COASTAL ENGINEERING SOLUTIONS

ROWES BAY / PALLARENDA SHORELINE EROSION MANAGEMENT PLAN

prepared for

Townsville City Council

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EXECUTIVE SUMMARY

The foreshores of Rowes Bay and Pallarenda offer a rich diversity of seascapes and landscapes - providing extensive recreational and lifestyle opportunities that are considerably enhanced by local cultural, heritage and environmental values. However the dynamic nature of the coastal environment means that some local reaches are experiencing erosion which is threatening essential infrastructure.

In recognition of the need to preserve this foreshore as a natural resource and to accommodate the ever increasing pressures of urban development on an eroding shoreline, Townsville City Council has commissioned this *Shoreline Erosion Management Plan*.

OBJECTIVES

The objectives of the Shoreline Erosion Management Plan are:

- to enable the Townsville City Council to proactively plan for erosion management in a way that is consistent with all relevant legislation (Commonwealth, State and Local) as well as all relevant coastal and environmental policies;
- to investigate and address the underlying causes of shoreline erosion and its likely future progression at the local scale;
- to determine cost effective and sustainable erosion management strategies that maintain natural coastal processes and resources; and
- to consider community needs in both the short- and long-term.

RECOMMENDED SHORELINE EROSION MANAGEMENT STRATEGY

Following a review of the prevailing coastal processes, risks and values of the Rowes Bay / Pallarenda foreshores the following activities are recommended by this Shoreline Erosion Management Plan:

Beach Nourishment

- The extent of the recommended Beach Nourishment is shown in the Figure on page v.
- Implement a trial of entrance training works at the mouth of Mundy Creek. This is to be implemented by using sand-filled geotextile bags to initially construct two training walls (approximately 80m long on the northern side of the entrance and 35m long on its southern side).
- At the same time as the training walls are constructed, sand must be placed on the outside flanks of each wall to create the beach fillets that would otherwise form naturally. This is necessary to avoid instigating erosion on the shoreline adjacent to the training walls if these fillets were allowed to be created naturally.

- Should funding constraints require staged construction of the training walls, it is recommended that the northern wall and its associated beach fillet be constructed first.
- Place sand as initial nourishment on the shoreline north of Mundy Creek and along the Soroptimist Park ocean frontage. The sand quantities required will depend upon the location of a Coastal Defence Line nominated by Council; and the degree of protection required (ie. the selected Design Event). Some guidance on the quantities of sand required in erosion buffers is provided in this Shoreline Erosion Management Plan.
- The sand for this initial nourishment is likely to be from sources previously utilised by Council for earlier beach nourishment campaigns at Rowes Bay. This supply could be supplemented by clearing deposited sand from the main channel of the Mundy Creek entrance (between the new training walls) and from the creek's lower reaches downstream of the Cape Pallarenda Road bridge.
- It is possible that this initial supply of sand could be obtained from the entrance shoals at Three Mile Creek; however this option would need to be explored further through surveys and appropriate sampling / testing.
- Implement appropriate dune management practices on newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
- Undertake annual sand back-passing campaigns to take 4,500 m^3 /year of sand from the vicinity of the Three Mile Creek entrance area (between mean sea level and low tide) and transport it to the renourishment areas north of Mundy Creek (4,000 m^3/year) and the ocean frontage of Soroptimist Park (500 m^3/year). Investigations undertaken for this Shoreline Erosion Management Plan show that impacts on foreshores downdrift of the extraction point are negligible.
- This back-passing can be achieved in one of two ways - either by using conventional earthmoving equipment, or by a "sand shifter" arrangement. The most appropriate application will be determined by costs and considerations of operational impacts on local communities. Guidance on these issues is offered in the Shoreline Erosion Management Plan.
- Monitor the effectiveness of training works at Mundy Creek entrance, making any alterations to the length and height of walls if appropriate. Upon successful completion of the trial, armour the temporary training walls for a more permanent arrangement. Alternatively completely remove the sand-filled geotextile bags that constitute the walls, returning sand to the beach system.
- Monitor the effectiveness of the sand back-passing arrangements, making alterations to equipment and operations as appropriate.

Do Nothing

- The extent of the recommended Do Nothing strategy is shown on the Figure on page v.
- Allow natural coastal processes to continue to shape the shoreline in those areas where no essential community infrastructure is threatened by erosion processes and where environmental values are not compromised by such processes. This applies to the following coastal reaches:
    - the northern flank of Kissing Point (where an existing seawall exists as far west as Soroptimist Park);
    - north of Beach Access N8, up to the southern side of the Three Mile Creek entrance; and
    - north of Beach Access N22, up to Cape Pallarenda.
- To ensure the future integrity of this management option, a supplementary strategy of Avoid Development is also recommended. This is relatively easy to implement by application of appropriate coastal management principles and policies under the existing State Coastal Plan.

Planned Retreat - Relocate Non-essential Infrastructure

- The extent of the recommended Planned Retreat strategy is shown in the Figure on page v. It does not affect any private property.
- Relocate non-essential community amenities so as to allow natural coastal processes to shape the shoreline unimpeded. This applies to the shoreline north of the Three Mile Creek entrance, up to Beach Access N22, and therefore includes the ocean frontage of the Pallarenda suburb.
- To ensure the future integrity of this management option, a supplementary strategy of Avoid Development is also recommended. Again, this is relatively easy to implement by application of appropriate coastal management principles and policies under the existing State Coastal Plan.
- A section of the power lines that provide electrical services to the suburb of Pallarenda is at risk of loss by erosion. Consideration needs to be given to relocating this section of the local power distribution network to a location further inland beyond erosion influences.

Project Design and Approvals

- Townsville City Council (in consultation with other stakeholders) to select the Design Event for which the erosion mitigation strategies recommended by this Shoreline Erosion Management Plan are to accommodate. This requires consideration and acceptance of the risk that such an event will occur (or be exceeded) within a 50 year planning period. Guidance on risk is offered in the Shoreline Erosion Management Plan. Nominating the Design Event requires selecting the Average Recurrence Interval (ARI) cyclone for which immunity is required.
- Should an event occur that is more severe than the selected Design Event, then the strategies and engineering works implemented in accordance with this Shoreline Erosion Management Plan may be compromised and coastal infrastructure could be damaged or destroyed as a consequence. The

selection of an appropriate Design Event is therefore an important consideration.
- Townsville City Council (in consultation with other stakeholders) to select the alignment of an appropriate Coastal Defence Line along the Rowes Bay / Pallarenda shoreline. Throughout the 50 year planning period, property and infrastructure landward of the Coastal Defence Line remain protected from long-term erosion effects; short-term erosion caused by the Design Event; and recession as a consequence of future climate change. Foreshore areas seaward of the Coastal Defence Line lie within the active beach system (ie. within the erosion buffers).
- Undertake engineering designs for works associated with the trial of training walls at the Mundy Creek entrance; and for the initial beach nourishment to the north and south of Mundy Creek.
- Prepare and submit appropriate approval applications based on designs for the proposed works.

