

Assessment of Coastal Erosion Hotspots in Western Australia



**For the Department of Transport and Department
of Planning, Lands and Heritage**

Seashore Engineering Pty Ltd

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Disclaimer

This document articulates the views of Seashore Engineering, with some information obtained from consultation with local coastal managers. Hence, the opinions contained within the report do not necessarily represent the views of the State Government or any of its Departments. Additionally, this investigation has been limited to a brief assessment of each hotspot, with some assessments taking place in 2016. As a result, inconsistencies can be expected, issues may have been missed, and the currency of the information contained in this report cannot be assured. The management and adaptation options presented are a guide and do not intend to be used as a final Coastal Hazard Risk Management and Adaptation Plan for each hotspot.

This assessment focuses on the planning component of the coastal management regulatory framework. We recognise the importance of Environmental (*Environmental Protection Act 1986*) and Heritage (*Aboriginal Heritage Act 1972* and *State Heritage Act 1990*) components, which should be considered for ultimate decision-making.



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Executive Summary

Erosion is a natural coastal process which creates hazard where there is an asset or value under threat. The need for coastal erosion hazard management and adaptation is expected to increase over time due to increasing infill development, investment in coastal recreational assets and the effects of projected sea level rise. While State Government policy designates that coastal development accounts for coastal hazards, there are a number of locations where historically developed coastal facilities are expected to be threatened by erosion hazard in the near future.

The aim of this assessment was to evaluate the potential scale and extent of locations affected by coastal erosion in WA over the short and medium terms, together with the potential cost arising from it. Broad objectives were identified as necessary to achieve this aim:

Objective 1: Identify coastal erosion hotspots across Western Australia. Determine potential management and adaptation pathways, based on identified sources of erosion hazard and impacted assets.

Objective 2: Evaluate implications of coastal management for hotspots and their future adaptation.

Objective 3: Demonstrate a range of possible adaptation pathways.

Objective 4: Identify issues restricting implementation of coastal management and adaptation strategies.

Objective 5: Provide a relative comparison of hotspot management importance.

This assessment allows the State and local coastal managers to strategically plan for impacts of coastal erosion and confirms the requirement to plan for erosion hazard and adaptation for each hotspot. Management and adaptation options presented are a guide only, and do not replace the need for dedicated comprehensive Coastal Hazard Risk Management and Adaptation Planning for locations subject to coastal hazards.

Methodology

Coastal erosion hotspots were identified based on the definition of a section of coastal land where erosion is highly likely to impact public and private physical assets, and requires management and adaptation action within the coming 25 years.

Three timeframes of Imminent (0–5 years), Expected (5–25 years) and Projected (25+ years) were used to assess potential erosion hazards, and to provide an indication of when management and adaptation options may be required at each hotspot. The timeframes allow for progressive decision-making, from present-day risk management to longer-term adaptation.

A geomorphic assessment was used to interpret dominant and contributing causes of erosion for each hotspot, to help predict the erosion hazard over time. Five main causes were identified:

- a) Erosion due to influence of artificial structures;
- b) Local instability due to geomorphology (e.g. foreshores created from dredge spoil, or naturally variable landforms such as cusped forelands);
- c) Geomorphic instability due to external processes (e.g. variable sediment supply);
- d) Nearshore structures which cannot withstand erosion (e.g. walling unable to tolerate the erosion stress); and
- e) Projected response expected due to forecast change (mostly sea level rise).



Assets and recreational activities threatened by erosion hazard were identified for each of the three timeframes. Trends in types of assets potentially susceptible to erosion hazard were identified by grouping assets into classes (Table A).

A framework for comparing (between hotspots) the importance of managing erosion was developed by considering public assets subject to erosion hazard, coupled with potential loss of recreational uses and private or leasehold property. This comparison led to assignment of low, moderate or high management importance to each hotspot over the three timeframes (Table B). The relative management importance between hotspots is influenced by the varying impact that coastal change scenarios are likely to have at each location. The present importance will alter over time as management and adaptation actions are undertaken, assets change, erosion pressures vary, and new problem areas emerge. The hotspots are not an exclusive set of locations where erosion may occur in WA, and the timeframes are indicative rather than predictive.

Existing Coastal Hazard Risk Management and Adaptation Plans (CHRMAPs) were reviewed where available and local coastal managers were consulted. Local coastal managers assisted with hotspot identification, confirmation of issues and assets susceptible to erosion hazard, identification of existing management, and determining constraints to coastal management for their organisation.

A high-level assessment of management and adaptation options was developed for each location with consideration of the *State Planning Policy 2.6: State Coastal Planning Policy* adaptation hierarchy of Avoid-Retreat-Accommodate-Protect (Table C). The changing nature of erosion hazard was used to determine how management and adaptation options may evolve, with management triggers and associated monitoring required to define when to shift between options. This provides an indication of the range of management and adaptation options that may be available.

Results

Results of the first pass assessment of erosion issues, assets susceptible to erosion hazard, management and adaptation pathways are included as a summary for each hotspot in Appendix D. The hotspot summaries have been formulated for readers interested in information about a single hotspot.

This assessment identified 55 locations (15 Perth Metropolitan and 40 Regional) as coastal erosion hotspots (Figure A). A total of 86 locations were considered, with 55 hotspots and an additional 31 locations designated as a watchlist for future investigation. Those on the watchlist are less likely than the hotspots to be subject to erosion hazard in the next five years, and less likely to require erosion management and adaptation within the next 5 to 25 years.

Erosion hazard was considered for the 55 hotspots across the three timeframes. Dominant issues on the developed foreshores of the hotspots are siting facilities in areas susceptible to erosion hazard, unstable coastal landforms and interruption of sediment transport by infrastructure.



Public recreational facilities with a finite life span of less than 30 years are the most prevalent asset subject to erosion hazard across all three timeframes (Table A, 'Recreation'). Although many of these assets may be considered relocatable, it is not expected that all recreational assets will be able to be retained due to erosion of foreshore reserves. It is also not expected that the existing quantity of recreational assets can be maintained over time, without transferring erosion pressure to other assets.

Table A: Summary of Hotspots with Asset Classes Susceptible to Erosion Hazard

Asset class	Timeframe		
	Imminent (0–5 years) ⁴	Expected (5–25 years) ⁴	Projected (25+ years) ⁴
Private	5 (10%)	10 (18%)	26 (47%)
Leasehold	9 (16%)	20 (36%)	22 (40%)
Road/Rail	5 (9%)	27 (49%)	42 (76%)
Services¹	8 (15%)	18 (33%)	36 (65%)
Recreation²	44 (80%)	46 (84%)	46 (84%)
Boating³	13 (24%)	17 (31%)	17 (31%)
Surf lifesaving club/rescue	1 (2%)	6 (11%)	6 (11%)
Sand beach access	39 (71%)	39 (71%)	39 (71%)
Sand boat launching	12 (22%)	18 (33%)	18 (33%)

Note: 1) Services are drains, electricity, water, communications, gas, sewerage, oil from Dial before you Dig. 2) Recreation includes paths, beach access (only fixed by concrete/bitumen or staircases), playgrounds, parklands and car parks. 3) Boating excludes sand ramps and beach launching with no associated stabilisation works. 4) Percentages in brackets indicate percentage of hotspots with that asset class susceptible to erosion hazard.

For nearly half of the hotspots, management of erosion pressure will require consideration of the interface between public and private assets in the Projected (25+ years) timeframe. More than a third of the hotspots may have leasehold property susceptible to erosion hazard in the Expected (5–25 year) timeframe. Over the next 25 years increasing management focus is anticipated on interruption of transport routes (road and rail). One hotspot, South Thomson Bay on Rottnest Island, has publicly owned holiday units that are high value assets potentially threatened by erosion hazard.



Figure A: Map of the 55 Hotspots

Overall, 21 hotspots can be considered to have high *relative* management importance (group ranking) within five years. These are the hotspots that have high management importance in the Imminent (0–5 year) or Expected (5–25 year) timeframes, therefore requiring planning in the short-term. In the Imminent (0–5 year) timeframe these 21 hotspots comprise three groupings (Table B):

- Two hotspots have high management importance (Port Beach and South Thomson Bay in Rottnest Island);
- Twelve hotspots have moderate management importance (Broome Town Beach, Monkey Mia, Drummond Cove, Grace Darling Park, Ledge Point, Seabird, Mettams Pool, Floreat Beach, Kwinana waterfront industrial, Rockingham Town Beach to Causeway, Mandurah Northern Beaches, Koombana); and
- Seven hotspots have low management importance (Denham townsite, Sunset Beach Geraldton, Grannies Beach, Cervantes, MAAC Seawall Joondalup, C.Y. O’Connor beach, Emu Point Albany).

Table B: Summary of Hotspot Management Importance

Group Ranking	Number of Hotspots			Management Importance		
	Total	Perth Metropolitan	Regional	0–5 years	5–25 years	25+ years
1	2	2 (inc 1 Rottnest)	0	H	H	H
2	12	4	8	M	H	H
3	7	2	5	L	H	H
4	6	2	4	M	M	H
5	19	4	15	L	M	H
6	5	0	5	L	M	M
7	1	1	0	L	L	H
8	3	0	3	L	L	L
<i>Total</i>	55	15 (27%)	40 (73%)			

Advanced management planning is recommended for these 21 hotspots. While there is a focus on hotspots with high management importance over the Expected (5–25 year) timeframe, appropriate management of coastal assets is required at all hotspots. Substantial variation between anticipated and actual coastal behaviour is possible where the timeframe is greater than a few years.

The number of hotspots with high management importance in future suggests that local coastal managers have typically not applied a long timeframe to decision-making for the placement of assets within the coastal zone. In many cases there is an opportunity, in the context of an approved and funded management plan, for temporary to medium-term use of highly valued coastal land before longer-term erosion hazards threaten assets or the foreshore reserve is exhausted.

Protect is the main strategy presently used by local coastal managers and is likely to continue for the Imminent (0–5 year) timeframe (Table C). Over the Expected (5–25 year) timeframe **Retreat** could be as widely and effectively implemented as **Protect**. This change is likely to require a complementary shift in funding patterns, changes to community attitudes, securing alternate land for relocated assets and demonstration of the socio-economic value of beaches and foreshore reserves. Consideration of the steps required to undertake retreat at individual hotspots indicated that it is not always a low cost strategy. Equally, recognition of erosion transfer and the value of beaches highlighted that protection is not always a complete solution to erosion pressure.

**Table C: Changing Management Approaches to Erosion Over Time**

Management approach	Number of hotspots with management approach (by timeframe) ¹			
	Existing	Imminent (0–5 years)	Expected (5–25 years)	Projected (25+ years)
Avoid	17	8	1	0
Retreat	12	18	37	42
Accommodate	15	21	23	10
Protect	42	37	31	25

Note: 1) A hotspot may have multiple management approaches in one timeframe.

The ability to **Avoid** erosion hazard reduces over time with a greater transition to **Retreat** and **Protect**. This is partly attributed to the transfer of erosion stress from existing erosion mitigation structures and ongoing interruption of sediment transport by facilities and erosion mitigation structures. Existing erosion buffers are likely to be exhausted within 20–40 years for many hotspots.

A strategy to **Accommodate** involves developing more tolerance to erosion hazard, particularly short-term stresses. In situations where the erosion hazard is more strongly episodic or cyclic, accommodate can have greater long-term effectiveness, which is reflected in the 10 hotspots for which accommodate has been identified as a long-term option.

The timeframes presented are notional, with triggers developed for when actions will be required in the next management phase. A range of simple monitoring techniques has been identified for the hotspots, based on triggers indicating when the management approach may need to change. These transitions were identified for erosion thresholds loosely corresponding to the ends of Imminent and Expected timeframes, recognising that triggering will occur at different times depending on the conditions experienced.

Effectiveness of implementing coastal management, planning mechanisms and adaptation for each hotspot was identified as being influenced by many factors, including:

- Community expectations to maintain or extend existing facilities, including protection against erosion;
- Low corporate knowledge due to high staff turnover, or lack of dedicated coastal staff, for many coastal management positions in local government;
- Insufficient understanding of causes of erosion, including potential for erosion mitigation structures to transfer erosion stress;
- Uncertainty in securing funding and in the financial responsibilities for erosion management on private and leasehold land;
- Uncertainty of management responsibility for erosion on Unallocated Crown Land;
- Uncertainty for local coastal managers on how to implement planning mechanisms; and
- Availability of coarse sand suitable for renourishment and rock for construction of erosion mitigation structures.

Recommendations

In undertaking this assessment, issues have been identified that are common across hotspots and their local coastal managers. To address these issues, actions have been recommended that could support coastal management by State and Local governments. The recommendations have been grouped into two themes:



- Actions relevant to governance and management of hotspots; and
- Options to address knowledge gaps relevant to hotspot management.

Governance and management of hotspots threatened by erosion

1. State Government to provide integrated coastal planning and engineering support to local coastal managers.
2. Local coastal manager to prepare fully developed and costed management and adaptation plans (hotspot-specific CHRMAPs) for their hotspots. Hotspot-specific CHRMAPs should include:
 - a) increased focus on:
 - determining coastal management responsibilities;
 - developing implementation plans and determining funding mechanisms;
 - resolving planning mechanisms (e.g. special control areas);
 - b) appropriate triggers for changing management phases;
 - c) community and stakeholder engagement regarding proposed solutions, outlining impacts on coastal values and ratepayers in terms of funding;
 - d) focus emphasis of the erosion hazard assessment on dominant erosion processes at the hotspot, with more detail noted in Recommendation 8 below;
 - e) consideration of alternative siting of roads or rail susceptible to erosion hazard, with planning undertaken for truncation or redirection of traffic where feasible;
 - f) reviewing lease agreements, to support adaptation pathways at hotspots where leasehold assets are susceptible to erosion hazard; and
 - g) developing a detailed asset register of infrastructure at the hotspots to identify ownership, replacement costs and value of individual assets susceptible to erosion hazard.
3. Prepare and implement a community education program, building on resources such as CoastAdapt, to raise awareness about the impacts of coastal processes and the adaptation options, particularly to improve the feasibility of implementing retreat as a management option for key public infrastructure (e.g. roads and services) through to recreational facilities with short life spans.
4. Statewide broad review of lease agreements to support coastal management and adaptation pathways.
5. Review and clarify management arrangements and responsibilities for hotspots containing Unallocated Crown Land.
6. Determine the socio-economic value of beaches and foreshore reserves when assessing options where these assets may be reduced or lost due to management actions or coastal processes.
7. Identify a more sophisticated method of assessing coastal change on developed coasts to better inform short- to medium-term adaptive management. This should incorporate refinements of generic erosion hazard assessment with additional active factors, including the effect of historic modifications, adjacent structures, rock control and ongoing sand management; along with appropriate storm events.



Address information gaps for coastal erosion assessments and management responses.

Effective coastal management and adaptation plans need to draw on a comprehensive knowledge base regarding each of the identified hotspots. Areas to improve the level of understanding of hotspots, based on identified information gaps, include:

8. Extended long-term record of coastal movements at all hotspots and watchlist locations.
9. Collection of information on coastal dynamics should be targeted to refine knowledge of specific local or episodic erosive processes, such as unstable landforms or interrupted sediment transport (see green and peach colours in Table 4-2).
10. Commission geotechnical investigations for hotspots identified in Table 4-2, starting with those where private, leasehold, road/rail and services are susceptible to erosion within 25 years.
11. Review the demand for, cost and availability of basic raw materials for coastal protection, including coarse sand for renourishment and rock for construction of erosion mitigation structures. This significantly impacts the feasibility and cost of coastal protection.
12. Develop improved hotspot management histories to refine projected coastal trends and use as a basis for recording ongoing maintenance. This should include information on dredged material disposal and historic engineering works from Public Works Department records.
13. Preparation of regionally-varying low-cost monitoring programs to assist local coastal managers in understanding their foreshore and determine when a change in management is triggered.
14. Identification of long-term and regional variations of oceanographic and meteorological data, mainly collected by Department of Transport and the Bureau of Meteorology, to support better interpretation of coastal trends.
15. Review of the hotspot and watchlist locations on a five-yearly basis, to determine if any watchlist locations should be considered as hotspots or if additional locations should be added to the watchlist. For new hotspot locations, management and adaptation plans should be developed.
16. Preparation of material illustrating Retreat case studies previously undertaken by local coastal managers in Western Australia. This will be available to consider when assessing retreat as an option for private property and leaseholds.



1. Introduction

Coastal erosion is a natural process which creates hazard where there is an asset or value under threat. Within this context, the Western Australian (WA) Government is working towards a whole of state approach to manage coastal erosion hazards.

The need for coastal erosion hazard management and adaptation is expected to increase over time. This is due to increasing infill development and investment in coastal recreational assets; and the effects of projected sea level rise. While present policy (WAPC 2013a) designates that coastal development accounts for coastal hazards, there are a number of locations where existing coastal facilities are expected to be threatened by erosion hazard in the near future.

Development of a whole of state approach requires statewide evaluation of coastal erosion threats. This assessment focuses on coastal erosion hotspots (herein referred to as hotspots), defined as a section of coastal land where the erosion hazard is expected to impact public and private assets within 25 years. This analysis provides an initial evaluation of the hotspots, including:

- comparison of issues in consultation with local coastal managers;
- qualitative techniques to identify relevant hazards; and
- provision of preliminary recommendations for management and adaptation options for each hotspot, which incorporates a measure of related costs.

Together, this information provides a summary of coastal erosion and possible trends in future management. An important outcome of this assessment was identification of the spatial extent and scale of costs required for coastal erosion management and adaptation around Western Australia for the next 25 years. This will allow the State and local coastal managers to strategically plan and budget for the potential impacts of coastal erosion.

This is a high-level assessment that allows for comparison between hotspots. More detailed investigations with implementation plans are required at a local scale as part of comprehensive coastal hazard risk management and adaptation planning.

1.1. ASSESSMENT OBJECTIVES

The aim of this assessment is to evaluate the potential scale and extent of coastal erosion in WA over the short and medium term. This is intended to assist Government in developing a strategic approach to the challenges presented by coastal erosion hazards. This aim has been pursued through a statewide identification and assessment of hotspots in Western Australia. The assessment tasks involved:

- Defining 'erosion hotspot';
- Identification of hotspots;
- Characterising the nature of the erosion issue for each hotspot and a comparison across all hotspots;
- Identification of assets, values and infrastructure that may be susceptible to erosion over short (0–5 years), medium (5–25 years) and longer (more than 25 years) terms. The timeframes used are indicative only;
- Consulting with local coastal managers to obtain input on erosion hotspots, issues and constraints to their management;



- Identification of high level management responses, any erosion mitigation works or planning actions to avoid and alternative options;
- Identification of further studies required for more detailed assessment and adaptation planning, along with a knowledge gap analysis;
- Identification of triggers for management actions and the required monitoring;
- Summarising the results into individual hotspot summaries (Appendix D); and
- First pass ranking of the relative management importance of hotspots;

Broad objectives of the hotspot assessment are described below.

1. *Identify coastal erosion hotspots across Western Australia. Determine potential management and adaptation pathways, based on identified sources of erosion hazard and impacted assets.* Identification of hotspots and first pass adaptation assessment supports targeted monitoring, the establishment of simple triggers to guide the sequence of investigations and allows for design and budgeting in a timely fashion. Determination of possible management and adaptation pathways for each hotspot, together with an estimate of related costs, provides guidance to each local coastal manager and can be used for planning and project scoping. An early assessment of problems helps to identify actions across the wider area likely to detrimentally affect future adaptation.
2. *Evaluate implications of coastal management for hotspots and their future adaptation.* Identification of hotspots likely to need major adaptation effort provides a practical basis for the scoping of future financial requirements where management and adaptation actions may be required. The need for this focus is also supported by the potentially long lead times necessary to establish financing for major works.
3. *Demonstrate a range of possible adaptation pathways.* Identifying management and adaptation pathways across all 55 hotspots demonstrates the range of possible pathways to mitigate erosion hazard available to local coastal managers. Examples of how to implement retreat, accommodate and protect mitigation strategies are provided over the three timeframes, illustrating the influence of management sequences. The range of pathways contrasts the feasibility of the long-term strategies of retreat and protect; and helps indicate whether non-structural hazard mitigation may be effective.
4. *Identify issues restricting implementation of coastal management and adaptation strategies.* Consultation with local coastal managers, and assessment of the 55 hotspots, allows the range of issues in governance, funding and decision-making presently hindering coastal management and adaptation to be identified.
5. *Provide a relative comparison of hotspot management importance.* Allows a first pass, relative measure of importance for addressing coastal erosion hazards at a hotspot and the need for subsequent funding of management and adaptation plans.

The approach used in this report can be applied to the assessment of other coastal erosion hotspots.



1.2. ASSESSMENT FRAMEWORK

This assessment was undertaken in four stages (see Figure 2-2 for methodology).

Stage 1: A methodology for a first pass assessment was developed and applied to 30 hotspots.

Stage 2: A statewide evaluation to identify hotspots not included in the first pass assessment was undertaken.

Stage 3: A final list of 55 hotspots and an additional 31 watchlist locations was created.

Stage 4: First pass assessment of the 55 hotspots using the methodology formulated in Stage 1 was carried out. Management and adaptation pathways were prepared for each hotspot.

Consultation with the local coastal managers was undertaken during all four stages.

2. Methodology

A strategic approach was used to identify and assess coastal erosion hazards at areas of concern (hotspots) in WA.

Initial hotspot identification was undertaken by the Department of Transport (DoT) through consideration of applications to their grants program, with subsequent hotspots identified by Seashore Engineering through a statewide assessment in conjunction with local coastal manager consultation.

An overview of the methodology used for hotspot identification, determining relative management importance of the hotspots, formulation of management and adaptation pathways for each hotspot, and finally the identification of knowledge gaps, conclusions and recommendations is presented in Figure 2-1. Information was prepared for each hotspot, including summary paragraphs and figures describing the issues and existing management strategies, which were then reviewed by local coastal managers.

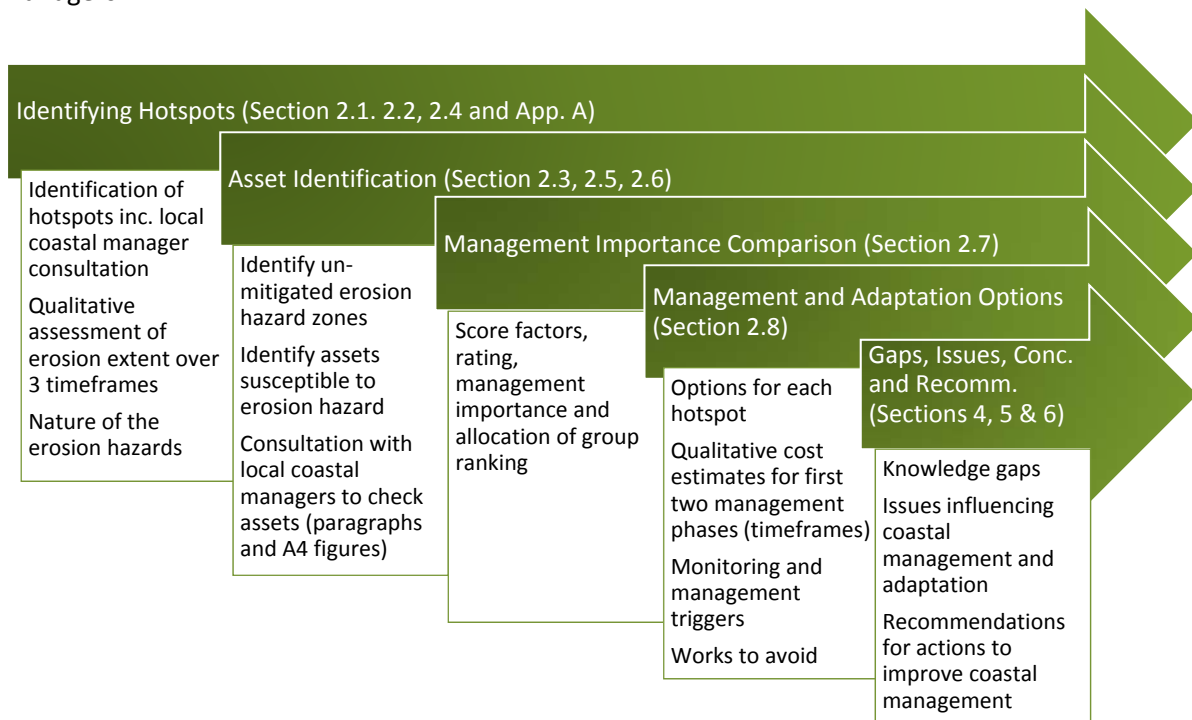


Figure 2-1: Methodology schematic

This approach is considered suitable for the assessment of future erosion hotspots and watchlist locations in Western Australia.

2.1. DEFINING THE HOTSPOTS

Steps used to define and evaluate the hotspots are summarised in Figure 2-2 with further detail in Appendix A. There were three main stages to defining the hotspots, following from Section 1.2:

Stage 1: DoT defined 30 hotspots by considering applications from local coastal managers for Coastal Adaptation and Protection (CAP) grant scheme funds.

Stage 2: The 30 hotspots were confirmed, and additional locations in WA likely to be affected by an erosion hazard were identified. The confirmation was based primarily upon the proximity of existing assets to the coast, and secondarily through interpretation of the extent of the probable erosion hazard.

Stage 3a: Further consideration was given to all locations to provide a refined list of hotspots. The refinement used a combination of internal review, cross-checking against available CHRMAP documents (listed in Section 7) and consultation with local coastal managers (Appendix E.1).

Stage 3b: All hotspots identified in Stage 3a were reassessed to determine a final list based on assets that may be susceptible to erosion hazard, their proximity to the coast, spatial scale of the hotspot, management responsibilities, and consistent adaptation strategies.

Additional detail for each stage is included in Appendix A.

