6 ASSET-BASED ADAPTATION ASSESSMENT

Pathways for adaptation have been evaluated for each identified asset. This scale has been selected to directly relate to existing decision-making processes, with divisions according to *governance*. It is recognised that ownership divisions affect decision-making at the asset scale, and prompt an increased tendency for hazard protection or tolerance. However, for the purpose of developing adaptation pathways, ownership divisions have been identified as barriers to implementation, rather than unchanging characteristics.

For each asset, the adaptation assessment is presented as three parts:

1. Current and Projected Coastal Management Issues
2. Adaptation Hierarchy
3. Coastal Monitoring and Management Triggers

These parts are described below.

Current and Projected Coastal Management Issues

A synopsis of present-day coastal management issues is provided, outlining the proximity of assets to the coast and the present means of managing coastal hazards. The extent of coastal change under which present-day management is likely to become impractical is identified, which is given an estimated time frame through comparison with the hazard scenario projections (Section 2.1).

Projected coastal management issues are indicated by considering the expected impacts at different levels of coastal change (considering erosion, sea level rise or dune mobility).

Adaptation Hierarchy

The assets are considered in terms of the preferred adaptation hierarchy described by WAPC [6] (Figure 6-1). The practicality of how each of the four adaptation strategies could be applied is described. Timeframes and approximate costs included where relevant.

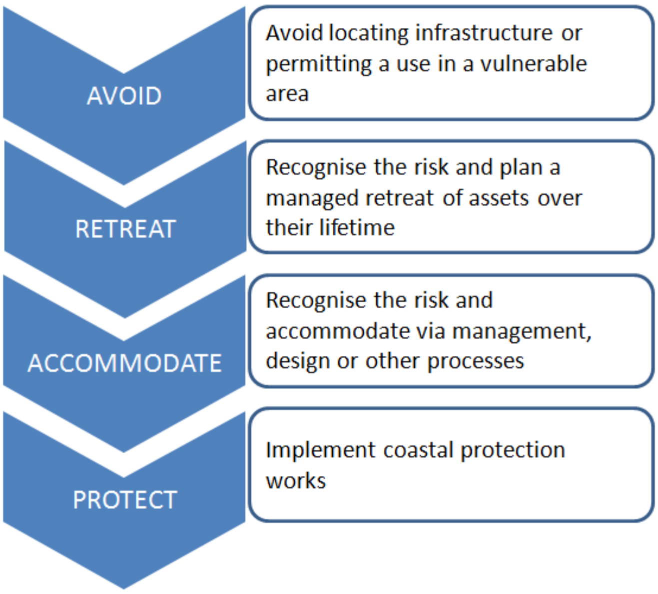

Figure 6-1: WAPC Preferred Adaptation Hierarchy

The community has identified a preferred coastal strategy of hazard avoidance, which is consistent with the WAPC hierarchy. Consequently, the hierarchy has been used to provide the order of an adaptation sequence. The precedence of retreat to accommodation has been swapped for situations where dune mobility is the main hazard, due to the relative costs and effectiveness of the two strategies. The adaptation sequence is presented as changing over time, relative to the key hazard parameter, and subsequently linked to estimated time frames using the hazard scenario projections (Section 2.1).

Management actions involved in the adaptation sequence have been rated according to the resources (financial and staff time) likely to be required for implementation (Table 6-1). This allows identification of 'no regrets' management actions and provides a basis for the evaluation of barriers to implementation of adaptation pathways that may be caused by inadequate resources (Section 8). Resource requirement levels have been assigned subjectively.

Table 6-1: Resource Requirement Levels for Management Actions

Level	Resource Requirement	Possible Determination
0	Negligible effect on resources	No cost associated
1	Requires reallocation of existing resources	Equivalent budget line item exists
2	Requires extension to existing resources	Positive cost-benefit for LGA only
3	Requires supplementary external resources	Positive cost-benefit including community values
4	Unlikely to obtain adequate resources. Relies on State capital expenditure.	Negative cost-benefit

The financial and social imperatives to maintain existing assets (particularly infrastructure) have been considered when evaluating adaptation sequences.

Coastal Monitoring and Management Triggers

The monitoring framework required to make decisions about when to implement actions (i.e. management triggers) is presented for each asset. Where practical, this has been linked to the methods and level of detail outlined in the regional Coastal Monitoring Action Plan [11]. The preferred approach towards monitoring is to use simple, low-cost observations as a supplement to existing instrumentation (e.g. Bunbury Port tide gauge) and monitoring programs (e.g. PNP oblique aerial monitoring program and Landgate vertical aerial imagery capture).

6.1 Binningup Town Site

6.1.1 Current and Projected Coastal Management Issues

Binningup Town Site has a length of approximately 1.7km along the coast which has presently been developed (Figure 6-2). The majority of the town's facilities are located landward of coastal dune, with a minimum buffer of 60m to residences, giving a nominal time frame of 40-50 years before erosion directly affects buildings (Table 6-2). The only major facility closer than 60m to the coast is the Binningup Seawall and access roads. Approximately 750m length of the town (50 residential lots) is located within 170m of the coast, and therefore may potentially be exposed to erosion hazard over a 100 year time frame.

The entire length of the town site is potentially exposed to dune mobility (from the west). However, with moderately active management through brushing and dune fencing, newly formed blowouts and sand sheets from an eroding dune can typically be kept within 30m of the coast. Consequently, dune mobility within the town site affecting roads or buildings is expected to occur with a recession distance of approximately 30m from the present coastal position, commencing within a nominal time frame of 10-30 years.

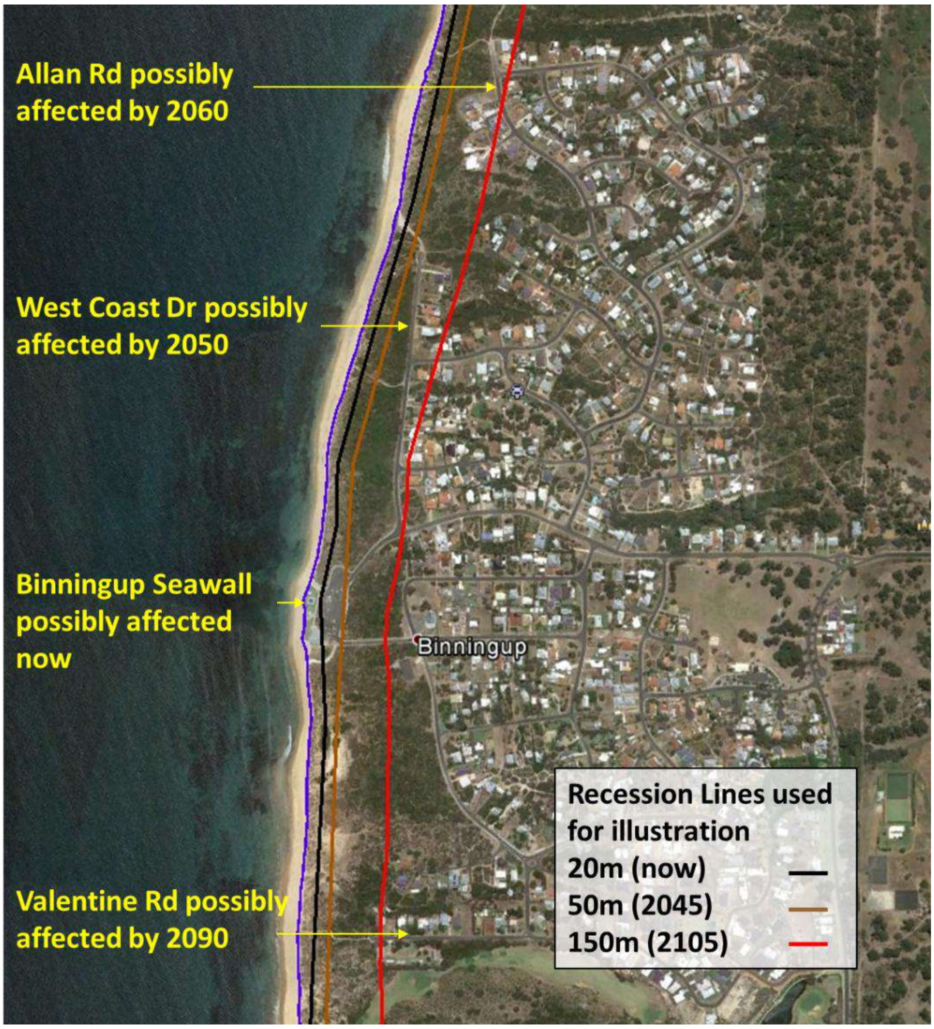

Figure 6-2: Binningup Town Site

Table 6-2: Recession Impacts on Binningup Town Site

Time Frame*	Estimated Recession	# Threatened Lots	Active Dune Management
2016	0-20m	0	0m
2025	10-30m	0	0m
2045	30-50m	0	250m
2065	60-80m	2	500m
2085	90-110m	9	1000m
2115	150-170m	50	1300m

***The time frame of recession may be strongly influenced by the presence of underlying rock, which has not yet been located and characterised.**

Order of magnitude costs per lot are $400,000 – $1,000,000 and $25 - $100/m/year for active dune management.

6.1.2 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy at Binningup town site:

Avoid – ensure town facilities (roads and buildings) are outside the influence of both erosion and dune mobility. This does not occur for the existing layout.

Retreat – relocate town facilities to reduce the exposure to erosion. The comparative cost of active dune management compared to relocation of either roads or buildings is low and therefore it is considered practical for dune management to occur in preference to retreat. The viability of retreat is limited by the small quantity of available or 'equivalent' land that could be used for land swaps, and therefore only considered viable when a few lots may be threatened, which is expected prior to 2065 (~60m recession). Subsequently, buy-back or purchase of privately held land would be required to support retreat and is therefore likely to be substantially more expensive.

Accommodate – involves physical or financial mechanisms to tolerate erosion without preventing it (e.g. buildings with stilt foundations, or covering financial costs through insurance). Accommodation is generally an impractical response for buildings, particularly when experiencing progressive recession, but is more likely to be effective for dune mobility.

Protect – construction of coastal works to protect the town site may be viable using either a seawall approach or a groyne field*. Due to the wave climate and variation of seabed depth, the structures need to be robust, and therefore only rock structures have been considered. Groynes may be used to take advantage of the alongshore sediment supply and have a lower relative cost, with two groynes having an order of magnitude cost of $2 – $5million. They should be implemented with a minimum remaining buffer of 30m, to support preservation of a dune, and therefore any installation after 2065 (~60m recession) would also require dune replenishment and planting, increasing in magnitude with further general recession. A seawall the length of the town site has an order of magnitude cost $5 – $20million, with the cost strongly influenced by the depth to underlying rock.

* For both types of coastal protection, the effect of hardening the coast will cause downdrift recession to the north side of the works. An approximate influence is landward an equal distance to the distance retained seaward (by the structure), and a length of approximately three times the retained length. Consequently, if groynes were built after 60m of recession had occurred, and extended 20m offshore, then they would initially cause around 5 hectares local recession. As general recession increases, this local impact would also increase, with 20 hectares local erosion by 2090 (~120m general recession). Key problems with the local erosion caused by coastal protection include compensation requirements to any affected landowner, and the greater difficulty of providing continuous beach access, particularly for vehicles.

The variation of erosion hazard management approach with different levels and the approximate timeline is suggested by Table 6-3. The relatively small impacts associated with recession up to around 2025 suggest that the preferred management option of avoiding erosion hazard is practical up to that point. Between 2025 and 2065 (approximately) it is estimated that sand drift associated with dune mobility will be required active dune management through brushing and drift fencing. By around 2065 (~60m recession) the threat to a small number of lots may be addressed using the small available capacity for land swaps within Binningup. Beyond 2085 (~90m recession) there is limited capacity for retreat and the risk to up to 50 lots provides a strong financial argument for the use of protective works.

Table 6-3: Anticipated Timeline of Changing Hazard Management Approach at Binningup
This timeline has been estimated without considering the presence of underlying rock features

Recession	Time Frame	Erosion Hazard	Landform Mobility	Management Action	Resources
20m*	2016	Avoided	Avoided	Monitoring	1
30m	2025	Avoided	Avoided	Monitoring	1
40m	2045	Avoided	Accommodate	Active dune management	2
60m	2065	Retreat	Accommodate	Active dune management	2
90m	2085	Protect	Protect	Coastal protection works	3
150m	2115	Protect	Protect	Coastal protection works	3

The significance of the potential erosion hazard is acknowledged to be possibly overstated, due to the presence of intermittently exposed beach rock along parts of the Binningup shoreline. The most frequently visible section of rock occurs towards the northern end of the town site (Figure 6-3). The potential implications of underlying rock for progressive recession are substantial for decision-making with respect to the shift from hazard avoidance to coastal protection. Considerably improved certainty for coastal planning may be provided through a geophysical investigation that extends at least the length of Binningup town site, preferably up to 5km to the north. The investigation should capture the level, extent and continuity of the underlying rock features.

Figure 6-3: Exposed Beach Rock at Northern End of Binningup Town Site

6.1.3 Coastal Monitoring and Management Triggers

Key parameters that may be used to support decision-making are the available buffer width (for dune mobility management) and the recession distance (for erosion management). It is recommended to establish a minimum of five land-based bench-marks along Binningup coast against which to measure distances to the coast. These provide a basis for monitoring triggers and associated management actions (Table 6-4). General recession distance should be established using the average of the five distances, with consideration of whether observed erosion is likely to be short-term or sustained recession [17]. Simple monitoring techniques (+/-5m accuracy) are applicable, such as measuring tape distance from fixed bench-marks, or vegetation line measurement off controlled aerial imagery.

Table 6-4: Management Triggers and Actions for Binningup Town Site

Dune Width	**Monitoring**	**Management Action**
> 30m	Annual	Stabilise dunes only if high mobility identified
< 30m	Quarterly	Actively stabilise dunes with brushing and drift fencing
Recession Distance (to 2015 position)	**Monitoring**	**Management Action**
< 40m	Annual	Monitoring only
40m	Annual	Negotiate for relocation of lots closest to the coast
60m	Annual	Review protective works & identify implementation trigger
90m	Annual	Implementation of protective works is considered

6.2 Binningup Road Access

6.2.1 Current and Projected Coastal Management Issues

Access to Binningup from Forrest Highway is constrained to a single road, which crosses a broad area of lowland that extends between Leschenault Estuary and Lake Preston. The lowland is subject to occasional runoff flooding, with drainage channels from Binningup Desalination Plant through to Leschenault Estuary. Prior to European settlement, the lowlands provided hydraulic connection from the Indian Ocean through to Lake Preston at a level of around +1.5m AHD, which represents a very extreme flood event, estimated as more than 500-year ARI. Structures have been built across the lowland, with road culverts (at Buffalo Rd, Springhill Rd and Binningup Rd) and flow barriers constructed toward the north end of the lowlands by Harvey Diversion Drain and Taranto Road (Figure 6-4).

