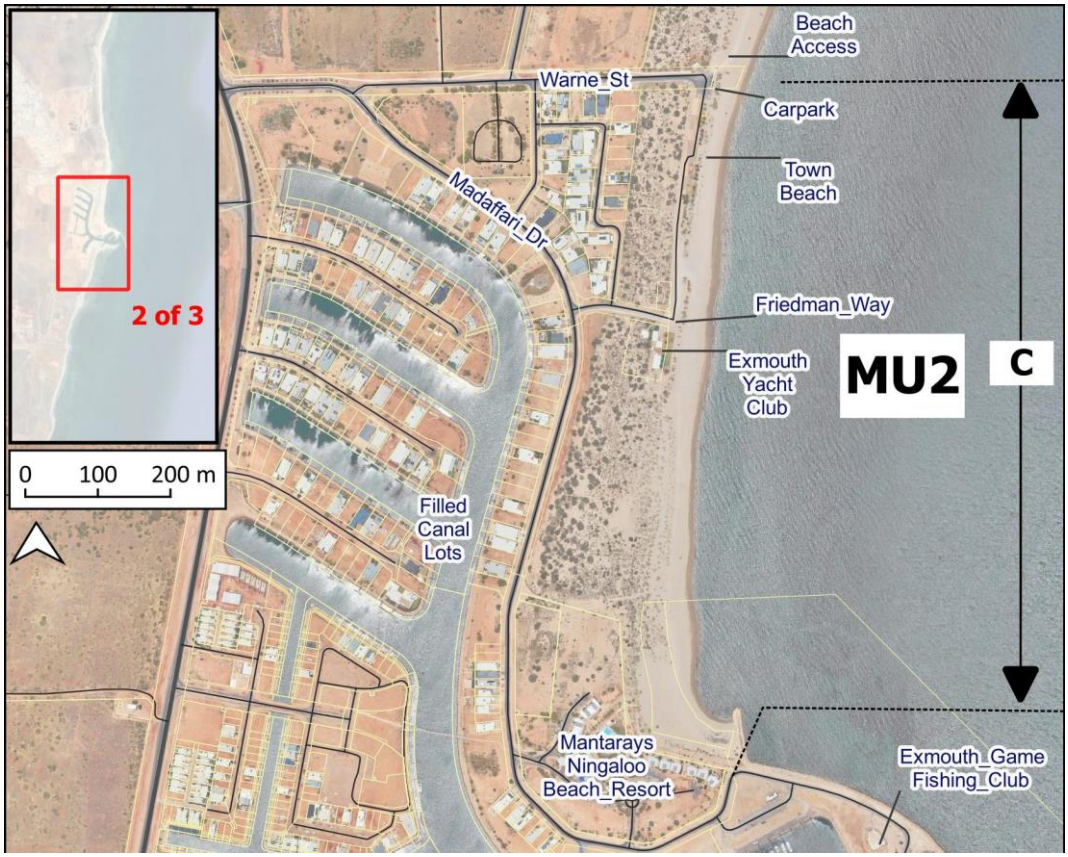


Figure 6-6: Town Beach Management Unit

Relative foreshore stability over 1996 to 2010 was considered for Exmouth Town Beach masterplan [7], including impact from TC Vance. However, physical changes observed since 2010 (Figure 6-7) have demonstrated challenges to maintaining beach amenity in MU2:

- In 2011, rapid erosion was observed north of Mantarays, associated with high water levels during La Niña climate phase.
- This was followed by sustained accretion on the north side of the harbour, corresponding to a change in the balance of northeast and southeast winds (67% NE dominant), compared to the preceding 30 years (80% SE dominant).
- Accumulation supported dune vegetation establishment, which was then identified as a constraint for material placement for sand bypassing. Material put along the beach was subject to rapid erosion, causing a 2m high scarp and leaving an accumulation of pebbles and cobbles along the active beach.

Figure 6-7: Beach utility and access on Town Beach
2011 – scarping due to transport reversal; 2021 – Subsequent progressive accretion; 2022 – scarping due to sand placement

MU2: TOWN BEACH Report Card	
MU2: Segment C	**Warne Street to Boat Harbour N**
Use and 'value'	Environmental, social, infrastructure assets along length of beach; focal point for community access at Yacht Club; foreshore recreation; high value tourist accommodation
Adaptation Objective:	Retain beach access and utility. Project high-value assets (Financial – Mantarays; Social – Yacht Club)
Hazard 	**Erosion:** progressive and switching. Foreshore facilities are susceptible to storm erosion, or potential long-term coastal retreat. **Inundation:** Coastal facilities subject to inundation hazard, with additional requirement to address wave runup.
Assets 	• Mantarays • Recreational Infrastructure • Yacht club infrastructure • Power, water, telecommunications at Warne St & Friedman way • Residential lots • Undeveloped lots
Damage 	• Assets on upper/active part of beach flat • Access reduced when scarping developed. • Erosion Hazard - Warne St & Friedman way; Mantarays, Yacht Club & Recreational infrastructure. • Inundation Hazard - Coastal facilities including Yacht Club buildings, Town Beach foreshore area and Ningaloo Resort walling and villas are subject to inundation hazard, with additional requirement to address wave runup.
Mitigation 	• Tradeoffs – e.g. financial incentive to protect assets however adaptation objective for the area is to retain access to and utility of the beach. This applies to both cross and alongshore.

Summary:

- Extreme erosion risk for a range of assets along the Town Beach foreshore by 2170, Yacht Club and Ningaloo Resort sitting on a modified dune area and presently exposed to erosion hazard.
- Foreshore is subject to progressive erosion through time but also have intense periods of retreat due to directional switching of sediment transport.
- Impacts are not consolidated; Key infrastructure assets at risk lie at opposite ends of the sediment cell with Mantarays to the South and the Yacht club with associated infrastructure and public access approximately 1km further North.
- The policy-based timeframes for erosion at this site are less meaningful than a consideration of a likely sequence of erosion and an associated adaptation sequence to address consensus driven adaptation objective **RETAIN BEACH ACCESS AND UTILITY** and the identified risk to coastal assets.

PROTECT and **RETREAT** are the only feasible options to deliver adaptation objective of retaining beach access (along and cross shore) and utility as primary coastal access point for the settlement.

6.4.2. Adaptive Pathways for Town Beach

The existing situation for Exmouth Town Beach is one where episodes of erosion or inundation pressure are occasional. Existing protective works are commensurate with asset values (Figure 6-8, Figure 6-9) with a deliberate focus to maintain beach access.

Figure 6-8: Town Beach area circa 2011
Relatively narrow coastal buffer, low dunes, development adjacent to beach, backed by canal estate in the middle background

Figure 6-9: Ningaloo Beach Resort, southern end of Town Beach adjacent to harbour

The adaptive approach involves identifying when existing management systems are no longer appropriate and determining long-term options to guide evolution of existing practice.

For Exmouth Town Beach, existing or short-term coastal hazard risk management is required for Town Beach facilities, including Friedman Way access and Exmouth Yacht Club. Risk is presently limited by the relatively low cost of infrastructure and protection works (Figure 6-11). Access to and along the beach, which has been rated as essential by the Exmouth community, is not presently restricted by the protective works, although it has been adversely affected by sand management practices (see Section 7.3).

In the longer term, these facilities are expected to be subject to progressively increasing erosion and inundation pressure, eventually also impacting on the facilities at Mantarays Resort. Progressive change, without intervention, involves:

- Reducing beach width/access
- Loss of beach in front of seawalls
- Damage to beach facilities, including artificial dune and seawalls
- Restriction of beach in front of dunes
- Outflanking of existing foreshore protection
- Dune scarping and mobility
- Increasing constraint to beach access
- Damage to infrastructure

Further description of these pressures is outlined in Table 6-6.

An estimate of the timeframe over which existing management may remain effective has been developed by considering beach position relative to Town Beach defences. A cost-benefit analysis (CBA) for the defences has been undertaken, considering asset protection and the changing risk of revetment failure with beach position (Figure 6-10). Community value of beach access, which is non-monetary, has been parameterized as a wide range of equivalent monetary values.

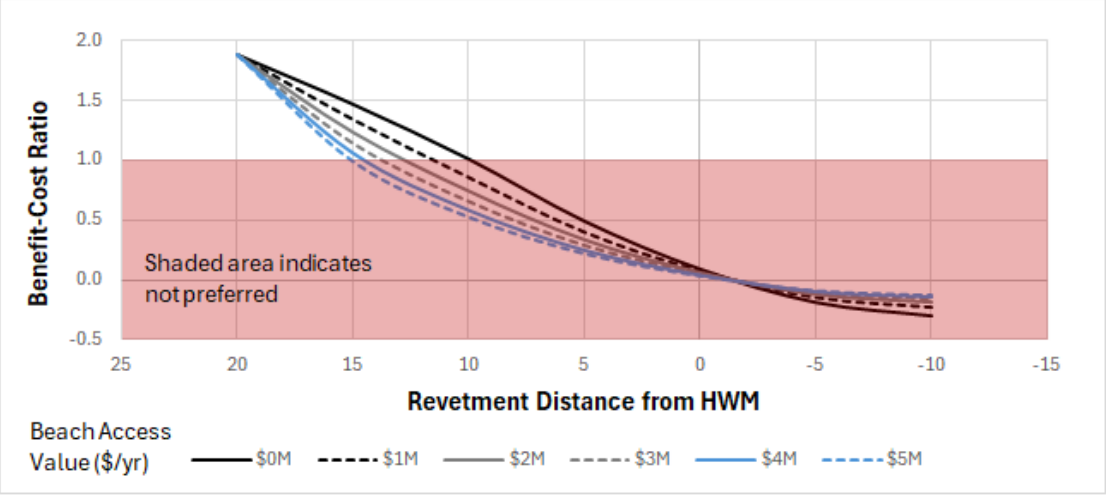


Figure 6-10: Cost-Benefit Evaluation for Town Beach Protection Considered with Existing Protection Level and Assets

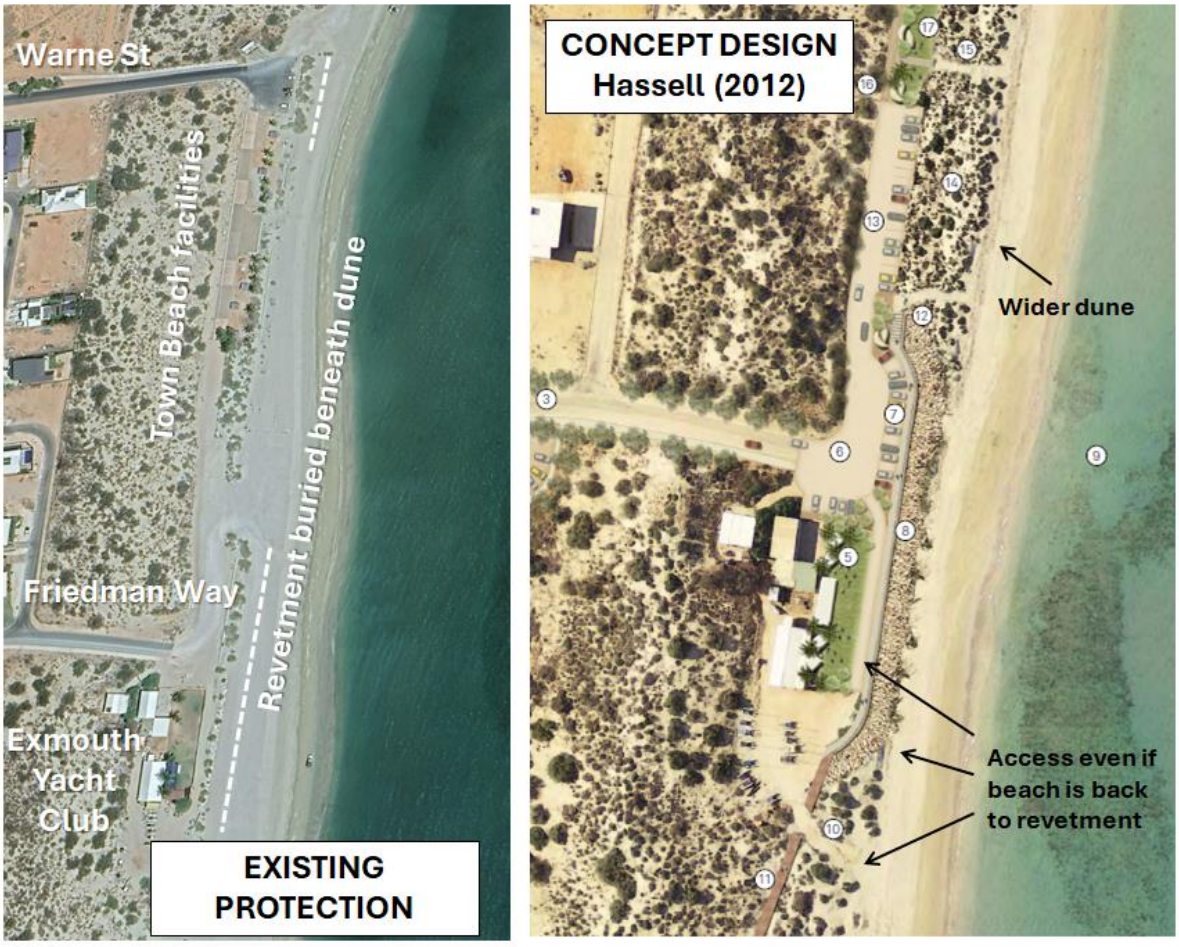


Figure 6-11: Existing Protective works and 2012 Concept Design for Yacht Club site
Note that dune loss has affected the original design intent

Assessment of Adaptive Pathways for Town Beach has followed general guidance from WAPC CHRMAP Guidelines [2] combining use of multi-criteria assessment to identify a short-list of viable options, coastal recession modelling to predict performance of these interventions, and cost-benefit analysis to indicate how the financial viability of options is expected to change over time (Figure 6-12).

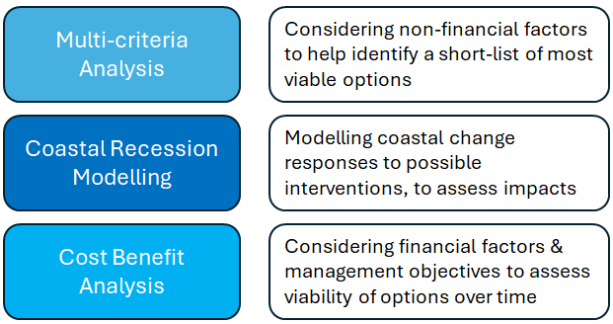


Figure 6-12: Assessment Sequence for Town Beach Adaptation Pathways

Table 6-6: Summary of key issues for Town Beach

Issue	Timeframe	Description	Options	Action
Beach Amenity	NOW	• Beach users have identified reduced amenity on Town Beach following sand management activities by the Department of Transport and Major Infrastructure, including excessive beach scarping & presence of rocks. • Sustained period of southward alongshore sand transport (since 2010) has occurred, after the preceding 30 years were northward. • Excavating material from the southern trap and placing to the north is not achieving effective bypassing. • Impacts to beach amenity have further occurred due to placing sand on the beach flat, to avoid dune vegetation.	• Future sand management activities should undertake a wider assessment of beach state (outside sand trap) prior to works, limit transport of cobbles, and sand placement should aim to reduce scarp formation. • Sand extraction and placement options should be subject to agreement by the Shire Works Manager prior to implementation	Shire to engage with DTMI
Access Along Beach	10-30yrs [c]	• Foreshore works include revetments and artificial dunes in front of Town Beach facilities, Exmouth Yacht Club and Exmouth Game Fishing Club. • These are in front of the primary dune & will restrict access along the beach if sustained erosion occurs. • Rapid sustained erosion of 5-10m will occur when prevailing winds return to 'normal'. • There is potential for progressive coastal erosion associated with sea level rise.	• Remove facilities & structures (gains ~25 years of beach access) • Modify dunes to provide access behind existing facilities. • Modify structure layout to provide access in front of existing facilities. • Extend structures to provide access in front of existing facilities. • Enhance beach stability to extend duration of access along the beach.	**Adaptive pathway recommended.** Decision appropriate at 10m recession.
Beach Facilities	NOW [d]	• Wave and erosion hazard from severe storms provides a risk to existing facilities along Exmouth Town Beach. Risk increases if the beach narrows.	• Remove structures & relocate facilities. • Remove structures & relocate / replace facilities (BBQ, paths & yacht club building) after 10m coastal retreat. • Remove structures & relocate facilities after damage occurs.	**Adaptive pathway recommended.** Decision appropriate at 10m recession.

[c] Establish plans before renewal / modification of existing facilities.

[d] Existing facilities susceptible to damage in 100-year storm. Revetment susceptible to failure in 100-year storm after 15m coastal erosion

Issue	Timeframe	Description	Options	Action
			• Extend protective structures in front of facilities. • Enhance protective structures after 10m coastal erosion. • Enhance beach stability to limit storm risk to facilities.	
Inadequate Foreshore Reserve	NOW	Existing town planning documents have defined 40m foreshore reserve width. Application of DPLH methods to estimate foreshore reserve gives much larger widths (140-170m). Definition of the foreshore reserve can give an expectation of when coastal engineering works may be needed, or requirements for retreat.	• Adopt larger foreshore reserves for all planning, limiting existing sites. • Adopt larger foreshore reserves for new developments only. • Enhance beach stability to limit storm risk to facilities.	**Adaptive pathway recommended.** Decision appropriate at 10m recession
Dune Management	NOW	Dunes are presently experiencing moderate degradation pressure, including effects of pedestrian and vehicle traffic. Instability is projected to increase with rising sea levels. Loss of vegetation from the dunes will cause dune movement landward and alongshore (northward). This is estimated to contribute 25m to foreshore reserve requirements.		Shire to develop and implement improved dune management practices.

Valuation of a cost-benefit ratio below CBR=1 indicates economic viability of the protection strategy is limited beyond 10m coastal recession, with consideration of beach access reducing this amount of change. However, it is noted the CBR is fundamentally developed by risk associated with damage from extreme events – this is often not perceptible or able to be supported by public decision-making until damage occurs, or beach access is constrained. Evaluation of the likelihood of a physical trigger has been examined through coastal erosion /recession modelling (see Section 6.4.4).

The presence of existing coastal protection modifies decision-making from adaptation for unprotected assets, where a coastal buffer less than the storm erosion allowance (S1) is a common trigger for adaptation. Consequently, 10m coastal recession is recommended as a trigger for coastal adaptation decision-making, with 20m coastal recession recommended as a trigger for adaptive implementation (Table 6-7, and refer to Figure 6-19). At 20m recession, performance of Town Beach's existing defences is uneconomic, and coastal retreat is likely to significantly restrict access along the beach.

Table 6-7: Variation of Risk Status and Adaptation with Recession for Town Beach

Coastal Recession	Risk Status	Decision-Making
0-10m	Beach access generally available. Tolerable risk to protective structures. Tolerable risk to assets to landward.	Reasonable to repair protective structures if damaged.
10-20m	Beach access occasionally restricted. Increasing risk to protective structures. Tolerable risk to assets to landward.	Requires decision about long-term risk mitigation. If damaged, protective structures should be removed (retreat option) or enhanced (protect option).
>20m	Beach access seasonally restricted. Intolerable risk to protective structures. Increasing risk to assets to landward.	Implement longer-term risk mitigation strategy, even if no protective structures are undamaged.

As with MU1 and MU2, existing dunes provide a significant erosion buffer and inundation barrier to substantial high value assets (residential lots along Madaffari Drive). Although there is a large existing buffer, its effectiveness will be reduced by dune instability. Low-cost dune management is considered essential for long-term coastal management along Town Beach. It is recommended a dune management plan be developed and implemented as an immediate action.

Under projected sea level rise, unmitigated coastal recession will result in the loss of all facilities along Exmouth Town Beach, including Mantarays Resort, with erosion into the dunes substantially restricting beach access and causing a total change to Exmouth Town Beach use and amenity. Future adaptation can consequently either involve accepting these changes (i.e. a 'retreat' strategy) or undertaking actions to limit processes of coastal recession (i.e. a 'protect' strategy).

6.4.3. Multi Criteria Analysis (MCA)

Retreat or protect approaches to risk mitigation have been considered for Town Beach through multicriteria analysis, which compares non-financial characteristics between options. Effectiveness, environmental impact, social values, aesthetics, future adaptability, and cost were rated for each option (Table 6-8). Each of these factors was given a rating out of 3 by the project team, except for effectiveness, which was given a rating out of 10. While ratings are subjective, they were validated through consultation with key Shire representatives, discussions in community workshops, targeted stakeholder meetings and a subsequent Council briefing session held in Exmouth in May 2023.

Six options were considered:

- Removal of assets from inside hazard area
- Beach nourishment or replenishment
- Groynes
- Seawalls / Revetments
- Artificial Reef
- Offshore breakwater

Effectiveness of different options was considered relative to their capacity to simultaneously offset long-term coastal recession, resist short-term storm erosion and support beach amenity. Consequently, seawalls or revetments are rated as moderately effective, as their placement significantly blocks beach use. Notably, to combine protection and amenity may require installation of a protection system, such as a combination of groynes and seawalls.

Table 6-8: MCA Assessment Criteria

Criteria	Description	Rating	
Effectiveness	Ability for the option to mitigate the coastal hazard risk (and deliver the adaptation objective)	Out of 10	1 = ineffective 5 = moderately effective 10 = Highly effective
Environmental	Impact on existing native vegetation / dunes / coastal processes considering construction / clearing impacts	Out of 3	1 = high env. Impact 3 = low env. impact
Social Value	Stakeholder and community impacts	Out of 3	1 = negative social value 3 = positive social value
Aesthetic	Visual appeal of the option; aesthetics tying into the wider Shire vision for Exmouth	Out of 3	1 = visually unappealing 3 = visually appealing
Adaptability	Whether the option is easily adaptable in future and if the option limits viability of shifting to alternatives	Out of 3	1 = low adaptive capacity 3= high adaptive capacity
Cost	Upfront capital costs. Ongoing maintenance cost	Out of 3	1 = relatively high cost 3 = relatively low cost

MCA results are presented in Table 6-9, with preferred options indicated in green and options deemed not applicable in red. Options coded 'yellow' were the middle ground – although these are not preferred options to meet stated adaptation objectives for Town Beach MU2, they may be applicable for wider, strategic management across the Management Unit. Options considered further, specifically evaluated for response to coastal erosion (Section 6.4.4) and financial viability via cost-benefit analysis (Section 6.4.5) include:

- Facility Removal
- Offshore Breakwater Construction
- Groynes.

Table 6-9: MCA for Town Beach foreshore (MU2)

Option	Effective - ness	Environ-mental	Social	Cost	Adapt-ability	Score	Comment
Removal of assets from inside hazard area	10	3	1	3	1	**18**	Suitable for low-value public assets such as foreshore recreational amenities. Potentially costly if triggers met before asset due for replacement. For the Town Beach area, this solution is problematic given the lack of available land to relocate assets. Suggestion to consider the vacant dune area adjacent to Mantarays for possible relation site for Yacht Club infrastructure
Beach nourishment or replenishment	3	3	3	2	3	**14**	Potentially very expensive and requires careful consideration due to local sediment dynamics associated with harbour and switching within sediment cell connected to changing wind conditions.
Groynes	6	3	2	3	2	**16**	A groyne near Mantarays (location B in Figure 6-13) will assist in preserving beach to the South of MU but may contribute to transference of erosion pressure to the North. Groynes generally lead to downdrift erosion issues if not designed and constructed appropriately; would require sand nourishment as part of works
Seawalls	4	2	2	2	1	**11**	Expensive option. Likely to lead to reduction or loss of usable sandy beach. Disconnection of foreshore with beach flagged as an issue with stakeholders. Revetments are already in use in this MU and therefore likely more tolerable than vertical seawalls.
Artificial Reef	2	2	2	3	1	**10**	Difficult to design submerged structures to work effectively, and costly to build and maintain
Offshore Breakwater	6	3	3	3	2	**17**	Can be costly to build and maintain but can be designed to work effectively and provide usable sandy beach. Social concerns about ocean views likely. Concerns could be offset by designing shore-attached structures.