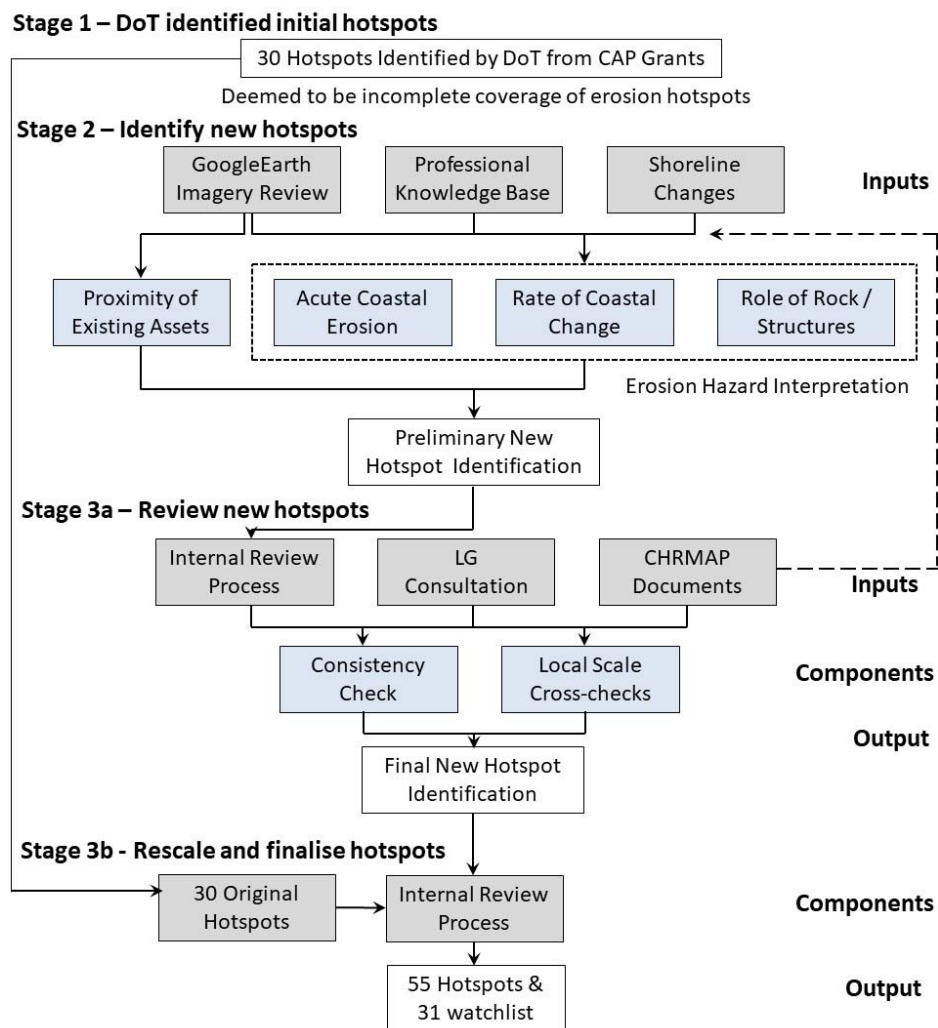


Figure 2-2: Hotspot identification process



Hotspot Characteristics

Characteristics typical of erosion hotspots are outlined below.

- *Proximity*: Infrastructure close to the existing shore, or landward of progressively and rapidly eroding coast;
- *Instability*: Typically subject to progressive or episodic erosion;
- *Mitigation cost*: Costs of likely forms of erosion mitigation are high;
- *Transfer*: Limited capacity to manage future erosion using existing coastal protection measures or extension of existing coastal protection works is considered likely to exacerbate erosion transfer; and
- *Community*: Highly valued by the community, as nominated by local government representatives.

Relevant characteristics for each hotspot and watchlist location are shown in Table 3-1 and Table B-1 in Appendix B, respectively. In most cases, the hotspots had three or four of the characteristics and the watchlist location had one or two of these characteristics. Three hotspots have only two of these characteristics and were included because of the severity of erosion or the scale of assets. A total of 55 hotspot and an additional 31 watchlist locations were defined according to these characteristics and mapped.

Hotspot Identification Constraints

Hotspot identification is constrained by the following parameters, noting that the identified hotspots are not intended to create an exclusive list of where erosion may occur in WA.

1. Focus on expected erosion hazard, within an approximate timeframe of 25 years. Other coastal hazards such as inundation, coastal sand drift, or tidal stream mobility require subsequent consideration;
2. Only coastal locations are considered. Locations within estuaries, such as canal estates, were excluded;
3. Port facilities and other maritime developments were not assessed;
4. Areas where ongoing coastal management (i.e. existing protection structures or sand nourishment programs) has provided historic coastal stability and setback buffers adequate for the next 20–30 years were not assessed (e.g. some sections of Geographe Bay)¹; and
5. Presently undeveloped locations were not considered further, regardless of land tenure.

It is important to note that the identification process does not provide a definitive predictor of whether any location will or will not be affected by erosion within 25 years. The localised nature of storm impacts and the irregular nature of many coastal phenomena make the timing and amplitude of erosion events highly unpredictable. The timing of erosion occurrence may also be influenced by coastal protection works, particularly if these act to transfer erosion stress alongshore. Any subsequent work using the hotspots and watchlist locations should ensure the lists are revised in line with up-to-date information of this nature (i.e. it is likely an equivalent list generated in three to five years would be slightly different).

¹ It is acknowledged that this approach means the total cost of managing coastal erosion at the hotspots (Section 2.8.1) should not be considered as a value representative of all coastal management costs in WA.



2.2. TIMEFRAMES

Three timeframes are used to assess susceptibility to erosion hazard and indicate when management actions may be required (Table 2-1). The timeframes allow focus on different elements of management decision-making, from present-day risk management to longer term adaptation. They also provide a filter for managing coasts with cyclic erosion patterns (acute) rather than erosion trends (chronic). The five-year timeframe for *Imminent* hazard is based on typical budget preparation times for capital works by coastal managers. The three timeframes provide capacity to recognise the benefit of connecting immediate action with long-term adaptation plans; this reduces the likelihood of implementing purely reactive management actions, especially those that will be ineffective in the longer term.

Table 2-1: Three timeframes

Description	Decision-making	Approx. Timeframe	Components	What is considered?
Imminent (almost certain)	Risk management	<5 years	Acute Erosion	Present state of the foreshore and sensitivity to acute events.
Expected (likely)	Management pathways	5–25 years	Acute Erosion + Chronic Erosion	Dynamics, life-cycle of existing or proposed stabilising structures and actions to increasing coastal resilience.
Projected (possible)	Adaptation strategy	25+ years	Acute Erosion + Chronic Erosion + Climate Change	Uncertainty related to future management choices and longer-term process variability. Scenarios considered over this scale may indicate potential pathways to improve coastal resilience.

Each timeframe is used to identify potential erosion hazard zones as described in Section 2.5.

2.3. LOCAL COASTAL MANAGER CONSULTATION

Consultation with Local Governments (LGs) was undertaken because they are most commonly the local coastal managers; hence they are the most directly involved and knowledgeable about present issues and management actions at their hotspots. The consultation ensured accuracy of information used in the assessment and captured additional issues regarding coastal management. Study findings and outcomes will be relevant to the local coastal managers.

Local coastal manager consultation was undertaken via telephone calls and online surveys to Local Governments and other local coastal managers. Both methods were used to obtain the necessary information from local coastal managers about hotspots within their local area. The 45 Local Governments with coastal boundaries were contacted to assist in determining the hotspots (Appendix E.1). Consultation in the first and final phases included provision of a survey to the local coastal managers of the first 30 hotspots and the additional 25 hotspots respectively, while telephone calls were used as the consultation method in the second phase. Additional information on the consultation process is contained in Appendix E.



This consultation was undertaken to:

- Identify any hotspots (coastal erosion focus) in addition to the first 30. The first online survey identified that the initial hotspots coverage was insufficient to adequately quantify the extent of the erosion issue in WA;
- Clarify the hotspot issues, including assets susceptible to erosion hazard, hotspot recreational uses, existing management practices, stakeholder issues outlined in the summary paragraphs and summary figure (Appendix D);
- Obtain copies of any previously prepared reports on community/stakeholder values at the hotspot, any management options unlikely to be acceptable by the community and if there are any planned changes to land use that will impact future management options; and
- Identify broader constraints affecting their capacity to effectively manage coastal hotspots.

2.4. DEFINING THE NATURE OF THE EROSION HAZARDS

The cause of erosion and its impacts varies between hotspots, influencing possible management solutions. Attributes to be considered include whether the erosion is related to cyclic or progressive change, alongshore or cross-shore, or whether the erosion is locally specific or part of a wider-area process. These attributes suggest the appropriate physical scale of response and whether management solutions should be robust or adaptable.

The nature of erosion hazard was explored to help select management pathways for individual hotspots. Based upon historic behaviour at the hotspots, five different causes of erosion were identified (Figure 2-3):

- a) Erosion due to influence of artificial structures;
- b) Local instability due to geomorphology (e.g. foreshores created from dredge spoil, or naturally variable landforms such as cusped forelands);
- c) Geomorphic instability due to external processes (e.g. variable sediment supply);
- d) Nearshore structures which cannot withstand erosion (e.g. wall at Binningup does not tolerate the erosion stress); and
- e) Projected response expected due to forecast change (mostly sea level rise).

Most hotspots exhibited symptoms of more than one cause (e.g. erosion may include cross-shore response to storm conditions and downdrift erosion due to the influence of a groyne).

The five causes of erosion are associated with differing time and length scales (Table 2-2; Table 4-1). Erosion resulting from artificial structures or geomorphic instability is generally localised in character while more widespread erosion is likely to be due to external processes or projected change. Erosion that has a localised character is typically suited to the use of retreat or focused protection while widespread erosion more commonly requires progressive retreat, or large-scale defensive approaches.

Each cause of erosion also varies over time. The effect of structures and geomorphic instability is typically a more acute response, whereas changes to sediment supply or projected sea level rise are likely to have increased significance over time. Imminent hazard (i.e. possibly occurring within five years) is largely related to acute processes whereas long-term hazard being largely determined by sustained and progressive processes (Table 2-2). This generalised shift with timescale can be applied to four of the five erosion causes with contributions due to acute, intermediate or progressive processes.

Erosion cause (d) is where structures have been built in the nearshore that were not able to withstand the naturally occurring shoreline variability (Figure 2-3d). The time and length scales for this cause of erosion hazard are related to the coastal processes occurring at each location and will vary across each hotspot. As a result, the time and length scales for this erosion cause cannot be generalised and it is excluded from Table 2-2.

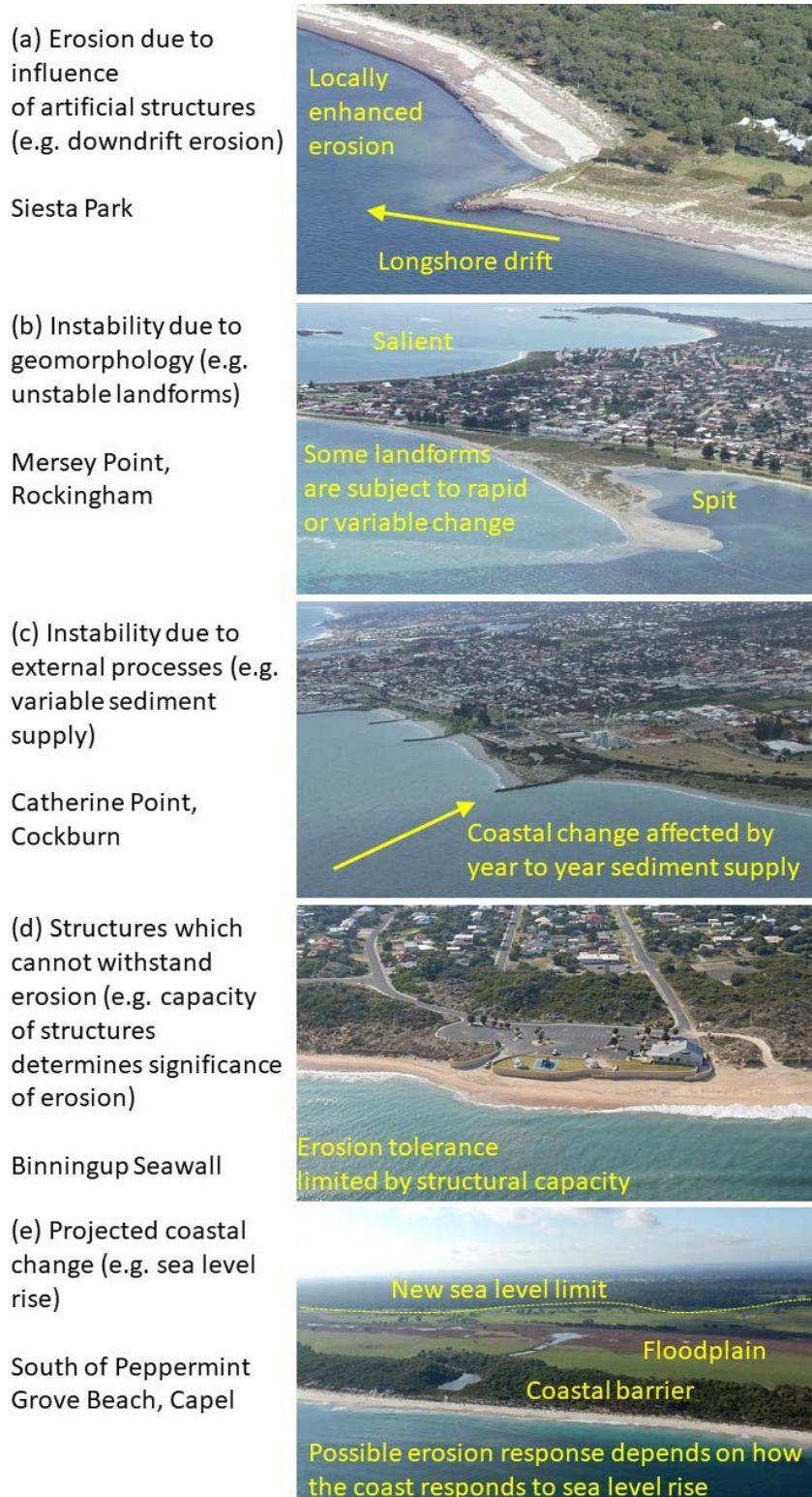


Figure 2-3: Illustration of five erosion causes



Table 2-2: Examples of different processes with time scale and erosion cause

This table is provided as an indication only of how erosion processes may vary over time and has therefore not been used as part of the assessment framework. The relative importance of different processes varies on a case-by-case basis. Evaluation of processes has been based upon the consultants' knowledge of individual hotspots and understanding of comparable situations.

Erosion Cause	Imminent (0–5 years)	Expected (5–25 years)	Projected (25+ years)
Erosion due to structures	Response after a storm	Progressive cumulative loss	Change to sediment budget
Local instability due to geomorphology	Cross-shore storm erosion ^[S1]	Landform erosion-recovery cycle	Coastal landform evolution ^[S2]
Geomorphic instability due to external processes	Reduced annual supply	Secular change due to inter-annual cycle	Cessation of ongoing supply
Response to projected change (SLR)	n/a	Beach rotation	Profile adjustment to sea level rise ^[S3]

^[Sx] processes corresponding to Schedule One allowances in SPP 2.6 (WAPC 2013a)

2.5. IDENTIFYING EROSION HAZARD ZONES

Exposure of existing public-owned assets, private and leasehold property to erosion was estimated by considering unmitigated erosion hazard zones for the three nominal timeframes (Section 2.2). The term unmitigated implies that erosion hazard zones in the Expected (5–25 year) and Projected (25+ years) timeframes have not altered in response to recommended erosion management actions in the previous timeframe.

These zones were used to characterise assets and values susceptible to erosion as well as to select possible management and adaptation options. Although quantified information was used to help evaluate these zones, the process required qualitative interpretation of episodic, cyclic and transferred erosion hazards, and therefore hazard zones were not formally mapped. The potential for inconsistency in the zones between hotspots was offset by the discrete nature of assets susceptible to erosion hazard (e.g. foreshore reserve width). Consequently, adaptation sequences were developed based upon management thresholds, rather than 'time-based' thresholds. Development of maps or datasets showing erosion hazard zones was not in the project scope.

The spatial distribution of erosion pressure for each of the three timeframes has been interpreted through professional judgement, based upon historic observations of coastal change at the hotspots, literature, landforms and potential landform change, potential rock controls, knowledge of the hotspot held by Seashore Engineering personnel and analogous situations from locations across Western Australia, particularly those where sediment transport has been disrupted. For most hotspots the erosion hazard zones are not a uniform distance landward from a datum. Evaluation of erosion hazard zones has been built upon components similar to those in Schedule One of the *State Planning Policy 2.6: Coastal Planning Policy* (SPP2.6: WAPC 2013a), with consideration of landform dynamics, transfer of erosion stress from hard structures and less intense storms than 100-year Average Recurrence Interval (ARI) events. It is noted that the standard means of evaluation in Schedule One of SPP2.6 are suitable for long-term (100+ year) erosion assessment on greenfield locations. Other factors influencing coastal change require consideration over the shorter timeframes (see Section 2.4).



It should be noted there is considerable uncertainty regarding the likelihood that a severe storm may impact a particular hotspot, or whether patterns of change observed over recent decades will continue, accelerate or reverse. Further uncertainty is introduced by the effects of future stabilisation works undertaken at or nearby to a hotspot.

These erosion hazard zones for the three timeframes were used to identify assets and recreational uses susceptible to erosion hazard, relative management importance and for selection of management and adaptation options. The shift from Imminent to Projected timeframes provides a sequence of increasing erosion extent, thereby providing a basis from which to consider how the management pathway may change over time.

2.6. ASSET IDENTIFICATION

Assets that may be susceptible to erosion hazard can be identified by considering their position within the unmitigated erosion hazard zones (Section 2.5). The indicative timeframes (Section 2.2) are used as a relative likelihood scale for asset damage/failure. The focus of the asset identification was to determine management importance and the appropriate management and adaptation options.

Assets were grouped into classes for both ease of identification and strategic assessment. The classes considered include private property, leasehold property, road/rail, services (drains, electricity, water, communications, gas, sewerage, oil), recreation assets (paths, beach access fixed by concrete/bitumen or staircases, playgrounds, parklands and car parks), fixed boating infrastructure, surf lifesaving or marine rescue clubs and non-fixed infrastructure (such as sandy beach access with no other improvements) and sand boat launching (sand access ramps and beach launching with no associated stabilisation works)².

The number of assets, type and relative cost (seaward of the erosion hazard zones over the three timeframes) was noted for use when comparing hotspot management importance (Section 2.7) and determining management actions, adaptation options and planning mechanisms (Section 2.8).

Assets were most readily identified from aerial imagery, photos and existing reports. Cadastre and zoning³ information was used to identify the number of private or leasehold properties within the projected hazard zones. At the scale of this investigation, some discrepancy is to be expected between the number of private properties identified by Seashore Engineering and those that may be identified by other methods, for example a uniform 100m buffer distance. Services and utilities were identified using 'Dial Before You Dig' and may therefore be incomplete with regard to local services.

² The Rottnest Island holiday units in South Thomson Bay are unique public assets and were not included in these classes.

³ Zoning information was provided by DPLH from April 2016 for the Perth Metropolitan Region Scheme and Local Planning Schemes

2.7. DETERMINING HOTSPOT MANAGEMENT IMPORTANCE (HMI)

A method for determining hotspot management importance (HMI) was developed to provide a strategic basis for the management of erosion issues across the state (Figure 2-4). HMI considers those public-owned assets subject to erosion hazard, coupled with the potential loss of recreational uses, and private or leasehold property; with a set of criteria contributing to each factor (Table 2-3). The relative management importance (low, moderate or high) indicates the consequences of erosion and potential likelihood of these occurring over the three timeframes for the hotspots.

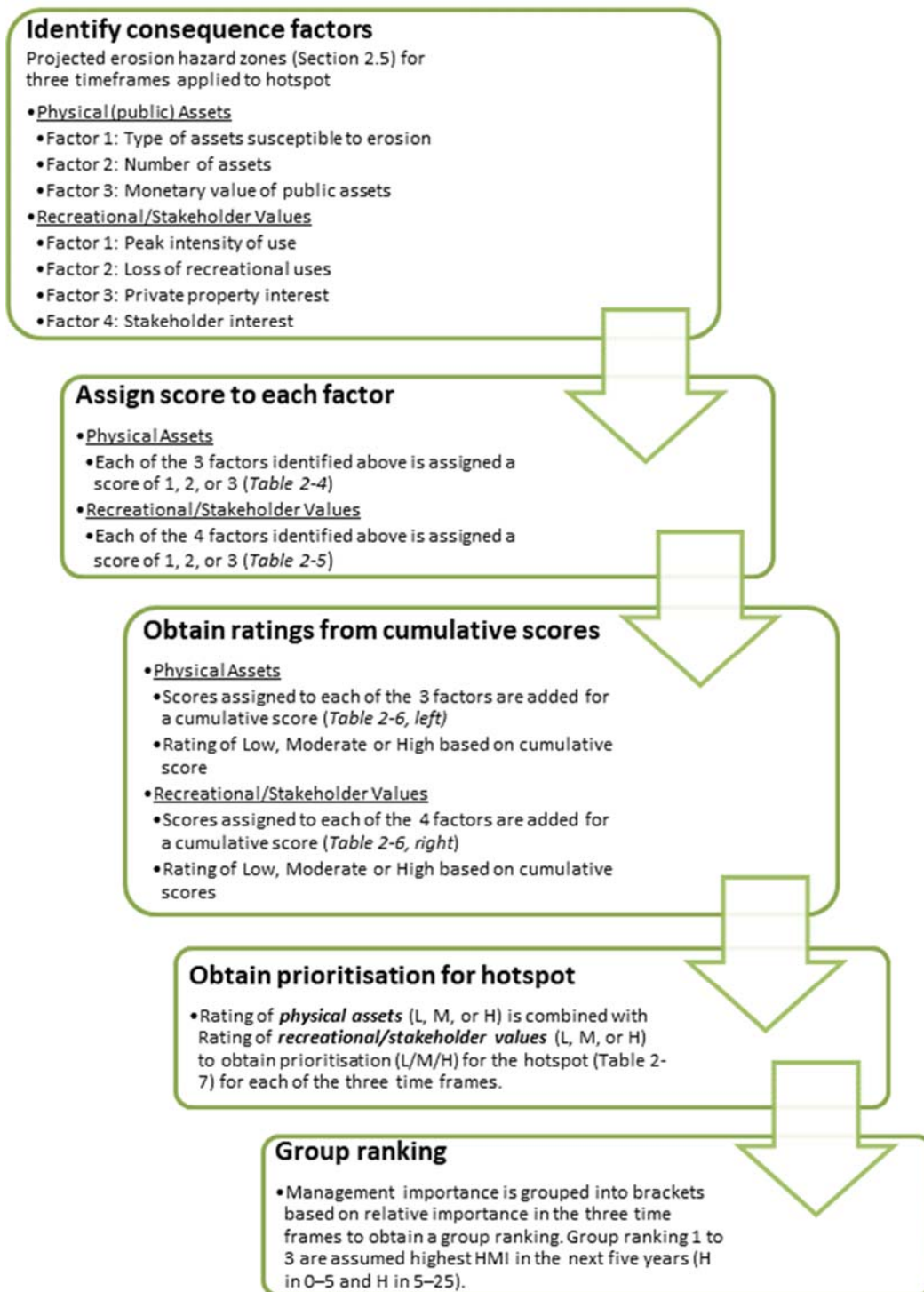


Figure 2-4: Flow chart for determining hotspot management importance



Identify consequence factors

The criteria for each consequence factor (Table 2-3) are considered in terms of their likelihood of being affected by the unmitigated erosion scenario hazards, i.e. if 'no additional management' were applied. In effect, this means any existing coastal protection structures, or renourishment programs, have been assumed to be maintained sufficiently to fulfil their existing roles, with no significant adaptation or extension. Each criterion was selected for ease of assessment based on remote sensing information and the knowledge of the hotspot held by Seashore Engineering personnel. Each criterion was allocated a score of 1 (low consequence) to 3 (high consequence) and combined to create a rating for each factor (low, moderate and high).

Table 2-3: Criteria used to develop consequence factors

Criteria used	Factor related to consequence	
	Public-owned Physical Assets	Recreational/Stakeholder Values
	Type of assets susceptible to erosion hazard	Peak intensity of use
	Number of assets	Loss of recreation uses
	Monetary value of public assets	Private property interest
		Stakeholder interest

Physical assets subject to erosion hazard

The first three criteria address the public-owned assets that may be susceptible to erosion hazard (Table 2-4). Private property susceptible to erosion hazard is incorporated in the assessment of recreational/stakeholder concern because there is a priority for use of government funds for common good rather than the benefit of private individuals. Physical assets include infrastructure, environmental and cultural features, with only infrastructure values used in consideration of replacement costs. Criteria include:

- *Type of assets susceptible to erosion hazard.* Assets which are considered temporary or relocatable are given a lower importance. Following the SPP2.6 (WAPC 2013a), this includes public recreation facilities with a finite lifespan (Section 7.1) and coastally dependant but easily relocatable development (Section 7.2). Surf lifesaving clubs (Section 7.6) are typically located in a coastal erosion hazard area because they require close proximity and vehicular access to the beach.
This criterion is modified for other features that may occur at the hotspot. This includes:
 - Contamination and groundwater pollution that could be impacted by erosion. Possible pollution is a score of 2 and known pollution is a score of 3;
 - A potential reduction in water quality is allocated a score of 2 (e.g. The Cut, Bunbury);
 - An established foreshore reserve including an area designated as a Bush Forever (DoP 2000) site is allocated a score of 2 (Perth Metropolitan only);
 - A European heritage site that is not relocatable is allocated a score of 3 (e.g. Broome pioneer cemetery). The widespread distribution of Aboriginal heritage sites, and in many cases the broad spatial nature of these sites (e.g. whole landforms) makes it difficult to assign simple ratings. Exclusion of Aboriginal heritage from the assessment of HMI is not an indication that these hotspots have low Aboriginal heritage value.
- *Number of assets.* Increase in the number of assets that may be susceptible to erosion hazard increases the importance for management. Cut-off values for medium and high levels are two and five assets respectively. For some assets protected by existing erosion mitigation structures within the timeframe of interest, an asterisk (*) is marked next to the relevant text in 'Assets susceptible to erosion hazard' rows in Appendix D.

- *Monetary value of public assets* susceptible to erosion hazard. An estimate of monetary value has been developed either as an approximate replacement cost for the most expensive infrastructure asset or the combined replacement cost where there are only low monetary value assets. Cut-off monetary values used in this assessment for moderate and high levels are \$250,000 and \$1,000,000 respectively. Environmental and cultural evaluation may be required for future hotspots.