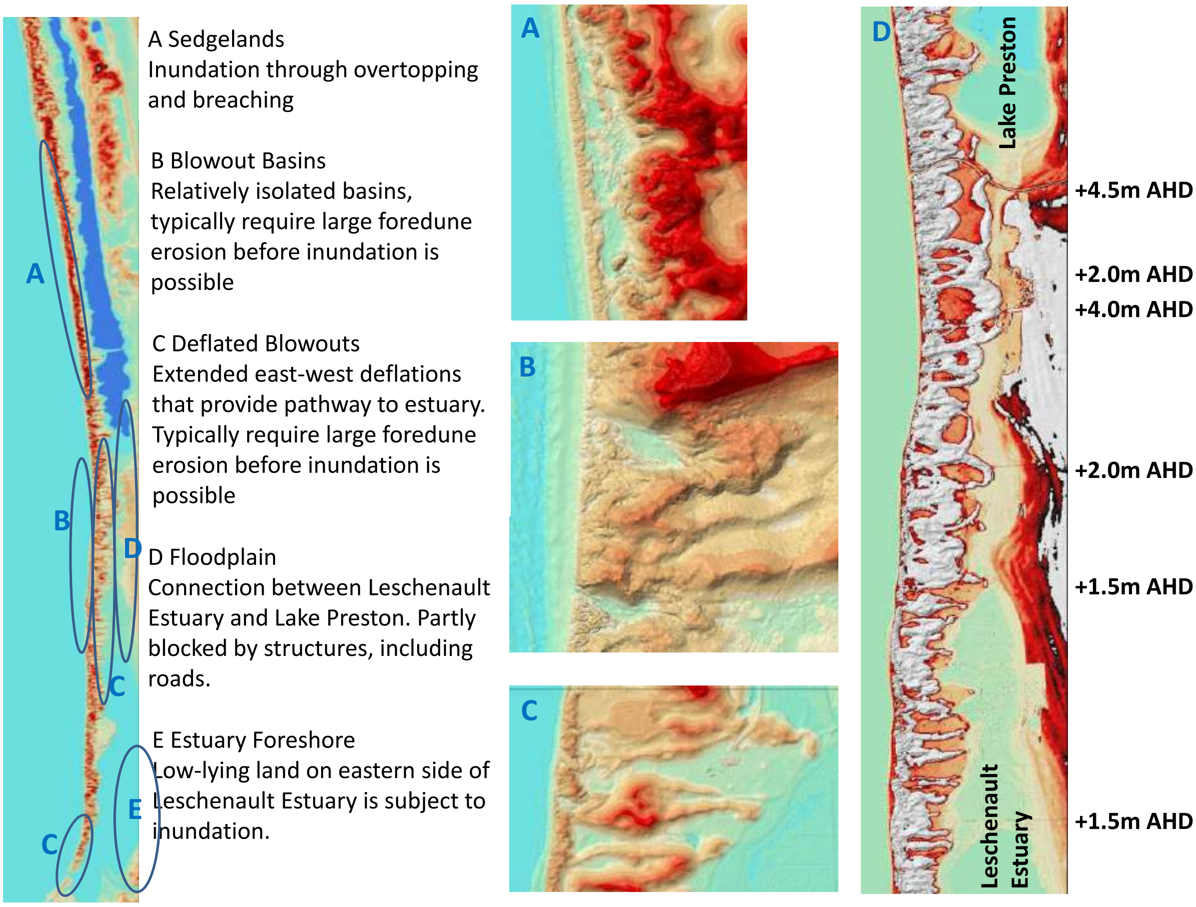

Figure 6-4: Harvey Coast Inundation Hazard Zones

The potential for coastal inundation is recognised as being extremely rare under present-day conditions, with less than 0.1% annual likelihood of reaching Binningup Road. However, the likelihood of flooding increases significantly with sea level rise (Table 6-5). Using a monotonic projection for sea level rise suggested for planning purposes, this becomes a ‘significant’ risk (>1% annual exceedance probability) by around 2040. For a 0.3m SLR, there is approximately 50% likelihood of being flooded per decade. By 2080, flooding is expected almost on a yearly basis.

Table 6-5: Change in Annual Flood Probability Due to Sea level Rise

Time Frame	Sea Level Rise	RL +1.5m AHD	RL +2.0m AHD	RL +2.5m AHD
2016	Present	0.1% AEP	< 0.01% AEP	< 0.01% AEP
2035	+0.1m	0.4% AEP	< 0.01% AEP	< 0.01% AEP
2050	+0.2m	2% AEP	< 0.01% AEP	< 0.01% AEP
2060	+0.3m	8% AEP	< 0.01% AEP	< 0.01% AEP
2070	+0.4m	30% AEP	< 0.01% AEP	< 0.01% AEP
2080	+0.5m	80% AEP	0.1% AEP	< 0.01% AEP
2105	+0.8m	99% AEP	8% AEP	< 0.01% AEP

AEP is annual exceedance probability, which is approximately the inverse of average recurrence interval, ARI.

The potential exposure of Binningup Road to flooding is illustrated by mapping of the +1.45m AHD and +1.57m AHD contours completed as part of the PNP Coastal Hazard Mapping [18] (Figure 6-5). The mapping indicates the road level is approximately +1.5m AHD, with the lower contour not shown north of the road because no direct hydraulic connection was identified (i.e. the culvert was not included, which is below +1.0m AHD).

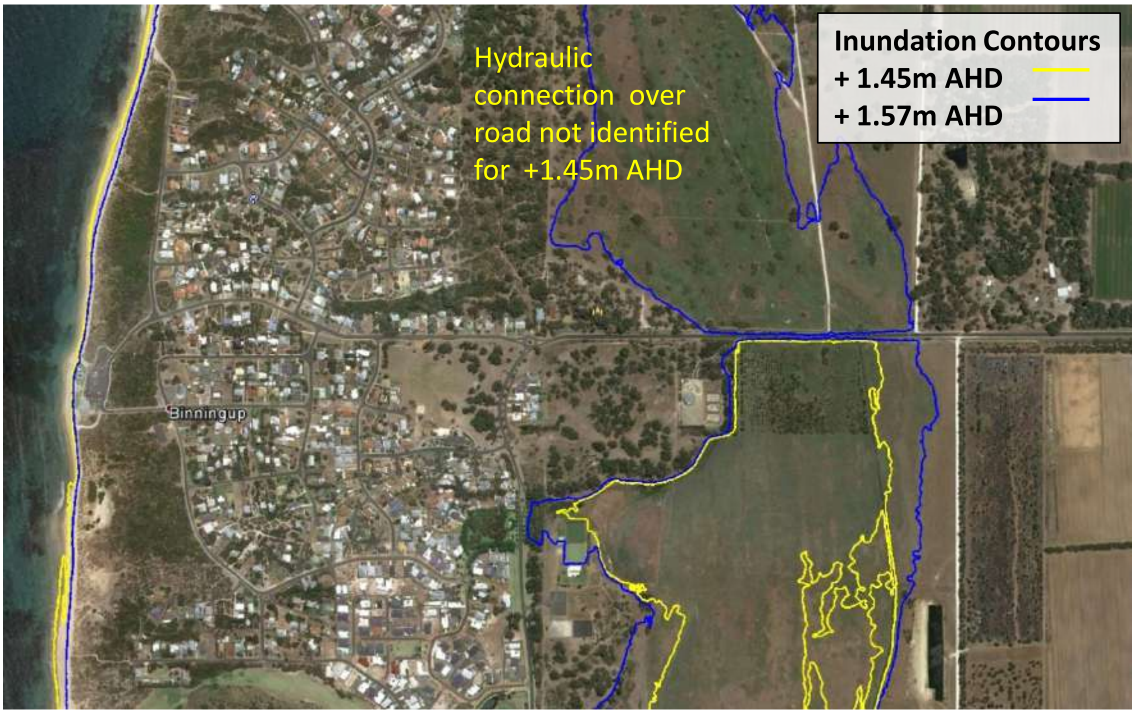

Figure 6-5: Binningup Road Extreme Flood Event Mapping

The effect of ocean water levels on Binningup Road and the causeway changes with sea level rise. This provides a sequence of impacts (in order of sea level rise) that shift from episodic through to seasonal, and from flows that affect only the channel and culvert, to those which may affect the larger causeway structure (Table 6-6). Although presented as a sequence, the inclusion of episodic events means that these impacts may not directly follow that sequence, or match the projected time frame.

Under present-day conditions, the road culvert only acts to control runoff drainage. For a small sea level increase (around +0.15m), the lowlands may be subject to occasional inundation during severe surge events. For a moderate sea level increase (around +0.25m), the existing drainage channel will be subject to seasonal tidal flows. In addition to instability of the channel (see Section 6.9), flow restriction through the road culvert will cause locally enhanced stress, potentially affecting the road embankment stability. For larger sea level rise (around +0.4m), the potential frequency of flows over the road is expected to require strengthening of the road embankment or possible flow control over a floodway, to prevent cutting through. By a sea level rise of around +0.6m, inundation is estimated to be sufficiently frequent that the existing embankment should be rebuilt to a marine standard, and raised to reduce the incidence of floods blocking access.

Table 6-6: Coastal Flooding Impacts on Binningup Road Access

Time Frame	Sea Level Rise	Impact	Possible Response	Resources
2016	–	–	–	0
2040	+0.15m	Upstream surge flow	One-way surge valve	2
2055	+0.25m	Tidal flows	Increase culvert size	2
2070	+0.40m	Overflow damage	Armour embankment; floodway	3
2090	+0.6m	Reduced access	Rebuild and raise embankment	3

Although inundation of the causeway can provide a substantial short-term barrier to access, the threat of floods cutting through the causeway is of greater significance, as it blocks access for a longer period. The importance of maintaining access roads should also be considered for scenarios of bushfires, floods or major accidents blocking a road.

6.2.2 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy for the Binningup road access:

Avoid – ensuring road access is outside the influence of coastal flood events, nominally above +2.4m AHD (~500 yr ARI flood event, plus 0.9m sea level rise). This does not occur for the existing layout, and is considered impractical for Binningup. Options to wholly avoid coastal inundation hazard include:

- Providing a northward pathway through to Taranto Road, connecting to the higher level roadway that has been built to support the desalination plant. This conflicts with the intent of locating the plant on a separate access road;
- Raising one or more of the existing roadways (Binningup Rd, Springhill Rd or Buffalo Rd) to above the flood level. This is arguably accommodating the flood hazard rather than true avoidance.

Retreat – progressively relocate road access to reduce the exposure to flooding impacts. Due to the shape of the lowlands, this effectively corresponds to the adaptation options described for hazard 'avoidance' above.

Accommodate – involves physical or financial mechanisms to tolerate flood impacts to the road access without preventing flooding. Due to the relative rarity and short duration of coastal flood events, inundation of the roadway is not a significant issue. However, damage to the roadway caused by flooding would represent a more severe scenario.

Strengthening the roadway to withstand inundation, expanding the culvert, installing a floodway and raising the road level are components of physical accommodation to coastal inundation hazard.

Protect – a physical barrier to flooding across the lowlands (e.g. reinforcing a road as a barrage or installing a flood control valve into culverts) may be constructed at any location south of Binningup Road. Obvious locations occur where there is an existing roadway, or a natural narrowing of the lowlands. Using this simple physical consideration, five flood barrage options (Table 6-7) have been considered:

Table 6-7: Comparison of Flood Barrage Options

Location	Height	Dimensions	Volume	Flood Area	Ratio (A:V)
Taranto Road *	4m AHD	750x30m	$2x10^4$m3	2 km^2	0.09
Binningup Road	2m AHD	960x15m	$4x10^4$m3	4 km^2	0.10
Springhill Road	1.5m AHD	980x15m	$5x10^4$m3	5 km^2	0.10
Springhill South **	1.0m AHD	605x15m	$4x10^4$m3	7 km^2	0.20
Buffalo Road **	1.5m AHD	1270x15m	$7x10^4$m3	11 km^2	0.16

* This option does not provide protection to Binningup Road, and therefore would require significant additional road works to provide a suitable pathway for town traffic.

** These options are located within the proposed Leschenault Regional Park [19], suggesting the need for environmental linkages between the estuary and the lowlands, which would be truncated by construction of a flood barrage.

A first-pass consideration of practicalities (traffic and environmental connectivity) suggests that likely feasible locations for a flood barrage would be either Binningup Road or Springhill Road. Springhill Road is considered the more practical, as it is already scheduled for improvement, to provide an alternative town access pathway. More detailed assessment requires consideration of town site access, barrage stability, runoff drainage, groundwater levels, value of flood-protected land and environmental connectivity. The implications of structural failure should be evaluated carefully when determining design criteria.

There is an implication that existing access via Buffalo Road will either be abandoned at some time in the future, or require raising to lift it above frequent flood levels.

The overall strategy for management of inundation hazard risk is likely to remain 'accommodation' over time, although changing in its form of implementation (Table 6-6). A decision to move towards a strategy of protection is likely to be based upon the viability of agricultural land that is subject to occasional inundation.

6.2.3 Coastal Monitoring and Management Triggers

Monitoring to support decision-making about Binningup Road access is related to the assessment of coastal inundation hazard (Section 5.3), with a recommended monitoring approach that follows from the PNP Coastal Monitoring Action Plan. Monitoring involves:

- Obtaining access to the Bunbury tide gauge data;
- Undertaking flood frequency analysis for a selected number of sites [d]; and
- Flood mapping for extreme water level events.

The tide gauge data provides a basis for identifying a range of water level processes, but it does not describe propagation inland through Leschenault Estuary or across the lowlands. Consequently, the flood frequency analysis and flood mapping provide the supplementary information needed to make properly informed decisions.

Criteria for management triggers can be related to the relative exceedance of different flood thresholds. Following Table 6-6, different impacts have been related to sea level rise, although they are governed by different levels and recurrence of flooding. For example, the effect of upstream surge flow is likely to be tolerated once a decade (approximately), whereas tidal flows through the road culvert are only likely to require modifying the culvert when they occur more than 30 times within a year. This enables their occurrence to be monitored as a guide to adaptation. The only impact for which there is intolerance to a single exceedance is damage to the roadway due to overflow, which requires proactive installation of flood protection.

Table 6-8: Impacts, Responses and Management Triggers for Binningup Rd Access

Impact	Possible Response	Observational Trigger	Sea Level Rise Trigger	Resources
Upstream surge flow	One-way surge valve	Flooding 2x/decade	+0.15m	2
Tidal flows	Increase culvert size	Scour due to tidal flow	+0.25m	2
Overflow damage	Armour embankment; floodway	Use SLR trigger	+0.40m	3
Reduced access	Rebuild and raise embankment	Access closed 2x/year	+0.6m	3

[d] Additional temporary installation of pressure gauges (3 gauges for approximately 3 months) could also be used to increase certainty of flood modelling for sites that are flooded via Leschenault Estuary.

6.3 Myalup Town Site

6.3.1 Current and Projected Coastal Management Issues

Myalup town site has an along-coast length of less than 300m, with a 50m wide footprint for the car park and beach access (Figure 6-6). The town is built landward of high and deeply furrowed dunes, with freehold residences located approximately 170m landward of the coast, and therefore outside the projected area of coastal erosion hazard, although susceptible to dune mobility which may be initiated by recession.

Myalup Caravan Park has buildings approximately 85m from the present-day coast. Although this provides 50-70 years before being directly affected by projected recession, the site has a much shorter period of effective land use, with dune mobility likely to make it unsuitable for existing land-use between 2030 and 2050.

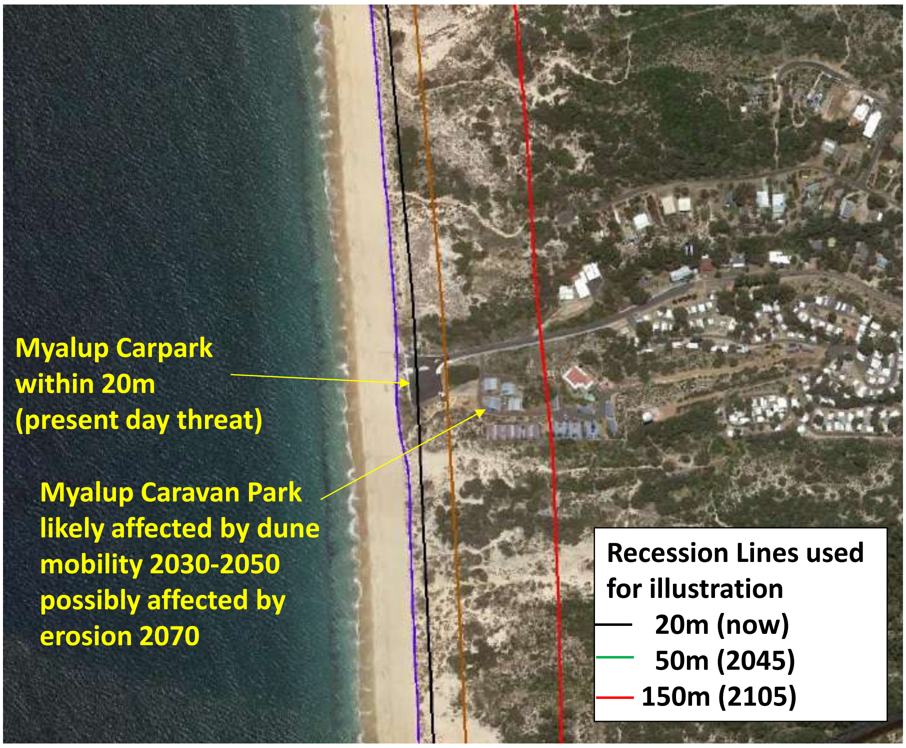

Figure 6-6: Myalup Town Site

Myalup beach car park is within 20m of the existing coastline, in line with the adjacent foredune to north and south. There is a very narrow strip of dune (5m) between the beach flat and the car park. Loss of this strip will cause high volumes of along-coast sand drift into the car park, mainly from the south. Although this material can be used to rebuild the small dune with brushing, the degree of effort required and the frequency with which works are required will increase with general recession of the coast. Rebuilding is considered to be impractical for a recession distance of around 10m, which gives an estimated *maximum* time frame of 10 years before the car park needs relocation landwards. Although sufficient space has been reserved adjacent to the beach access road to support car park relocation, the practicality of having a car park at a higher elevation requires consideration.