6.4.4. Coastal Erosion & Recession Modelling

A model for coastal erosion and recession was developed for Exmouth Town Beach, based on consideration of historic rates of coastal change, storm events, variable alongshore sediment transport, projected future coastal recession, and coastal erosion transfer due to potential configurations of coastal defence structures. Coastal segments defined by groyne or offshore breakwater fields was considered, incorporating effects of using 0, 1, 2, 3 or 4 structures into beach position forecasts – thereby defining cells A-E (Figure 6-13).

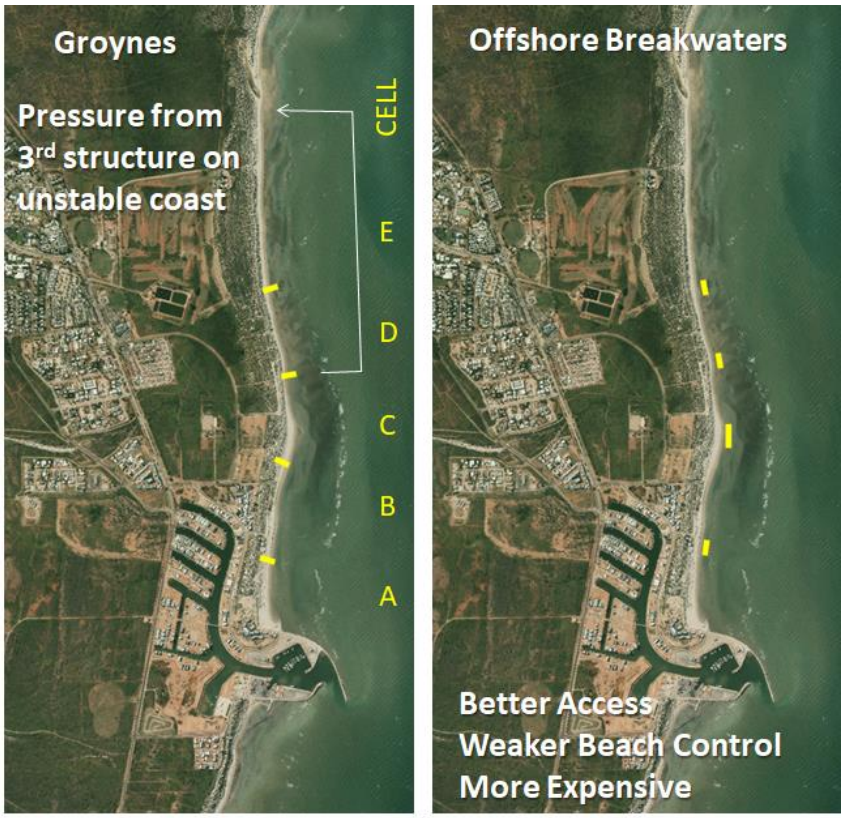


Figure 6-13: Nominal Position of Control Structures for Exmouth Town Beach

Simulations of 'possible futures' were undertaken:

- Annual storminess was generated as a random event, statistically matched to estimated storm bite and storm intensity.
- Alongshore sediment transport was simulated as a slowly varying process, with cycles of varying duration, typically 5-8 years long, corresponding to El Niño / La Niña cycles.
- Rates of coastal recession in response to sea level rise were alternately based on SPP2.6 allowances (1:100 ratio of sea level rise to recession), or a reduced rate (1:50 ratio) based on the presence of the wide nearshore rock platform along Town Beach.

Figure 6-14 shows an example of a simulated future, and the varied response to different protection configurations. This demonstrates the tendency for transfer of erosion pressure from a retained cell to the adjacent downdrift cell. A set of 1,000 simulated futures were subsequently generated, and occurrence of erosion values were converted into an occurrence distribution for each year (Figure 6-15).

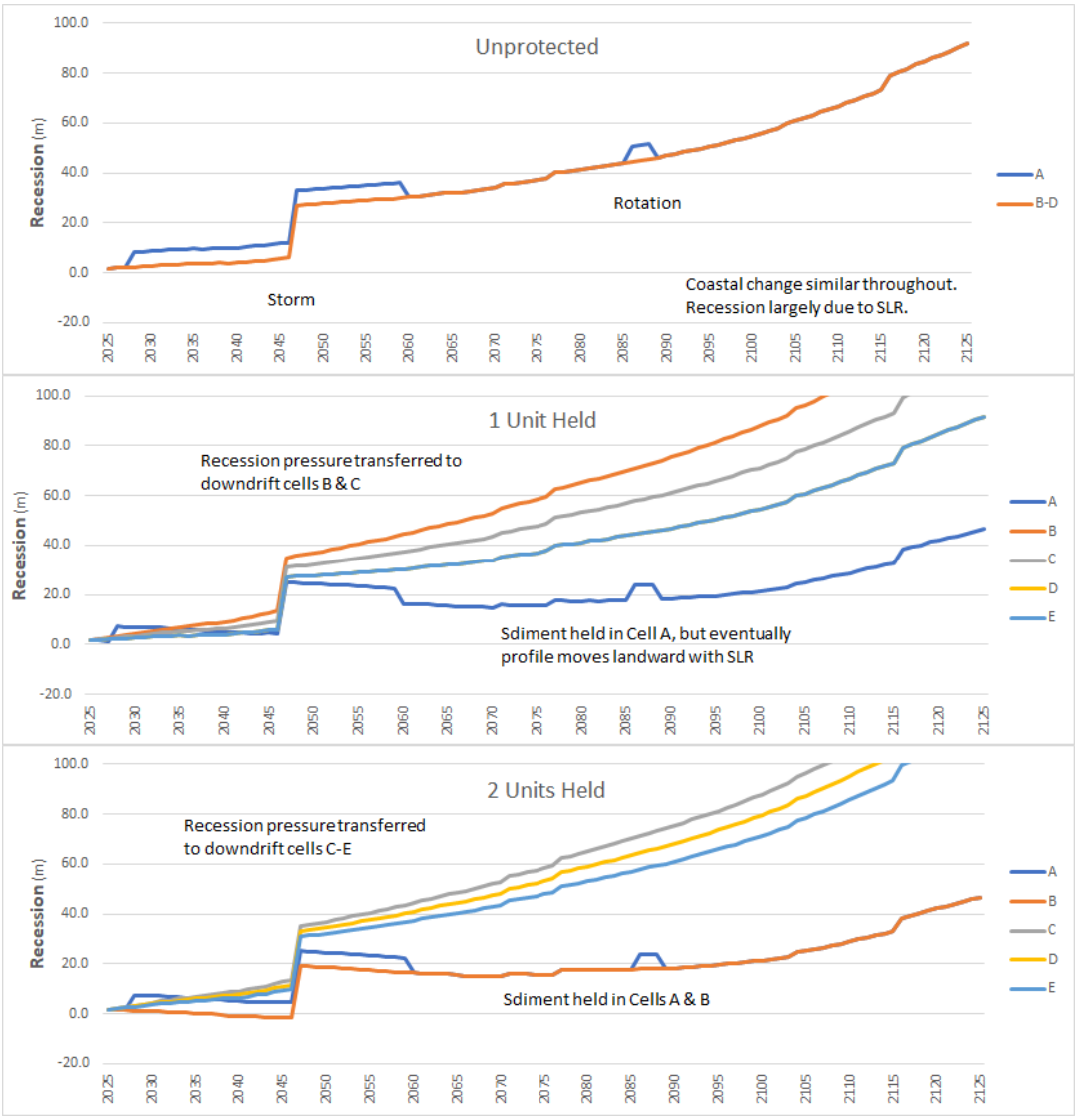


Figure 6-14: One Erosion Simulation, with 3 Different Protection Configurations
Retention defers coastal recession but transfers it to the adjacent (downdrift) cell. In the longer-term, overall coastal recession will also begin to affect the retained cell.

Outcomes from the coastal erosion and recession modelling relevant to decision-making include:

1. There is substantial difference between a policy-based 'future' projection (Section 3) and anticipated behaviour based on the topography and bathymetry (Figure 6-16)
2. The first 'decision point' separating retreat from other strategies occurs when beach access along Town Beach is constrained (~20-30 years at earliest).
3. Protection is able to defer removal of existing infrastructure for an extra 10-30 years, which may extend its effective life to 2060-2115 (Figure 6-17).
4. However, protecting Town Beach will act to transfer erosion pressure to the north, bringing coastal erosion pressure forward by ~10-20 years.
5. Protection cannot effectively extend beyond Warne Street due to transfer of pressure to the breakout area, which would cause extensive damage to the dunes and prevent access along the foreshore (i.e. it directly counters the objective for protection to support foreshore accessibility).

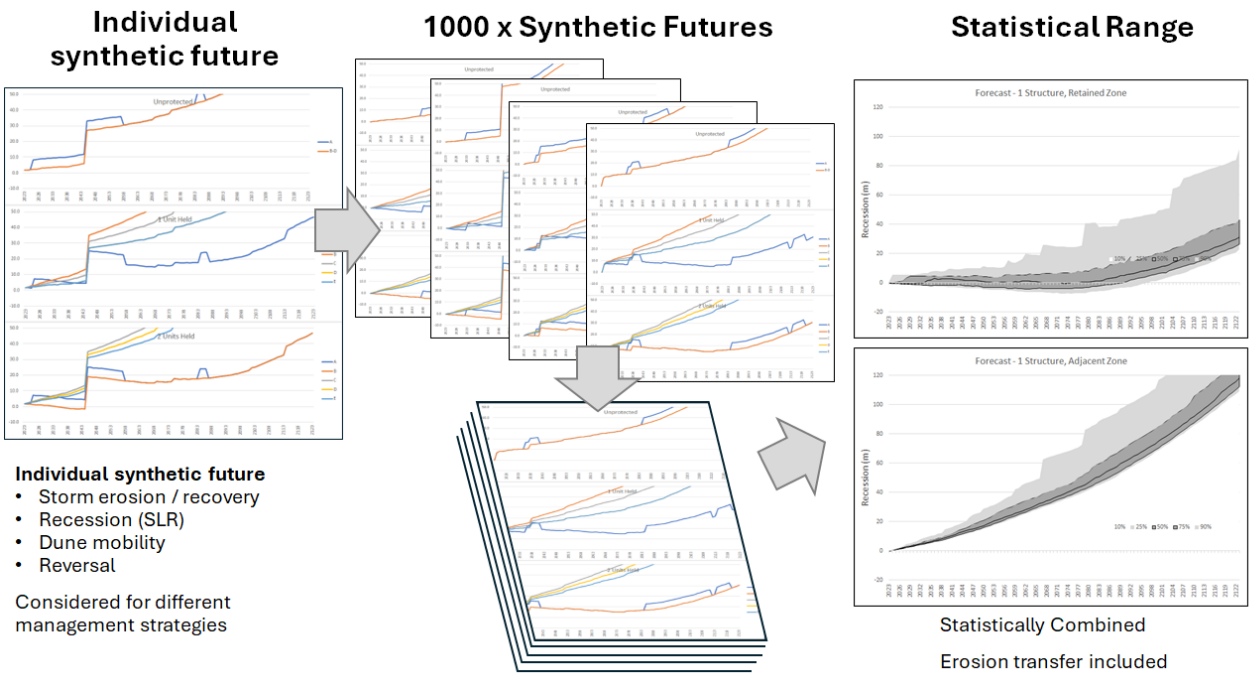


Figure 6-15: Combining Erosion Simulations

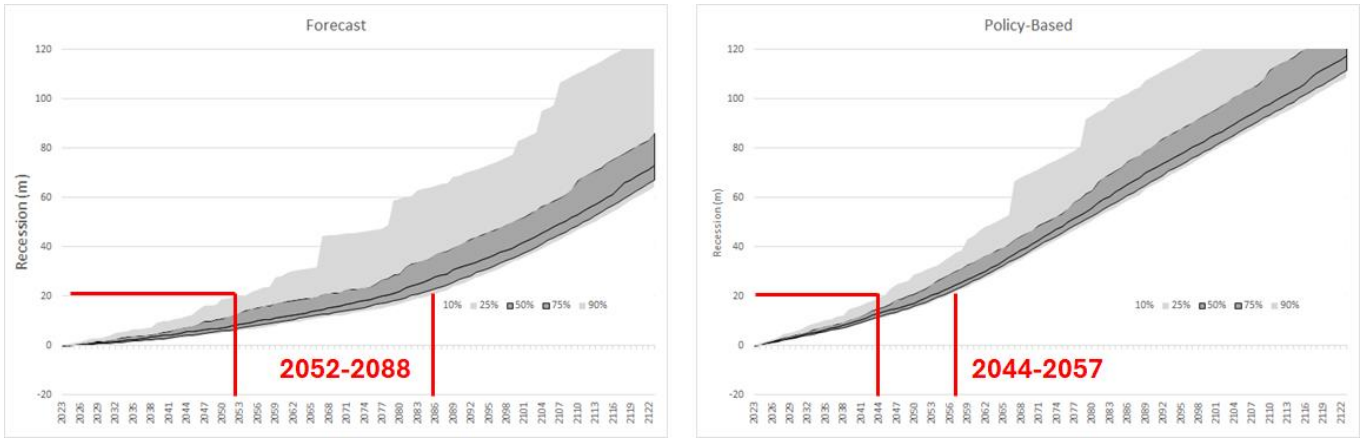


Figure 6-16: Time Range for Adaptive Change with No Protection

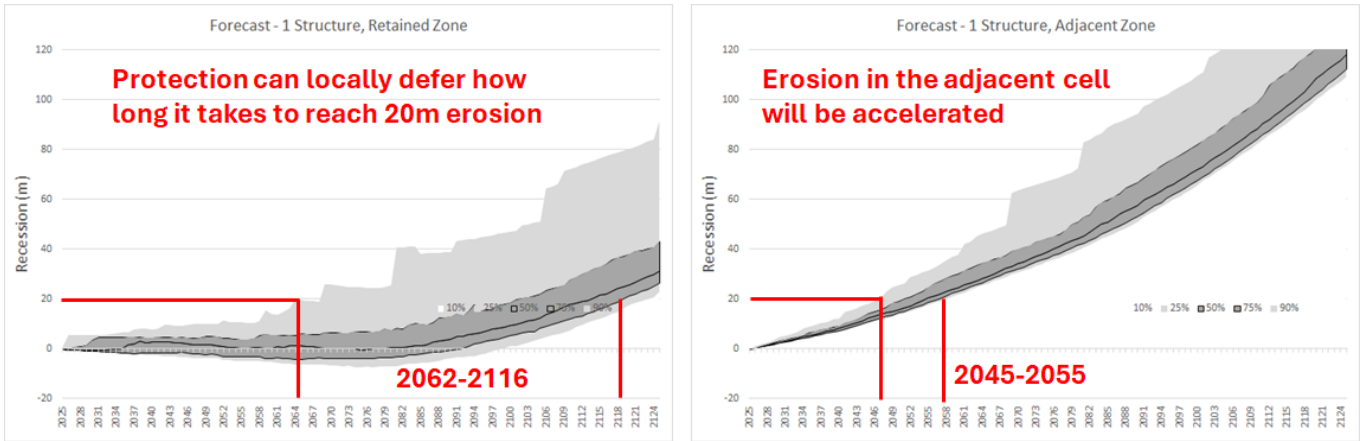


Figure 6-17: Time Range for Adaptive Change with 1 Protection Structure

6.4.5. Cost Benefit Analysis (CBA)

The purpose of the Cost-Benefit Analysis (CBA) is to compare financial aspects of adaptation options. All major values and costs of the selected options (Table 6-10), both at present and over the option's intended design life are balanced, reported as benefit-cost ratios (BCR) and net present value (NPV). Both costs and benefits are considered across a range of discount rates, notionally to account for opportunity cost.

Table 6-10: Monetary Value Elements Applied to CBA

Item Considered	Cost Elements
Damage to Existing Assets	Est. $2.6M for seawall, yacht club building & landscaping infrastructure. 0% damage at 10m erosion, 100% damage at 40m erosion, as the lowered seabed would cause seawall failure through undermining.
Reduction Tourism Lot Value	Assumed $2.0M variation in lot value. 0% loss at 40m erosion, 100% loss at 120m erosion.
Town Beach Amenity *Non-monetary*	For 'fixed' financial evaluations, $100,000 p.a. value assumed, with 100% benefit for <10m erosion and 0% value for >30m erosion.
Northern Beach Amenity *Non-monetary*	For 'fixed' financial evaluations, $20,000 p.a. value assumed, with 100% benefit for <20m erosion and 0% value for >50m erosion.
Groyne Construction	Estimated $600,000 per groyne, assumed installation 2025, 2055, 2085.
Offshore Breakwater Construction	Estimated $800,000 per breakwater, assumed installation 2025, 2055, 2085.
Beach Nourishment	Assumed $30/$m^3$, with 2,150 m^3 required to offset 1m recession*. Due to high uncertainty with both pricing and volumes required, an additional factor of 3x has been applied as a 'high' cost scenario for sand nourishment.

For each option, the projected median coastal position (as per Section 6.4.4) has been used to estimate relative costs as the coast evolves over time.

It is noted the key benefit associated with management of Town Beach is provided by beach amenity. This is a non-monetary benefit, and therefore its value is highly subjective. To cater for this, as well using 'fixed' benefit rates to derive BCR and NPV, monetary factors have been used to derive a 'required' beach value, above which the costs for coastal management are deemed justifiable.

For 'fixed' benefit rates, the BCR, NPV and net outlay/loss are presented for discount rates of 0%, 7% or 15%, for forecasts over 50-years or 100-years (Table 6-11). These figures highlight the relative time bias introduced by the discount rate, and the relative emergence of coastal erosion pressure over time:

- 'No change' is the best option for the short-term focus (7% or 15% discount, 50 year forecast), as the limited erosion pressure on Town Beach prompts low financial justification for coastal intervention. Notably 'no change' is the best option for a 100 year forecast, effectiveness representing managed retreat, as it involves loss of assets exposed to coastal erosion.

- Sand nourishment (low estimate) is the best option for the 0% discount rate, 50 year forecast case. This case effectively gives increased weighting to erosion pressure from 2050-2075 and demonstrates financial impact of forecast damage to existing assets during this phase if there is no protection (from nourishment or structures). It is highlighted that uncertainty regarding effectiveness of sand nourishment is significant, with the x3 estimate for sand nourishment being financially unviable, having a negative NPV and BCR <1.0.
- Emergence of greater financial viability for groynes & breakwaters with the 100-year forecast reflects the greater rates of coastal recession and erosion anticipated after 2075. However, in the longer term, these structures defer, but do not prevent coastal retreat.

Table 6-11: Financial Evaluation for 'Fixed' Beach Amenity

Blue indicates positively viable (CBR >2.5), **grey** indicates potential viability (1 < CBR <2.5) and **red** suggests non-viability on a financial basis, although these options might be better preferred under a wider consideration of project factors.

50-year Forecast	0% discount (cash-flow)			7% discount (intermediate)			15% discount (short-term)		
Option	BCR	NPV	Outlay / Loss	BCR	NPV	Outlay / Loss	BCR	NPV	Outlay / Loss
No change	1.8	$2.6M	$0.9M	**18.7**	**$1.6M**	**$0.9M**	**230**	**$0.8M**	**$0.9M**
Groynes	1.8	$4.2M	$1.2M	2.5	$1M	$1.2M	1.3	$0.2M	$1.2M
Breakwaters	1.4	$2.5M	$1.6M	1.9	$0.8M	$1.6M	1.0	$0M	$1.6M
Nourishment	**2.7**	**$7.6M**	**$1.3M**	**4.8**	**$1.4M**	**$1.3M**	**5.5**	**$0.7M**	**$1.3M**
Nourishment x3	0.9	-$1.4M	$3.9M	1.6	$0.6M	$3.9M	1.8	$0.4M	$3.9M
100-year Forecast	**0% discount (cash-flow)**			**7% discount (intermediate)**			**15% discount (short-term)**		
Option	BCR	NPV	Outlay / Loss	BCR	NPV	Outlay / Loss	BCR	NPV	Outlay / Loss
No change	**6.3**	**$4.6M**	**$3.4M**	**26.1**	**$1.6M**	**$3.4M**	**240**	**$0.8M**	**$3.4M**
Groynes	**5.1**	**$4.9M**	**$5.5M**	**2.5**	**$1M**	**$5.5M**	1.3	$0.2M	$5.5M
Breakwaters	**3.8**	**$4.5M**	**$6.6M**	1.9	$0.8M	$6.6M	1.0	$0M	$6.6M
Nourishment	**4.7**	**$4.8M**	**$4.5M**	**5.0**	**$1.3M**	**$4.5M**	**5.5**	**$0.7M**	**$4.5M**
Nourishment x3	1.6	$2.3M	$13.5M	1.7	$0.7M	$13.5M	1.8	$0.4M	$13.5M

Although each option has been considered applied separately, over the whole forecast, an interpretation of the financial evaluation is that different options are more or less viable over time. Indicatively, this could involve interim use of sand nourishment (early) or coastal structures (later) to mitigate low rates of erosion, with transition to managed retreat as recession becomes advanced or higher rates of erosion develop (Figure 6-18).

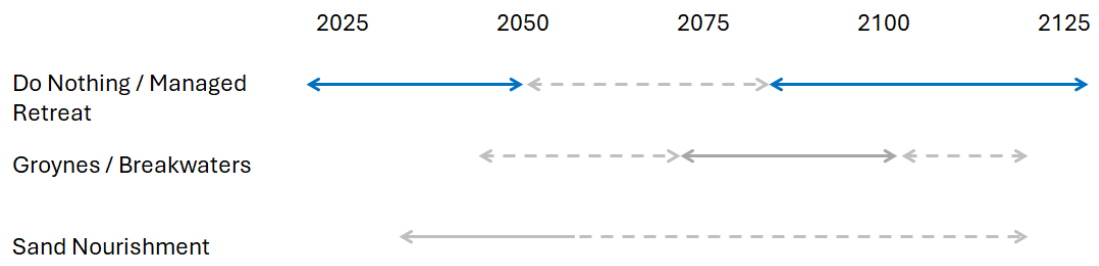


Figure 6-18: Schematic of Option Viability over Time

Solid line indicates higher viability. **Blue** has CBR >2.5 and **grey** has 1 < CBR < 2.5.

Financial-based decision-making is not definitive when a substantial proportion of the costs or benefits are non-monetary, or when there is inequity in the distribution of costs and benefits. For Exmouth Town Beach, the non-monetary benefit of beach amenity is a significant component. Economics of this situation have been considered by evaluating the equivalent financial benefit required to bring the overall BCR to 2.5, for each option (Table 6-12).

Table 6-12: Required Beach Amenity Benefit for BCR = 2.5

Option	7% discount 50 year forecast	7% discount 100 year forecast	0% discount 100 year forecast
No change / Retreat	$15K p.a.	$10K p.a.	$40K p.a.
Groynes	$100K p.a.	$100K p.a.	$50K p.a.
Breakwaters	$135K p.a.	$135K p.a.	$65K p.a.
Nourishment	$55K p.a.	$50K p.a.	$55K p.a.
Nourishment x3	$155K p.a.	$150K p.a.	$160K p.a.