Table 2-4: Criteria to score the physical public assets susceptible to erosion hazard

Score	Physical public assets susceptible to erosion hazard (public assets)		
	Type of public assets	Number of assets	Monetary value of public assets
1 Low	No non-relocatable assets	<2	(i) Maximum value to replace most expensive asset <\$250k; OR (ii) The sum of values where only low-value assets are present is <\$250k
2 Moderate	(i) 1 non-relocatable asset; OR (ii) Possible contaminated site or polluted groundwater sites that could be impacted by erosion; OR (iii) Established foreshore reserve includes an area designated as a Bush Forever site; OR (iv) Potential reduction in water quality	2 to 5	(i) Maximum value to replace most expensive asset is between \$250k and \$1M; OR (ii) The sum of values where only low-value assets are present is between \$250k and \$1M
3 High	(i) >=2 non-relocatable assets; OR (ii) Known contaminated site or polluted groundwater area likely to be impacted by erosion; OR (iii) European heritage site	>5	(i) Maximum value to replace most expensive asset is >\$1M; OR (ii) The sum of values where only low-value assets are present is >\$1M
Relocatable assets are described by SPP 2.6 clauses 7.1, 7.2 or 7.6			

Recreational/Stakeholder Values

Four criteria are used to score the likely impetus to address coastal erosion due to recreational and stakeholder pressures (Table 2-5). This is effectively applying a use and stakeholder value weighting to the physical assets subject to erosion hazard.

Criteria used to develop the score of recreational and stakeholder values include:

- *Peak season intensity of use*. If the coast is not heavily used it reduces the need to assign the hotspot a high management importance because fewer people would be impacted by coastal erosion hazards. This criterion considers the number of people using the hotspot daily in peak season and the number of coast-related uses. Cut-off values for medium and high levels are, respectively: use by 50 or 100 people daily, and 2 or 5 coast-related uses. It is acknowledged this may place increased importance on the Perth Metropolitan area. The peak intensity of use was based on the knowledge of Seashore Engineering personnel of the beaches, existing literature (e.g. CHRMAPs and Eliot *et al.* 2005) and consultation with local coastal managers.
- *Recreation*. The coast-dependent recreation uses were based on the knowledge of Seashore Engineering personnel of the beaches, existing literature (e.g. CHRMAPs) and consultation with local coastal managers. If more coast-dependent recreational uses are threatened by the erosion hazard at the hotspot, it will increase the demand to mitigate the hazard. This is

a subjective measure that considers loss of ability to recreate (e.g. walk, swim, access the beach, use of a continuous cycle path) within the hotspot by looking at the recreation uses and consideration of projected erosion hazard zones. Cut-off values for medium and high levels are a loss of 10 and 40% respectively of coast-dependent recreational uses in the immediate vicinity of the hotspot.

- *Private property interest.* Private property damage from coastal erosion hazards gains significant media attention and increases pressure to address coastal erosion hazards. Cut-off values for medium and high levels are 2 and 4 properties respectively. A second criterion was added for the alongshore length of coast with private property frontage to account for some hotspots with large properties.
- *Stakeholder interests.* A resident or stakeholder group using the media or frequently protesting to government to publicise coastal erosion hazard impacts on their hotspot will increase the demand to address hazards.

In attributing scores, leasehold assets were considered both as public assets with private property interest and stakeholder interest because the land and buildings were generally owned by the local coastal manager with the commercial interests of the lessee.

Table 2-5: Criteria to score recreational/stakeholder values of coastal areas susceptible to erosion

Score	Recreational/stakeholder values			
	Peak season intensity of use	Recreation	Private property interest	Stakeholder interests
1 (Low)	(i) 1 or 2 coast-related uses; OR (ii) Used by <50 people daily in peak season	Loss of <10% of coast-dependent recreational uses	None or 1 private property, <100m alongshore	Individual resident or small group working directly with the local coastal manager
2	(i) 3–5 coast-related uses; OR (ii) Used by 50–100 people daily in peak season	Loss of 10–40% of coast-dependent recreational uses	2–3 private properties, 100–500m alongshore	Community or stakeholder group working with the local coastal manager or occasionally using media
3 (High)	(i) >5 coast-related uses; OR (ii) Used by >100 people daily in peak season	Loss of >40% of coast-dependent recreational uses	>=4 private properties, >500m alongshore	Resident/stakeholder group actively involved in decision-making or frequently using media to develop public support

Cumulative scores, rating and management importance

The HMI is obtained by combining the physical asset rating with a recreational/stakeholder value weighting. Separate ratings for physical assets susceptible to erosion hazard and for recreational/stakeholder values are derived by summing scores for the criteria outlined in Table 2-4 and Table 2-5. A three-point rating of low, moderate and high was developed (Table 2-6). For each of the three timeframes one erosion hazard zone is considered (Section 2.5) in allocating the scores. The shift from Imminent to Projected timeframes provides a sequence of increasing erosion, thereby providing a basis from which to consider how the management pathway may change over time.

Table 2-6: Deriving ratings from the cumulative scores

Rating	Physical public assets susceptible to erosion hazard [Table 2-4]		Recreational and stakeholder values [Table 2-5]	
	Number of criteria	Cumulative scores	Number of criteria	Cumulative scores
Low	3 (Range 3 to 9)	3 – 4	4 (Range 4 to 12)	4 – 6
Moderate		5 – 7		7 – 9
High		8 – 9		10 – 12

Ratings for physical assets and recreational/stakeholder values were then used to generate a relative management importance with regard to addressing erosion hazard (Table 2-7; Figure 2-4). Hotspots identified as having a high management importance may require more detailed consideration of specific hazards, such as how erosion patterns could change in response to the installation of erosion mitigation structures. In particular, it is important to identify whether existing pressures are due to an erosion cycle, which may encourage pre-emptive or overinvestment in coastal protection works.

Table 2-7: Deriving hotspot management importance from the ratings

		Weighting based on recreational and stakeholder values (rating)		
		L	M	H
Rating of physical assets susceptible to erosion hazard	L	L	L	M
	M	L	M	H
	H	M	H	H

Group Ranking

Due to the uncertainty in forecasting the extent and timing of erosion hazards, individual management importance provides an indication of relative importance to the other hotspots. Consequently, hotspots have been clustered in brackets of low, moderate or high importance, rather than presented as a list. Further simplification has been achieved through grouping sets of hotspots into group rankings that have the same importance in each timeframe (Table 3-10). Group ranking 1 to 3 have been assumed as HMI within five years including:

- Identified as a High importance in the Imminent (0–5 year) timeframe; and
- Identified as Low/Moderate importance in the Imminent (0–5 year) timeframe, which change to High importance for the Expected (5–25 year) timeframe. This is considered a HMI as plans and strategies need to be developed now to mitigate future hazards.

This technique compares and groups hotspots as a strategic basis for the management of erosion issues across the state. The measure of relative management importance uses quantifiable parameters at the scale of interest and does not prioritise the importance of individual assets. Environmental values, Aboriginal heritage values, economic value of beaches, and economic value of the assets have been excluded, with only approximate replacement costs considered. The likelihood of damage to assets and loss of recreational uses has been determined by qualitatively basing the erosion hazard on landform indicators, historic trends, and available hazard assessments (Section 2.5). It is noted that there is limited distinction between relocatable recreational assets and those which require total replacement. This distinction is indicated instead by the relative monetary value given in Table 2-4. Management importance and group ranking developed through this method will alter over time as management and adaptation actions are undertaken, assets change, erosion pressures vary and new problem areas emerge.



2.8. IDENTIFYING MANAGEMENT AND ADAPTATION OPTIONS

A high-level assessment of coastal management, adaptation options and planning mechanisms was developed for each hotspot with consideration of the WAPC (2013a, 2014) adaptation hierarchy including:

- **Avoid.** This includes ‘do nothing and monitor’ on foreshores with sufficient buffer to tolerate erosion for the planning timeframe;
- **Retreat.** This can include removing assets, relocating assets, land swaps and land acquisition;
- **Accommodate.** This can include sand extraction, implementing easements, realignment of property access, altering structures (to improve effectiveness or extend landward); and
- **Protect.** This includes maintaining existing structures, building new erosion mitigation structures, repair and extension/deepening/raising of structures and construction of artificial dunes. It also refers to renourishment, bypassing and dune reconstruction.

Options are considered with respect to the existing strategies for each hotspot and the three timeframes. The changing nature of erosion is used to determine how the management and adaptation options may evolve, with high-level management triggers and associated monitoring indicating when to shift between options. This illustrates the range of management and adaptation options that may be available for each hotspot.

Response-based triggers likely to precipitate change to the required management actions can be determined in line with the coastal dynamics and assets susceptible to erosion hazard for each hotspot. Triggers are a means by which to avoid implementing a management technique before it is needed, sometimes with consideration of acceptable damage for certain assets. The refinement of triggers is required locally for hotspots with private property or leasehold land with the aim to maintain a reserve for public access (WAPC 2017). Local coastal managers can refine triggers in line with monitoring techniques already being undertaken at their hotspots.

Options presented should be considered by local coastal managers, but they do not replace a hotspot-specific management and adaptation plan (e.g. CHRMAP) prepared and endorsed by the local coastal manager. The options presented are effectively a summary of erosion mitigation without consideration of funding sources. Detailed information on the amount of money to spend at a hotspot may limit the proportion of the coast which can effectively be protected and may result in increased use of lower cost mitigation pathways and areas with no mitigation.

The management requirements presented may also change over a 25-year timeframe due to land or assets changing in value, degradation, or simply an increased perception of hazard. Increased development, or management works that transfer erosion stress may increase the effort required for erosion hazard mitigation.

2.8.1. Future Cost Estimation

A qualitative estimate of the costs of erosion management and adaptation pathways was developed. Cost classes were developed for the Imminent (0-5 years) and Expected (5–25 years) timeframes. Estimates were not prepared for management options beyond 25 years because of the unknown factors, dependence on previous works, and no predictable end-point of the management period.

Cost classes for management and adaptation pathways were developed using an order of magnitude approach. For every management option of each hotspot (refer to Table 3-12), approximate cost



information was used to classify whether the option would be in a low, moderate or high cost class. The three classes are deliberately broad to accommodate approximate costs with ranges of <\$0.5M (low), \$0.5M–\$2M (moderate) and \$2M–\$30M (high).

Qualitative cost estimates typically combined the physical scale of the erosion issue with linear or area cost rates for similar management interventions undertaken in Western Australia over the last decade. Estimates were not adjusted to account for scale effects, inflation, geography or availability of plant. For context, the \$500k upper limit of the low cost class approximates coastal protection with two groynes or 100m of a low-height seawall. The \$2M upper limit of the moderate cost class corresponds to coastal protection with a high or deep seawall, 500m in length (i.e. demonstrating economy of scale). It is noted that although these rates are based on real projects, many examples of higher unit rates have been observed over the last decade, with prices fluctuating according to market demand and the availability of construction materials.

A further cost category of \$50,000 (estimated) was applied to the preparation of planning frameworks to facilitate managed retreat in the next management phase and for review of lease agreements. For example, if retreat was identified in the Projected (25+ years) timeframe, a \$50,000 cost was added to the previous timeframe (Expected) for preparation of the planning framework to facilitate implementation of the retreat when the trigger for the next management phase is reached. Review of lease agreements was included to clarify erosion management responsibilities for leasehold land and assets, and revise the lease period to ensure adaptation pathways can be implemented.

An example of cost allocation is provided for Hotspot 14, Grannies Beach, in the Shire of Irwin (Table 2-8). For the Imminent timeframe (0–5 years), an approximate cost estimate for the Protect option was developed with this option falling into the low cost class.

Costs in the Imminent timeframe were also influenced by management options in the Expected timeframe (5–25 years), with \$50k allocations for (i) reviewing the caravan park lease agreement; and (ii) preparation of planning frameworks for the future retreat of Ocean Drive and the pathway, including identification of funding mechanisms. For the Expected timeframe (5–25 years), the option of Protect was evaluated for an estimated length of 150m⁴.

Table 2-8: Cost estimate example for Grannies Beach (Hotspot 14)

Timeframe	Management and approximate cost estimate	Cost class
Imminent (0–5 years)	Maintain ~250m revetment	Low
	Review lease agreement	\$50k
	Planning for retreat	\$50k
Expected (5–25 years)	Retreat northern section of Indian Ocean Drive (notionally ~150m, but greater length expected)	High
	Extend revetment ~150m to the North	Moderate

⁴ The moderate cost class for continuing to Protect, by extending the revetment, would be retained if the combined effect of length and cost rate falls into the range of -33% to +200%. The high cost class for Retreat of the northern section of Ocean Drive is achieved for any length of road >100m, shown in Table 2-8 as a 150m notional length. The high cost would still be retained if the length of erosion were reduced as low as 100m or if the linear cost rate was reduced by less than 33%.



Cost estimates were determined relatively simply, potentially with a conservative bias, as they are based historic practices and costs of protective works, asset relocation and property values. However, it is recognised that actual costs for coastal erosion management and adaptation within Western Australia will include costs for locations that are not presently identified as hotspots; and that the cost rates for basic raw materials such as rock and sand nourishment are strongly affected by demand.



3. Assessment Results

This section contains information on all hotspots and allows a strategic view of:

- the extent and nature of coastal erosion in WA;
- contrast between hotspots; and
- the challenges presented by coastal erosion hazards.

A summary of each hotspot has been developed and presented in Appendix D as described in Section 3.2.

3.1. EROSION HOTSPOTS

A total of 86 locations were identified, comprising 55 hotspots and an additional 31 watchlist locations. Erosion hotspots have been defined, characterised and mapped according to the methodology described in Section 2.1 and Appendix A.

3.1.1. Fifty-five Erosion Hotspots

This section includes:

- The name and number of each hotspot from 1 to 55 from north to south;
- A map identifying the hotspots in Figure 3-1; and
- The local coastal manager and characteristics of the hotspots in Table 3-1.

The approximate spatial extent for each hotspot is included in the figures in Appendix D, with relevant spatial datasets listed in Section 3.1.4.

The three most typical characteristics across all hotspots were (Table 3-1):

- *Proximity*: Infrastructure close to the existing shore, or landward of progressively and rapidly eroding coast;
- *Instability*: Typically subject to progressive or episodic erosion; and
- *Community*: Highly valued by the community.



Figure 3-1: Map of the 55 hotspots

Table 3-1: Hotspots and characteristics

ID	LG / Local Coastal Manager	Hotspot	Proximity	Instability	Mit. Cost	Transfer	Community
1	Shire of Broome	China Town, Broome	✓		✓		✓
2	Shire of Broome	Broome Town Beach	✓		✓		✓
3	Town of Port Hedland	Goode St, Port Hedland	✓	✓		✓	
4	Town of Port Hedland	Laurentius Point, Port Hedland	✓		✓	✓	
5	Shire of Exmouth	Warne St & Yacht Club, Exmouth	✓	✓		✓	✓
6	Shire of Carnarvon	Pelican Point, Carnarvon	✓	✓	✓		
7	Shire of Shark Bay	Monkey Mia	✓	✓		✓	✓
8	Shire of Shark Bay	Denham Townsite	✓	✓		✓	✓
9	Shire of Northampton	Horrocks Foreshore	✓	✓		✓	✓
10	City of Greater Geraldton	Drummond Cove, Geraldton	✓	✓	✓	✓	✓
11	City of Greater Geraldton	Sunset Beach, Geraldton	✓	✓			
12	City of Greater Geraldton	Beresford, Geraldton	✓	✓			✓
13	City of Greater Geraldton	Point Moore, Geraldton	✓	✓		✓	✓
14	Shire of Irwin	Grannies Beach, Irwin	✓	✓		✓	✓
15	Shire of Dandaragan	Cervantes	✓	✓		✓	
16	Department of Biodiversity, Conservation and Attractions (DBCA)	Grey	✓	✓			✓
17		Wedge	✓	✓			✓
18	Shire of Gingin	Grace Darling Park, Lancelin	✓	✓			✓
19	Shire of Gingin	Ledge Point	✓	✓			✓
20	Shire of Gingin	Seabird Foreshore, Gingin	✓	✓	✓	✓	✓
21	City of Wanneroo	Two Rocks northern coast	✓	✓		✓	
22	City of Wanneroo	Quinns Beach	✓	✓	✓		✓
23	City of Joondalup	MAAC Seawall, Joondalup	✓			✓	✓
24	City of Stirling	Watermans Bay, Stirling	✓	✓	✓	✓	✓
25	City of Stirling	Mettams Pool	✓	✓	✓		✓
26	Town of Cambridge	Floreat Beach	✓	✓	✓		✓
27	Fremantle Ports & City of Fremantle	Port Beach	✓	✓		✓	✓
28	Rottneest Island Authority	Rottneest – South Thomson Bay	✓	✓			✓
29	City of Cockburn	C.Y. O'Connor Beach, Cockburn	✓	✓		✓	
30	City of Kwinana	Kwinana waterfront industrial	✓	✓	✓	✓	
31	City of Kwinana	Kwinana Beach		✓		✓	✓
32	City of Rockingham	Rockingham Townsite to Causeway	✓			✓	✓
33	City of Rockingham and DBCA	N Point Peron (W of Causeway)	✓	✓		✓	✓
34	City of Rockingham and DBCA	Point Peron (N Shoalwater Bay)	✓	✓			
35	City of Rockingham	Waikiki Beach, Rockingham	✓	✓		✓	✓
36	City of Mandurah	Mandurah Northern Beaches	✓	✓	✓		✓
37	City of Mandurah	Doddies Beach, Roberts Point	✓	✓			✓
38	City of Mandurah	Falcon Bay to Rakoa St	✓	✓			✓
39	Shire of Harvey	Binningup Seawall	✓			✓	✓
40	City of Bunbury, Shire of Harvey and DBCA	The Cut, Bunbury			✓		✓
41	City of Bunbury	Koombana Beach	✓	✓	✓	✓	✓
42	City of Busselton	Wonnerup Beach (East)	✓	✓			✓
43	City of Busselton	Wonnerup Beaches	✓	✓			✓
44	City of Busselton	King St	✓	✓		✓	✓
45	City of Busselton	Craig St, Busselton	✓	✓		✓	
46	City of Busselton	Abbey, Busselton	✓	✓		✓	✓
47	City of Busselton	Locke Estate	✓	✓			✓
48	Shire of Augusta–Margaret River	Gnarabup S	✓	✓			✓
49	Shire of Manjimup	Windy Harbour Foreshore		✓		✓	✓
50	Shire of Denmark	Peaceful Bay	✓	✓			✓
51	Shire of Denmark	Denmark, Ocean Beach	✓	✓			✓
52	City of Albany	Emu Pt, Albany	✓	✓			✓
53	Shire of Jerramungup	Bremer Bay Fishery Beach		✓		✓	✓
54	Shire of Ravensthorpe	Hopetoun Foreshore	✓	✓			✓
55	Shire of Esperance & Southern Ports Authority	Esperance Town Beach	✓	✓	✓	✓	✓
Total			51	48	15	29	45



3.1.2. Watchlist Locations

Information on the watchlist locations is included in Appendix B, including a table of locations and characteristics (Table B-1), a map indicating the locations (Figure B-1) and approximate alongshore extents (Figure B-2 to Figure B-9).

In most cases, these locations have some coastal asset which is in close proximity to the coast, but there are reasons why erosion may not affect the location (e.g. some rock protection, a history of relative stability) or the assets susceptible to erosion hazard are considered to be of low or moderate value. The presence of five locations along the Broome coast highlight the proximity of development to the coast, but the susceptibility to erosion hazard is strongly offset by the large tidal range (as this range causes very flat intertidal beach profiles and substantially reduced occurrence of wave action above the tide range).

There is an increased tendency for locations in the northern half of the state to have very slowly changing coastlines, with a greater potential for acute erosion. Due to the episodic nature of tropical cyclones and their local impact, their potential to cause acute erosion is less apparent than the more regular mid-latitude storms occurring in the southern half of the state.

Watchlist locations may not require a large, active management expense imminently other than in the occurrence of an extreme event. An exception to this is if sediment transport or supply is interrupted, or a large investment in built assets is undertaken closer to the ocean than the existing assets.

3.1.3. Inundation Locations

An initial list of inundation locations was collated during the hotspot evaluation and is included in Appendix C as a table (Table C-1). This identification was not systematic or exhaustive, but was developed opportunistically when seeking information about erosion hazards.

Coastal inundation is generally a secondary hazard across Western Australia, although the consequences of an event can be high. The majority of coastal landforms were developed during eras with higher sea level, or built vertically through the sustained supply of coastal sediments. Most locations prone to coastal inundation are found on low-lying sheltered land (e.g. Bunbury or Busselton).

For northern WA locations, the potential for inundation is largely determined by extreme tropical cyclones, with most developed coastal areas having a degree of susceptibility to inundation hazard. Between Port Hedland and Wyndham, the hazard likelihood is partly reduced by the large tidal range. Areas most exposed to coastal inundation occur between Geraldton and Karratha, where moderate tides are coincident with potential for extreme storm surges.

There are a number of estuarine locations that may be subject to coastal flooding (e.g. Swan River, Peel Inlet, Blackwood River, Wilson Inlet), but hazard mitigation is largely focused on runoff flooding.



3.1.4. Datasets of Hotspots and Watchlist Locations

A series of shapefiles and KMLs have been provided to support the interpretation and use of this assessment and are listed in Table 3-2. Spatial datasets include the point and extents of the hotspots and watchlist locations.

Table 3-2: Spatial datasets provided

Type of information	File name	Data represented
Hotspots	SE052 Hotspots.shp SE052 Hotspots.kml	Hotspot point
	SE052 Hotspot Extents.shp SE052 Hotspot Extents.kml	Hotspot extent
Watchlist locations	SE052 Watchlist Locations.shp SE052 Watchlist Locations.kml	Watchlist location point
	SE052 Watchlist Extents.shp SE052 Watchlist Extents.kml	Watchlist location extent

3.2. INDIVIDUAL HOTSPOT SUMMARIES

The results of the first pass assessment of erosion issues, assets susceptible to erosion hazard, along with management and adaptation pathways are included as a summary for each hotspot in Appendix D. The information summaries include:

- Hotspot issue briefly summarised;
- Hotspot summary figure (A4);
- Extent of hotspot;
- Hotspot erosion characteristics;
- Coastal dynamics studies required in addition to shoreline movement plots;
- CHRMAP status;
- Assets within projected hazard zones;
- Management and adaptation options;
- Indicative cost classes for the Imminent (0–5 years) and Expected (5–25 years) timeframes;
- Monitoring and triggers to change management phases;
- Alternate management options, if applicable; and
- Works to avoid.

The hotspot issue description and figures were reviewed by local coastal managers to confirm the hotspot issues before preparing the management and adaptation pathways.

An abbreviated and simplified example of an individual hotspot summary is provided in Figure 3-2.

The hotspot summaries have been formulated for readers interested in information about a single hotspot; information comparing hotspots has not been included within the summary. Hotspot specific erosion issues (Table 3-3 and Table 3-4), and any comparison of the hotspots, such as relative management importance, are provided in Section 3.

	Timeframe		
	Imminent (0-5 years)	Expected (5-25 years)	Projected (25+ years)
Erosion Issue	Erosion due to influence of artificial structures (dominant) Enhanced response expected due to projected change (mainly SLR) Nearshore structures intolerant to erosion Local instability due to geomorphology		
Assets at risk	8 public assets	11 public assets 8 private properties	15 public assets 16 private properties
Potential management options	<i>Accommodate</i> – Continue annual bypassing <i>Protect</i> – maintain groynes <i>Prepare plans for retreat</i>	<i>Retreat</i> – removal of recreational facilities and non-access roads, retreat car parks <i>Accommodate</i> – Continue annual bypassing <i>Protect</i> – downdrift ‘back-up’ revetments	<i>Protect</i> – extend groynes ‘L-shape’
Trigger for change of management	Acute erosion damages Ormsby Terrace infrastructure 3+ times in 10 years	Ormsby Terrace damage that prevents access to houses, not managed by ‘back-up’ revetments or housing buy-back (i.e. cost-benefit of houses supports massive engineering works)	
Monitoring for triggers	Photographic monitoring	Comet Bay monitoring program, assessing acute and progressive erosion.	
Works to avoid	No additional armoured facilities north of groynes (e.g. Mandurah SLSC north of San Remo groyne) as these effectively use the sand buffer necessary for the beach segments to withstand seasonal downdrift erosion; No in-fill development to the north; No additional sand retention works west of Henson Street.		

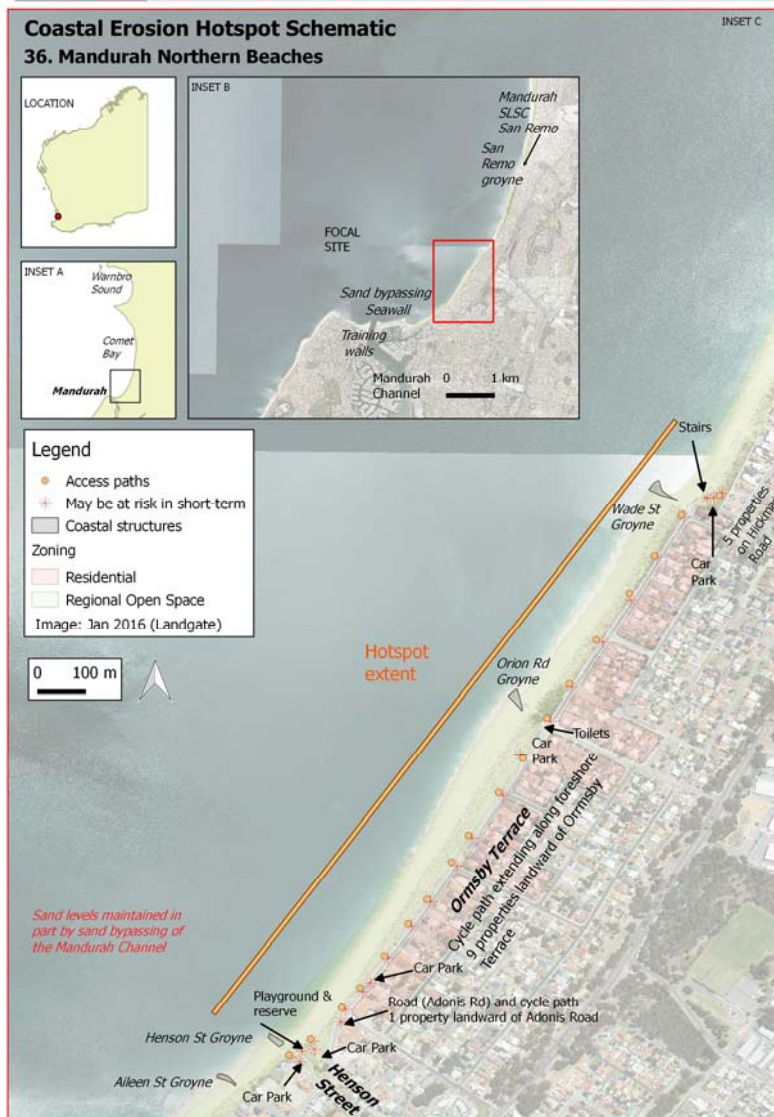


Figure 3-2: Example of hotspot summaries – simplified Mandurah Northern Beaches

See Appendix D.36 for the expanded summary



3.3. NATURE OF THE EROSION HAZARDS

A first pass classification of the nature of erosion hazards at each hotspot was undertaken (Table 3-3) using the five broad causes described previously in Section 2.4. This classification guided interpretation of those assets susceptible to erosion hazard and indicated the type of management responses likely to be effective.

