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R1818 Rev 0

July 2023

RAC Tourism Assets

Ningaloo Reef Resort
Coastal Hazard Risk Management & Adaptation Plan

marinas
boat harbours
canals
breakwaters
jetties
seawalls
dredging
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Limitations of this Document

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1. Introduction

RAC has a publicly stated strategy of developing a portfolio of tourist accommodation assets in Western Australia. RAC's strategy focuses on accommodation that provides its 900,000 Western Australian members, and the broader tourist community, with a better standard of mid-range, value for money, family friendly accommodation in iconic established tourist destinations around Western Australia. RAC's focus is on providing amenities that can be enjoyed by RAC members and non-members alike whilst also contributing to and supporting local communities in regional locations. To sustain the strategy, RAC seeks to achieve reasonable returns on member funds for reinvestment into the strategy.

RAC purchased Ningaloo Reef Resort (NRR) in 2015 (the 'Resort'). If economically feasible, it is intended that the Resort will be redeveloped, resulting in a $80 million investment in the local community, with corresponding increases in tourist patronage to the region as a result of the development.

The existing Resort is a 40-year-old ocean front, 3-star hotel on an irregular shaped allotment which comprises a bar (with alfresco area to the front), restaurant, reception / office, 34 accommodation rooms, below ground swimming pool and staff accommodation located to the rear within a number of in-situ buildings and eight transportable buildings that are to be removed. The property is aged and at the end of its economic life.

RAC's vision for the redevelopment is to provide:

> *"a contemporary four-star beach Resort experience at World Heritage Ningaloo Reef where members can relax, explore and reconnect with loved ones. RAC Ningaloo Resort will deliver high quality, value for money accommodation, service and amenity, offering both self-catering and full-service experiences for a range of target markets with a focus on families. A flagship Resort asset in the RAC portfolio, it will showcase the renowned and unique casual 'sandy feet' Coral Bay experience in accommodation that complements the quality of the natural environment on its doorstep."*

Furthermore, it is intended that the Resort redevelopment will:

- Interpret the high standard of marine and terrestrial activities in the region to encourage length of stay.
- Retain a large area of green lawn and open spaces in which to relax and play, providing the option for all markets to enjoy a low-key Resort experience at the property as well as the range of activities outside the property.
- Provide accommodation types that target the family, grey nomad and coach markets (across RAC member, domestic and international visitor types).
- Be capable of satisfying escorted coach travellers, fly-in guests and weddings/functions.
- Provide RAC flagship standards of presentation and service for RAC members, their families and the WA community at large.

The above outcomes will help to increase the level of tourist patronage in the region which will have a direct benefit to the local economy.

As the Resort has a coastal frontage (Figure 1.1), the risks posed to the site from coastal hazards need to be considered both now and into the future. Notwithstanding the potential risks, RAC is committed to pursue redevelopment of the resort if economically feasible. Redevelopment, for the benefit of its members and the broader community, will provide world class, yet affordable, family orientated accommodation and amenities, which will provide a boost to the WA Tourism Industry.

1.1 Coastal Hazard Assessment Requirements

Within Western Australia, State Planning Policy 2.6: State Coastal Planning Policy (SPP2.6; WAPC, 2013) provides guidance on the assessment of coastal hazard risks for assets or infrastructure located in close proximity to the coast. The objectives of SPP2.6 are wide ranging, however a key component of SPP2.6 is to provide focused areas of the coast for use by the public to access and enjoy the coastal amenity that is inherent in the Western Australian lifestyle. This includes allowing for tourism developments at appropriate locations through provision of access to the foreshore reserve in these areas. Table 1.1 provides further details of how the proposed redevelopment of the Resort is consistent with the stated objectives of SPP2.6.

Table 1.1 Alignment of Proposed Development with SPP2.6 Objectives

SPP2.6 Policy Objectives	Details of Proposed Resort Redevelopment
1. Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical criteria.	The Resort site is already significantly developed and has been in place for approximately 40 years. Over this time there is significant documented evidence that indicates that this section of coastline is stable.
2. Ensure the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities.	The Resort has existed for over 40 years in its current location and is strongly supported by key stakeholders including State and Local Governments. The Resort is already used for; tourism, recreation, ocean access, commercial and other activities. The redevelopment of the site is also consistent with the site use identified within the Coral Bay Settlement Structure Plan (as discussed in subsequent sections of this report).
3. Provide for public coastal foreshore reserves and access to them on the coast.	As above at (2). This site is extensively used by local visitors, domestic and international tourists with a long history of successful public access and cooperation with neighbouring entities.
4. Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.	The proposed redevelopment is consistent with previous planning for the Coral Bay Settlement. The proposed redevelopment will significantly increase the capacity of the Resort through better utilisation and densification of the existing area. This development approach therefore eliminates the requirement for additional land to be made available to cater for increased tourist accommodation, thereby reducing the impact on the local landscape, biodiversity and ecosystem integrity, as well as areas of indigenous and cultural significance.

The guidance on the assessment of coastal hazard risk is provided within SPP2.6 in the form of a methodology to assess the potential extent of coastal hazard impacts, as well as for the development of a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Further details in this regard are also provided in the CHRMAP Guidelines (WAPC, 2019).

The key requirement of a CHRMAP is to develop a risk based adaptation framework for assets or infrastructure that could be at risk of impact by coastal hazards over the relevant planning timeframe. Importantly, the balance of these risks needs to be considered with reference to the expected lifetime of the asset/infrastructure.

To provide guidance regarding the risks posed by coastal hazards, RAC engaged specialist coastal and port engineers, M P Rogers & Associates Pty Ltd (MRA), to complete a CHRMAP for the Resort. This CHRMAP covers the following key items.

- Establishment of the context.
- Coastal hazard assessment.
- Risk analysis and evaluation.
- Risk management and adaptation planning.
- Implementation Plan.

Details regarding each of these items will be provided in this report.

2. Context

2.1 Purpose

The potential vulnerability of the coastline and the subsequent risk to the community, economy and environment needs to be considered for any coastal development.

SPP2.6 requires that the responsible management authority or development proponent prepares a CHRMAP where an existing or proposed development may be at risk from coastal hazards over the planning timeframe. The main purpose of the CHRMAP is to define areas of the coastline which could be vulnerable to coastal hazards and to outline the preferred approach to the monitoring and management of these hazards where required.

A CHRMAP can be a powerful planning tool to help provide clarity to existing and future developers, users, managers, or custodians of the coastline. This is done by defining levels of risk exposure, management practices and adaptation techniques that the development proponent, with agreement from the appropriate management authority, considers acceptable in response to the present and future risks posed by coastal hazards.

Specifically, the purpose of this CHRMAP is as follows.

- Confirm the specific extent of coastal hazards.
- Outline the risks associated with the Resort and how this risk may change over time.
- Establish the basis for present and future risk management and adaptation, which will be used to inform the development of the masterplan for the redevelopment of the site.
- Provide guidance on appropriate management and adaptation planning for the future, including monitoring.

2.2 Objectives

The key objective of this plan is to assess the coastal hazard risks associated with the redevelopment of the Resort. Once these risks have been assessed, adaptation strategies can be developed to help mitigate the risks where necessary. These need to be considered in the context of the risks posed to existing assets, as any future mitigation strategies for existing assets may impact the proposed redevelopment.

Whilst the risks of coastal hazards are to be considered for different timeframes, the future behaviour of the shoreline could be variable for a variety of reasons. As a result, the requirement to consider the implementation of future adaptation strategies should be informed by an ongoing coastal monitoring regime. A recommended monitoring regime is included within this report.

2.3 Scope

The *CHRMAP Guidelines* (WAPC, 2014) provide a specific framework for the preparation of a CHRMAP. This is outlined in the flowchart presented in Figure 2.1 which shows the risk management and adaptation process.

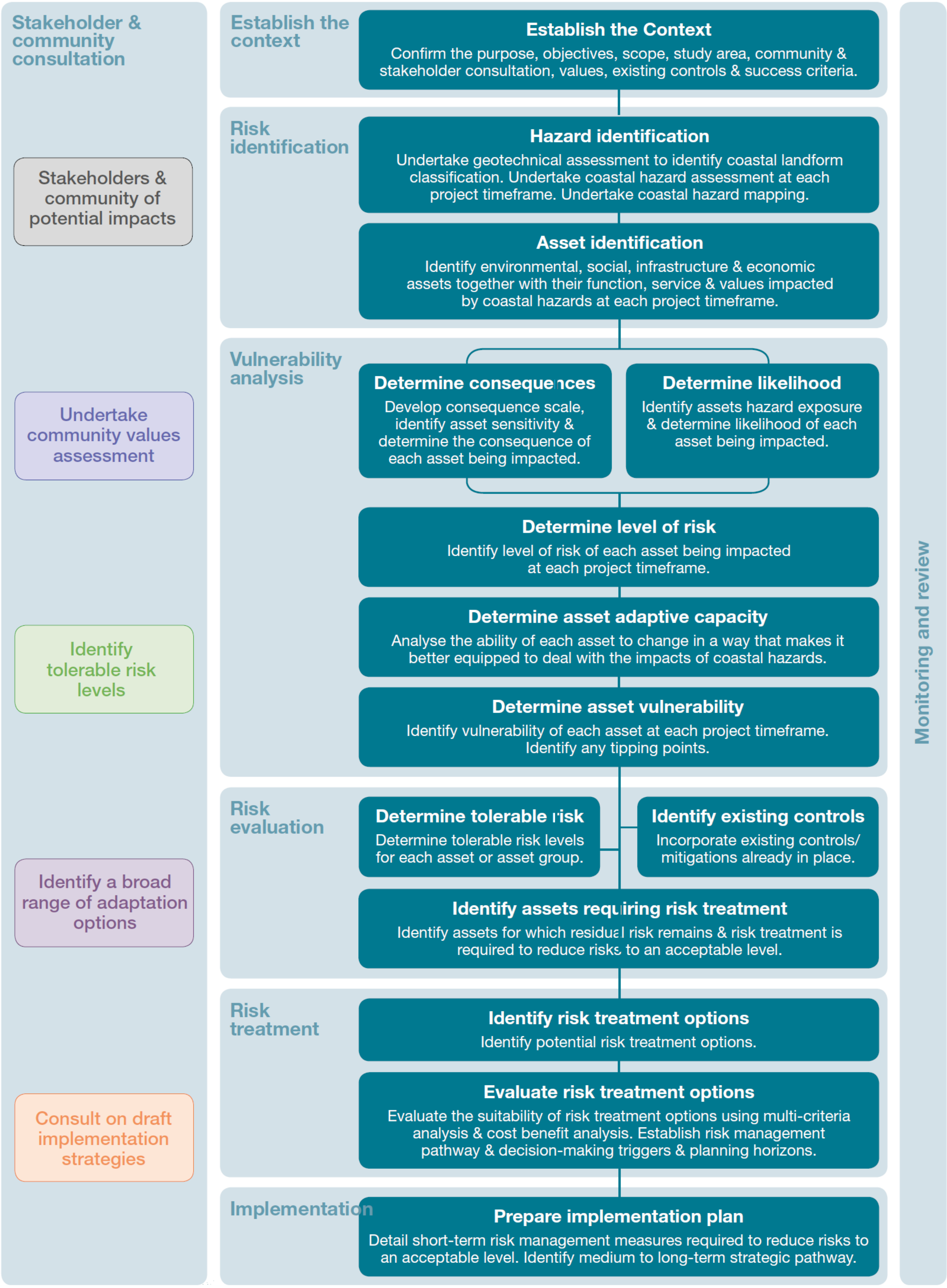


Figure 2.1 Risk Management & Adaptation Process Flowchart (WAPC 2019)

As presented in the flowchart, the process for the development of a meaningful CHRMAP requires a number of fundamental inputs. These inputs enable the assessment and analysis of risk, which should ultimately be informed by input received from key stakeholders, to help shape the subsequent adaptation strategies. Typically, key stakeholders would include members of the local community, however given that Coral Bay is a tourist centre, with no significant residential population, meaningful community consultation would not be possible. The consultation has therefore relied heavily on input from the Shire of Carnarvon to help guide management strategies and adaptation requirements.

Notwithstanding, the engagement process has focussed on the following key agencies/entities.

- Shire of Carnarvon (Shire).
- Department of Biodiversity, Conservation and Attractions (DBCA).
- Department of Aboriginal Affairs.
- Department of Fire and Emergency Services (DFES).
- Department of Planning, Lands and Heritage (DPLH).
- Department of Transport (DoT).

Through the early stages of stakeholder consultation, it has become apparent that the project enjoys strong support, particularly from the State and Local Government.

The management of coastal hazard risk associated with the Resort will be required to present a proposed adaptation plan that is acceptable to the stakeholders. As a result, the approach that has been taken for this plan is to develop a management methodology that allows for flexibility into the future.

The development of the adaptation plan will be informed by the assessment of the coastal erosion and inundation hazards. Assessment of the coastal erosion and inundation hazards is presented within Section 3 of this report.

This CHRMAP will consider the potential risks posed by coastal hazards over a range of timeframes covering a 100 year planning horizon. This planning horizon is required by SPP2.6 for development on the coast.

Intermediate planning horizons will also be considered in order to assess how risk profiles may change in the future and to inform the requirement for adaptation strategies. Intermediate planning horizons that will be considered are below.

- Present Day.
- 25 years.
- 40 years.
- 50 years.
- 100 years.

Based on the results of the risk and vulnerability assessment, risk mitigation strategies will be developed, where required, in order to provide a framework for future management. However, it is important to realise that the risk assessment will be based on the outcomes of the coastal vulnerability assessment, which, by their nature, are justifiably conservative. This is due to the uncertainty around coastal dynamics when predicting impacts over long timeframes. As a result, the framework for future risk management strategies should be considered to be a guide of future requirements.

The actual requirement for implementation of these management actions should ultimately be informed by a coastal monitoring regime. The purpose of this coastal monitoring regime would be to identify changes in the shoreline or sea level that could alter, either positively or negatively, the risk exposure of the proposed infrastructure. A recommended coastal monitoring regime is included within the implementation plan, presented within Section 7 of this report.

2.4 The Site

Coral Bay is located on the West Australian coast approximately 1,120 kilometres north of Perth and is within the Ningaloo Reef region which became a world heritage listed area in 2011. Coral Bay is approximately 140 kilometres south of Exmouth and approximately 220 kilometres north of Carnarvon (refer Figure 2.2).

Coral Bay town-site is a small tourist settlement comprising a handful of freehold allotments. In addition to the Resort, there are 2 caravan parks, a new tavern, a small commercial complex, a backpacker's lodge and approximately 15 houses. The Resort is the western most tourist site overlooking the ocean at Coral Bay.

The Resort site is an irregular shape with road frontages to both the front (northern) boundary and rear (southern) boundary. The southern boundary abuts an unmade road (Banksia Ave) that is identified within the Coral Bay Settlement Structure Plan (discussed further in Section 2.6). The site generally lies above road level and rises slightly towards the rear (south).

Preliminary site investigations have been completed at the Resort and the proposed development includes some fill at the western portion of the site to achieve appropriate grades and levels across the site. The proposed levels have been taken into account by the coastal hazard assessment in Section 3.

Access to the property is from a dual way vehicular crossover from Robinson Street which leads to a small car park. Robinson Street is the main road extending through the town.

It is proposed by the Shire that Banksia Drive (south and west of the Resort) will be constructed and used as the main access to the subject property and adjoining properties at a later date.

Figure 2.2 Location of the Resort Site

2.4.1 Physical Setting

The shoreline frontage of the Ningaloo Reef Resort is very well protected by the adjacent fringing Ningaloo Reef. The elevation and extent of the reef is such that only low waves are experienced at the shoreline (Short 2006). The extent of the reef is best illustrated on the local nautical chart, an extract from which is provided in Figure 2.3.

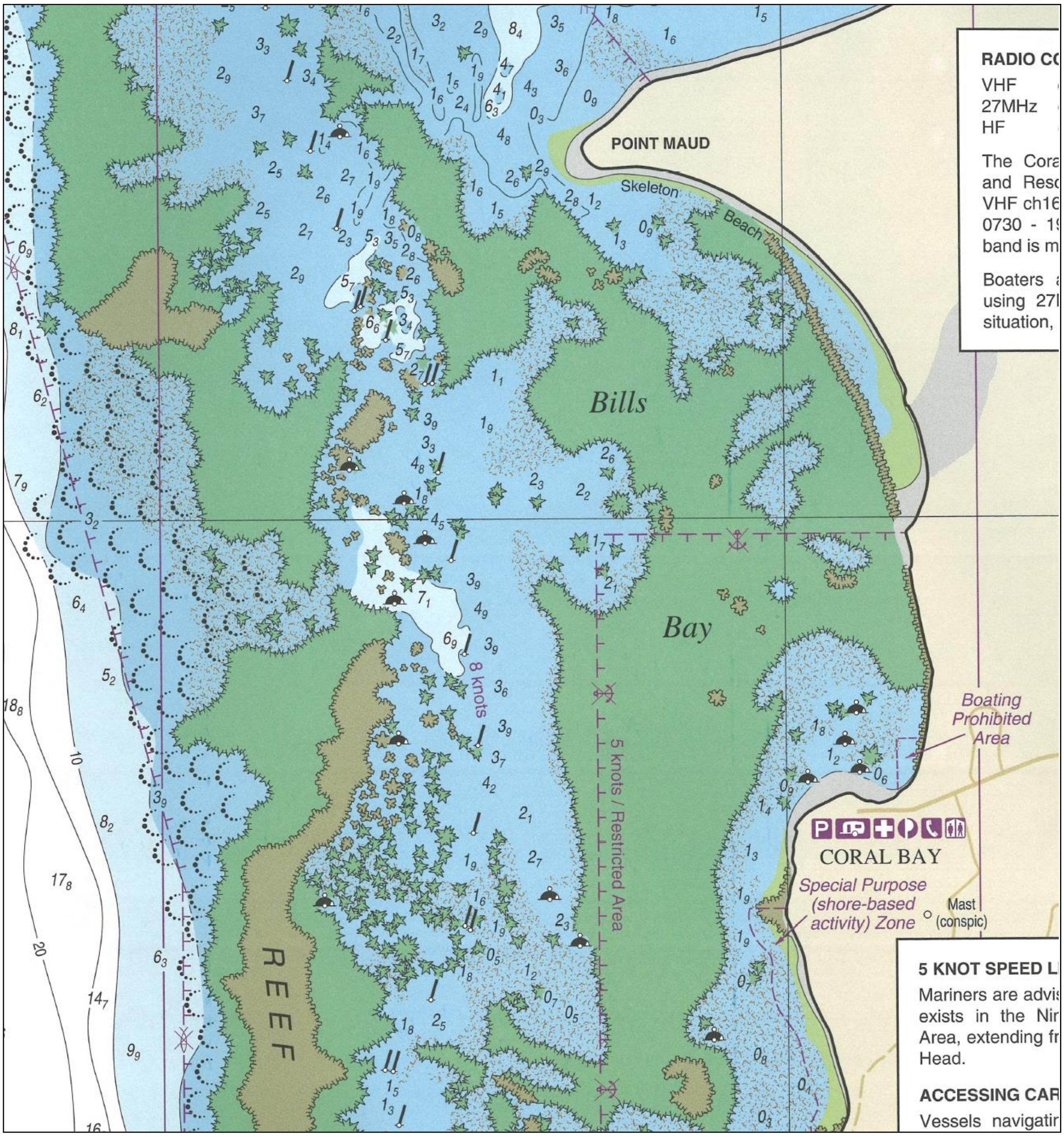


Figure 2.3 Extract from Local Nautical Chart (source DoT 1108)

The main frontage of the Resort site has a northerly aspect across Bills Bay. The northern aspect of this shoreline coupled with the prevailing southerly wind regime, means that there is only a low elevation dune system present in front of the Resort.