These outcomes indicate the effect of evolving erosion pressure over time, with discounted rates being focused on more immediate conditions, and the long-term 0% discount forecast providing an overall cash-flow consideration.

In the context of community consultation indicating critical value for beach amenity, the real costs of coastal hazard mitigation are moderate. However, they require dedicated funding, to be strategically assembled, with some uncertainty of timing due to the nature of coastal erosion pressure (see Section 6.4.4).

6.4.6. Adaptive Pathways and Decision Points

Forecast coastal erosion pressure does not immediately require selecting a strategy for management of Town Beach MU2. This presents an opportunity for flexible decision-making, with a series of alternative adaptive pathways available. An indication of pathways available is presented relative to observed coastal recession, along with the decision points that may stimulate an appropriate change of management actions (Figure 6-19).

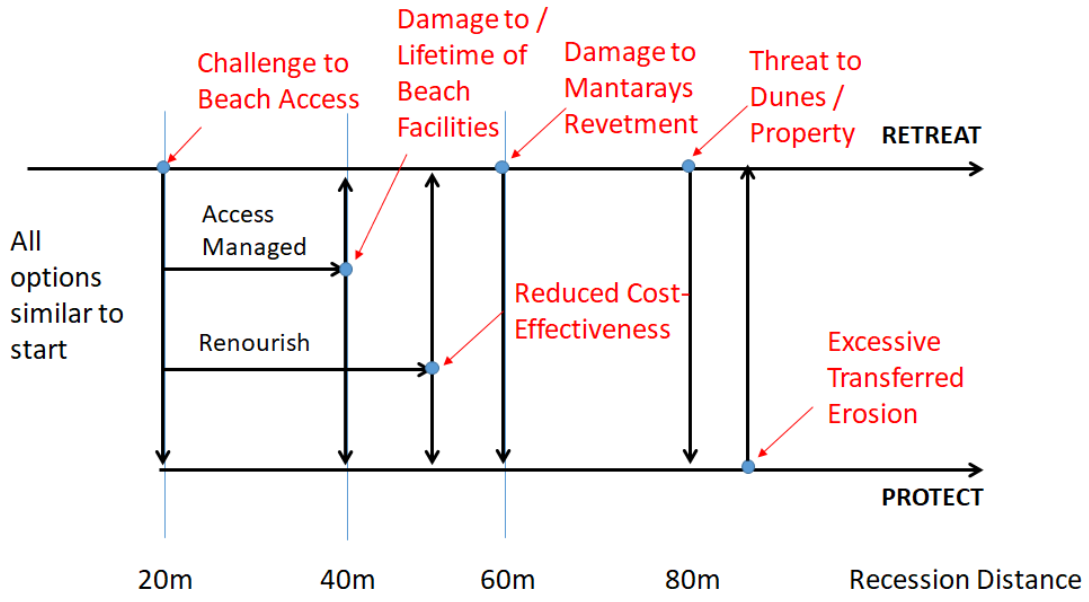


Figure 6-19: Town Beach Adaptive Pathways & Decision-Points

As an example, while recession is <20m, the 'do nothing' approach is viable. Once recession reaches around 20m, beach access will become restricted, which could be managed by:

- Accepting the loss of access
- Providing locally improved access
- Undertaking beach nourishment to offset recession
- Installing protection to mitigate the recession

These responses are all likely to remain viable until the next decision point is reached through subsequent recession.

The adaptive pathways and decision points have been used as a basis for adaptation triggers.

Relative costs of different adaptation pathways, including asset losses by 50 or 100 years are suggested by the 0% discount rate scenarios in Table 6-11. These suggest:

- By 2125, the 'no change' or managed retreat approach corresponds to $2.6M loss of existing assets along Town Beach foreshore (revetment & foreshore assets) over 2050-2095 and loss of part of the tourist lots' effective value ($0.8M) from 2095 onward [e]. Financial outlay is associated with costs of removal prior to structure failure (managed retreat) and landward extension of the revetment at Mantarays.
- Interim protection from groynes or breakwaters, with a cost of $1.8M or $2.4M, delays damage to Town Beach assets but brings forward damage to the tourist lots. For groynes, loss of Town Beach facilities is projected to occur around 2100, and slightly earlier for breakwaters, around 2090. Loss of the tourist lots' value is projected to occur over 2080-2125.
- Renourishment is projected to cost $4.5M to $13.5M. Note, sand bypassing and renourishment are separate activities, with renourishment involving placement of additional sand int the coastal system. The cost of sand bypassing has not been incorporated in adaptation cost estimates.

Renourishment is noted as the only 'full protection' option, where it is assumed able to offset erosion pressure. However, effectiveness of renourishment cannot be guaranteed. Alternative 'full protection' options using structures would require either (i) transferring recession pressure to a natural area of equivalent accretion – not present along Exmouth coast; or (ii) installing alongshore control structures that transfer erosion pressure to a sacrificial section of foreshore downdrift. Protecting a length of foreshore would increase erosion pressure for approximately 2-3x that length downdrift. i.e. if a 3km groyne field were constructed, say for $3.0M, the next 6-9km downdrift, to the north, would experience accelerated loss (Figure 6-20). The end structure should be located on a rock formation that extends landward – presence of such features has provisionally been confirmed through geophysical investigations to support dune stability assessment [15].

Issues anticipated to affect Town Beach, their anticipated time frames and recommended actions are outlined in Table 6-13. As the need for implementation is not imminent, and either retreat or interim protection options may be viable, the required timeframe and actions are noted as (R) for managed retreat or (P) for interim protection strategies.

[e] Long-term projected risk is dominated by modelled coastal recession due to sea level rise (permanent change of the coastal position) with a smaller distance considered for short-term storm erosion impacts. Modelling has considered different cross-shore mechanisms for change, such as offshore sediment transfer or landward transfer via dunes. However, actual response is likely to be influenced by both underlying geology and the alongshore redistribution of sediment, particularly within the coastal sediment cell framework. The uncertainty of projected recession requires careful application of adaptive coastal management, incorporating monitoring.

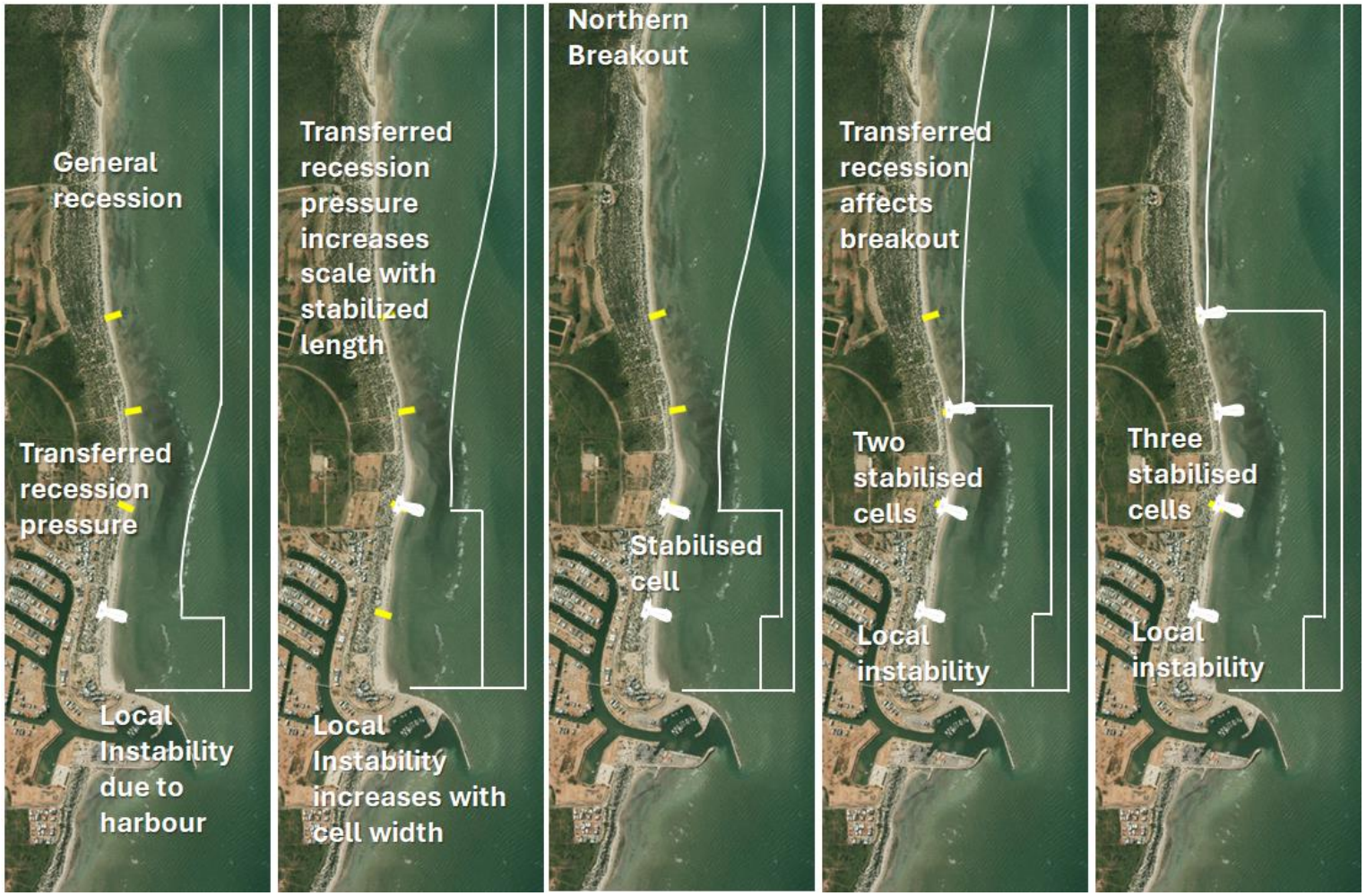


Figure 6-20: Transfer of recession pressure due to stabilisation

Table 6-13: Recommended Actions for Town Beach MU2

Issue	Required Timeframe	Recommendation
Dune Management	Immediate	Develop and implement a dune management plan, to reduce dune destabilization through traffic.
Sand Management	Immediate	Liaise with DTMI to have existing sand management practices amended to reduce scarp development.
Access Management	Immediate	Develop and implement a beach access management plan, to facilitate beach use and limit adverse impacts.
Restricted Beach Access	10-30 years	Identify and implement preferred coastal management strategy.
Instability of Existing Defences	25-50 years (R) 55-85 years (P)	(R) Monitor change & progressively remove threatened assets (P) Enhance and extend existing protection
Outflanking of Mantarays revetment	55-85 years (R) >100 years (P)	Enhance and extend existing protection (Figure 6-21)
Reducing Tourist lot value due to erosion	60-90 years (R) 40-70 years (P)	Review lot management – consider retreat or local protection. Requirements should be defined under coastal SCA.

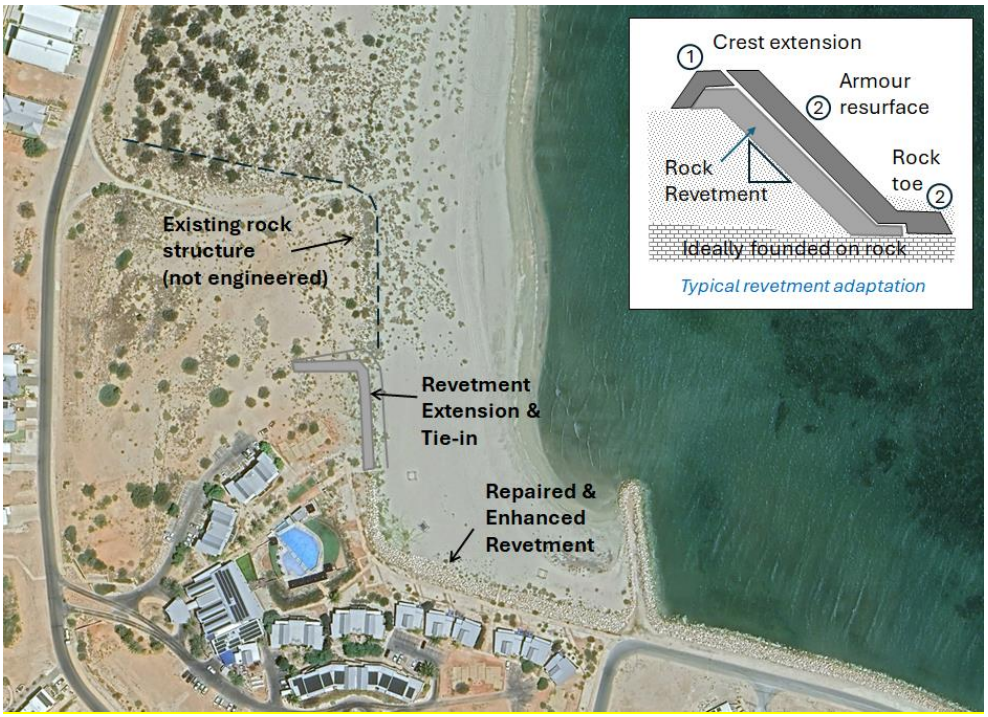


Figure 6-21: Local revetment extension and adaptation adjacent to Mantarays

6.5. MU3: Harbour & Canal Lots

Exmouth Boat Harbour and Exmouth Marina Village (Figure 6-22) contain the most intensive infrastructure development along Exmouth coast. Exmouth Boat Harbour was built in 1997-1999, with subsequent extension of a canal system from the harbour basin forming Exmouth Marina Village (EMV), built over 2004-2010. Many of the structures within the boat harbour and EMV are designed for direct interface with the sea, including revetments, jetties and boat ramps (Figure 6-24), which consequently will have changing performance with projected sea level rise.

The Department of Transport and Major Infrastructure manages the Boat Harbour facility, and the Shire of Exmouth has overall management of Exmouth Marina Village, with private land ownership of canal lots encompassing jetties and canal walling inside EMV.

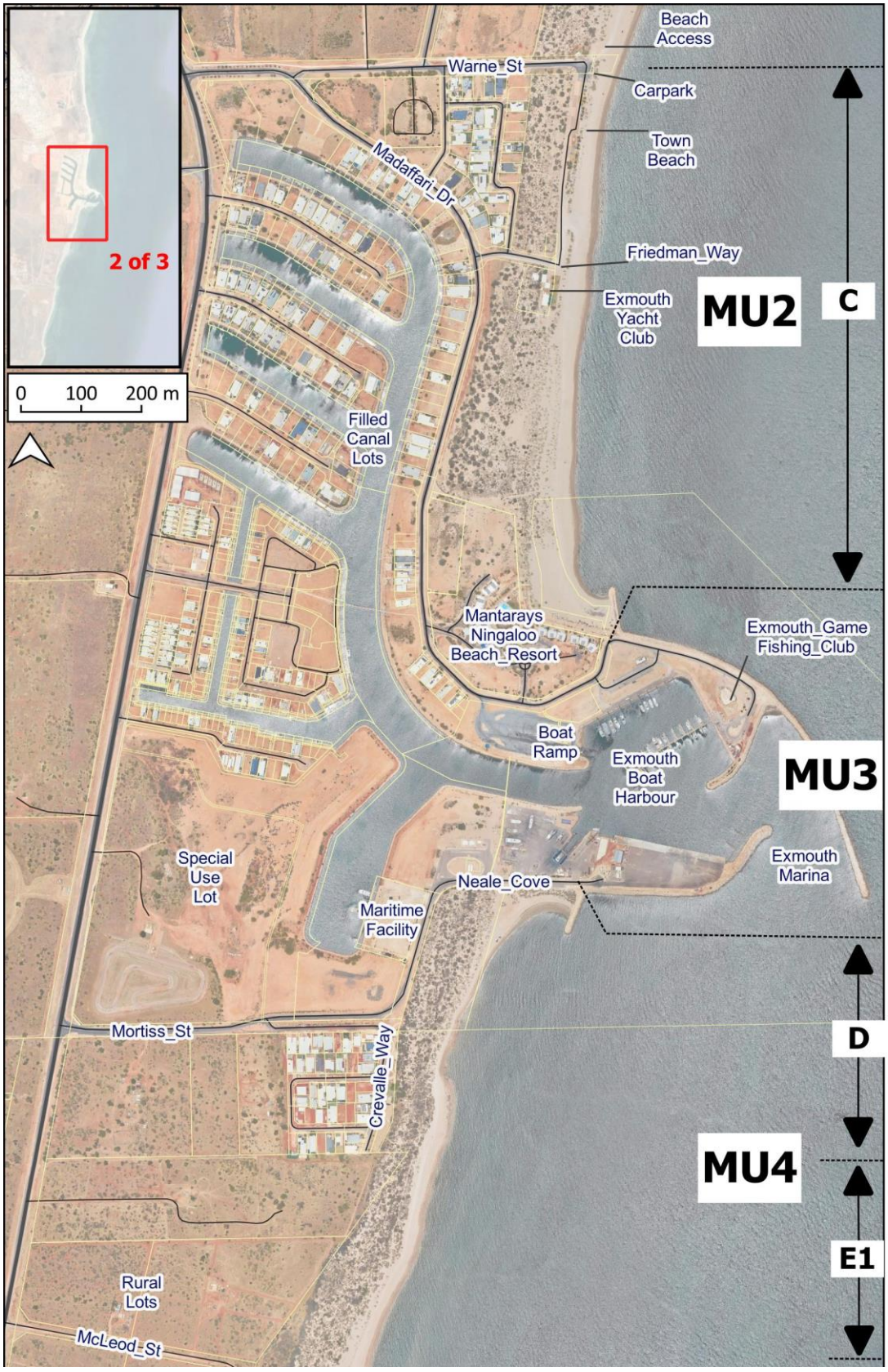


Figure 6-22: Exmouth Boat Harbour and Exmouth Marina Village (Canal Lots)

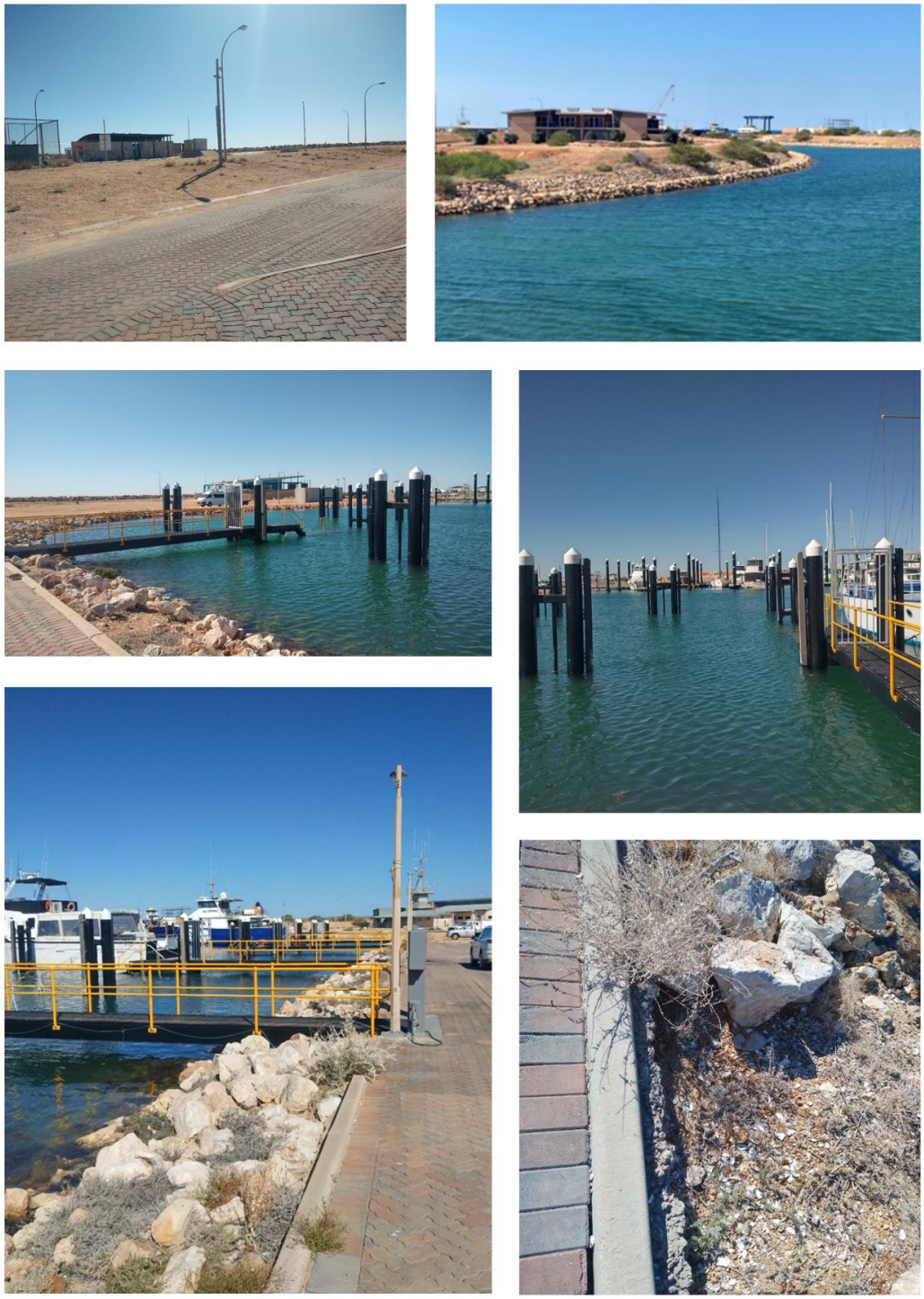


Figure 6-23: Facilities within MU3 Exmouth Marina and Canal Lots

Exmouth Boat Harbour and Marina Village are enclosed by substantial breakwaters (Figure 6-24). Although severe coastal recession may ultimately require landward extension of the breakwaters, they are considered to effectively mitigate erosion hazard to the infrastructure and assets in the boat harbour and canal lots. Consequently, identified coastal hazard is mainly related to inundation (Table 6-14), except in the longer-term, where wider-scale coastal recession may affect Neale Cove foreshore.

It is noted that progressive adaptation of Exmouth Boat Harbour breakwaters will be required and is likely to be integrated into ongoing maintenance of these structures by the Department of Transport and Major Infrastructure. Increasing wave conditions and requirements for raising the breakwater crest with projected sea level rise have been assessed [16].

Assets where existing management does not adequately cater for coastal hazards, based on the risk assessment process in Section 5, include Exmouth Game Fishing Club and the wider areas of hardstand throughout Exmouth Boat Harbour. Masterplanning for the Boat Harbour [17] further indicates potential for changing asset types within the boat harbour, which may reduce tolerance to inundation hazard.

Table 6-14: Assets deemed to require Hazard Management in MU3

Exmouth Canal Facilities (Jetties & Walkways) were not identified through the vulnerability assessment, but will likely require planning modification, likely with a long time for establishment.