Constraints to beach access at Myalup are discussed further in Section 1.8. The steep gradient from the crest of the dune to the beach flat is likely to provide increasing difficulty with recession. Reconfiguration of the access road by curving it to the north provides a possible means of managing steepness of the access.

Dune mobility is the main coastal hazard potentially affecting Myalup. This is suggested by a cross-section through the town site (Figure 6-7). The seaward face of the frontal dune extends more than 100m from the coast, and the residences are built mainly in an interdunal depression.

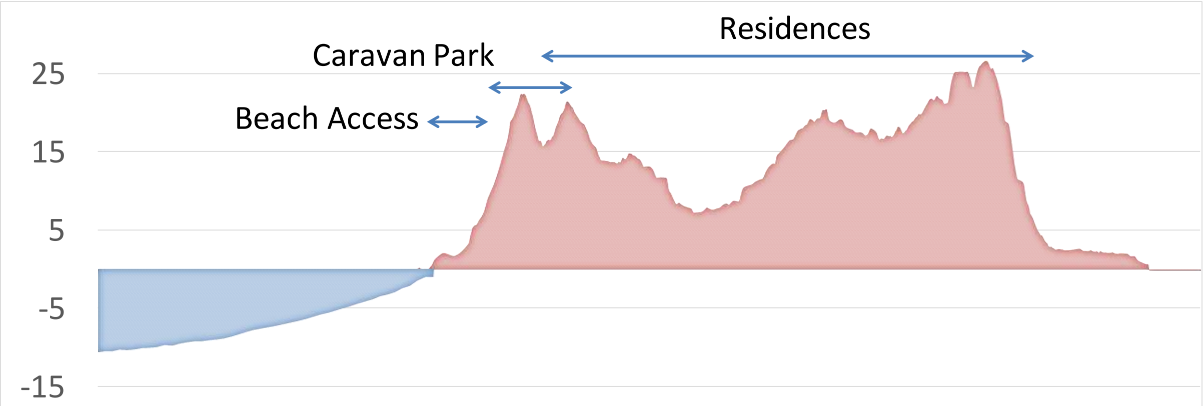

Figure 6-7: Myalup Dune Cross-Section

The existing structure implies that dune management is occasionally required for the town site, and that it will be increasingly required in the future. There is presently a small vegetated foredune in front of the primary dune face, which provides a small buffer to erosion of approximately 25m. Loss of this buffer is likely to cause activation of the dune face, with loss of vegetation, formation of sand sheets and sand drift towards the town residences. Loss of the foredune is possible under present-day conditions, but may take as long as 2040 to occur.

Myalup caravan park is highly sensitive to dune mobility due to its location on the dune face, which is likely to require relocation or removal of caravan park facilities well before the site is directly threatened by erosion. At present, the slope is approximately 1 in 3.5. With active dune management, this can be steepened to around 1 in 3, potentially extending the site's use for up to 10 years. Terracing can be used to further steepen the dune face, but will generate sand drift issues if followed by an accretive phase.

Table 6-9: Recession and Dune Mobility Impacts on Myalup Town Site

Time Frame	Estimated Recession	Affected Assets
2016	0-20m	Car park damage
2025	10-30m	Car park loss
2045	30-50m	Sand drift at caravan park
2065	60-80m	Recession threat to caravan park
2085	90-110m	Caravan park loss, Sand drift may affect residences
2115	150-170m	Recession threat to residences

Order of magnitude costs are $25 - $100/m/year for active dune management.

6.3.2 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy at Myalup town site:

Avoid – ensure town facilities (roads and buildings) are outside the influence of both erosion and dune mobility. This does not occur for the existing layout, although it is acknowledged that the majority of the town residences are outside erosion hazard, and have limited exposure to dune mobility. For the residences, dune mobility can be intercepted to seaward using active dune management (i.e. a form of Accommodation).

Retreat – relocate town facilities to reduce the exposure to hazard. Retreat of residential buildings is not considered viable due to the high relative cost of relocating compared with active dune management, which is deemed likely to be effective.

There is some potential for progressive retreat within the caravan park footprint, provided that the foredune area remains actively managed as a vegetated buffer to drift (Figure 6-8). However, because the caravan park is located on the front dune face, major failure of the buffer is likely to activate drift over the majority of the caravan park area, illustrated by the existing blowout to the south of the park. This requires a wide vegetated buffer to be maintained (>30m) and limits relocation of facilities within the park footprint. The existing buffer is anticipated to be unviable by around 2040, requiring partial relocation of facilities. Even with buffer rebuilding and relocation, relocation of the caravan park is likely to be required between 2050 and 2065.

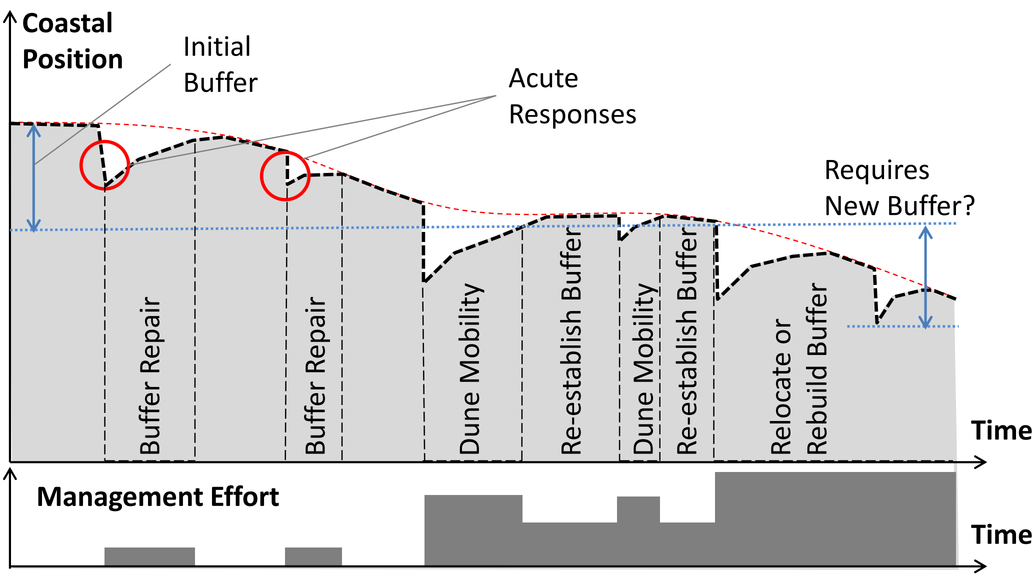

Figure 6-8: Dune Buffer Management Sequence for an Eroding Coast

The beach car park is presently exposed to dune mobility, which is being accommodated through active dune management. Further recession will require the car park to be relocated landward, within approximately 10 years. Although suitable space is available along the beach access road, the difference in elevation between the car park and beach flat will require consideration. A reconfiguration of the roadway with a northward curve may be appropriate.

Accommodate – involves physical or financial mechanisms to tolerate hazard without preventing it (e.g. building design or offsetting management costs). Existing accommodation to dune mobility is provided by the vegetation buffer that is maintained along the front of the town through brushing, planting, fencing and pedestrian control.

The threat of dune mobility to residences may be effectively managed through active dune management as it can be readily intercepted seaward of the buildings but is anticipated to be less effective for the car park and caravan park due to their position on the dune face. Minor improvement of tolerance to sand drift can be achieved through careful building design such as wall angles, raised floors, porous foundations, window structure and earthworks. However, building design does not mitigate the loss of amenity caused by drift around the residences, which is the most common form of adverse impact.

Physical accommodation to erosion is not considered practical for the car park or the caravan park. The large vertical differences in ground level between existing and eroded states require expensive engineering solutions (piling) that is not viable.

As noted previously, active dune management through brushing, fencing and dune rebuilding provides physical accommodation to the hazard of dune mobility. However, the level of effort required increases significantly under progressive recession. This is enhanced on a high dune face, such as Myalup, as failure of the buffer may cause dune mobility across the majority of the face. Consequently, use of a vegetated buffer to protect the caravan park from dune mobility cannot continue indefinitely, even with partial buffer retreat.

The existing level of dune management at the car park is understood to be moderate under present conditions. However, with a very small recession of the existing vegetation line, sand drift is likely to occur through alongshore sand movement as part of foredune processes. Typical costs for keeping a car park clear are in the order of $10-$50,000 per annum, with costs strongly influenced by the frequency of clearing.

Protect – the location of residential buildings beyond the projected erosion hazard over the 100 year planning horizon suggests that protective works are not justified for Myalup. Protective works for a car park or caravan park are not justified on an economic basis and the comparative ease of reconstructing these facilities further landward.

The variation of hazard management approach with recession distance and the approximate timeline is summarised by Table 6-10. Up until around 2065, dune management for the car park and caravan park is expected to provide appropriate mitigation for the residential buildings.

Table 6-10: Anticipated Timeline of Changing Hazard Management Approach at Myalup

Recession	Time Frame	Car Park	Resources (Res.)	Caravan Park	Res.	Residential Buildings	Res.
20m*	2016	Dune Management	1	Dune Management	1	(Secondary)	–
30m	2025	Relocate	3	Dune Management	1	(secondary)	–
40m	2045	–	–	Retreat	2	(Secondary)	–
60m	2065	–	–	Relocate	3	Static Dune Buffer	0
90m	2085	–	–	–	–	Dune Management	1
150m	2115	–	–	–	–	Dune Management	1

6.3.3 Coastal Monitoring and Management Triggers

Myalup foreshore already uses active dune management to mitigate against the hazard of dune mobility and has been carefully planned with lower cost (and shorter life) structures located in the area susceptible to erosion hazard over the planning horizon. Management practices should change if active management is determined to be ineffective or unviable and therefore the recommended monitoring program is based on dune stability indicators.

Width of the vegetated buffer provides a measurement basis for active dune management (Table 6-11), with the frequency of sand drifts (to landward) or dune reconstruction indicating the need for landward relocation. Dune width should be determined as the minimum cross-shore distance along the length of Myalup town site, not including controlled pathways through the vegetated buffer. Simple monitoring techniques (+/-5m accuracy) are applicable, such as measuring tape distance or vegetation line measurement off controlled aerial imagery.

Table 6-11: Management Triggers and Actions for Myalup Town Site

Dune Width	Monitoring	Management Action
> 30m *	Annual	Stabilise dunes only if high mobility identified
< 30m *	Quarterly	Actively stabilise dunes with brushing and drift fencing
Sand Drifts		
1-2 x / 10 years	Log	Widen vegetation buffer
3+ / 10 years	Log	Review management approach – consider relocation
Dune Reconstruction		
2-3 x / 10 years	Log	Relocate buffer landward (retreat)
4+ / 10 years	Log	Review management approach – relocate facilities

* Base width of 30m may be widened as a form of management

6.4 Other Residential Areas

6.4.1 Current and Projected Coastal Management Issues

North of Myalup, much of the Harvey coast is privately owned, with residential or holiday dwellings constructed sparsely along and landward of the primary dune ridge (refer to the *Harvey CHRMAP Summary of Key Issues*, Document 246-00-08). These residences have been developed under a range of land-titles, and include both individual freehold and strata lots. For parts of the coast, land ownership extends to high water mark.

The dune structure north of Myalup is predominantly high primary dunes, many of which have smaller foredunes to landward, separated by low lying interdunal depressions (refer to the *Harvey CHRMAP Coastal Hazard Assessment*, Document 246-00-07). The depressions are heavily used for 4WD traffic, much of it illegal, due to relatively greater stability and compaction than on the beach flat. This traffic increases the pressure on foredune mobility, primary dune vegetation (Section 6.11) and the ephemeral marshes which occur in the depressions (Section 6.12).

The implications of foredune and primary dune mobility are widely recognised by local residents, who have limited their exposure to dune mobility hazard through selection of building sites (Figure 6-9). Although there is no formal guide to site development to accommodate dune mobility, it is one of the factors considered during the Shire building approvals process. It is understood that historic dune mobility has been partly used as a guide (Figure 6-9), but this may be obscured by the regrowth which has occurred over the last 20 years, when the coast has remained comparatively stable. In some instances where dune mobility affects strata sites, residents have used planting and brushing to assist dune stability in their immediate vicinity.

Development control is not effectively provided by the State Coastal Planning Policy SPP 2.6. The policy defines a coastal hazard zone based on erosion allowances, which requires in the order of 150-170m development setback from the coastal vegetation line. This is achieved for virtually all residential dwellings outside the town sites (2 are within 150m). Although the policy requires consideration of landform mobility, it is not otherwise specified.

Existing coastal management responses include:

- Building site selection, with regulation through the building approvals process;
- Local brushing and planting by resident groups;
- Fencing and signage to control vehicle access;
- Using a loader to physically block 4WD tracks through the foredunes;
- Brushing and planting on sections of dune that are subject to heavy 4WD pressure, mainly adjacent to Myalup and Binningup; and
- Communication with landowners to discourage illegal land-use and 4WD traffic.

The effect of projected future coastal change is to cause coastal recession. This will initially cause foredune loss and subsequently reactivate primary dune mobility along the Harvey coast. Although sand sheet migration is spatially variable, it can be expected to typically exceed the rate of recession.

The differences in dune structure, position of buildings and sand sheet response mean that projecting the timing and scale of impacts cannot be undertaken with confidence. However, by considering projected sea level rise and anticipated recession, some outcomes can be forecast:

- Loss and landward migration of the existing foredunes is expected to increase progressively. Based on existing dune structure, the entirety of the foredune is likely to be lost with 50m recession (projected to occur between 2045 and 2055);
- Increased mobility of the primary dune face is expected to occur, with any coast not protected by foredune likely to become active, producing sand sheets. This can be partly managed through construction of a vegetated dune buffer, although it is estimated to require re-establishment for every 20-30m of recession;
- Sand sheet movement will cause increasing pressure on existing buildings. As buildings have largely been placed landward of the mobile sheets in the 1980s, there is likely to be some tolerance to change provided by the subsequent regrowth of dune vegetation. A similar level of sand mobility to that experienced in the 1980s is estimated to be caused by a 30m recession, projected to occur between 2025 and 2045. Requirements to manage sand drift for individual lots are expected to substantially increase over this period, and by 2065, it is anticipated that drift management will require a greater effort than is practical at a single strata lot level.

Figure 6-9: Properties and Historic Dune Mobility North of Myalup

6.4.2 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy applied to dune mobility for residential buildings outside the town sites of Binningup and Myalup involves:

Avoid – ensure buildings are outside the influence of dune mobility, including the effects of projected coastal change over a time frame of 100 years. Although buildings have generally been placed landward of historically active sand sheets, increased dune mobility caused by coastal recession has the potential to affect almost half of the existing dwellings by 2115.

Retreat – relocate facilities as increasing pressure from dune mobility occurs. As the comparative cost of active dune management is low compared to relocation of buildings, it is therefore considered practical for dune management to occur in preference to retreat. The viability of retreat is limited by the width of the dune barrier, as available 'equivalent' land

reduces with coastal recession. Retreat is only considered viable when considered relative to building life cycles.