Project Monitoring

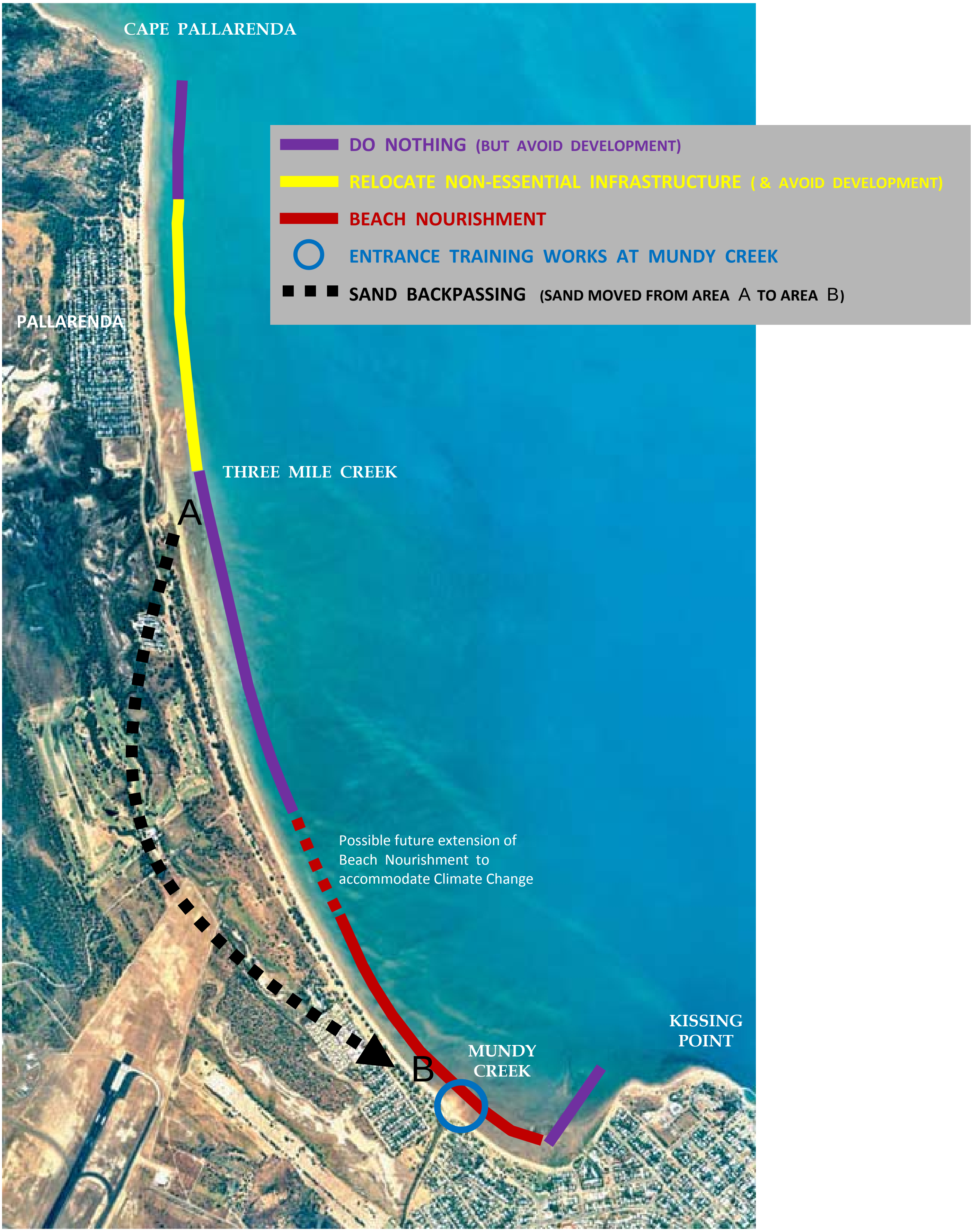
- Establish and undertake pre-project monitoring survey on beach transects at 250 metre intervals along the 2.5km long shoreline between the southern end of Soroptimist Park and Beach Access N8. This will require the establishment of three new transect lines in addition to those transects already located in this priority area.
- Reinstate transect line TOWN37 at Three Mile Creek.
- Include surveys of all Beach Transects between TOWN29 and TOWN42 in a pre-project monitoring survey.
- Undertake beach transect surveys annually on all of these TOWN Beach Transect Lines.
- However on the shoreline south of Beach Access N8, beach transect surveys to be undertaken twice annually - with additional surveys on these transects immediately after major erosion events.
- All surveys are to extend offshore for a minimum distance of 500m from the line of mean sea level on the beach.

Existing Emergency Foreshore Protection Works

- In response to major storm erosion in recent years, emergency protection works have been implemented on the foreshore north of Mundy Creek. This entailed the installation of sand-filled geotextile tubes and bags that were buried at the rear of the upper beach slope.
- Approvals for these geotextile structures was forthcoming on the basis that they were temporary works, undertaken as emergency measures only and were to be removed at some time in the future.
- In relation to these emergency foreshore protection works, it is recommended as follows:
    - since the works are currently protecting essential infrastructure (primarily Cape Pallarenda Road) as well as the iconic banyan trees along the foreshore, they should remain in place until the beach

nourishment proposed by this Shoreline Erosion Management Plan is implemented; and

- when preparing designs and approvals for the recommended beach nourishment, (following selection of the Coastal Defence Line and the ARI Design Event by project stakeholders) a detailed assessment of the impact of the existing emergency works on beach processes should be undertaken. This would then enable a decision to be made as to whether or not the works need to be removed.
- If it is appropriate to leave them in place, then the emergency works should be included in the approval applications for the beach nourishment works recommended by this Shoreline Erosion Management Plan.



Recommended Shoreline Erosion Management Plan

ESTIMATED COSTS

The estimated costs associated with the above recommended strategies are summarised below.

At this early stage, these estimates must be considered as indicative only - since no detailed design has been undertaken. They have been based on an approximation of sand volumes for initial beach nourishment to provide a buffer to an assumed Coastal Defence Line - the location of which requires confirmation or amendment by the project's stakeholders.

SEMP component	Cost	Annual Cost
Project Design and Approvals		
Design of trial training walls at Mundy Creek entrance	$15,000	
Design of initial beach nourishment	$5,000	
Obtain appropriate approvals	$20,000	
Project Monitoring		
Establish & undertake initial pre-project surveys	$18,000	
Annual survey of all beach transects		$12,000
Additional bi-annual survey of priority area		$8,000
Beach Nourishment		
Implementation of trial training walls at Mundy Creek	$175,000	
Operation of trial for training walls (assume 2 years duration)	$30,000	
Implementation of initial beach nourishment :		
for 50 year ARI immunity	*$3,470,000*	
for 100 year ARI immunity	*$4,870,000*	
for 200 year ARI immunity	*$5,470,000*	
for 500 year ARI immunity	*$6,470,000*	
for 1,000 year ARI immunity	*$8,770,000*	
Implementation / maintenance of dune management program	$50,000	$10,000
On-going renourishment by conventional earthmoving equipment		$60,000
Convert to permanent training walls at Mundy Creek	$230,000	
Maintenance of training walls		$10,000
Totals (for various initial beach nourishment options)		
for 50 year ARI immunity	**$4,013,000**	**$100,000**
for 100 year ARI immunity	**$5,413,000**	**$100,000**
for 200 year ARI immunity	**$6,013,000**	**$100,000**
for 500 year ARI immunity	**$7,013,000**	**$100,000**
for 1,000 year ARI immunity	**$9,313,000**	**$100,000**

1 INTRODUCTION

The foreshores of Rowes Bay and Pallarenda offer a rich diversity of seascapes and landscapes - providing extensive recreational and lifestyle opportunities that are considerably enhanced by local cultural, heritage and environmental values. The historical development of the area has consequently focused on the shoreline - as residents and visitors seek to enjoy the unique character of this coastal precinct.

The complex interaction of waves, tidal currents, winds and creek flows are continually shaping and reshaping the shoreline between Kissing Point and Cape Pallarenda. The dynamic nature of the coastal environment means that some local reaches are experiencing erosion which is threatening essential infrastructure.

In recognition of the need to preserve this foreshore as a natural resource and to accommodate the ever increasing pressures of urban development on an eroding shoreline, Townsville City Council has commissioned this *Shoreline Erosion Management Plan*. Its purpose is to provide a framework for the sustainable use, development and management of foreshore land vulnerable to erosion.