To the west of the Resort site the shoreline is characterised by a more prominent dune system, with elevations typically greater than 10 mAHD. Visible rock is also present along this section of shoreline, with a prominent section of rock at the northern end of the beach acting as a key shoreline control point. Exposed sections of rock can be observed along much of this section of beach, with outcropping visible within the dunes.

Photographs of the northern and western shorelines are provided in Figures 2.4 to 2.6.

Figure 2.4 View of Resort Site from Northern Shoreline

Figure 2.5 View North across the Northern Shoreline from the Resort

Figure 2.6 View of Western Shoreline Including Exposed Rock

2.5 Stakeholder Engagement

RAC's project team have engaged with a number of government agencies, including the Shire of Carnarvon. This consultation seeks to build upon previous consultation that was completed during preparation of the *Coral Bay Settlement Structure Plan* and the approved *Overall Development Plan* (discussed in Section 2.6.2) which forms part of the Shire's Local Planning Scheme 11. The consultation for this project is ongoing to ensure all agencies are fully briefed and aware of the redevelopment proposal as it progresses. Consultation shall continue throughout the planning process for the redevelopment.

Of particular significance to the proposed development, consultation with the Shire has identified that, whilst the Shire are yet to undertake a formal CHRMAP process for Coral Bay, the intention of the Shire is to maintain Robinson Street until the extent of coastal change makes it uneconomical to do so (should that eventuate). Whilst any action that seeks to maintain Robinson Street in its current location would also benefit the Resort site, for the purposes of this assessment such additional management actions have not been considered.

In summary, the project enjoys strong support from the State and Shire. Tourist guests and visitors have long called for this redevelopment.

2.6 Existing Planning Controls

The proposed redevelopment of the Ningaloo Reef Resort has regard for a number of planning requirements and/or considerations. Details of these are provided within this section.

2.6.1 Land Tenure & Ongoing Management

The proposed tourism accommodation and associated infrastructure shall be contained with the following three titles:

Table 2.1 Relevant Land Titles

Lot	Existing Site Use	Diagram/Plan	Volume/Folio	Registered Proprietor
Lot 1	Resort Site	77929	2082/383	RAC Tourism Assets Pty Ltd
Lot 54[1]	Holiday Home	192641	LR3104/261	Leasehold Now subject to a pending lease agreement between RAC and the DPLH. Responsible agency: DPLH
Lot 68	UCL, Pump Station An 898m2 easement is located within the western portion of Lot 68	37167	LR3157/300	Unallocated Crown Land Primary interest holder: State of Western Australia

RAC is committed to the ongoing management of coastal risk and the acceptance of this risk as part of the redevelopment across the three titles. This acknowledgement is discussed in later stages of this report.

The risk management and adaptation requirements for these lots will be determined in the next phase of the CHRMAP process, however construction of coastal protection works to protect these sites is not something that would be contemplated by RAC unless the Shire's future CHRMAP identified this as the preferred adaptation strategy for the broader region.

2.6.2 Strategic Planning Considerations

Draft Gascoyne Coast Sub- Regional Strategy

The Western Australian Planning Commission (WAPC) released its Draft Gascoyne Coast Sub-Regional Strategy during the first quarter of 2017. Coral Bay has been identified under the draft Strategy as a 'Tourism Centre'. According to the Strategy:

> *Tourism centres have a small population base and their local economies are focused on tourism. These centres experience significant fluctuations in population due to the seasonal influxes of tourists; and as such are generally service and experience oriented with some associated retail functions. Despite sitting on the same level in the settlement hierarchy as Subregional centres, Tourism centres generally contain minimal civic and social infrastructure as they predominantly service an itinerant population base.*

The Strategy outlines three strategic directions in the context of encouraging tourism:

- Encourage the expansion and diversification of the tourism sector.
- Supporting the development of strategic and sustainable tourism and recreation infrastructure and services to cater for an anticipated increase in demand.
- More intensive, higher-impact tourism development should be concentrated in the existing regional and Subregional centres of Carnarvon, Exmouth and Denham; and to a lesser degree in the tourism centres such as Coral Bay.

Carnarvon Tourism Strategy

The Shire of Carnarvon Tourism Strategy outlines Carnarvon's tourism potential, and how to realise this opportunity. Coral Bay has been identified as a key contributor to the region, aligning with the State's vision of enhancing these secluded locations. The Strategy outlines an action plan specific to Carnarvon, however it mentions the importance of Coral Bay in promoting the region as a tourism destination.

Shire of Carnarvon Local Planning Strategy

The Shire of Carnarvon Local Planning Strategy was established to guide land-use and decision-making in the Shire for the next 10-15 years. Key aims include the following.

- Set out the key aspirations of stakeholders.
- Accommodate the future needs of the community.
- Create opportunities to enhance and protect local attributes.
- Provide a framework to achieve long-term local and regional objectives and goals.

Under the strategy, the Coral Bay Local Planning Strategy Plan outlines actions specific to the Coral Bay region. One of these actions is to ensure the ongoing protection of the foreshore reserve and public open space areas. This is relevant to the subject site, proposing the enhanced interaction between the foreshore area and tourism development. Long-term opportunity for tourism development in Coral Bay is outlined as another action, highlighting the need to ensure investment is sustainable and protected from associated coastal processes.

Shire of Carnarvon Local Planning Scheme No. 11

The Coral Bay Townsite, inclusive of the subject site, is zoned 'Coral Bay Settlement' pursuant to the Shire of Carnarvon Zoning Scheme No. 11 (the Scheme) and located within the 'Ningaloo Policy Area'. Lot 1 is located within the 'Tourism Precinct'.

> *"'Tourism Precinct' Goal:*
>
> *To promote development of a variety of short stay accommodation facilities and associated amenities which are consistent with the overall theme and scale of Coral Bay."*

The redevelopment of the subject site for tourism accommodation purposes is therefore consistent with the local, regional and state strategic framework. This planning framework seeks to shape Coral Bay as a key tourism destination node, with an objective of facilitating continued growth. This government framework therefore aligns with the Development and Settlement Policy measures of SPP 2.6 referred to under 5.2 (iii):

> *"Ensure that when identifying areas suitable for development, consideration is given to strategic sites for coastal access and commercial development that is demonstrably dependent on a foreshore location…"*

2.6.3 Environmental Requirements

Bushfire Prone Areas

Portions of the site are currently located within a designated bushfire prone area. As the site is cleared for the required accommodation areas and supporting infrastructure the fuel load levels shall be reduced significantly. In particular, the proposed clearing or maintenance of fuel loads within specific areas adjacent to the site (i.e. new car park along the western boundary, the construction of the currently unmade Banksia Terrace reserve along the southern boundary). In accordance with SPP 3.7 and the associated guidelines, the internal road and tourist accommodation layout shall be influenced by the outcomes of the Bushfire Attack Level contour plan and associated Bushfire Management Plan.

Flora and Vegetation

An Environmental Evaluation Report prepared by Strategen in 2012 revealed that 22 native plant species were located on site, with the common plant genus observed in the area as Acacia, Triodia and Atriplex. No declared rare flora protected under the Wildlife Conservation Act 1950 or threatened species listed under the Environmental Protection and Biodiversity Act was found. Three introduced weed species were identified as; Cenchrus ciliaris (buffel grass), Aerva javanica (Kapock bush) and Tamarix aphylla (athel pine). Buffel grass and athel pine are listed as Weeds of National Significance and athel pine is listed as a declared plant under the Agriculture and Related Resources Protection Act 1976. The flora on the site is generally degraded with little resemblance to the original vegetation association.

Fauna

Stratagen undertook a fauna assessment of the site, identifying that the Ardeotis australis (Australian bustard) may occur in the study area. In addition to this, three turtle species namely: Caretta (loggerhead turtle), Chelonia mydas (green turtle), Eretmochelys imbricate (hawksbill turtle), may nest along the adjacent shore line.

Foreshore Area

The Coral Bay Foreshore Management Plan was initiated by the former Department of Environment and Conservation (now known as the DBCA) with the intent of identifying clear objectives for the management of the foreshore that reflect the needs of recreational and commercial users of Coral Bay/ Ningaloo Marine Park. The foreshore area in Coral Bay covers approximately 39 ha including 17.3 ha of Reserve and 21.7 ha of Unallocated Crown Land (UCL), including a 5.4 ha C-Class reserve.

The planning objective for the foreshore is "*to reserve remaining foreshore areas in the north and south of Coral Bay tourist settlement and manage the reserve to ensure protection of the coastal environment for the benefit of the greater community*". Key management issues have been identified as: strategic planning, community consultation, socio-cultural context and biophysical context. Management objectives must ensure that high use foreshore areas are managed to prevent conflict between coastal users, while limiting degradation or ecological and cultural values.

The Management Plan identifies foreshore zones, with zones 1a and 1b relevant to the subject site.

Table 2.2 Foreshore Zones

Zone	Context	Management Issues		Recommendations
		Biophysical	Socio-Cultural	
1a – Fletcher Hill. High Use/ Active Recreation	-Fletcher Hill is set on a sandy, eroded headland to the west of Baz's Park. -The proposed parking area to be accessed from Banksia Drive has numerous tenures including UCL, closed road reserve, crown release, foreshore reserve, day use car parking and hotel. No managing authority has been identified for this infrastructure. -The foreshore zone is adjacent to the subject site.	-Potential drainage issues associated with the proposed car park. -Uncontrolled access to the beach has led to track proliferation and blowouts.	-Fletcher Hill lookout is in poor structural condition and has a considered safety hazard. -Evidence of activity conflict is apparent, particularly with water based activities and commercial tour operators.	-Amend land tenure from UCL to Foreshore Reserve under DBCA's management to ensure consistent future management efforts are applied to the foreshore. -Ensure all car park drainage is captured and infiltrated as close to the source as possible before draining into the foreshore reserve.
2a – High Use/ Conservation	-West-facing, undulating dune area forms the southern complex connecting Fletcher Hill to southern extent of town site. -The foreshore zone is adjacent to the southern extent of the subject site.	-Buffel grass within the dune system is competing with local flora. -Uncontrolled access has led to track proliferation. -Management issues associated with extreme climatic conditions.	-Currently zoned UCL and past management efforts have been limited by tenure. -Uncontrolled access over a long time.	-Amend land tenure from UCL to Foreshore reserve under DBCA's management to ensure consistent future management efforts. -Construct identified secondary paths providing designated beach access.

It is clear from the Foreshore Management Plan that the DBCA intend to invest in coastal infrastructure adjacent to the subject site. Opportunities to minimise the potential impact to the foreshore reserves as a result of development are addressed throughout the Plan.

2.7 Key Assets

The proposed redevelopment of the Resort is being prepared with the specific requirement to not impact the social and environmental values of the area, as to do so would be an unacceptable outcome to key stakeholders and would detract from the tourism potential for the site. As a result, the preservation of social and environmental values are considered to be inherent in the development of the redevelopment plan.

It has therefore been identified that a coastal adaptation strategy will need to be prepared to ensure that there is no impact on the social and environmental values of the area. This will require a coastal adaptation strategy that, pending the results of the coastal hazard assessment, ensures the Resorts facilities are appropriately designed and managed to safeguard against adverse impacts. This assessment will be completed with regard for the expected economic life of the facilities that will be constructed for the resort. For instance, it is envisaged that the design life of structures within the Resort will be limited to around 40 years. Beyond this period it is expected that the condition of the facilities would be such that they would need to be replaced, similar to the current scenario with the existing Resort.

In this regard, whilst the key social and environmental assets are discussed below, the planning for the development has already addressed the risks associated with these assets. Further details in this regard will be discussed below, as well as in later sections of this report.

2.7.1 Social Assets

The Ningaloo Reef Resort itself is a key social asset and a domestically and internationally significant tourist destination. Redevelopment of the Resort will ultimately make this facility more available to visitors, increasing tourism patronage – which is consistent with the Shire and State's current objectives. The popularity of this asset is undeniably linked to the natural beauty of the adjacent beaches and the ability to interact with the surrounding coral reef and marine life. Whilst these are both considered to be environmental assets, the social importance of these cannot be underestimated. In this regard, both of these assets must be preserved into the future. The planning for the proposed development ensures that this is the case.

2.7.2 Environmental Assets

Section 2.6.3 provided details of the environmental requirements across the site. However, from a coastal perspective the most critical issue is the preservation of the adjacent beaches and the protection of the Ningaloo Reef and marine fauna. As stated previously, it is inherent within this proposal that the beach and foreshore be maintained and that there be no impact on the Ningaloo Reef and surrounding marine life. For this reason management and adaptation strategies have been proposed to circumvent any issues that could arise. Full details of these strategies will be discussed in later sections of this report; however, the strategies include the following.

- Installation of shut off valves on services to prevent any potential leakage during severe coastal events.

- Recognition that facilities may need to be migrated landward in the future to avoid risks associated with coastal hazards.

2.7.3 Economic Assets

A preliminary masterplan for the redevelopment of the Resort is presented in Figure 2.7. This preliminary masterplan has been included to show the types of assets that are expected on the site. It should be noted that the layout for the proposed development could change slightly from that shown in Figure 2.7. Nevertheless, any such changes to the layout would only be completed if the changes were consistent with the outcomes and recommendations of this CHRMAP.

The key economic assets (existing and proposed) within the Resort have been summarised in Table 2.3. As the management of social and environmental assets are inherent within the proposal, the risk assessment will focus on these economic assets. The purpose of this process is twofold. First, to assist with the planning for the redevelopment of the Resort and the understanding of the financial risk exposure, and second, to help inform risk management strategies where required.

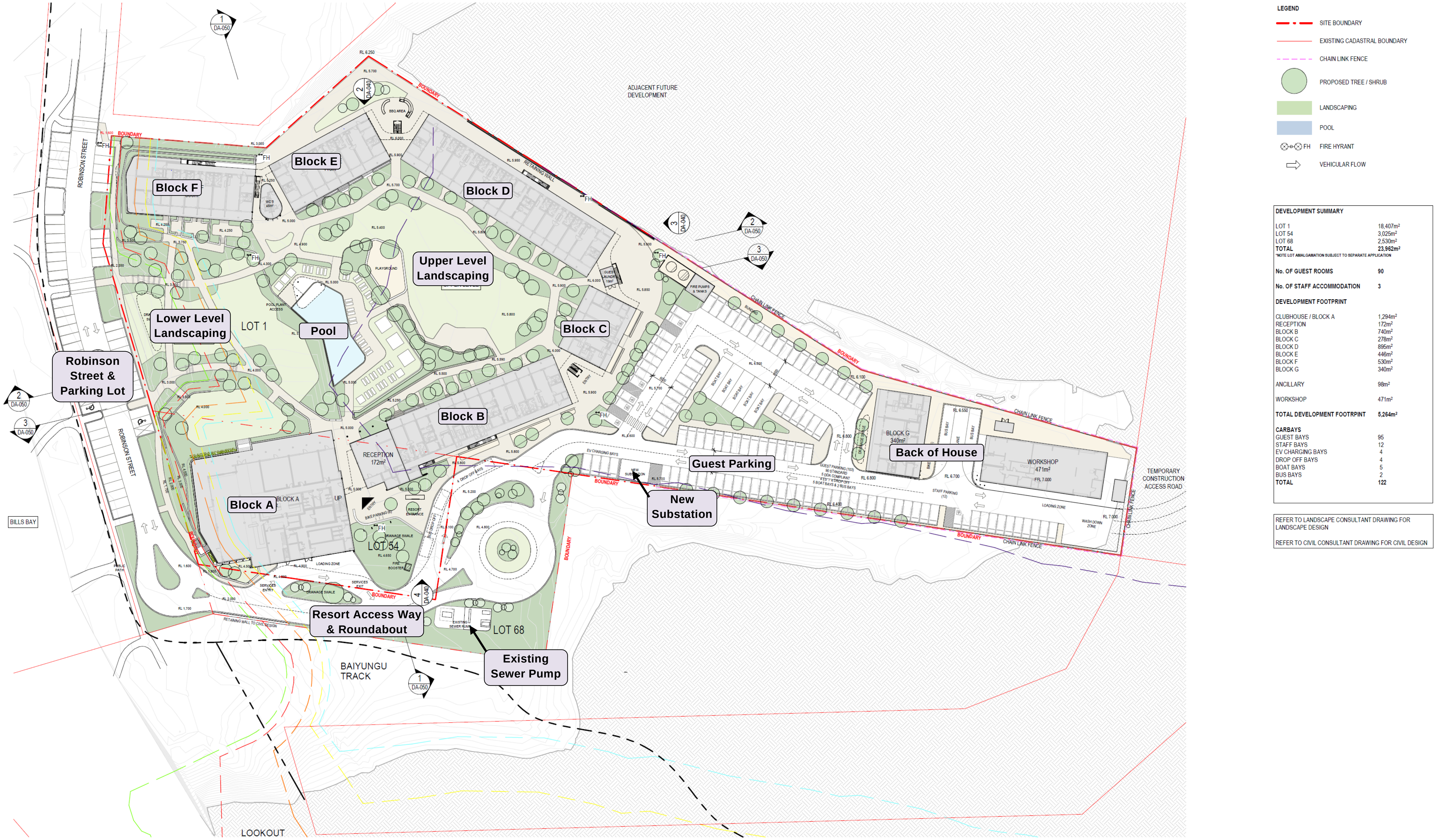


Figure 2.7 Preliminary Architectural Drawings

Table 2.3 Key Assets within and Surrounding the Resort

Key Assets	Elevation (mAHD)
Block A - Clubhouse	4.9
Block B - Accommodation	>5.0
Block C - Accommodation	6.0
Block D - Accommodation	6.0
Block E - Accommodation	6.0
Block F - Accommodation	5.0
Back of House (including workshop, laundry, office, gas storage tank and general store area)	>5.6
Existing Sewer Pump	5.0
New Substation	>5.6
Pool	5.0
Lower Level Landscaped Areas	3.5
Upper Level Landscaped Areas	5.0
Guest Parking Areas	>5.6
Resort Access Way and Roundabout	2.5
Robinson Street & Parking Lot	~2.0

Notes: 1. Elevations are based on the lowest proposed development ground level for each asset group.

2.8 Success Criteria

The success criteria for the CHRMAP will ultimately be as follows.

- To understand the potential extent of impact of coastal hazards on the Resort.
- To understand the potential/likelihood of infrastructure within the Resort being impacted by coastal hazards over each planning horizon.
- To understand the consequences of infrastructure being exposed to the different coastal hazards.
- To determine total risk ratings for each item of infrastructure.
- Development of an acceptable risk management and adaptation strategy for the proposed development whilst maintaining a high level of social and environmental amenity.

- Development of an implementation plan to outline the requirements and responsibilities over time.

The outcomes of the success criteria listed above are presented in the following sections of the report.

3. Coastal Erosion Hazard Identification

An understanding of the coastal hazards and risks is critical for the assessment and determination of management and adaptation actions.

Schedule One of SPP2.6 presents the recommended methodology for calculation of coastal erosion hazards for coastal development. This assessment methodology requires that consideration be given to the potential impacts of each of the following.

- Severe storm erosion associated with the 1% Annual Encounter Probability (AEP) event – which is equivalent to a 100 year Average Recurrence Interval (ARI) event – (termed the S1 Allowance).
- Long term shoreline movement (termed the S2 Allowance).
- Sea level rise (termed the S3 Allowance).
- Appropriate allowances for uncertainty.

The calculations of the erosion allowances are presented in the following sections.

3.1 S1 Erosion Allowance – Severe Storm Erosion

Severe storm events have the potential to cause increased erosion to a shoreline, through the combination of higher, steeper waves generated by sustained strong winds, and increased water levels. These two factors acting in concert allow waves to erode the upper parts of the beach not normally vulnerable to wave attack.