Accommodate – involves physical or financial mechanisms to tolerate dune mobility without wholly preventing it. In this instance, active dune management through earthworks, brushing and planting may be used to build a buffer that limits the landward extent of dune mobilisation. This requires progressive rebuilding and retreat of the buffer in a situation of progressive recession (Section 5.2).

Protect – construction of coastal works to stabilise the existing coastline, and therefore reduce the capacity for dune mobility are considered wholly impractical for this section of coast due to the low density of development and the likelihood of simply transferring erosion stress further along the coast.

6.4.3 Coastal Monitoring and Management Triggers

Management to mitigate potential adverse impacts of dune mobility has four phases, related to the relative area of mobility, moving landward from the foredune to the primary dune face (Table 6-12). Each of the phases should be measured using a different parameter (Figure 6-10).

Table 6-12: Management Triggers and Actions for Dune Mobility outside Townsites

Phase	Management Focus	Management Activities	Monitoring Parameter	Trigger for next phase	Action	Resources
1	Foredune Management (Accommodate)	Earthworks, brushing, planting, vehicle control, fencing, signage	Foredune Area	Dune Width < 10m	Phase 1	1
2	Vegetation Buffer (Accommodate)	Earthworks, brushing, planting, buffer rebuilding, relocation	Buffer Width	Buffer Width < 15m	Phase 2	1
3	Scarped Buffer (Accommodate)	Reprofiling, brushing, planting, drift management	Scarp Height	Scarp Height > 5m	Phase 3	2
4	Building Position (Retreat)	Drift management, building relocation	Drift Speed	< 5 years forecast	Relocate Buildings	3

The anticipated progressive nature of erosion along the Harvey coast means that the each of these phases is likely to be experienced over time. However, each set of management actions (for the first three phases) effectively defers more expensive and intensive management activities which are subsequently required. The relative cost from phases 1 to 4 increases by at least an order of magnitude, with an increasing proportion of the coast affected, greater frequency of recurrence and a wider strip of coast over which works must be undertaken.

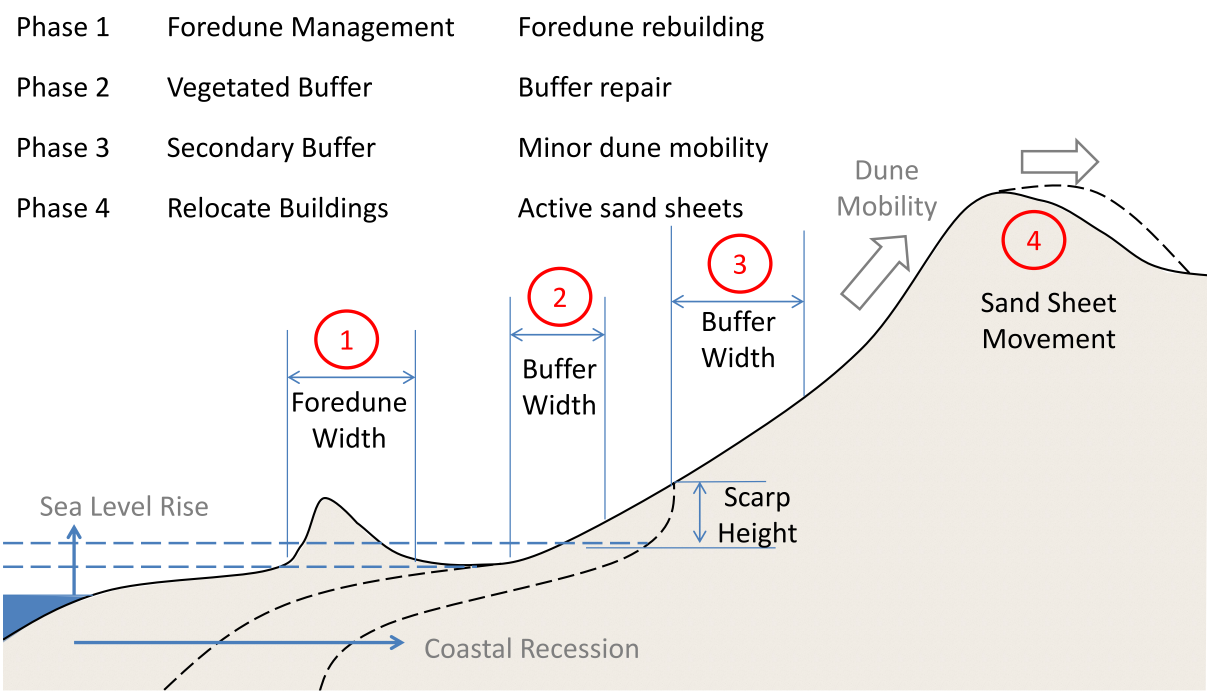

Figure 6-10: Schematic Illustrating Dune Management Phases

6.5 Dune Vegetation

6.5.1 Current and Projected Coastal Management Issues

Instability of coastal dunes in the Shire of Harvey has been a primary coastal management issue for all land managers. Responses have varied according to the local dune structure, active pressures on dune stability, available resources and governance (Figure 6-11). Significant active dune management has been undertaken by DPaW for the southern portion of the Harvey coast, as part of rehabilitation following industrial waste disposal. Active management has also occurred near to Binningup and Myalup town sites, in response to vehicle and pedestrian pressures, although this section of coast has the most stable dune structure. Elsewhere, management has been moderate, with privately owned land north of Myalup largely developed landward of historically active sand sheets. Increased dune stability since the 1980s has been strongly influenced by comparative stability of the narrow foredune ridge.

Figure 6-11: Variability of Dune Management along Harvey Coast

The type of dune instability varies along the coast, with a corresponding difference in appropriate management tools (Table 6-13). The relative effectiveness of management is demonstrated by the differences in dune structure occurring in the unallocated crown land (UCL) and the more managed coast to both north and south. The most common management tool is traffic management through signage, fencing and earthworks [20].

Management of dune blowouts and sand sheets is the most resource intensive (expensive and time consuming) form of dune management. The most cost-effective means of managing blowouts is for them to be disrupted at their coastal limit (see Section 5.2), although they have also been largely avoided through adequate setback.

Table 6-13: Dune Instability, Key Processes and Typical Management Tools

Type of Instability	Key Processes	Location	Management Tools
Foredune instability	Coastal erosion Vehicle traffic	North of Binningup	Traffic management Dune rebuilding
Primary dune instability	Wind movement	North of Binningup & South of golf course	Planting Blowout management
Inter-dunal tracks	Vehicle traffic	North of Myalup & UCL	Traffic management
Cross-coast tracks	Pedestrian & vehicle traffic	Entire coast	Fencing Traffic management

Coastal change projected to occur includes widespread coastal erosion. For a moderate recession distance of 20m, this will increase the need to manage foredune instability (north of Binningup) and substantially increase the mobility of the primary dunes along the entire Harvey coast. By 2035, this is estimated to require approximately three times the existing level of management. This increase will probably not be progressive, but triggered by severe storm erosion.

A major challenge for effective dune management is the way in which existing land tenure has influenced dune management. Existing foreshore reserves are limited, and in some places non-existent. For areas of low intensity development, this has resulted in management of dune instability largely through building setbacks. Sporadic efforts by private landowners for traffic management or vegetation planting have been constrained by either incomplete participation or a lack of sufficient resources (e.g. privately owned coast is not eligible for government coastal management grants).

Identifying an approach towards improved dune management requires a more detailed review of planning tools for the Shire of Harvey coast (see Section 7.2). The existing planning framework and some of its constraints and degrees of freedom for this issue are discussed in Harvey CHRMAP *Summary of Key Issues* (Document 246-00-08). Importantly, more effective dune management may be a subject of governance rather than tenure (Figure 3-1). Community willingness to be involved in dune management was identified in the project consultation phase, with constraints to the financial and technical resources available to private landowners acknowledged.

6.5.2 Management Adaptation, Monitoring and Decision-Triggers

The adaptation hierarchy suggested for SPP 2.6 is not meaningful for dune management. However, it is notable that the type and scale of dune management is expected to change substantially over time, which will require appropriate decision-triggers.

Existing infrastructure and development is presently used as the major factor influencing dune management activities for the town sites and residential properties north of Myalup (see Sections 6.1, 6.3 and 6.4). However, the dunes themselves have significant environmental value, which warrants an appropriate level of management. This is further enhanced by the significantly greater costs of rehabilitating an advanced dune blowout compared with managing an incipient blowout.

Potential decision-triggers to increase the level of active dune management along a section of coast may include:

- Threat to infrastructure by sand drift within a time frame of <10 years;
- Increase of sand sheet area >15% sustained over 20 years; or
- Sand sheet increase following storm-induced blowouts without recovery apparent within 5 years.

Where existing infrastructure is not a consideration, appropriate dune management is a combination of the rate of coastal erosion and the rate of sand sheet development. The extensive nature of dune blowouts along the Harvey coast means that it is unlikely available resources for dune management will ever be sufficient for total stabilisation. Therefore, a basis for prioritisation is presented (Table 6-14).

Table 6-14: Basis for Dune Management Priority

Priority	Coastal Erosion	Measure	Time Scale	Management	Resources
1	Storm erosion (typically 10-20m)	Area of sand sheet (>0.5ha)	< 5 years	Manage head of blowout	1
2	<10m/decade progressive erosion	Area of sand sheet (>2ha)	5-30 years	Manage head of blowout	2
3	>1 m/decade progressive erosion	Area of sand sheet (>2ha)	< 5 years	Manage sand sheet	3

Manage storm-induced blowouts first, then progressively growing sheets.

6.6 On-Beach Activities

6.6.1 Current and Projected Coastal Management Issues

On-beach activities including fishing, swimming, surfing, walking and driving are popular and highly valued by the Harvey community. The relatively low density of general use enables a range of activity to occur with limited conflict, although a series of bollards have been installed at Myalup and Binningup to reduce the interaction of vehicular and pedestrian beach traffic. The otherwise continuous nature of beach access is one of the appealing features of the Harvey coast, identified as precious to the Binningup and Myalup communities. In this regard, the beach itself is a social and community asset, rather than the value being developed by infrastructure.

Occasional periods of heavy beach use occur, particularly during school holidays and long weekends from spring through to autumn. This highlights potential conflicts associated with the mixture of beach activities with a higher density of use, although it is also recognised that short-term visitors typically lack the sense of custodianship that the community holds for the Harvey coast.

Seasonal variation in beach width occurs, with a narrow beach during winter and sections of exposed beach rock. Combined with high scarps at the face of dunes, this may severely restrict the continuity of the beach for vehicle access. In some instances, this results in increased 4WD use of the dunes, cutting alternative access paths landward of the beach restriction. The seasonal timing of beach width is in phase with visitor numbers, such that there is normally a wide beach when there is the seasonally greatest beach activity.

Projected change on the Harvey coast is for progressively increasing erosion. Although some beach narrowing is expected, the seasonal variation of beach width will continue to provide a wide beach during summer months. However, the continuity of the beach along Harvey coast is anticipated to reduce, with more sections of rock exposed along the beach, more frequently. The height of dune scarps will also increase, particularly following loss of the existing foredunes.

Inspection of the coast to support development of this CHRMAP revealed the presence of rock or lithified sediments at number of sites and highlighted that much of the rock is buried except following storm erosion.

Projected changes to active beach use include:

- Increased conflict between beach users due to narrowing of the beach and greater use due to population increases;
- Reduced continuity of vehicle access along the beach, leading to increased pressure on dune management and 4WD access points.

The effect of a sequence of rock features being exposed is illustrated schematically (Figure 6-12). The response of 4WD users is to create a path around a beach pinch point when it is exposed. For multiple obstructions, this path gradually extends to being a track behind the foredune, with consequent stress on dune mobility. At early stages, disturbance is less than would be created by access from the roadway, but for a longer section of restricted beach access, then road-based access is likely to be less disturbing to dunes than an extended informal path.

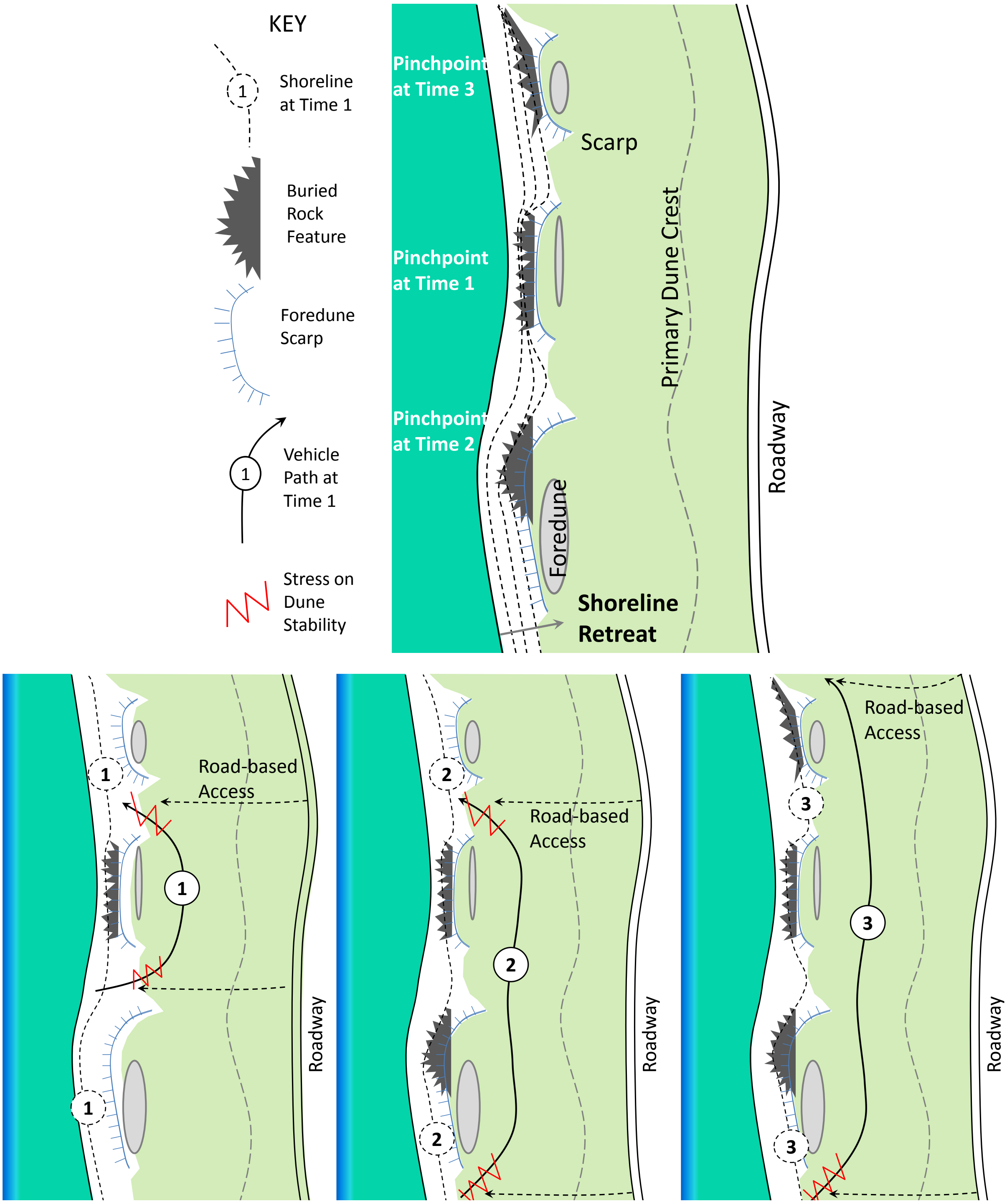

Figure 6-12: Typical Development of Informal Paths due to Pinch Points

6.6.2 Coastal Monitoring and Management Triggers

The adaptation hierarchy included in SPP 2.6 is not relevant to on-beach activities and therefore has not been applied. However, an adaptive framework that uses monitoring to guide triggering of management actions remains a useful and practical tool for effective beach management.