	Erosion Hazard	Inundation Hazard
Present-day Risk *Requires mitigation now*		Exmouth Game Fishing Club Exmouth Harbour
Projected Risk *Requires adaptation plan now*		
Emerging Risk *Integrate into planning*		
Possible Risk *Consider long-term management*	Neale Cove Foreshore	Residential lots adjacent to Crevalle Way

Figure 6-24: Exmouth Boat Harbour and Exmouth Marina Village

MU3: EXMOUTH MARINA & CANALS Report Card	
Use and 'value'	• Maritime facilities • Marina and canal estate area • Crevalle Way residential lots
Adaptation Objectives	Increased sea levels will require facilities to be modified progressively.
Hazard 	**Erosion:** Related to the structural integrity of works **Inundation:** Working facilities – dependent on constructions levels (oceanic flooding) Marina/canal estate – land levels set well above inundation levels but walkways and stores built on low lying concrete areas subject to inundation hazard
Assets 	• Harbour infrastructure • Canal residences • Walkways; Public and private access • Residential lots & foreshore reserve
Damage 	• Damage to walkways and loss of public access along canal estates • Potential damage to harbour infrastructure and working facilities
Mitigation: 	**Inundation** Increased sea levels will require facilities to be modified progressively. • Adaptation sequences for residential facilities linked to decision making with stakeholder groups – roles and responsibilities; tradeoffs between private responses versus centralized adaptive efforts and appropriate mechanism to allow this to be achieved. • Adaptation sequences for working facilities related to construction levels, life cycle of structures; requirement to integrate with waterways management plans with revised water levels for jetty construction every 10 years.

6.5.1. Coastal Risk Management for Exmouth Boat Harbour and Canal Lots

Inundation and flooding pressures vary throughout Exmouth Boat Harbour and the Canal Lots. There are four distinct ways in which hydrodynamics processes affect the need for inundation (or flooding) risk management:

1. Around the edge of the Boat Harbour, inundation is developed by **wave overtopping** or water passing through the harbour breakwaters, with ocean water level being an important secondary process. Wave overtopping inundation affects a higher ground level than the ocean water level. Wave overtopping can be mitigated by building the breakwaters higher, modifying the face to reduce wave runup, increasing development setback from the breakwater crest, or enhancing the drainage pathways for overtopping. Choice of an appropriate strategy should be incorporated within Exmouth Boat Harbour masterplanning, and ongoing maintenance and adaptation of the breakwaters by the Department of Transport and Major Infrastructure.

2. Inside the boat harbour, inundation is determined mainly by the **ocean water level**, which consequently is directly affected by projected sea level rise. Inundation risk outlined in the Coastal Hazard Assessment (Appendix B) is directly relevant to this hazard, with consideration of appropriate freeboard [18].

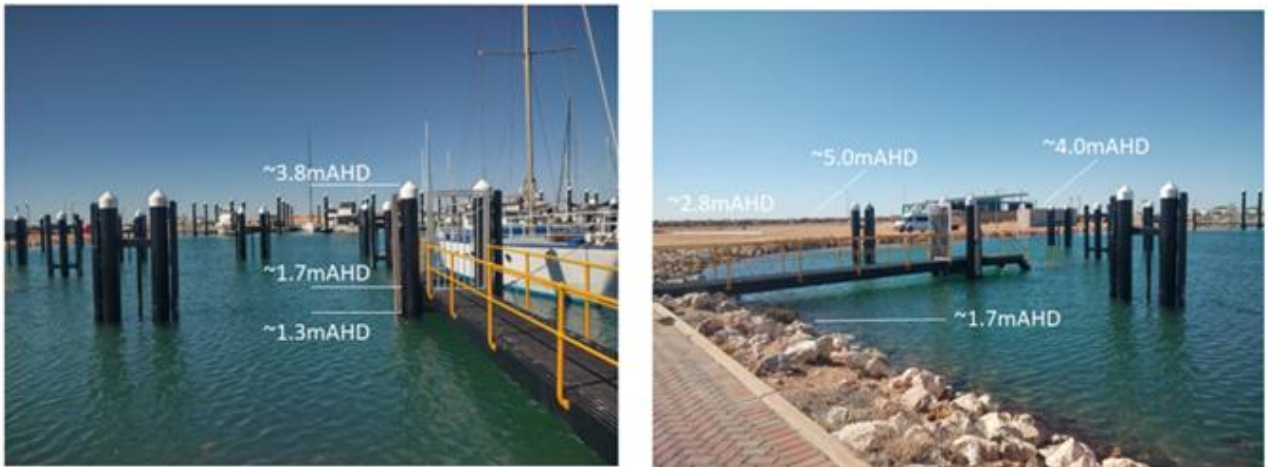


Figure 6-25: Harbour Infrastructure Levels, MU3

3. Canal lot elevation is NOT related to coastal inundation, with the level of +5.25m AHD based on **runoff flooding** along Murat Road. This is above the best estimate limit of coastal inundation for 500-yr ARI plus sea level rise (+4.6m AHD).

4. Within the canals, inundation affects the edge walling and associated facilities (walkways, jetties & storage sheds). Inundation is mainly associated with ocean water levels, with potential for **super-elevation** due to runoff drainage, or canal-surge interactions. Although water levels in the canals can be slightly higher than the corresponding ocean level, in general it is difficult for these processes to occur at the same time as extreme ocean water levels (e.g. peak runoff is usually several hours after the storm peak). Consequently, guidance regarding adaptation for these areas has been based on tide gauge analyses reported in Appendix B.

For marine facilities inside the boat harbour and canal lots, increasing inundation generally constrains the amount of time the facility can be used effectively or safely (Figure 6-26).

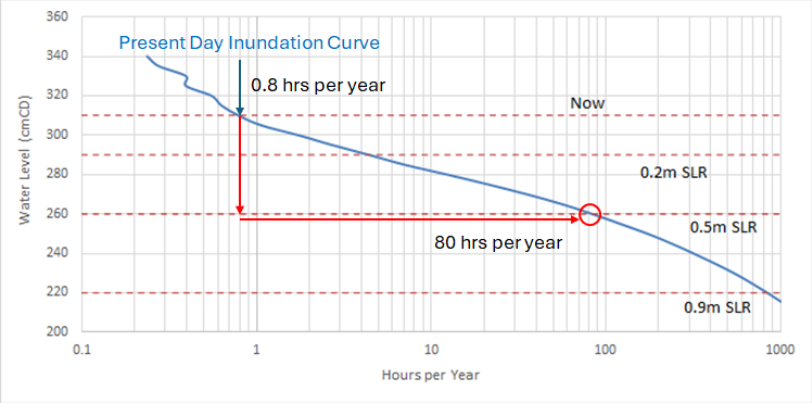


Figure 6-26: Inundation Occurrence and Change with SLR
Change to inundation occurrence noted for walkway level +1.7m AHD (+3.1m CD)

Inundation risks can be managed by:

- Modifying the level of inundation exposure (i.e. raising assets)
- Increasing asset robustness or tolerance to inundation (e.g. flood proofing)
- Modifying the way in which assets are used (e.g. accepting reduced access).

Where these activities are achievable in a practical sense, they may form alternative management pathways or 'options'. However, they are more typically used in a complementary fashion: for example, level raising is usually done as a discrete action, say every 20-30 years, with modification of tolerance or changing asset use mitigating the changing hazard profile for the periods between asset lifts.

With some variation, structures within the boat harbour precinct can be categorised as:

- Boat harbour facilities, including moorings for fishing vessels, industrial facilities, and larger recreational craft. The boat harbour is owned and managed by the Department of Transport and Major Infrastructure, and includes breakwaters, areas of hardstand, revetments, and boat ramps.
- Canal estate facilities built as part of the overall EMV establishment and subsequent Superlot A development. These include revetments, spillways, walkways, and jetties. EMV is a Shire asset, with active management supported by Department of Transport and Major Infrastructure, and ownership of private facilities, including jetties and walling, being the responsibility of individual landowners.
- Canal estate facilities built as part of the Superlot B development differ substantially from those developed for Superlot A, as tilt-up concrete walling has been used for the canal edge treatment, with buildings located on top of the upper walls. Ownership and management of the walling is the responsibility of individual lot owners, but there is strong interaction between adjacent properties, and access to jetties via the walkway is provided through common-use access points, which are managed by the Shire.

Variation in ownership and management of revetments, jetties and walkways creates potential challenges to future adaptation. This is illustrated by the existing walkway level of +1.7m AHD, which is presently inundated <1 hour per year, but with 0.5m SLR, it will be inundated ~100 hours (over ~30 days) per year. Although Exmouth Boat Harbour Boat Mooring and Management Plan [19] provides a framework with which to raise jetty levels with SLR, this will result in a mix of old and new jetty abutment levels, likely making the walkway dysfunctional. This has a potential knock-on of requiring an increasing number of access points from the canal lots to the jetties.

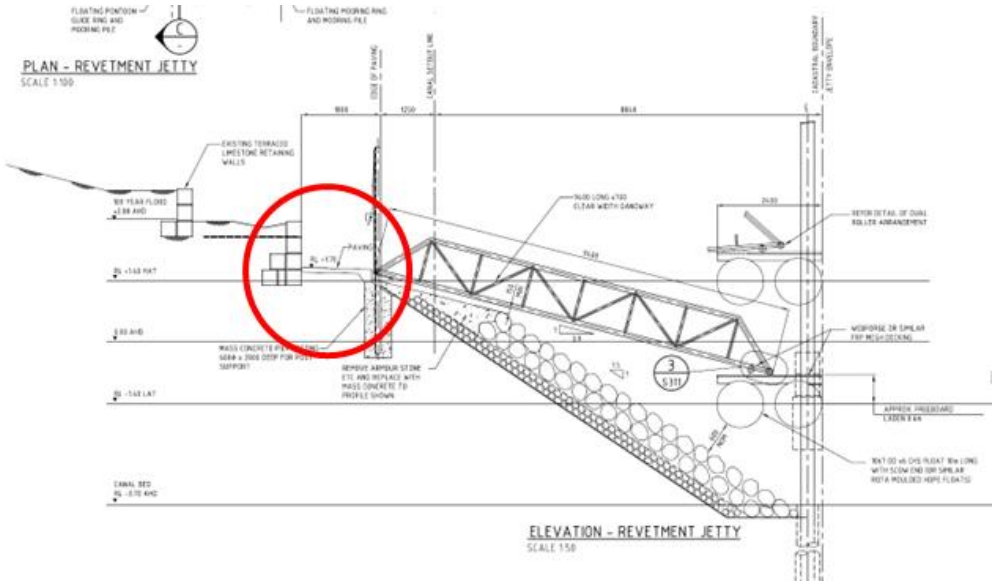


Figure 6-27: Typical Canal Revetment Structure
Walkway Level at +1.7m AHD

6.5.2. Adaptive Pathway for Exmouth Boat Harbour

Existing land levels for Exmouth Boat Harbour are variable, including sections of lower-level hardstand to facilitate transfer at the jetty deck level and a raised area at Exmouth Game Fishing Club (Figure 6-25). Comparison of approximate inundation coverage at different levels (Figure 6-28) shows that inundation of the hardstand areas starts below the 12yr ARI level, and virtually all the facility would be underwater for an event reaching +2.5m AHD.

Figure 6-28: Inundation Extents for Exmouth Boat Harbour & Marina Village
Water levels shown are described with present-day recurrence.

Adaptive requirements for the boat harbour precinct depend on the tolerable frequency of inundation, which is largely a function of use (Table 6-15). Although harbour hardstand may tolerate occasional inundation with minor damage, a minimum fill level is required to avoid the inconvenience of frequent inundation. Activities proposed within Exmouth Boat Harbour Masterplan, including hotel development, would require additional fill levels due to lower tolerance to inundation risk.

Table 6-15: Required Harbour Land Levels & Fill Requirements

Harbour Use	Desired Behaviour	Required Level	Volume	Cost @$100/m^3
'Wet-use'	Dry for HAT +0.5m	2.0m AHD + SLR	110,000 m^3	$11M
General Use	Dry for 100yr ARI + 0.5m	3.4m AHD+SLR	150,000 m^3	$15M
Accommodation	Dry for 500yr ARI + 0.5m	4.1m AHD + SLR	200,000 m^3	$20M

It is possible to use different fill levels or floor levels for varied uses (e.g. a building may have office facilities >1.0m above the shed floor). However, for this to be effective, evacuation pathways should be established that maintain (rising) elevations heading further landward. Isolated elevated levels, such as Exmouth Game Fishing Club (visible as a high point up to 3.0m AHD in Figure 6-28) do not provide effective evacuation. It is further noted that an evacuation path should be away from the breakwater, due to potential effects of wave overtopping.

6.5.3. Adaptive Pathways for Canal Lots

A high-level adaptation sequence for Canal Lots is provided for two discrete areas:

Working facilities

a. All jetties need an adaptive sequence tied to the boat mooring and management plan or waterways management plan (jetty lifespan approx. 25yrs so need to cope with sea level change within this timeframe. When updating management plan every 10 yrs for example).
b. Working level life cycle of predicted change for structures with revised water level every 10 years.

Residential facilities

c. **Marina/canal estate area**: Land levels in marina area are set well above inundation levels (runoff flooding) – 5.25m –– this is well above the coastal inundation level.
d. **Walkway**: At the present time, flood level frequency does not provide a significant hazard or impediment to public or private access to the canal estates. Presently, the flooding occurs for approximately 1-2 hours per year but with projected sea level rise of approximately +0.2m, there will be around a 10-fold increase, and around 100 hours of walkway flooding per year for SLR of +0.5m. While this is not structurally significant, it would equate to 30 days per year when water has encroached on footpaths presenting a functional inconvenience.
e. **Walling**: **Under present policy it is the landowner's responsibility to fix or adapt structures –** while this may be an appropriate response for the walling, there are clear examples of where this has not worked on a national basis (e.g NSW and Yunderup). Particularly problematic at the walkway and floodway.

Therefore, three options that should be considered are:

i. Implementing changes via waterways management plan, placing onus on landowners.
ii. Change by-laws to transfer responsibility from individual landowners requiring them instead to contribute to a centralized adaptation fund.
iii. Requirement for landowners to provide their own access.

6.5.4. Adaptive Pathway for Neale Cove Foreshore

Neale Cove foreshore is part of both MU3 for Exmouth Boat Harbour and MU4 for South of Harbour. This is because existing foreshore and dune provides a critical erosion buffer to the single road entrance to the south side of Exmouth Boat Harbour, whilst also protecting residential development on the south side of the harbour precinct. The connected nature of erosion hazard along this length suggests that a linear coastal defence (e.g. revetment) is likely to be appropriate.

Coastal recession at Neale Cove has reduced likelihood to occur as it is on the south side of the Harbour, which in the long-term, has acted as a sink for alongshore sediment transport. However, only 15m erosion would be needed to expose the landward end of the harbour southern breakwater, making the road susceptible to sand drift and potentially causing flanking to landward. Activities to offset this could include stopping sand bypassing, extending the sand trap spur, or extending the original breakwater ~80m with a revetment.

For recession in the order of 40m, protection of the Neale Cove residential area would require ~350m revetment, including tie-ins, partly mitigated by underlying rock [15] (see Appendix B). The wider dune buffer along the harbour road means that protection may not be required until recession reaches 60m, which would involve a ~180m long revetment connecting the other two sections. Geophysical assessment indicated higher levels of rock underlying the dune through this section [15] (it is <2m AHD adjacent to Neale Cove residential area).

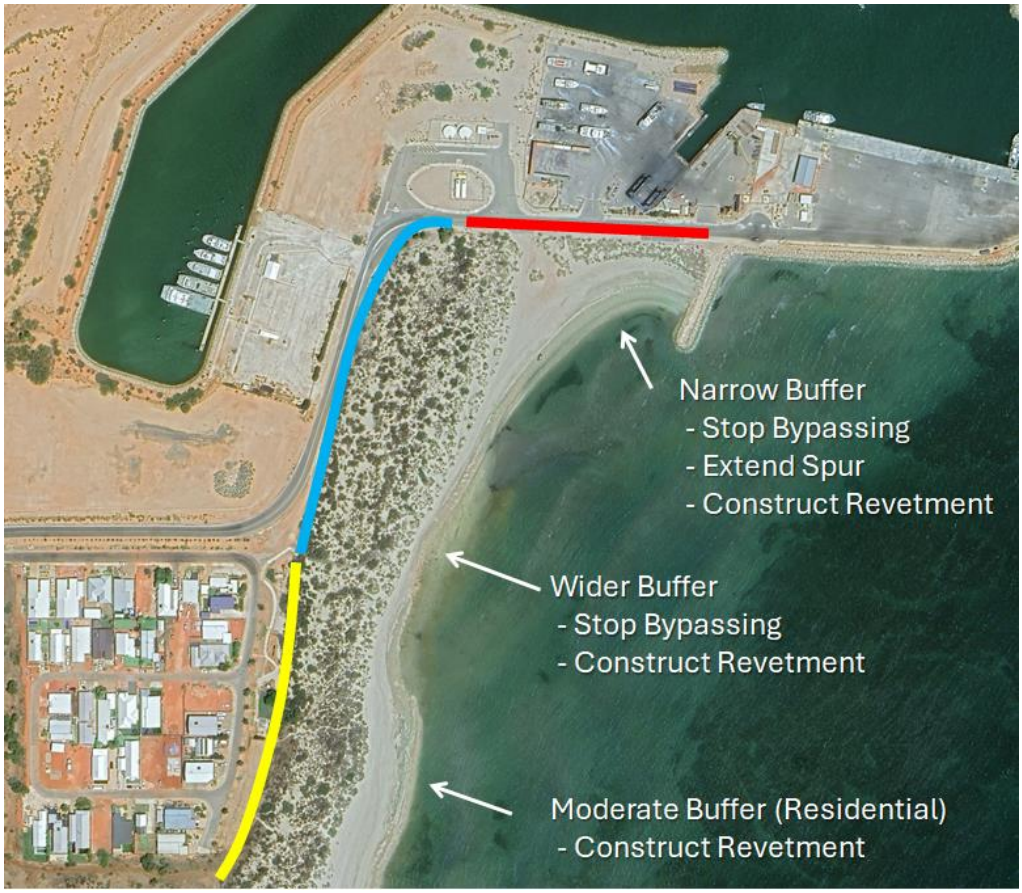


Figure 6-29: Segments for Neale Cove Erosion Management

6.5.5. Recommended Actions for Exmouth Boat Harbour & Marina Village

A recommended pathway for risk treatment in MU3 is:

Table 6-16: Recommended Actions for MU3

Issue	Timeframe	Recommendation
Private jetties	0-10 years (ongoing)	Update BMMP every 10 years with revised sea levels & jetty design requirements.
Concrete walkway	Immediate	Identify management options to landowners. Request DTMI to support development of adaptive design *. Update BMMP to provide direction for adaptation.
Revetment walkway	Immediate	Identify management options to landowners *. Update BMMP to provide direction for adaptation.
Landward limit of south breakwater	10-25 years	Extend south breakwater landward by ~80m to prevent impacts from recession (Figure 6-29).
Revetment walling	10-25 years	Managed by landowners *. Adapt walling as part of repairs / replacement cycle.
Concrete walling	10-25 years	Managed by landowners *. Adapt walling as part of repairs / replacement cycle.
Public boat ramp	15-25 years	Managed by Transport. Adaptation to be incorporated in maintenance program.
Harbour walling	15-30 years	Managed by Transport. Adaptation to be incorporated in maintenance program.
Harbour land levels	30 years **	Managed by Transport. Levels to be reviewed for modified land-use within Harbour Masterplan. Adaptation to be incorporated in maintenance program.
Public jetties	15-30 years	Adapt jetties as part of repairs / replacement cycle.
Road adjacent to Neale Cove (1)	45-90 years	Construct ~350m long revetment to protect harbour access road
Road adjacent to Neale Cove (2)	65+ years	Construct ~180m long revetment to protect harbour access road

* Walkway and walling structures maintenance and adaptation is the responsibility of landowners. However, piecemeal adaptation is likely to have high cost and reduce facility effectiveness. It is recommended that a preferred adaptation sequence be identified, guiding landowners to integrate adaptation into their maintenance actions.
These walkways are largely on private land, but give continuous access along the waterway, and consequently provide a perception of public access.

** Relative need to raise harbour land levels is strongly affected by harbour land-use. Levels would need to be raised before development of short-stay or residential facilities.

6.6. MU4: South of Exmouth Boat Harbour

South of Exmouth Boat Harbour is the least intensively developed part of Exmouth townsite foreshore, with a small area of residential development at Crevalle Way (see Figure 6-22 and Figure 6-29), and a mixture of semi-rural and special use lots along McLeod street (Figure 6-30). Lots are generally on low-moderate elevation floodplain areas, behind the coastal dune barrier of 40-60m width. A number of lots closest to the coast are prone to coastal inundation, with water able to pass through the dune via creek breakouts and dune blowouts.

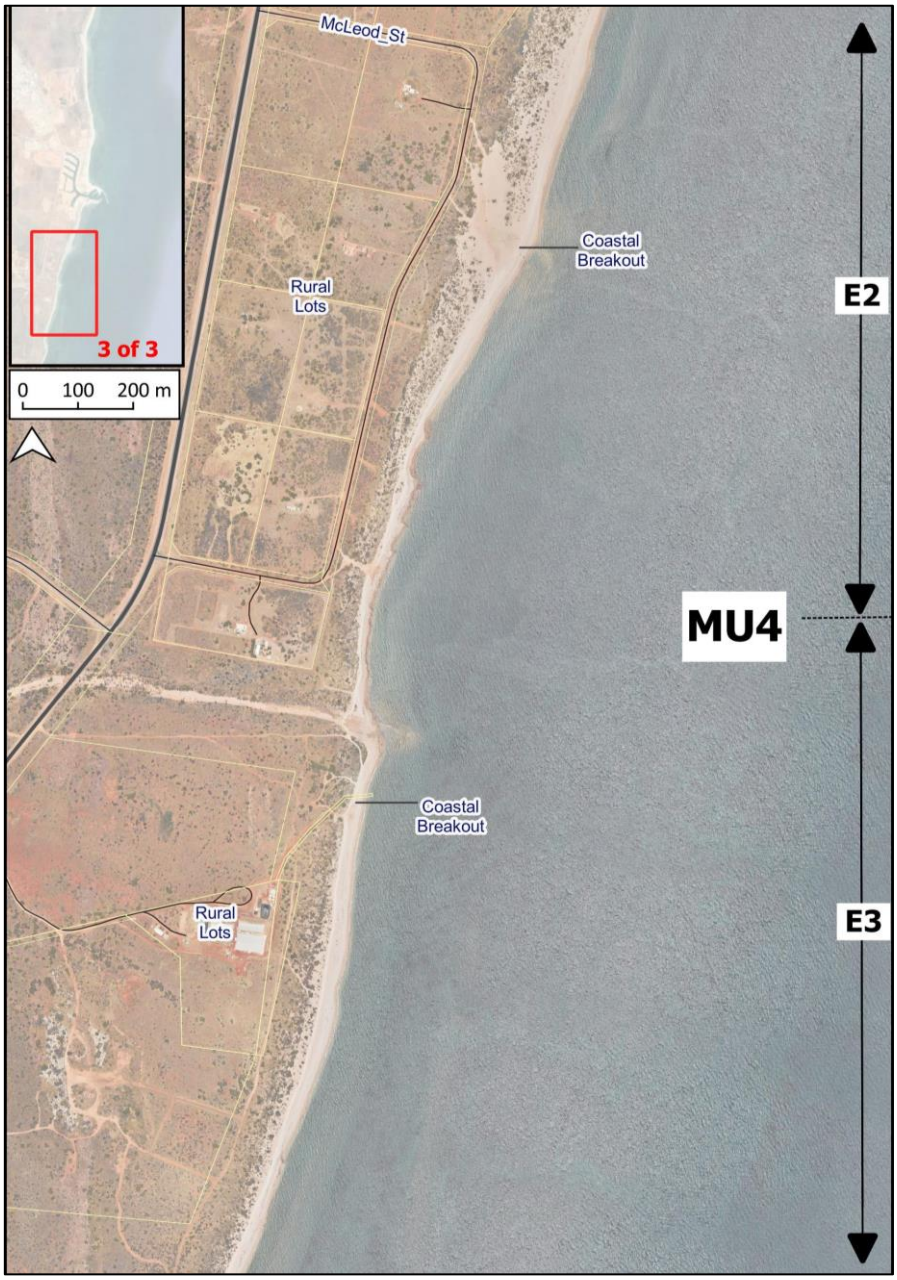


Figure 6-30: South of Harbour: MU4 encompassing Segments E2 & E3

Evaluation of risks, accounting for community values, suggests a priority for inundation hazard management of the lots adjacent to Crevalle Way (Table 6-17). Erosion and inundation hazards along McLeod Street were given lower priority, largely due to existing low density of development. Further development would increase the priority for hazard management.