Review of the hotspots highlighted that erosion hazards are typically developed through a combination of processes. Therefore, each of the five causes of erosion process was allocated a weighting based on the historic importance of that process at each hotspot (Table 3-3). The table uses shading to demonstrate the relative weighting of the five erosion processes from most important (black) to least important (white). This is a cursory assessment based on present day land use and it does not demonstrate any shifts in process importance that may have occurred over time. For example, in the Projected (25+ year) timeframe, all hotspots are affected by coastal recession due to projected sea level rise. However, in the Imminent and Expected timeframes it is considered a minor component.

Most hotspots respond to more than one cause of erosion. The most important issues for many hotspots are vulnerable siting of facilities; unstable coastal landforms; and interruption of sediment transport by infrastructure. Unstable landforms include foreshores modified by dredged material, or variable landforms such as cusped forelands.

Transfer of erosion pressure to adjacent shores by coastal protection works is the most important erosion issue for the hotspots. This can result in the permanent loss of a beach (a primary community asset) in proximity to the protection works. Better understanding of the cause of erosion can lead to the improved siting of facilities in areas potentially affected by erosion in the longer-term, thus reducing the need for short-term or emergency protection works. Once coastal protection (emergency and planned) is in place, the combined effects of response to the structure and transfer of erosion stress may focus pressure on the adjacent coast. This can lead to a sequence where erosion is managed through a succession of additional protection structures (Griggs 2005, Stancheva *et al.* 2011, Melius & Caldwell 2015). This may result in the need for ongoing capital protection works, and increased expenditure, to address erosion hazard.

A discrepancy between the causes of erosion identified at hotspots and those considered in predictive modelling was identified. Assessment of coastal dynamics at the 55 hotspots identified the occurrence of several common causes of erosion pressure, including landform instability or transfer of erosion pressure due to coastal structures. These causes of erosion were not generally identified in the CHRMAPs reviewed as part of this project. It is considered that this is a result of the long-term perspective used for Schedule One of SPP2.6 (WAPC 2013a), which has been widely used as a basis for CHRMAPs coastal hazard forecasting. Supplementary issues that exacerbate the perception of erosion threat are discussed in Section 5.1.

Erosion is highly variable, brought about by changes in tide and weather conditions, with different coastal response according to the configuration of the coast at the time, the presence of erosion resistant features (natural or artificial) and the availability of sediment. Interactions of these components produce an array of coastal changes, ranging from small-scale change occurring over seconds, through to extremely large-scale changes, developed over thousands of years.

**Table 3-3: Erosion issue for each hotspot**

Relative importance shown by shading from most important (black) to least important (white).

	(a) Erosion due to influence of artificial structures	(b) Local instability due to geomorphology	(c) Instability due to external processes (variable sed. supply)	(d) Nearshore structures which cannot withstand erosion	(e) Enhanced response due to projected change (mainly SLR)
1. China Town	Black	Black	White	White	White
2. Broome T.B	Black	Black	White	White	White
3. Goode St, P.H.	Black	Black	White	White	White
4. Laurentius Point	Black	White	White	White	Black
5. Exmouth	Black	White	White	Black	White
6. Pelican Point	Black	White	White	White	White
7. Monkey Mia	Black	White	Black	White	White
8. Denham	Black	White	White	White	White
9. Horrocks	Black	Black	White	White	White
10. Drummond C.	Black	White	White	Black	White
11. Sunset Beach	Black	White	White	Black	White
12. Beresford ¹	Black	Black	Black	White	Black
13. Point Moore	Black	White	White	Black	White
14. Grannies Beach	Black	White	White	White	White
15. Cervantes	Black	White	White	Black	White
16. Grey	Black	White	White	White	White
17. Wedge	Black	White	White	White	Black
18. Grace Darling P.	Black	Black	White	White	White
19. Ledge Point ¹	Black	Black	Black	White	Black
20. Seabird	Black	White	White	Black	White
21. Two Rocks N	Black	White	White	White	Black
22. Quinns Beach	Black	Black	White	White	White
23. MAAC Seawall	Black	White	White	White	Black
24. Watermans	Black	White	White	Black	White
25. Mettams Pool ¹	Black	Black	Black	White	Black
26. Floreat	Black	White	White	White	White
27. Port Beach	Black	White	White	White	White
28. S Thomson Bay	Black	White	White	White	White
29. C.Y. O'Connor	Black	White	White	White	White
30. Kwinana Ind.	Black	White	White	White	White
31. Kwinana Beach	Black	White	White	Black	White
32. Rockingham	Black	White	White	Black	White
33. N Point Peron	Black	White	White	White	White
34. N Shoalwater	Black	White	White	White	White
35. Waikiki Beach	Black	White	Black	White	Black
36. Mandurah N	Black	White	White	White	White
37. Doddies Beach	Black	White	White	Black	White
38. Falcon to Rakoa	Black	White	White	White	White
39. Binningup	Black	White	White	Black	White
40. The Cut	Black	White	White	White	White
41. Koombana	Black	White	White	White	White
42. Wonnerup E.	Black	White	White	Black	White
43. Wonnerup	Black	White	White	White	White
44. King St	Black	White	White	White	White
45. Craig St	Black	White	White	White	White
46. Abbey	Black	White	White	White	White
47. Locke Estate	Black	White	White	White	White
48. Gnarabup S	Black	White	White	Black	White
49. Windy Harbour	Black	White	White	Black	White
50. Peaceful Bay	Black	White	White	White	White
51. Ocean Beach	Black	White	White	White	White
52. Emu Pt, Albany	Black	White	White	White	White
53. Bremer Bay	Black	White	White	White	White
54. Hopetoun	Black	White	White	White	White
55. Esperance	Black	White	White	White	White
Most Important Issue	28	17	8	18	3

Note: 1) some hotspots (12, 19 and 25) have four issues of equal importance (dark grey) with all included in the sub-totals.

A summary of the time and space scales associated with erosion at each hotspot is provided in Table 3-4. It is noted if the erosion problem is progressive, cyclic or episodic; and whether it is spatially constrained, transferable or broad-scale in nature. Time and space scales associated with erosion at each hotspot can provide an indication of the type of works that may be appropriate. For example, if the erosion is progressive and transferable, as it is for 13 hotspots, protection will cause extensive ongoing costs. The majority (36) of hotspots are not spatially constrained and should not be considered in isolation of the surrounding coast. The minimum spatial scale considered should be a tertiary sediment cell scale (Stul *et al.* 2015). A shift towards more progressive erosion is expected if an increasing proportion of coast is stabilised using engineering works, transferring erosion; and over time due to the effect of sea level rise.

Table 3-4: Erosion timeframe and spatial scale (number of hotspots)

		Erosion Spatial Scale			
		Spatially constrained	Transferable	Broad-scale	Total
Erosion Timeframe	Cyclic	6	8	0	14
	Progressive	8	13	3	24
	Episodic	4	11	1	16
	Nearing stability	1	0	0	1
	Total	19	32	4	

3.4. ASSETS SUSCEPTIBLE TO EROSION HAZARD

Assets susceptible to erosion hazard have been identified for the three timeframes for each hotspot following the methodology described in Sections 2.5 and 2.6. Similar assets have been classed together to allow strategic assessment. Information is included on:

- The number of hotspots with the susceptible asset classes (Table 3-5);
- Asset class for each hotspot (Table 3-6);
- Private property (Section 3.4.1); and
- The count and type of assets for each hotspot (Appendix D).

Table 3-5: Number of hotspots with asset classes that may be susceptible to erosion hazard

The figures in brackets indicate the percentage of 55 hotspots with that asset class susceptible to erosion hazard. Most hotspots have assets in multiple classes.

Asset class	Imminent (0–5 years)		Expected (5–25 years)		Projected (25+ years)	
Private	5	(10%)	10	(18%)	26	(47%)
Leasehold	9	(16%)	20	(36%)	22	(40%)
Road/Rail	5	(9%)	27	(49%)	42	(76%)
Services	8	(15%)	18	(33%)	36	(65%)
Recreation	44	(80%)	46	(84%)	46	(84%)
Boating	13	(24%)	17	(31%)	17	(31%)
SLSC/rescue	1	(2%)	6	(11%)	6	(11%)
Sand beach access	39	(71%)	39	(71%)	39	(71%)
Sand boat launching	12	(22%)	18	(33%)	18	(33%)

Table 3-6: Asset class susceptible to erosion hazard for each hotspot

Shaded indicates asset class susceptible to erosion hazard. Table sorted N to S.

	Private ¹			Leasehold			Road/rail			Services ²			Recreation ³			Boating ⁴			SLSC/rescue		
	0-5	5-25	25+	0-5	5-25	25+	0-5	5-25	25+	0-5	5-25	25+	0-5	5-25	25+	0-5	5-25	25+	0-5	5-25	25+
1. China Town	X	X	X																		
2. Broome T. B.	X	X	X																		
3. Goode St, P.H.		X	X																		
4. Laurentius Point	X	X	X																		
5. Exmouth																					
6. Pelican Point																					
7. Monkey Mia																					
8. Denham																					
9. Horrocks																					
10. Drummond C.			X																		
11. Sunset Beach																					
12. Beresford																					
13. Point Moore																					
14. Grannies Beach																					
15. Cervantes			X																		
16. Grey ⁵																					
17. Wedge ⁵																					
18. Grace Darling P.																					
19. Ledge Point	X	X	X																		
20. Seabird	X	X	X																		
21. Two Rocks N																					
22. Quinns Beach																					
23. MAAC Seawall,																					
24. Watermans																					
25. Mettams Pool																					
26. Floreat																					
27. Port Beach																					
28. S Thomson Bay ⁶																					
29. C.Y. O'Connor																					
30. Kwinana Ind.																					
31. Kwinana Beach																					
32. Rockingham																					
33. N Point Peron																					
34. N Shoalwater																					
35. Waikiki Beach																					
36. Mandurah N		X	X																		
37. Doddies Beach																					
38. Falcon to Rakoa																					
39. Binningup																					
40. The Cut																					
41. Koombana																					
42. Wonnerup E.		X	X																		
43. Wonnerup																					
44. King St																					
45. Craig St																					
46. Abbey			X																		
47. Locke Estate																					
48. Gnarabup S																					
49. Windy Harbour																					
50. Peaceful Bay																					
51. Ocean Beach																					
52. Emu Pt, Albany																					
53. Bremer Bay ⁷																					
54. Hopetoun																					
55. Esperance																					
Total	5	10	26	9	20	22	5	27	42	8	18	36	44	46	46	13	17	17	1	6	6

Note: 1) X = Freehold land without a road to seaward. 2) Services are drains, electricity, water, communications, gas, sewerage, oil from Dial before you Dig. 3) Recreation includes paths, beach access (fixed by concrete/bitumen or staircases), playgrounds, parklands and car parks. 4) Boating excludes sand access ramps and beach launching with no associated stabilisation works. 5) Structures at Grey and Wedge were not considered as assets because of their informal status. 6) South Thomson Bay has public-owned holiday cottages separate to these asset classes. 7) Erosion at Bremer Bay Fishery Beach is not a threat to public assets. Boat ramp sedimentation will increase.



Most hotspots (44) have recreational assets with Imminent susceptibility to erosion hazard. Although many of these assets may be considered relocatable, it is not expected that all recreational assets will be able to be maintained due to erosion of foreshore reserves. The highest pressure is anticipated to occur on naturally unstable landforms or reclaimed foreshores, being roughly one-third of the identified hotspots. Fourteen hotspots have private or leasehold property susceptible to erosion hazard in the Imminent timeframe increasing to 28 hotspots in the Expected timeframe. There are 12 hotspots with road/rail or services susceptible to erosion hazard in the Imminent timeframe increasing to 33 hotspots in the Expected timeframe.

3.4.1. Private Property

This assessment does not consider coastal erosion risk to individual private properties. Accuracy of the number of properties identified is discussed in Section 2.6.

The number of freehold private properties that may be susceptible to erosion hazard in each of the identified timeframes is shown in Table 3-7. Hotspots without a public road asset between the ocean and the properties are identified.

Five hotspots have private property that may be susceptible to erosion in the Imminent timeframe, with an additional five (10 total) in the Expected timeframe and an additional 16 (26 total) in the Projected timeframe. In the Projected timeframe (25+ years) less than half of the hotspots (26) have private property susceptible to erosion hazard, with most of the properties landward of a road.

Eleven hotspots have private properties fronting the ocean without a public road to seaward, including:

- Five hotspots may have private property susceptible to erosion hazard in the Imminent (0–5 year) timeframe, including China Town, Broome Town Beach, Laurentius Point, Ledge Point and Seabird (dependent on seawall performance).
- Three additional hotspots (eight total) may have property susceptible to erosion hazard in the Expected (5–25 year) timeframe, including Goode Street in Port Hedland, Mandurah Northern Beaches and Wonnerup Beach (East).
- In the Projected (25+ years) timeframe three additional hotspots (11 total) of Drummond Cove, Cervantes and Abbey (Busselton) may have private property susceptible to erosion hazard without a road to seaward. These three hotspots also contain some private properties that may be susceptible to erosion hazard that are landward of a road.

There are an additional two hotspots (Denham and Rockingham) with private property susceptible to erosion with a road to seaward for the Expected (5–25 year) timeframe.

Table 3-7: Hotspots with private property that may be susceptible to erosion hazard

Hotspot	Road (Y/N) ^{2,3}	Number private properties susceptible to erosion hazard ¹		
		Imminent (0–5 years)	Expected (5–25 years)	Projected (25+ years)
1. China Town, Broome	N	1 (seawall)	8	8
2. Broome Town Beach	N	1 (seawall)	>8 inc. vacant lots	>11 inc. vacant lots
3. Goode St, Port Hedland	N		3	3
4. Laurentius Point	N	5 inc. 2 behind revetment	5 inc. 2 behind revetment	5
8. Denham Townsite	Y		19 inc. 7 vacant lots	19 inc. 7 vacant lots
9. Horrocks Foreshore	Y			21
10. Drummond Cove	Y/N for one property			7
12. Beresford	Y			10
13. Point Moore	Y			8
15. Cervantes	N			22
19. Ledge Point	N	6	8	13
20. Seabird Foreshore	N	15 (seawall)	16 including Strata Caravan Park	17 including Strata Caravan Park
21. Two Rocks northern coast	Y			6
22. Quinns Beach	Y			15
24. Watermans Bay, Stirling	Y			11 inc. 2 vacant lots
32. Rockingham Townsite to Causeway	Y		8	113
35. Waikiki Beach	Y			33
36. Mandurah Northern Beaches	Y/N for 3 properties in 5–25 and 5 properties in 25+		8	16
37. Doddies Beach, Roberts Point	Y			6 inc. 2 vacant lots
38. Falcon Bay to Rakoa St	Y			5
42. Wonnerup Beach (East)	N		3	3
43. Wonnerup Beaches	Y			14 inc. 4 vacant lots
45. Craig St, Busselton	Y			9
46. Abbey, Busselton	Y/N for 6 properties			15 residential, 1 Aged Care facility and 5 resorts
54. Hopetoun Foreshore	Y			7
55. Esperance T. B.	Y			27
Total		5 hotspots	10 hotspots	26 hotspots

Note: 1) The number of private properties identified was using simple cadastral information and the erosion hazard zones identified by Seashore Engineering (Sections 2.5 and 2.6); 2) Hotspots without a public road asset between the ocean and the properties are noted as N in the 'Road' column and those with a public road asset between the ocean and properties noted as Y; 3) Three hotspots have Y/N in the road column with some properties having a road between the ocean and the properties. The number of properties without a road to seaward is noted.

3.5. HOTSPOT MANAGEMENT IMPORTANCE (HMI)

A framework for determining relative hotspot management importance (HMI) has been developed and applied to the 55 hotspots to facilitate a strategic approach to coastal erosion management efforts in WA. The methodology is described in Section 2.7 to derive management importance (L/M/H) at the hotspot, linked to two components: public assets susceptible to erosion (number, type and monetary value) and recreational/stakeholder values (level of use, loss of use, number of private properties and level of stakeholder interest).

Table 3-8 provides context for how the management importance was obtained, including the two component ratings (physical assets and recreational/stakeholder) and the final HMI. The first set of columns is the public-owned physical assets susceptible to erosion hazard derived from the method in Table 2-4 and Table 2-6. The second set of columns is the ranking from recreational and

stakeholder values derived from the method in Table 2-5 and Table 2-6. The final HMI combines the two component ratings using the method in Table 2-7.

Table 3-8: Management importance and component ratings for each hotspot

Hotspot	Physical Asset rating			Recreation/ Stakeholder rating			Management Importance		
	0-5 years	5-25 years	25+ years	0-5 years	5-25 years	25+ years	0-5 years	5-25 years	25+ years
1. China Town, Broome	L	M	H	M	M	H	L	M	H
2. Broome Town Beach	M	M	H	M	H	H	M	H	H
3. Goode St, Port Hedland	L	M	M	L	M	M	L	M	M
4. Laurentius Point, Port Hedland	L	M	H	M	M	M	L	M	H
5. Warne St & Yacht Club Exmouth	M	M	H	M	M	H	M	M	H
6. Pelican Point, Carnarvon	M	M	H	L	M	H	L	M	H
7. Monkey Mia	M	H	H	M	H	H	M	H	H
8. Denham townsite	M	H	H	L	H	H	L	H	H
9. Horrocks Foreshore	L	M	H	M	M	H	L	M	H
10. Drummond Cove, Geraldton	M	H	H	M	M	H	M	H	H
11. Sunset Beach, Geraldton	M	H	H	L	M	H	L	H	H
12. Beresford, Geraldton	L	M	H	M	M	H	L	M	H
13. Point Moore, Geraldton	M	M	H	M	M	H	M	M	H
14. Grannies Beach, Irwin	L	H	H	M	H	H	L	H	H
15. Cervantes	M	H	H	L	M	H	L	H	H
16. Grey	L	L	L	M	M	M	L	L	L
17. Wedge	L	L	L	M	M	M	L	L	L
18. Grace Darling Park, Lancelin	M	M	H	M	H	H	M	H	H
19. Ledge Point	L	M	M	H	H	H	M	H	H
20. Seabird Foreshore, Gingin	M	H	H	M	H	H	M	H	H
21. Two Rocks northern coast	M	M	H	L	M	H	L	M	H
22. Quinns Beach	M	M	H	M	M	H	M	M	H
23. MAAC Seawall, Joondalup	L	M	H	M	H	H	L	H	H
24. Watermans Bay, Stirling	L	M	H	M	M	H	L	M	H
25. Mettams Pool	M	M	H	M	H	H	M	H	H
26. Floreat Beach	M	H	H	M	H	H	M	H	H
27. Port Beach	M	M	H	H	H	H	H	H	H
28. Rottneest – South Thomson Bay	H	H	H	M	M	H	H	H	H
29. C.Y. O’Connor beach, Cockburn	L	M	H	M	H	H	L	H	H
30. Kwinana waterfront industrial	M	H	H	M	H	H	M	H	H
31. Kwinana Beach	L	M	H	L	M	M	L	M	H
32. Rockingham T. Beach to Causeway	M	H	H	M	H	H	M	H	H
33. N Point Peron (W of Causeway)	L	L	M	L	M	H	L	L	H
34. Point Peron (N Shoalwater Bay)	M	H	H	L	L	M	L	M	H
35. Waikiki Beach, Rockingham	M	M	H	M	M	H	M	M	H
36. Mandurah Northern Beaches	M	H	H	M	H	H	M	H	H
37. Doddies Beach, Roberts Point	L	M	H	L	M	H	L	M	H
38. Falcon Bay to Rakoa St	M	M	H	L	M	H	L	M	H
39. Binningup Seawall	L	M	M	L	M	M	L	M	M
40. The Cut, Bunbury	M	M	M	L	M	M	L	M	M
41. Koombana Beach	M	H	H	M	H	H	M	H	H
42. Wonnerup Beach (East)	L	M	M	M	M	H	L	M	H
43. Wonnerup Beaches	L	M	H	M	M	H	L	M	H
44. King St	M	M	M	L	M	M	L	M	M
45. Craig St, Busselton	M	M	H	L	M	H	L	M	H
46. Abbey, Busselton	M	M	H	L	M	H	L	M	H
47. Locke Estate	L	M	M	M	M	H	L	M	H
48. Gnarabup S	M	M	M	M	M	H	M	M	H
49. Windy Harbour Foreshore	L	M	M	L	M	M	L	M	M
50. Peaceful Bay	M	M	H	M	M	M	M	M	H
51. Denmark, Ocean Beach	L	M	M	M	M	H	L	M	H
52. Emu Pt, Albany	L	M	M	M	H	H	L	H	H
53. Bremer Bay Fishery Beach	L	L	L	L	M	M	L	L	L
54. Hopetoun Foreshore	L	M	H	L	M	H	L	M	H
55. Esperance Town Beach	L	M	H	M	M	H	L	M	H

Table 3-9 shows the changing level of hotspot management importance over the three timeframes, reflecting the effects of progressive change, and projected broad-scale coastal recession respectively.

Table 3-9: Changing level of hotspot management importance over identified timeframes

Hotspot management importance	Timeframe		
	Imminent (0–5 years)	Expected (5–25 years)	Projected (25+ years)
Low	35	4	3
Moderate	18	30	5
High	2	21	47

Relative management importance for each hotspot is included in Table 3-10 firstly in order of group ranking and then by location from north to south, with a summary of the number of hotspots in each group ranking in Table 3-11. Use of a group ranking is to demonstrate the requirement for advanced planning for locations that may have a high management importance in the subsequent management phase, because of the uncertainty as to when that management response will be triggered. Group ranking 1 to 3 have the highest management importance within five years, including any hotspots identified as high management importance in the Imminent or Expected timeframes, therefore requiring planning in the short-term.

Port Beach and South Thomson Bay on Rottnest Island were assigned a high management importance in the Imminent timeframe and are group ranking 1. Port Beach has many recreational public assets susceptible to erosion hazard in the Imminent timeframe (moderate physical asset rating), with a high recreational /stakeholder rating due to the impact on recreational uses, lessees and stakeholders. The Holiday Units at the Rottnest Island Hotspot are public assets, resulting in a high number of permanent, high value public assets that may be susceptible to erosion hazard.

The 21 hotspots with high management importance in the Expected (5–25 year) timeframe (group ranking 1 to 3 in Table 3-10; Table 3-11), have highest importance mainly due to the large number of assets exposed to a combination of progressive and severe storm erosion. Asset classes susceptible to erosion hazard for these 21 hotspots in the Expected timeframe include (Table 3-6):

- Six hotspots support private property, four without a road to seaward;
- One hotspot, Rottnest Island, has publicly owned holiday units;
- Ten leasehold hotspots;
- Thirteen hotspots with roads, including two with rail;
- Nineteen hotspots with public recreation facilities with short life span (7.1 in SPP 2.6); and
- Three surf lifesaving clubs or marine rescue facilities.

There are a higher proportion of locations with private property, leasehold assets and roads in the erosion hazard areas for the 21 hotspots with HMI than for the total 55 hotspots.

Progressive coastal change has a greater influence on longer-term scenarios, at Expected (5–25 year) and Projected (25+ year) timeframes. Management of hotspots for which progressive change is influential, for example those with a spread of assets to landward, can be well supported by planning ahead using an adaptive management approach with monitoring and management triggers. The greatest need for forward planning occurs if there is a threshold at which the impacts due to erosion increase rapidly. Consequently, the transition to high management importance from Imminent (0–5 year) to Expected (5–25 year) timeframes has been used an indication of sensitivity.

Table 3-10: Comparison of management importance with corresponding group ranking

Hotspot (Listed N to S within each group ranking)	Group Ranking	Management Importance		
		Imminent (0-5)	Expected (5-25)	Projected (25+)
27. Port Beach	1	H	H	H
28. Rottneest – South Thomson Bay		H	H	H
2. Broome Town Beach	2	M	H	H
7. Monkey Mia		M	H	H
10. Drummond Cove, Geraldton		M	H	H
18. Grace Darling Park, Lancelin		M	H	H
19. Ledge Point		M	H	H
20. Seabird Foreshore, Gingin		M	H	H
25. Mettams Pool		M	H	H
26. Floreat Beach		M	H	H
30. Kwinana waterfront industrial		M	H	H
32. Rockingham Town Beach to Causeway		M	H	H
36. Mandurah Northern Beaches		M	H	H
41. Koombana Beach		M	H	H
8. Denham townsite	3	L	H	H
11. Sunset Beach, Geraldton		L	H	H
14. Grannies Beach, Irwin		L	H	H
15. Cervantes		L	H	H
23. MAAC Seawall, Joondalup		L	H	H
29. C.Y. O'Connor Beach, Cockburn		L	H	H
52. Emu Pt, Albany		L	H	H
5. Warne St & Yacht Club Exmouth	4	M	M	H
13. Point Moore, Geraldton		M	M	H
22. Quinns Beach		M	M	H
35. Waikiki Beach, Rockingham		M	M	H
48. Gnarabup S		M	M	H
50. Peaceful Bay		M	M	H
1. China Town, Broome	5	L	M	H
4. Laurentius Point, Port Hedland		L	M	H
6. Pelican Point, Carnarvon		L	M	H
9. Horrocks Foreshore		L	M	H
12. Beresford, Geraldton		L	M	H
21. Two Rocks northern coast		L	M	H
24. Watermans Bay, Stirling		L	M	H
31. Kwinana Beach		L	M	H
34. Point Peron (N Shoalwater Bay)		L	M	H
37. Doddies Beach, Roberts Point		L	M	H
38. Falcon Bay to Rakoa St		L	M	H
42. Wonnerup Beach (East)		L	M	H
43. Wonnerup Beaches		L	M	H
45. Craig St, Busselton		L	M	H
46. Abbey, Busselton		L	M	H
47. Locke Estate		L	M	H
51. Denmark, Ocean Beach		L	M	H
54. Hopetoun Foreshore		L	M	H
55. Esperance Town Beach	L	M	H	
3. Goode St, Port Hedland	6	L	M	M
39. Binningup Seawall		L	M	M
40. The Cut, Bunbury		L	M	M
44. King St		L	M	M
49. Windy Harbour Foreshore		L	M	M
33. N Point Peron (W of Causeway)	7	L	L	H
16. Grey	8	L	L	L
17. Wedge		L	L	L
53. Bremer Bay Fishery Beach		L	L	L

While there is a focus on hotspots with high management importance over the Expected (5–25 year) timeframe, appropriate management of coastal assets is required at all other hotspots. Substantial variation between anticipated and actual coastal behaviour is possible where the timeframe is greater than a few years.