Monitoring and investigations may be used to:

- Determine the extent and timing of beach width movements;
- Evaluate the presence of rock features which may seasonally affect beach access; and
- Characterise the intensity and location of on-beach activities, to determine where high pressure for 4WD access is likely to occur.

When combined, these can provide a basis for identifying when on-beach activities are likely to be constrained. A classification of rock position relative to beach movements (Figure 6-13) provides a simple indication of the likely pressure for alternate 4WD pathways. On a receding coast, the occurrence of rare or seasonal rock exposure provides an indication of sites that are likely to become regular pinch points to beach access. Consequently, early identification of the presence of seasonally buried rock may support better planning and management of 4WD access paths.

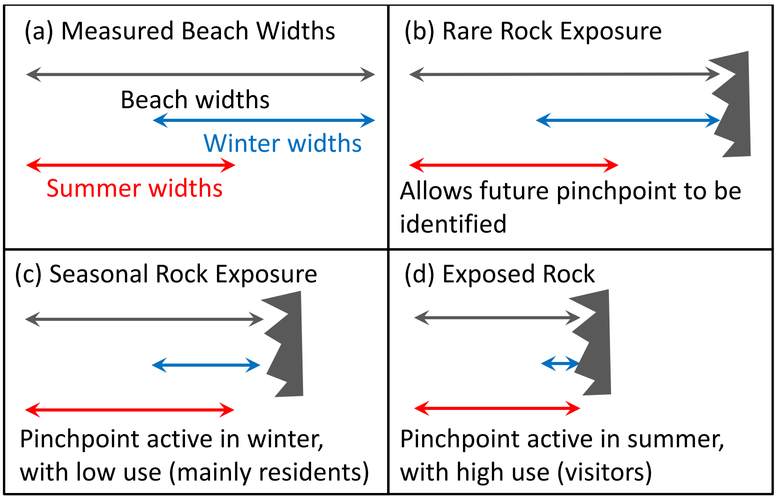

Figure 6-13: Interpretation of Beach Widths Relative to Rock Features
Note that dune damage is not necessarily proportional to beach use, as the wider beach in summer allows more traffic to pass without needing to pass through the dunes.

Recommended monitoring involves:

- Photographic monitoring (monthly to quarterly), to identify the presence and relative exposure of rock features. This is part of general monitoring for erosion (Section 5.1);
- Twice-annual measurement of beach width to characterise summer and winter beach widths. This is part of general monitoring for erosion (Section 5.1);
- Informal inspection of beach-use intensity and location, which may be conducted by ranger or environmental staff. Provision of a simple pro-forma sheet to enable ease of logging use may be developed. This should note date and time, length of coast visited, estimated beach user numbers, location and a code for their main activities (e.g. F – fishing, S – surfing, W – Walking).

More advanced information could be obtained through:

- A physical survey or oblique photographic run to be conducted after a severe storm;
- Geophysical survey to identify the extent and depth of rock;
- Higher frequency beach width measurements; or
- Use of drone surveys.

Although the information obtained from monitoring may be quantified, its interpretation to guide management triggers is largely qualitative. Two types of interpretation are outlined below.

Using Information to Manage Along Coast Access

Comparison of the beach width measurements to the position of the rock allows the degree of exposure to be classified as rarely exposed, seasonal or exposed most of the time. Combined with an understanding of relative beach use, this may be used to guide whether proactive management of alongshore access is appropriate (Table 6-15).

Table 6-15: Determining Access Requirements based on Rock Exposure and Beach Use

Exposure of Rock Feature	Immediacy	Beach Use		
		Low	**Moderate**	**High**
Rarely Exposed	Low	Not Required	Monitor	Plan Access Install Signs
Seasonal	Moderate	Monitor Install Signs	Plan Access Install Signs	Install Access*
Mostly Exposed	High	Plan Access Install Signs	Install Access*	Install Access

* Prior to installation, it is appropriate to review available beach measurements and photographs to determine whether the exposure is a result of short-term conditions (e.g. low summer widths due to an extreme or late season storm), and the beach is likely to experience significant recovery.

Determination of an appropriate form of alongshore access should be undertaken on a case-by-case basis. This is a non-trivial exercise, which requires a strong understanding for the whole of Harvey coast of the level of use, the position of rock features likely to restrict access, the sensitivity of the adjacent dune systems and the constraints provided by land ownership. It should be acknowledged that on a progressively eroding coast with buried rock features, alongshore access is anticipated to become discontinuous within 20-30 years.

An indicative set of access management actions based on obstruction length and beach use are outlined (Table 6-16).

Table 6-16: Access Management Actions based on Obstruction Length and Beach Use

Obstruction Length	Beach Use		
	Low	Moderate	High
Short (< 50m)	Not Required	Warning Signs	Access over / adjacent to rock
Moderate (50-500m)	Warning Signs	Access over / adjacent to rock	Access in foredune*
Long (>500m)	Warning Signs	Indicator Barrier	New access to road

Using Information to Identify Beach Use Conflicts

The monitoring information provides opportunity for improved understanding of potential beach use conflicts. This information should be reviewed in combination with the beach width information to assess:

Tools for management of beach use conflicts may include:

- Signage;
- Designated or marked-off areas, with the swimming areas at Binningup and Myalup being an example of permanent barriers;
- Increased ranger presence; or
- Alternative access pathways.

Table 6-17: Resources Required for Identified Beach Access Management Tools

Management Tool	Resources
Signage	1
Designated or marked-off areas, with the swimming areas at Binningup and Myalup being an example of permanent barriers	1
Increased ranger presence	2
Alternative access pathways	2

6.7 Coastal 4WD Access Points

6.7.1 Current and Projected Coastal Management Issues

The movement of 4WD vehicles between the beach and the dunes frequently provides the Shire of Harvey and other coastal managers with management challenges. The strong community interest in beach use is balanced against the instability of the foredune and dune vegetation. Access difficulties are caused by the high relief of the coastal dunes and the large seasonal variation in beach levels.

Existing 4WD access to the beach is provided through a network of formal access points, informal tracks and improvised 4WD paths. The relative distribution of these access ways is strongly affected by the overall management and the local topography, with a high density of informal and improvised tracks occurring between Springhill and Buffalo roads. A low density of informal and improvised tracks occurs along the Leschenault Peninsula coast managed by DPaW and in the vicinity of Binningup and Myalup town sites.

Formal access points at Myalup, Binningup and south of Buffalo Road are suitable for 4WDs, potentially with small trailerable vessels. The small number of sites was developed in order to minimise the exposure to erosion and foredune mobility, with positioning to match population density and coastal management by either the Shire or DPaW. The cost of formalised access back to the road network is high due to the width of the dune field.

Challenges presently experienced with the existing network of 4WD beach access include:

- Destabilisation of dune vegetation, increasing the potential for dune blowouts;
- Rapid expansion of informal and improvised paths when they are uncontrolled, with recent expansion in the vicinity of Taranto Road following road improvement as part of the Southern Seawater Plant development;
- Seasonally occurring scarps causing drop-offs that are unsafe for 4WD use, and therefore prompt further improvised paths;
- Areas of 'boggy' sand caused by heavy vehicle use, particularly during the spring-summer beach building phase. This can provide a safety issue for 4WD use, but most commonly causes an increased number of improvised paths;
- Slow delivery of vehicles to the beach, particularly those with trailerable vessels, leading to conflict between beach users. This also causes increased pressure on informal and improvised paths.

One approach to locally addressing these challenges was undertaken at Binningup through construction of Binningup Seawall (Section 6.8).

Projections of population growth and progressive coastal recession are anticipated to increase the challenges presently faced, leading to a demand for additional access. This demand will be exacerbated by restrictions to alongshore access caused by exposed rock or dune scarping (Section 6.7). Existing formal access points will require sequential rebuilding, to avoid smothering by sand drift and erosion hazard (Section 6.1 and 6.3). The capacity to construct new access points is likely to be limited by land ownership and instability of the coastal dunes.

6.7.2 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy for beach access:

Avoid – as beach access involves connection to the landform which is changing (the beach), avoiding erosion and landform mobility is not possible.

Retreat – progressively relocate beach access points to reduce the exposure to dune mobility and erosion. This also requires consideration of the change in relative elevation as facilities are moved landward.

Accommodate – involves physical or financial mechanisms to tolerate progressive erosion or dune mobility without preventing the hazard.

Protect – a physical barrier to dune mobility or erosion. This presents a challenge on the Harvey coast, as protection of beach access effectively implies beach stabilisation. For a progressively eroding coast, stabilisation of a section will transfer erosion pressure downdrift and therefore any form of protection will reduce access to the downdrift coast (to the north).

The existing strategy for beach access can largely be considered retreat, with limited accommodation to dune mobility at the formal beach access sites through foredune management. Binningup Seawall is an exception to this general strategy, although it does not specifically act to protect access (Section 6.8).

Some improvement to the existing challenges of boggy sand and drop-offs from access paths can be managed through deployment of short-term facilities such as a geosynthetic mat as an access ramp. At a number of informal paths, these issues may be reduced through better path orientation to reduce wind-blown sand drift (facing NW), although this may need to consider the practicalities of getting from the beach to the path and view lines to ensure beach user safety. Despite local reduction of some of the problems associated with beach access, these management actions do not substantially improve the capacity to withstand coastal recession or dune mobility, and the overall strategy to changing conditions remains retreat.

A change to the beach access strategy may be possible if the beach structure changes substantially due to the exposure of rock features that are presently buried. Where substantial rock features emerge, these may act as fixed points, from which beach access may be achieved. Given the prevailing conditions, access should generally be from the northern end of a beach compartment. A stronger understanding of where buried rock features exist is required to plan for these access points, which may be identified either through observation following a severe storm event, or through geophysical assessment (see Section 7.4).

6.8 Binningup Seawall

6.8.1 Current and Projected Coastal Management Issues

Binningup Seawall (Figure 6-14) was built to replace a previous formal beach access point, which was similar to the present layout at Myalup (Figure 6-6). A key objective was to provide a facility that substantially improved the delivery of 4WD vehicles with trailerable vessels to the beach. All-season access was specifically targeted to support surf lifesaving and marine safety operations. A facility including three ramps (one for pedestrian access) was initially constructed in 2007, with the land between the two southern ramps raised and held by a limestone retaining wall. The walling was extended to the northern ramp in 2011, with a wing wall on the northern side.

Binningup Seawall presently retains a landscaped recreational park, a car park and a building, which houses Binningup Water Sports Association and Surf Lifesaving Club. Stormwater drainage from the car park was incorporated within the walling. A crushed limestone vehicle access was constructed to the south of the facility to help separate vehicles and pedestrians.

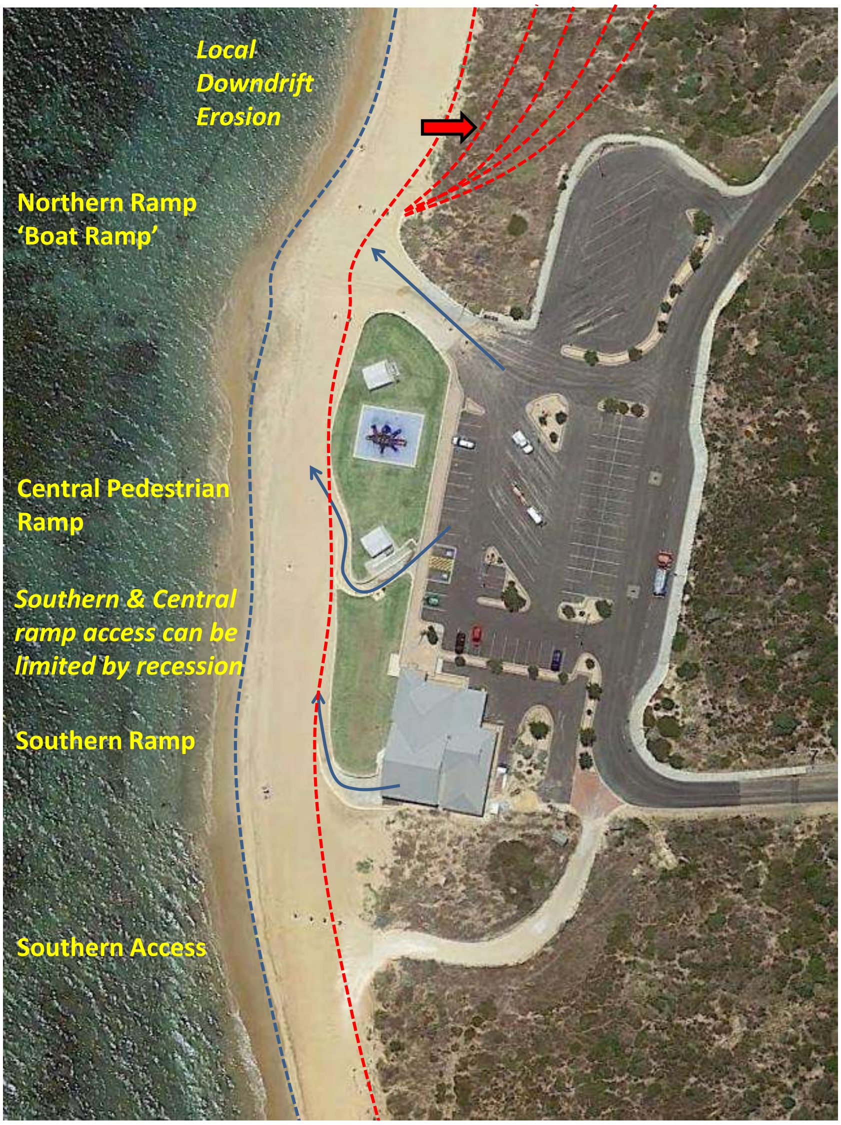

Figure 6-14: Binningup Seawall and Adjacent Facilities

The existing facility is affected by variation in beach width, with large variation both seasonally and from year to year (Figure 6-15). Storm waves occasionally reach the wall when the beach is narrow (usually in winter), but typically there is a beach flat of 10-30m width which prevents direct wave loading on the wall. Beach access from the ramps is limited when the beach narrows, particularly to the north, with the active beach face sometimes being directly adjacent to the dune scarp.

Figure 6-15: Beach Width Variability at Binningup Seawall

Dune erosion has been observed both to the north and south of the facility.

On the southern side, dune erosion occurred during a northwesterly storm in September 2013, exposing the landward end of the limestone wall (Figure 6-16). The wall has subsequently been extended landward, with limited recovery of the original dune position. Dune rebuilding is likely affected by the location of the southern access path, which blocks drift along the dune face.

Erosion on the northern side is characteristic of downdrift erosion, with the facility interrupting sand movement by both winds and waves. Exposure of the seawall to wave action only during severe storms means there is only partial interruption of wave-driven sand transport.

Design and specification of the wall has not been assessed. However, non-interlocking limestone block walls that have not been specifically designed for waves typically can withstand up to 0.4m height waves. This capacity, and the orientation of the ramps suggest that the facility can tolerate a limited amount of coastal recession (approximately 15m) before requiring adaptation.

Figure 6-16: Exposure of Seawall Southern End Following September 2013 Storm

Projected coastal erosion is expected to significantly affect the amenity and structural integrity of the Binningup Seawall facility. As the coast recedes, the facility will increasingly project out from the line of the dunes, with increased marine exposure and wave loading. Eventually, it will act as a short groyne, retaining sand primarily on its southern side.

The effect of increased marine exposure will be to significantly amplify downdrift and flanking erosion, which will further constrain beach access to the north. With sufficient exposure, wave reflection from the vertical wall will also cause deepening of the beach in front of the facility, increasing stress on the ramps, foundations and walling. In the order of 1m deepening may occur during a single storm.

Projected effects of recession are to reduce beach access to the north and increase the rate at which damage occurs to the wall (Table 6-18). A recession distance of 30m, which may occur as early as 2025, will effectively make the facility dysfunctional and is likely to compromise the wall's structural integrity. The likelihood of conditions capable of damaging the walls increases with recession.