Table 6-17: Assets deemed to require Hazard Management in MU4

	Erosion Hazard	Inundation Hazard
Present-day Risk *Requires mitigation now*		Lots adjacent to breakouts
Projected Risk *Requires adaptation plan now*	McLeod St Special Use Lots	
Emerging Risk *Integrate into planning*	McLeod Street Rural Lots South of McLeod St	
Possible Risk *Consider long-term management*	Rural Lots N & W of McLeod St	Lots behind dunes susceptible to erosion

Figure 6-31: MU4 South of Exmouth Boat Harbour

6.6.1. Coastal Risk Management for South of Harbour (MU4)

Existing perception of coastal risk is strongly linked to roles played by coastal dunes south of Exmouth Boat Harbour. Where there are breaches in the dune, due to creek breakouts or dune blowouts, the risk is heightened, either as pathways for inundation, or as openings through which storm wave action can locally enhance erosion hazard. The dunes along this section of the foreshore are relatively narrow, with low-lying floodplain behind (Figure 6-32). A number of the breakouts provide drainage pathways for runoff.

Preliminary evaluation of dune stability has been undertaken by looking at cross-sectional areas, indicating dunes east of McLeod Street are susceptible to breaching during severe storms in the present-day (see Appendix B Coastal Hazard Assessment). Coastal recession will progressively increase the susceptibility of the dunes protecting MU4, with the entire dune barrier either lost or susceptible to breaching with recession of 50m.

Although planning allowances for coastal recession are in the order of 140-170m, with further landward exposure to erosion through dune breaches, it is expected that coastal recession is likely to be smaller than the allowance, due to:

1. Presence of a wide intertidal rock platform reduces the capacity for offshore transport of sediment used to project response to sea level rise.
2. Sections of exposed rock along the beach and lower dune suggest the presence of higher underlying rock formations, which may act as a foundation for the coastal dunes, increasing coastal stability. A geotechnical (geophysical) investigation may support improved definition of coastal hazard risk along this foreshore (see Section 7.1).
3. Historically, net (annual) alongshore sediment transport has mainly been northwards, which occasional reversals. Exmouth Boat Harbour therefore traps sediment on its south side, with the accumulated material potentially offsetting part of the projected coastal recession. The rate of sediment trapping will be influenced by ongoing sand management for Exmouth Boat Harbour (Section 7.3).

Relative protection provided by the dunes provides a coastal hazard management sequence in the context of coastal recession (Table 6-18):

Table 6-18: Coastal Hazard Management Sequence for MU4

Recession	Hazard Pathway	Hazard Management
0-10m	Coastal inundation through existing breakouts	• Encourage property level protection • Consider capacity for breakout management, including drainage
10-25m	Dunes increasingly susceptible to breaching. May be subject to landward migration.	• Dune management / reinforcement to enhance stability
>25m	Dunes largely ineffective for hazard mitigation	• Retreat from coastal erosion • Property level protection for inundation • Evaluate capacity for protection

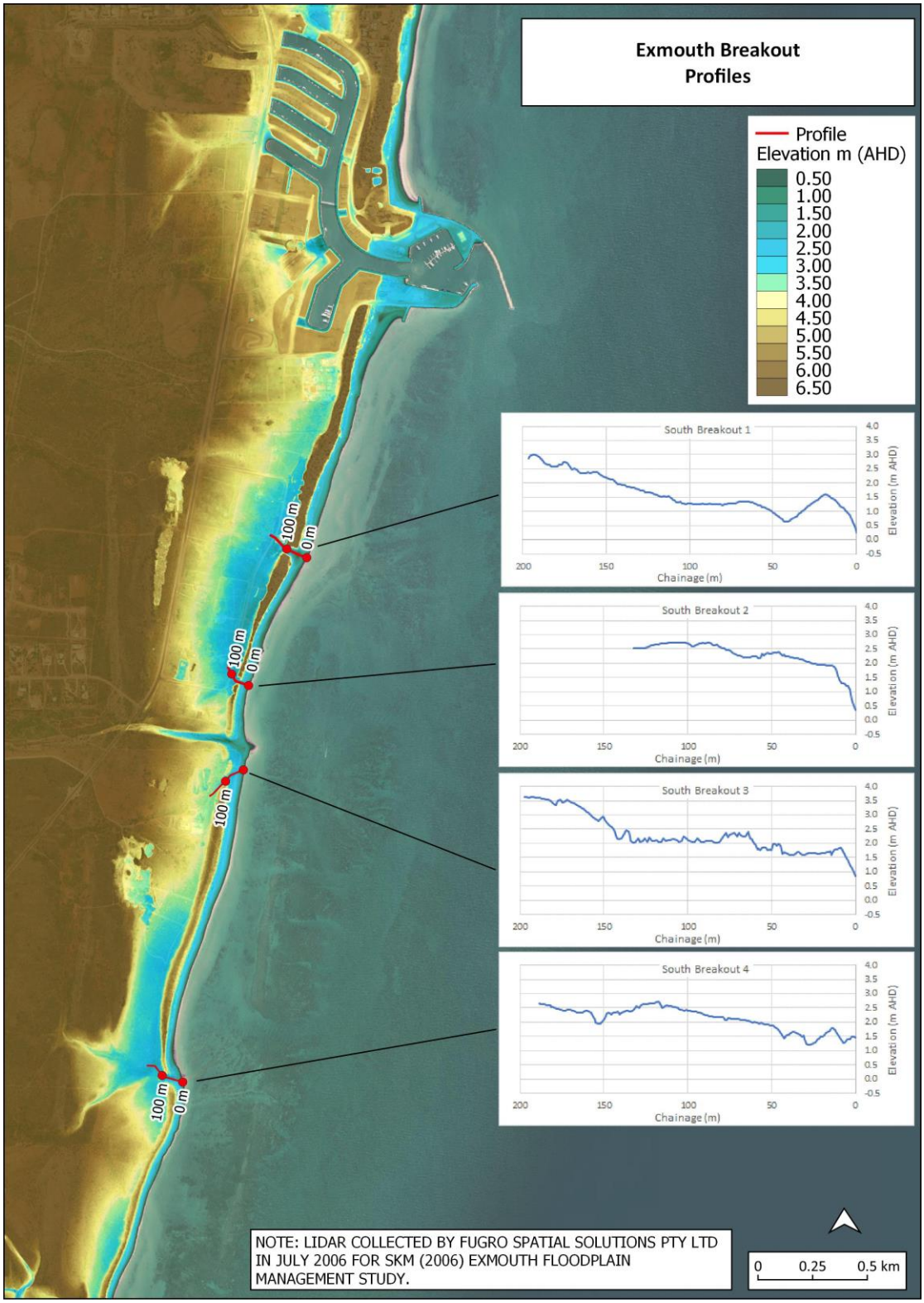


Figure 6-32: Dune Structure, Breakouts & Floodplain South of Boat Harbour (MU4)

MU 4: SOUTH OF HARBOUR Report Card	
Use and 'value'	• Neale Cove - Sediment sink adjacent to boat harbour (source for bypassing to Town Beach) • Neale Cove – maritime infrastructure • Crevalle Way - Foreshore and residential area at Crevalle Way • South of Crevalle Way along McLeod St – rural lots
Hazard 	**Erosion:** • Erosion hazard immediately south of the harbour linked to sand management strategy, with the existing strategy of removal from the Neale Cove area contributing to greater erosion hazard for Segment D • Crevalle Way area exposed to erosion hazard by 2070, with residential area by 2125. Neale Cove and adjacent maritime area is exposed by 2125. • Further south erosion hazard is variable, with present-day risk associated with dune breaching in Segment E2. **Inundation:** • South of Exmouth Harbour rural sites occupy relatively low-lying land which can be inundated through low parts of the coastal dune. • Inundation hazard first crosses the lowest parts of Murat Road near Gnulli Court, with Murat Road near McLeod Street also subject to inundation hazard. This may affect town access in evacuation scenarios.
Assets 	Neale Street (Segment D): • maritime facility; private dwellings Crevalle Way (Segment D): • Foreshore • Road • Residential area McLeod Street (Segment E): • Rural lot zone special use N or McLeod Street • Rural Lot N of McLeod Street
Damage 	Loss of dune, damage to road and adjacent maritime facilities in the area adjacent to Neale Cove by 2125. Damage to road at Crevalle Way and foreshore area and access by 2070 Residential area at Crevalle way likely to be impacted by dune erosion and dune mobility by 2125. Rural lots in Segment E1, E2 and E3 impacted by dune breaching and sand mobility.
Mitigation: 	• Tradeoffs – e.g. ongoing sediment management programme removing sand from sink at Neale Street to bypass to Town Beach; protection at Neale Street versus Geotech survey and/or active dune management (now) and targeted protection of corner of road potentially at risk and sea wall adjacent to private dwellings (later); further South, active dune management for rural lots to stabilize and enhance resilience of dunes v fill of low lying land on lots in line with policy. • Implications of dune mobility for sub-division of lots.

6.6.2. Adaptive Pathways for South of Harbor (MU4)

As noted in Section 6.5.4, proximity of Crevalle Way to Exmouth Boat Harbour means that adaptation to coastal erosion pressure should be linked to Neale Cove foreshore management. Additionally, there is a pathway for potential inundation risk from floodplain basin to the south. A suggested adaptive sequence includes:

- Geotechnical assessment to establish extent and elevation of rock.
- Increasing dune stability (monitoring & active dune management)
- Fill low lying land landward of dune and south of Crevalle Way to reduce incidence of *inundation*: note that fill in this area does not offset the erosion hazard associated with dune instability.
- Alongshore structural protection, integrated with protection of Neale Street.

Outcomes from the geotechnical assessment will guide relative efforts on dune management and protective works:

1 – Geotechnical survey of the area is undertaken, and no rock is located: In this scenario the adaptation sequence would commence with active dune management across the length of the area.

2 – Rock located at discrete sites: Targeted dune management for areas lacking rock control.

3 – Comprehensive rock coverage: Monitoring and review of dune areas with adaptive approach to management as required.

Consideration of pros and cons for management of inundation and erosion is provided for MU4 (Table 6-19).

Table 6-19: Adaptation Options for MU4

Option	Location	Considerations
Do nothing* *Assumption that status quo in terms of sediment management is retained	**Neale Street** – continued sediment bypassing will lead to decreased stability to the south (but increased resilience at Town Beach With coastal recession, the dune will erode through the southern section (the extent of which determined by presence or absence of rock control) creating intolerable risk to existing private lots.	Can continue to do this in the short term but will require attention with SLR Timing – not occurring at the present but there will be a point at which land becomes unsaleable
Protect	**Neale Street** – Under policy allowances 80m recession would result in: 1. Dune drift (up to about 30m width of dune) 2. Erosion (less than 30m of dune remain) of road; threat to private residences A foreshore revetment would be required along Neale Street and Crevalle Way – with underlying rock approximately 1-2m AHD.	PROS – Notionally creating resilient land that can be subdivided CONS – implications for beach access and utility (although this area is not as heavily used or 'valued' as Town Beach foreshore)
	Area around McLeod ST FILL land level above 2.9m in line with policy – requires construction of drainage system. Threat associated with dune instability reduces by filling the area landward of the dune. **This is not recommended.**	PROS – raising land level address issues of dune mobility and decreases inundation hazard. Development requirement to fill is at the cost of the landowner. CONS – unlikely to provide significantly more 'resilient' dune – sand eroded will be transported north.
Soft protection	Increase dune resilience and therefore enhance capacity to withstand erosion, widening and raising the dune 1. Early options – sand management and minimal expenditure on enhancing, monitor and review and hope dune retain size 2. Build dune up – 25 m^3/m @ $500/m3 along about a 200m stretch of coast at a cost of about $0.25M – reduces risk of breaching during a severe storm.	PRO – adaptive management approach; cost effective and iterative. CON – requires ongoing investment with benefit to the landowner but cost is to the Shire.

6.6.3. Summary of Recommendations

A recommended pathway for risk treatment in MU4 is:

Table 6-20: Summary of Recommendations for MU4

Issue	Timeframe	Recommendation
Inadequate dune capacity to resist severe storm	Immediate	Set lease time limits. Do not consider conversion to freehold.
	Immediate	Liaise with WALGA to arrange geophysical assessment & revise dune stability evaluation.
	10-30 years	Enhanced dune management to build dune capacity over time.
Inadequate foreshore reserve (lots south of harbour)	Immediate	Geotechnical assessment to guide adaptation pathway, extending the survey conducted from Town Beach to Neale Cove [15]. Underlying rock is likely to partly mitigate risk.

6.6.4. Exmouth-Minilya Road

Beyond MU4, Exmouth-Minilya Road provides a single road route connecting the Exmouth and the Northwest Cape to the rest of Western Australia. This route is critical for the Town, as the pathway for gas delivery essential to Exmouth's power supply.

Existing management of Exmouth-Minilya Road by Main Roads WA and supported by the Shire of Exmouth, presently copes with disruptions associated with flash flooding events along a series of small, steep creeks [20]. The frequency and character of management has potential to change with sea level rise causing coastal inundation.

Preliminary mapping indicates likely impact to Exmouth-Minilya Road by coastal inundation around +3.35m AHD (not considering the effect of wave action). This has a present-day recurrence of approximately 0.3% per annum, which is considered a tolerable risk for road damage, which is usually targeted at 1-5% per annum.

With projected sea level rise, coastal inundation of Exmouth-Minilya Road increases in likelihood, reaching a 1% per annum likelihood for +0.5m sea level rise, projected by around 2075. This is considered an emerging problem, which should be acknowledged in long-term regional planning and ongoing discussions with Main Roads WA.

Figure 6-33: Extreme Coastal Flood Extent on Exmouth-Minilya Road (+3.35m AHD)

7. TARGETED ACTIONS

7.1. Coastal Monitoring and Geophysical Investigation

Coastal monitoring should be comprised of observations of the beach and the dune. Decisions regarding Town Beach can largely be related to the available width of the beach (above high tide) in front of assets (see Figure 6-19), which provides an indication of beach access, and potential for erosion impacts. The first hard trigger point for decision making occurs with 20m of recession from the present-day shoreline, which corresponds to no effective beach in front of the existing seawall at high tide.

Monitoring activities 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 7-1). In general, low-cost monitoring is considered viable for Exmouth Town Beach, potentially using moderate or high-cost monitoring at baseline and every 5-10 years, to provide a framework for lower resolution assessment.

Table 7-1: Alternative Monitoring Levels

	Beach Measurement	Dune Condition	Coverage
Low Cost	Beach Width	Site Photos & Review of Landgate imagery	Beach width @ 200m centres. 10-15 selected dune 'problem points'
Moderate Cost	RTK Beach scarp, dune toe, dune crest	Transects with Species ID	Continuous (~5m) line surveys, with transects @ 200m centres to back of dune
High Cost	Topographic survey	Drone Survey & Multispectral	Continuous 2D coverage (~5m max), extending >20m behind back of dune

Results from ongoing coastal monitoring should be assessed with reference to sustained long-term coastal monitoring activities, specifically including:

- Measurement of sea levels at Department of Transport and Major Infrastructure's Exmouth tide gauge.
- Measurement of atmospheric conditions at the Bureau of Meteorology's Weather Station 005007 at Learmonth 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 [21]. Geoscience Australia provide a free product suitable for characterisation of long-term trends.

It is recommended that development of a first baseline survey included development of a coastal monitoring manual, to ensure integration with lower cost approaches, and cater for staff changes. A core element of the monitoring is the ability to distinguish between long-term coastal recession and short-term erosion-recovery cycles. This will typically involve ongoing comparison of high-water mark 'shorelines' or contours (e.g. 2.0m AHD), subject to interpretation following severe storms.

Decision-making regarding appropriate adaptation pathways can be refined through evaluation of rock presence within the dune system, and subsequently by ongoing coastal monitoring. This has been undertaken via geophysical assessment from Town Beach through to Crevalle Way [15]. Extension further south is not an immediate priority but is considered a necessary piece of information to develop longer-term adaptation planning for this area.

7.2. Dune Management

For detailed guidance on dune management activities, refer to WAPC (2003) *Coastal Planning and Management Manual* [22].

The coastal dune along Exmouth foreshore provides a significant present-day buffer to erosion and inundation. However, with projected sea level rise, it is expected that coastal recession will reduce protection provided by the dune. Consequently, low-cost efforts to enhance dune stability may help to defer the time before hazard mitigation may require more extensive forms of mitigation (i.e. protection or retreat).

Coastal dunes develop at the interface between the beach and the land, when a supply of sand can be captured by dune vegetation. Conventionally, dune behaviour has been considered as a disturbance-recovery cycle, with severe storms taking sand away and wind-blown transport providing recovery. However, these transfers are developed through a mixture of marine processes, wind-driven transport and human impacts (Figure 7-1), with the stability of dune vegetation being critical to the capacity for sand to be held within the dune. With extensive areas of vegetation loss, sand can be more rapidly transferred landward or along the coast, reducing the capacity of the dune to provide a buffer against erosion or inundation.

Effective dune restoration, blowout repair and access management can substantially offset dune instability, reducing sand loss to landward, estimated to reduced projected rates of coastal recession by 25-50%. This is a crucial hazard mitigation tool where dunes are acting as barriers against storm inundation.

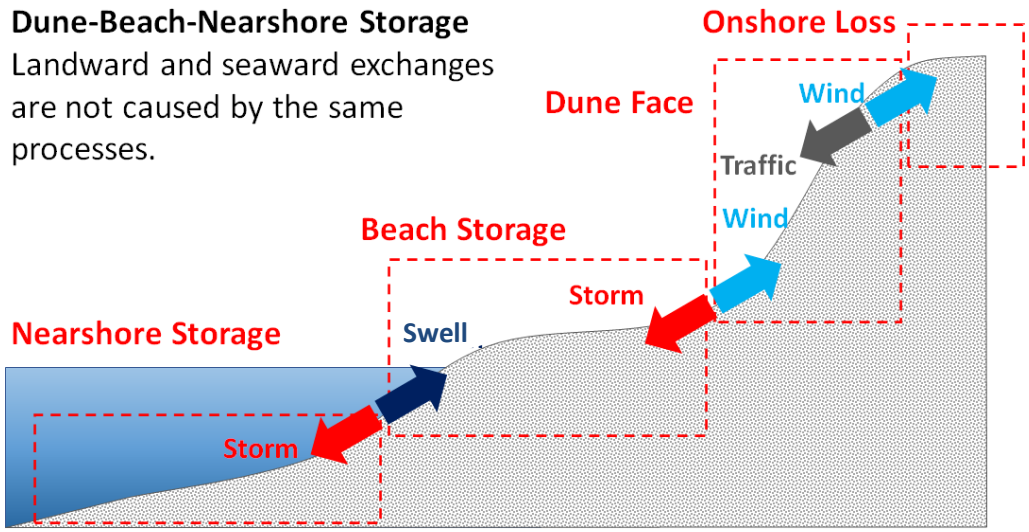


Figure 7-1: Beach-Dune Sediment Exchanges

Preliminary evaluation of dune pressures along Exmouth foreshore (refer to Appendix B.6 in the Coastal Hazard Assessment) identified six types of dune mobility, including pedestrian access, vehicle impacts, dune blowouts, dune scarps, mobile dune faces and along coast sand drift. Each of these requires a different form of management. Examples of vegetation loss are shown in Figure 7-2and Figure 7-3.

It is recommended the Shire develop and implement a dune management plan, which helps to control access and defines activities to reduce ongoing destabilisation. It is noted that natural variability of environmental conditions, including droughts or storm impacts, can contribute to dune instability.

Figure 7-2: Examples of Dune Vegetation Loss

Following from the Community's focused interest in providing coastal accessibility, it is important that access to the beach is provided through the dunes. Consequently, dune management needs to be sensitive to focal areas of activity, which can change over time. However, provision of defined access pathways may reduce the proliferation of dune disturbance (Figure 7-3).

Figure 7-3: Example of Dune Vegetation Loss through Vehicle Access

7.3. Sand Management

Sand management for Exmouth Boat Harbour was identified as an ongoing activity to reduce the impact of the harbour breakwaters on coastal dynamics [23]. Predictive modelling prior to harbour construction indicated low certainty regarding alongshore sediment transport, with potential to move either north or south at a low rate (<5,000 m^3 per year), depending on weather conditions and the relative contributions of wind waves and swell.

Uncertainty regarding this impact was managed through construction of spurs on either side of the harbour, effectively forming two sand traps. Performance of these traps was monitored, and after early coastal disturbance by TC Vance in 1999, ongoing accretion in the southern sand trap was observed. Sand management for Exmouth Boat Harbour from 2004 was subsequently based on an assumption that material accumulated in the southern trap represented the rate of net alongshore sediment transport. Intermittent bypassing, roughly every two years was undertaken, taking approximately 3,000 m3/yr on average and placing it on Exmouth Town Beach (Figure 7-4).

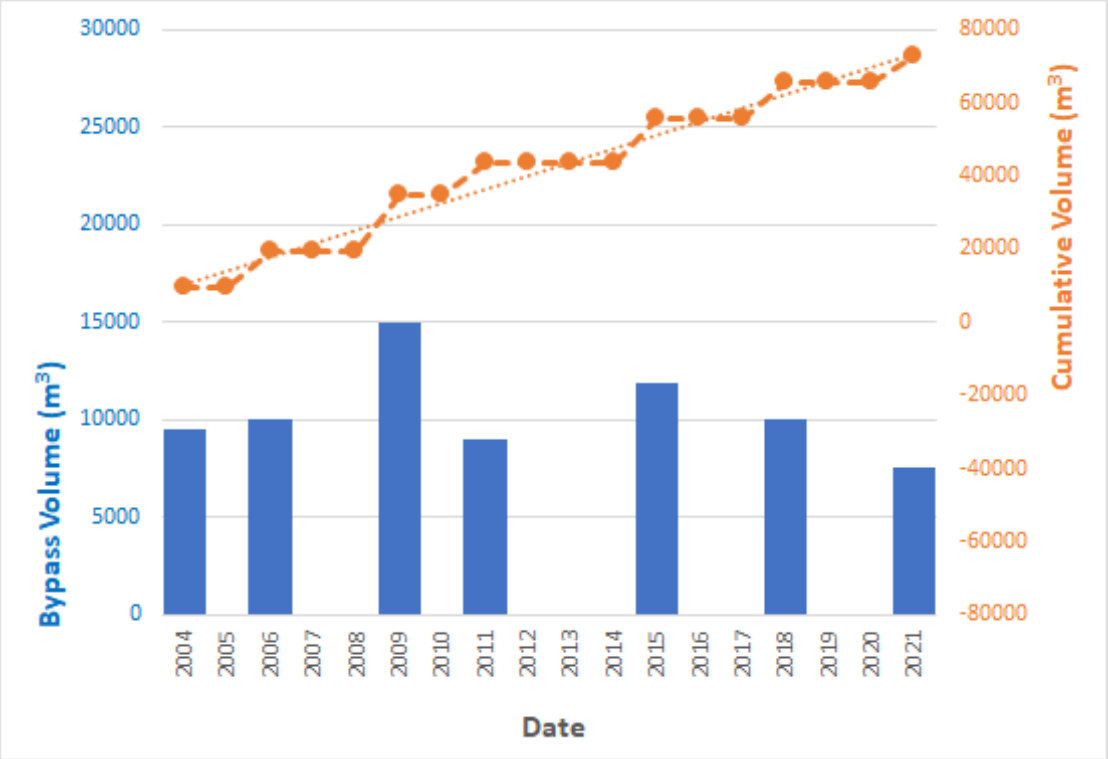


Figure 7-4: Exmouth Boat Harbour Sand Management Quantities

The overall principle of 'sand into trap = sand out' has not been wholly successful:

1. The northern side of the boat harbour remained relatively stable from 2004 to 2010 but accreted substantially over 2011-2012. This is apparently related to a shift in the balance of northeast and southeast winds (Exmouth Coastal Hazards Report Appendix A.3).
2. Accumulation in the traps is higher than for the adjacent shore (i.e. they effectively draw material into the traps). Decline in the beach width outside the southern sand trap since bypassing commenced suggests that sand removal, combined with changing wind conditions, has caused erosion.