If the initial width of the surf zone is insufficient to dissipate the increased wave energy, this energy is often spent eroding the beach face, beach berm and sometimes the dunes. The eroded sand is transported offshore with the return water flow to form offshore bars. As these bars grow, they can cause incoming waves to break further offshore, decreasing the wave energy available to attack the beach. This is shown diagrammatically in Figure 3.1 for a sandy coastline.

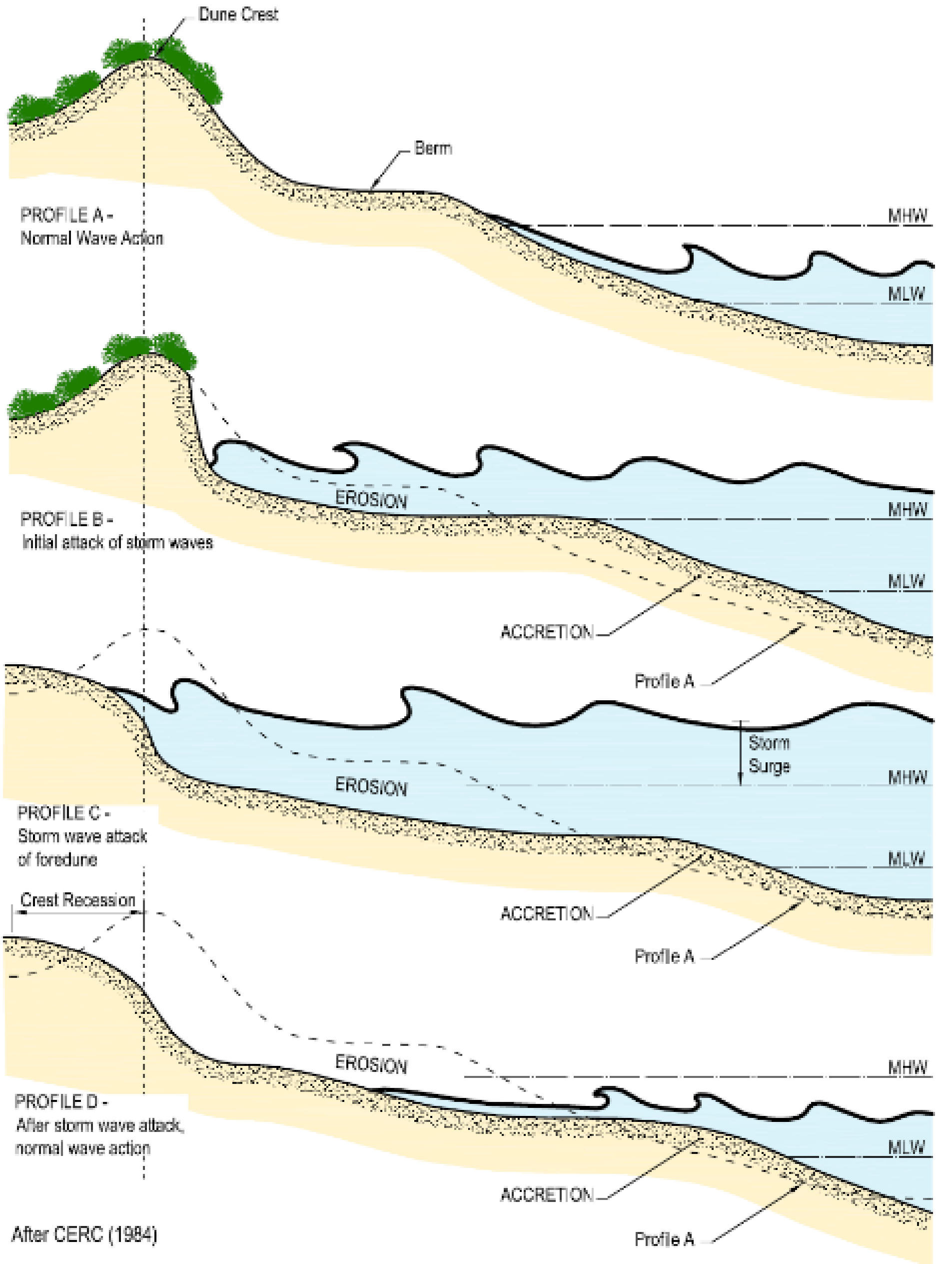


Figure 3.1 Storm Wave Attack

SPP2.6 recommends that potential cross shore erosion be determined by modelling the impact of an appropriate storm sequence using acceptable models such as SBEACH (WAPC, 2013). It is also specified that the modelled storm should have an annual exceedance probability (AEP) of 1% with regard to beach erosion. This is equivalent to a storm with an ARI of 100 years.

Coral Bay is located in a cyclone prone area, which means that a cyclone is likely to represent the critical, 100 year ARI storm event for erosion at the Resort. Cyclones produce high waves and water levels for relatively short periods of time compared to severe storms associated with the passage of cold fronts in south-west Western Australia.

GEMS (2005) has previously completed cyclone modelling for Coral Bay. This modelling considered several cyclone scenarios with varying intensity, track and water level components.

The track for the design events was selected to allow near normal crossing of the coast with the cyclone's region of maximum winds passing directly over Coral Bay to provide estimates of the worst case storm induced surge at Coral Bay.

More recently in 2018, Seashore Engineering published *Design Storms for Western Australian Coastal Planning: Tropical Cyclones*. The report identifies tropical cyclone scenarios for town sites along the Western Australian coast between Augusta and the WA-NT border, including Coral Bay. Review of region specific storm scenarios with varying characteristics such as cyclone intensity, frequency, scale and track was completed to develop design storms for the town sites. The study has been distributed by DoT and is intended to complement the SPP2.6 in determining coastal hazards, albeit inundation levels defined within the document are noted as being deliberately conservative.

As outlined by Seashore Engineering (2018), Coral Bay does not have a tide gauge with which to determine the most significant historical storms. Exmouth, approximately 140 kms North, has the closest tidal gauge which is operated by DoT and has historical data available back to 1997.

It is important to understand the typical duration of peak storm surge. The water level record from Exmouth during the passage of Tropical Cyclone Vance, the most severe cyclone recorded at the gauge, illustrates the acuteness of this peak. As shown on Figure 3.2, the measured water level is significantly higher than the predicted tidal level for a period either side of the peak, however the more significant build up to the peak water level is less than 3 hours in total duration, with the actual peak water level in existence for less than around half an hour.

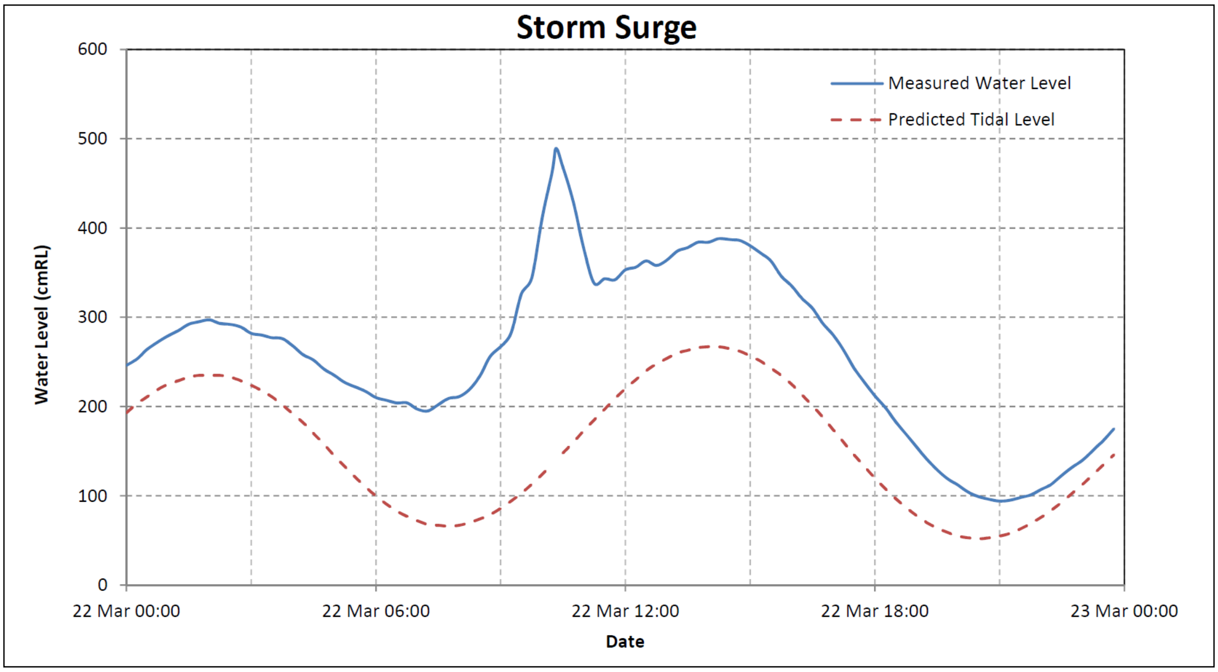


Figure 3.2 - Exmouth Water Level Record for Tropical Cyclone Vance

A further example of the limited duration of the peak storm surge level is provided in Figure 3.3. This data was recorded during the passage of Tropical Cyclone Yasi across the Queensland coast in February of 2011 (DERM, 2011). Similar to the Tropical Cyclone Vance observations, the duration of the peak water level build up for Tropical Cyclone Yasi is observed to be in the order of around 3 hours, with the actual peak water level only present for a period of less than half an hour.

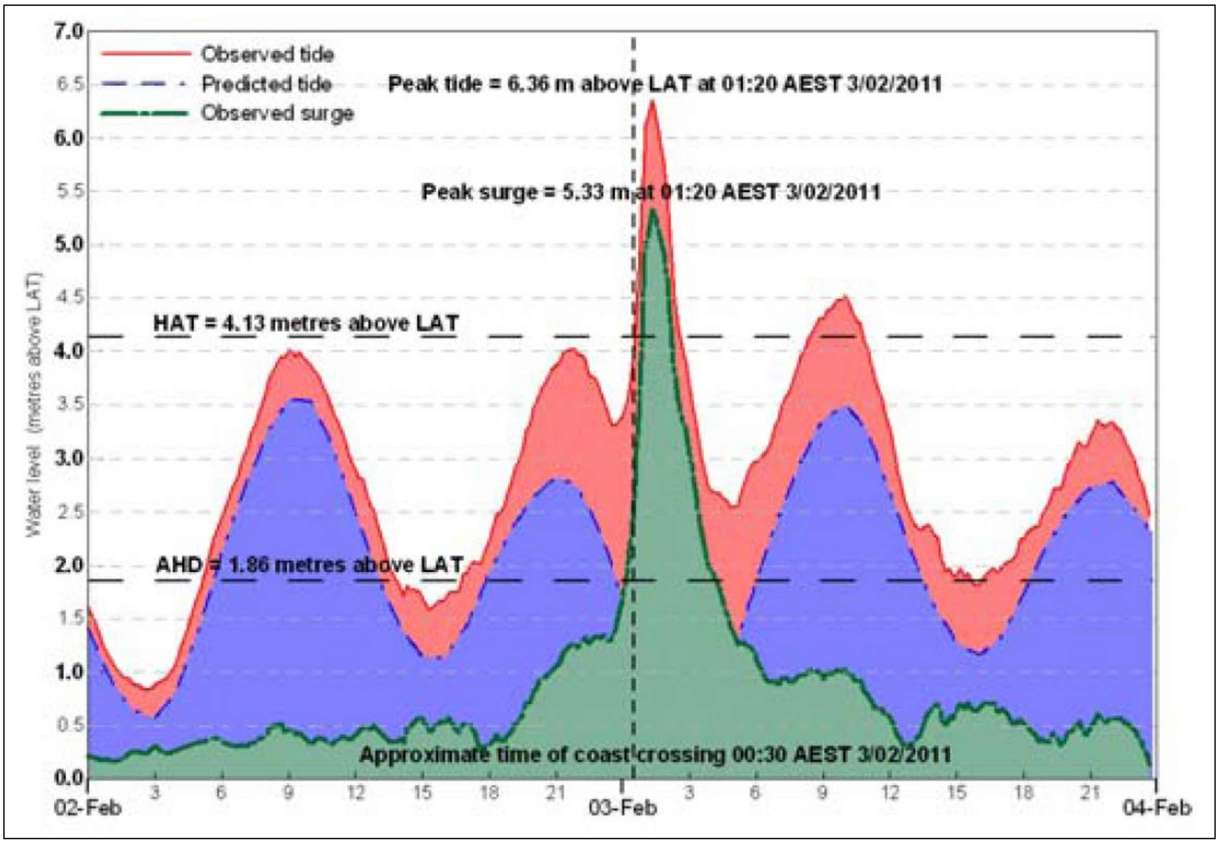


Figure 3.3 - Water Level Record for Tropical Cyclone Yasi (DERM, 2011)

Whilst differences in the duration of the peak water level are specific to each event with regard to the strength, proximity and speed of the cyclone, the general trend will be consistent with only short durations for the peak water level. This is an important consideration with regard to planning for development in cyclone effected areas, as discussed in later sections of this report.

Seashore Engineering (2018) provides a preliminary set of estimated average recurrence interval inundation levels, including for the Coral Bay townsite. It is to be noted that in the absence of targeted and more detailed modelling, the levels presented by Seashore Engineering are deliberatively conservative. The potential inundation levels for Coral Bay determined for both 100 and 500 year ARI events are 3.4 mAHD and 4.6 mAHD respectively. Although likely conservative, the 100 year ARI level is considered appropriate for use in modelling the severe storm erosion (S1).

In order to estimate the severe storm erosion expected at Coral Bay during the 100 year ARI event, a cyclone event time history was synthesised by combining a tidal signal for Coral Bay with a recorded residual water level measured at Exmouth during the passage of Tropical Cyclone Vance. The duration of the synthesised event was 36 hours, with three repeats of this event being simulated in accordance with the requirements of SPP2.6, equating to a total simulation duration of 108 hours.

The residual water level was scaled to achieve the estimated 100 year ARI peak water level of 3.4 mAHD at the shoreline, with the peak residual aligned with a period where the water level corresponds to mean sea level.

The time history of the synthesised water level, prior to transformation in SBEACH, is provided in Figure 3.4.

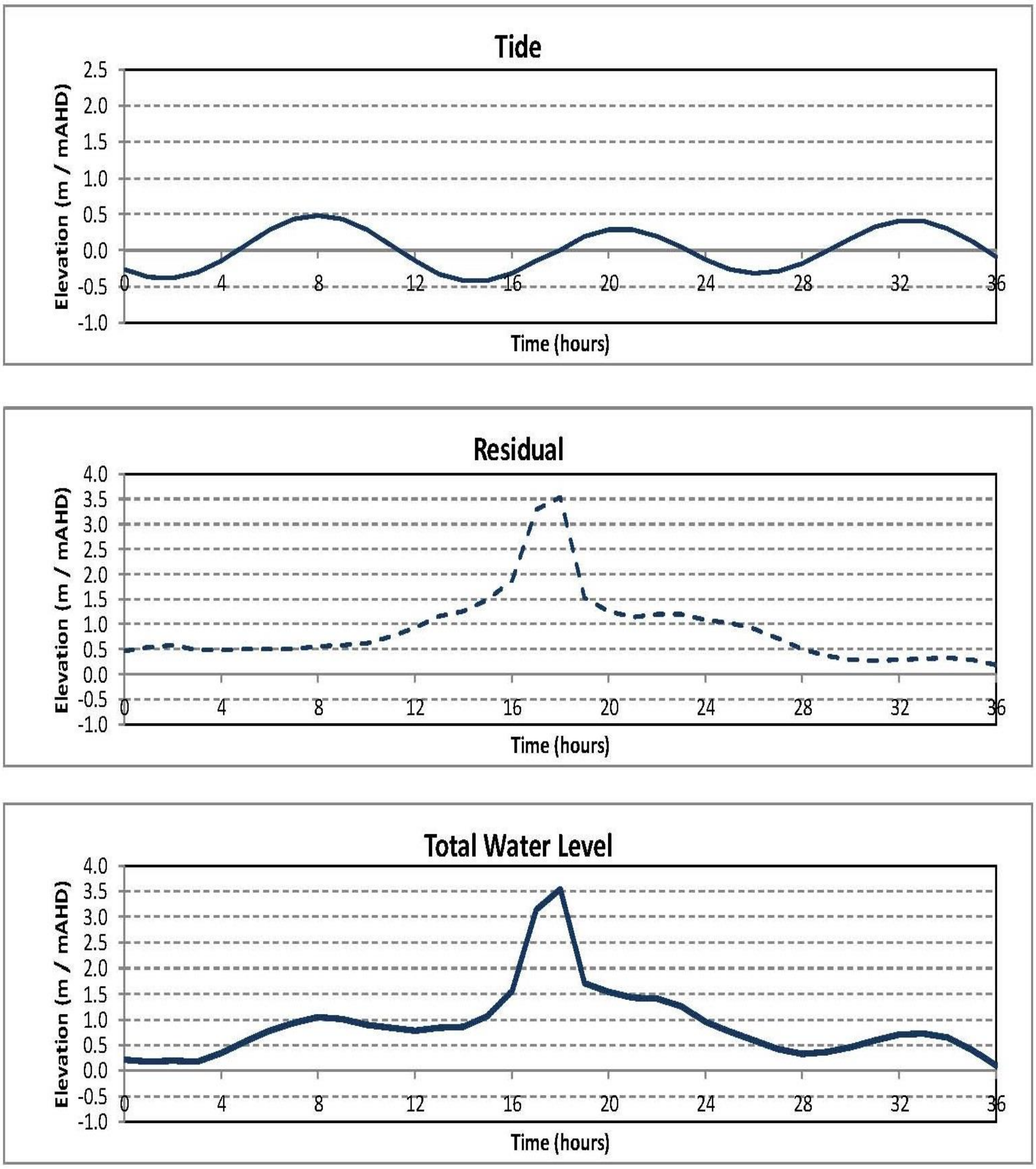


Figure 3.4 Synthesised Inshore Water Level Prior Transformation in SBEACH

To accompany the synthesised water level, a synthesised wave history was also required. GEMS (2005) provide modelled wave heights for both offshore and the inshore area. Offshore wave heights at Coral Bay are expected to vary between approximately 8.7 and 9.2 m during the peak of Category 4 and 5 cyclone events.

The shallow outer reef and similarly shallow reef within Bills Bay (shown in Figure 2.3) induce depth limited breaking and therefore limit the maximum nearshore wave heights, however to ensure that the impacts of this depth limitation were considered within the study the offshore wave conditions were input and the SBEACH model was allowed to calculate the potential depth limitation over the reef. The results of this SBEACH simulation of depth limited breaking are expected to be conservative as the wave breaking algorithm within SBEACH does not consider the impacts of roughness and frictional losses over platform reef, which have been shown by Hardy et al. (1990) to increase depth limited breaking to a factor of around half the total water depth. However, SBEACH typically implements a depth limited breaking factor greater than 0.5 in reducing the wave heights as they pass over the reef, typically in the order of 0.5-0.7. This is demonstrated by the SBEACH outputs later in this Section.

The synthesised time history of the offshore wave heights used in SBEACH is provided in Figure 3.5. This is expected to be a conservative estimate of the possible offshore wave heights, as the peak modelled wave heights presented by GEMS have been applied over the entire duration of the event. A maximum synthesised wave of 9.2 m was also applied conincident with the peak water level, which is itself also conservative.