This is to be achieved through appropriate consideration of local environmental, social and economic values as well as the physical coastal processes shaping the shoreline. Figure 1.1 illustrates the extent of the area considered by this Shoreline Erosion Management Plan.

Figure 1.1 : Study Area for this Shoreline Erosion Management Plan

1.1 Regional and Local Setting

With a population exceeding 175,000 spreading across some 3,750 square kms, Townsville is the largest city in North Queensland. It is one of the State's two fastest growing Local Government Areas outside of southeast Queensland. The southern shores of the Rowes Bay / Pallarenda study area are located only 3kms from the Central Business District of Townsville.

As illustrated in Figure 1.2, the study area is located on the western shores of Cleveland Bay - which is an approximately 15km wide and 15km long embayment. Cape Cleveland forms its eastern boundary and Magnetic Island forms its western boundary. Both of these topographical features play an important role in defining the wave climate, tidal hydrodynamics and ocean water levels on the foreshores and nearshore regions throughout the Bay.

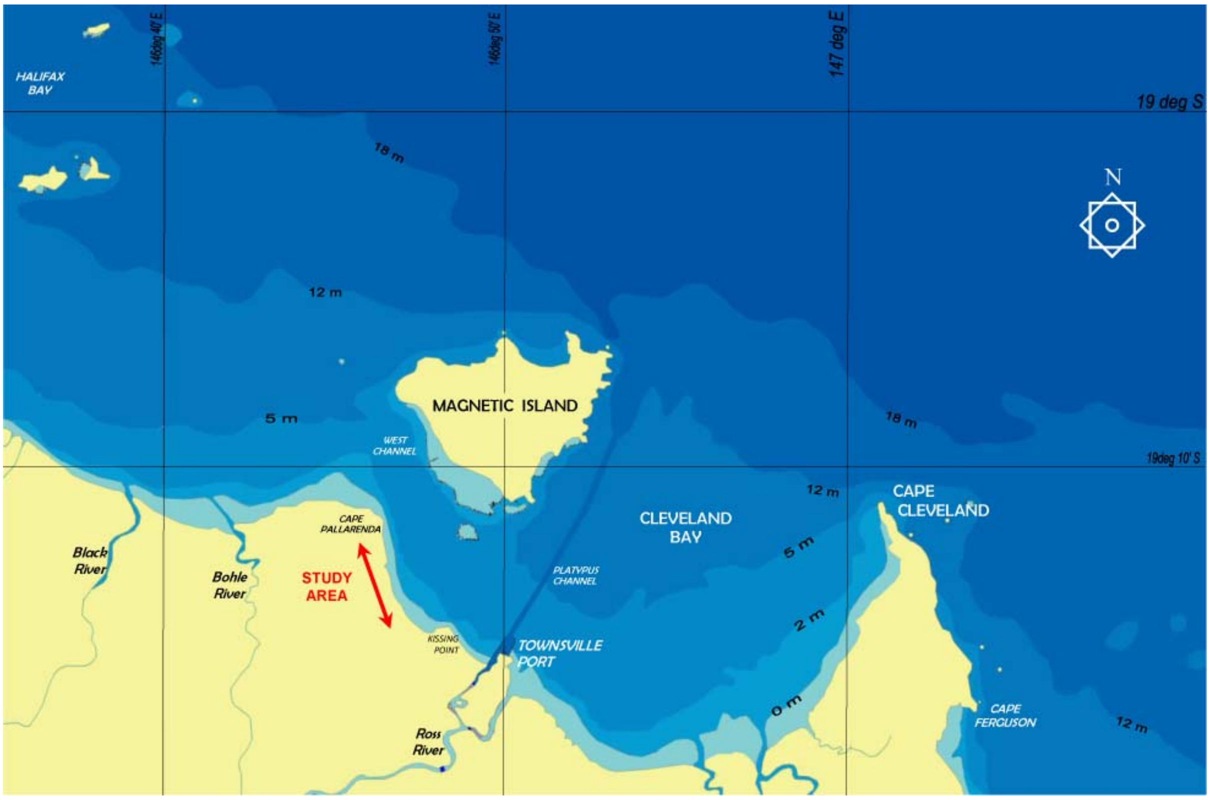


Figure 1.2 : Location of the Study Area in the Regional Context

Cleveland Bay is a somewhat shallow embayment facing north-east onto the broad open waters between the mainland and the Great Barrier Reef. At its seaward limit, the Bay is only some 12 metres deep (below the level of the Lowest Astronomical Tide). The seabed approach slopes onto local foreshores are therefore very flat. These flat shallow approach slopes, in conjunction with the surrounding land features of Magnetic Island and Cape Cleveland, provide natural protection and wave energy attenuation for the foreshore precincts of Rowes Bay and Pallarenda - particularly during extreme storms and tropical cyclones.

Nevertheless, the fetches to the north-east and east of Cleveland Bay are quite long, with the main Great Barrier Reef system being some 70kms offshore. It is from across these open north-east and east fetches that the largest waves can propagate into Cleveland Bay. The shallow West Channel between Magnetic Island and Cape Pallarenda allows some waves that are generated in Halifax Bay (across north-western fetches) to also propagate to the project foreshores.

1.2 The Erosion Problem

The prevailing coastal processes in Cleveland Bay result in a south-to-north transport of sand along the foreshore between Kissing Point and Cape Pallarenda.

Prior to European settlement, the natural supply of sand around Kissing Point and into the Rowes Bay embayment was derived from sediments being delivered to Cleveland Bay by the Ross River, primarily during flood events. This sand was then transported off the shoals at the river entrance by waves. Littoral drift processes slowly carried the sand northwest along the Strand Beach and around Kissing Point, gradually feeding onto the sandy shores of Rowes Bay.

As a consequence of port construction in the later decades of the 19th century, as well as subsequent flood mitigation and storage works on the Ross River, this natural ongoing supply of sand to local foreshores has diminished. The longshore transport mechanisms on the downdrift beaches of the Strand and Rowes Bay have still been moving sand along these beaches at the same rate as previously. However because of the diminished supply from the Ross River, the longshore sand transport rates are greater than the rate that sand is now being supplied. Consequently these downdrift beaches have been steadily eroding.

Because the downdrift transport rates have been slow and somewhat episodic, the effects of the changes to the sand supply regime at the Ross River entrance did not become evident on Rowes Bay foreshores until around the 1950’s (Mabin, 2002).

Since the prevailing sand transport is from south towards north, the diminished supply around Kissing Point has resulted in the southern shores of Rowes Bay being the first to experience erosion. The extent of this erosion has gradually migrated northwards since the 1950’s, threatening local infrastructure as well as vital road, power and telecommunication corridors to communities further north – particularly those at Pallarenda. Of particular concern in the Rowes Bay suburb is the threat to the foreshore north of Falcon Street, where during storms the shoreline has retreated to within six metres of Cape Pallarenda Road.

This erosion along the southern shores of Rowes Bay is derived from the steady removal of sand by longshore sand transport mechanisms, thereby reducing sand reserves in the upper beach area which would otherwise provide an erosion buffer during severe storms and tropical cyclones.

In response to this erosion threat, Townsville City Council has undertaken a number of beach renourishment campaigns in recent years that have placed imported sand along at-risk sections of the Rowes Bay foreshore. This strategy of ongoing beach nourishment to create and maintain adequate erosion buffers on eroding sections of the shoreline has proven to be effective. Nevertheless the strategy has been reviewed when preparing this Shoreline Erosion Management Plan.