Table 3-11: Summary of hotspot management importance and group ranking

Local coastal managers with hotspots of high management importance in the Expected timeframe (i.e. hotspots within group ranking 1, 2, and 3) should start preparing detailed implementation plans now.

Group Ranking	Number of Hotspots			Management Importance per Timeframe		
	Total	Perth Metropolitan	Regional	Imminent (0–5 years)	Expected (5–25 years)	Projected (25+ years)
1	2	2 (inc 1 Rottneest)	0	H	H	H
2	12	4	8	M	H	H
3	7	2	5	L	H	H
4	6	2	4	M	M	H
5	19	4	15	L	M	H
6	5	0	5	L	M	M
7	1	1	0	L	L	H
8	3	0	3	L	L	L
<i>Total</i>	55	15 (27%)	40 (73%)			

3.6. MANAGEMENT AND ADAPTATION OPTIONS

Management and adaptation options were identified for each hotspot and are presented in Table 3-12, along with monitoring and adaptation triggers suitable to guide transition between management phases, following the method described in Section 2.8. This allows multiple options along the hotspot foreshore to be identified within a chosen timeframe.

Table 3-13 provides an overview of the transition of options over time. The high-level nature of the method used to identify possible management options should be recognised. For each hotspot with proposed coastal protection works, it is essential to undertake a hotspot-specific, fully developed and costed CHRMAP, with supporting community and stakeholder engagement regarding proposed solutions. It would be prudent to prepare the plans for the 21 hotspots with high management importance (group ranking 1 to 3) as identified in Table 3-10.

Existing management and adaptation strategies (Table 3-12) tend to rely on an erosion buffer or sufficient setback (avoid), altering structures (accommodate) and the use of erosion mitigation structures (protect). The recommended strategies for the Imminent (0–5 year) timeframe include more emphasis on accommodation and retreat than the existing approach.

Detail for each hotspot, including triggers for changing to the next management phase, is provided in Appendix D. This includes:

- Existing management strategy;
- Options considered appropriate;
- Indicative cost classes in the Imminent (0–5 year) and Expected (5–25 year) timeframes;
- Triggers for management actions, corresponding monitoring and alternative options; and
- Actions to be avoided by local coastal managers. Ensuring inappropriate actions are not undertaken helps support the capacity for effective long-term management, retain beach amenity or reduce transfer of erosion stress.



Almost all hotspots will have an exhausted foreshore reserve by the Projected timeframe, requiring consideration of the feasibility of coastal protection. Protective solutions can be separated into four broad categories:

- dealing only with storm response;
- holding a beach;
- building a buffer by increasing setback width; and
- holding the line.

Protect is the main strategy presently practiced by local coastal managers and is expected to be continued for the Imminent (0–5 year) timeframe (Table 3-12). Protect may include hard and soft (sand renourishment) engineering solutions. Protect is a management option presently used for 75% (42) of hotspots and decreases to 45% (25) of the hotspots in the Projected (25+) timeframe, with retreat and accommodation often required in conjunction with the protection works. Over the Expected (5–25 year) timeframe, Retreat could be as widely and effectively implemented as Protect (Table 3-13). A shift towards Retreat will require a complementary shift in existing funding patterns and community attitudes.

Retreat of assets, many of which are recreational facilities, is identified as an option for at least 67% of the 55 hotspots beyond the next five years. Thirty-seven hotspots have had retreat identified as an option in the Projected (5–25 year) timeframe, compared to 18 in the Imminent (0–5 year) timeframe. Where relocation of assets is the preferred option alternative land will need to be secured. This is particularly important in areas with a narrow remaining foreshore reserve.

Reliable and confirmed sources of sediment are required for ongoing renourishment as a management approach (see Section 5). The ability to Avoid erosion hazard reduces over time with a greater transition to Retreat and Protect. This is partly attributed to the transfer of erosion stress and ongoing interruption of sediment transport from existing facilities and erosion mitigation structures. Existing erosion buffers are likely to be exhausted within 20–40 years for many hotspots. Finding and securing sand for beach renourishment rapidly becomes a critical issue.

A strategy to Accommodate involves developing more tolerance to erosion hazard, particularly short-term stresses. As increased tolerance typically comes with increasing cost, it is normal to select an erosion threshold, which represents an acceptable level of risk. In situations of progressive erosion, which is common to many of the identified hotspots, the threshold will be approached over time ultimately reaching an unacceptable level of risk. Consequently, use of Accommodate effectively defers the erosion threat with approximately 40% (21–23) hotspots incorporating accommodation strategies in the next 25 years. In situations where the erosion hazard is more strongly episodic or cyclic, Accommodate can have greater long-term effectiveness, which is reflected in the 10 hotspots for which Accommodate has been identified as a long-term option. It is further noted that without a rigid assessment timeframe or real budget constraints, the relative value of Accommodate may be understated in this assessment.

Table 3-12: Management and adaptation options for each hotspot

	Existing				Imminent (0–5 year)				Expected (5–25 year)				Projected (25+)			
	Avoid	Retreat	Accom.	Protect	Avoid	Retreat	Accom.	Protect	Avoid	Retreat	Accom.	Protect	Avoid	Retreat	Accom.	Protect
1. China Town				✓				✓				✓		✓		✓
2. Broome T. B.	✓			✓	✓			✓	✓		✓	✓			✓	✓
3. Goode St, P.H.	✓			✓			✓	✓				✓		✓		✓
4. Laurentius Point				✓				✓				✓				✓
5. Exmouth			✓	✓			✓				✓			✓		
6. Pelican Point			✓	✓			✓			✓	✓			✓		
7. Monkey Mia	✓			✓				✓		✓		✓		✓		
8. Denham				✓			✓	✓		✓	✓	✓		✓	✓	
9. Horrocks		✓	✓	✓			✓	✓		✓	✓	✓		✓		✓
10. Drummond C.		✓		✓		✓		✓		✓				✓		
11. Sunset Beach		✓		✓			✓			✓				✓		
12. Beresford	✓		✓	✓		✓	✓	✓			✓	✓				✓
13. Point Moore		✓				✓	✓			✓	✓			✓		✓
14. Grannies Beach				✓				✓		✓		✓		✓		✓
15. Cervantes	✓			✓	✓	✓		✓				✓		✓	✓	✓
16. Grey	✓					✓				✓				✓		
17. Wedge	✓					✓				✓				✓		
18. Grace Darling P.		✓		✓				✓		✓				✓		
19. Ledge Point	✓			✓	✓		✓			✓	✓			✓		
20. Seabird				✓		✓		✓		✓		✓		✓		✓
21. Two Rocks N	✓				✓	✓				✓		✓				✓
22. Quinns Beach				✓		✓		✓		✓		✓				✓
23. MAAC Seawall,				✓				✓				✓		✓		
24. Watermans				✓				✓		✓		✓		✓		✓
25. Mettams Pool			✓				✓			✓	✓			✓		✓
26. Floreat		✓	✓	✓		✓	✓			✓				✓		
27. Port Beach		✓		✓			✓	✓		✓	✓			✓	✓	✓
28. S Thomson Bay			✓				✓	✓		✓	✓			✓		✓
29. C.Y. O'Connor	✓	✓		✓	✓		✓			✓				✓	✓	✓
30. Kwinana Ind.	✓			✓	✓		✓					✓		✓		✓
31. Kwinana Beach				✓			✓			✓		✓		✓		
32. Rockingham		✓		✓			✓	✓		✓	✓	✓		✓		✓
33. N Point Peron			✓	✓			✓	✓		✓	✓			✓	✓	
34. N Shoalwater		✓		✓		✓		✓				✓		✓		
35. Waikiki Beach				✓			✓			✓		✓				✓
36. Mandurah N			✓	✓			✓	✓		✓	✓	✓				✓
37. Doddies Beach				✓		✓				✓				✓		
38. Falcon to Rakoa			✓	✓			✓	✓		✓	✓	✓		✓		✓
39. Binningup			✓				✓			✓	✓			✓	✓	
40. The Cut			✓				✓	✓				✓			✓	
41. Koombana				✓			✓			✓		✓		✓		✓
42. Wonnerup E.	✓					✓					✓	✓		✓		
43. Wonnerup			✓	✓		✓	✓	✓			✓	✓		✓		
44. King St				✓		✓		✓		✓		✓		✓		
45. Craig St	✓			✓				✓				✓				✓
46. Abbey	✓			✓			✓	✓			✓	✓		✓		✓
47. Locke Estate		✓		✓			✓			✓		✓		✓		✓
48. Gnarabup S			✓	✓		✓					✓			✓		
49. Windy Harbour	✓				✓		✓			✓	✓			✓	✓	
50. Peaceful Bay	✓					✓				✓				✓		
51. Ocean Beach				✓			✓			✓				✓		
52. Emu Pt, Albany		✓		✓		✓		✓		✓				✓		
53. Bremer Bay			✓				✓				✓				✓	
54. Hopetoun	✓				✓						✓	✓				✓
55. Esperance				✓				✓			✓	✓		✓		✓
TOTAL	17	12	15	42	8	18	21	37	1	37	23	31	0	42	10	25

Table 3-13: Changing management approaches to erosion over time (number of hotspots)

Option	Number of hotspots with management approach (by timeframe)			
	Existing	Imminent (0–5 years)	Expected (5–25 years)	Projected (25+ years)
Avoid	17	8	1	0
Retreat	12	18	37	42
Accommodate	15	21	23	10
Protect	42	37	31	25

Transitions to future management strategies require:

- Monitoring to identify when a trigger for progressing to the next management phase is reached (see Section 3.6.2 and Appendix D).
- Preparation of planning frameworks to ensure any planned retreat can be facilitated in the subsequent management phase (Table 3-14). This includes ensuring land is available to facilitate retreat, as well as implementing relevant planning controls, such as rezoning of land.
- Listing certain works to be avoided to ensure future plans can be achieved (Appendix D).
- Review of lease agreements for relevant hotspots to terminate the lease or reframe the lease with clarification of responsibility for erosion mitigation and adaptation pathways (Table 3-14).
- Education strategies to ensure Protect is not the only selected solution and the consequences of Retreat are understood.

Table 3-14: Strategic review of leases and preparation of planning frameworks for Retreat

	Timeframe	
	Imminent (0–5 years)	Expected (5–25 years)
Planning frameworks for Retreat	39	42
Review leases	16	Assumed reviewed in Imminent timeframe

Over the next 25 years increasing management focus is expected for leasehold arrangements (21 hotspots) and transport routes (28 hotspots). Leaseholds are mainly holiday parks, yacht clubs, surf lifesaving clubs and cafes/restaurants with residential leaseholds at Drummond Cove. This modifies the scope of appropriate mitigation actions and provides increased opportunity for use of Retreat and Accommodate strategies. For example, partial Retreat at Drummond Cove, and structural modifications and building relocation with financial contributions by lessees at Locke Estate.

3.6.1. Management and Adaptation Options in the Imminent (0–5 year) Timeframe

The distinction between hotspots with low, moderate and high management importance within the Imminent timeframe provides a potential basis for placing priority on useful management actions across the state. Information on the recommended broad management actions for the Imminent (0–5 year) and Expected (5–25 years) timeframes for the 21 high management importance (group ranking 1 to 3) hotspots is presented in Appendix F.

However, as the erosion hazard associated with this timeframe is largely associated with acute coastal change, it is possible for any hotspot to be affected by erosion. Efforts should not only be focused on hotspots with high management importance. The actions (Appendix D) for the 55

hotspots in the Imminent (0–5 year) timeframe should be considered now. All actions for the 21 hotspots with high management importance (group ranking 1 to 3) in the Expected (5–25 year) timeframe should be considered when relevant monitoring triggers have been exceeded. All actions should be undertaken within the existing local coastal manager management and decision-making frameworks.

3.6.2. Monitoring for Management Triggers

Monitoring and triggers have been identified to guide the transition between management actions for the Imminent, Expected and Projected scenarios. An example of how the monitoring and triggers are used to change management phases is demonstrated in Figure 3-3. In some cases, the monitoring and triggers change upon implementation of the next management phase.

The recommended monitoring required to identify the triggers for transitioning from present-day conditions to those expected notionally within 25 years is included in Table 3-15, with details on each trigger included for each hotspot in Appendix D. Ten monitoring types have been recommended. Those most often needed are:

- Photographic/visual/structural inspections for 34 hotspots; and
- Buffer width (dune or buffer volume) for 33 hotspots.

Most hotspots require a combination of monitoring types, with a change to monitoring typically associated with progress to the next management phase.

Some local coastal managers, particularly those with staff who have limited coastal experience (see Section 5), would benefit from a technical overview of the monitoring and interpretation of triggers.

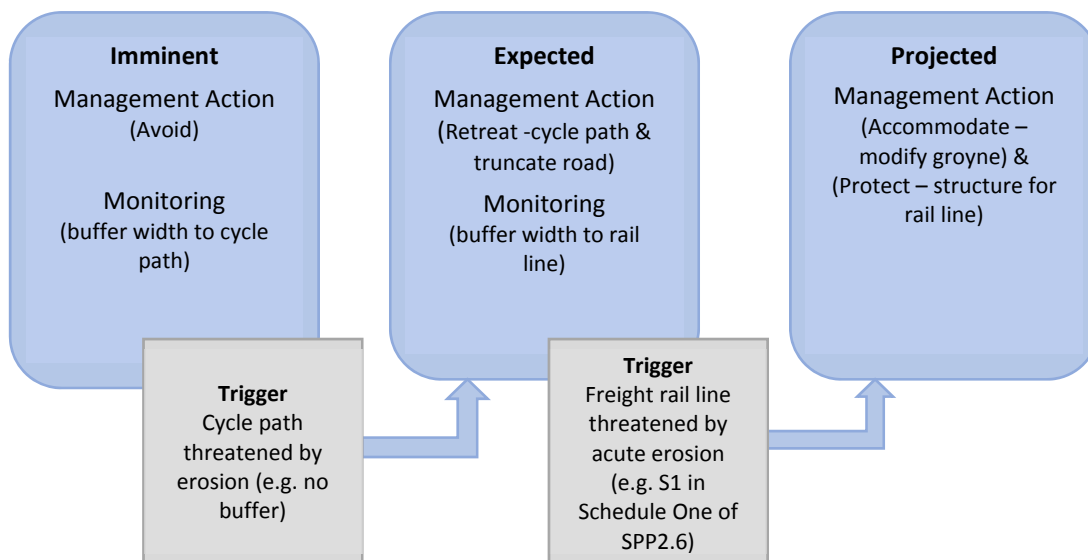


Figure 3-3: An example of using monitoring and triggers for changing management phases

Table 3-15: Monitoring to support trigger-based management transition
 Transition from Imminent (0–5 year) to Expected (5–25 year), and Expected to Projected (25+ year) management phases shown in light grey and dark grey respectively. Detail in Appendix D.

	(0–5) to (5–25) transition	Photographic/visual/structural inspection	Beach level	Beach width	Beach Profiles	High water level inspection (e.g. wrack lines)	Scarp	Buffer width (dune or buffer volume)	Aerial imagery	Sand drift / spit breach	Broader bay/foreshore monitoring program	Shoreline Profiles	Water level												
	(5–25) to (25+) transition																								
1. China Town																									
2. Broome T. B.																									
3. Goode St, P.H.																									
4. Laurentius Point																									
5. Exmouth																									
6. Pelican Point																									
7. Monkey Mia																									
8. Denham																									
9. Horrocks																									
10. Drummond C.																									
11. Sunset Beach																									
12. Beresford																									
13. Point Moore																									
14. Grannies Beach																									
15. Cervantes																									
16. Grey																									
17. Wedge																									
18. Grace Darling P.																									
19. Ledge Point																									
20. Seabird																									
21. Two Rocks N																									
22. Quinns Beach																									
23. MAAC Seawall,																									
24. Watermans																									
25. Mettams Pool																									
26. Floreat																									
27. Port Beach																									
28. S Thomson Bay																									
29. C.Y. O'Connor																									
30. Kwinana Ind.																									
31. Kwinana Beach																									
32. Rockingham																									
33. N Point Peron																									
34. N Shoalwater																									
35. Waikiki Beach																									
36. Mandurah N																									
37. Doddies Beach																									
38. Falcon to Rakoa																									
39. Binningup																									
40. The Cut																									
41. Koombana																									
42. Wonnerup E.																									
43. Wonnerup																									
44. King St																									
45. Craig St																									
46. Abbey																									
47. Locke Estate																									
48 Gnarabup S																									
49. Windy Harbour																									
50. Peaceful Bay																									
51. Ocean Beach																									
52. Emu Pt, Albany																									
53. Bremer Bay																									
54. Hopetoun																									
55. Esperance																									
TOTAL		27	23	2	1	4	7	2	1	0	1	0	2	25	23	2	3	2	2	0	7	0	5	0	1

3.6.3. Cost Classes

Cost classes (Table 3-16; Appendix D tables) are presented for management and adaptation options in the Imminent and Expected timeframes for the 55 hotspots, following the L/M/H (low/medium/high) classification described in Section 2.8.1. A further estimated cost category of \$50,000 (shown as '50k' in Table 3-16) was applied for the preparation of planning frameworks to facilitate managed Retreat in the next management phase and for review of lease agreements (Table 3-14; Table 3-16).

Table 3-16: Estimate costs (50k/L/M/H) for works in the Imminent and Expected timeframes

Hotspot	Estimation of cost for works in 2016 costs (50k/L/M/H)	
	Imminent (0–5 years) timeframe	Expected (5–25 years) timeframe
1. China Town	Protect – L	Protect – H; Prepare plans – 50k
2. Broome T. B.	Avoid – None; Protect – L for false talus for cemetery. No public cost for private landowners	Avoid – None; Accommodate – M; Protect – M for false talus for cemetery. No public cost for private landowners.
3. Goode St, P.H.	Accommodate – M; Protect – L	Protect – L; Prepare plans – 50k
4. Laurentius Point	Protect – L	Protect – H
5. Exmouth	Accommodate – L; Review Lease Agreement – 50k	Accommodate – M; Prepare plans – 50k
6. Pelican Point	Accommodate – L; Prepare Plans – 50k	Retreat – M; Accommodate – L (assuming sediment is sourced locally)
7. Monkey Mia	Protect – L; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – M; Protect – L; Prepare plans – 50k
8. Denham	Protect – M; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – M; Accommodate – L; Protect – M; Prepare plans – 50k
9. Horrocks	Accommodate – L; Protect – L; Prepare Plans – 50k	Retreat – M; Protect – M; Prepare plans – 50k
10. Drummond C.	Retreat – M; Protect – L; Prepare Plans – 50k	Retreat – M; Prepare plans – 50k
11. Sunset Beach	Accommodate – L (assuming no compensation required for caravan park lease agreement); Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – M (assuming no compensation required for leasehold buildings); Prepare plans – 50k
12. Beresford	Retreat – L; Accommodate – L; Protect – H	Accommodate – M; Protect – H
13. Point Moore	Retreat – L; Accommodate – L; Prepare Plans – 50k	Retreat – H; Accommodate – L; Protect – L Prepare plans – 50k
14. Grannies Beach	Protect – L; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – H; Protect – M; Prepare plans – 50k
15. Cervantes	Avoid – None; Retreat – L; Protect – cost to lessee; Review Lease Agreement – 50k	Protect – H; Prepare plans – 50k
16. Grey	Retreat – L (assuming shack owners are responsible for removing shacks); Prepare Plans – 50k	Retreat – M (assuming shack owners are responsible for removing shacks); Prepare plans – 50k
17. Wedge	Retreat – L (assuming shack owners are responsible for removing shacks); Prepare Plans – 50k	Retreat – H (assuming owners are responsible for removing shacks. More area to rehabilitate than Grey); Prepare plans – 50k
18. Grace Darling P.	Protect – L; Prepare Plans – 50k	Retreat – M (cost may be higher dependent on land availability); Prepare plans – 50k
19. Ledge Point	Avoid – None; Accommodate – L; Prepare Plans – 50k	Retreat – H; Accommodate – L; Prepare plans – 50k
20. Seabird	Retreat – L; Protect – L; Prepare Plans – 50k; Review Strata Agreement – 50k	Retreat – M; Protect – H; Prepare plans – 50k
21. Two Rocks N	Avoid – None; Retreat – L; Prepare Plans – 50k	Retreat – L; Protect – H
22. Quinns Beach	Retreat – M; Protect – M; Prepare Plans – 50k	Retreat – M; Protect – H
23. MAAC Seawall,	Protect – L; Review Lease Agreement – 50k	Protect – M; Prepare plans – 50k
24. Watermans	Protect – L (if storms); Prepare Plans – 50k	Retreat – L; Protect – H; Prepare plans – 50k
25. Mettams Pool	Accommodate – L; Prepare Plans – 50k	Retreat – M; Accommodate – L; Prepare plans – 50k
26. Floreat	Retreat – L; Accommodate – M; Prepare Plans – 50k Review Lease Agreement – 50k	Retreat – H (assuming new leasehold buildings will be at cost to City and not to surf club); Prepare plans – 50k
27. Port Beach	Protect – M; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – H; Accommodate – M
28. S Thomson Bay ⁵	Accommodate – L; Protect – L; Prepare Plans – 50k	Retreat – H (assumed >6 cottages); Accommodate – L; Prepare plans – 50k
29. C.Y. O'Connor	Avoid – None; Protect – L; Prepare Plans – 50k	Retreat – M
30. Kwinana Ind.	Avoid – None; Protect – M; Review Lease Agreement – 50k	Protect – H; Prepare plans – 50k
31. Kwinana Beach	Protect – M; Prepare Plans – 50k	Retreat – L; Protect – M; Prepare plans – 50k
32. Rockingham	Accommodate – L; Protect – L; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – M; Accommodate – L; Protect – M; Prepare plans – 50k

Hotspot	Estimation of cost for works in 2016 costs (50k/L/M/H)	
	Imminent (0–5 years) timeframe	Expected (5–25 years) timeframe
33. N Point Peron	Accommodate – L; Protect – L; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – L; Accommodate – L; Prepare plans – 50k
34. N Shoalwater	Protect – M	Protect – M; Prepare plans – 50k
35. Waikiki Beach	Protect – M; Prepare Plans – 50k	Retreat – M; Protect – H; Prepare plans – 50k
36. Mandurah N	Accommodate – M; Protect – L; Prepare Plans – 50k	Retreat – H; Accommodate – H; Protect – M
37. Doddies Beach	Retreat – L; Prepare Plans – 50k	Retreat – M; Prepare plans – 50k
38. Falcon to Rakoa	Accommodate – L; Protect – M; Prepare Plans – 50k	Retreat – L; Accommodate – L; Protect – M; Prepare plans – 50k
39. Binningup	Accommodate – L; Prepare Plans – 50k	Retreat – H; Accommodate – L; Prepare plans – 50k
40. The Cut	Accommodate – H; Protect – H	Accommodate – H
41. Koombana	Protect – M; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – L; Protect – M; Prepare plans – 50k
42. Wonnerup E.	Retreat – L	Accommodate – L; Protect – M; Prepare plans – 50k
43. Wonnerup	Retreat – L; Accommodate – M; Protect – L	Accommodate – M; Protect – M; Prepare plans – 50k
44. King St	Protect – L; Prepare Plans – 50k	Retreat – M; Protect – M; Prepare plans – 50k
45. Craig St	Retreat – L (if required); Protect – L; Prepare Plans – 50k	Retreat – L (if required); Protect – H
46. Abbey	Retreat – L (if required); Accommodate – L; Protect – M; Prepare Plans – 50k	Retreat – L (if required); Accommodate – M; Protect – H; Prepare plans – 50k
47. Locke Estate	Protect – L; Prepare Plans – 50k	Retreat – No public cost; Protect – M; Prepare plans – 50k
48. Gnarabup S	Retreat – L; Review Lease Agreement – 50k	Accommodate – M; Prepare plans – 50k
49. Windy Harbour	Avoid – None; Accommodate – L; Prepare Plans – 50k	Retreat – L; Accommodate – L; Prepare plans – 50k
50. Peaceful Bay	Retreat – L; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – M; Prepare plans – 50k
51. Ocean Beach	Protect – M; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – M; Prepare plans – 50k
52. Emu Pt, Albany	Protect – L; Prepare Plans – 50k; Review Lease Agreement – 50k	Retreat – M; Prepare plans – 50k
53. Bremer Bay	Accommodate – L	Accommodate – L
54. Hopetoun	Avoid – None	Accommodate – M; Protect – M
55. Esperance	Protect – M; Prepare plans – 50k; Review Lease Agreement – 50k	Retreat – L; Protect – H; Prepare plans – 50k

Historic practice suggests that high cost classes will tend to dominate management effort, with higher cost also requiring a longer lead time to establish funding. Consequently, hotspots management with a high cost class are listed in Table 3-17. This demonstrates that the majority of sites are located in regional Western Australia, with the number of sites forecast to require high cost management increasing from the Imminent (0-5 years) to Expected (5-25 years) timeframes. Importantly, it is recognised that there may be opportunity to achieve mid-range or lower costs if there is sufficient design effort and project planning in advance.

Cost class estimates do not consider additional costs for enhancement of amenity above existing levels (e.g. works proposed for Beresford), or extension of the area subject to erosion hazard over this period. A risk to the order of magnitude cost estimates is the future availability and cost of appropriate basic raw materials for coastal protection, such as coarse sand for renourishment or rock for erosion mitigation structures. This is particularly relevant for when competition for resources (e.g. within Perth Metropolitan area) may lead to increased transport costs from quarries.