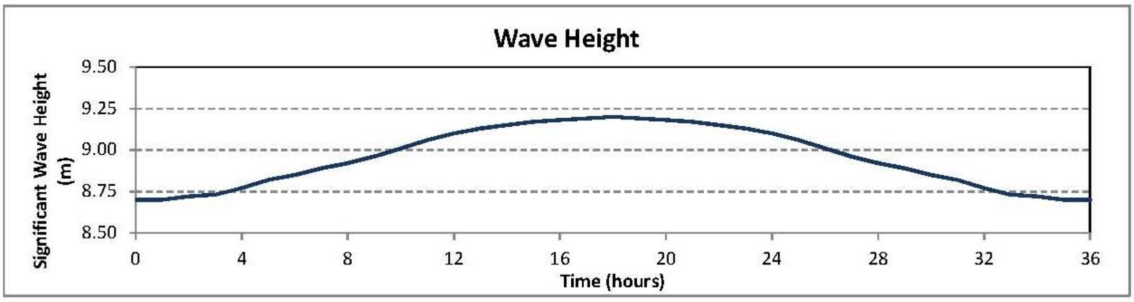


Figure 3.5 Synthesised Inshore Wave Heights for SBEACH Modelling

Using the cyclone conditions provided in Figures 3.4 and 3.5, the SBEACH model was used to simulate the effect of the 100 year ARI cyclone event conditions on the shoreline. The modelling was completed for the profiles shown in Figure 3.6, and incorporated the extent of rock visible on site as well as sections of reef noted on the local nautical chart.

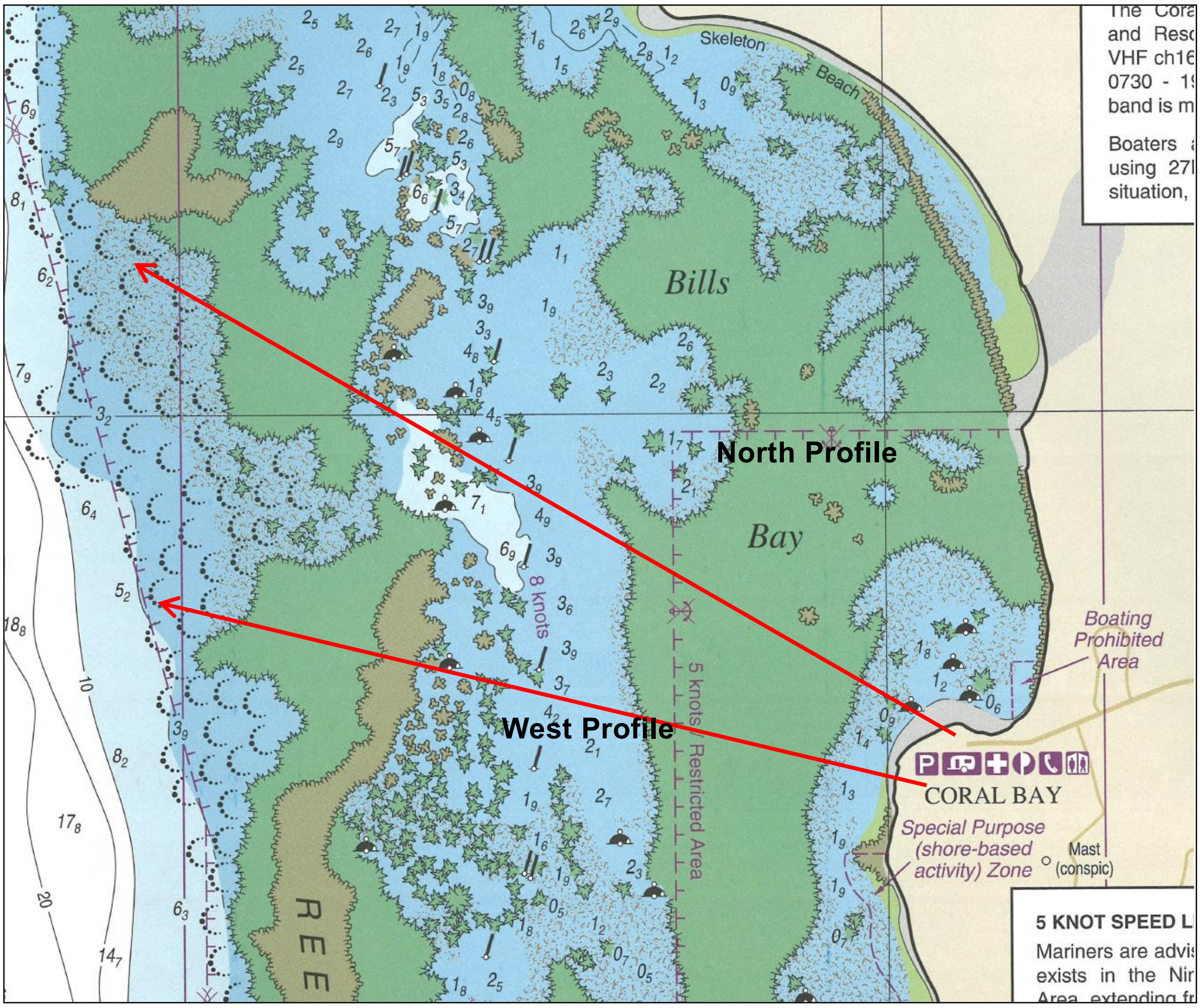


Figure 3.6 Location of SBEACH Profiles (source: DoT 1108)

A sediment size (d_{50}) was determined from the laboratory analysis of a sediment sample completed previously for the shoreline fronting the Resort (MRA 2011). The sample included approximately equal parts from the waterline, beach berm and the toe of the dune to best represent the overall sediment size of the beach. The Particle Size Distribution Graph of the sample is shown below in Figure 3.7 and shows that a d_{50} of 0.3 mm is appropriate for use at the Resort.

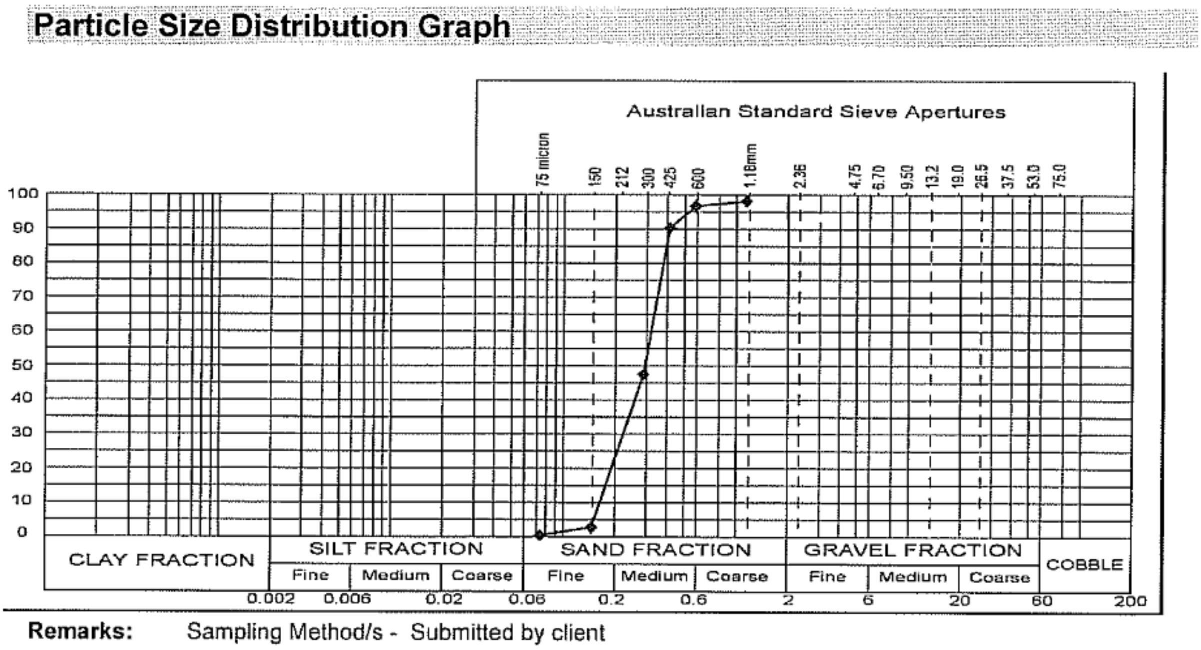
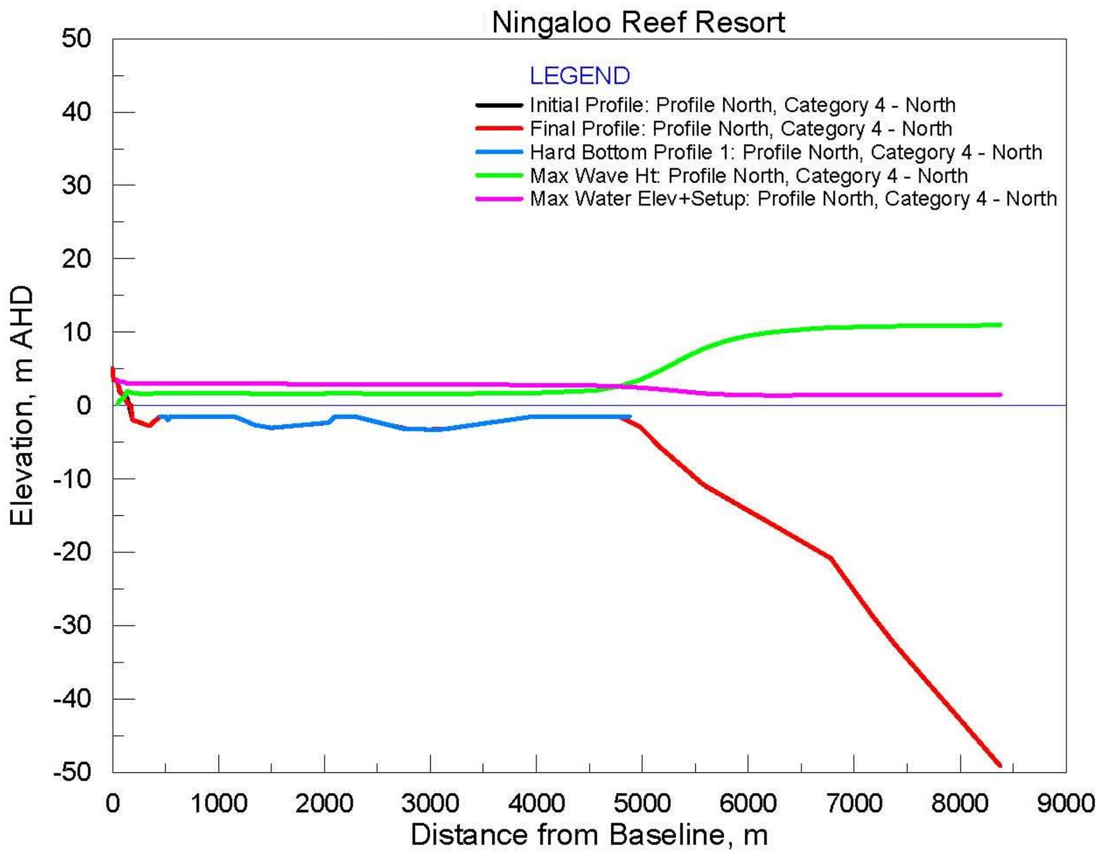


Figure 3.7 Particle Size Distribution Graph for Resort Sediment Sample

The model output from the SBEACH simulations are provided in Figures 3.8 and 3.9. SBEACH model reports are provided in Appendix A.



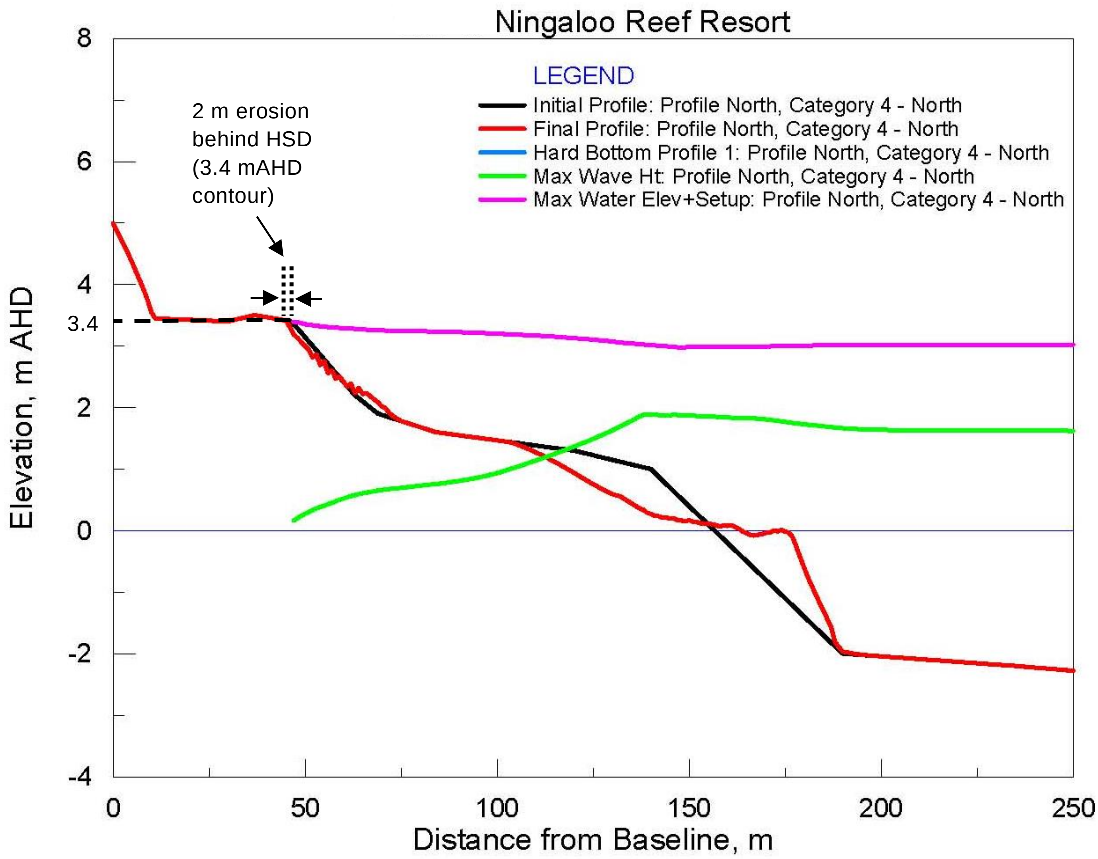


Figure 3.8 Outputs from SBEACH Simulation for the North Profile

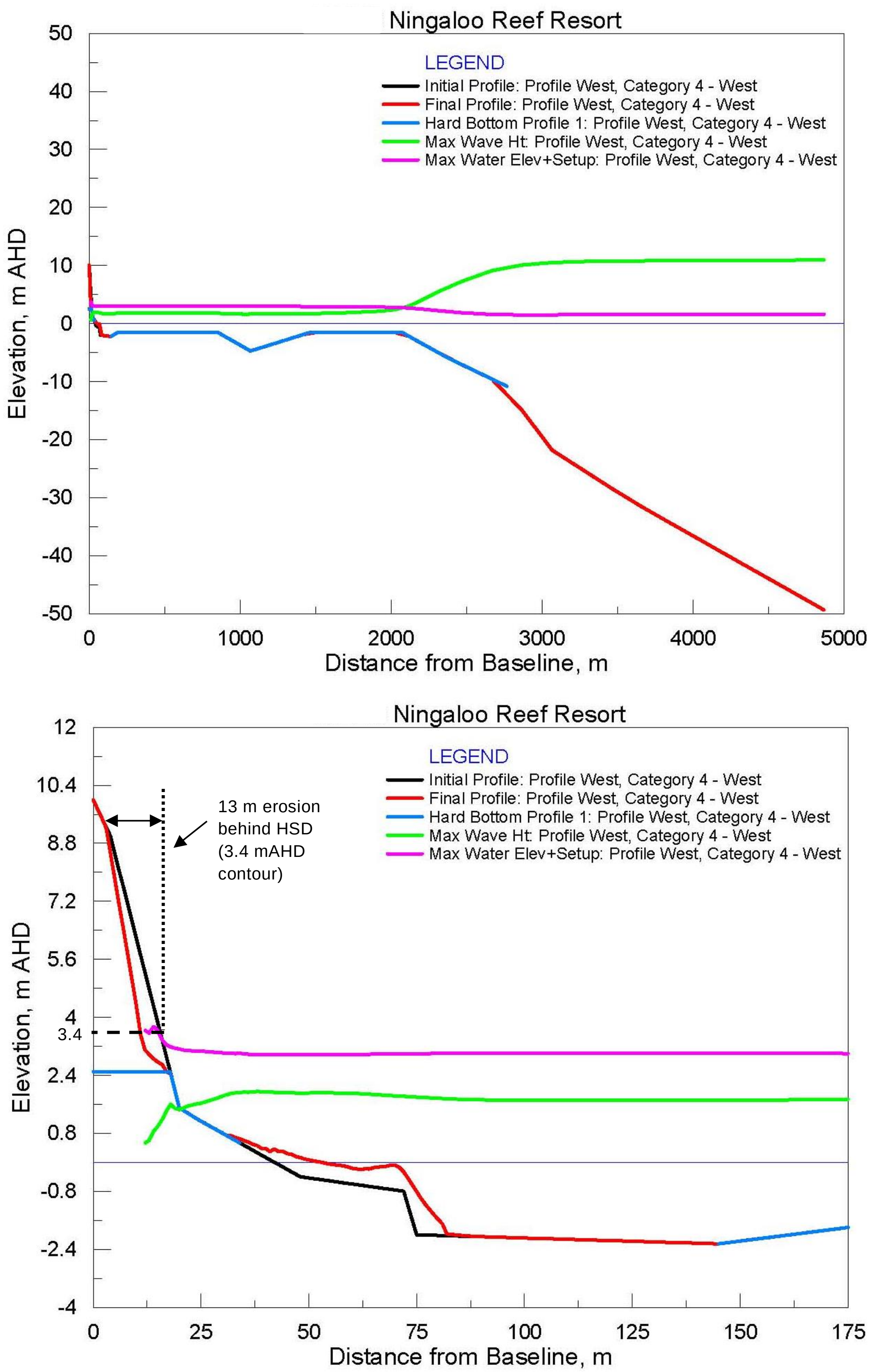


Figure 3.9 Outputs from SBEACH Simulation for the West Profile

Figure 3.8 shows that erosion of the northern profile would be expected during the design storm. In this case the MSL contour receded by around 10 m. However, the movement of the MSL contour has minimal direct effect on the safety of development located adjacent to the coast. SPP2.6 states that S1 should be the recession from the horizontal shoreline datum (HSD; which is defined contour corresponding to the peak steady water level experienced during the design storm) to the landward extent of the storm erosion as calculated by the model. During the design storm only a small amount of erosion was predicted behind the HSD. The extent of this erosion was around 2 m, therefore the S1 allowance for the northern shoreline is taken to be 2 m.

Figure 3.9 shows that 13 m of erosion was experienced behind the HSD on the western profile. Therefore, a 13 m allowance is required for S1 on the western shoreline.

It is to be noted that the different erosion amounts for the north and west profiles determined by SBEACH can be attributed to the significant differences in the beach profiles themselves as shown previously in Figures 2.5 and 2.6. The gradually sloping and generally accreting north profile experiences more erosion on the lower section of the profile as the waves break, however this does not impact the areas higher on the profile. However, the steeper dunes on the western profile slump when erosion occurs at lower elevations, leading to greater recession at the higher elevations of the dune.

3.2 S2 Erosion Allowance – Long Term Shoreline Movement

Historically, changes in shorelines occur on varying timescales from storm to post storm, seasonal and longer term (Short 1999). The S1 Erosion allowance accounts for the short term storm timescale of beach change. The S2 Erosion allowance is intended to account for the longer term movement of the shoreline that may occur within the planning horizon. To determine the S2 Erosion allowance, historical shoreline movement trends are examined and likely future shoreline movements predicted.

3.2.1 Shoreline Movement Analysis

SPP2.6 recommends that shoreline movement trends be based on the review of available shoreline records. This can include analysis of historical aerial photography, High Water Mark (HWM) surveys or previously extracted coastal vegetation lines available from DoT.