1.3 Objectives of this Shoreline Erosion Management Plan

The objectives of the Shoreline Erosion Management Plan are:

- to enable the Townsville City Council to proactively plan for erosion management in a way that is consistent with all relevant legislation (Commonwealth, State and Local) as well as all relevant coastal and environmental policies;
- to investigate and address the underlying causes of shoreline erosion and its likely future progression at the local scale;
- to determine cost effective and sustainable erosion management strategies that maintain natural coastal processes and resources; and
- to consider community needs in both the short- and long-term.

Shoreline Erosion Management Plans (SEMP's) are the Department of Environment and Resource Management's preferred method to address shoreline erosion issues at the local government level.

1.4 Structure of this Shoreline Erosion Management Plan

The Shoreline Erosion Management Plan has been structured as follows:

- This Section 1, which consists of an introduction and provides some background to the need and development of the Plan.
- Section 2 provides an assessment of the environmental and social "values" of the Rowes Bay / Pallarenda coastal precinct.
- Then in Section 3 the natural physical processes that have in the past, are currently, and will in the future, shape the project shoreline are discussed.
- This is followed in Section 4 by a discussion of the risks that these various natural processes represent to local coastal values and infrastructure.
- Section 5 then offers a number of potential strategies to mitigate these risks, and then provides a ranking of each - leading to the establishment of a preferred erosion management strategy.
- Section 6 provides details as to the recommended erosion mitigation strategy, including its costs.
- The process of implementing the preferred strategy is then presented in Section 7.
- Appendices to support the technical content of the Plan are then included. These contain an outline of the commonwealth, state and local government

planning and legislative framework affecting the implementation of the Plan; detailed assessments of the local marine and terrestrial environments; historical beach surveys; and plots showing the erosion vulnerability of local foreshores.

2 COASTAL VALUES

The foreshores of Rowes Bay and Pallarenda offer a diversity of seascapes and landscapes - providing extensive recreational and lifestyle opportunities to residents and visitors that are enhanced by considerable environmental, social and cultural values.

2.1 The Marine Environment

A technical and more detailed appraisal of the marine environment of Rowes Bay undertaken by C&R Consulting specifically for this Shoreline Erosion Management Plan is presented in Appendix B. However a discussion of the more important aspects is offered here.

The local nearshore marine environment of the Rowes Bay and Pallarenda coastal precinct includes a small mangrove forest, a rocky shoreline, estuarine creeks, sandy intertidal flats and several rubble reef areas. Seabed approaches to the shore are at very gentle gradients. Consequently the nearshore region is quite shallow with large areas exposed at low tide, creating an extensive intertidal environment. This diversity of habitats is home to a high species richness of invertebrates, which in turn provide food for fish and marine reptiles at high tide, and for birds and terrestrial vertebrates at low tide.

There is a small mangrove forest at the southern end of Rowes Bay, along the northern flank of the Kissing Point headland. A number of invertebrate species utilise this habitat, including a range of crustaceans and gastropods. Immediately offshore of the mangroves is a rocky / rubble intertidal region. The rocky shore areas of Rowes Bay provide shelter and complex habitat for a variety of organisms. Algal biomass is removed by a multitude of herbivorous molluscs, and the rocks themselves provide attachment points for sessile invertebrates such as barnacles and oysters (Townsville City Council, 2003). An intertidal soft-sediment area lies immediately offshore of the rubble zone.

Soft sediment areas extend northwards along the shore and are the main habitat immediately offshore of the sandy beach that stretches up to Cape Pallarenda. They are characterised by a range of sediment sizes, from fine silts to coarse-grained sands. Invertebrate communities living within the sediments change according to their sediment type preferences.

It is possible that the seabed offshore off Rowes Bay and Pallarenda has been affected by sediment plumes from port dredging operations over the past twenty years (Kettle, et al., 2002).

A recent survey documented what are essentially three seagrass meadows in the vicinity of Rowes Bay and Pallarenda, these being:

- a small dense meadow (of approximately 72 ha) off the southern shores of Rowes Bay composed of *Halodule uninervis;*

- a narrow band of *Halodule uninervis* of moderate density which extends some two-thirds of the way along the foreshore (approximately 56 ha); and
- a larger meadow of low density *Halophila spinulosa* and *Halodule uninervis* further offshore (constituting approximately 2538 ha).

The approximate extent of the various seagrass meadows is shown schematically on Figure 2.1.

These local seagrass beds are an important food resource for juvenile and adult turtles, and for dugongs (Taylor, et al., 2008). Seagrasses are sensitive to a number of characteristics of their environment, including changes in water turbidity (especially to light attenuation resulting from suspended sediments in the water), as well the volumes and rates that sediments settle directly onto the meadows, the hydrodynamics of tidal water circulation, any reduction in salinity and any increase in nutrients (Collier, et al., 2009).

Possible causes of these changes include natural events (such as increased wave activity during storms; and high rainfall run-off from creeks and rivers during such events) as well as human-related activities - such increased turbidity as a consequence of dredging for ports and marinas. Seagrasses on this western side of Cleveland Bay (as opposed to those adjacent to Cape Cleveland) are likely to be highly ephemeral, responding to changes in water chemistry and water quality brought about by the wet and dry seasons.

Nevertheless the Rowes Bay / Pallarenda seagrass meadows are likely to be vulnerable to any additional pressures such as erosion. The Rowes Bay / Pallarenda area is considered to be one of the key areas in the Great Barrier Reef Marine Park for continued monitoring of impacts (Rasheed, et al., 2007).

The landward extent of seagrasses along the foreshore is determined by seabed sediment characteristics. The establishment and growth of local seagrass meadows is likely to be restricted to the more favourable finer marine sediments that exist offshore of the beach. Since the beach responds to ever-changing seasonal and episodic variations in wave climate, the toe of the sandy beach slope continually migrates onshore and offshore.

These fluctuations in beach toe position mean that this nearshore region of dynamic beach change is not particularly conducive to the long-term establishment and growth of seagrasses. Consequently the landward extent of seagrass meadows is expected to be defined by the seaward-most location of the 'toe' of the active beach system.

Long-term monitoring of the status of seagrass meadows in Rowes Bay is being conducted under a Seagrass-Watch program, with the assistance of Belgian Gardens and Rowes Bay primary schools.