**Table 3-17: Management and adaptation actions with high cost (up to approximately 25 years)**

<i>Imminent (0–5 Year) timeframe</i>	
Hotspot	Actions with high costs
12 Beresford, Geraldton	Protect – extension of existing coastal protection alongshore
38 Falcon Bay to Rakoa Street	Protect – planned upgrade to walling with expectation of future retreat (i.e. short to medium-term)
40 The Cut, Bunbury	Accommodate – raise training wall revetment, Protect – improved stability of central section on north training wall
41 Koombana Beach	Protect – renourish. Extend Busaco Point revetment in 2017 with possible discussion of extended groyne
<i>Expected (5–25 Year) timeframe</i>	
Hotspot	Actions with high costs
1 China Town, Broome	Protect – strengthen protection to meet a standard throughout
4 Laurentius Point, Port Hedland	Protect – deepen revetment to 0.5m below sand surface
12 Beresford, Geraldton	Protect – protection to extend the 1.5km length of Beresford
13 Point Moore, Geraldton	Retreat – relocate/truncate Marine Terrace
14 Grannies Beach, Irwin	Retreat – remove path seaward of Ocean Drive; Relocate road
15 Cervantes	Protect – renourish using the considerable sand volume deposit at cusplate foreland
17 Wedge	Retreat – remove shacks and rehabilitate informal access tracks. Shacks should be removed before construction material eroded and litters foreshore
19 Ledge Point	Retreat – eight private properties
20 Seabird	Protect or Retreat – Retreat boat ramp, access, private properties and caravan park. The protect option is to extend seawall further northwards.
21 Two Rocks northern coast	Protect – construction of 'back-up' seawall
22 Quinns Beach	Retreat – remove facilities seaward of Ocean Drive
24 Watermans Bay, Stirling	Protect – replace GSC revetment with rock revetment. Option: Install groynes to reduce beach mobility and renourish beach
26 Floreat Beach	Retreat – further carpark realignment, modify shape of vehicle access ramp, some lease buildings may require shifting
27 Port Beach	Retreat – remove carpark revetments; retreat SLSC, Coast pub, carparks by relocating to Leighton Beach. This will require management of the site contamination
28 Rottnest – South Thomson Bay	Retreat – local retreat for at least 3 cottages, up to 12
30 Kwinana waterfront industrial	Protect – Maintain existing structures. Beach rotation between groynes, leading to installation of revetments where foreshore reserve is lost. Extension of artificial headlands. Note: renourishment may partly extend life of artificial headlands
35 Waikiki Beach, Rockingham	Protect – increase renourishment rates using external sources (contributing to high cost). Artificial dune built along extended area (annually), 'back-up' seawall for restricted facilities
36 Mandurah Northern Beaches	Retreat – remove short-term facilities north of groynes Remove facilities seaward of Ormsby Terrace, Remove sections of Ormsby Terrace not required for access, Retreat car parks on N side of groynes Accommodate – continue annual bypassing, with part placement further north, seek buy-back of properties and implement easements
39 Binningup Seawall	Retreat – remove facility and construct new facility to landward (redesign requires better understanding of underlying rock)
40 The Cut, Bunbury	Accommodate – reduce seaward length of training walls, widen the channel, Consider placement of Bunbury Port dredge spoil to assist
45 Craig St, Busselton	Protect – construct new short groyne to east, with nourishment; large-scale nourishment and extend/relocate groyne
46 Abbey, Busselton	Protect – change to adaptable active management; build dunes; look for renourishment opportunities; investigate the feasibility of timber/GSC groynes
55 Esperance Town Beach	Protect – extension of selected groynes to provide beach amenity; Upgrade of sections. Ongoing sand renourishment

4. Knowledge Gaps

Knowledge gaps that may impact future management of erosion hazard at the hotspots were considered from two perspectives:

- Information gaps that could be addressed to improve coastal erosion assessment; and
- Apparent knowledge gaps of decision-makers leading to discrepancies between science, policy and implementation of coastal management and adaptation decision-making.

These knowledge gaps are discussed briefly in this section, along with some potential pathways to address them. Recommendations to address these knowledge gaps to facilitate erosion management and adaptation at the hotspots are included in Section 6.2.

4.1. INFORMATION GAPS FOR COASTAL EROSION ASSESSMENT

As noted in Section 2.1, the localised nature of storm impacts and the irregular nature of many coastal phenomena make the timing and amplitude of erosion events unpredictable. This leads to a relatively high level of uncertainty regarding erosion assessment for coastal decision-making, which varies according to the level of susceptibility to erosion hazard and the forecast timeframe required for decision-making (Table 4-1).

Table 4-1 is provided as an indication of how information needs may vary according to the perceived susceptibility of the hotspot to coastal erosion. This has not been used as part of the hotspot assessment framework. Assessment and monitoring approaches for each hotspot should be developed on a case-by-case basis, and may be varied over time to account for different levels of stress or foreshore development.

Relationships exist between susceptibility to erosion hazard, information needs and the decision-making framework. For example, negligible information is required if a reactive approach is considered acceptable, while a high level of information may be required where quantified active management is to be undertaken (e.g. sand-bypassing works at Mandurah). Information needs may also be influenced by the hotspot characteristics, particularly different aspects of coastal dynamics, including the effects of rock features or coast–structure interactions.

Table 4-1: Levels of information for coastal erosion decision-making

These are indicative only.

	Level				
	1	2	3	4	5
Level of susceptibility	Negligible	Low	Moderate	High	Very High
Decision-making timeframes	>30 years	5–30 years	1–5 years	Annual	Active
Metocean spatial coverage	Regional		Local	Hotspot	Real-time
Coastal dynamics monitoring frequency	5-yrs	Annual	6-months	Post-event	Real-time
Possible measure	Veg Lines	Beach width	Profiles		Fixed cameras
Hazard Assessment	Schedule One SPP2.6 ¹		Include local processes		Detailed
Management Plans	Regional CMP		Local FMP		Asset plan

Note: 1) Default measures of Schedule One of SPP2.6 may be appropriate as a first pass for consideration of Avoid at broad spatial scales on undeveloped foreshores with low levels of susceptibility to erosion hazard.



Available information relating to coastal dynamics and its management is summarised in Table 4-2. This summary should be confirmed for individual hotspots when designing more detailed data collection studies. Hotspots where further information is likely to be useful have been determined on a subjective basis, as the preferred approach to future hazard management (i.e. reactive, planned or active) has only been interpreted based upon historic practices.

In general, the majority of the state is covered by regional information suitable for decision-making over long timeframes (e.g. regional metocean data, vegetation line measurements and assessment using Schedule One of SPP 2.6) with some collected by the Department of Transport and Bureau of Meteorology. Identification of sediment cells and coverage by LIDAR bathymetry covers the majority of the hotspots, which largely reflects relative population density.

At a number of the hotspots additional data needs have been suggested to better resolve coastal dynamics and facilitate improved management of erosion hazard. These are where there is historic evidence to suggest that there are significant, locally relevant processes which have not been captured within the information typically collected. These additional studies are represented by green (considered beneficial) and peach (possibly beneficial) in Table 4-2. This is a high-level assessment of existing information that local managers may use when considering their individual needs in more detail.

Projection of coastal trends, which is required to forecast erosion hazard timeframes, is partly limited by available information. Existing coastal change information may be better interpreted in the context of the hotspot history (e.g. works causing coastal change) and long-term or regional patterns of change (e.g. storminess cycles). This may provide a clearer distinction between acute, cyclic or progressive erosion stresses, and can be derived from existing long-term data collection programs.

In summary, information gaps that could be addressed to improve the certainty regarding coastal erosion prediction include:

1. Improved long-term records of coastal movements at all hotspots and watchlist locations. This would include ongoing five-yearly flights to capture aerial imagery and digitise coastal movements;
2. Targeted information on coastal dynamics to refine knowledge of specific local or episodic erosive processes, such as unstable landforms or interrupted sediment transport (see green and peach colours in Table 4-2);
3. Geotechnical investigations, particularly in areas with high value assets that are identified as susceptible to erosion hazard (see Table 4-2);
4. Management histories at hotspots to refine projected coastal trends and use as a basis for recording ongoing maintenance; and
5. Identification of long-term and regional variations of meteorological and oceanographic data, to support better interpretation of coastal trends. This will save local coastal managers expense by avoiding repeated analyses of the same data by multiple consultants.

Table 4-2: Identified coastal dynamics and management information

Coastal movement data are required at all hotspots. This is a high-level assessment of existing information that local managers may use when considering their individual needs. White cells represent *not required* for Coastal Dynamics and *unavailable* for other columns. Additional data/studies are suggested to resolve *coastal dynamics* (only) to be able to facilitate management of erosion hazard. The additional data/studies are considered beneficial (green) and possibly beneficial (peach) for Coastal Dynamics only.

	Metoccean					Coastal Dynamics							Hazard Assess.			Man. Plan		Asset	
	Continuous Data	Site Deployment	Local Deployment	Regional Data	Modelling	Geotechnical	Sedimentology	Renourish Source	Littoral Transport	Sandbar Dynamics	LIDAR	Sediment Cells	Regional Hazards	Hotspot Hazards	CHRMAT	CHRMAT Parts	Regional coastal		Local foreshore
1. China Town, Broome																			
2. Broome Town Beach																			
3. Goode St, Port Hedland																			
4. Laurentius Point, Port Hedland																			
5. Warne St & Yacht Club Exmouth																			
6. Pelican Point, Carnarvon																			
7. Monkey Mia																			
8. Denham townsite																			
9. Horrocks Foreshore																			
10. Drummond Cove, Geraldton																			
11. Sunset Beach, Geraldton																			
12. Beresford, Geraldton																			
13. Point Moore, Geraldton																			
14. Grannies Beach, Irwin																			
15. Cervantes																			
16. Grey																			
17. Wedge																			
18. Grace Darling Park, Lancelin																			
19. Ledge Point																			
20. Seabird Foreshore, Gingin																			
21. Two Rocks northern coast																			
22. Quinns Beach																			
23. MAAC Seawall, Joondalup																			
24. Watermans Bay, Stirling																			
25. Mettams Pool																			
26. Floreat Beach																			
27. Port Beach																			
28. Rottnest – South Thomson Bay																			
29. C.Y. O'Connor Beach, Cockburn																			
30. Kwinana waterfront industrial																			
31. Kwinana Beach																			
32. Rockingham T. B. to Causeway																			
33. N Point Peron (W of Causeway)																			
34. Point Peron (N Shoalwater Bay)																			
35. Waikiki Beach, Rockingham																			
36. Mandurah Northern Beaches																			
37. Doddies Beach, Roberts Point																			
38. Falcon Bay to Rakoa St																			
39. Binningup Seawall																			
40. The Cut, Bunbury																			
41. Koombana Beach																			
42. Wonnerup Beach (East)																			
43. Wonnerup Beaches																			
44. King St																			
45. Craig St, Busselton																			
46. Abbey, Busselton																			
47. Locke Estate, Busselton																			
48. Gnarabup S																			
49. Windy Harbour Foreshore																			
50. Peaceful Bay																			
51. Denmark, Ocean Beach																			
52. Emu Pt, Albany																			
53. Bremer Bay Fishery Beach																			
54. Hopetoun Foreshore																			
55. Esperance Town Beach																			

Not considered within the scope of this assessment

Considered beneficial
 Possibly beneficial
 Unavailable OR not required
 • Available, but limited
 Available



4.2. KNOWLEDGE GAPS AFFECTING IMPLEMENTATION

There is a discrepancy between scientific understanding of coastal dynamics and the general community intolerance to erosion, which is expressed as a desire to preserve existing coastal assets and amenity. Local coastal managers require the participation of the community, councillors and other stakeholders in decision-making, particularly in developing CHRMAPs. Participative decision-making may include a limited appreciation of the potential consequences and long-term costs of coastal management actions. Improved understanding of the impermanence of amenity and assets on a fluctuating coast is required, with greater acceptance of transfer, or relocation and transfer, of erosion stress from some erosion mitigation works.

The separation between coastal science and decision-making has been indirectly supported by the refined nature of coastal policy for determining an erosion buffer (Avoid) for Greenfield locations (Schedule One of SPP 2.6). This formulaic approach has, by default, become a standard method of evaluation for all locations and is recommended in the CHRMAP Guidelines (WAPC 2014). Although the policy suggests incorporating coast–structure interactions (Section 4.4.1 (S1) and Item 5.7 iii (a) and iv (c)), this has mainly been neglected within most CHRMAPs reviewed to date by Seashore. The substantial influences of historic management are also significant for most developed hotspots.

Additional uncertainty regarding management responsibilities, lease agreements, economic value of beaches and reserves, and availability of basic raw materials are knowledge gaps identified in Section 5 that may affect implementation of management and adaptation pathways for erosion hazard.

External knowledge gaps that could be addressed to improve coastal management decision-making include (numbering continues from Section 4.1):

6. Understanding of the community, Local Government officers, Local Government councillors, State Ministers and other decision-makers regarding coastal mobility and the viability of relocating or removing assets from the coastal zone;
7. Improved education regarding interactions between erosion mitigation structures and the coast (e.g. transfer of erosion stress);
8. Coastal monitoring to support adaptive decision-making. Focusing coastal monitoring on response-based management triggers can allow lower-cost techniques to be applied. This approach could vary regionally and build on work prepared for the City of Busselton (Shore Coastal 2013), Peron Naturaliste Partnership (Damara WA 2015) and for Gingin (Seashore Engineering 2017);
9. Uncertainty regarding the future availability and cost of appropriate basic raw materials for coastal protection, including coarse sand for renourishment and rock for erosion mitigation structures. This is particularly relevant when competition for resources (e.g. in Perth Metropolitan area) may lead to increased transport costs from quarries;
10. Management responsibility for erosion hazard mitigation, which is particularly relevant for unallocated Crown land and leasehold land. Existing leases may not have sufficient information regarding financial responsibility and period of the lease to ensure adaptation pathways can be achieved; and
11. The socio-economic value of beaches and foreshore reserves. This information can be used to quantify the impact of beach loss if protection is pursued and foreshore reserve loss if retreat is pursued.

5. Coastal Management Issues

Effectiveness of implementing coastal management, planning mechanisms and adaptation at each hotspot is influenced by uncertainty stemming from many factors which are not necessarily related to erosion hazard. These factors, or 'supplementary issues to erosion', were identified by consultation with local coastal managers and observations by Seashore Engineering during assessment of the hotspots. Examples of these issues include: community attitudes, existing funding patterns and low corporate knowledge due to high staff turnover of many local coastal management positions.

5.1. ISSUES IDENTIFIED BY LOCAL COASTAL MANAGERS

Twenty-nine Local Governments (LGs) with hotspots were surveyed to assist confirm information about the hotspots (through provision of hotspot summary paragraphs and figures in Appendix D) and for details on their coastal management constraints (Section 2.3, Table 5-1 to Table 5-4 and Appendix E.2). Survey responses were received from 28 of 29 LGs, with not all LGs replying to every question. A summary of four questions related to broader management within the LG is provided in Table 5-1 to Table 5-4 separated into Perth Metropolitan (eight LGs) and Regional (21 LGs) areas.

Table 5-1: Mechanisms used to raise funds for coastal management

	Perth Metropolitan LGs	Regional LGs	Total
Number of LG responses	7	20	27
Responses (LGs could select more than one mechanism)			
Internal budget allocation process (emergency, annual or 5-yearly)	6	18	24
External grant application(s)	7	19	26
Percent of annual rates or LG budget	0	5	5
Differential or specified area rating and budget	0	1	1

Table 5-2: Estimated budget available for coastal management over the next 5 years

	Perth Metropolitan LGs	Regional LGs	Total
Number of LG responses	8	18	26
Responses¹			
<\$25k/year (on average over 5 years)	1	9	10
\$25k–\$100k / year (on average over 5 years)	5	4	9
>\$100k/year (on average over 5 years)	2	5	7

Note: 1) Some LGs did not include external grant funding in this budget allocation

Table 5-3: Coastal management capacity in terms of staff and equipment

	Perth Metropolitan LGs	Regional LGs
Number of LG responses	6	20
Responses		
Staff (engineering/environment/planning). Not all coastal staff. ¹	2.2 staff average. Range 1 to 4 ¹	3.6 staff average. Range 0 to 10 ¹
Equipment	4 with in-house equipment, 2 with contractor	13 with in-house equipment, 4 with contractor, 4 LG with nil
Other (e.g. coastcare volunteers)	5	11

Note: 1) Not all LGs noted full time equivalence (FTE). Many regional LGs had 0 to 0.4 FTE for coasts.

**Table 5-4: Planning controls or development agreements for coastal management**

	Number of LGs
Number of LGs responses	27
Responses (LGs could select more than one planning control or development agreement)	
Plans	
Foreshore management plan	2
CHRMAP ¹	10
Climate change assessment	1
Coastal monitoring annual report/coastal management strategy	2
Local coastal planning policy	2
State land agreements	3
Town planning scheme/local planning scheme/structure plan	6
Special Control Area	2

Note: 1) Some LGs have undertaken CHRMAPs since the first consultation was undertaken in July 2016.

Issues and constraints to coastal management identified by local coastal managers during the consultation process (Section 2.3) are included below and in Appendix E.2. The main issues, challenges and constraints to better coastal management were (in descending number of respondents):

- Funding constraints;
- Staffing issues – a lack of experienced staff or dedicated coastal staff was a constraint to coastal management;
- Community expectations;
- Further studies;
- Land tenure;
- Legislative frameworks;
- Knowledge level; and
- Suitable sand sources for renourishment.

Funding available to local coastal managers is generally lower than cost estimates for erosion mitigation (Table 5-2 and Appendix D). In Perth Metropolitan areas, the modal budget available for coastal management is \$25k–\$100k a year and in Regional areas it is <\$25k a year. Local coastal managers suggest that there is insufficient funding to undertake erosion mitigation, particularly for large coastal projects and managed retreat, as well as maintaining amenity. Uncertainty regarding ongoing contribution from annual grants programs was identified as a concern.

Additional information from the survey is included in Appendix E.2.

5.2. ADDITIONAL ISSUES INFLUENCING COASTAL MANAGEMENT

A list of supplementary issues to erosion that influence decision-making is included in Table 5-5 This was derived in part from the information provided by local coastal managers during consultation (Section 5.1 and Appendix E). In addition, a number of issues were identified by Seashore Engineering through comparison and contrast across the 55 hotspots. A prevalent issue devolves from a common perception that assets and amenity should be preserved for as long as practical in their existing location. This perception creates bias towards robust coastal interventions which maximise local coastal stability, but transfer erosion elsewhere, in preference to more flexible or adaptable responses to coastal change.

Table 5-5: Supplementary issues for coastal management

Issue	Description
Perception the foreshore is stable	<ul style="list-style-type: none"> Siting infrastructure on mobile landforms or renourished foreshores limits the capacity for sediment exchange (i.e. local erosion–accretion balance). Foreshore reserves were allocated as erodible land in a setback allowance (SPP2.6), causing community pressure that <i>Protect</i> should be used for reserves and parkland. Public perception is that the government will keep the foreshore stable. As a result, <i>Retreat</i> is strongly opposed by many local communities.
Asset-based focus	<ul style="list-style-type: none"> Decision-making on asset scale increases the tendency to <i>Protect</i>, often neglecting impacts and incapable of identifying scope for alternative actions (e.g. relocation).
Low value placed on reserves by managers	<ul style="list-style-type: none"> <i>Protect</i> options that cause transfer of erosion to adjacent foreshore reserves is often accepted, even though these reduce the buffer's (<i>Avoid</i>) effectiveness. <i>Protect</i> options reduce the capacity for local erosion-accretion balance, which can create a larger section of instability than has been stabilised. Desire to use foreshore reserves, intended as erosion buffers, as development opportunities or recreational spaces due to the perception that this high value land (valued due to coastal proximity) is being under-utilised can lead to depletion of valuable reserves required as buffers to coastal erosion. The perception that land designated as an erosion buffer has low value is also implied by common acceptance of actions which transfer the erosion hazard alongshore (e.g. <i>Protect</i> options transferring heightened erosion to an adjacent buffer). Knowledge of the socio-economic value of reserves could be used to quantify the impact of foreshore reserve loss if protection is pursued on adjacent foreshores or if retreat is pursued for a foreshore reserve.
Protection works inconsistent with policies or strategies	<ul style="list-style-type: none"> Public recreation facilities with limited lifespan which should be removed (<i>Retreat</i>) or modified (<i>Accommodate</i>) if threatened by erosion (Section 7.1 SPP2.6). There is a history in WA of placing rocks, without adequate design, to <i>Protect</i>. <i>Protect</i> options for private property with public funds for capital works (Seabird). <i>Protect</i> options for caravan parks (Dongara, Emu Point). <i>Protect</i> options for access (including car parks) that cause loss of beach amenity (i.e. the reason for access). Knowledge of the socio-economic value of beaches could be used to quantify the impact of beach loss if protection is pursued. <i>Protect</i> requires ongoing maintenance, which is often deferred or neglected.
Inefficient renourishment	<ul style="list-style-type: none"> Renourishment sand can be too fine, inappropriately placed or of insufficient volume; causing the perception that it is not effective, is a waste of money and erodes quickly.
Rock substrate	<ul style="list-style-type: none"> Knowledge of locations with rock substrate is generally not well-known.
Leasehold sites	<ul style="list-style-type: none"> Freeholding coastal land effectively extends the timeframe over which coastal management may be expected to keep the hotspot stable. This limits the capacity to use <i>Retreat</i> and reduces the range of management options applicable to those hotspots. Under lease arrangements, it can be unclear who is responsible for coastal management (e.g. holiday parks and yacht clubs).
Governance	<ul style="list-style-type: none"> LGs typically manage the foreshore, commonly with advice from State Government agencies and consultants. They are often subjected to high staff turnover (loss of local knowledge), and/or staff with non-coastally focused training and a tendency towards reactive coastal management. Staff turnover occurred for approximately a third of the relevant local coastal managers during the 14 months this project was undertaken, demonstrating the difficulty for small LGs to support staff with appropriate coastal knowledge. Collaboration across jurisdictional boundaries is commonly limited (unique cases of collaboration exist where resources are available). Some issues require management across a broader sediment cell level, covering more than one LG. Decision-making by politicians in contrast to coastal management advice. Uncertainty regarding management responsibilities for Unallocated Crown Land. Funding frameworks and focus on individual assets can lead to selection of the <i>Protect</i> management option and a failure to consider alternatives. LG limitation to secure funding for ongoing renourishment programs (<i>Protect</i>). Use of an approach developed for determining an erosion buffer for greenfields locations (Schedule One of SPP2.6) to assess coastal processes in areas of complex interactions between structures, assets and modified coasts. Funding availability for <i>Retreat</i>, <i>Accommodate</i> and <i>Protect</i>.



6. Conclusions and Recommendations

Conclusions and recommendations in this section are framed to facilitate management and adaptation at a regional or Statewide scale. It covers findings that have a wider scope as well as those which are common to many hotspot sites. Nevertheless, these findings may not always be applicable to every site.

Recommendations for each hotspot are provided in Appendix D to assist local coastal managers in implementing a response to the erosion hazard at a local scale.

6.1. CONCLUSIONS

A whole of state assessment of coastal erosion hotspots in WA has been completed, describing the scale and extent of coastal erosion threat to existing facilities and assets. This assessment addressed the five objectives outlined in Section 1.1.

Objective 1: Identify coastal erosion hotspots across Western Australia. Determine potential management and adaptation pathways, based on identified sources of erosion hazard and impacted assets.

1.1 Hotspot Identification

The approach used to characterise erosion threat involved Statewide identification of existing assets near to the coast through a visual assessment of aerial imagery. Erosion hazard for each hotspot (i.e. at a smaller scale) was interpreted by combining historic coastal change observations, anticipated landform response, anticipated transfer of erosion stress from erosion mitigation structures, default setback allowances, model outcome and analogous situations from WA, where available. The capacity for management and adaptation was developed based upon professional knowledge or inference regarding the sites and existing coastal structures, including a transition over time from acute erosion hazard through to the increased impact of progressive processes.

Eighty-six locations were identified by Seashore Engineering, in consultation with local coastal managers, where erosion hazard was assessed as highly likely to impact many existing public-owned assets within 25 years, or to have a substantial cost of management. Locations for which erosion management is imminent were classified as erosion hotspots, with 55 locations determined. A further 31 locations were classified as watchlist, indicating that anticipated management effort is subject to the conditions experienced, and it is plausible that limited erosion management may be required over the next five years. Five characteristics were used to demonstrate why locations were selected for further assessment. Hotspots have three to four of those characteristics and watchlist locations have one to two. Most hotspots were characterised by having infrastructure close to unstable foreshores, which are highly valued by the community.

1.2 Hotspot Issues

Five sources of erosion hazard (erosion issues) were identified in this assessment from the historic observations of coastal change. For the developed foreshores of the hotspots, common erosion issues included placement of facilities within an expected or observed erosion hazard zone (i.e. inappropriate siting or insufficient tolerance to erosion pressure); location on or adjacent to naturally unstable coastal landforms; or locally enhanced erosion pressure due to interruption of sediment transport by adjacent coastal infrastructure. These erosion issues may vary substantially



between locations and typically require identification on a case-by-case basis to provide meaningful forecasting of erosion hazard. When characterising susceptibility to erosion hazard in the short- to medium-term, these erosion issues on developed foreshores require consideration.

Exposure of existing public-owned assets, private and leasehold property to erosion was identified for three nominal timeframes, to account for transition from present-day stresses, to accumulated impact over time by progressive erosion or cycles. The spatial distribution of erosion pressure has been interpreted through professional judgement, based upon historic observations of coastal change at the hotspots, and analogous situations from sites across Western Australia, particularly those where sediment transport has been disrupted. Forecasting the time at which assets are likely to be affected by erosion (i.e. within each of the timeframes) has been used for comparing management importance and identification of management and adaptation options. However, there is considerable uncertainty regarding when a severe storm may hit a hotspot, or whether patterns of change observed over recent decades will continue, accelerate or reverse. In addition, further uncertainty is introduced by the effects of additional stabilisation works undertaken at or nearby a hotspot. The relatively high occurrence of transferred erosion pressure across the hotspots highlights that the use of coastal protection works as a management tool should be considered carefully.