Available aerial photographs extend back over 50 years to 1970. The following aerial photographs were purchased and the vegetation line extracted.

- 1970.
- 1982.
- 1990.
- 2003.
- 2010.
- 2017.
- 2020.
- 2022.

The coastal vegetation lines were extracted from the aerial photographs using the methodology outlined in DoT (2009). The accuracy of the photogrammetry technique is expected to be in the order of ± 5 m. The position of the vegetation line was analysed at 100 m chainages, as shown in Figure 3.10.

Figure 3.10 Shoreline Movement Plot & Chainages

The movements of the shoreline relative to the 1970 coastal vegetation line were estimated at each of the chainages and are presented in Figure 3.11. The corresponding average annual rates of shoreline movement are presented in Figure 3.12.

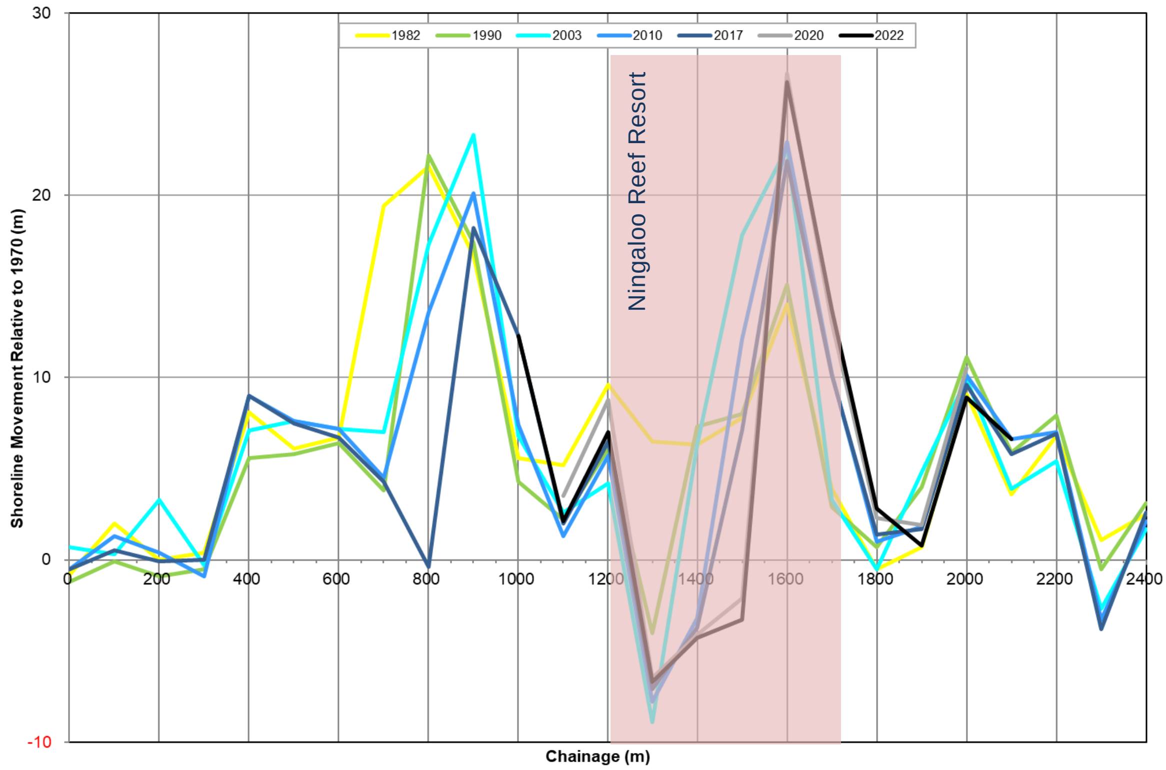


Figure 3.11 Shoreline Position Relative to 1970

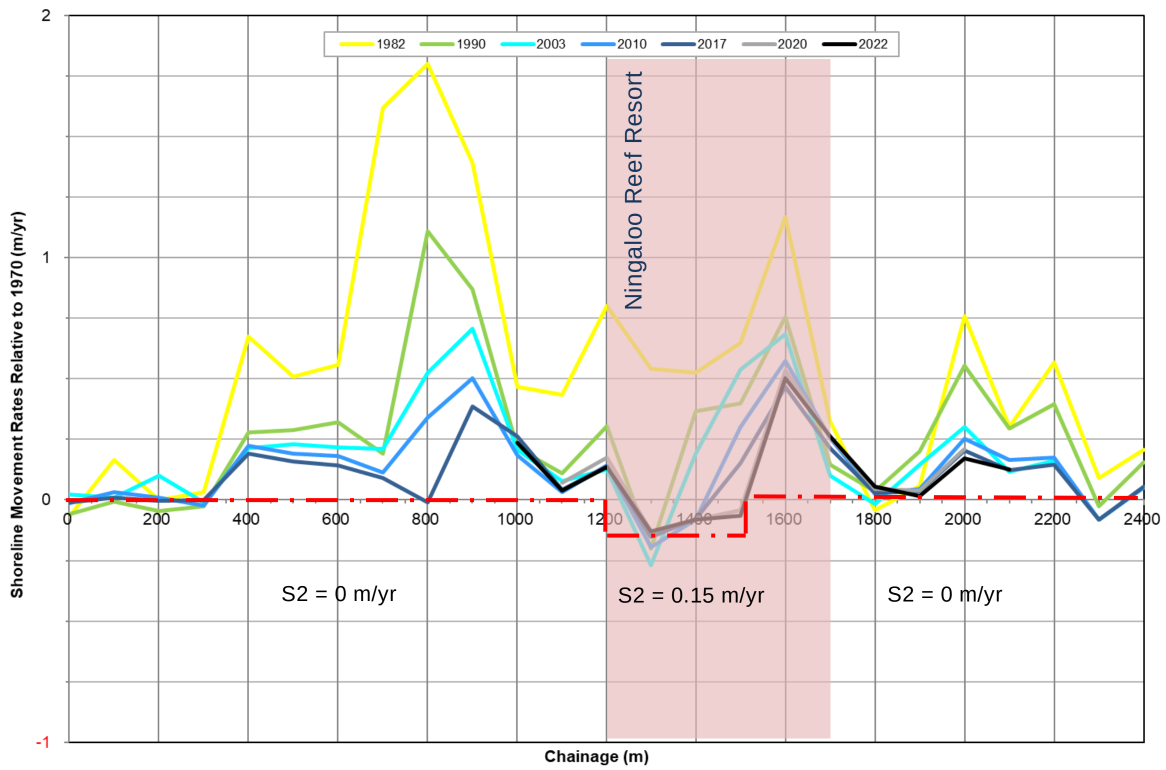


Figure 3.12 Annual Shoreline Movement Rates Relative to 1970

A general accretion trend has been experienced across the majority of the shoreline. However, for chainages 1,200 m to 1,500 m an erosion trend was observed. It is noted that exposed sections of rock are now visible along this section of shoreline. Therefore it is anticipated that future erosion of this shoreline would be unlikely, however given that no detailed geotechnical assessment has been completed and the continuity and competency of this rock has not been verified, the presence of this rock will not be considered within the S2 assessment.

The maximum rate of erosion observed over the long term for the section of shoreline between chainages 1,200 m to 1,500 m was 0.13 m/yr. Therefore, for these chainages an S2 erosion allowance of **0.15 m/yr** is recommended. For the remainder of the shoreline, a **0 m/yr** S2 erosion allowance is recommended. This is summarised in the following table.

Table 3.1 S2 Allowance Summary

Chainages (m)	S2 Allowance (m/yr)
0-1200	0
1,200-1,500	0.15
1,500-2,400	0

3.3 S3 Erosion Allowance – Sea Level Rise

The Intergovernmental Panel on Climate Change (IPCC) has presented various scenarios of possible climate change and the resultant sea level rise in the coming century. The range of these projections is shown in Figure 3.13 (IPCC 2023).

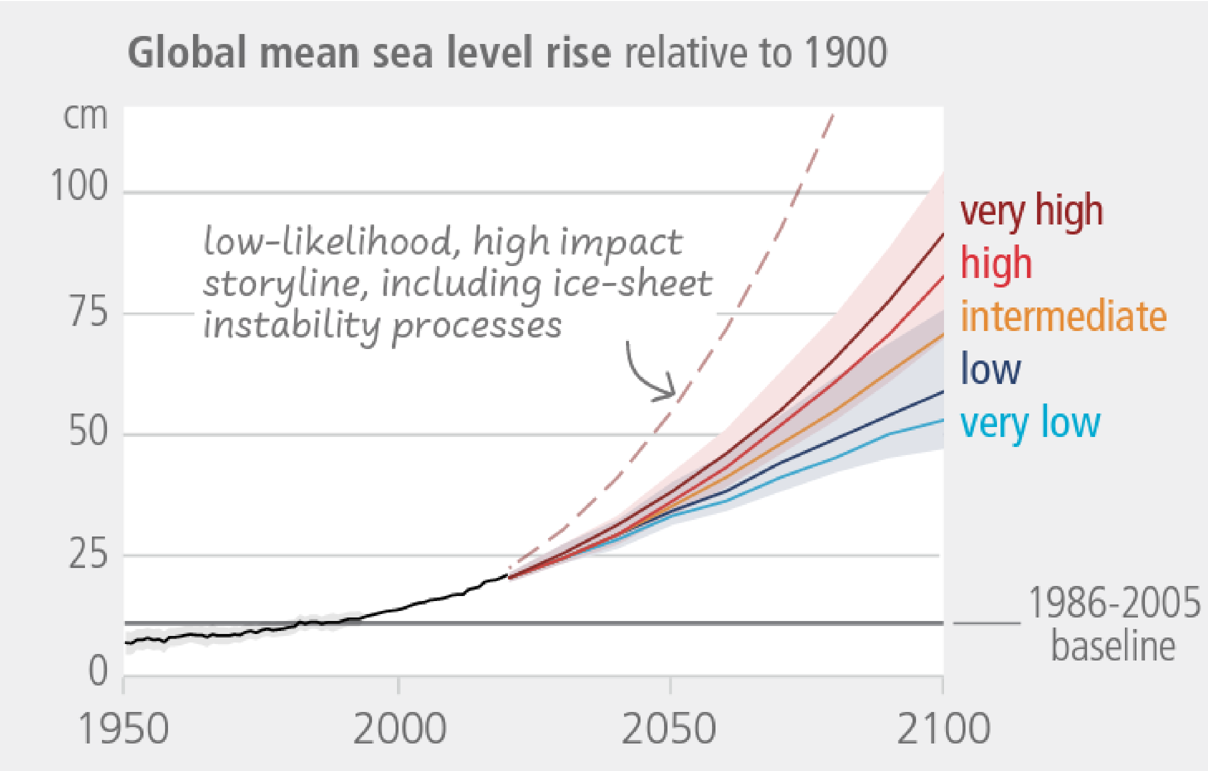


Figure 3.13 IPCC Scenarios for Sea Level Rise (IPCC 2023)

The results of the on-going increase in sea level and the anticipated impacts of accelerated increases are difficult to predict. Nevertheless, such increases in global sea level are likely to lead to beach erosion, as a sea level rise usually results in deepening of nearshore waters, allowing larger waves to reach the shore and erode the beach face (Bird 2000).

Komar (1998) provides a reasonable treatment for sandy shores, including examination of the Bruun Rule (Bruun 1962). The Bruun Rule relates the recession of the shoreline to the sea level rise and slope of the nearshore sediment bed:

$$R = \frac{1}{\tan(\theta)} S$$

where: R = recession of the shore.

θ = average slope of the nearshore sediment bed.

S = sea level rise.

The basic notion behind the Bruun Rule is that a sea level rise would cause erosion of the upper beach, and transference of sand from the beach to the adjacent sea floor. In due course, this process would restore the previous transverse profile in relation to the higher sea level, albeit at a more landward location (Bird 2000; Komar 1998).

DoT (2010) completed an assessment of the potential increase in sea level that could be experienced on the Western Australian coast in the coming 100 years. This assessment extrapolated work by Hunter (2009) to provide sea level rise values based on the IPCC (2007) A1FI climate change scenario projections to the year 2110. The derived sea level rise scenario was subsequently adopted by the Western Australian Planning Commission (and SPP 2.6) for use in coastal planning along the Western Australian coast. This is the sea level rise scenario adopted for this assessment and is presented in Figure 3.14.

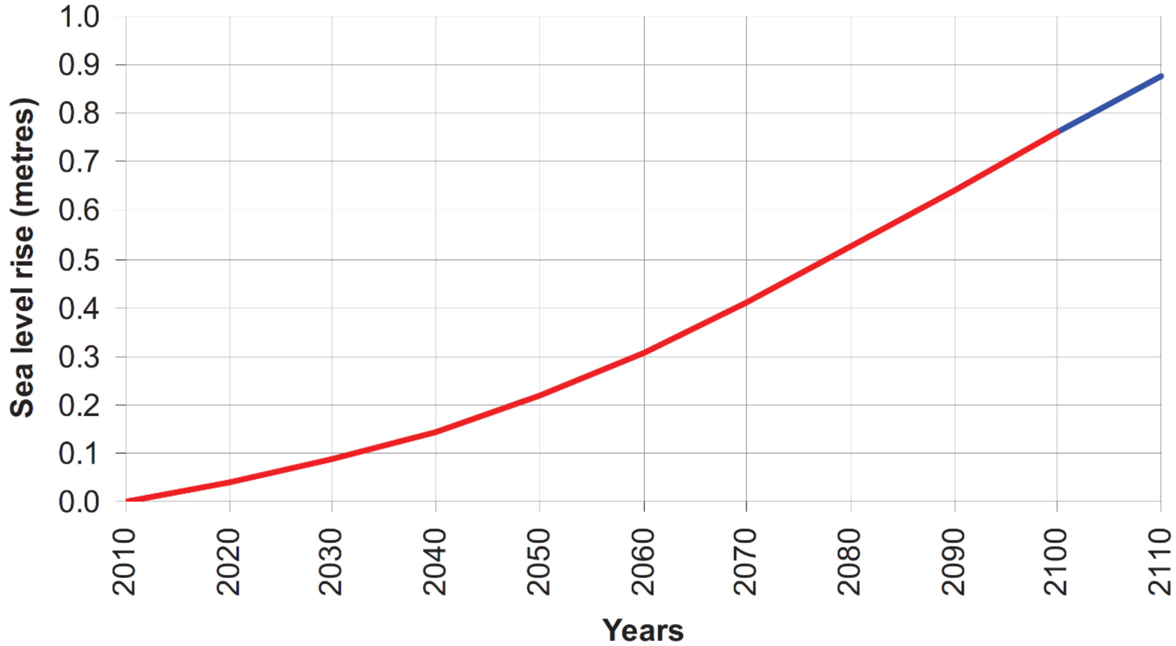


Figure 3.14 Recommended Sea Level Rise Scenario for Coastal Planning in Western Australia (DoT 2010)

SPP2.6 notes that the allowance for erosion caused by future sea level rise on sandy coast should be calculated as 100 times the adopted sea level rise value of 0.9 m over a 100-year planning horizon or 90 m.

Table 3.2 summarises the sea level rise values and S3 Erosion allowances for the range of previously presented planning horizons.

Table 3.2 Sea Level Rise Allowances

Planning Horizon	Potential Sea Level Rise (m)	S3 Erosion Allowance (m)
Present Day	0	0
25 year	0.15	15
40 year	0.29	29
50 year	0.39	39
100 year	0.98	98

Notes: 1. Based on recommendations in DoT (2010) with a 2023 base year.

3.4 Summary of Erosion Allowances

Each of the erosion allowances were determined over 25, 40, 50, 75 and 100 year planning horizons. A present day scenario was also considered. The allowances are combined with a 0.2 m/yr allowance for uncertainty to create a coastal erosion hazard line for each planning horizon. Table 3.3 presents the results of these combinations for the chainages relevant to the

Resort. For this particular site it is noted that the HSD is significantly remote from the active beach area and actually sits on the southern side of Robinson Street. This means that the typical action of the natural coastal processes on the shoreline will not impact the position of the HSD over the short to medium term until such time as erosion occurs beyond Robinson Street. In this regard, the S1 allowance is most critical in the short to medium term planning horizons, until such time as the entire beach area in front of Robinson Street is lost, if this does occur in the future. As a result, the coastal hazard lines have been based on the combination of the S1 allowance and the allowance for uncertainty behind the HSD or the impact of the total coastal erosion allowance on the shoreline alignment, whichever is the greater.

Table 3.3 Summary of Coastal Erosion Allowances over each Planning Horizon

Planning Horizon	Approximate Chainages (m)	S1 (m)	S2 (m)	S3 (m)	Allowance for Uncertainty (m)	Total
Present Day	1,200-1,500	13	0	0	0	13
	1,500-2,400	2	0	0	0	2
25	1,200-1,500	13	4	15	5	37
	1,500-2,400	2	0	15	5	22
40	1,200-1,500	13	6	29	8	56
	1,500-2,400	2	0	29	8	38
50	1,200-1,500	13	8	39	10	70
	1,500-2,400	2	0	39	10	51
100	1,200-1,500	13	15	98	20	146
	1,500-2,400	2	0	98	20	110

Notes: 1. The total coastal erosion hazard allowance is to be measured in a landward direction from the HSD, which is the 3.4 mAHD contour.

It is important to understand that these coastal erosion hazard lines are not intended to be predictions of the future shoreline location, but rather to provide conservative estimates of possible future shoreline retreat that are appropriate for consideration in coastal planning. For instance, assessment of aerial photography at the site since 1970 has shown that there has been very little movement of the shoreline, despite having been around 15 cyclone events that would have affected the area over the period. This provides an indication of the stability of the shoreline over the longer term. Nevertheless, the coastal hazard lines will be used in this plan to inform the potential future risk associated with the redevelopment and operation of the Resort.

Coastal erosion hazard lines for the Resort site are presented in Figure 3.15.