Table 6-18: Recession Impacts on Binningup Seawall

Recession	Time Frame	Access (N)	Walling	Damaging Storm
0m	2016	~90% / year	(Progressive dune loss)	~5% / yr
10m	<2025	~70% / year*	North end flanked	~15% / yr
20m	<2035	~30% / year	Foundation exposed	~50% / yr
30m	2025-2045	~10% / year	Wall failure likely	~90% / yr

* Equivalent access to a sand ramp

6.8.2 Consideration of the Facility's Primary Objective

The primary objective of the facility is to provide effective access of vehicles and trailerable vessels to the beach for the majority of the year. This objective is met by two concrete ramps, which are separate by approximately 80m, including retaining walls running roughly parallel to the beach and a pedestrian access ramp. The ramps have been built on the western side of the facility, curving towards the north to reduce wind-driven sand drift accumulation.

The facility provides good vehicle access under present day conditions, but is sensitive to erosion, exacerbated by the effects of the facility on the coast. Landward movement of the beach will cause the facility walls to act like a groyne, with greater retention expected on the southern side and downdrift erosion on the northern side. This causes pressure on effective use of the facility, as the first 'pinch point' of narrow beach will occur at the public ramp, with traffic northwards along the beach constrained. Access to the SLSC ramp will also be restricted by moderate erosion. The rate of erosion will be accelerated if wave action reaches the walling with any frequency. Sand retention on the southern side of the facility means that the crushed limestone southern access path is likely to have increased use over time.

6.8.3 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy for the Binningup Seawall facility:

Avoid – this is not achievable for the existing facility, as it is presently exposed to marine conditions. As the primary role of the facility is to provide beach access, alternate facilities will also be subject to coastal hazards.

Retreat – progressively relocate the facility (landwards) to continue to maintain similar levels of amenity and risk. Without other forms of modification, the facility would need to be relocated for every 20m of recession to continue to provide better access than a sand ramp. On average, this means replacement every 20 years, with an approximate cost of $2-3 million for the walling, ramps and building. There is limited opportunity for material recovery.

It is noted that the cost of replacement is substantially determined by the distance between the two ramps. Although the ~80m of limestone retaining walls provides a high amenity recreational facility, the playground, BBQ facilities and car park are not dependent on proximity to the coast. A smaller along-coast footprint may reduce the cost of repeated replacement.

Accommodate – involves physical or financial mechanisms to tolerate shoreline change impacts to the facility without preventing erosion. This effectively requires consideration of an alternative facility, such as sand ramps supported by temporary structures (e.g. underlying geogrid).

Protect – armouring the existing facility by constructing a marine standard revetment in front of it is possible. However, deepening in front of the revetment and downdrift erosion would mean that the facility no longer provides beach access, which is its primary purpose. Protecting the existing facility (without significant layout changes) has not been considered further.

An alternative facility that is designed to remain fixed in place as the coast recedes requires consideration of how the coastal plan form will change. This requires construction of new public ramps. By 2035, a marine grade revetment would need to be installed, with the pedestrian ramp and SLSC ramp closed due to a lack of adequate beach width. Prediction of an appropriate alignment for the northern extension of the facility would be strongly influenced by the relative presence of rock along Binningup foreshore, which should be evaluated using a geotechnical investigation (Section 7.4).

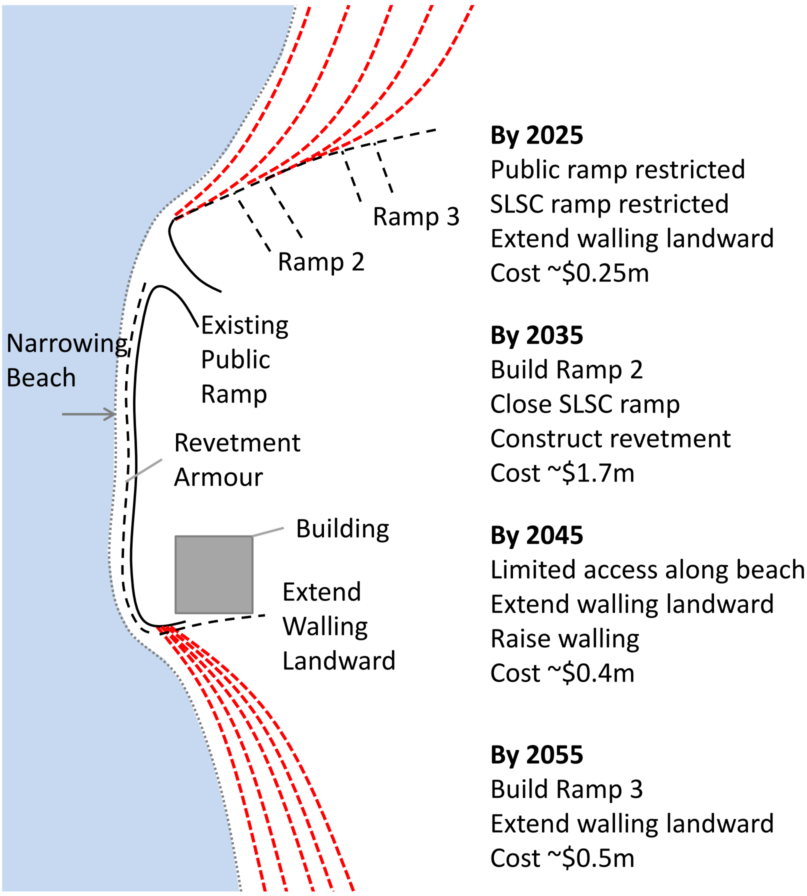

Figure 6-17: Concept for Fixed Facility Based on Existing Layout

6.8.4 Management Pathways, Decision Points and Coastal Monitoring

Management of Binningup Seawall involves several trade-offs and may be undertaken through several adaptation pathways (Table 6-19). Community valuation of both the facility and access along the beach will come into direct conflict with approximately 15-20m of erosion. If the facility is subsequently armoured, then the downdrift erosion will approximately halve the time before road or building relocation is required along West Coast Drive.

Comparison of the alternative pathways suggests that there is no clearly preferable option for management of the facility. The option with the lowest cost (removal) provides low amenity, whilst protection of the existing facility comes at a high cost and provides less beach amenity than using retreat of either a similar or reduced facility. For each of options (2), (3) and (4), approximately half the cost is likely to be incurred by around 2035, when the wall is expected to require replacement and the existing layout will provide limited access along the beach.

Table 6-19: Alternate Pathways for Management of Binningup Seawall

	Pathway	Infrastructure Cost by 2065	Access to Beach	Access Along Beach	Recreational	Residential
(1)	Remove Facility	$0.25m	Low	Good	No Park	No Effect
(2)	Retreat every ~20 years	$4.0m	Good	Moderate	Park Maintained	Limited effect
(3)	Small facility with retreat	$3.05m	Good	Moderate	No Park	Limited Effect
(4)	Armoured facility	$3.85m + house impacts	Moderate	Low	Park Maintained	2-4 Houses downdrift

Negative Neutral Positive

Costs presented in present-day dollar value (no inflation or discount rate presented)

Three decision-triggers for management may be considered, based upon identified community values:

1. *When the facility causes downdrift erosion sufficient to destabilise the dunes immediately to the north*. This decision-trigger has already been reached, with a steep scarp present on the foredune north of the facility. Although dune damage was noted by some residents, community valuation of Binningup Seawall remains positive overall;
2. *When access to the beach provided by the facility is insufficient*. Erosion will cause the facility to provide reduced benefits to beach access, with no access benefits likely after 20m of erosion, likely to occur between 2016 and 2045; or
3. *When the facility is at unacceptable structural risk*. Erosion will cause increased exposure of the facility to marine loading. The capacity of the facility to withstand any exposure has not been identified and requires investigation (Section 7.4), although it is considered likely to require removal or structural improvement between 2016 and 2045, depending on storm events and the erosion sequence.

The second and third decision-triggers are relevant to all of the options. Although they are estimated to be reached around 2025 and 2035 respectively, the capacity for acute erosion means that both could be reached with a single severe storm (in the present-day). Establishing a preferred option early (say between 2017 and 2020) potentially reduces the time between decision-trigger and implementation. However, all options could remain viable until implementation, suggesting that review of initial decision-making is likely to occur after the decision-trigger is reached.

Monitoring of coastal erosion effects relevant to Binningup Seawall can be integrated within the coastal monitoring program outlined in the PNP Coastal Monitoring Action Plan (see Section 5.1). However, additional interpretation should be developed regarding how beach movements affect access along the beach, and the corresponding level of community satisfaction. This may be incorporated through existing community forums.

Structural monitoring of the seawall is recommended on annual basis in Spring, or following severe storms that cause waves to reach the walling. This may typically be conducted by the Shire's building approval staff, with maritime engineering inspection required less frequently (approximately once every 5-10 years). The basis and frequency of structural monitoring should be reviewed following an initial structural investigation (Section 7.4).

Table 6-20: Resources Required for Management of Binningup Seawall

Management Activities	Timing	Resources
Structural investigation	2016-2017	2
Design of preferred option	2017-2020	2
Coastal monitoring & assessment of access	2017-2035*	1
Structural monitoring (Shire staff)	2017-2035*	1
Structural assessment (maritime engineer)	2017-2035*	2
Improved beach access	2017-2025*	2
Review of initial preferred option	2017-2035*	2
Implementation of preferred option	2017-2045*	4

* Timing will largely be determined by future storminess and the corresponding acute coastal erosion. The range of times presented spans between the influence of a severe storm (say in 2017) through to the effect of progressive erosion, without severe storms.

6.9 Desalination Plant

6.9.1 Current and Projected Coastal Management Issues

The Water Corporation's Desalination Plant is operated by Southern Seawater Alliance. It was constructed to supplement other forms of potable water supply to Perth, Bunbury and parts of the southwest region. The plant takes in seawater from the ocean, extracts a portion of freshwater and releases brine to the ocean. Two alternative intake points are used, allowing an intake point updrift of the discharge to be used. The intake and discharge pipes were tunnelled from the landward side of the coastal dune using a pipe jacking approach, and therefore avoiding dune disturbance.

The tunnelled intake requires a level of cover to ensure stability of the pipeline. Since construction, bed scour has occurred on several occasions, related to seasonal cross-shore sediment movement. This has been managed through the placement of dredge spoil from Bunbury Port. This management action forms a turbid plume due to suspended sediment and causes local bed smothering due to seabed sediment transport. Both of these impacts are considered likely to be tolerable for small quantities of coarse sediment, but will have increased impact for larger sediment mass or finer sediment. Management of sediment quality, including any potential for contaminated material, may be undertaken through pre-dredge sampling and analysis.

Increased pressure regarding management of pipeline stability is projected to occur. Coastal erosion, which is exacerbated by sea level rise, includes both landward and downward movement of the seabed profile. Maintaining a suitable weight of cover over the pipelines will either require sand placement at an increasing rate or the installation of more robust pipeline ballast, which may include rock or concrete.

The land-based facilities of the desalination plant are located landward of the main coastal dune, approximately 380m from the coast. These facilities are considered to be outside the range of the influence of erosion over a planning horizon of 100 years. Access to the site is above 4.0m AHD (refer to the *Harvey CHRMAP Coastal Hazard Assessment*, Document 246-00-07) and therefore considered to effectively avoid coastal flooding.

Substantially increased 4WD tracks have developed since surfacing of Taranto Road to support the desalination plant. This is an area of local focus for dune vegetation management (Section 6.5).

6.9.2 Adaptation Hierarchy

The land-based facilities of the desalination plant are considered to be outside the range of the influence of erosion and coastal flooding over a planning horizon of 100 years. This represents use of 'Avoid' strategy for coastal hazard management, which is preferred by WAPC.

Consideration of future adaptation for the intake and outfall pipelines is strongly influenced by the value of the desalination plant to the State's potable water supply and the potentially high capital costs associated with adaptation actions (Table 6-21). The existing management strategy represents a low cost approach towards an issue which has (to date) been largely episodic.

Table 6-21: Adaptation Hierarchy Applied to Desalination Plant Pipelines

Strategy	Management Action	Comment
Avoid	Install new pipelines with depth to account for long-term coastal profile change, or determine alternative intake and outfall arrangements	Extremely expensive
Retreat	Replace pipelines when depth of cover is no longer adequate. Install new pipelines with depth to account for moderate-term coastal change	Extremely expensive
Accommodate	Place sediment as required to maintain adequate cover	Low expense
	Install pipeline anchoring system to reduce sensitivity to bed scour	Moderate expense
Protect	Install protective covering system which provides ballast and limits depth of bed scour	Moderate expense

6.9.3 Coastal Monitoring and Management Triggers

The key parameter influencing the need for management of the desalination plant intake and outfall pipelines is the elevation of the seabed. The most likely adverse impact of existing management actions (sand dumping) is smothering of benthic flora on the seabed. As both management trigger and impact are related to the seabed, it is practical to use a monitoring approach which can combine the two. Typical approaches may include the use of high resolution multi-beam survey, or a combination of single-beam survey over the pipelines combined by with benthic video survey. Due to the seasonal nature of cross-shore sediment movement, monitoring on an annual basis is considered to be practical.

Definition of management triggers deserves a detailed evaluation by the Water Corporation. However, considering the expected shift in behaviour with progressive erosion, triggers are likely to change from measuring the area of seabed smothering to the effective depth of cover (Table 6-22).

Table 6-22: Desalination Plant Pipeline Management Sequence for Progressive Erosion

Situation	Measure	Strategy	Possible control
Bed scour occurs on an occasional basis (<2 times in 5 years)			
Existing situation	Area of seabed smothering	Dump dredge spoil on an as-needed basis	Modify particle size and volume of dumped material
Bed scour occurs on a regular basis (2+ times in 5 years)			
Adequate cover maintained continuously	Area of seabed smothering	Dump dredge spoil on an as-needed basis	Modify particle size and volume of dumped material
Partial cover maintained continuously	Depth of Cover	Use pipeline anchoring system	Anchoring system varies to suit available cover
Adequate cover maintained continuously	Depth of Cover	Install protective covering system	Protection designed to minimise seabed disturbance

6.10 Harvey Diversion Drain

6.10.1 Current and Projected Coastal Management Issues

Harvey Diversion Drain is managed by the Water Corporation. It was constructed as part of flood mitigation works for the agricultural land between Harvey townsite and Harvey Estuary, and also as a potential source of irrigation. More than 20km of open channel provides an alternative westerly flow path for the Harvey River waters, with the majority excavated through the original terrain. Where it crosses the lowlands near Myalup, the channel is contained between levees. At the coast, a low level limestone training wall was constructed to limit the mobility of the mouth cutting into the adjacent primary dunes.

The Diversion presently interacts with the coast when floodwaters flow through to the ocean or ocean waters flow into the channel. Both of these interactions are partially buffered by the presence of the beach, which limits the capacity of flood waters to move in either direction until the flood is above the beach level. Subsequently, channel cutting through the beach may occur (Figure 6-18), locally affecting beach and foredune stability. Minor breaching through the beach typically occurs most winters, but the entrance commonly closes over rapidly due to coastal sand transport. Cutting of a large channel (allowing it to stay open) has been rare historically, and its likelihood has been further reduced by construction of Harvey Dam.

Figure 6-18: Harvey Diversion Drain Ocean Entrance Plan Form

The influx of marine water to the Diversion during ocean flooding events has not been identified as causing management issues.

Figure 6-19: Harvey Diversion Drain Ocean Entrance Oblique View

Expected consequences of projected sea level rise include coastal erosion and a higher beach level. These provide a sequence of management issues which change over time:

- In the short-term, narrowing of the beach will increase the potential for breaching. Interrupted access along the beach is likely to become more frequent. This phases is likely to be active between 2015 and 2045;
- Increased coastal flooding effects are likely to occur if the channel is open for longer periods;
- Further erosion will likely destabilise the minor training wall by 2025-2045, increasing mobility of the channel mouth;
- Channel mobility and coastal erosion will destabilise the dunes adjacent to the channel entrance, increasing aeolian sand drift and 'plugging' the channel. This phase is likely to be active by approximately 2035-2065;
- The combination of higher beach levels and increased sand drift will raise the level of runoff flooding needed to cut through to the ocean and therefore increase terrestrial runoff flood levels; and
- Structural adequacy of the levees on the approach to Myalup may be affected by higher flood levels.