3. Placement of bypassed sand has been limited to the beach area, to avoid establishing dune vegetation. This has resulted in an increasingly long area of placement, closer to the water, where initial response causes more rapid movement and greater scarp development. Sand management in 2022 caused scarping of up to 2m height, providing a major constraint to beach amenity.
4. Sand management in 2022 was anecdotally reported by community members to include a large quantity of small rocks. It is noted the lower mobility of these rocks compared to sand will result in increasing concentration of rocks as the sand is washed along the shore.

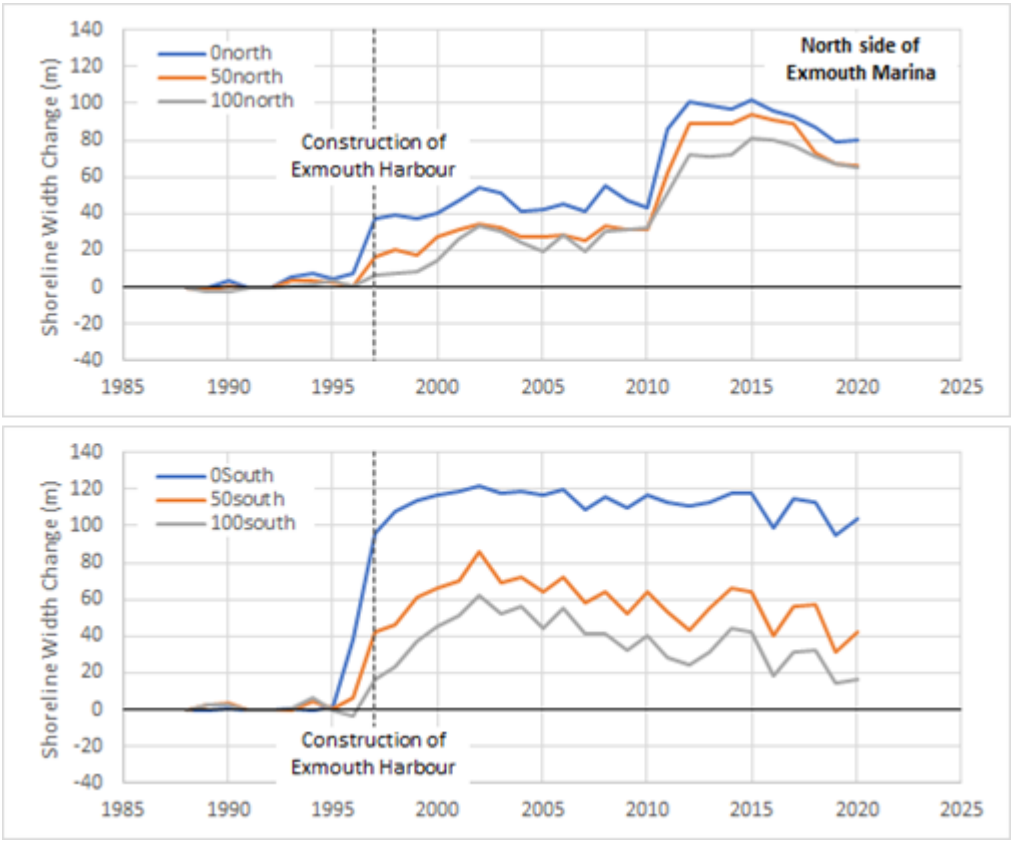


Figure 7-5: Shoreline Change North & South of Exmouth Boat Harbour

It is recommended that established practices of sand management by the Department of Transport and Major Infrastructure for Exmouth Boat Harbour be revised:

1. Determination of sand bypass volumes should be based on wider consideration than the southern sand trap, including the state of beaches north and south of the harbour.
2. Environmental constraints of placing sand to avoid dune vegetation should be revised. It is noted that landward placement (preferably strip placement across the dune) to reduce scarp formation may require mulching and planting, with an added project cost.
3. Occurrence of rock fractions (say >25mm) within bypassed material should be assessed, to cater for the potential for concentration on the shore as the sand fraction washes away. Opportunities for pre-works assessment, screening during works, or post-placement clean-up should be evaluated, and a pathway for monitoring and decision-making established. Material placed further landward is less sensitive to the presence of rocks, so it may be practical to screen a smaller quantity of bypassed material for placement on the beach.

Sand management is a strategy identified to mitigate the coastal impacts for Exmouth Boat Harbour, aiming to generally mimic sediment transfer driven by wave action, which is almost continuous alongshore. However, sediment transport varies over time, depending on tidal and weather phases, as well as changing coastal conditions.

Sand management practices need to be responsive to changing sediment supply and transport direction. This should not simply involve measurement of the sand trap, as sediment is able to be drawn into the trap, even under conditions of negligible supply. Prior to bypassing, it is recommended to assess beach conditions for at least 500m south of the harbour breakwater.

In the longer term, coastal recession is anticipated to occur in response to projected sea level rise. This will modify availability of coastal sediments to be transported by alongshore processes, likely to occur as phases of both higher and lower sediment supply. Presence of rock underlying much of the Exmouth coastal dunes means it is likely that sediment supply will ultimately decline, reducing the benefits achieved by ongoing sand management.

It is noted that sand management and renourishment are separate, albeit related, management actions. Renourishment specifically involves bringing in *additional* sand, to offset coastal erosion and recession.

8. STEP 6: IMPLEMENTATION

Evaluation of coastal hazards for Exmouth has shown there are assets which may be impacted by erosion or inundation, with increasing impact anticipated in the longer term. Most of the present-day risk relates to relatively lower cost public facilities within the existing foreshore reserve, with the coastal dune providing a buffer against marine processes.

The existing (informal) coastal management strategy, which provides high coastal amenity but limits financial exposure to hazard, has been largely effective under conditions of low-moderate coastal change, but is likely to be challenged by more rapid change (e.g. cyclones) or substantive change anticipated under long-term projected sea level rise. It is noted that acute erosion pressure experienced over 2010-2015, which resulted in Town Beach being identified as a coastal erosion hotspot [3], was a consequence of a switch in prevailing wind conditions (identified from BOM Learmonth wind records) – although future switching can be expected to occur, these impacts are unlikely to be sustained and progressive.

Consideration of coastal hazards over the longer-term indicates potential for transition towards wider impacts, including areas landward of the existing foreshore reserve, particularly where dune instability may reduce its effectiveness to mitigate coastal hazards. These impacts are not certain to occur, and therefore it is appropriate to:

- Acknowledge that hazards may extend beyond the existing foreshore reserves.
- Shift towards adaptive coastal management, which allows detection of change and proactive intervention in a timely manner. A step to achieve this is to incorporate principles of the State Coastal Planning Policy [1] and CHRMAP Guidelines [2] into the Shire's local planning framework (Section 8.1).
- Prepare funding and observational frameworks to support possible coastal management futures. These are considered in the context of recommended actions for each of the management units (8.2).
- Undertake low-cost activities that may be able to offset development of longer-term hazard, particularly dune management (Section 7.2) and modification of existing sand management practices (Section 7.3).

8.1. Local Planning Framework

The significance of the Ningaloo coastal region has been acknowledged through development of *State Planning Policy 6.3 – Ningaloo Coast* (SPP 6.3), which provides objectives for management of the Ningaloo region, including Exmouth [24].

The Shire of Exmouth Local Planning Strategy 2015-2025 [25] acknowledges the importance of managing coastal hazards, through both SPP 2.6 (Coastal Planning Policy) and SPP 6.3. This is further supported in the Exmouth region by the *Ningaloo Coast Regional Strategy* [26]. Despite acknowledgement of coastal hazards, there is limited identification of coastal inundation, as runoff flood risk occurs in the same locations, to generally higher levels. A special control area for Exmouth floodplain (SCA5) is identified in Exmouth Local Planning Scheme 4 [27]. Other planning documents include:

- Exmouth Marina Village ODP & Broad Design Guidelines [28]
- Exmouth Townsite Structure Plan [29]
- Exmouth South Structure Plan [30]

- Exmouth Town Centre and Foreshore Revitalisation Plan [7]

General considerations of how land use planning instruments may be used for the Shire to incorporate longer-term hazard considerations identified through this CHRMAP include:

- Coastal hazard and adaptation planning to be considered during the revision and update of the Shire's Local Planning Strategy and Scheme to account for CHRMAP outcomes.
- Where the local planning framework requires further detailed site investigations and planning, (for instance during the preparation of Structure Plans, scheme amendments or Local Development Plans).
- Establishment of Special Control Areas or other identified planning instruments under the Local Planning Scheme that can be used to regulate development in areas that have been identified under the CHRMAP as being at higher risk.
- Reservation of coastal areas that have been identified under the CHRMAP as being exposed to coastal hazard at present and in the future.
- Placing Notifications on Titles when new lots are created or development is approved to identify the land is subject to hazard exposure. This will increase awareness of potential property owners to present and future risks in relation to the site.
- Local Planning Policies (LPP) can be prepared and adopted in relation to managing current and future development along the coastline.
- Reservation of land under the Local Planning Scheme to prevent intensification of land use.
- Establishment of a program whereby land can be Compulsorily Acquired for land that has been identified under the CHRMAP as being at a high risk and therefore intolerable for habitation of any form.
- Consideration of land swaps or leaseback arrangements (likely to occur outside of the planning system).

Within the context of providing closer alignment to SPP2.6 [1] and its supporting tools, suggested amendments to existing land-use planning instruments for the Shire of Exmouth have been identified (Table 8-1).

Evaluation of Exmouth's land-use planning instruments for the purpose of managing coastal inundation were evaluated as part of the Statewide Coastal Inundation Assessment [31]. The planning instruments acknowledged interactions between coastal inundation and runoff risks and identified that opportunities for growth of Exmouth town site may include undertaking flood management and mitigation works. However, criteria for tolerable coastal inundation hazard (including sea level rise) were not identified, and preferred adaptation pathways are not described explicitly.

Exmouth's planning framework acknowledges the role of emergency management and building design guidelines in mitigation of flooding and inundation hazard. These factors are not explicitly incorporated into SPP 2.6 and supporting tools, but if included in the proposed revision of Exmouth Floodplain Management Strategy, they should also be considered in the context of coastal inundation.

Table 8-1: Suggested Amendments to Land-Use Planning Instruments

Local Planning Strategy 	CHRMAP outcomes should be addressed as an amendment to the Shire's Local Planning Strategy, with areas at risk not being identified for further intensification of development. 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.
Local Planning Scheme 	The Local Planning Scheme should be amended to reflect changes in the Local Planning Strategy. On undeveloped land that is currently UCL, an adequate foreshore reserve should be identified. In other areas (zoned *Tourism* or *Residential Development*) the provisions of a Special Control Area should be implemented.
Special Control Area 	The introduction of a Special Control Area (SCA) for all 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, Vulnerable Coastal Area notifications on title, requirements for time limited approvals.
Local Planning Policy 	To provide context for the Special Control Area is it is recommended that that the Shire of Exmouth prepare a Local Planning Policy. The Local Planning Policy should address matters such as: • Requirements for Development Applications in areas affected by the SCA. • Guidelines for exempted development • Guidance for the shire when considering strategic planning proposals, subdivision referrals and development applications.
Foreshore Management Plan 	It is recommended that the Shire prepare a Foreshore Management Plan for Town Beach to address immediate management issues including access, environmental management, dune management, community use and provision of facilities.

To implement the SCA, the Shire should initiate an amendment to Local Planning Scheme No. 4 to insert sub-clause 5.8 under Part 5 – Special Control Areas, as per Table 8-2.

In addition to the suggested amendments, it is recommended the Shire consider:

- Alignment with SPP2.6 will require a structure plan to consider coastal processes in relevant situations. The Local Planning Scheme (LPS) is the head power for implementing a Special Control Area (SCA), Local Planning Policy (LPP), or Reservation of Land (in a planning sense).
- The Shire of Exmouth are recommended to consider a SCA head power in the Scheme, with associated LPP. The LPP may suggest that a notification on title occur, through agreement with the landowner (via the Shire), as part of planning approval (via the Shire, through S70A of the Transfer of Land Act 1893), or during subdivision (via WAPC, under S165 of the P&D Act 2005).

Considerations of how the planning instruments may interface with this CHRMAP are summarised in Table 8-3, distinguished by Management Unit. It is noted that development of beach access and dune management plans recommended in Section 6 (and Section 8.2) could be undertaken individually, or incorporated within an overall Foreshore Management Plan structure.

Table 8-2: Proposed Amendment to Local Planning Scheme 4

5.8 Coastal Hazard Special Control Area (SCA7) 	***5.8.1 Purpose***	*To provide guidance for land use and development within these areas subject to coastal erosion and inundation.*
	Objectives	*Objectives of SCA7 are:* *a) To identify land within Exmouth at risk of erosion and inundation by coastal processes by 2125.* *b) To ensure public health and safety and reduce risk associated with coastal erosion and inundation.* *c) To protect new development from the impacts of coastal erosion and inundation.* *d) To avoid inappropriate land use and development of land at risk of coastal erosion and inundation.* *e) To ensure land in the coastal zone is continuously available for coastal foreshore management, public access, recreation and conservation purposes.* *f) 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.* *g) To ensure coastal processes are accounted for in preparing strategic planning proposals and in assessing subdivision and development applications.*
	**5.8.2 Additional Provisions**	a) Notwithstanding any other provision of the Scheme, all proposed development within SCA 1 requires the development approval of the local government. b) In considering any application for development approval, or its advice in relation to a proposed structure plan, or application for subdivision of land within SCA 1, the local government is to have particular regard to: (i) The Shire of Exmouth Coastal Hazard Risk Management and Adaptation Plan. (ii) State Planning Policy 2.6 – State Coastal Planning Policy. (iii) The Shire of Exmouth Coastal Hazard Local Planning Policy. (iv) The likely effect on public safety and the risk associated with coastal inundation and erosion. (v) The existing and likely future effect of coastal erosion or inundation on the land. (vi) The vulnerability of any roads providing access to the land and any public utility infrastructure servicing the land. (vii) The continued suitability of servicing the land with an onsite effluent disposal system, where reticulated sewer is not available. (viii) The impact that any proposed earthworks, retaining walls or other protective measures will have on the amenity of the locality and water flows. (ix) The adequacy of the coastal foreshore reserve to provide for continued coastal foreshore management, public access, recreation, conservation and landscape amenity. c) Where the local government decides to approve an application for development approval it may impose conditions so as to: (i) constrain the location of development. (ii) control the form of construction, including foundations and associated works. (iii) determine the form, location and construction of access. (iv) require a minimum floor level for development.

		(v) limit the term of the approval. (vi) 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 (vii) require the registration of a notification under section 70A of the Transfer of Land Act 1893 on the Certificate of Title of the subject land at the cost of the landowner advising: a. that the lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years. b. of any limited term of a development approval. and c. of any requirement to remove approved development and restore the land as near as practicable to its condition immediately before the development started to the satisfaction of the local government upon a trigger event occurring. d) Where an application for subdivision of land within SCA 1 is referred to the local government, it may recommend that the Commission applies conditions requiring: (i) the finished surface level of the land, or the level of public roads providing access to the land are raised sufficient to reduce the risk of coastal inundation. (ii) building envelope/s, where applicable, provide a specified area of land that is located above the coastal inundation level. (iii) 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. e) Notwithstanding the provisions of above, development approval is not required within SCA7 for the following development if such development is otherwise exempt from requiring development approval under the Scheme: (i) temporary or non-permanent structures not used for human habitation. (ii) extensions to an existing single, grouped or multiple dwelling where the net floor area of the proposed extensions is no more than 50m^2. (iii) a change of use where no new structures are proposed.

Table 8-3: Considerations for Planning Instruments to Interface with the CHRMAP

Management Unit (MU)	Adaptation Objectives	Planning Considerations	Instruments
MU1: Northern Floodplain	Coastal dunes provide an effective barrier against wave action and a substantial barrier against erosion and inundation. The continued **protection of the coastal dunes** should be undertaken through creating a coastal reservation.	1. Retain the low-key tourism uses (caravan park, camping) as currently depicted in the Local Planning Strategy 2. Amend LPS to explicitly include provisions for coastal process and adaptation in accordance with CHRMAP (ie add SCA7). 3. Create appropriate width foreshore reserves when/if UCL parcels are considered for future development. 4. If management orders are being created, or land being normalised – then the Shire should seek to create a foreshore reserve with Management Order to the Shire to create reserve. 5. Should the Shire look to obtain the management orders for these parcels of UCL, and subsequently lease the lot/s to an operator, it is recommended that specific provisions be incorporated into the leasing documents to acknowledge potential coastal impacts (as outlined in the CHRMAP Hazard Assessment Report), and to avoid impacts, and where appropriate to allow for planned/managed retreat or accommodation.	 **LPS**  **SCA**
MU2: Town Beach	Exmouth Town Beach was previously identified as a coastal erosion hotspot due to a "rapid observed rate of erosion and public assets close to the shore". Continued **access to and utility of Town Beach** has been identified as an adaptation priority for the Shire.	1. Town Beach is currently a 'Reserve' under the Shire's Local Planning Scheme No.4 and therefore largely protected under the Scheme for development. Assets within this area are likely to be owned and managed by the Shire and therefore, can be protected by the Shire from any identified hazards. 2. The remainder of the land is zoned Tourism and Special Control Area 6 – Exmouth Marina. There are detailed provisions for both areas in relation to development outlined under LPS4. 3. Proposed SCA7 will put in place additional development provisions in relation to potential future identified hazards. Under the scheme areas that will be subject to identified hazards should be noted and development provisions under the scheme should control development to be of a transitionary nature that is removable or can be responsive to change and that no significant development should occur. 4. Should residential development occur within these areas, notifications should be placed on titles. 5. The Yacht Club has capacity within its existing reserve to slowly retreat as required over time. 6. Consideration of Benefit Distribution Analysis (BDA) for existing sea wall, to assist with apportioning the costs (capital and recurrent e.g. maintenance) based on the beneficiary pays principle.	 **SCA**  **FMP**
MU3: Harbour and Canal Estate	Continued **operation** and effective use of harbour and associated facilities; **Access** to canal estate (walkways) and adjacent properties.	Since the Marina was developed it has had an impact on the coastline within the Shire. A Special Control Area 5 (SCA5) is already identified around the Marina under the Shire of Exmouth Local Planning Scheme No.4 (LPS4).	 **SCA**

Management Unit (MU)	Adaptation Objectives	Planning Considerations	Instruments
		Sea level rise will modify water level occurrence relative to marine facilities, such as jetties, revetments and boat ramps. This includes how often facilities are inundated, or the relative freeboard to resist wave action, affecting their use. For most facilities, there is some tolerance to changing water levels, allowing facilities to be modified progressively, incorporated with their renewal, typically every 15-30 years. Keeping ahead of this requires recognition of tolerable performance for each facility, and identification of changing sea levels via a reliable measure, such as Exmouth tide gauge record. This planning mechanism provides additional requirements in relation to development approval, scheme amendment, structure plan or subdivision application. In terms of lots within the Marina, it is suggested a condition of any development approval within the Marina would involve notifications placed on titles identifying the possible hazards that may occur over the subject site in the future.	 BMMP  NOT
MU4: Harbour South (Residential land)	The existing dune doesn't provide sufficient protection against an extreme storm. **Protect and Accommodate** Increase resilience of coastal dunes with active programme of dune management (with geotechnical assessment to establish rock control as a precursor) enhancing the protective role dunes can play for adjacent land/development	Residential Land south of the Marina also contains areas covered by the SCA5 designation under the Shire's LPS4 which also designates additional development requirements over the land. Most of the land is zoned 'Urban Development' under the Shire's LPS4 where a Structure Plan is required to be prepared prior to any subdivision or development taking place. As part of the structure planning process for the site, CHRMAP outcomes should inform the design of the future residential lots, in particular around Crevelle Way which was identified as having a 'high' risk, as well as the area, further south adjacent to the dunes where geotechnical assessment should be undertaken to establish the extent of rock control which has implications for dune migration landward and associated erosion issues or sand burial problems that may be encountered for residential properties. Further should development take place within this area, notifications should be placed on titles informing of possible hazards in relation to identified coastal hazards through the CHRMAP process. The following is recommended in this area: 1. Structure plan should identify appropriate coastal reserve – this should be ceded to Shire free of cost. 2. Notifications required on titles. 3. SCA for coastal hazards placed on existing lots – requiring development to be approved by Shire – may require minimum floor level. 4. Shire to consider seeking Management Order for the large reserve in front of the residential land – and put in place a plan to ensure dune system is strengthened as required.	 SCA  LPS  SP  NOT  FMP

8.2. Summary of Recommended Actions

Recommended actions from each of the Management Units have been combined, and classed as:

- Actions for Coastal Change (Table 8-5)
- Actions for Marine Facilities (Table 8-6)
- Actions for Dune Management (Table 8-7)
- Actions for Floodplain Management (Table 8-8)

Actions are summarized spatially in Figure 8-1 and Figure 8-2.

For each action, indicative costs, asset managers and potential grant pathways have been identified. It is noted that asset managers have been distinguished as:

- **Landowners**: assets are wholly the responsibility of private landowners
- **Shire**: assets are wholly the responsibility of the Shire
- **Shire (State)**: assets are formally managed by Shire, but commonly supported by the State Government, typically financially.
- **Shire / State**: assets are ultimately the responsibility of the Shire, but coordination is shared between the Shire and State Government, sometimes largely managed by the State on behalf of the Shire.
- **State Govt**: assets are wholly managed by the State Government.
- **Commonwealth**: land is reserved for the Department of Defence.

Overall, many of the recommended actions can be completed through modification of existing practices, or as part of asset renewal, with effectively minimal additional cost. New actions, that would require additional funding to be established, have an estimated initial outlay of ~$500k within the next 0-5 years, and ongoing costs for coastal change and dune management are anticipated to progressively increase over time, from around ~$200k per decade towards ~$700k per decade (Table 8-4).

Table 8-4: Summary of Projected Additional Costs for Recommendation Actions

Note: All costs based on 2025 values.