Recreational assets are the most prevalent asset class subject to erosion hazard across all three timeframes. Although many of these assets may be considered relocatable, contraction of the foreshore reserves due to erosion is likely to reduce the area available for recreational assets and, in many cases, it is not expected that the existing quantity of recreational assets can be maintained over time without transferring erosion pressure to other assets.

For nearly half of the hotspots, management of erosion pressure will require consideration of the interface between public and private assets over the Projected (25+ years) timeframe. This can involve reconciling disparate visions for erosion mitigation approaches and opportunities for funding erosion mitigation. More than a third of the hotspots have leasehold property such as surf lifesaving clubs, caravan parks or restaurants susceptible to erosion hazard over the Expected (5–25 year) timeframe. There is some uncertainty regarding the responsibilities of lessee and lease-holder for erosion management of these assets as identified from queries received by local coastal managers. Transport routes are subject to low Imminent threat, mainly affecting local traffic. Over the Expected (5-25 year) timeframe, interruption of transport routes is expected to become a more prevalent issue for almost half the hotspots, including the potential impact on more substantial transport routes (road and rail).

1.3 Management and Adaptation Pathways

Management and adaptation options were identified for each hotspot for the three timeframes, along with monitoring and adaptation triggers suitable to guide transition between levels of management. Protect is the main strategy presently used by local coastal managers and is likely to continue for the Imminent (0–5 year) timeframe. Over the Expected (5–25 year) timeframe Retreat could be as widely and effectively implemented as Protect. A shift towards Retreat will require a complementary shift in funding patterns, an adjustment in community attitudes, securing alternate land for relocated assets, modification to length of leases (where relevant) and demonstration of the



socio-economic value of beaches and foreshore reserves. Existing erosion buffers are likely to be exhausted over 20–40 years for many hotspots.

Erosion hazard due to acute coastal change is associated with the Imminent (0–5 year) timeframe. Damage and severity are strongly determined by the conditions experienced. It is possible for any of the hotspots to be affected by erosion in the short term. This generally means that the coastal manager should be ready to react, and consequently many of the identified actions for the Imminent (0–5 year) timeframe (Tables F–1 to F–3 in Appendix F) relate to the development of action plans. All actions should be undertaken within the existing local coastal management and decision-making frameworks.

Over longer timeframes, the increased chance of having a severe storm, combined with the effects of progressive erosion, means that the impacts over the Expected timeframe are less likely to depend on the conditions experienced. Early scheduling and implementation of monitoring, and management and adaptation pathways linked to monitoring triggers, is considered a viable approach. Efforts may also be applied to the 54 actions identified for the 21 high management importance (group ranking 1 to 3) hotspots in the Expected (5–25 year) timeframe (Tables F–4 to F–6 in Appendix F) when relevant monitoring triggers have been exceeded.

A range of simple monitoring techniques has been identified for the hotspots, based on triggers indicating when the management approach may need to change. These transitions were identified for erosion thresholds loosely corresponding to the ends of the Imminent and Expected timeframes, recognising that triggering will occur at different times dependent upon the conditions experienced.

Objective 2: Evaluate implications of coastal management for hotspots and their future adaptation

Historic practice suggests that those hotspots requiring high cost management will tend to dominate management effort, with higher cost also requiring a longer lead time to establish funding. Identification of hotspots with a high cost class demonstrates that the majority of sites are located in regional Western Australia, with the number of sites forecast to require high cost management increasing from 4 in the Imminent (0-5 years) timeframe to 23 in the Expected (5-25 years) timeframe. Importantly, it is recognised that there may be opportunity to achieve mid-range or lower costs if there is sufficient design effort and project planning in advance. This includes the managing the supply of basic raw materials such as rock and sand nourishment, for which cost is strongly affected by demand.

Objective 3: Demonstrate a range of possible adaptation pathways.

Statewide evaluation of hotspots demonstrated a range of different situations and viable management responses to future erosion pressure, including non-structural treatments.

The approach of a Statewide evaluation of options demonstrated the relative value of overall hazard management strategies (Avoid, Accommodate, Retreat or Protect) for hotspots with existing development. The most prevalent viable long-term options were either to Retreat or Protect. Due to the method of defining hotspots where existing assets are subject to erosion stress, the overall strategy to Avoid hazard was not applicable to the hotspots. The strategy to Accommodate hazard



typically acted to defer a transition to more long-term solutions. It is recognised that in the context of this assessment, where locations are all subject to progressive erosion and the longest time scale was not fixed, the relative benefits of deferral were underplayed. For more detailed ‘real life’ assessments, particularly those considering budgetary time dependence, it is anticipated that the Accommodate will have a greater role.

Consideration of the steps required to undertake retreat at individual hotspots, to maintain a public foreshore and move/remove assets susceptible to erosion hazard, highlighted that it is not always a lower-cost strategy. Equally, recognition of erosion transfer and the value of beaches highlighted that protection is not always a complete solution to erosion pressure.

Objective 4: Identify issues restricting implementation of coastal management and adaptation strategies

Effectiveness of implementing coastal management, planning mechanisms and adaptation at hotspots was identified as being influenced by many factors, including:

- Community expectations to maintain or extend existing facilities, including protection against erosion;
- Low corporate knowledge due to high staff turnover, or lack of dedicated coastal staff, for many coastal management positions in local government;
- Insufficient understanding of causes of erosion, including potential for erosion mitigation structures to transfer erosion stress;
- Uncertainty in securing funding and in the financial responsibilities for erosion management on private and leasehold land;
- Uncertainty on the capacity of lease agreements to support future adaptation pathways;
- Uncertainty of management responsibility for erosion on Unallocated Crown Land;
- Uncertainty for local coastal managers on how to implement planning mechanisms;
- Availability and cost of coarse sand suitable for renourishment and rock for construction of erosion mitigation structures.

Objective 5: Provide a relative comparison of hotspot management importance

A framework for determining a relative measure of HMI has been developed and applied to the 55 hotspots to facilitate a strategic approach to coastal erosion management efforts in WA. The relative management importance considers public-owned assets susceptible to erosion hazard and level of recreational/stakeholder interest. Overall, 21 hotspots have high management importance in the Expected (5–25 year) timeframe, including two hotspots (Port Beach and South Thomson Bay) with high management importance in the Imminent timeframe (0–5 years). For each hotspot, management importance generally increases over time, reflecting greater exposure of existing assets to erosion hazard due to progressive erosion. The relative HMI will evolve as management actions are undertaken, assets change and erosion pressures vary.

The number of high management importance hotspots in future suggests that many local coastal managers have not applied a long timeframe to decision-making for the placement of assets within the coastal zone. In many cases there is an opportunity, in the context of an approved and funded



management plan, for temporary to medium-term use of highly valued coastal land before longer-term erosion hazards threaten assets or the foreshore reserve is exhausted.

6.2. RECOMMENDATIONS TO FACILITATE MANAGEMENT AND ADAPTATION

Common themes have been identified in the management issues for the hotspots, and the review of local coastal manager survey responses, as summarised in the Conclusions (Section 6.1). These have been drawn together to provide two groups of recommended actions that could support coastal management by State and Local Government agencies, including:

- Actions relevant to governance and management of hotspots; and
- Options to address knowledge gaps relevant to hotspot management.

Options to assess investigations for coastal management pressures additional to coastal erosion hotspots are included in Box 6-1 for scoping additional projects.

Governance and management of hotspots threatened by erosion

1. State Government to provide integrated coastal planning and engineering support to local coastal managers.
2. Local coastal managers to prepare fully developed and costed management and adaptation plans (hotspot-specific CHRMAPs) for their hotspots. Hotspot-specific CHRMAPs should include:
 - a) increased focus on:
 - determining coastal management responsibilities;
 - developing implementation plans and determining funding mechanisms;
 - resolving planning mechanisms (e.g. special control areas);
 - b) appropriate triggers for changing management phases;
 - c) community and stakeholder engagement regarding proposed solutions, outlining impacts on coastal values and ratepayers in terms of funding;
 - d) focus emphasis of the erosion hazard assessment on dominant erosion processes at the hotspot, with more detail noted in Recommendation 8 below;
 - e) consideration of alternative siting of roads or rail susceptible to erosion hazard, with planning undertaken for truncation or redirection of traffic where feasible⁵;
 - f) reviewing lease agreements, to support adaptation pathways at hotspots where leasehold assets are susceptible to erosion hazard⁶; and
 - g) a detailed asset register of infrastructure at the hotspots to identify ownership, replacement costs and value of individual assets susceptible to erosion hazard.
3. Prepare and implement a community education program, such as building on CoastAdapt resources, to raise awareness about the impacts of coastal processes and the adaptation options, particularly to improve the feasibility of implementing Retreat as a management option for key public infrastructure (e.g. roads and services) through to recreational facilities with short life spans.

⁵ This commonly includes changing the point of access to adjacent residential lots. Existing practices for the placement of civil infrastructure services (e.g. gas, water, electrical and sewerage) should be refined, to provide an exception for coastal roads. Where feasible, these services should not be consolidated adjacent to coastal roads, as the longer infrastructure life extends the planning timeframe, increasing the imperative to protect and reducing the capacity for retreat.

⁶ This may be undertaken in conjunction with establishing guidelines for lease agreements for retreat and contribution to coastal protection works, similar to Locke Estate.



4. Statewide broad review of lease agreements to support coastal management and adaptation pathways.
5. Review and clarify management arrangements and responsibilities for hotspots containing Unallocated Crown Land.
6. Determine the socio-economic value of beaches and foreshore reserves when assessing options where these assets may be reduced or lost due to management actions or coastal processes.
7. Identify a more sophisticated method of assessing coastal change on developed coasts to better inform short- to medium-term adaptive management. This should incorporate refinements of generic erosion hazard assessment with additional active factors, including the effect of historic modifications, adjacent structures, rock control and ongoing sand management; along with appropriate storm events.

Address information gaps for coastal erosion assessments and management responses.

Effective coastal management and adaptation plans need to draw on a comprehensive knowledge base regarding each of the identified hotspots. Areas to improve the level of understanding of hotspots, based on the information gaps noted in Sections 4.1 and 4.2, include:

8. Extended long-term record of coastal movements at all hotspots and watchlist locations.
9. Collection of information on coastal dynamics should be targeted to refine knowledge of specific local or episodic erosive processes, such as unstable landforms or interrupted sediment transport (see green and peach colours in Table 4-2).
10. Commission geotechnical investigations for hotspots identified in Table 4-2, starting with those where private, leasehold, road/rail and services are susceptible to erosion hazard within 25 years.
11. Review the demand for, cost and availability of basic raw materials for coastal protection, including coarse sand for renourishment and rock for construction of erosion mitigation structures. This significantly impacts the feasibility and cost of coastal protection.
12. Develop improved hotspot management histories to refine projected coastal trends and use as a basis for recording ongoing maintenance. This should include information on dredged material disposal and historic engineering works from Public Works Department records.
13. Preparation of regionally-varying low-cost monitoring programs to assist local coastal managers in understanding their foreshore and determine when a change in management is triggered.
14. Identification of long-term and regional variations of meteorological and oceanographic data, mainly collected by the Department of Transport and the Bureau of Meteorology, to support better interpretation of coastal trends.
15. Review of the hotspot and watchlist locations on a five-yearly basis, to determine if any watchlist locations should be considered as hotspots or if any additional locations should be added to the watchlist. For new hotspot locations, management and adaptation plans should be developed.
16. Preparation of material illustrating Retreat case studies previously undertaken by local coastal managers in Western Australia. This will be available to consider when assessing Retreat as an option for private property and leaseholds⁷.

**Box 6-1: Quantify the extent of other coastal management pressures.**

This assessment focused on erosion hazard on open ocean coasts. Recommended actions listed below, in addition to the main project recommendations, aim to quantify the scope of other foreseeable coastal and estuarine management pressures.

- Hotspot evaluation for estuarine locations subject to erosion hazards, to be completed in conjunction with local coastal managers and the Department of Water and Environmental Regulation and the Department of Biodiversity, Conservation and Attractions.
- Completion of a separate hotspot assessment for locations subject to future inundation hazards, initially based on the locations in Appendix C. This assessment could be in conjunction with the Department of Water and Environmental Regulation and Department of Fire and Emergency Services.
- Coastal hazards other than erosion and inundation could be assessed from a hotspot perspective. These hazards include tidal creek and tidal entrance stability; adjustment of mangrove forests; dune collapse through overwash, washout or mobility in response to changing wind regimes; and sand drift and smothering. Their assessment may involve identifying relevant hotspots for those processes and an alternate assessment technique for each hazard.

⁷ For example, land has previously been resumed by agreed purchase at Mandurah, leases reduced in Busselton and pre-Federation freeholding modified in Geraldton. Supporting information for these examples has been provided by Bill Andrew. In Geraldton, blocks seaward of Marine Terrace are shown to extend into the ocean in Public Works Department drawing PWD 17358-3-1, with a later mark-up showing the rail to the new port (1930s) within those properties. It is likely they were formally resumed for the railway under the *Land Acquisition and Public Works Act 1902*. In Mandurah some blocks near Henson Street were resumed when erosion reached their fences. In Busselton the Bay Scouts Association lease was formally reduced in the 1960s/1970s with compensation of a reconstructed ablutions block further landward (erosion in PWD48203-02-06A).



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Appendix A Erosion Hotspot Identification



An overview of the method used to identify the coastal erosion hotspots is provided in Section 2.1. Additional information on the three stages of the identification process is included below.

Stage 1: Initial hotspot identification by DoT

Thirty locations were identified by DoT as erosion hotspots in 2015, many of which were given this status on the basis of recent applications by local coastal managers for Coastal Adaptation and Protection (CAP) grant scheme funds to undertake coastal management. Most of the identified hotspots have a history of repeated erosion stress, or have required active management through engineering works.

Initial consultation with local coastal managers suggested that the 30 hotspots did not necessarily provide a complete picture of asset exposure to coastal hazards. This was confirmed in a review of the identified hotspots by Seashore. Results from the local coastal manager survey indicated the identified hotspots are only demonstrative of a much wider range of locations expected to experience erosion pressure in the next 25 years.

Consequently, a systematic evaluation of locations around the state was undertaken in Stages 2 and 3a, to better scope locations potentially subject to coastal erosion hazard within the next 20-30 years.

Stage 2: Preliminary Location Identification

Hotspots were primarily identified through a review of GoogleEarth imagery, in combination with interpretation of locally relevant erosion hazard by an experienced coastal engineer. An initial 'workshop' session was used by Seashore staff to develop consistency between different staff when identifying hotspots or interpreting hazard.

The WA coast was subsequently sub-divided according to staff experience. Each section was evaluated by the engineer most familiar with that coast, then reviewed by a second engineer.

For each section, significant assets close to the coast (generally less than 50m) were identified visually⁸. These included both built assets (e.g. roads, private or public property) and foreshore reserves known to contain high use recreational assets. Limited distinction was made for assets that are privately owned or support existing foreshore recreation, including car parks and surf lifesaving clubs. Isolated assets (e.g. individual buildings, parkland or 'non-strategic' roads) were typically not considered further at this stage, as the smaller management (or replacement) cost implies low significance when scoping of statewide coastal hazard risk management and adaptation effort. In parallel with identification of near-coast assets, locations which had a historic record of rapid and progressive coastal erosion were also identified from historical shoreline change records.

⁸ A distance of approximately 50m allowed visual screening when assessing using GoogleEarth. This was applied as a 'soft' measure, with locations identified through screening subsequently reviewed based on erosion rates and proximity, with most locations having infrastructure less than 30m from the vegetation line.



The potential for acute and progressive erosion at each location was interpreted qualitatively:

1. Assets with extensive rock clearly apparent in aerial imagery were not considered further;
2. Acute erosion potential was interpreted from knowledge of nearby locations, available CHRMAP documents, historic records and regional comparisons of acute erosion calculations (Oceanica & Shore Coastal 2010; Mariani *et al.* 2012). It was noted that historic estimations of erosion due to tropical cyclones were typically larger than those calculated using numerical modelling, and therefore a 30m allowance for acute erosion was used;
3. Progressive erosion was interpreted from historical shoreline change records, GoogleEarth imagery and available CHRMAP documents (see Section 7). An additional allowance was made at locations with highly sensitive coastal landforms (e.g. low-lying cusped forelands or reclaimed foreshores) or locations with erosion mitigation structures expected to directly transfer erosion stress along the shore.

Acute and progressive erosion was considered over an *approximate* timeframe of 25 years, however in most cases this timeframe was irrelevant. Locations most likely to require extensive long-term management were usually those likely to be affected by erosion at an earlier date (typically 5-15 years).

The combination of broad asset value and the immediacy of exposure to erosion hazard was used to determine hazard level, notionally following a process which is schematically shown in Figure A-1. Cycles of coastal change and the effects of existing coastal protection measures were considered in the evaluation. Locations rated as hazard Level 1 or 2 were collated for further assessment.

A preliminary list of 71 locations was identified through this process.

Stage 3a: Final Additional Hotspot Identification

The approach used for Stage 1 required application of engineering judgement and therefore required subsequent review for consistency between locations with local-scale cross-checking against available CHRMAP documents and through consultation with local coastal managers.

A first-pass internal screening was undertaken by four engineers separately reviewing the entire preliminary list. In effect, this meant that each location was subsequently evaluated by two engineers who had not examined the location as part of the preliminary location identification. A number of preliminary locations (17) were discarded through this process. Locations were further distinguished by apparent severity of erosion or the scale of assets susceptible to erosion hazard, with a watchlist developed for locations subject to less severe erosion or which have comparatively few assets susceptible to erosion hazard (generally corresponding to hazard Level 2, following Figure A-1). The hotspot extent (Appendix D summary figures; and digital dataset described in Section 3.1.4) was reviewed by more than one engineer.

		INFRASTRUCTURE	
		Lower Value	Higher Value
		<4 houses, car parks, parklands, roads with moderate access or alternate routes	>3 houses, large facilities, major roads with key access and no alternate routes
Active	Presently susceptible to acute erosion hazard	Level 2'	Level 1'
Immediate	Subject to acute erosion hazard if progressive erosion continues for up to 10 years	Level 3'	Level 2'
Proximal	Subject to acute erosion hazard if progressive erosion continues for 10 to 25 years	Level 4'	Level 3'

Initial Level X' is modified by:

- +1 if coastal change over time is known to be cyclic
- 1 if existing coastal defences show pattern of erosion transfer
- +2 if it is considered likely that existing coastal defences can be extended effectively

Figure A-1: Basis for determining relative hazard level (Schematic)

Opportunity for inconsistency between reviewers occurs when evaluating locations with coastal protection works. As noted in the previous review, many of the recurrent erosion hotspots have some form of management that has transferred erosion stress along shore (Seashore 2016a). Any erosion transfer may consequently increase the erosion threat at a location. However, if coastal protection works are deemed likely to be effective, or can be readily extended to protect adjacent coastlines from transferred erosion stress, then they may effectively offset the erosion threat. This difference provides opportunity for subjective judgement when identifying hotspots, which may be affected by personal bias of the assessor. In general, only locations with an obvious pathway through which transfer of erosion stress can threaten coastal assets were included in the additional hotspot list. Where known, differences in ownership were considered when evaluating the threat of erosion transfer.

A further opportunity for inconsistency between reviewers arose where locations were adjacent or nearby to other hotspots. Following the findings of the initial hotspot assessment, where it was determined that the physical scale of the location affected the perceived management importance, it was determined that nearby locations would be split if different forms of adaptation were considered likely to be appropriate. This approach resulted in some 'expected' locations being excluded from the lists (e.g. Waikiki Beach, Rockingham) and some locations having multiple entries (e.g. Broome Town Beach).



Local scale cross-checks using available CHRMAP documents were undertaken, with a particular focus upon locations expected to be affected by erosion within 25 years. In general, this provided a high degree of consistency and differences between the two approaches could be rationalised (e.g. they relate to neglecting the influence of rock or local erosion transfers when deriving CHRMAP hazard lines).

Consultation with local coastal managers was undertaken to capture local perception of the erosion threat. This yielded a considerable range of perceptions of what comprised a threat, but it also gave a useful ranking of local community values at affected locations. In general, the locations identified by Seashore were also the areas of greatest concern to the local coastal managers.

Local scale cross-checks from CHRMAPS and local consultation modified the screened location list slightly, ultimately resulting in 25 locations recommended for consideration as additional hotspots, and 25 locations on the watchlist.

This evaluation identified 50 locations in addition to the 30 original hotspots. All may require management of coastal erosion within the next 20–30 years based upon observed patterns of acute and progressive erosion, referenced to existing coastal assets. A subset of 25 additional hotspots was recommended for further assessment, as these were considered to have the most extensive coastal management needs. These locations, in addition to the original hotspots, were considered to provide a practical basis for scoping the overall coastal management and adaptation effort required to deal with coastal erosion hazard along the WA coast.

Stage 3b: Combining and rescaling hotspots and watchlist locations

The first 30 hotspots, the 25 hotspots subsequently determined, and the 25 watchlist locations identified in Stage 1 and Stage 3a were rescaled and reassessed.

A hotspot was reconsidered if:

- (1) it was comprised of multiple hotspots;
- (2) hotspots were near each other but considered in separate studies; and
- (3) hotspots from the first assessment were deemed watchlist locations.

Most of the locations rescaled were within Cockburn Sound and Geographe Bay.

A similar approach to the hotspot characterisation and identification in Stage3a was used in Stage3b, with a further refinement if there were significant coastal assets susceptible to erosion hazard and it was likely a similar adaptation strategy be required across the hotspot.

A total of 55 coastal erosion hotspot and 31 watchlist locations were defined, mapped and characterised. A summary of characteristics for the watchlist locations is provided, with the remainder of the assessment focusing on the 55 erosion hotspots.

Appendix B Watchlist Locations and Extents

The watchlist of additional locations are described in Section 3.1.2 and are summarised in Table B-1 and Figure B-1 labelled from W01 to W31. Characteristics of the watchlist locations are included in Table B-1 following the definitions in Section 2.1. In most cases, these locations have some coastal asset near the coast, but there are possible reasons why erosion may not affect the location (e.g. some rock, a history of relative stability), the assets susceptible to erosion hazard are deemed to be of low or moderate value, or the existing management actions and plans reduce the overall hazard. The extent of each watchlist location is shown in Figure B-2 to Figure B-9.

Table B-1: Watchlist locations
Locations are listed from North to South

ID	LG / Coastal Manager	Location	Proximity	Instability	Mit. Cost	Transfer	Community
W01	Shire of Derby - West Kimberley	Derby	✓				
W02	Shire of Broome	Ardayaloon	✓				
W03	Shire of Broome	Cable Beach, Broome			✓		✓
W04	Shire of Broome	Riddell Beach (Kavite Road)	✓				
W05	Shire of Broome	Broome Town Beach W	✓				✓
W06	Shire of Broome	Eco Beach Broome Resort	✓				
W07	Town of Port Hedland	Sutherland Street, Port Hedland	✓	✓	✓		
W08	City of Karratha	Point Samson	✓	✓			
W09	Shire of Ashburton	Onslow Townsite	✓	✓			
W10	Shire of Carnarvon	Coral Bay	✓				✓
W11	Shire of Shark Bay	Denham (central)	✓	✓			✓
W12	Shire of Shark Bay	Useless Loop	✓				
W13	City of Greater Geraldton	Bluff Point	✓	✓			
W14	Shire of Irwin	Dongara	✓			✓	
W15	City of Joondalup	Mullaloo SLSC			✓		✓
W16	City of Stirling	Bay Beaches Trigg - Hillarys	✓			✓	
W17	City of Stirling	Scarborough Beach	✓				✓
W18	City of Cottesloe	North Cottesloe	✓				✓
W19	Rottneest Island Authority	Rottneest – Geordie Bay	✓	✓			✓
W20	City of Fremantle	South Beach	✓	✓			✓
W21	City of Cockburn	Coogee SLSC	✓				✓
W22	City of Cockburn	Woodman Point	✓			✓	✓
W23	City of Mandurah	Old San Remo Townsite	✓				✓
W24	City of Bunbury	Ocean Drive, Hastie St to Scott St	✓			✓	
W25	Shire of Capel	Peppermint Grove Beach	✓				
W26	Shire of Capel	South Forrest Beach	✓				
W27	City of Busselton	Siesta groyne east, Busselton				✓	✓
W28	Shire of Augusta-Margaret R.	Margaret River mouth	✓	✓			✓
W29	Shire of Augusta-Margaret R.	Albany Terrace & Flinders Bay	✓				✓
W30	City of Albany	Little Grove (Chipana Drive)	✓			✓	
W31	City of Albany	Cheynes Caravan Park	✓				
Total			28	8	3	6	15