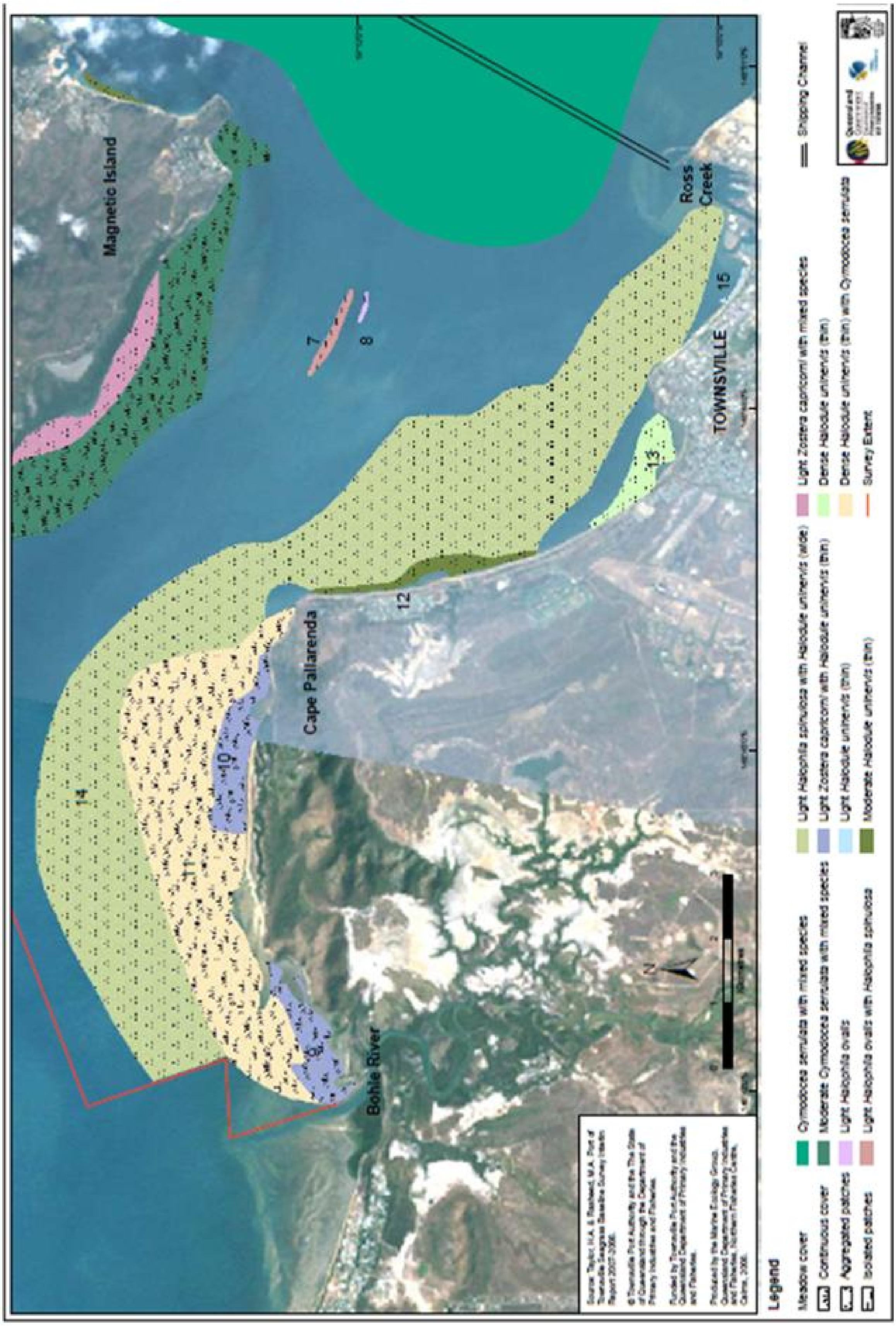


Figure 2.1 : Extent and types of seagrass recorded off Rowes Bay and Pallarenda

above is reproduced from Taylor and Rasheed (2008).

The offshore marine habitats within the area are also characterised by a patchwork of unconsolidated coral reef, sponge gardens, seagrass beds, algal beds and other aggregations of sessile benthic organisms such as ascidians and soft corals. These are scattered over a wide area in the general vicinity of Virago Shoal and Middle Reef - which are bathymetric features located in Middle Channel (ie. the strait of water between Magnetic Island and the mainland) some 1.6kms and 4kms offshore respectively.

These localities are home to a range of juvenile fish of commercial importance - including trout, snappers, trevallies and emperors. These benthic biota and the mobile animals that utilise them have unfortunately never been systematically quantified in a publically available format.

Anecdotal evidence (QPWS, pers. comm.) suggests that marine turtles, including the green turtle nest above high water mark along Rowes Bay beach. Dolphins have also been recorded in the waters off Rowes Bay and Pallarenda.

Estuarine crocodiles transit through the Cleveland Bay area on an irregular basis (QPWS, 2007) and are occasionally sighted from Townsville beaches, including from Rowes Bay. However, it is expected that crocodiles observed in Cleveland Bay are transient, and are unlikely to regularly use habitats around Townsville.

A number of sea birds and shorebirds, including some threatened species such as the little tern and the beach stone curlew are known to occur along the beach. A number of migratory species listed under various international treaties, including JAMBA and CAMBA are also known to occur or are likely to occur in the area.

There are three tidal creeks that flow into Cleveland Bay along the Rowes Bay / Pallarenda coastal reach - these being Mundy Creek, Three Mile Creek, and an unnamed ephemeral creek at Cape Pallarenda. The lower reaches of these waterways contain mangroves. Consequently they are of habitat value to estuarine organisms and of potential nursery value to fish and crustacean species, some of which are commercially caught in the area.

Clearly the rich diversity of habitats and their associated marine flora and fauna in the Rowes Bay / Pallarenda area represents environmental resources and values that require protection and careful management. This is recognised through the designation of the surrounding waters as a Conservation Park Zone of the Great Barrier Reef Marine Park.

When considering appropriate erosion management strategies for Rowes Bay and Pallarenda it is necessary to consider the following specific issues relating to the local marine environment:

- the proximity of nearshore habitats (such as seagrass meadows, rubble beds and soft sediment communities) to the beaches;
- proximity of nearshore reef systems (such as Virago Shoal);
- sea turtle nesting activities;
- activities of sea birds and shorebirds.

2.2 The Terrestrial Environment

A detailed and more technical appraisal of the terrestrial environment of Rowes Bay which has been undertaken specifically for this Shoreline Erosion Management Plan by C&R Consulting is presented in Appendix B. Nevertheless a discussion of the more important characteristics is offered below.

The terrestrial values study undertaken for this Shoreline Erosion Management Plan includes the local terrestrial environment of Rowes Bay and Pallarenda which may be impacted by coastal erosion processes. It extends some 2km inland.

This includes areas designated as Land Zones 1 and 2, and small areas of Land Zone 3. A Land Zone is a simplified geology/substrate landform classification that is utilised throughout Queensland. Land Zones are used for Regional Ecosystem Classification, and are combined with details of different vegetation types within a particular bioregion to give a Regional Ecosystem description to a particular patch of vegetation, on a particular substrate in that bioregion. A total of seven regional ecosystems occur within the Rowes Bay / Pallarenda area - reflecting the wide diversity of the local coastal ecosystem.

The shoreline is subject to salt-laden winds which strongly influences vegetation types. The foreshore comprises a highly modified foredune which is mapped as non-remnant vegetation having elements of remnant herbland and grassland that are quite dense in areas. Some *Casuarina* open-forest to woodland remnants occur along the foreshore and the eastern side of Cape Pallarenda. Other scattered trees or shrubs also occur along the foreshore, as do a number of introduced and invasive plant species.

Several large Banyan Figs (*Ficus benghalensis*) occur along the foreshore parkland. These iconic trees are of heritage, aesthetic and social value. The threat of their loss to coastal erosion has been a consideration when implementing foreshore protection measures in recent years.

Cape Pallarenda Road and related infrastructure currently serves as a linear obstruction affecting the zonation of coastal vegetation, preventing tertiary successional species from gaining any foothold in areas on the seaward side of the road.

Immediately to the west of the coastal foredune a series of mangrove forests, saltpans and wetlands occur. These wetland areas are dissected by small tidal channels which are typically only inundated during the highest spring tides. Small areas of mangrove forest occur along or in close proximity to these tidal creeks and channels.

A system of dunes and swales occur at the western extent of the Rowes Bay terrestrial environment, comprising old beach ridge open-woodland, with Melaleuca dominating the swale vegetation.

The Townsville Town Common Conservation Park covers an extensive area west of the Cape Pallarenda Road - along the northern part of the Rowes Bay / Pallarenda foreshore. It protects remnants of the once extensive Bohle River floodplain. It is an area of constant change. In some years the dry saltpans and grasslands are transformed by summer rains into a large wetland habitat, attracting large flocks of waterbirds.

Figure 2.2 illustrates the nature and extent of the terrestrial values of the local foreshore.