Simply put, there is a balance between managing sand transport (marine or aeolian) which may block the channel against increased runoff flood effects.

Management of the Harvey Diversion Drain by the Water Corporation and management of the adjacent dunes by the Shire require integration. Ongoing liaison should be undertaken to ensure that the coastal management approach adopted by the Water Corporation is consistent with that of the Shire (See Section 7.1).

6.10.2 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy for management of the Harvey Diversion Drain:

Avoid – the role of the Harvey Diversion Drain requires connection to the Ocean and therefore avoiding coastal processes is impractical. Avoidance could potentially be achieved if it is determined that the Diversion no longer provides necessary flood mitigation or irrigation functions.

Retreat – progressively relocating the Diversion mouth training wall landward as coastal erosion occurs.

Accommodate – involves management of sand drift either through reconfiguration of the dunes or occasional excavation/dredging of the Diversion entrance. The viability of using excavation reduces as the speed of sand drift increases, which is related to the height of dune cut by erosion.

Protect – large training walls to provide a stable ocean exit for the Harvey Diversion Drain are considered impractical. Under ambient conditions, the walls would act as a groyne, causing downdrift erosion to affect Myalup.

Reduced runoff flooding risk from the Diversion (due to Harvey Dam) determines that there is less imperative to keep the ocean entrance clear than when it was first built. Consequently, a more dynamic entrance managed through a strategy of accommodation is considered to be the most effective management strategy.

Table 6-23: Anticipated Timeline for Changing Management Approach at Harvey Diversion Drain

Recession / SLR	Time Frame	Strategy	Actions	Resources
20m*	2016	Avoid		0
30m	2025	Accommodate	Tolerate reduced beach access	0
35m	2035	Accommodate	Review role of training wall	2
40m*	2045	Avoid / Retreat	Remove the training wall	3
40m	2045	Accommodate	Manage dune vegetation	3
60m	2065	Accommodate	Excavation of channel entrance	2
90m	2085	Accommodate	Reconfigure dunes near entrance	3
+0.5m SLR	2070	Not determined	Review runoff flood risks	2
+0.9m SLR	2115	Not determined	Manage runoff flood risks	3

6.10.3 Coastal Monitoring and Management Triggers

Dune management (Section 6.5) and vehicle control (Section 6.6) are required in the vicinity of Harvey Diversion Drain, with additional management pressure brought about when the channel cuts through the beach. Regular beach inspection is required to identify constraint to vehicle access, which may be most practical through a community representative. When the beach is cut through, signs should be installed temporarily at Myalup and Taranto Road.

Management of the dunes should generally follow the same methods as other parts of the Harvey coast (Section 6.5), supported by annual visual/photographic monitoring and 5-yearly vertical aerial imagery. However, additional dune dynamics due to the channel cutting through the beach or into the dunes needs to be identified.

The beach width indicates the degree of threat to the existing training wall and provides a basis for projection of dune mobility and sand drift rates. Monitoring of coastal erosion relevant to Harvey Diversion Drain can be integrated within the coastal monitoring program outlined in the PNP Coastal Monitoring Action Plan (see Section 5.1).

Management of the Diversion entrance relates to the quantity and rate of sand drift entering the channel. Monitoring of channel closure should be a visual assessment of the how much the channel has closed over due to sand drift, measured approximately in line with the front face of the dune.

Table 6-24: Monitoring and Management Triggers Relevant to Harvey Diversion Drain

Phase	Management Focus	Monitoring Parameter	Trigger	Action	Resources
1	Vehicle Access	Beach Width	Width < 10m	Close beach access	1
2	Structural stability	Structural condition	>20m wall damage	Remove training wall	2
3	Dune stability	Dune condition	Bare scarp >12 months	Reshape dune	3
4	Flood risk mitigation	Channel area	>50% closed	Excavate channel	2
5	Flood risk mitigation	Infill rate	Excavate 3x/year	Reconfigure entrance	3
5	Beach stability	Dune condition	Channel causes scarp	Reconfigure entrance	3
6	Beach stability	Dune condition	Reconfigure 2x/10 years	New training wall	3

6.11 The Cut

6.11.1 Current and Projected Coastal Management Issues

A rock training wall was built as part of flood mitigation works for Bunbury in the 1950s, which included diversion of Preston River and truncation of Leschenault Estuary. The ocean entrance was relocated to "The Cut", which was excavated through Leschenault Peninsula. Instability of the ocean entrance subsequently occurred, which affected navigability, including development of a flood-tide delta inside the estuary entrance [21] and an ebb-tide sill outside the training walls. A second training wall was built in the 1970s. Coastal movement in the vicinity of the Cut became enhanced, with a net erosive trend broadly related to the flood-tide delta development: rapid initial coastal erosion was coincident with delta accretion, with both apparently slowing over time.

In winter 2012, the training walls breached at a structural transition (from trapezoidal to revetment structure), causing beach sand to spill into the Cut and form a substantial mound within the channel. Emergency repairs were co-ordinated by the Department of Transport in 2014. Concerns raised regarding the breach included restrictions to navigation and estuarine water quality, although it is noted that the only identified objective of the Cut was to manage floodwater drainage. The entrance bathymetry is acknowledged to change significantly following storm events (Figure 6-20).

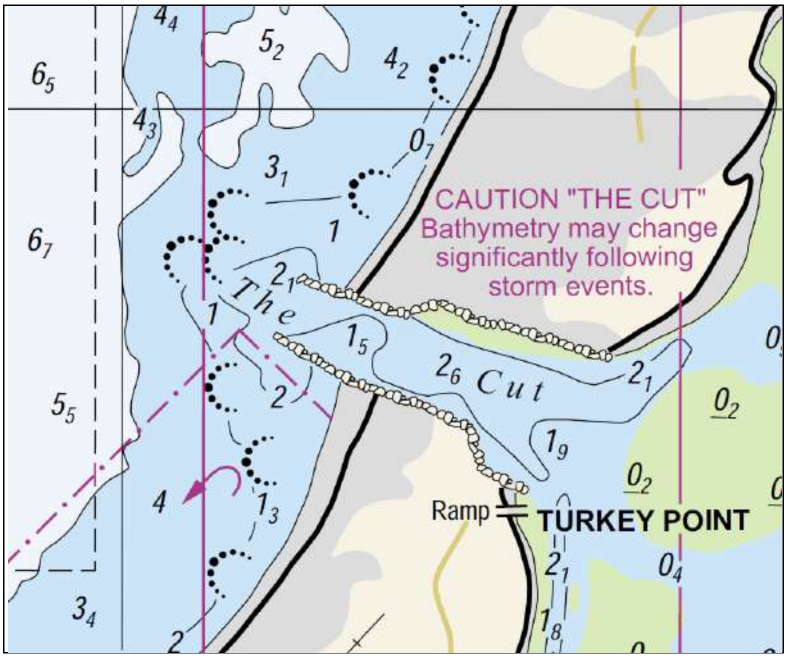

Figure 6-20: Note Regarding Bathymetry at The Cut
Extract from DOT Chart WA776

The Cut and training walls are State government assets, originally built by the Public Works Department. However, management responsibilities for the Cut are unclear, with the Departments of Transport and Water having State responsibilities for coastal and flood management respectively. The adjacent land is managed by DPaW. Flood management benefits are provided to the Southern Ports Authority, City of Bunbury and the Shires of Harvey and Dardanup. The Leschenault Catchment Council provides community-led strategic, educational and on grounds projects to support natural resource management within the catchments and Leschenault Estuary.

Future changes projected to occur at the Cut are related to the overall pattern of progressive erosion, plus additional changes caused by sea level rise. Potential impacts include:

- Further coastal retreat will put increasing pressure on the structural integrity of the training walls, with exposure of the revetment section;
- The ebb-tide sill and flood-tide delta will rise in response to increased sea level, capturing sand from the coast and causing locally enhanced erosion. Capture rates will vary with storminess and tidal modulation, with a long-term average of 20,000m^3/yr estimated to balance a 0.9m sea level rise over 100 years. This is estimated to contribute 27m to the average erosion distance between Bunbury Power Station groyne and Buffalo Road, which is a local addition to the regional coastal response to sea level rise and regional progressive erosion;
- Increased tidal prism is likely to cause higher flows for the narrow section between the Cut training walls, deepening the scour hole and increasing channel mobility. At the wider and shallower end of the channel, tidal flows are estimated to reduce marginally (Figure 6-21);
- The relative efficiency of tidal exchange through the Cut is anticipated to reduce, as the estimated 30% tidal prism increase by 2115 is less than the >50% increase to average depth over Leschenault Estuary.

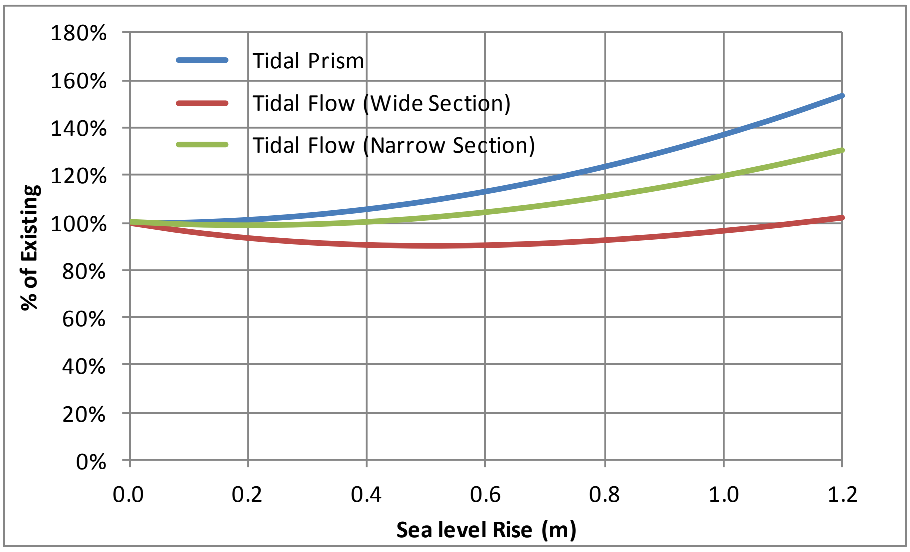

Figure 6-21: Change to Tidal Prism & Flows at the Cut from a Simple Flux Model

6.11.2 Adaptation Hierarchy

Consideration of the WAPC preferred adaptation hierarchy for the Cut training walls:

Avoid – the role of the Cut requires connection to the Ocean and therefore avoiding coastal processes is impractical. Removal of the training walls (as an infrastructure asset) would enhance coastal instability and significantly reduce vessel safety. Degradation of water quality within Leschenault Estuary is considered likely. Removal of the training walls has not been considered a plausible option.

Retreat – the training walls may be modified to match progressive erosion, with the seaward length reduced and the trapezoidal section extended landward, at least 60m of the ‘active’

shoreline at each retreat phase. Reducing the offshore length is likely to reduce the ebb-tide sill volume, with a small reduction of the local erosion rate.

Accommodate – modification of the training walls may include redesign, with the objective of reducing the tendency for sill and delta formation, thereby reducing the locally enhanced erosion. This could involve widening of the gap between the training walls. The potential to adversely affect the efficiency of tidal exchange or change navigability of the entrance make this a relatively high risk option for moderate benefit.

Protect – continuing with the existing position of the training walls will require progressively reinforcing and deepening of the structure, with landward extension of the trapezoidal cross-section. Holding to the existing position as the coast erodes does not provide any identified benefit.

The extended structural life of rock structures and the high capital cost of the training walls determine that decision-triggers for adaptation are likely to be widely spaced. The degraded state of the training walls and the identified need for repairs [22] suggests that there may presently be an opportunity to consider adaptation. The estimated cost of repairing the existing structure is $20m.

The overall strategy for management of The Cut training wall deserves a more detailed evaluation. However, the existing seabed structure and damage to the walls suggests that consideration of structural accommodation is warranted.

6.11.3 Coastal Monitoring and Decision-Triggers

A preliminary understanding of beach movements in the vicinity of the Cut may be gained through vertical aerial imagery. Long-term assessment of net erosion may be supported by widely spaced imagery, such as collected by Landgate. Evaluation of beach dynamics necessary to support retreat or accommodation strategies requires higher frequency sampling, which may be available through Nearmap or drone-based surveys.

Monitoring required to assess the performance of the Cut should be undertaken to capture the landward and seaward movements of the beach position on either side of the training walls, including the position and depth of the beach toe adjacent to the walls. Monitoring to depth requires boat-assisted surveys, which are outside the scope of the Coastal Monitoring Action Plan, and therefore require additional resources.

Decision-triggers occur when the existing structure is deemed inadequate, through structural damage, when it is no longer effective for flood mitigation, or when the entrance, including sill and delta landforms, is impeding water exchange. A potential management trigger is when there is less than 40m distance from the beach to the landward end of the trapezoidal cross-section, as this represents the potential erosion distance which can occur 'overnight'. Under the present situation, this condition is already 'triggered'. Information collected to date is insufficient for redesign, but it appears likely that improvement could be made by widening, and possibly shortening the length of the training walls. A detailed assessment is recommended within the time frame of 2017-2020.

6.12 Sedgelands

6.12.1 Current and Projected Coastal Management Issues

Sedgelands occurring towards the north of the Harvey coast are an unusual habitat, which provide fresh to brackish water to native dune fauna, particularly birdlife. Sedges occur in low-lying depressions between the foredune and primary dune which become seasonal wetlands through a combination of rainfall runoff and groundwater. The basins in which the sedgelands occur are typically long and linear, with a gentle bare sand slope on the eastern side forming the base of the main primary dune ridge.

Figure 6-22: Oblique Aerial View of 700m Long Interdunal Basin

Threats to the existing sedgelands are developed through vehicle traffic, storm erosion of the foredune and change to the groundwater regime (see Section 5.3 in Harvey CHRMAP *Summary of Key Issues*, Document 246-00-08). Traffic is occasionally managed by residents and the Shire by earthworks or fencing to block vehicles from entering the sedgelands through the foredunes. However, these efforts are interrupted by a combination of coastal erosion and opportunistic track-making by 4WDs. On the landward side of the sedgeland, the nearly flat and smooth natural surface encourages increased and higher speed 4WD traffic, which is discouraged by private fencing on a limited number of properties.

The viability of the sedgeland habitats is anticipated to be strongly challenged by sea level rise and associated erosion. These processes are expected to cause loss of the existing foredunes by 2035 to 2055, which will result in smothering of the sedge communities. The potential sensitivity of the sedgelands to these and other issues (traffic and groundwater) determines that a deeper understanding of these habitats needs to be developed to identify an appropriate course of management (see Section 7.4).

6.12.2 Sedgeland Management

Although the sedge habitat is expected to be destroyed by projected coastal change, their environmental value may warrants management to defer damage from other sources of change, particularly 4WD traffic. Factors to be evaluated may include:

- Historic patterns of sedgeland degradation, based upon aerial photographs;
- The potential capacity to manage each basin separately;
- The role of adjacent tenure and associated traffic management.

Management actions may include:

- Installing signs or fencing to manage traffic away from sedges;
- Controlling 4WD access points across foredunes; and
- Rehabilitation of protective foredune areas following storm erosion.

The apparent importance of how 4WDs are managed landward of the sedges (by private property owners) upon traffic levels suggests a possible basis for improved sedgeland management. Identification of properties which may affect traffic within each particular sedgeland basin may provide a basis for small community groups, and in turn support better co-ordinated management. Challenges for effective sedgeland basin management are otherwise similar to those of dune vegetation management (see Section 6.5), with inadequate foreshore reserves to provide direct management through the Shire.

Monitoring of the foredune cross-sectional area may be used to indicate the need for reinforcement. A cross-section of approximately $50m^2$ above high water mark represents a foredune that is unlikely to collapse under severe storm attack (although it may be eroded). A cross-section of less than $10m^2$ above high water mark represents a foredune that is potentially threatened by moderate storm attack, indicating the need for reinforcement prior to the next winter storm season.