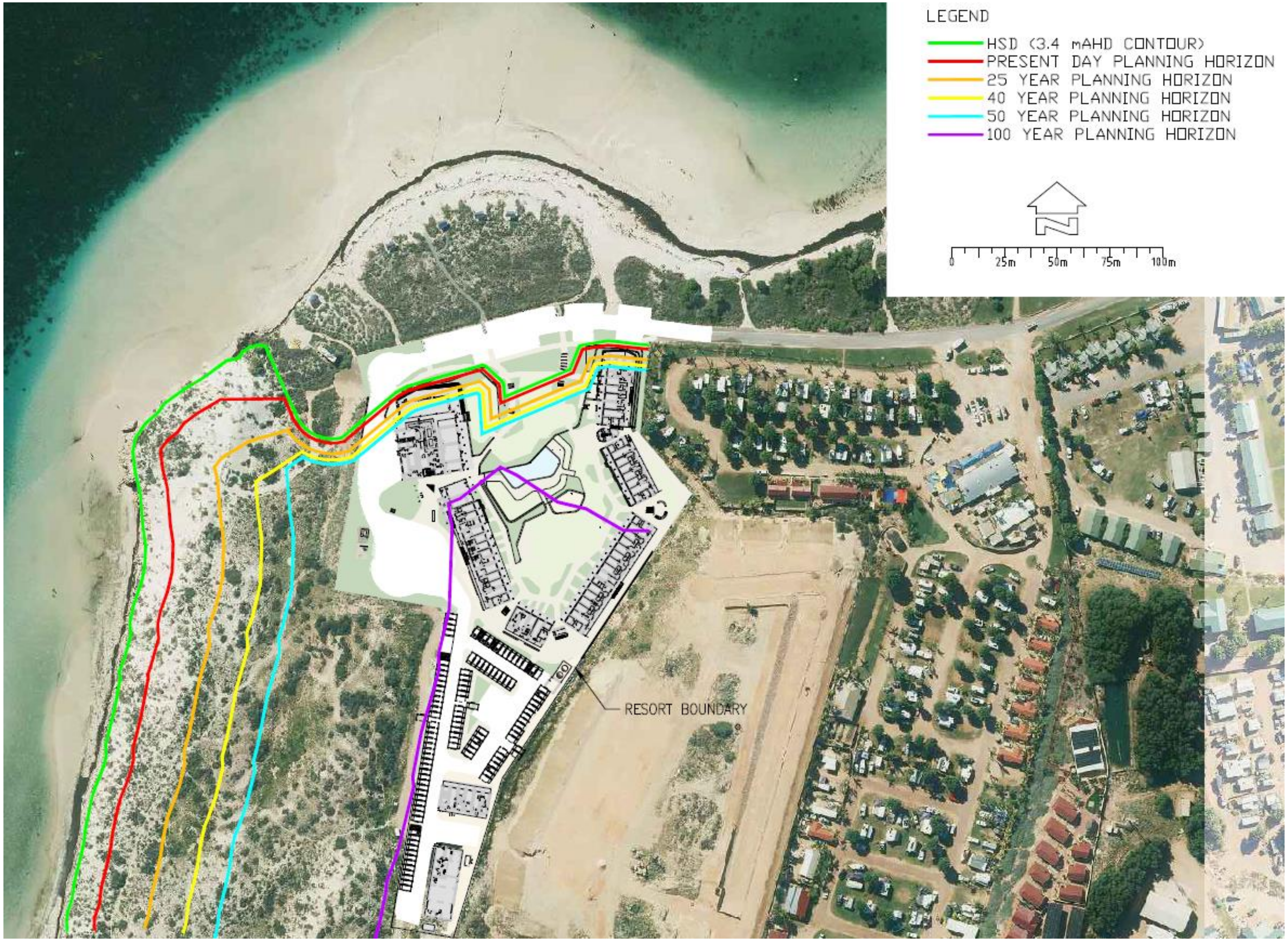


Figure 3.15 Coastal Erosion Hazard Mapping Lines for the Shoreline Fronting the Resort

4. Coastal Inundation Hazard Identification

SPP2.6 requires that the allowance for inundation (termed the S4 Allowance) be taken as the maximum extent of inundation experienced during a water level event with a 0.2% AEP (500 year ARI) plus the appropriate allowance for sea level rise. This is the critical aspect when considering public safety and significant assets, however for tourist based assets where public safety is managed, consideration of less severe inundation events could be appropriate.

Assessment of the inundation levels requires consideration of peak storm surge, including wave setup. A storm surge occurs when a storm with high winds and low pressures approaches the coastline (refer Figure 4.1). The strong, onshore winds and large waves push water against the coastline (wind and wave setup) and the barometric pressure difference creates a region of high water level. These factors acting in concert create the storm surge. The size of the storm surge is influenced by the following factors.

- Wind strength and direction.
- Pressure gradient.
- Seafloor bathymetry.
- Coastal topography.

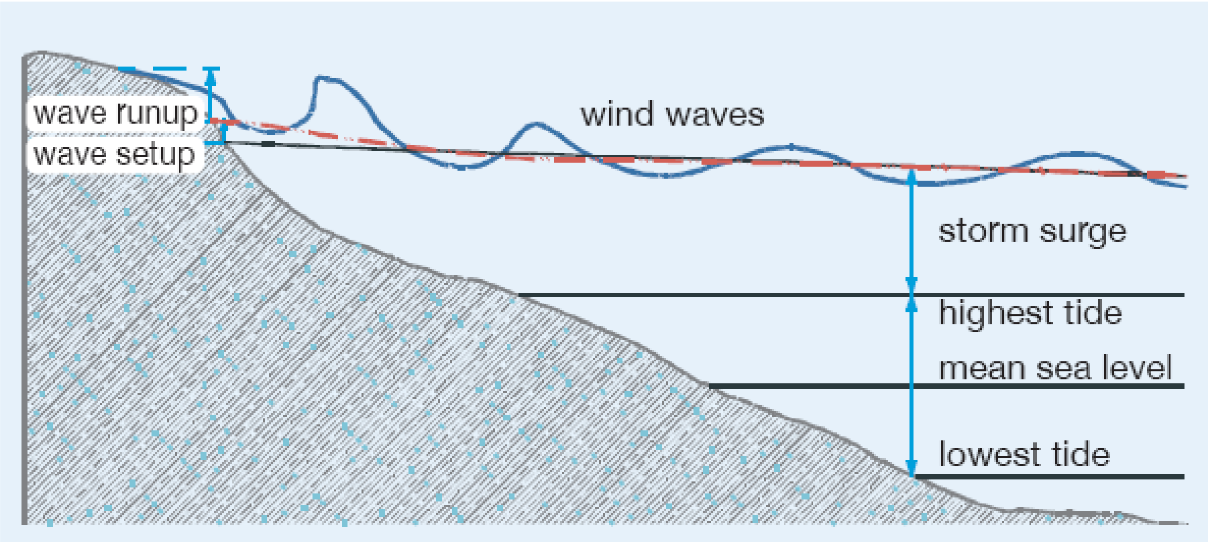


Figure 4.1 Storm Surge Components

Coral Bay is located in a cyclone prone area, which means that a cyclone is likely to represent the critical 500 year ARI inundation event at the Resort.

As discussed previously, Seashore Engineering (2018) recently published preliminary inundation levels for various coastal towns around Western Australia, which included a 500 year ARI water level of 4.6 mAHD at Coral Bay. As the projected levels are given for the shoreline, they are assumed to include the nearshore wind and wave setup during the events.

The resulting inundation levels for each of the planning horizons are provided in Table 4.1.

Table 4.1 S4 Inundation Levels

Planning Horizon	Potential Sea Level Rise Allowance (m)	500 yr ARI Water Level (mAHD)	Inundation Level (mAHD)
Present Day	0	4.6	4.6
25 year	0.15	4.6	4.8
40 year	0.29	4.6	4.9
50 year	0.39	4.6	5.0
100 year	0.98	4.6	5.6

These potential inundation levels should be considered as part of the CHRMAP to comply with the requirements of SPP2.6.

5. Vulnerability Assessment

In accordance with WAPC (2019) a risk based approach has been used to assess the hazards and required mitigation and adaptation options for the Resort. As coastal hazards are the focus of this assessment, it is the likelihood and consequences of these coastal hazards that need to be considered, coupled with the likely adaptive capacity of the assets. As stated previously, it is inherent in the redevelopment proposal that there be no negative social or environmental impacts as a result of this development, with mitigation strategies already highlighted to address these issues.

5.1 Likelihood

Likelihood is defined as the chance of something happening (AS/NZS ISO 31000:2009). WAPC (2019) defines the likelihood as the chance of erosion or storm surge inundation occurring or how often they impact on existing and future assets and values. This requires consideration of the frequency and probability of the event occurring over a given planning timeframe.

The probability of an event occurring is often related to the AEP or the Average Recurrence Interval (ARI). The use of the AEP to define impacts of coastal hazards over the planning timeframe assumes that events have the same probability of occurring each year. In the case of climate change and sea level rise, which has a large influence on the assessed coastal hazard risk, this is not true. In addition, there is insufficient data available to properly quantify the probability of occurrence. A scale of likelihood has therefore been developed, which follows the Australian Standard Risk Management Principles and Guidelines (AS/NZS ISO 31000:2009). This is presented in Table 5.1.

Table 5.1 Scale of Likelihood

Rating	Description / Frequency
Almost certain	There is a high possibility the event will occur as there is a history of frequent occurrence 90-100% probability of occurring over the timeframe
Likely	It is likely the event will occur as there is a history of casual occurrence 60-90% probability of occurring over the timeframe
Possible	The event may occur 40-60% probability of occurring over the timeframe
Unlikely	There is a low possibility that the event will occur 10-40% probability of occurring over the timeframe
Rare	It is highly unlikely that the event will occur, except in extreme / exceptional circumstances 0-10% probability of occurring over the timeframe

The likelihood and consequences of coastal hazards are different for erosion and inundation. As a result, the likelihood and consequence of erosion and inundation should be considered separately. The likelihood of the coastal hazard impacts are discussed in the following sections.

5.1.1 Coastal Erosion

Assessment of the relative likelihood of each of the identified key assets being impacted by coastal erosion hazards is presented in Table 5.2.

The likelihood ratings given are based on the coastal hazard lines presented in Figure 3.15 and the consideration of the probabilities of each of the allowances occurring within the respective planning horizons.

It is important to note that the hazard lines reaching a particular asset at the end of the planning horizon do not necessarily mean this will occur. This is due to the fact that it requires all of the following to occur.

- Reversal of the shoreline movement trend at the northern beach in the future from accretion to erosion (i.e. the accretion trend reversing plus the additional allowance for uncertainty).
- The upper estimate of erosion caused by sea level rise.
- The severe storm event to be experienced at the end of the planning timeframe (i.e. when the other allowances have been realised).

Only if all of these occur will the erosion hazard lines be realised.

Table 5.2 Assessment of Likelihood of Coastal Erosion Impact

Key Assets	Planning Timeframe				
	Present Day	25 year	40 year	50 year	100 year
Block A - Clubhouse	Rare	Rare	Unlikely	Possible	Almost Certain
Block B - Accommodation	Rare	Rare	Rare	Rare	Unlikely
Block C - Accommodation	Rare	Rare	Rare	Rare	Rare
Block D - Accommodation	Rare	Rare	Rare	Rare	Rare
Block E - Accommodation	Rare	Rare	Rare	Rare	Possible
Block F - Accommodation	Rare	Rare	Unlikely	Possible	Almost Certain
Back of House	Rare	Rare	Rare	Rare	Rare
Existing Sewer Pump	Rare	Rare	Rare	Rare	Possible
New Substation	Rare	Rare	Rare	Rare	Rare
Pool	Rare	Rare	Rare	Rare	Possible
Lower Level Landscaped Areas	Rare	Possible	Likely	Almost Certain	Almost Certain
Upper Level Landscaped Areas	Rare	Rare	Rare	Rare	Unlikely
Guest Parking Areas	Rare	Rare	Rare	Rare	Rare
Resort Access Way and Roundabout	Rare	Unlikely	Possible	Likely	Likely
Boat Trailer and Coach Parking	Rare	Rare	Rare	Rare	Possible
Robinson Street & Parking Lot	Rare	Possible	Likely	Almost Certain	Almost Certain

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

The assessment of likelihood of coastal erosion impact shows the following.

- The likelihood of coastal erosion impact on the resort assets over the 40 year planning horizon is typically rare. The exceptions to this are Block A, Block F, the lower level landscaped areas and the resort access way and roundabout. The likelihood of impact to Robinson Street increases to likely at the end of the 40 years, indicating that this is the most likely asset to be impacted over this timeframe.

- It is almost certain that some assets would be impacted by the end of a 100 year planning horizon, however this is well beyond the service life of any assets within the resort.

5.1.2 Coastal Inundation

Assessment of the likelihood of coastal inundation is slightly different to that for coastal erosion. This is due to the fact that the potential for coastal inundation will change in the future as the sea level rises. This means that an area that would only be inundated during a very severe event in the present day could potentially be inundated by a much less severe event in the future. Assessment of the probability of an area being inundated within a given planning horizon therefore needs to consider the changing probability of event occurrence throughout that planning timeframe.

As an example, based on the estimated inundation levels, an area with an elevation of around 4.6 mAHD would just be inundated by the 500 year ARI event in the present day. However, it may be inundated by around the 300 and 200 year ARI events in approximately 2093 and 2118 respectively. Cumulative probabilities of occurrence of inundation at each level within the proposed development were combined on an annual basis. These probabilities have been used to determine the likelihood of each of the key assets being impacted by inundation for each planning timeframe.

The results of the assessment of likelihood of coastal inundation for each of the key assets is presented in Table 5.3.

As shown in the rating table, the majority of the assets achieve a likelihood classification of rare over the 40 year planning horizon for the resort and even over the full 100 year horizon. The only resort assets that achieve ratings higher than rare within the service life of the resort are the lower level landscaped area and the public parking area. Both of these areas are required to interface with the existing foreshore areas, thus meaning that inundation is largely unavoidable.

Table 5.3 Assessment of Likelihood of Coastal Inundation Impact

Key Assets	Finished Floor Level (mAHD)	Planning Timeframe				
		Present Day	25 year	40 year	50 year	100 year
Block A - Clubhouse	4.9	Rare	Rare	Rare	Rare	Unlikely
Block B - Accommodation	>5.0	Rare	Rare	Rare	Rare	Unlikely
Block C - Accommodation	6.0	Rare	Rare	Rare	Rare	Rare
Block D - Accommodation	6.0	Rare	Rare	Rare	Rare	Rare
Block E - Accommodation	6.0	Rare	Rare	Rare	Rare	Rare
Block F - Accommodation	5.0	Rare	Rare	Rare	Rare	Unlikely
Back of House	>5.6	Rare	Rare	Rare	Rare	Rare
Existing Sewer Pump	5.0	Rare	Rare	Rare	Rare	Unlikely
New Substation	>5.6	Rare	Rare	Rare	Rare	Rare
Pool	5.0	Rare	Rare	Rare	Rare	Unlikely
Lower Level Landscaped Areas	3.5	Rare	Unlikely	Possible	Possible	Likely
Upper Level Landscaped Areas	5.0	Rare	Rare	Rare	Rare	Unlikely
Guest Parking Areas	>5.6	Rare	Rare	Rare	Rare	Rare
Resort Access Way and Roundabout	2.5	Rare	Possible	Possible	Likely	Almost Certain
Robinson Street & Parking Lot	~2.0	Rare	Likely	Likely	Almost Certain	Almost Certain

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

5.2 Consequence

The second part of the risk assessment is determining the consequence of the coastal hazards on the Resort. A scale of consequence has been developed which provides a range of impacts and is generally consistent with the Australian Standard Risk Management Principles and Guidelines (ISO 31000:2009).

Table 5.4 Scale of Consequence

Rating	Social	Economic	Environment
Catastrophic	Loss of life and serious injury. Large long term or permanent loss of services, employment wellbeing, finances or culture (75% of community affected), international loss, no suitable alternative sites exist	Damage to property, infrastructure or local economy > $20M	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage
Major	Serious injury. Medium term disruption to services, employment wellbeing, finances or culture (<50% of community affected), national loss, limited alternative sites exist	Damage to property, infrastructure or local economy > $5M to $20M	Severe loss of environmental amenity and a danger of continuing environmental damage
Moderate	Minor injury. Major short or minor long term disruption to services, employment wellbeing, finances or culture (<25% of community affected), regional loss, many alternative sites exist	Damage to property, infrastructure or local economy > $500,000 to $5M	Isolated but significant instances of environmental damage that might be reversed with intensive efforts. Recovery may take several years.
Minor	Small to medium disruption to services, employment wellbeing, finances or culture (<10% of community affected), local loss, many alternative sites exist	Damage to property, infrastructure or local economy > $50,000 to $500,000	Minor instances of environmental damage that could be reversed. Consistent with seasonal variability, recovery may take one year.
Insignificant	Minimal short-term inconveniences to services, employment, wellbeing, finances or culture (<5% of community affected), neighbourhood loss, many alternative sites exist	Damage to property, infrastructure or local economy < $50,000	Minimal environmental damage, recovery may take less than 6 months.

Similar to the assessment of likelihood, the consequence rating has been completed separately for coastal erosion and coastal inundation. Typically for infrastructure and assets, the consequences associated with coastal erosion are more significant than those associated with coastal inundation. This arises due to the fact that coastal erosion is generally more permanent and more difficult to overcome than coastal inundation. For instance if the foundations of a house were undermined by erosion it is likely that the house would fall. However if a house was inundated, while there may be some damage, structural failure would be less likely.

The consequence ratings for coastal erosion and coastal inundation are outlined in the following sections. These consequence ratings are ultimately provided to inform RAC of the risks given their future management liabilities as outlined in Section 2.6.

5.2.1 Coastal Erosion

The assessed consequences of coastal erosion for each of the planning timeframes are outlined in Table 5.5. As shown in the table, the consequences of erosion vary for some key assets over different timeframes due to the potential effects of increased erosion.

Table 5.5 Assessment of Consequence of Coastal Erosion Impact

	Planning Timeframe				
Key Assets	**Present Day**	**25 year**	**40 year**	**50 year**	**100 year**
Block A - Clubhouse	Minor	Moderate	Moderate	Moderate	Moderate
Block B - Accommodation	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Block C - Accommodation	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Block D - Accommodation	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Block E - Accommodation	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Block F - Accommodation	Minor	Moderate	Moderate	Moderate	Moderate
Back of House	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Existing Sewer Pump	Insignificant	Insignificant	Insignificant	Insignificant	Minor
New Substation	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Pool	Insignificant	Insignificant	Insignificant	Insignificant	Minor
Lower Level Landscaped Areas	Minor	Minor	Minor	Minor	Minor
Upper Level Landscaped Areas	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Guest Parking Areas	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Resort Access Way and Roundabout	Insignificant	Minor	Minor	Minor	Moderate
Robinson Street & Parking Lot	Minor	Minor	Moderate	Moderate	Moderate

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

The rationale behind the key consequence ratings for coastal erosion are provided below.

- Erosion is deemed to have a low consequence on an asset if the asset is landward of the coastal hazard line for the assessed planning horizon. For example, the Back of House has an Insignificant consequence of erosion over all planning horizons, as it is landward of all coastal hazard lines.

- Where erosion could impact a given asset, the consequence of that impact has been assessed based on the extent of the issue that it would create. More minor erosion has less potential to cause severe consequences, whereas more significant erosion could increase the extent of damage.

5.2.2 Coastal Inundation

The assessed consequence of coastal inundation for each of the key assets and each of the planning horizons is presented in Table 5.6. Similar to erosion, the consequence of inundation changes over the planning horizons for various assets due to the likely increased consequence of a higher water level as sea level rise is realised over time.

Importantly, this assessment of the consequence of coastal inundation has been completed on the basis that the public safety risk is managed for inundation events. Given that the major inundation events are likely to be associated with the passage of cyclone events, management of public safety is something that already occurs through the Resorts own emergency management plan and the emergency management procedures of DFES. This is discussed further in Section 6.

Table 5.6 Assessment of Consequence of Coastal Inundation Impact

	Planning Timeframe				
Key Assets	**Present Day**	**25 year**	**40 year**	**50 year**	**100 year**
Block A - Clubhouse	Minor	Minor	Minor	Minor	Moderate
Block B - Accommodation	Minor	Minor	Minor	Minor	Moderate
Block C - Accommodation	Insignificant	Insignificant	Insignificant	Insignificant	Minor
Block D - Accommodation	Insignificant	Insignificant	Insignificant	Insignificant	Minor
Block E - Accommodation	Insignificant	Insignificant	Insignificant	Insignificant	Minor
Block F - Accommodation	Minor	Minor	Minor	Minor	Moderate
Back of House	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Existing Sewer Pump	Insignificant	Insignificant	Insignificant	Insignificant	Minor
New Substation	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Pool	Insignificant	Insignificant	Insignificant	Insignificant	Minor
Lower Level Landscaped Areas	Minor	Minor	Minor	Minor	Minor
Upper Level Landscaped Areas	Insignificant	Insignificant	Insignificant	Insignificant	Minor
Guest Parking Areas	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Resort Access Way and Roundabout	Minor	Minor	Minor	Minor	Minor
Robinson Street & Parking Lot	Minor	Minor	Moderate	Moderate	Moderate

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

The impacts of inundation are assessed to be Insignificant where an asset is located well above the potential inundation level, or otherwise have been classified as Minor over the 40 year planning horizon of the resort. This is due to the fact the cost for the repair of each of the assets after a short duration inundation event would be expected to be less than $500,000. However, whilst these assets are being assessed in isolation, it is incumbent upon RAC to consider the combined effect on each of these assets, as all assets could be impacted within a single event.