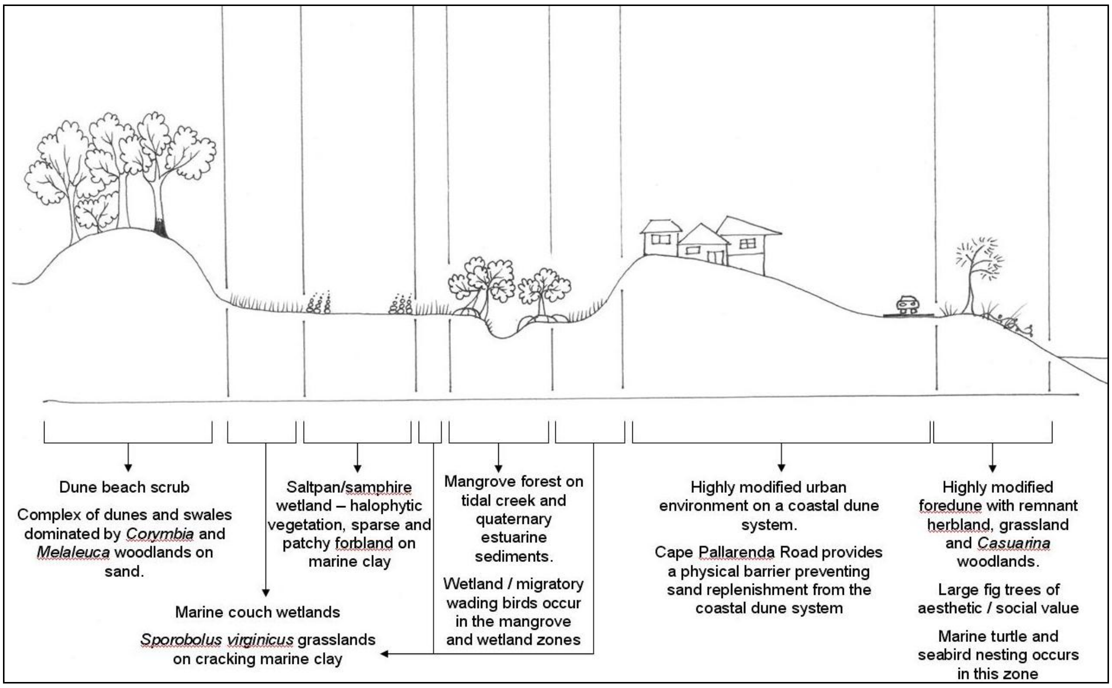


Figure 2.2 : Extent and types of local terrestrial vegetation

2.3 The Social Environment

The traditional owners are the Bindal and Wulgurukaba peoples, who are the first known people to have lived in the region.

The approximate extent of the lands of the Bindal people is from the Haughton River in the south, up north as far as approximately the Black River, east to the Barrier Reef (but excluding Magnetic Island) and west to the Mingela Range. The approximate lands of the Wulgurukaba Traditional Owners are those on Magnetic Island; and west to Reid River, south to the Haughton River and north up to around Rollingstone.

Nowadays the suburbs of Rowes Bay and Pallarenda are home to over 1,600 people (Australian Bureau of Statistics, 2006) and are among the most desirable places to live in the Townsville region. This is reflected in the median house prices in these areas, which are reputedly more than 40% higher than elsewhere in the region (Domain, 2009). Permanent residents of Rowes Bay also include those of RSL Care's Rowes Bay Retirement Community and the popular Rowes Bay Caravan Park.

Cape Pallarenda Road provides the only access to the suburb of Pallarenda, the RSL retirement community, the caravan park, Rowes Bay Golf Course and the Townsville Town Common Conservation Park.

At the southern end of this 7km long coastal reach is Soroptimist Park, a much-utilised park with lawns, picnic and barbecue facilities and an adventure playground designed specifically to be suitable for all children including those with disabilities.

A coastal walking path shaded by large banyan fig trees follows much of the bay foreshore between Soroptimist Park and Cape Pallarenda. Numerous small car-parks are located at some of the twenty-two formal beach access points; these Beach Accesses are shown on Figure 2.3 and Figure 2.4. A section of foreshore provides one of only two beaches in the city that are designated as off-leash areas for Townsville residents to exercise their dogs.

Immediately south of the Three Mile Creek entrance near Pallarenda lies the spacious Robertson Park. The park’s nearshore waters are utilised extensively for water sports, particularly kitesurfing.

Further north is Pallarenda Park which has long been a popular place for locals - with recreational opportunities ranging from boating and safe swimming to picnics and beach walks. During World War II, Pallarenda Park was transformed into a 500 bed military hospital. The 2/24 Army General Hospital was located immediately alongside the coastal dunes. The park now includes a boat ramp which offers ready boating access to Cape Pallarenda, West Point, Middle Reef and Cockle Bay. It also has a permanent marine stinger enclosure for safe swimming.

The Cape Pallarenda Conservation Park at the northern-most end of the Rowes Bay / Pallarenda coastal reach is the site of a former quarantine station dating from 1915. Some of the buildings have been converted to a small museum that documents the activities of the station, along with a history of the Pallarenda area. The park features ruins and relics from World War Two, when the Cape was part of Queensland’s east coast defences. It is a popular destination for tourists.

Clearly the Rowes Bay and Pallarenda foreshores are of considerable value to residents of Townsville. They contribute to the quality of life in the immediate residential areas by attracting permanent residents through lifestyle and retirement choices.

Figure 2.3 : Location of Beach Access Points on Southern Shores of the Study Area

Figure 2.4 : Location of Beach Access Points on Northern Shores of the Study Area

The sandy beaches offer a quieter and less crowded alternative to the nearby Strand Beach, but are nevertheless within close proximity to Townsville's CBD. Consequently the area contributes significantly to public recreation, relaxation and enjoyment – not only for the local population but also to the many tourists who visit the Townsville region.

When considering appropriate erosion management strategies it is necessary to consider the following specific issues relating to the social environment of the Rowes Bay / Pallarenda area:

- maintaining existing public use and access to the beaches and foreshore areas;
- maintaining the high visual amenity of the foreshore.

3 PHYSICAL PROCESSES ANALYSIS

The coastal environment responds continually to the ever-changing influences of waves, tides, ocean currents, winds and the supply of littoral sediments. Collectively these complex and dynamic coastal processes shape the physical environment of the Rowes Bay and Pallarenda coastline.

This section of the Shoreline Erosion Management Plan defines and quantifies the natural processes that are contributing to the existing and future erosion threats on these foreshores.

3.1 Regional Sediment Supply and Transport Mechanisms

Prior to considering the local sand transport mechanisms and erosion processes within the Rowes Bay / Pallarenda coastal reach itself, it is informative to firstly view the supply and transport of sand from a regional perspective.

Beach sands in the Townsville area are composed predominantly of quartz, and have been derived from the weathering of the acidic igneous rocks of the region - which have then been delivered to the coastal environment through local creek and river systems. Within Cleveland Bay these systems would include Ross River, Ross Creek, Three Mile Creek, Sandfly Creek, Crocodile Creek, Alligator Creek and numerous other smaller creeks and ephemeral waterways.

Beyond Cleveland Bay there are also several large river systems which historically have delivered substantial quantities of sediments to the coast - notably the Bohle, Black, Houghton and Burdekin Rivers. For example the flood plume of the Burdekin River has reputedly been observed to carry suspended sediments northward along the coastline as far as Cairns (Sinclair Knight Merz, 1996). However sediments transported to Cleveland Bay in suspension from distant catchments are predominantly fine clays and silts, not the heavier and more rapidly settling sands that are typically on local beaches. So the rivers beyond Cleveland Bay do not contribute any significant volumes of sand-sized sediments to the Bay's foreshores.