7 SUMMARY OF OVERALL MANAGEMENT

7.1 Regional Management Context

The Shire of Harvey coast includes moderate to large coastal development setbacks and has a lower exposure of infrastructure to erosion and inundation than much of the Peron-Naturaliste coast. However, dune mobility is extremely high, with the potential for extensive sand drift problems along the length of the coast if moderate erosion occurs. This sensitivity should be acknowledged in regional coastal management, such as the Peron-Naturaliste Partnership forum, along with implementation and any further refinement of the Greater Bunbury Regional Scheme and Local Planning Strategy.

There is a need to include the following broad coastal management objectives in Shire policy and practices:

- Maximise the retention of coastal sediments, particularly on the beach and in the foredunes; and
- Minimise activities capable of disturbing coastal dune vegetation.

Applied to coastal management, these objectives support the existing coastal management strategy to avoid coastal hazards; they also provide a consideration for planning, infrastructure development and building approvals within the coastal dunes. The practice of residential development being preferentially focused within the coastal town sites at Binningup and Myalup is an example of minimising dune disturbance.

Effective coastal management also requires the significance of these objectives is conveyed to decision-makers external to the Shire whose actions may influence the Harvey coast. In this respect, the Shire should:

- Lobby the Southern Ports Authority for effective bypassing of Bunbury Port that will positively contribute to sediment supply on the Harvey coast (i.e. avoid offshore disposal or extractive use). This objective was identified in port dredging plans [23];
- Ensure that the objectives are recognised and acknowledged within development approvals processes, particularly for extractive or industrial works (i.e. within the Shire, OEPA, WAPC, DRD and DMP); and
- Ensure that decision-making for existing infrastructure along the Harvey coast (Desalination Plant, Harvey Diversion Drain and The Cut training walls) considers larger area and longer-term implications for adjacent and regional land. In particular, works which reduce existing coastal buffers should be considered in the context of bringing forward (in time) the forecast coastal adaptation process.

The latter consideration also applies to infrastructure managed by the Shire, particularly the Binningup Seawall (Section 6.8).

Coastal management within the Shire of Harvey may have implications for the long-term supply of coastal sediment to the north, which is anticipated to reduce with projected sea level rise. Balancing out regional impacts requires continuation of regional assessments and dialogue between local coastal managers, which has been achieved effectively through the Peron-Naturaliste Partnership.

7.2 Policy and Tenure Revision

The existing land tenure provides potential barriers to implementation of effective coastal management within the existing policy framework. A combination of policy and tenure revisions is required to streamline governance of the coastal margin, supporting management and longer-term adaptation. A preliminary discussion of options is contained in *Harvey CHRMAP Summary of Key Issues*, Document 246-00-08. At this stage, selection of a practical and functional pathway requires considerable further evaluation and discussion between the Shire and WAPC.

It is recommended that the Shire set aside funds and staff resources to deal with policy and tenure revision for the 2017-2018 budget, with ongoing resources likely to be needed with progressive coastal change.

7.3 Community Education

Community feedback indicated that private land owners were interested in obtaining knowledge of appropriate dune management practices. It is recognised that significant technical and practical knowledge is held by DPaW, The Department of Planning and natural resource management agencies. Distillation of this knowledge into a practical set of dune management and stabilisation guidelines suitable for local landowners (e.g. fact sheets) to use may support improved practices by private residents.

The potential benefit of a simple set of guidelines for dune management extends beyond the Shire of Harvey, with a number of rural councils from the South, Southwest and Mid-west coasts facing similar issues. It is recommended that the Shire seek the involvement of PNP, WALGA, NRM groups, DPaW and the Department of Planning in the funding and development of a set of guidelines, with potential financial support through the CoastWest grants program.

7.4 Investigations

Technical investigations are recommended within the asset-based adaptation assessments. These actions address existing uncertainties and have the capacity to improve the efficacy of adaptive management decisions, improving the effort to reward ratio for conducted works. Recommended investigations are listed in Table 7-1.

Table 7-1: Recommended Investigations

Investigation	Organisation	Uncertainty Addressed	Time Frame
Geophysical	Shire of Harvey	Coastal erosion response	2017-2020
Inundation Modelling	State Government	Overland flood propagation	2020-2030
Seawall Assessment	Shire of Harvey	Marine capacity of walling	2016-2017
Sedgelands	DPaW	Effective lifetime	2017-2020

A brief description of each investigation follows, with reference to the relevant asset-based adaptation sections:

- Geophysical or geotechnical investigation is appropriate to determine the presence of coastal rock along the Binningup foreshore. This should inform the management of townsite development (Section 6.1), beach access (Sections 6.6 and 6.7) and Binningup Seawall (Section 6.8). Available evidence of seasonally exposed 'reefs' (Figure 7-1) suggests that the investigation should be undertaken from Buffalo Road to Taranto Road.

Figure 7-1: Exposed rocky coast, north of Binningup, February 2015

- Inundation modelling is required to clarify how extreme ocean flooding could propagate through Leschenault Estuary and up through the drainage network to impact on the lowlands between the estuary and Lake Preston. An understanding of how flood lag and damping may be affected by sea level rise should also be developed through the modelling.
- The capacity of the Binningup Seawall to withstand exposure to marine conditions has not been identified. Limited available information and inspection of damage suggests that the structure maybe inadequate to withstand direct wave exposure. An understanding of the walling capacity should be developed to set a trigger for removal or armouring of the existing facility (Section 6.8).
- A review of existing information relevant to the coastal sedgelands, to evaluate their potential sensitivity to sea level rise and identify appropriate further studies. This information is required to develop a forecast lifetime for the sedgelands, to support decision-making regarding appropriate management (Section 6.12).

7.5 Monitoring

Required monitoring to support the Harvey CHRMAP is mainly comprised of the erosion and inundation monitoring outlined in the PNP Coastal Monitoring Action Plan (Table 7-2). Application of the coastal erosion monitoring to decision-making is described in Section 5.1, and application of the inundation monitoring is described in Section 5.3. The monitoring program includes high expense items of aerial photography and tide gauge instrumentation that are collected by State Government agencies.

Table 7-2: Monitoring Program Outlined by PNP CMAP

Minimum Monitoring Level 1 Low Risk Level with Planned Coastal Management	• Supports forecast of time for which a foreshore buffer may give protection (i.e. before hazard phase) • Should allow distinction between a trend and a fluctuation	Relevant CHRMAP Sections
Decision-making Time Frame	5 to 10 years	
Coastal Erosion Monitoring		Sections 6.1, 6.3, 6.6, 6.8 and 6.9
1) Photographic Monitoring	Monthly, for indicator sites	
2) Beach Widths	Annual or twice yearly (12 sites)	
3) Oblique Imagery	Annual or twice yearly *Co-ordinated by PNP*	
4) Vertical Imagery	Every 5 to 10 years	
5) Dune monitoring	Annual	Sections 6.4 and 6.5
Local Monitoring	Binningup Seawall	
6) Beach profiles / crest line	Annual (Sep-Oct)	Section 6.8
Inundation Monitoring		Section 6.2
1) Tide gauge measurement	Ongoing observation *Gauge managed by DoT*	
2) Flood frequency log	Ongoing observations	
3) Flood mapping	Opportunistic	
Estuary Entrance Monitoring	*State Government responsibility*	Section 6.11
1) Structure photographs	5-Yearly	
2) Structural monitoring	Every 5 to 10 years	
3) Soundings	Annual	
4) Hydrographic survey	Every 20 Years	
5) Low-tide photographs	Every 2-3 Years	
6) Current profiling	To be undertaken	

Additional monitoring which is relevant to coastal management for the Shire of Harvey includes:

- Dune buffer monitoring (see Section 5.2). This is relevant to Sections 6.1, 6.3, 6.4 and 6.12.
- Beach use assessment (see Section 6.6)
- Beach access inspection (see Section 6.7)
- Structural monitoring (see Sections 6.8, 6.9 and 6.11)

Dune buffer, beach use and beach access monitoring are all straight forward observations, which may be undertaken with existing staff resources. Structural monitoring for Binningup Seawall, Harvey Diversion Drain and The Cut require basic knowledge of engineering, with the Seawall being the only facility managed by the Shire.

7.6 Management Actions

Key management actions for each identified asset are summarised in Table 7-3, listed according to approximate time frames based upon projected coastal change (Figure 2-1). The sequence of actions for each asset is based upon the adaptation hierarchy preferred by WAPC, modified according to practical management considerations. The relatively discrete nature of individual assets means that there are effectively no conflicts.

The majority of coastal management required is to support community use of the beach, in response to coastal erosion and dune mobility, which will remain significant issues for the Shire. The established capacity (funding and logistics) to undertake dune stabilisation and beach access management will require increased commitment anticipated over time. Improved use of limited resources will require regular coastal monitoring and is likely to be supported by investigations of the underlying rock and patterns of beach use (Section 7.4). Constraints to effective management of the coastal strip due to land ownership require resolution, which needs a revision to planning policy to support suitable governance.

Coastal inundation is expected to remain generally a low to moderate hazard in the Shire of Harvey for a number of decades, with extreme flooding potentially affecting access to Binningup by around 2065. Existing roads provide an obvious means of creating flood defence, with high costs for re-engineering, requiring advanced planning for capital expense.

Overall, there is limited change required to existing coastal management practices for the next 10 years, with exceptions being management of the Binningup Seawall and The Cut. These facilities are expected to become increasingly unviable over the next 10 years, due to functionality and structural capacity. Planning for an alternative facility (to Binningup Seawall) to provide beach access, including identification of funding sources, should be undertake within the next few years. Modification of the Cut training walls should be considered within the presently deferred repair works.

Sedgeland habitats north of Myalup are likely to be degraded by coastal change and are expected to eventually be smothered by foredune retreat.

	Approximate Timing	2016-2020	2021-2025	2026-2035	2036-2045	2046-2055	2055-2065	2065-2075	2076-2085	2086-2095	2096-2105	2106-2115
5.1	**Binningup**	Coastal Monitoring				Active Dune Management				Coastal Protection Works		
5.2	**Binningup Access**	Inundation Monitoring			Surge Valve	Increase Culvert		Armour Embankment		Raise Embankment		
5.3	**Myalup**	Dune Management		Relocate Carpark		Retreat Caravan	Relocate Caravan	Dune Buffer	Active Dune Management			
5.4	**Other Residential**	Foredune Management		Vegetation Buffer		Scarped Buffer		Building Relocations				
5.5	**Dune Vegetation**	Existing Management		Foredune Loss		Increasing Primary Dune Mobility						
5.6	**On-Beach Activities**	Existing Management Establish Baseline		Minor Constraints to Beach Access Expected				Major Constraints to Beach Access Expected				
5.7	**Beach Access**	Existing Management		*New Beach Access Paths Required at Majority of Sites*								
5.8	**Binningup Seawall**	Monitor & Redesign	Manage Access	Implement Revised Option			*Future Pathway Depends on Option Selected*					
5.9	**Harvey Diversion**	Monitor	Reduced Access	Remove Training Wall Manage Dune Vegetation			Excavate Channel Entrance		Reconfigure Channel Entrance			Manage Flood Risk
5.10	**The Cut**	Review Structure Design & Function		*Implement Progressive Retreat & Modification*								
5.11	**Sedgelands**	Foredune & Traffic Management			*Sedgelands Likely to be Lost*							

Table 7-3: Summary of Management Actions

8 IMPLEMENTATION

8.1 Implementation Plan (2016-2020)

The set of actions outlined for each of the identified assets in Section 6 and more briefly summarised in Section 7 require different levels of implementation by the Shire and co-ordination with other agencies. Four levels have been identified:

- **Implementation** components are those which should be physically delivered within the next 5 years. They have been identified from management actions within the 2016-2020 timeframe (Section 7.6);
- **Budget** components are those which require inclusion in Shire budget forecasts. They have been identified from management actions within the 2021-2035 timeframe;
- **Planning** components are those which should be integrated into Shire planning documents or require external capital funding sources. They have been identified from management actions within the 2035-2065 timeframe; and
- **Strategic** components are those for which a strategy requires further development. They have been identified from management actions within the 2065-2115 timeframe.

Actions required in the next 5 years are summarised in Table 8-1. Undertaking policy and tenure revision to support more effective long-term coastal management (through better governance) is a complex task and therefore requires focus within the next 5 years.

Table 8-1: Actions Required in the Next 5 Years

Components	Action in the Next 5 Years	Action By	Co-ordinate With
Implementation	Policy & tenure revision	Shire	Planning
	Dune management education	Shire	DPaW
	Coastal monitoring program	Shire	PNP
	Beach use assessment	Shire	
	Geophysical investigation	Shire	
	Redesign Binningup Seawall	Shire	Community
	Assess sedgelands & develop strategy	DPaW	Land-owners
	Review Cut training walls	State Govt	
Budget	Coastal monitoring program	Shire	PNP
	Active dune management	Shire	
	Relocate Myalup carpark	Shire	Community
	Rebuild beach access points	Shire	
	Modify Cut training walls	State Govt	
Planning	Replace Binningup Seawall Facility	Shire	Community
	Relocate Myalup caravan park	Shire	Lease-holders
	Building relocations north of Myalup	Shire	Land-owners
	Modify Binningup Road access	Shire	Land-owners
	Modify Harvey Diversion entrance	Water Corp	Shire
Strategic	Binningup land swap / purchase	Shire	
	Binningup coastal protection	Shire	

Consideration of the resources required to undertake recommended actions is presented in Table 8-2. Tasks are coloured using the resource allocation scheme from Table 6-1. These show the generally low resource requirements within 10 years and the increasing requirements at later dates.

	Approximate Timing	2016-2020	2021-2025	2026-2035	2036-2045	2046-2055	2055-2065	2065-2075	2076-2085	2086-2095	2096-2105	2106-2115
5.1	**Binningup**	Coastal Monitoring				Active Dune Management				Coastal Protection Works		
5.2	**Binningup Access**	Inundation Monitoring			Surge Valve	Increase Culvert		Armour Embankment		Raise Embankment		
5.3	**Myalup**	Dune Management		Relocate Carpark		Retreat Caravan	Relocate Caravan	Dune Buffer	Active Dune Management			
5.4	**Other Residential**	Foredune Management		Vegetation Buffer		Scarped Buffer		Building Relocations				
5.5	**Dune Vegetation**	Existing Management		Foredune Loss		Increasing Primary Dune Mobility						
5.6	**On-Beach Activities**	Existing Management Establish Baseline		Minor Constraints to Beach Access Expected				Major Constraints to Beach Access Expected				
5.7	**Beach Access**	Existing Management		*New Beach Access Paths Required at Majority of Sites*								
5.8	**Binningup Seawall**	Monitor & Redesign	Manage Access	Implement Revised Option			*Future Pathway Depends on Option Selected*					
5.9	**Harvey Diversion**	Monitor	Reduced Access	Remove Training Wall Manage Dune Vegetation			Excavate Channel Entrance		Reconfigure Channel Entrance			Manage Flood Risk
5.10	**The Cut**	Review Structure Design & Function		*Implement Progressive Retreat & Modification*								
5.11	**Sedgelands**	Foredune & Traffic Management			*Sedgelands Likely to be Lost*							

Resources

Negligible	Reallocation	Extension	Supplementary	Major Capital

Table 8-2: Resources Required for Management Actions

8.2 CHRMAP Evaluation and Revision

This CHRMAP has been developed as an initial version, based upon existing knowledge. Application of the plan will demonstrate opportunities for refinement. It is recommended that the CHRMAP be treated as a live document, with ongoing evaluation and revision.

A practical approach is for a document custodian to be identified, who will act to collate knowledge relevant to implementation of the CHRMAP. A register of information will be collected by the custodian, which identifies alternate components of the CHRMAP and is able to make them available as addenda. Revision of the CHRMAP is appropriate either when new information is in direct conflict with the existing version, or a large number (say 10) of minor addenda have been developed.

It is anticipated that the CHRMAP will require revision on approximately a 5-10 years basis, which is a practical timeframe for updating the 5-year implementation plan (Table 8-1).

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