Again, it is noted this assessment is on the basis that public safety would already be managed by DFES initiatives, as discussed in detail in Section 6.

5.3 Risk Level

The risk rating from a risk assessment is defined as "likelihood" x "consequence." A risk matrix defining the levels of risk from combinations of likelihood and consequence has therefore been developed for the coastal hazards. This risk matrix is presented in Table 5.7.

Table 5.7 Risk Matrix

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

A risk tolerance scale assists in determining which risks are acceptable, tolerable and unacceptable. The risk tolerance scale used for the assessment is presented in Table 5.8.

Table 5.8 Risk Tolerance Scale

Risk Level	Action Required	Tolerance
Extreme	Immediate action required to eliminate or reduce the risk to acceptable levels	Intolerable
High	Immediate to short term action required to eliminate or reduce risk to acceptable levels	Intolerable
Medium	Reduce the risk or accept the risk provided residual risk level is understood	Tolerable
Low	Accept the risk	Acceptable

The risk tolerance scale has been reviewed and accepted for use by RAC and shows that the extreme and high risks need to be managed.

The risk assessment for the study area will be completed in accordance with the recommendations of AS5334 (Standards Australia, 2013), which requires a detailed risk analysis to include a vulnerability analysis to thoroughly examine how coastal hazards and climate change may affect the assets. This includes consideration of the adaptive capacity and vulnerability of an asset.

5.3.1 Coastal Erosion Risk Evaluation

Based on the results of the risk analysis completed previously, Table 5.9 presents the coastal erosion risk levels for each of the identified key assets.

Table 5.9 Preliminary Assessment of Coastal Erosion Risk Level

Key Assets	Risk Level				
	Present Day	25 year	40 year	50 year	100 year
Block A - Clubhouse	Low	Low	Medium	Medium	High
Block B - Accommodation	Low	Low	Low	Low	Low
Block C - Accommodation	Low	Low	Low	Low	Low
Block D - Accommodation	Low	Low	Low	Low	Low
Block E - Accommodation	Low	Low	Low	Low	Low
Block F - Accommodation	Low	Low	Medium	Medium	High
Back of House	Low	Low	Low	Low	Low
Existing Sewer Pump	Low	Low	Low	Low	Medium
New Substation	Low	Low	Low	Low	Low
Pool	Low	Low	Low	Low	Medium
Lower Level Landscaped Areas	Low	Medium	Medium	Medium	Medium
Upper Level Landscaped Areas	Low	Low	Low	Low	Low
Guest Parking Areas	Low	Low	Low	Low	Low
Resort Access Way and Roundabout	Low	Low	Low	Medium	Medium
Robinson Street & Parking Lot	Low	Medium	Medium	High	High

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

The results of the assessment show that all resort assets have a Low or Medium risk of being impacted by erosion over the 40 year planning horizon. Based on Table 5.8, these risks are deemed to be tolerable, but steps should be taken to reduce the risk where possible. Once again, the combined impact of all of these items should be considered, as it is likely that the combined effect of the impacts on Block A, Block F and the lower level landscaped areas could result in a high overall project risk.

Beyond the 40 year planning horizon the risks levels increase, however this is beyond the timeframe for the assets that are part of the resort development.

5.3.2 Coastal Inundation Risk Evaluation

Based on the results of the risk analysis completed previously, Table 5.10 presents the coastal inundation risk levels for each of the identified key assets. Once again, this risk assessment is on the basis that public safety is effectively managed as discussed in Section 6.

Table 5.10 Preliminary Assessment of Coastal Inundation Risk Level

	Risk Level				
Key Assets	**Present Day**	**25 year**	**40 year**	**50 year**	**100 year**
Block A - Clubhouse	Low	Low	Low	Low	Medium
Block B - Accommodation	Low	Low	Low	Low	Medium
Block C - Accommodation	Low	Low	Low	Low	Low
Block D - Accommodation	Low	Low	Low	Low	Low
Block E - Accommodation	Low	Low	Low	Low	Low
Block F - Accommodation	Low	Low	Low	Low	Medium
Back of House	Low	Low	Low	Low	Low
Existing Sewer Pump	Low	Low	Low	Low	Low
New Substation	Low	Low	Low	Low	Low
Pool	Low	Low	Low	Low	Low
Lower Level Landscaped Areas	Low	Low	Medium	Medium	Medium
Upper Level Landscaped Areas	Low	Low	Low	Low	Low
Guest Parking Areas	Low	Low	Low	Low	Low
Resort Access Way and Roundabout	Low	Medium	Medium	Medium	Medium
Robinson Street & Parking Lot	Low	Medium	Medium	High	High

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

The results of the assessment show that all assets have a Low risk of being impacted by inundation at present and for the 40 year planning horizon with the exception of the lower level landscaped areas and the resort access wayand roundabout. These items have a medium risk, so are deemed to be tolerable but steps should be taken to reduce the risk where possible.

5.4 Adaptive Capacity

The vulnerability of the assets is related to their level of exposure to coastal hazard risks, as well as their sensitivity to the impacts caused by these hazards and their ability to respond to them, termed their adaptive capacity. A scale of adaptive capacity has been prepared for this assessment and is presented in Table 5.11. This scale is used to define how well each of the different assets can adapt to the potential impacts from the respective coastal hazards.

Table 5.11 Scale of Adaptive Capacity

Rating	Description / Frequency
Insignificant Impact; N/A	The impact of the coastal hazard on the asset would have an insignificant impact. This includes where the control or asset would be re-established naturally before further damage would likely occur.
Very High	Very high ability to absorb coastal hazard impacts or where capacity can be restored at relatively low cost. Capacity would be restored naturally over time.
High	Reasonable ability to absorb coastal hazard impacts, with functionality able to be restored . Natural restoration of capacity may occur slowly over time.
Moderate	Small amount of ability to absorb coastal hazard impacts. Restoration of functionality would be difficult, though possible.
Low	Little to no ability to absorb coastal hazard impacts. Functionality would be unable to be restored.

The adaptive capacity of an asset is likely to be different in response to coastal erosion or inundation hazards. The assessed adaptive capacities are outlined in the following sections.

5.4.1 Coastal Erosion

The adaptive capacity of an asset to coastal erosion is generally related to how tolerant that asset is to changes in surface levels. For instance, structures with very deep foundations (piles, etc) may be less prone to impacts from coastal hazards than assets with shallow foundations that could easily be undermined. The potential extent of coastal hazard impact (i.e. the depth of erosion) would also have an impact, for similar reasons to those just described. As a result, the level of adaptive capacity of an asset to coastal erosion can change over time.

The adaptive capacities of the various assets to the assessed coastal erosion hazards are presented in Table 5.12.

For the majority of assets it has been assessed that there is an insignificant impact or not applicable requirement for adaptive capacity as the assets are located well away from the potential areas of coastal erosion hazard impact, particularly over the 40 year planning horizon for the resort. The notable exceptions within the resort are Block A, Block F, the lower level landscaped areas and the resort access way and roundabout. These assets have generally been assessed as having a low adaptive capacity, with the exception of the landscaping, which has a moderate level due to the fact that is easier to restore the functionality of a landscaped area following impact. Outside of the resort development, Robinson Street has also been assessed as having a low adaptive capacity.

Table 5.12 Assessment of Adaptive Capacity to Coastal Erosion Impact

	Planning Timeframe				
Key Assets	**Present Day**	**25 year**	**40 year**	**50 year**	**100 year**
Block A - Clubhouse	Moderate	Low	Low	Low	Low
Block B - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Block C - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Block D - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Block E - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Low
Block F - Accommodation	Moderate	Low	Low	Low	Low
Back of House	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Existing Sewer Pump	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Low
New Substation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Pool	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Low
Lower Level Landscaped Areas	Moderate	Moderate	Moderate	Moderate	Moderate
Upper Level Landscaped Areas	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Guest Parking Areas	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Resort Access Way and Roundabout	Insignificant Impact; N/A	Low	Low	Low	Low
Robinson Street & Parking Lot	Low	Low	Low	Low	Low

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

5.4.2 Coastal Inundation

Similar to coastal erosion hazards, the adaptive capacity to coastal inundation hazards can change over time. This is on the basis that impacts caused by inundation to a depth of a few centimetres will be very different to those caused by inundation depths of greater than a metre.

The assessed adaptive capacity to coastal inundation is presented in Table 5.13.

Across the timeframe of the resort the only assets that have been rated as having a moderate adaptive capacity are the lower level landscaped areas and the resort access way and roundabout. For all other assets it has been assessed that the adaptive capacity would be classified as insignificant impact or not applicable.

Table 5.13 Assessment of Adaptive Capacity to Coastal Inundation Impact

	Planning Timeframe				
Key Assets	**Present Day**	**25 year**	**40 year**	**50 year**	**100 year**
Block A - Clubhouse	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Block B - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Block C - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Block D - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Block E - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Block F - Accommodation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Back of House	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Existing Sewer Pump	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Low
New Substation	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Pool	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Lower Level Landscaped Areas	Moderate	Moderate	Moderate	Moderate	Moderate
Upper Level Landscaped Areas	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Moderate
Guest Parking Areas	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A	Insignificant Impact; N/A
Resort Access Way and Roundabout	Moderate	Moderate	Moderate	Moderate	Moderate
Robinson Street & Parking Lot	Moderate	Moderate	Moderate	Moderate	Moderate

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

5.5 Asset Vulnerability

The overall vulnerability rating is defined as the “adaptive capacity” x “risk level”. A vulnerability matrix defining the vulnerability from combinations of adaptive capacity and risk level has therefore been developed. This risk matrix is presented in Table 5.14.

Table 5.14 Vulnerability Matrix

VULNERABILITY LEVELS		ADAPTIVE CAPACITY				
		Insignificant Impact; N/A	Very High	High	Moderate	Low
RISK LEVEL	Extreme	Low	Medium	High	Extreme	Extreme
	High	Low	Low	Medium	High	High
	Medium	Low	Low	Low	Medium	Medium
	Low	Low	Low	Low	Low	Low

Similarly to the assessment of risk, a vulnerability tolerance scale assists in determining at what level the vulnerability is acceptable, tolerable or intolerable. The vulnerability tolerance scale used for the assessment is presented in Table 5.15.

Table 5.15 Vulnerability Tolerance Scale

Risk Level	Action Required	Tolerance
Extreme	Immediate action required to eliminate or reduce the risk to acceptable levels	Intolerable
High	Immediate to short term action required to eliminate or reduce risk to acceptable levels	Intolerable
Medium	Reduce the risk or accept the risk provided residual risk level is understood	Tolerable
Low	Accept the risk	Acceptable

The assessed vulnerability levels for coastal erosion and inundation are presented below.

5.5.1 Coastal Erosion Vulnerability Assessment

The results of the coastal erosion vulnerability assessment are provided in Table 5.16. The vulnerability assessment confirms that within the 40 year planning horizon of the resort Block A, Block F and the lower level landscaping will have a medium level of vulnerability to coastal erosion. Whilst this level of vulnerability is deemed to be tolerable, the combination of effects on each of these assets at the same time may increase the vulnerability level to high. Thus, opportunities to minimise the risk associated with this level of vulnerability will be reviewed in the Section 6 of this report.

Table 5.16 Assessment of Vulnerability to Coastal Erosion Impact

	Planning Timeframe				
Key Assets	**Present Day**	**25 year**	**40 year**	**50 year**	**100 year**
Block A - Clubhouse	Low	Low	Medium	Medium	High
Block B - Accommodation	Low	Low	Low	Low	Low
Block C - Accommodation	Low	Low	Low	Low	Low
Block D - Accommodation	Low	Low	Low	Low	Low
Block E - Accommodation	Low	Low	Low	Low	Low
Block F - Accommodation	Low	Low	Medium	Medium	High
Back of House	Low	Low	Low	Low	Low
Existing Sewer Pump	Low	Low	Low	Low	Medium
New Substation	Low	Low	Low	Low	Low
Pool	Low	Low	Low	Low	Medium
Lower Level Landscaped Areas	Low	Medium	Medium	Medium	Medium
Upper Level Landscaped Areas	Low	Low	Low	Low	Low
Guest Parking Areas	Low	Low	Low	Low	Low
Resort Access Way and Roundabout	Low	Low	Low	Medium	Medium
Robinson Street & Parking Lot	Low	Medium	Medium	High	High

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

Even though not within the planning horizon of the resort, over the longer term the level of vulnerability would increase for a number of assets. This suggests that any extension of development beyond the initial 40 year horizon would require a complete reassessment to determine the appropriate sites for future development.

The other item to note is that Robinson Street has the highest level of vulnerability of all of the assets. Whilst this is separate to the resort development, it is worth noting that adaptation planning for Robinson Street should be completed.

5.5.2 Coastal Inundation Vulnerability Assessment

The assessed level of coastal vulnerability to inundation is typically low across all assets within the 40 year planning horizon of the resort. The only assets that experience a medium level of vulnerability are the lower level landscaped areas and the resort access way and roundabout. This result is reflective of the fact that the main built form elements of the development are all located at elevations that essentially avoid the inundation risk over the relevant planning horizon. For the two assets that are at a medium risk, further adaptation strategies have been considered in Section 6 of this report.

Similar to the coastal erosion variability, Robinson Street is the asset that is deemed to have the highest degree of vulnerability to inundation, and future planning will need to consider how this risk is managed.

Table 5.17 Assessment of Vulnerability to Coastal Inundation Impact

	Planning Timeframe				
Key Assets	**Present Day**	**25 year**	**40 year**	**50 year**	**100 year**
Block A - Clubhouse	Low	Low	Low	Low	Medium
Block B - Accommodation	Low	Low	Low	Low	Medium
Block C - Accommodation	Low	Low	Low	Low	Low
Block D - Accommodation	Low	Low	Low	Low	Low
Block E - Accommodation	Low	Low	Low	Low	Low
Block F - Accommodation	Low	Low	Low	Low	Medium
Back of House	Low	Low	Low	Low	Low
Existing Sewer Pump	Low	Low	Low	Low	Low
New Substation	Low	Low	Low	Low	Low
Pool	Low	Low	Low	Low	Low
Lower Level Landscaped Areas	Low	Low	Medium	Medium	Medium
Upper Level Landscaped Areas	Low	Low	Low	Low	Low
Guest Parking Areas	Low	Low	Low	Low	Low
Resort Access Way and Roundabout	Low	Medium	Medium	Medium	Medium
Robinson Street & Parking Lot	Low	Medium	Medium	High	High

Notes: 1. Based on most exposed location of each asset group.
2. The development has a maximum planning horizon of 40 years. Timeframes beyond this are included for completeness, but are not relevant to the current proposal.

6. Risk Adaptation & Mitigation Strategies

SPP2.6 outlines a hierarchy of risk adaptation and mitigation options, where options that allow for a wide range of future strategies are considered more favourably. This hierarchy of options is reproduced in Figure 6.1.

Figure 6.1 Risk Management & Adaptation Hierarchy

These options are generally outlined below.

- Avoid – avoid new development within the area impacted by the coastal hazard.
- Retreat – the relocation or removal of assets within an area identified as likely to be subject to intolerable risk of damage from coastal hazards.
- Accommodation – measures which suitably address the identified risks.
- Protect – used to preserve the foreshore reserve, public access and public safety, property and infrastructure.

The assessment of options is generally done in a progressive manner, moving through the various options until an appropriate mitigation option is found.

6.1 Proposed Mitigation Strategies

6.1.1 Assets

The requirement for coastal hazard risk mitigation strategies within the Resort is ultimately informed by the risk tolerance of RAC. In the preparation of this CHRMAP RAC has acknowledged and accepted the coastal hazard risks for each of the assets within the redevelopment. This acceptance is on the basis that the risk management and adaptation principles, as previously discussed and further outlined herein, are put in place.

A key element of this adaptation planning is the response to potentially increasing risks of coastal impacts, both erosion and inundation. The results of the risk and vulnerability assessment indicate that the level of risk posed to each of the individual assets is at a level that is generally tolerable to the RAC over the 40 year service life. However, beyond this initial service life, a decision will need to be made as to whether any replacement assets are relocated to an area further landward or are removed. This essentially adopts a **managed retreat** or **abandon** management approach, with the future decisions to be informed through the completion of an updated coastal hazard risk assessment at the time of asset replacement. This approach is also essential to ensure that social and environmental assets, including the foreshore, remain unaffected over the initial and future planning horizons.

It is acknowledged that if the shoreline recedes to the location of the 100 year erosion hazard line, then not all assets that currently form part of the Resort could be retained, with some assets potentially having to be removed and not replaced. Nonetheless, it should be noted that if such erosion did occur the implications for the entire town site of Coral Bay would be significant.

Despite advice that the risks over the initial 40 year service life are acceptable to RAC, the As Low As Reasonably Practical (ALARP) approach has been adopted for the planning to reduce the extent of impacts should a severe event occur. The focus of this risk reduction is primarily on Block A and Block F as these are the proposed built assets that would potentially be subject to the most adverse effects should coastal erosion hazards be realised over the service life.

These assets will all be designed in accordance with the minimum prescriptive requirements of codes and standards typically considered mandatory for cyclonic regional and coastal built forms. This will form the baseline design criteria for all proposed structures within the Resort. Moreover, a review of the structural design of the proposed structures will include consideration of the available and estimated storm and cyclone event conditions and pressures from both water and wind. This will form the ultimate design criteria where structural review(s) identify strategies beyond the baseline criteria that directly address site specific, historical and/or anticipated coastal hazards.

To reduce coastal risks from erosion on Blocks A and F, RAC propose to complete the construction of the resort with modular elements that can easily be removed if the coastal hazard risks and subsequent coastal vulnerability are realised within the planning horizon of the resort. This development approach will enable a nimble response to any such risk that may eventuate. Triggers for the removal of infrastructure are discussed further below as well as in the implementation plan in Section 7.

Whilst the above approach presents a strategy for managing the overall erosion risk that may be realised over time, to provide additional protection against acute impacts that could occur, the foundations of the structural elements of Blocks A and F that are within the coastal hazard line for the 40 year planning horizon will be more deeply set. This will enable any risk from acute coastal erosion to be accommodated if this occurs before the infrastructure can be moved. The modelling of potential erosion presented in Section 3 did not identify a significant erosion depth at the upper elevation of the profile, mainly due to the short duration of the higher water levels being experienced, however to provide additional protection, foundations will be installed to a depth of at least 1 m below ground level.

One of the other assets that had a medium level of vulnerability to coastal erosion was the lower level landscaped area. Being a landscaped area that also aims to provide a ramped public access into the resort, this is unavoidable and is also the reason why this asset also has a medium level of vulnerability to coastal inundation. To help reduce the impacts of coastal hazards, robust elements that are less sensitive to the effects of inundation are proposed to be used in this area. This will help to accommodate the risks, however ultimately it is accepted that some degree of maintenance or remediation may be required following sever events.

The only other asset that had a medium level of vulnerability was the resort access way and roundabout. The vulnerability of this asset is really limited to the northern portion of the site. As a result this area is to be designed to ensure that it can accommodate inundation with as little damage as possible and to also ensure that there is appropriate drainage so that any inundation is cleared quickly when the water level recedes.

In addition to the above, other design approaches are also proposed for the site to further incorporate the ALARP approach. This will include the following.

- Locating key service lines as far landward as possible to reduce the potential for exposure to coastal hazards.
- Incorporating systems that allow for easy isolation of services in different areas so that areas that could be at risk from coastal hazards are able to be shut down easily if required.
- Locating all electrical service points (GPO's, etc) as high as possible, or ideally above 4.9 mAHD for the initial service life, to reduce the impacts should inundation occur.
- Storing all hazardous materials at or above a level of 4.9 mAHD to reduce the risk of environmental damage should inundation occur.
- Development of a coastal hazard response plan that outlines steps to be taken by staff pre and post coastal hazard impact to manage and mitigate any risks. This includes the risk to public safety, which is discussed further in the following section.