Other than Ross River, the creeks and waterways within Cleveland Bay are too small to contribute any significant volumes of sediments to the coast. It is therefore the Ross River catchment which has morphologically been the main source of sand for the beaches of the Strand and Rowes Bay / Pallarenda.

The sediment distribution in Cleveland Bay shows quite distinctively that sand-sized sediments are confined to the upper intertidal zone on the Rowes Bay / Pallarenda beaches.

The boundary between the active beach face and the intertidal flats immediately in front is marked by a very abrupt change in slope and sediment type. The beach face consists of quite coarse sands having average grain sizes generally in the range of 0.3mm and 0.6mm (Beach Protection Authority, 1996), - although coarser sand of around 0.8mm is reported north of Mundy Creek entrance (Mabin, 1999a) which may be the remnants of earlier beach nourishment activities.

However the surface sediments of the intertidal flats and deeper areas offshore of the beach slope are comprised predominantly of much finer unconsolidated silts and clays with very minimal sand content (Mabin, 1991 and Comarine Consulting, 1993).

Therefore the transport of sand supplied by the Ross River occurs predominantly along the dynamic beach face of local shorelines rather than across the wide intertidal flats immediately offshore.

Whilst tidal currents can potentially initiate and sustain movement of the finer offshore sediments during large tides, they are not of sufficient strength to move the coarse sand that exists along the land/sea boundary that constitutes the Rowes Bay and Pallarenda foreshores (refer to discussions in Section 3.2.2). It is wave action that moves this sand.

Tides play an indirect role - in that the variable ocean levels allow waves to access various parts of the beach face. Also, since the amount of wave energy that reaches the beach is determined by the depth of water over the shallow intertidal approach slopes (by causing larger waves in the sea state to break before reaching the beach) tides play another indirect role by influencing the rate at which waves will move sand.

Waves are generated by winds blowing on the surface of the ocean. Consequently the south-easterly waves generated by persistent south-easterly trade winds that occur during the North Queensland dry season move sand along the western shores of Cleveland Bay towards the north and north-west. Sea breezes and wet season winds from more northerly directions result in sand being moved to the south and south-east on these shores.

However the strength and persistence of the south-easterly winds, in conjunction with the greater length and depth of the open water fetches across which they blow, result in more wave energy arriving on local foreshores from this particular sector.

In other words, whilst sand moves along the western shores of Cleveland Bay in both directions, the net movement is towards the north and north-east, driven by the dominant south-easterly wave climate.

3.1.1 Historical Processes

In the past, the delivery of sand into Cleveland Bay by the Ross River was primarily during major flood events - when substantial flows would flush the accumulated deposits from the lower reaches of the river. Any material that was finer than sand tended to be distributed widely as the flood waters dispersed through Cleveland Bay and beyond. Whereas the coarser sand fractions that were swept out by floods would be deposited closer to the Ross River entrance - resulting in substantial sand shoals near the river mouth. Waves would then work these sand deposits onto and along adjacent foreshores.

As discussed above, given that the predominant wave energy in the vicinity of the Ross River entrance is from the south-east, the prevailing littoral drift processes slowly carried the sand north-west off the entrance shoals, along the Strand Beach and around Kissing Point - gradually feeding onto the sandy shores of Rowes Bay.

The supply of sand around Kissing Point into Rowes Bay was likely to have been intermittent. Sand transported northwards around Kissing Point would have accumulated in submerged sand bars that extended north-west from the Point into Rowes Bay. Early hydrographic charts of Cleveland Bay record these bathymetric features (Mabin, 2002). Under ambient wave conditions there would not have been sufficient energy to move large volumes of sand off these submerged sand banks and onto the foreshore of Rowes Bay. It would have required storms or periods of high south-easterly wave energy to carry the sand off the Kissing Point sand shoals and onto the Rowes Bay shore to the north.

From here littoral processes carried sand northwards along the shore towards the rocky projection of Cape Pallarenda which (along with Many Peaks Range in more geologically distant times) acted as a barrier to the prevailing northward sand transport. The northward moving sand was trapped against this barrier, causing the shoreline of the shallow embayment between Kissing Point and Cape Pallarenda to gradually prograde eastwards.

Now that the shoreline has built out to the eastern end of Cape Pallarenda, the progradation has stopped - and Many Peaks Range no longer acts as a total barrier to northward sand transport. Sand moving along the shoreline by the longshore drift processes within the upper intertidal zone of the beach face is swept northwards beyond Cape Pallarenda – feeding the extensive shoals that exist to the north-west of the Cape (ie. off Shelley Beach).

There have been a number of studies undertaken previously which describe the regional sediment transport regime of the Rowes Bay / Pallarenda coastal reach. Perhaps the most comprehensive of these are the geomorphological investigations undertaken by Mabin (2002).

That work considered recent geological history and sediment transport mechanisms over the last 5,000 to 6,000 years to determine the rate that the Kissing Point – Cape Pallarenda embayment filled with sand supplied to the coast from the Ross River catchment. This allows an estimate to be made of the historical long-term rate of sand supply and transport along this coastal reach. An average rate of around 2,500 to 3,300 m^3 per year was determined by that study. Computer modelling of contemporary coastal processes estimated similar longshore transport rates (Coastal Engineering Solutions, 1998).

Rather than a steady annual rate, the supply of this amount of sand to the Rowes Bay / Pallarenda coastal reach would have been somewhat episodic (since the supply of sand to the coast by the Ross River relied on infrequent major floods, in conjunction with the need to have storms or sustained periods of strong south-easterly conditions to sweep sand around Kissing Point).

Consequently there would have been periods where actual sand supply would not have matched the ongoing northward sand transport of 2,500 to 3,300 m^3 per year along the Rowes Bay / Pallarenda shoreline – resulting in periods of erosion. However these erosion phases would have been followed by periods of beach recovery when greater sand supply was initiated during years of more energetic wave activity.

Whilst there would have been these cycles of beach erosion and accretion, over time a steady-state would have prevailed whereby the shoreline between Kissing Point and Cape Pallarenda maintained a dynamically stable position.

In other words, whilst there were cycles of local erosion and accretion, there was nevertheless a long-term balance in these processes because the rate of northwards longshore sand transport was matched by the long-term net supply of sand from the south.

In summary then, the historical broad scale regional sediment supply and longshore transport regime can be summarised as follows:

- Sand has been delivered to the coastal environment of Cleveland Bay primarily by the Ross River. This was likely to have been during periods of major floods.
- Once delivered into the shoals near the entrance to the Ross River, sand was then worked by littoral drift processes which slowly carried the sand north-west along the Strand Beach and around Kissing Point, gradually feeding onto the sandy shores of Rowes Bay. This primarily occurred along the beach face rather than on the shallow intertidal flats immediately offshore.
- Sand was supplied to the embayment between Kissing Point and Cape Pallarenda at an average long-term rate of around 2,500 to 3,300 m^3 per year. This was also the long-term average rate of sand transported northward along the shoreline of this coastal reach.
- Many Peaks Range acted as a barrier to this northerly transport, resulting in the shoreline of the Kissing Point – Cape Pallarenda embayment gradually prograding eastward as sand was trapped against the southern flanks of the

range. The shoreline has now built out to the end of Cape Pallarenda and progradation of the shoreline in this area has effectively ceased.

- In more recent times there would have been cycles of beach erosion and accretion due to short-term disparity in supply and longshore transport, nevertheless over time a steady-state would have prevailed whereby the shoreline between Kissing Point and Cape Pallarenda maintained a dynamically stable position.

However European settlement of the Townsville region has initiated some changes to local coastal processes that have resulted in notable impacts to the Rowes Bay / Pallarenda foreshore.