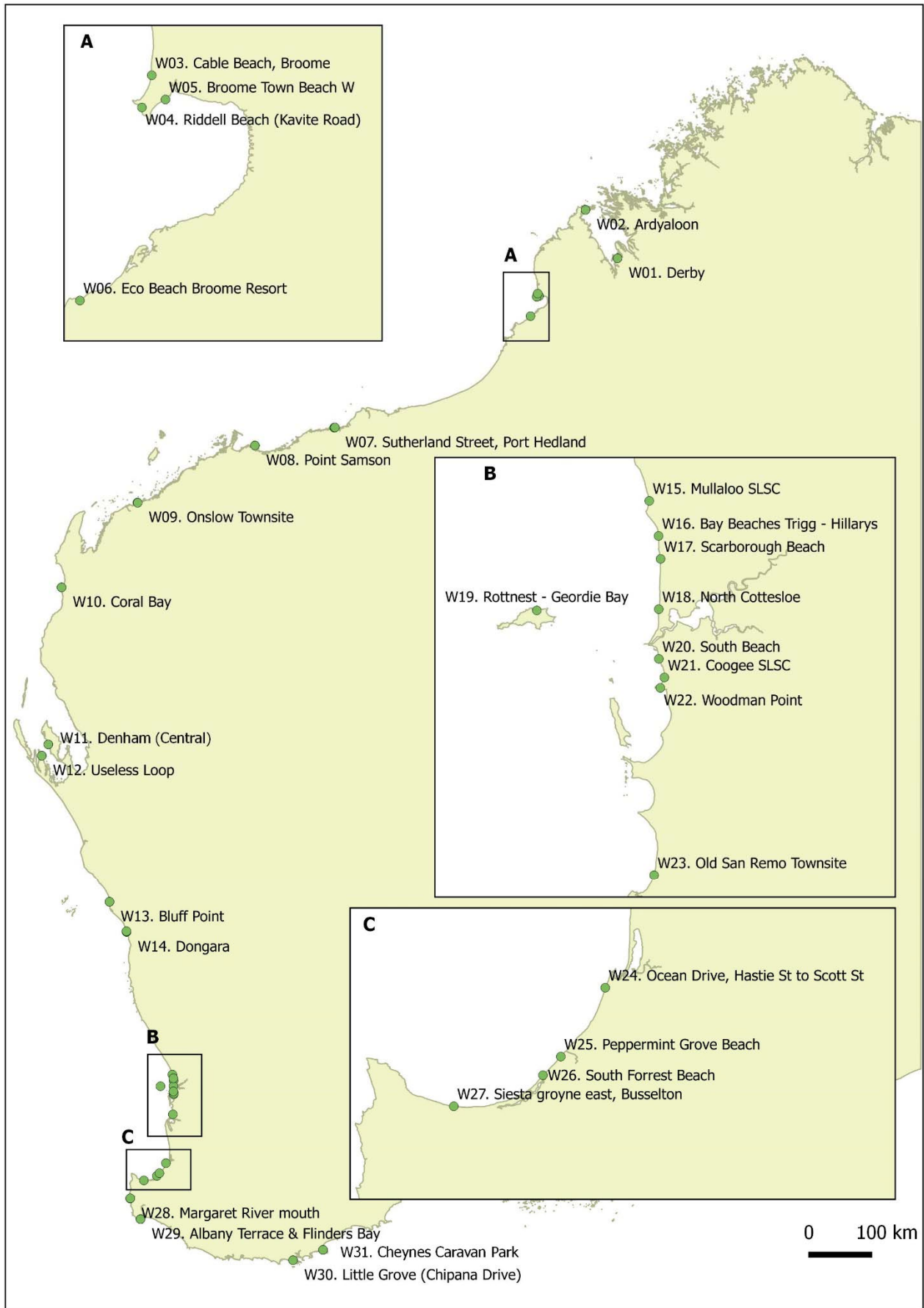


Figure B-1: Map of watchlist locations

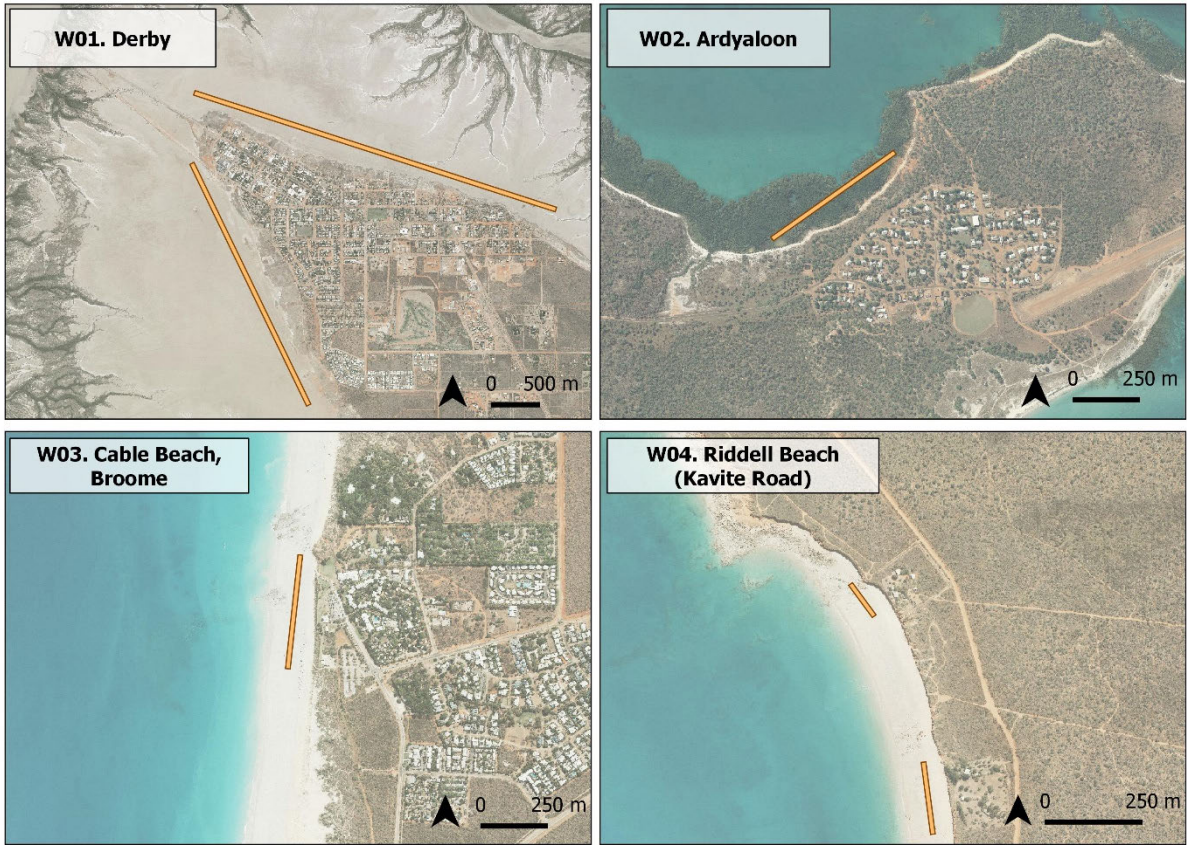


Figure B-2: Map of watchlist extents, W01 to W04

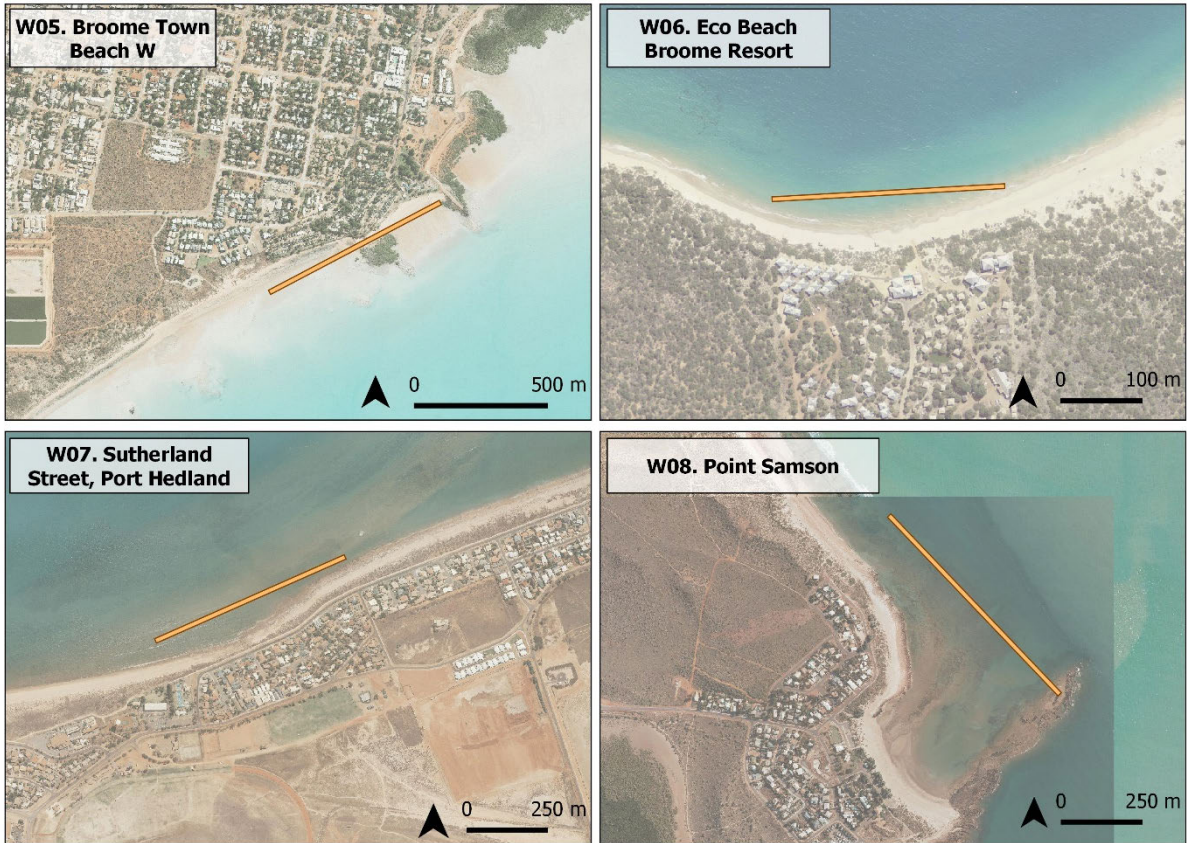


Figure B-3: Map of watchlist extents, W05 to W08

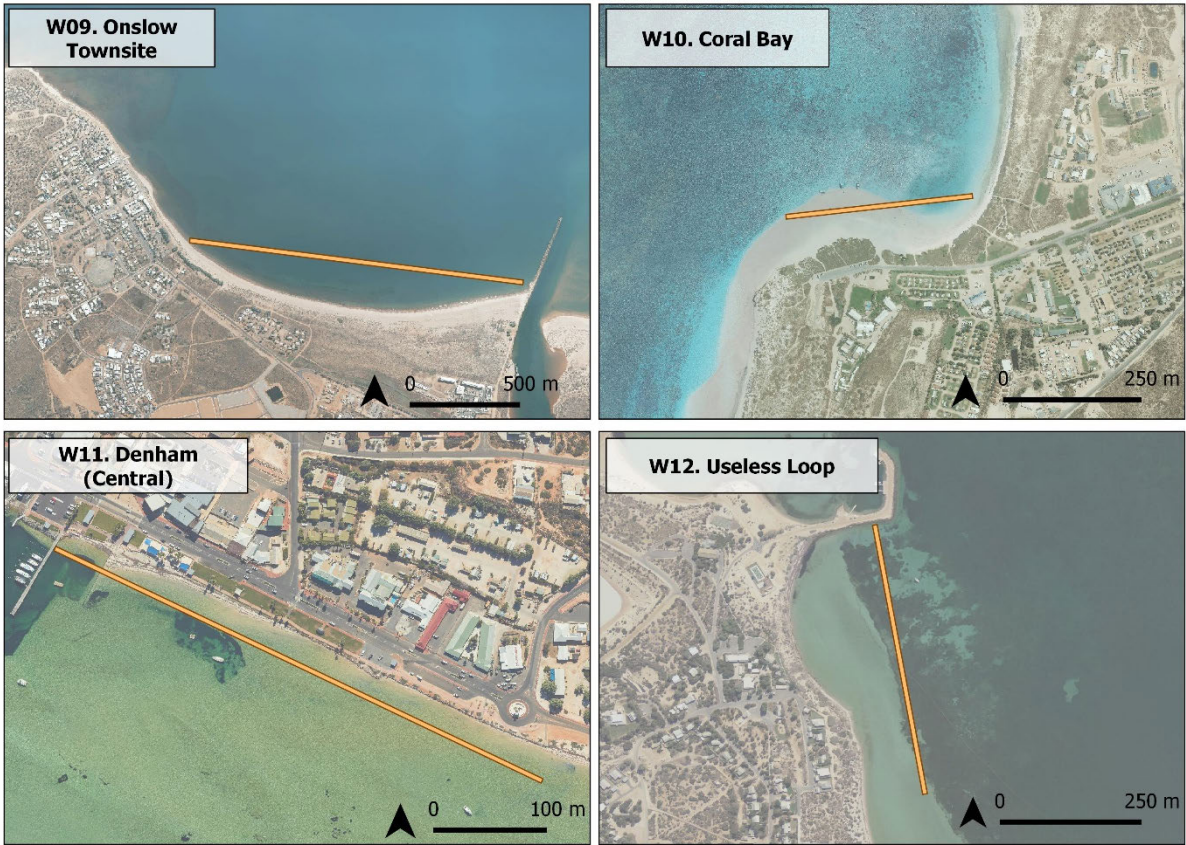


Figure B-4: Map of watchlist extents, W09 to W12

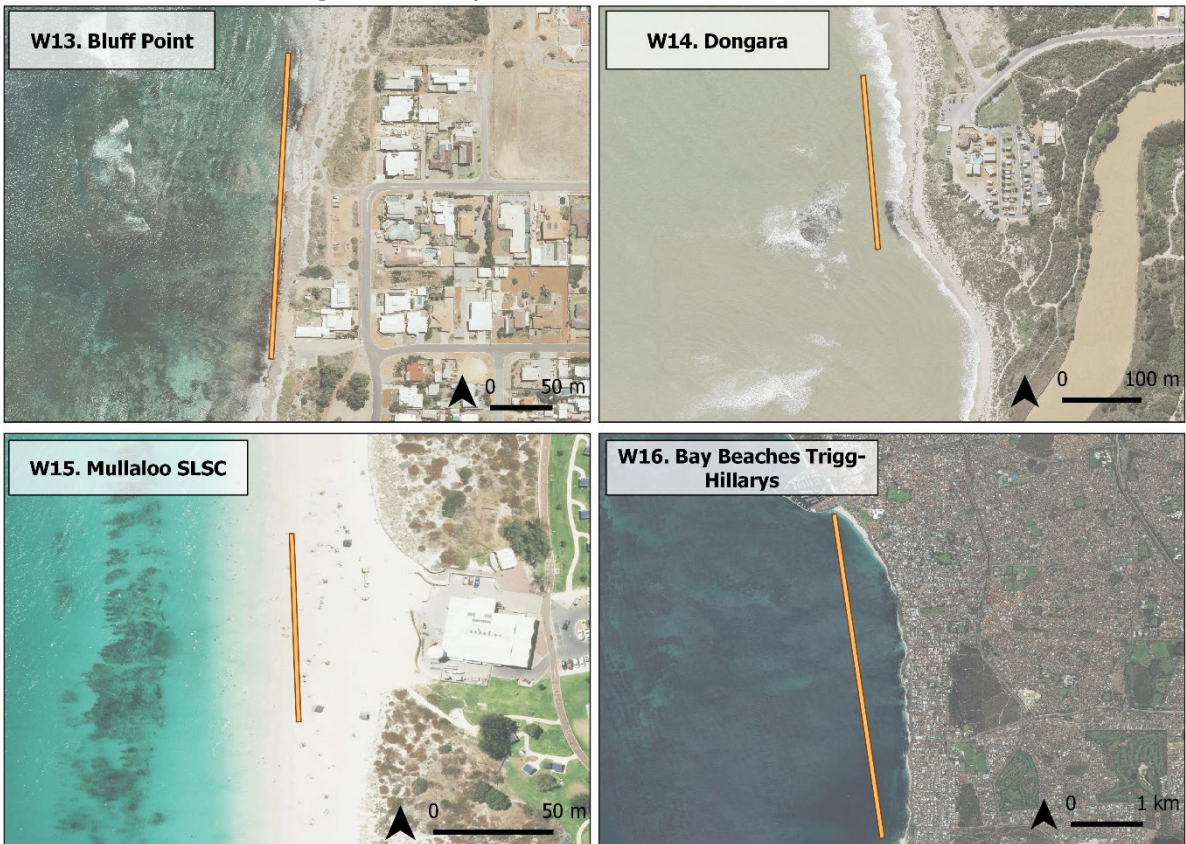


Figure B-5: Map of watchlist extents, W13 to W16

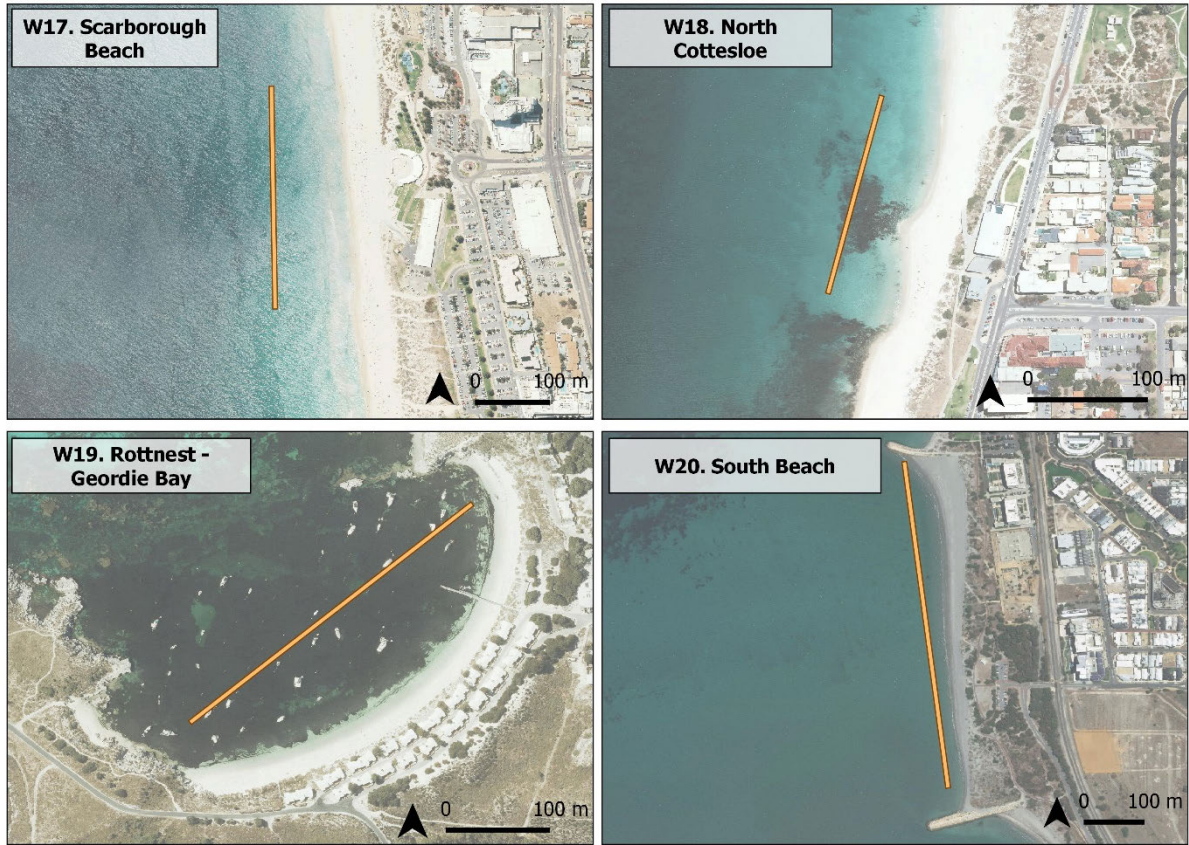


Figure B-6: Map of watchlist extents, W17 to W20



Figure B-7: Map of watchlist extents, W21 to W24

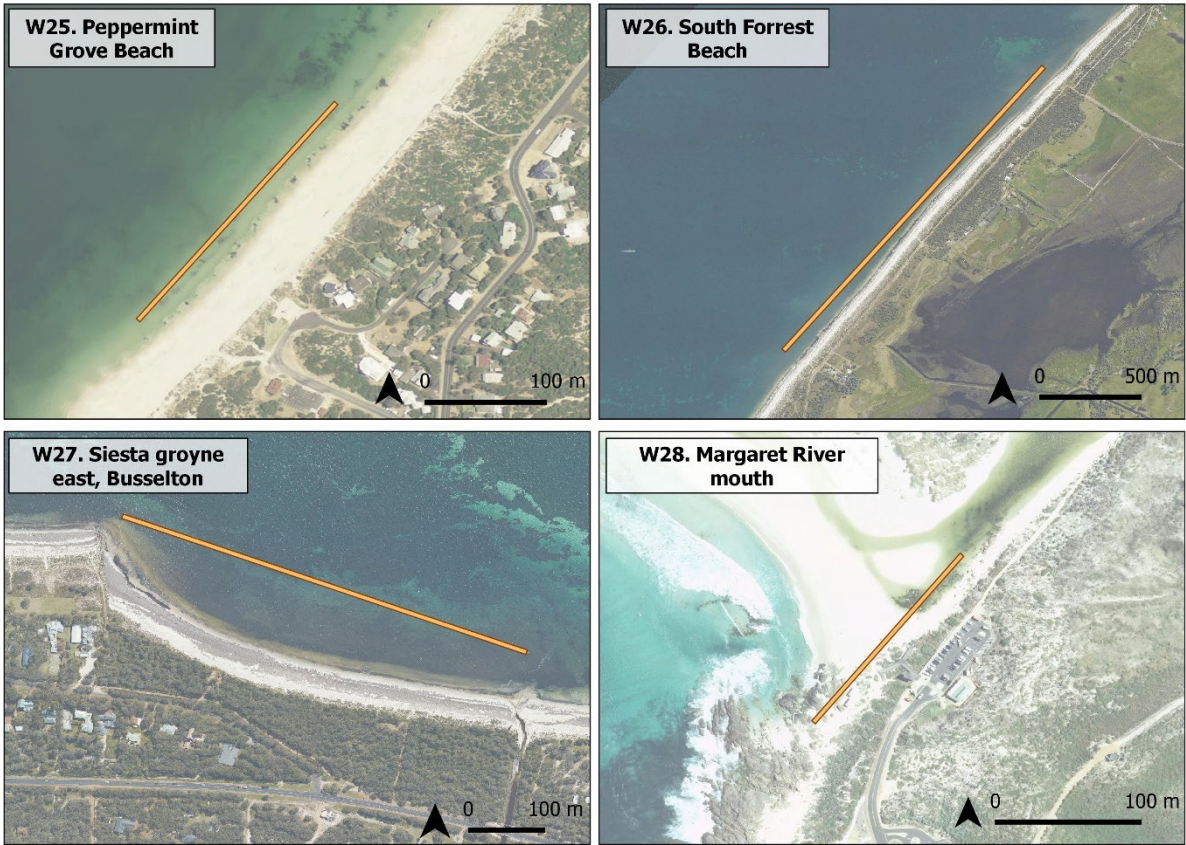


Figure B-8: Map of watchlist extents, W25 to W28

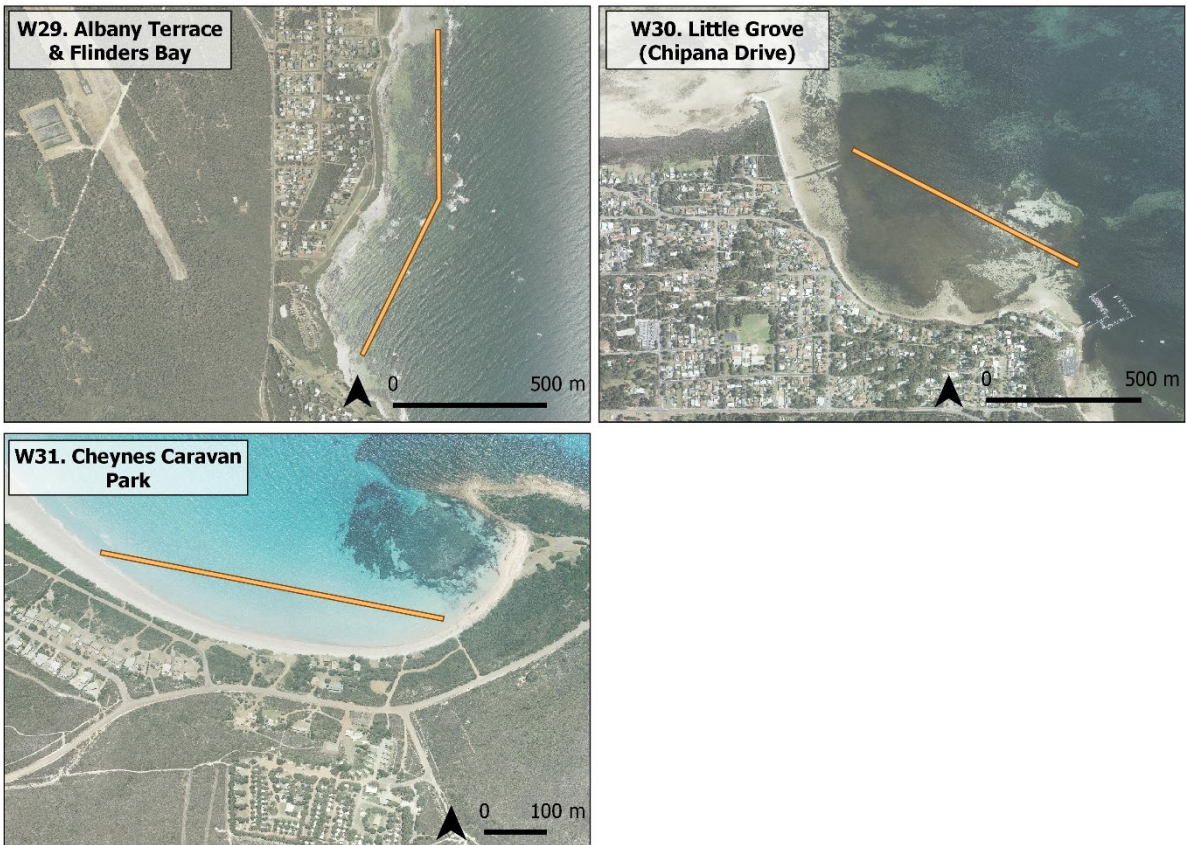


Figure B-9: Map of watchlist extents, W29 to W31



Appendix C Inundation Hazard Locations



An initial list of inundation locations was collated during the erosion hotspot evaluation as described in Section 3.1.3. This identification was not systematic or exhaustive, but was developed opportunistically when seeking information about the erosion hazards. The inundation locations are summarised in Table C-1 labelled from D01 to D25.

Table C-1: Inundation locations

ID	LG / Coastal Manager	Location
D01	West Kimberley	Derby
D02	Broome	Willies Creek
D03	Broome	Broome Town Beach N
D04	Broome	Bidyadanga
D05	Port Hedland	Port Hedland
D06	Roebourne	Karratha
D07	Ashburton	Onslow
D08	Carnarvon	Coral Bay
D09	Carnarvon	Quobba
D10	Carnarvon	Carnarvon (South Carnarvon, Babbage & Whitlock Islands)
D11	Shark Bay	Monkey Mia
D12	Shark Bay	Denham
D13	Shark Bay	Disappointment Loop
D14	Shark Bay	Useless Loop
D15	Northampton	Horrocks Beach
D16	Geraldton	Geraldton (Point Moore)
D17	DBCA	Abrolhos Islands
D18	DBCA	Wedge
D19	Rockingham	Rockingham Town Beach
D20	Mandurah	Mandurah
D21	Harvey	Australind
D22	Bunbury	Bunbury CBD
D23	Busselton	Busselton
D24	Busselton	Marybrook (Smith St)
D25	Albany	Princess Royal Harbour