Implementation of the above strategies will help to manage the risks to the overall asset that is the Ningaloo Reef Resort. Furthermore, implementation of these items will also ensure that the social and environmental values of the area are maintained.

It is important to note that monitoring of the shoreline will form a key part of the adaptation planning response. Monitoring of the shoreline is discussed in Section 7.4. One of the main purposes of this monitoring is to provide an early indication of shoreline change that can be used to prompt adaptation measures, such as the **managed retreat** or **abandonment** (with removal) of certain assets.

The trigger for these management actions need to be related to the movement of the shoreline. For instance, if sustained erosion of the shoreline, observed over a period of years, results in shoreline retreat of more than 20 m, then specialist coastal engineering advice should be sought regarding the risk and the required timeframe for relocation/removal of the assets. Specific investigations should be completed at this time to determine at what point the infrastructure needs to be relocated.

If, on the other hand, the position of the shoreline recedes to the point where these triggers are reached as a result of the passage of a storm/cyclone event, then specialist coastal engineering advice should be sought to ascertain the potential for recovery of the shoreline before any relocation is completed. The basis for this difference in response between erosion caused by chronic or acute events is driven by the different mechanisms that lead to the erosion in both cases.

Chronic erosion of the shoreline occurs due to creation of a net sediment deficit in an area, typically due to either imbalances in longshore transport rates or continual losses to the offshore environment. Such chronic erosion if often not reversible. Acute erosion, caused by cyclone or storm events, often results in sediment losses on the shoreline that are more temporary, with shoreline recovery often experienced thereafter. Thus, the requirement to trigger adaptation measures may, in some instances, be more pressing as a result of chronic erosion than from acute erosion.

6.1.2 Public Safety

As outlined previously, the risk and vulnerability ratings that were determined for inundation hazards, and consequently the risk mitigation strategies outlined above, are provided on the basis that public safety is already managed by both the RAC and DFES. DFES's management occurs along the entire coastline of Western Australia in response to cyclone events, which are the key contributor to inundation hazards at the Resort site (refer Section 4).

Essentially, to manage risks associated with cyclone inundation, DFES communicate with the Bureau of Meteorology to receive updates on the potential cyclone tracks and associated storm surge and areas of inundation. Evacuations are then completed as required in order to manage public safety prior to event impact.

It is also important to note that there would be some degree of self-management of these risks by patrons of the Resort at the time of such events, as many travellers would be aware of the risks and would likely leave the area before conditions became too severe. Nevertheless, despite the potential self-management by travellers and the management by DFES, RAC will develop a specific inundation risk management plan for the Ningaloo Reef Resort. This plan will outline steps that should be taken as severe events approach, as well as evacuation pathways and routes to relevant evacuation centres. This plan will be developed in consultation with DFES and the Shire.

As a result of the evacuation policies that are already in place, as well as any further development of these policies that may be required specifically for the Resort, the management of public safety due to coastal hazards is ensured. It must be noted that the Resort already has a mandatory evacuation policy for guests in the event of cyclone or other coastal risk warning.

7. Implementation Plan

The risk mitigation and adaptation strategy outlined in Section 6 set out the general proposed coastal management approach for the development. Direct guidance on when, what, how and by who these processes will be completed is provided within this implementation plan. For ease of reference, these details have been broken down to outline the requirements for each stage of the project and/or asset life.

7.1 Planning & Initial Construction

Coastal planning for this development, largely informed by the findings of this CHRMAP, has identified that a coastal hazard risk exists for the existing Robinson Street and for the proposed assets within the Resort redevelopment. The sole responsibility for the risk associated with assets that are part of the resort development is something that has been acknowledged and accepted by RAC.

The other element that is key during the planning and construction phase is to ensure that the designs of each of the individual assets that comprise the redevelopment of the Resort are appropriate to be able to respond to the potential impacts of coastal hazards.

A summary of the requirements of the planning and construction stage is presented in Table 7.1.

Table 7.1 Implementation Plan Summary – Planning & Initial Construction Stage

Requirement	Timing	Responsibility
Acceptance of disclosed hazards/vulnerability	Planning Stage	RAC (note: completed through acknowledgement and acceptance of risks outlined within this report)
Appropriate design of Resort structural elements and levels to ensure that erosion and inundation risks are managed as best as possible	Planning & Construction Stage	RAC (supported by engaged design team)

7.2 Operation Over the Infrastructure Service Life

Over the service life of each of the assets there will be a requirement to monitor the shoreline to ascertain whether the risk to assets is increasing. Further details of the monitoring requirements are outlined in Section 7.4. This monitoring will be responsibility of the RAC.

If, at some stage during the service life of the infrastructure the risk from coastal hazards becomes untenable, the assets that are under threat will be removed or relocated in accordance with the managed retreat adaptation strategy. In this way a foreshore area will always be maintained fronting the site.

The other items that need to occur during the operation are to ensure that the evacuation and emergency management procedures are enacted during extreme events. This will be the responsibility of RAC, but will ultimately be informed by advice from DFES prior to and during the passage of the events. This management will include both evacuation as well as management of the site, such as shut off of all services to ensure no spillage / leakage during the events.

A summary of the requirements during the operation of the assets over their service life is presented in Table 7.2.

Table 7.2 Implementation Plan Summary – Operation over the Infrastructure Service Life

Requirement	Timing	Responsibility
Monitoring coastal hazard risk to assess if risk becomes untenable and assets need to be relocated (Refer Section 7.4)	Operation over service life	RAC
IF REQUIRED Asset removal / retreat in accordance with the requirements outlined in Section 7.3	When risk level becomes untenable	RAC
Evacuation and Emergency Management (including shut off of services etc to manage environmental risks as required)	During extreme events over service life	RAC (will be informed by DFES advice prior to/during events)

7.3 Asset Removal / Replacement

Replacement of assets after their service life requires that they be relocated to an area where the risk to that asset over its remaining service life is considered to be acceptable. To do this will require a revised coastal hazard risk assessment to be completed in accordance with the requirements at that time. The appropriate location for the replacement assets can then be chosen based on the acceptable risk level. Alternatively, that particular asset could be removed and not replaced, which is essentially an abandon management approach. The responsibility for these actions would rest with the RAC.

A summary of the requirements during the removal / replacement of assets is presented in Table 7.3.

Table 7.3 Implementation Plan Summary – Operation over the Service Life

Requirement	Timing	Responsibility
Complete a revised coastal hazard risk assessment to quantify the risk level at that time	When risk to existing assets becomes untenable	RAC
Determine appropriate retreat location for replacement infrastructure based on acceptable risk level OR Remove infrastructure and abandon for that particular asset	Planning for asset removal / replacement	RAC
Complete relocation / removal of relevant assets	When risk to existing assets becomes untenable	RAC

Beyond the service life of the resort development, any future development that is proposed will need to also meet the coastal planning and risk management requirements at that time. This will require completion of a revised coastal hazard risk assessment to inform where new development can be located. It is noted that if the shoreline does erode, then there may be little available space for a future resort and as a result the site may have to be abandoned.

A summary of the requirement for future replacement of infrastructure at the end of the initial service life of the resort is provided in Table 7.4.

Table 7.4 Implementation Plan Summary – End of Service Life

Requirement	Timing	Responsibility
Complete a revised coastal hazard risk assessment to quantify the risk level at that time	During planning for the future redevelopment	RAC
Determine appropriate layout for new resort assets OR Remove infrastructure and abandon site if development is not feasible	During planning for the future redevelopment	RAC
Complete development in accordance with layout approved at that time	Following approval of future resort redevelopment	RAC

7.4 Monitoring & Review

Coastal monitoring and review is essential in order to track changes to the shoreline over time. Whilst the results of Section 3 provide an indication of the potential changes to the shoreline (and incorporate a justifiable level of conservatism), the system is inherently complex and the actual shoreline response could be different to that presented. Monitoring should therefore be completed to track changes over time and indicate whether the timing for risk mitigation should be adjusted. Triggers for further assessment of the shoreline movement have previously been discussed. As a result the following triggers will be used.

- Retreat of the shoreline by 20 m from its current location as a result of chronic erosion will prompt review by a specialist coastal engineer to determine at what stage vulnerable infrastructure needs to be relocated or removed.
- Retreat of the shoreline by 20 m from its current location caused by acute erosion will prompt review by a specialist coastal engineer to ascertain the potential for recovery of the shoreline and to determine if any further management measures are required. .

The shoreline monitoring should be completed using a combination of onsite measurements and photo-monitoring as well as review of aerial photography captured by Landgate.

If the rate of change in shoreline position observed during the monitoring is materially different from that allowed for with the erosion hazard assessment, it would be recommended that this CHRMAP be updated to quantify any changes to the risks posed by coastal hazards.

Likewise, should the State Government guidance for the determination of the required allowances change as a result of new information becoming available, the CHRMAP should also be updated. This is especially the case for information regarding climate change and projected sea level rise, however may also apply for the calculation of severe storm erosion, shoreline movement erosion and inundation allowances. The responsibility for both of these actions would rest with the RAC.

A summary of the requirements for the monitoring and review is presented in Table 7.5.

Table 7.5 Implementation Plan Summary – Monitoring & Review

Requirement	Timing	Responsibility
Shoreline monitoring	Ongoing throughout the development – to be assessed on a yearly basis or as required based on the triggers being met or exceeded	RAC
Revision of CHRMAP	If shoreline behaviour changes substantially from that identified within this CHRMAP OR If guidance changes on the determination of the required allowances as a result of new information becoming available	RAC

9. Conclusions

This CHRMAP has been completed to provide guidance on required adaptation and management actions associated with existing and proposed assets within the Ningaloo Resort. It has been completed in line with the recommendations of SPP2.6 and WAPC (2014).

The completion of the coastal hazard risk assessment for this site has shown that there is a risk of coastal hazards adversely impacting the site, however, over the 40 year planning horizon associated with the proposed asset service lives the risk is deemed to be at an acceptable level (as advised by RAC). Despite the level of risk being acceptable, the ALARP approach has been adopted for the development and additional risk mitigation strategies have been proposed for implementation by RAC. This includes both a built form response for newly constructed assets as well as an overall management approach.

Finally, this plan was developed on the basis that the risk to public safety as a result of cyclone inundation is already managed within the Resort and by DFES. Regardless of this fact, RAC will develop a management plan for the redeveloped Resort. This plan will be developed in consultation with DFES and the Shire.

Notwithstanding the results of the coastal hazard assessment, it is noted that aerial photography of the beach fronting the Ningaloo Reef Resort documenting 52 years of coastal processes and covering a period when around 15 significant cyclones would have influenced the shoreline, indicates that this is a stable coastal environment and that the risk assessment is balanced against the considerable social and economic benefit to the region created by this development, as provided for by SPP2.6 Item 4, Policy Objectives 2 and 3.

10. References

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11. Appendices

Appendix A SBEACH Reports

Appendix A SBEACH Reports

K1443 Ningaloo Reef Resort
Reach: Profile North Storm: Category 4 - North

Report

Project: K1443 Ningaloo Reef Resort
Reach: Profile North
Storm: Category 4 - North

MODEL CONFIGURATION

INPUT UNITS (SI=1, AMERICAN CUST.=2): 1
NUMBER OF CALCULATION CELLS: 987
GRID TYPE (CONSTANT=0, VARIABLE=1): 1
NUMBER OF GRID CELL REGIONS: 4
NUMBER CELLS AND CELL WIDTH IN REGION 1: 400, 1.0
NUMBER CELLS AND CELL WIDTH IN REGION 2: 300, 2.0
NUMBER CELLS AND CELL WIDTH IN REGION 3: 256, 5.0
NUMBER CELLS AND CELL WIDTH IN REGION 4: 31,200.0
NUMBER OF TIME STEPS AND VALUE OF TIME STEP IN MINUTES: 1296, 5.0
TIME STEP(S) OF INTERMEDIATE OUTPUT 1: 5
TIME STEP(S) OF INTERMEDIATE OUTPUT 2: 432
TIME STEP(S) OF INTERMEDIATE OUTPUT 3: 864
NO COMPARSION WITH MEASURED PROFILE.
PROFILE ELEVATION CONTOUR 1: 2.30
PROFILE ELEVATION CONTOUR 2: 0.00
PROFILE ELEVATION CONTOUR 3: 2.00
PROFILE EROSION DEPTH 1: 0.01
PROFILE EROSION DEPTH 2: 1.00
PROFILE EROSION DEPTH 3: 0.00
REFERENCE ELEVATION: 3.40
TRANSPORT RATE COEFFICIENT (m^4/N): 1.75E-6
COEFFICIENT FOR SLOPE DEPENDENT TERM (m^2/s): 0.0020
TRANSPORT RATE DECAY COEFFICIENT MULTIPLIER: 0.50
WATER TEMPERATURE IN DEGREES C : 20.0

WAVE TYPE (MONOCHROMATIC=1, IRREGULAR=2): 2
WAVE HEIGHT AND PERIOD INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE WAVE HEIGHT AND PERIOD INPUT IN MINUTES: 60.0
WAVE ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WAVE ANGLE: 0.0
WATER DEPTH OF INPUT WAVES (DEEP WATER = 0.0): 50.0
SEED VALUE FOR WAVE HEIGHT RANDOMIZER AND % VARIABILITY: 4567, 20.0
TOTAL WATER ELEVATION INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE TOTAL WATER ELEVATION INPUT IN MINUTES: 60.0
WIND SPEED AND ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WIND SPEED AND ANGLE: 30.0, 0.0

TYPE OF INPUT PROFILE (ARBITRARY=1, SCHEMATIZED=2): 1
DEPTH CORRESPONDING TO LANDWARD END OF SURF ZONE: 0.30
EFFECTIVE GRAIN SIZE DIAMETER IN MILLIMETERS: 0.30
MAXIMUM PROFILE SLOPE PRIOR TO AVALANCHING IN DEGREES: 45.0

NO BEACH FILL IS PRESENT.

NO SEAWALL IS PRESENT.

HARD BOTTOM IS PRESENT.

COMPUTED RESULTS

DIFFERENCE IN TOTAL VOLUME BETWEEN FINAL AND INITIAL PROFILES:
0.0 m^3/m

MAXIMUM VALUE OF WATER ELEVATION + SETUP FOR SIMULATION

K1443 Ningaloo Reef Resort

Reach: Profile North Storm: Category 4 - North

3.39 m

TIME STEP AND POSITION ON PROFILE AT WHICH MAXIMUM VALUE
OF WATER ELEVATION + SETUP OCCURRED
649, 47.0 m
MAXIMUM ESTIMATED RUNUP ELEVATION: 2.40 m
(REFERENCED TO VERTICAL DATUM)

POSITION OF LANDWARD MOST OCCURRENCE OF A 0.01 m EROSION DEPTH:
46.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 0.01 m EROSION DEPTH:
0.1 m

A 1.00 m EROSION DEPTH DID NOT OCCUR ANYWHERE ON THE PROFILE.

MAXIMUM RECESSION OF THE 2.30 m ELEVATION CONTOUR:
0.13 m

THE 0.00 m CONTOUR DID NOT RECEDE

THE 2.00 m CONTOUR DID NOT RECEDE

Report

Project: K1443 Ningaloo Reef Resort
Reach: Profile West
Storm: Category 4 - West

MODEL CONFIGURATION

INPUT UNITS (SI=1, AMERICAN CUST.=2): 1
NUMBER OF CALCULATION CELLS: 761
GRID TYPE (CONSTANT=0, VARIABLE=1): 1
NUMBER OF GRID CELL REGIONS: 4
NUMBER CELLS AND CELL WIDTH IN REGION 1: 400, 1.0
NUMBER CELLS AND CELL WIDTH IN REGION 2: 335, 2.0
NUMBER CELLS AND CELL WIDTH IN REGION 3: 13,100.0
NUMBER CELLS AND CELL WIDTH IN REGION 4: 13,200.0
NUMBER OF TIME STEPS AND VALUE OF TIME STEP IN MINUTES: 1296, 5.0
TIME STEP(S) OF INTERMEDIATE OUTPUT 1: 5
TIME STEP(S) OF INTERMEDIATE OUTPUT 2: 432
TIME STEP(S) OF INTERMEDIATE OUTPUT 3: 864
NO COMPARSION WITH MEASURED PROFILE.
PROFILE ELEVATION CONTOUR 1: 2.30
PROFILE ELEVATION CONTOUR 2: 0.00
PROFILE ELEVATION CONTOUR 3: 2.00
PROFILE EROSION DEPTH 1: 0.01
PROFILE EROSION DEPTH 2: 1.00
PROFILE EROSION DEPTH 3: 0.00
REFERENCE ELEVATION: 3.40
TRANSPORT RATE COEFFICIENT (m^4/N): 1.75E-6
COEFFICIENT FOR SLOPE DEPENDENT TERM (m^2/s): 0.0020
TRANSPORT RATE DECAY COEFFICIENT MULTIPLIER: 0.50
WATER TEMPERATURE IN DEGREES C : 20.0

WAVE TYPE (MONOCHROMATIC=1, IRREGULAR=2): 2
WAVE HEIGHT AND PERIOD INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE WAVE HEIGHT AND PERIOD INPUT IN MINUTES: 60.0
WAVE ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WAVE ANGLE: 0.0
WATER DEPTH OF INPUT WAVES (DEEP WATER = 0.0): 50.0
SEED VALUE FOR WAVE HEIGHT RANDOMIZER AND % VARIABILITY: 4567, 20.0
TOTAL WATER ELEVATION INPUT (CONSTANT=0, VARIABLE=1): 1
TIME STEP OF VARIABLE TOTAL WATER ELEVATION INPUT IN MINUTES: 60.0
WIND SPEED AND ANGLE INPUT (CONSTANT=0, VARIABLE=1): 0
CONSTANT WIND SPEED AND ANGLE: 30.0, 0.0

TYPE OF INPUT PROFILE (ARBITRARY=1, SCHEMATIZED=2): 1
DEPTH CORRESPONDING TO LANDWARD END OF SURF ZONE: 0.30
EFFECTIVE GRAIN SIZE DIAMETER IN MILLIMETERS: 0.30
MAXIMUM PROFILE SLOPE PRIOR TO AVALANCHING IN DEGREES: 45.0

NO BEACH FILL IS PRESENT.

NO SEAWALL IS PRESENT.

HARD BOTTOM IS PRESENT.

COMPUTED RESULTS

DIFFERENCE IN TOTAL VOLUME BETWEEN FINAL AND INITIAL PROFILES:
6.1 m^3/m

MAXIMUM VALUE OF WATER ELEVATION + SETUP FOR SIMULATION

3.74 m

TIME STEP AND POSITION ON PROFILE AT WHICH MAXIMUM VALUE
OF WATER ELEVATION + SETUP OCCURRED
650, 14.0 m
MAXIMUM ESTIMATED RUNUP ELEVATION: 2.41 m
(REFERENCED TO VERTICAL DATUM)

POSITION OF LANDWARD MOST OCCURRENCE OF A 0.01 m EROSION DEPTH:
3.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 0.01 m EROSION DEPTH:
12.9 m

POSITION OF LANDWARD MOST OCCURRENCE OF A 1.00 m EROSION DEPTH:
7.0 m

DISTANCE FROM POSITION OF REFERENCE ELEVATION ON INITIAL PROFILE
TO POSITION OF LANDWARD MOST OCCURRENCE OF A 1.00 m EROSION DEPTH:
8.9 m

MAXIMUM RECESSION OF THE 2.30 m ELEVATION CONTOUR:
0.01 m

MAXIMUM RECESSION OF THE 0.00 m ELEVATION CONTOUR:
8.60 m

MAXIMUM RECESSION OF THE 2.00 m ELEVATION CONTOUR:
0.00 m

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