Time Period	Coastal Change	Marine Facilities	Dune Management	Floodplain Management
Immediate (0-5 years)	~$80k	~$85k	~$90k	~$200k
Medium Term (5-25 years)	$10-15k / yr	Costs depend on integration with facility renewal *	~$5k / yr	To be identified through revised FMS
Long Term (> 25 years)	$40-60k / yr (averaged)		~$10k / yr	

* The practice of ensuring adaptation can be incorporated into facility renewal may be efficiently undertaken through Building Information Management and Asset Management tools. Alternatively, a program of marine asset condition assessment can be undertaken.

Table 8-5: Implementation Actions for Coastal Change

MU	Type	Issue	Required Timeframe	Recommendation	Resources	Funding	Grant Schemes
MU2	Environ.	Access Management	Immediate	Develop and implement a beach access management plan, to facilitate beach use and limit adverse impacts.	$30k +$10k / yr	Shire (State)	CMPAP
MU2	Environ.	Sand Management	Immediate	Liaise with DTMI to have existing sand management practices amended, to reduce scarp formation and presence of rock.	In-house	Shire / State	
All	Monitor	Detection of change	0-5 years	Undertake baseline coastal & dune survey. Develop coastal monitoring manual to support ongoing assessment.	$60k	Shire	CAP
MU4	Planning	Inadequate foreshore reserve	5-10 years	Extend geotechnical assessment to guide adaptation pathway.	TBC	TBC	
MU1	Planning	Limited erosion buffer	10-30 years	Apply time-limited leasehold to Truscott Crescent Special Use lots.	In-house	Shire	
MU1	Monitor	Transferred erosion stress	Subject to MU2 management	Undertake coastal monitoring.	$10k / yr	Shire	CAP
MU1	Planning	Transferred erosion stress		Identify coastal adaptation response as part of stabilization design for MU2.	$20k	Shire	CAP
MU2	Works	Restricted Beach Access	10-30 years	Identify and implement preferred coastal management strategy. (Costs assume use of renourishment, groynes or breakwaters)	$500-800k / 30 years	Shire (State)	CAP
MU2	Works	Instability of Existing Defences	25-50 years (R) 55-85 years (P)	(R) Monitor change & progressively remove threatened assets (P) Enhance and extend existing protection	~$300k $500k	Shire	CAP
MU2	Works	Outflanking of Mantarays revetment	55-85 years (R) >100 years (P)	Enhance and extend existing protection	$250k	Shire	CAP
MU2	Works	Reducing Tourist lot value due to erosion	60-90 years (R) 40-70 years (P)	Review lot management – consider retreat or local protection.	TBC	Shire	
MU2	Works	Road adjacent to Neale Cove (1)	30m recession 45-90 years	Construct ~350m long revetment to protect harbour access road	$1,000k	State Govt.	
MU2	Works	Road adjacent to Neale Cove (2)	50m recession 65+ years	Construct ~180m long revetment to protect harbour access road	$550k	State Govt.	

CMPAP – Coastal Management Plan Assistance Program; CAP – Coastal Adaptation and Protection grant scheme.

Table 8-6: Implementation Actions for Marine Facilities

MU	Type	Issue	Required Timeframe	Recommendation	Resources	Funding	Grant Schemes
MU3	Planning	Private jetties	0-10 years (ongoing)	Update BMMP every 10 years with revised sea levels & jetty design requirements.	$10k / decade	Shire (State)	RBFS
MU3	Design	Concrete walkway	Immediate	Identify management options to landowners. Request Transport to develop adaptive design *. Update BMMP to provide direction for adaptation.	$50k	Shire (State)	RBFS
MU3	Design	Revetment walkway	Immediate	Identify management options to landowners. Update BMMP to provide direction for adaptation.	$25k	Shire (State)	
MU3	Works	Revetment walling	10-25 years	Managed by landowners. Adapt walling as part of repairs / replacement cycle.	–	Landowners	
MU3	Works	Concrete walling	10-25 years	Managed by landowners. Adapt walling as part of repairs / replacement cycle.	–	Landowners	
MU3	Works	Public boat ramp	15-25 years	Managed by Transport. Adaptation to be incorporated in maintenance program.	–	State Govt	
MU3	Works	Harbour walling	15-30 years	Managed by Transport. Adaptation to be incorporated in maintenance program.	–	State Govt	
MU3	Works	Harbour land levels	30 years *	Managed by Transport. Levels to be reviewed for modified land-use within Harbour Masterplan. Adaptation to be incorporated in maintenance program.	HIGH	State Govt	
MU3	Works	Public jetties	15-30 years	Adapt jetties as part of repairs / replacement cycle.	–	Shire	RBFS
South	Design	Exmouth-Minilya Road	15-30 years	Assess inundation hazard to roadway and review options for mitigation.	$100k	Shire (State)	
MU1	Works	Wastewater treatment plant	40-60 years *	Mitigate inundation hazard to WTP	HIGH	State Govt	
South	Works	Exmouth-Minilya Road	40-60 years *	Mitigate inundation hazard to roadway. Potential to adapt road as part of repairs / replacement cycle.	HIGH	State Govt	

RBFS – Recreational Boating Facility Scheme

Table 8-7: Implementation Actions for Dune Management

MU	Type	Issue	Required Timeframe	Recommendation	Resources	Funding	Grant Schemes
MU1 MU2 MU4	Environ.	Dune management	Immediate	Develop and implement a dune management plan, to reduce dune destabilization through traffic.	$30k	Shire	CW, CAP
MU4	Tech Study	Inadequate dune capacity	5-10 years	Liaise with DTMI to arrange geophysical assessment (extension south of Crevalle Way) & revise dune stability evaluation.	$60k	Shire	CAP
MU4	Protection	Inadequate dune capacity	10-30 years	Enhanced dune management to build dune capacity over time.	$120k +$30k / decade	Shire	CW, CAP

CW – Coastwest grants; CAP – Coastal Adaptation and Protection grant scheme.

Table 8-8: Implementation Actions for Floodplain Management

MU	Type	Issue	Required Timeframe	Recommendation	Resources	Funding	Grant Schemes
MU1	Planning	Runoff flooding	Immediate	Liaise with DWER to develop revised Floodplain Management Strategy. This should consider coastal dynamics and instability of northern breakout.	$150k	Shire / State	FM, DRF
MU1	Planning	Development in floodplain	5-10 years	Prepare and implement guidelines for development within the floodplain SCA 5, including identification of required finished floor levels and evacuation planning.	$30k	Shire	FM
MU1	Tech Study	Breakout instability	Immediate	Study to identify minimum channel area required for drainage (may be part of Floodplain Management Strategy)	$15k	Shire / State	FM
MU4	Planning	Inadequate dune capacity	Immediate	Set lease time limits. Do not consider conversion to freehold.	In-house	Shire	
MU1	–	Floodplain salinisation	20-50 years	No action presently deemed necessary.	–		
MU1	Planning	Coastal inundation hazard	40-60 years *	Amend SCA 5 wording. Advise occupants regarding limitations of insurance.	In-house	Shire	

FM – Floodplain Management grants; DRF – Disaster Ready Fund grants

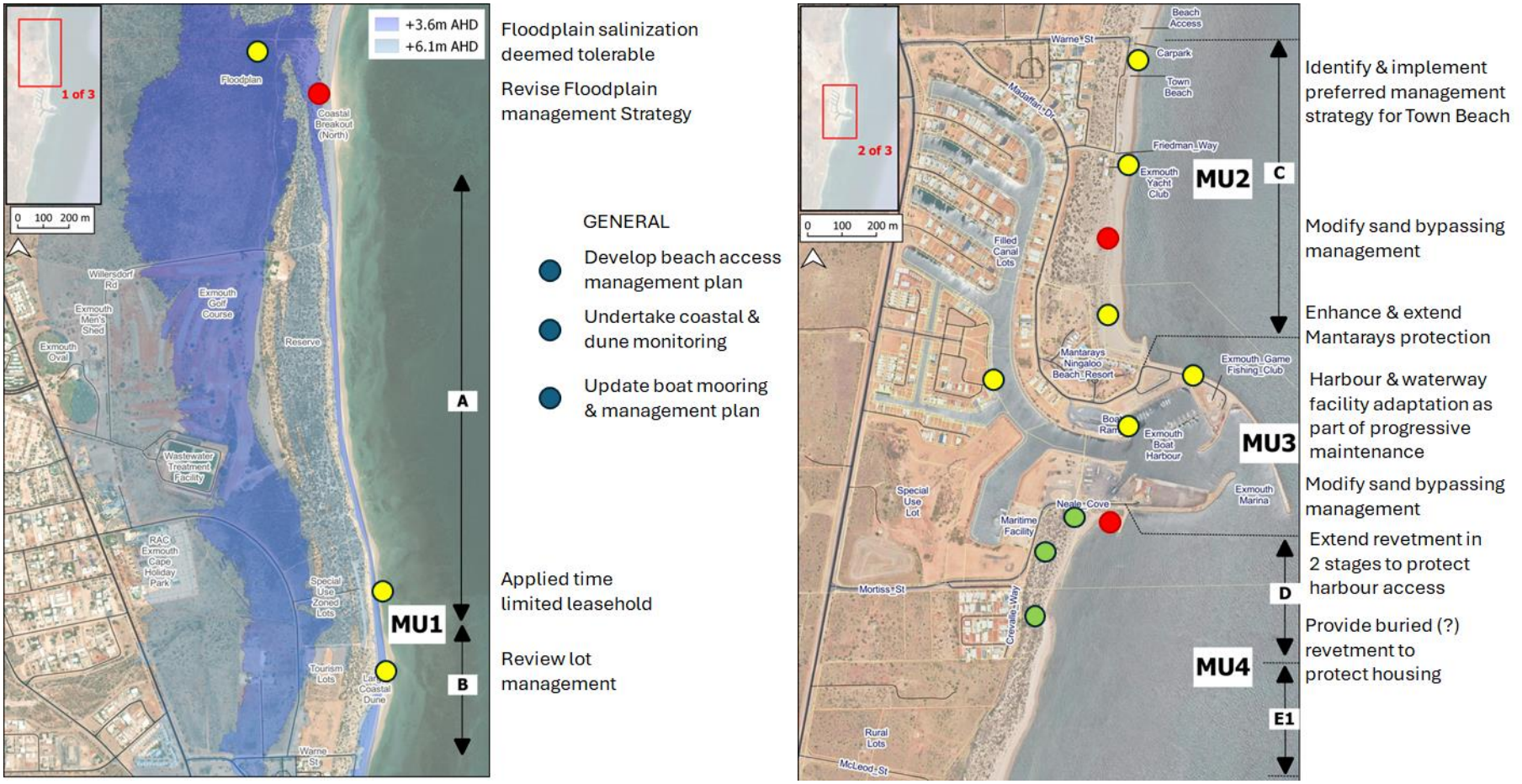


Figure 8-1: Location of Recommended Actions (North & Central)

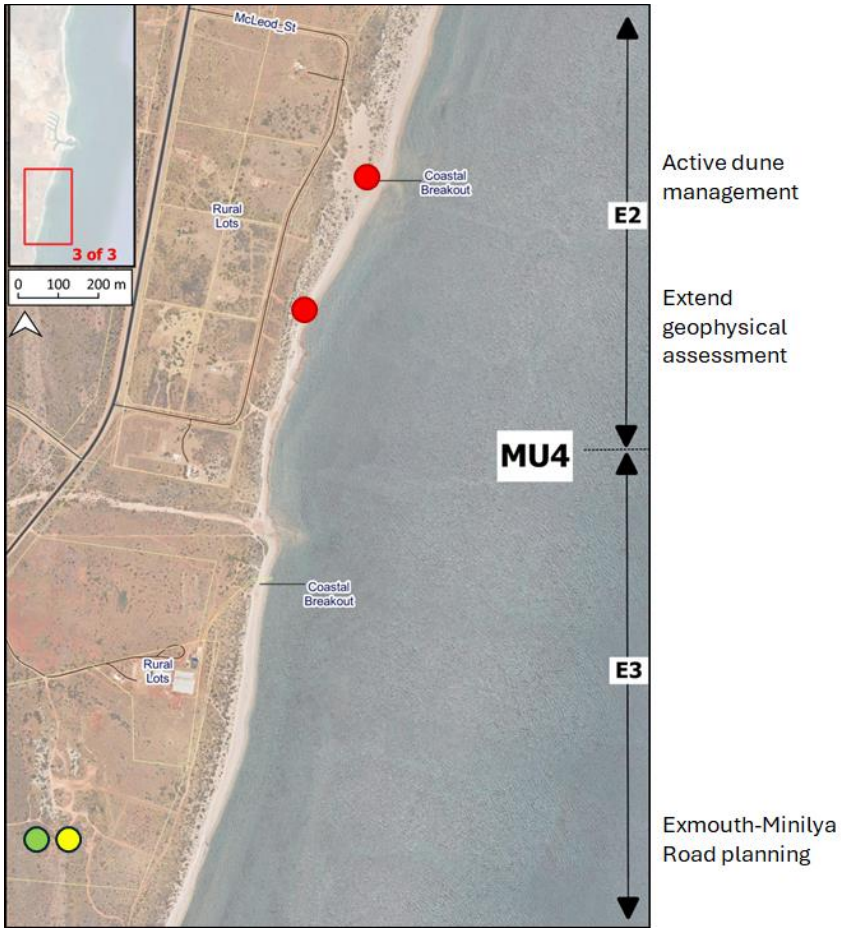


Figure 8-2: Location of Recommended Actions (South)

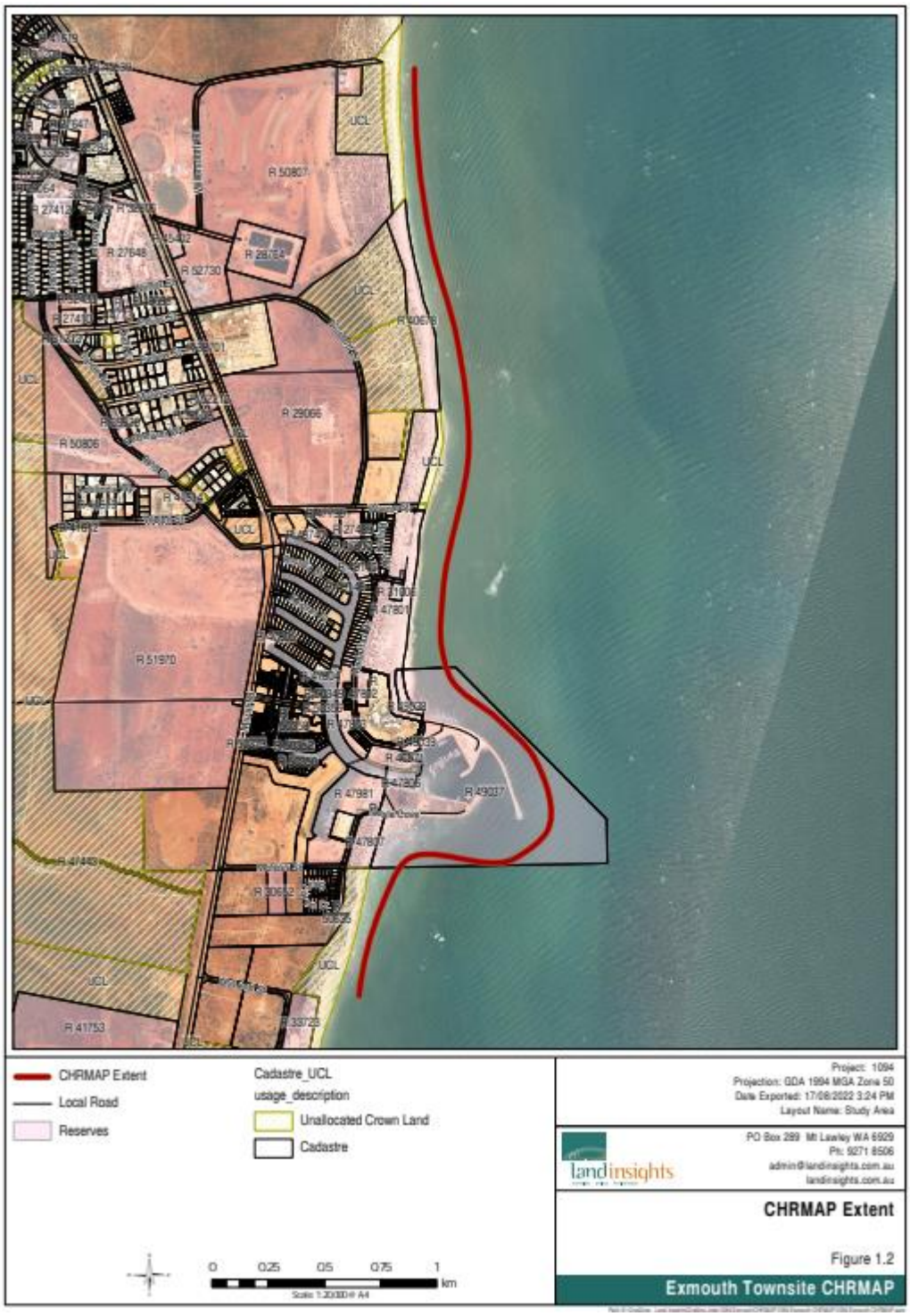
9. REFERENCES

1. Western Australian Planning Commission. (2013) State Planning Policy 2.6: State Coastal Planning Policy. Prepared under Part Three of the State Planning and Development Act 2005, Perth.
2. Western Australian Planning Commission and Department of Planning. (2014) Coastal hazard risk management and adaptation planning guidelines.
3. Seashore Engineering Pty Ltd. (2019) Assessment of Coastal Erosion Hotspots in Western Australia. Report SE052-01-Rev1. For the Department of Transport and Department of Planning, Lands and Heritage.
4. Taylor Burrell & Barnett. (2014) Exmouth Local Planning Strategy.
5. Taylor Burrell & Barnett. (2014) Exmouth Local Planning Policy.
6. Taylor Burrell & Barnett. (2014) Exmouth Local Planning Scheme.
7. Hassell Pty Ltd. (2013) Exmouth Town Centre and Foreshore Revitalisation Plan.
8. Damara WA Pty Ltd. (2015). Caravan Park Development at Lots 1403 and 1404 Truscott Crescent, Exmouth – Coastal Setbacks. Report 250-01.
9. Seashore Engineering Pty Ltd. (2016) Lots 149 & 150 Hunt Street, North West Cape - Coastal Processes Study. Project SE036-01-A.
10. Land Insights (2023) Exmouth Town Beach CHRMAP: Establish the Context.
11. Seashore Engineering Pty Ltd. (2023) Shire of Exmouth. Coastal Hazard Assessment. Report SE134-01-01.
12. Nadimpalli K, Mohanty I, Vidyattama Y, Kalantari M & Rajabifard A. (2018) Australian Natural Hazards exposure information Framework: Guidelines for national consistency and comprehensive information.
13. SKM (2007) Exmouth Floodplain Management Study.
14. Shire of Exmouth. (date) Exmouth Area Defence Sites Protection. Local Planning Policy No 6.
15. GBGMaps (2023) Geotechnical Investigation for Coastal Erosion Vulnerability Assessment. Exmouth, Shire of Exmouth WA. Report 3095B Rev-1.
16. GHD. (2017) Exmouth Boat Harbour Expansion Northern Breakwater Risk Assessment.
17. Department of Transport. (2022) Exmouth Boat Harbour Masterplan. Draft.
18. Egis Consulting Australia. (1999) Exmouth Boat Harbour. Assessment of Storm Water Levels. RW1302-RP-000-001.
19. Department of Transport. (2016) Exmouth Boat Harbour Boat Mooring and Management Plan.
20. Hyd2o Hydrology. (2014) Exmouth Hydrological Study. Prepared for the Shire of Exmouth. Western Australia.
21. Bishop-Taylor R, Nanson R, Sagar S & Lymburner L. (2021). Mapping Australia's dynamic coastline at mean sea level using three decades of Landsat imagery. Remote Sensing of Environment, 267, 112734.
22. Western Australian Planning Commission: WAPC. (2002) Coastal Planning and Management Manual: A community Guide for Protecting and Conserving the Western Australian Coast. WAPC, Perth.
23. Coastal Information & Engineering Services: CIES. (1996) Exmouth Boat Harbour Breakwater Design.
24. Western Australian Planning Commission. (2004) Statement of Planning Policy SPP 6.3. Ningaloo Coast.

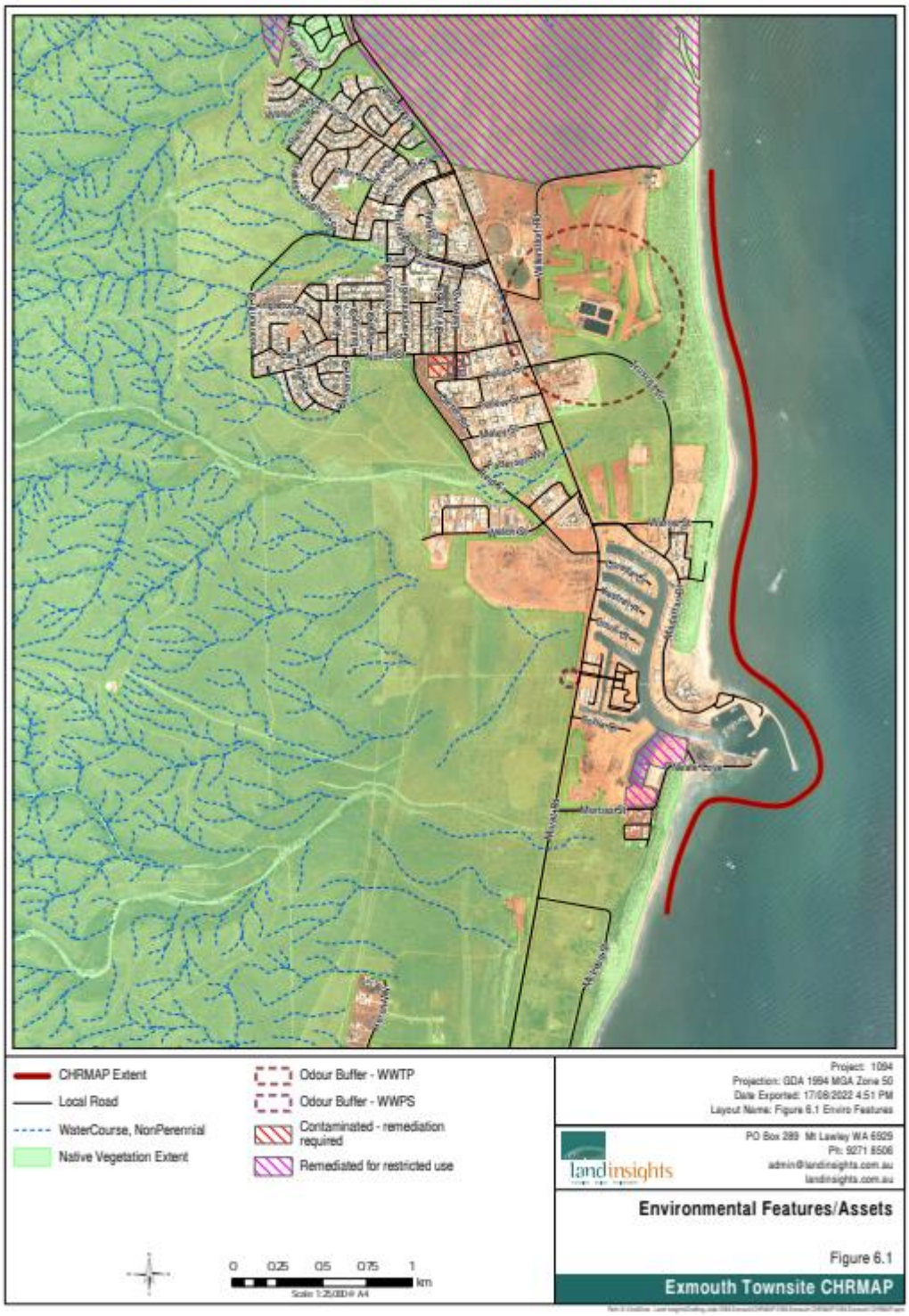
25. Taylor Burrell & Barnett. (2016) Exmouth Local Planning Strategy 2015-2025.
26. Western Australian Planning Commission. (2004) Ningaloo Coast Regional Strategy. Carnarvon to Exmouth.
27. DPLH (2021) Shire of Exmouth Local Planning Scheme No. 4.
28. Taylor Burrell & Barnett. (2011) Exmouth Marina Village ODP & Broad Design Guidelines.
29. Taylor Burrell & Barnett. (2011) Exmouth Townsite Structure Plan.
30. TME (2013) Exmouth South Structure Plan.
31. Seashore (2024) A Statewide Coastal Inundation Assessment for WA. Report SE133-02-01.


Shire of
Exmouth
CHRMAP

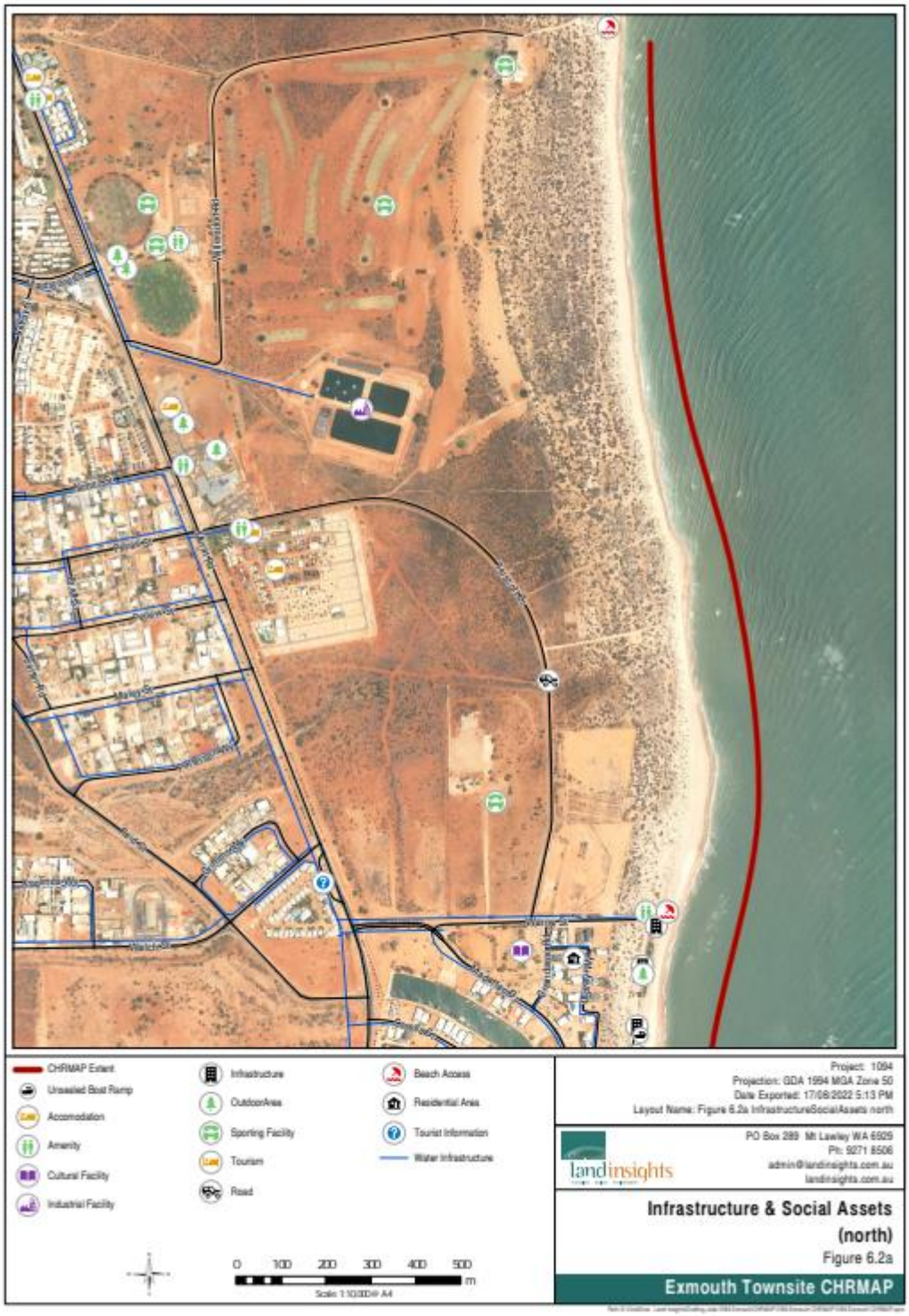
APPENDIX A: Exmouth Town Beach CHRMAP: Establish the Context



CHRMAP Extent



Environmental Features & Assets



Infrastructure & Social Assets (North)

Infrastructure & Social Assets (South)

Asset Value Information

Asset	Details	Category	Function & Service	Per Unit	Total Value
Warne St. Carpark & revetment	50 m walling constructed in 2013 backed by carpark; No pricing provided but assumption that walling costed at same rate as Yacht Club revetement	Foreshore	Coastal access, recreation		307,750.00
Town Beach Public Conveniences	Warne St. carpark (Shire Asset Register)	Foreshore	Recreation and public health		180,000.00
Dwellings - Warne St. to Friedman Way	Value from AEIP based on 32 buildings *	Residential	Provides housing for resident population and future population	1,022,812.50	32,730,000.00
Town Beach infrastructure	**Shire Asset register 2022** Wave shelters BBQ Picnic Tables Drink Fountains Fencing	Foreshore	Ongoing access, community services, recreation and health benefits.		109,693.18
	Eclipse Upgrades 2023 New concrete accessways New boardwalks 7 shade pergolas Low walls and fences Landscaping (turf, trees, reticulation etc) Drainage Lighting & electrical works	Foreshore	Upgraded facilities for influx of tourist population associated with solar eclipse, April 2023		638,614.00
	TOTAL BEACH INFRASTRUCTURE				748,307.18

Asset	Details	Category	Function & Service	Per Unit	Total Value
Yacht Club revetment	Shire Asset register 2022	Recreational		923,250.00	923,250.00
Yacht Club infrastructure	Value derived through consideration of AEIP values**	Recreational	Strong community attachment and service; Provides local employment. Tourist drawcard. Seasonal population. Contributes to local economy.		700,000.00
Madaffari Drive	Value derived from per km costings for the Gascoyne from WALGA 2014/2015***	Economic & Infrastructure: Road	Provides transport services	346,780	624,204.00
Dwellings - Madaffari Drive Canal lots	Value from AEIP based on 42 dwellings along Madaffari Drive from Warne St to Harbour in South	Residential	Provides housing for resident population and future population	1000000	42,000,000.00
Mantarays Ningaloo beach Resort	Value provided as of 2006 by Mantarays owner Larry Birkett and adjusted using the Australian Reserve Bank inflation rate to 2022****	Economic & Infrastructure: Resort	Provides employment and contributes to economy	34,000,000	50,370,000.00
Town Beach	Value derived through consideration of beach usage by local population; tourist population and tourism value *****	Environment: Foreshore	Coastal access, recreation and conservation. Tourist drawcard. Geo-morphological features of locality. Buffer to other 'higher value' assets.		17800000^

Shire Assets ^^	2,159,307.18
Commercial	50,370,000.00
Private	74,730,000.00
Total	**129,331,818.36**

APPENDIX B: Coastal Hazards Report

APPENDIX C: Workshop 2: Community Risk Assessment Workshop

APPENDIX D: Workshop 3: Stakeholder Briefing Session

APPENDIX E: Existing Land-use Planning

Runoff flooding hazard has historically provided a focus for flood management, with coastal inundation identified as a secondary threat, typically occurring at lower elevations. Consequently, existing flood mitigation, through site identification, emergency management and minimum fill levels, provide effective controls to coastal inundation.

The significance of the Ningaloo coastal region has been acknowledged through objectives for management of the Ningaloo region, including Exmouth.

The Shire of Exmouth Local Planning Strategy acknowledges the importance of managing coastal hazards, through both SPP 2.6 (Coastal Planning Policy) and SPP 6.3 (Ningaloo Coast). This is further supported in the Exmouth region by the Ningaloo Coast Regional Strategy (2004). Despite acknowledgement of coastal hazards, there is limited identification of coastal inundation, as runoff flood risk occurs in the same locations, to generally higher levels.

A special control area for Exmouth floodplain (SCA5) is identified in Exmouth Local Planning Scheme 4.

Evaluation of Exmouth's planning framework with a view to establishing its relevance in mitigating inundation impacts provided the following (Seashore Engineering 2024):

- Interactions between coastal inundation and runoff flooding risks are identified.
- There is no defined scenario for coastal inundation hazard, with runoff flooding levels generally above coastal inundation levels at the 100-year ARI recurrence used for town planning. Allowance for sea level rise is not clearly reported, and there is no requirement or provisions for adaptation.
- Information regarding coastal inundation hazard is not reported in the Local Planning Strategy or LPS4.
- Exmouth Local Planning Strategy identifies that opportunities for growth of Exmouth town site may include undertaking flood management and mitigation works.
- Minimum floor levels are recommended.
- The need for potential adaptive management along Exmouth coast is identified in the Local Planning Strategy, acknowledging SPP 2.6. Adaptation pathways are not described explicitly.
- The planning framework acknowledges the role of emergency management and has incorporated provisions supporting access evacuation in the Local Planning Strategy.
- Exmouth Local Planning Strategy and LPS4 acknowledge the role of ABCB guidance for buildings.
- A special control area for Exmouth Floodplain (SCA5) encompasses the area subject to coastal inundation hazard, except for Exmouth Boat Harbour. Definition of SCA5 based on runoff flooding, without additional reference to its role to mitigate coastal inundation may impede SCA use to support strategic coastal interventions or adaptation.

APPENDIX F: Northern Flood Basin Evaluation

Preliminary evaluation of the Northern Flood Basin has been undertaken through review of SKM (2007) Exmouth Floodplain Management Strategy, JDA (2002), Australian Rainfall & Runoff and hypsometry of the flood basin, derived from LIDAR.

Exmouth Northern Flood Basin Hypsometry

Contour	Area (m^2)	Volume (m^3)
1.5 m AHD	-	-
2.0m AHD	60,000	15,000
2.5 m AHD	450,000	142,500
3.0m AHD	1,400,000	605,000
3.5 m AHD	2,300,000	1,530,000
4.0m AHD	3,000,000	2,855,000
4.5 m AHD	3,750,000	4,542,500
5.0m AHD	4,400,000	6,580,000
5.5 m AHD	4,800,000	8,880,000
6.0m AHD	5,150,000	11,367,500

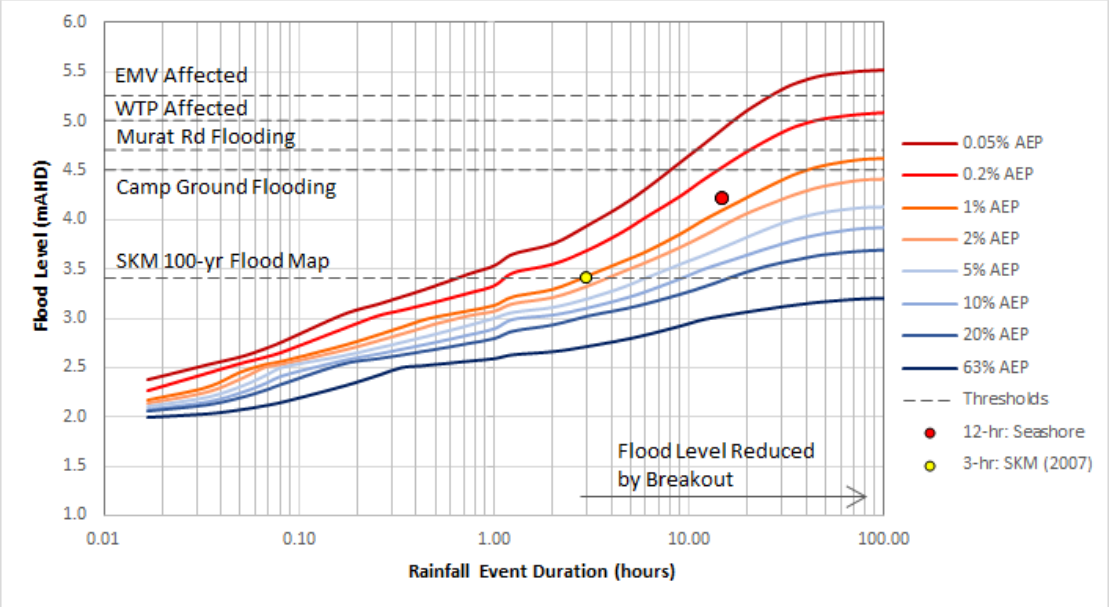
It was noted that flood mapping derived for SKM (2007) used rainfall duration of 3-hours, which was based upon creek catchment areas. Although this is considered likely to be reasonable for flooding extent adjacent to the creek channels, it understates the capacity for flooding of the northern flood basin, which takes a longer time to infill, with JDA (2002) previously applying a 12-hour rainfall duration.

The stream flooding Special Control Area (SCA) based on SKM (2007) overlies most of the area possibly subject to coastal inundation, delineated by 500 yr ARI estimates plus 0.9m SLR. This implies existing flood mitigation activities should generally be valid for mitigation of coastal inundation hazard, acknowledging differences to insurance coverage and some increases to relative damage (at the same flood level) associated with salt-water flooding.

Comparison of potential runoff volumes against basin geometry for a 'closed' scenario, with no effective drainage from the northern breakout suggests the lower rainfall duration potential understates flood risk. However, it also shows that the storage volume of the basin is sufficient to hold most flood events without reaching existing assets, except for extremely intense or sustained rainfall. This suggests limited requirement to maintain a specific cross-sectional area for the northern breakout, although it remains important for an outlet to be there, allowing drainage following a flood event.

The existing structure of the northern flood basin has a primary drainage pathway towards the northern breakout. There are several local sub-basins, with low relief constrictions at the northern end of the golf course, adjacent to the wastewater treatment plant and near Truscott Crescent. The former drainage pathway to the south has been significantly reduced through construction of Madaffari Drive, with the spillway crest level around +3.5m AHD, limiting its role as a secondary flow pathway.

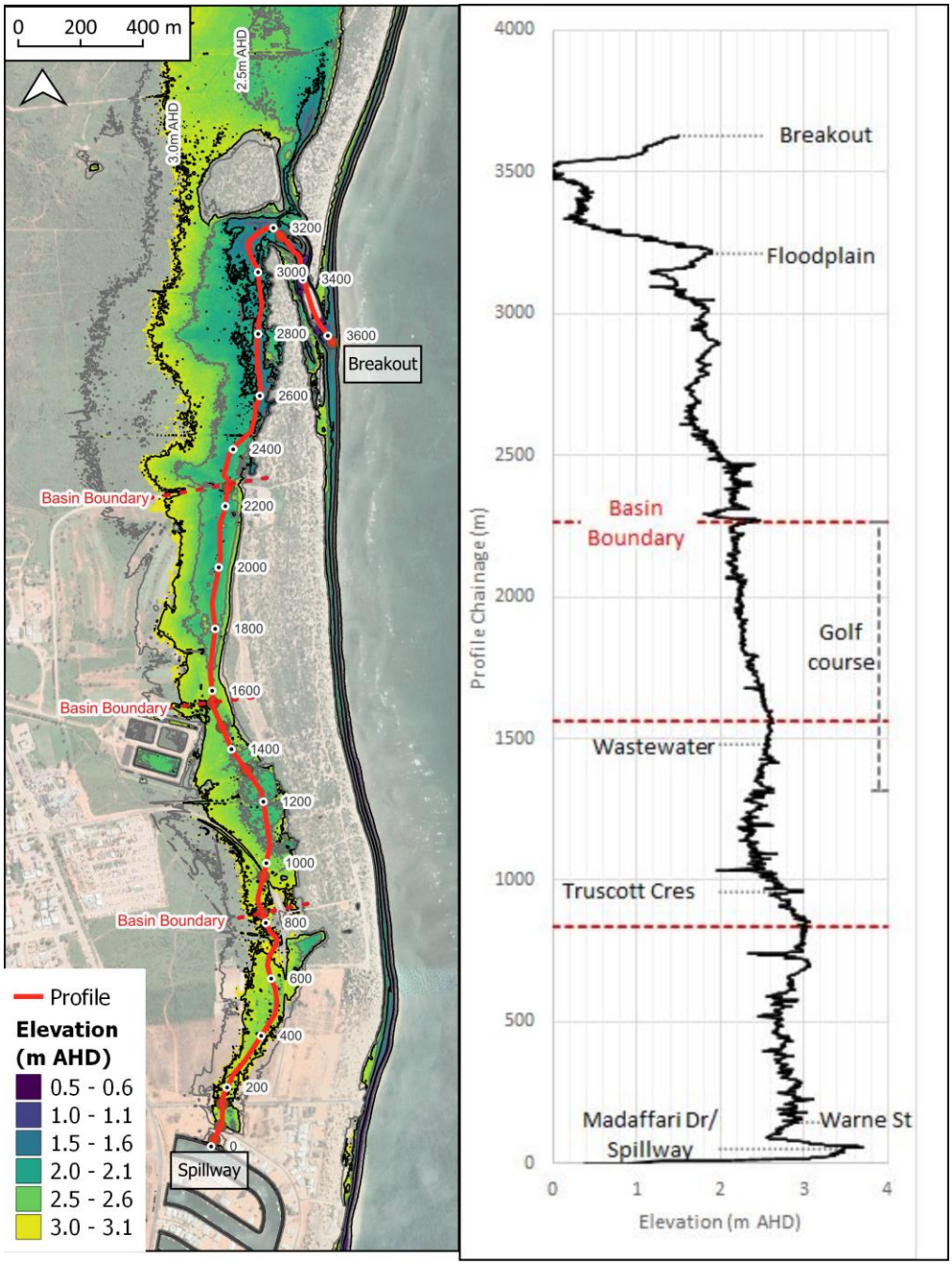
Comparison of Floodplain Areas subject to Runoff Flooding (yellow) and potentially subject to Coastal Inundation (green) with inclusion of +0.9m sea level rise.



Estimated Flood Levels for 'Closed' Basin Scenario

Development infill of the northern flood basin requires consideration of both the reduced storage volume of the basin, and hydraulic effectiveness of drainage through the flood basin. This means that assessment of infill development on the floodplain should consider:

- Minimum development ground and floor levels, in accordance with accepted risk.
- The total amount of infill development in the flood basin should be capped, to ensure that reduced flood storage does not increase flood risks to unacceptable levels for the existing development fringing the basin.
- Infill shall not 'block' north-south water flow through the flood basin. The need for stabilisation (e.g. retaining walls) resulting from flow focusing should be assessed.
- Potential for evacuation pathways (i.e. not be isolated).



Northern Flood Basin Structure

References

[1] Western Australian Planning Commission. (2013) *State Planning Policy 2.6: State Coastal Planning Policy*. Prepared under Part Three of the State Planning and Development Act 2005, Perth.

[2] Western Australian Planning Commission and Department of Planning. (2014) *Coastal hazard risk management and adaptation planning guidelines*.

[3] Seashore Engineering Pty Ltd. (2019) *Assessment of Coastal Erosion Hotspots in Western Australia*. Report SE052-01-Rev1. For the Department of Transport and Department of Planning, Lands and Heritage.

[4] Taylor Burrell & Barnett. (2014) Exmouth Local Planning Strategy.

[5] Taylor Burrell & Barnett. (2014) Exmouth Local Planning Policy.

[6] Taylor Burrell & Barnett. (2014) Exmouth Local Planning Scheme.

[7] Hassell Pty Ltd. (2013) *Exmouth Town Centre and Foreshore Revitalisation Plan*.

[8] Damara WA Pty Ltd. (2015). Ca*ravan Park Development at Lots 1403 and 1404 Truscott Crescent, Exmouth – Coastal Setbacks*. Report 250-01.

[9] Seashore Engineering Pty Ltd. (2016) *Lots 149 & 150 Hunt Street, North West Cape - Coastal Processes Study*. Project SE036-01-A.

[10] Land Insights (2023) *Exmouth Town Beach CHRMAP: Establish the Context*.

[11] Seashore Engineering Pty Ltd. (2023) *Shire of Exmouth. Coastal Hazard Assessment*. Report SE134-01-01.

[12] Nadimpalli K, Mohanty I, Vidyattama Y, Kalantari M & Rajabifard A. (2018) Australian Natural Hazards exposure information Framework: Guidelines for national consistency and comprehensive information.

[13] SKM (2007) *Exmouth Floodplain Management Study*.

[14] Shire of Exmouth. (date) *Exmouth Area Defence Sites Protection*. Local Planning Policy No 6.

[15] GBGMaps (2023) Geotechnical Investigation for Coastal Erosion Vulnerability Assessment. Exmouth, Shire of Exmouth WA. Report 3095B Rev-1.

[16] GHD. (2017) *Exmouth Boat Harbour Expansion Northern Breakwater Risk Assessment*.

[17] Department of Transport. (2022) *Exmouth Boat Harbour Masterplan*. Draft.

[18] Egis Consulting Australia. (1999) *Exmouth Boat Harbour. Assessment of Storm Water Levels*. RW1302-RP-000-001.

[19] Department of Transport. (2016) *Exmouth Boat Harbour Boat Mooring and Management Plan*.

[20] Hyd2o Hydrology. (2014) Exmouth Hydrological Study. Prepared for the Shire of Exmouth. Western Australia.

[21] Bishop-Taylor R, Nanson R, Sagar S & Lymburner L. (2021). Mapping Australia's dynamic coastline at mean sea level using three decades of Landsat imagery. *Remote Sensing of Environment*, 267, 112734.

[22] Western Australian Planning Commission: WAPC. (2002) Coastal Planning and Management Manual: A community Guide for Protecting and Conserving the Western Australian Coast. WAPC, Perth.

[23] Coastal Information & Engineering Services: CIES. (1996) *Exmouth Boat Harbour Breakwater Design*.

[24] Western Australian Planning Commission. (2004) *Statement of Planning Policy SPP 6.3. Ningaloo Coast.*

[25] Taylor Burrell & Barnett. (2016) *Exmouth Local Planning Strategy 2015-2025*.

[26] Western Australian Planning Commission. (2004) *Ningaloo Coast Regional Strategy. Carnarvon to Exmouth*.

[27] DPLH (2021) Shire of Exmouth Local Planning Scheme No. 4.

[28] Taylor Burrell & Barnett. (2011) Exmouth Marina Village ODP & Broad Design Guidelines.

[29] Taylor Burrell & Barnett. (2011) Exmouth Townsite Structure Plan.

[30] TME (2013) Exmouth South Structure Plan.

[31] Seashore (2024) A *Statewide Coastal Inundation Assessment for WA*. Report SE133-02-01.