3.1.2 Following European Settlement

The impacts of European settlement on the local littoral regime were primarily initiated by:

- the establishment of port infrastructure at the mouth of the Ross River and Ross Creek;
- the implementation of water storage and flood mitigation works on the Ross River; and
- the establishment and operations of sand extraction industries on the Ross River.

Whilst these works and activities have delivered considerable benefits and prosperity to the urban and rural communities of the Townsville region, collectively they have had adverse impacts on sand that historically was supplied to local foreshores from the Ross River catchment.

3.1.2.1 Establishment of port infrastructure

In 1874 works associated with the establishment of Townsville Port commenced. By 1891 the main eastern breakwater and the western breakwater located directly west of the Ross River and Ross Creek entrances were completed. These structures extend some 1.5kms out from shore and immediately upon their completion became a barrier to the north-westerly transport of any sand that was delivered to Cleveland Bay by the Ross River (and to a lesser extent by Ross Creek).

Because the offshore end of these structures are in water depths that are too great to allow sand to be transported northward by wave action, the supply of sand to the downdrift foreshores of the Strand, Rowes Bay and Pallarenda was significantly impeded.

3.1.2.2 Water storage and flood mitigation works

To secure essential water supplies to the developing Townsville region, as well as to alleviate the potentially devastating impacts of floods on local communities, water storage and flood mitigation works have been constructed on the Ross River.

Approximately 95% of the Ross River catchment is upstream of the Ross River Dam. The size and relatively shallow nature of the dam means that significant volumes of sediments derived from the catchment are trapped behind the dam wall rather than pass over the spillway and continue downstream into lower reaches of the river.

In addition, there are three weirs located below the Ross River Dam which also trap sediments (these being Black's Weir, Gleeson's Weir and Aplin's Weir). It is very rare for the Ross River to simultaneously flow over all four structures.

Not only are sediments trapped by these various structures (and thereby prevented from migrating to the lower reaches of Ross River), but the river flows have been regulated so that the large floods that historically flushed any sand out of the lower reaches and into Cleveland Bay have been significantly reduced.

In effect, there is now no significant supply of sand to Cleveland Bay from the Ross River catchment.

3.1.2.3 Sand extraction activities

As the City of Townsville has grown, there has been an increasing demand for building products. In response to these demands, sand and gravel have been extracted from the Ross River for use in concrete and other building applications.

Historical records of extraction rates indicate that they are likely to have exceeded the rate at which sand was naturally supplied – meaning that these extraction activities were not just removing active accumulations of sand from the bed of the river but were depleting resources which by virtue of the Ross River Dam and the three weirs had become non-renewable (Sinclair Knight Merz, 1996).

Furthermore, should there be any residual flushing of sand from the catchment during extreme floods that overtop the Ross River Dam and the weirs; the removal of sand from the downstream river bed has created a "trap" within the existing river system into which any delivered sand accumulates.

Consequently the removal of sand reserves from the lower reaches of the river reduces the flushing of any resupplied sediments from the river – at least until the original river bed profiles are re-established.

3.1.2.4 Implications to the Rowes Bay / Pallarenda coastal reach

As a consequence of the various human activities instigated since European settlement of the Townsville region, the natural ongoing supply of sand to local foreshores has diminished significantly – and have likely ceased altogether. The longshore transport mechanisms on the downdrift beaches of the Strand and Rowes Bay have still been moving sand along these beaches at the same rate as previously. However because of the diminished supply from the Ross River, the longshore sand transport rates are greater than the rate that sand is now being supplied. Consequently these downdrift beaches have been steadily eroding.

The beach nourishment works completed on the Strand in 1999 have since resulted in the creation of a dynamically stable and enclosed beach compartment along that coastal reach, thereby rectifying to a degree the problem of inadequate sand supply to that particular shoreline. But the lack of sufficient littoral sand supply to the Rowes Bay foreshore remains an ongoing problem.

Because the downdrift transport rates have been slow and somewhat episodic, the effects of the changes to the sand supply regime at the Ross River entrance did not become evident on Rowes Bay foreshores until around the 1950's.

An analysis of shoreline changes in Rowes Bay (Mabin, 2002) which considered historical aerial photographs and beach profile surveys identified two broad phases of beach behaviour – shoreline accretion up until 1952, followed by shoreline erosion (a phase which is presently continuing).

Unless a supply of sand to the southern end of Rowes Bay is re-established, the erosion will continue and will migrate northwards. It is in response to this on-going erosion that Townsville City Council has undertaken emergency protection works and beach nourishment campaigns in recent years.

3.2 Local Coastal Processes

The preceding Section 3.1 provides an overview of broad scale regional sand supply and transport mechanisms.

However within the coastal reach of Rowes Bay / Pallarenda there are variations in the coastal processes that shape this shoreline and it is important to have a sound understanding of these more intricate local processes. Otherwise there is the very real risk that any future strategies to mitigate local erosion will be ineffectual, costly and potentially compromise the environmental and social values of the area.

The term "*coastal processes*" refers to the complex interaction of ocean water levels, currents and waves that drive the transport of coastal sediments – including the sand on beaches. Some discussion of each of these individual influences is offered in the following sections.

3.2.1 Ocean Water Levels

When considering the processes that shape shorelines it is necessary to consider the ocean water levels that prevail from time to time. This appreciation not only relates to the day-to-day tidal influences, but also to the storm surges which occur as a result of extreme weather conditions. The expected impacts of climate change on sea level also need to be considered.

Ocean water levels will have a considerable influence on the wave climate of the Rowes Bay / Pallarenda region. As ocean waves propagate shoreward into shallower water, they begin to "feel" the seabed. The decreasing depths cause the waves to change direction so as to become aligned to the seabed contours and to also shoal up in height until such time as they may break - dissipating their energy as they do so.

Just how much wave energy reaches the shoreline is therefore determined largely by the depth of water over the seabed approaches. Ocean water levels and the seabed bathymetry are important aspects in this process of wave energy transmission.

Consequently it is necessary to have a thorough understanding of the following ocean levels on local foreshores:

Astronomical Tide - this is the "normal" rising and falling of the oceans in response to the gravitational influences of the moon, sun and other astronomical bodies. These effects are predictable and consequently the astronomical tide levels can be forecast with confidence.

Storm Tide - this is the combined action of the astronomical tide and any storm surge that also happens to be prevailing at the time. Surge is the rise above normal water level as a consequence of surface wind stress and atmospheric pressure fluctuations induced by severe synoptic events (such as tropical cyclones).

3.2.1.1 Astronomical tides

The tidal rising and falling of the oceans is in response to the gravitational influences of the moon, sun and other astronomical bodies. Whilst being complex, these effects are nevertheless predictable, and consequently past and future astronomical tide levels can be forecast with confidence at many coastal locations. Tidal planes have been published for Cape Pallarenda (MSQ, 2009) and these are presented in Table 3.1 below.

Tidal Plane	to AHD	to Chart Datum
Highest Astronomical Tide (HAT)	2.12 metres	4.00 metres
Mean High Water Springs (MHWS)	1.18 metres	3.06 metres
Mean High Water Neaps (MHWN)	0.32 metres	2.20 metres
Mean Sea Level (MSL)	0.10 metres	1.98 metres
Mean Low Water Neaps (MLWN)	-0.31 metres	1.57 metres
Mean Low Water Springs (MLWS)	-1.17 metres	0.71 metres
Lowest Astronomical Tide (LAT)	-1.88 metres	0.00 metres

Table 3.1 : Tidal Planes on the Rowes Bay / Pallarenda Coastal Reach

In a lunar month the highest tides occur at the time of the new moon and the full moon (when the gravitational forces of sun and moon are in line). These are called "*spring*" tides and they occur approximately every 14 days. Conversely "*neap*" tides occur when the gravitational influences of the sun and moon are not aligned, resulting in high and low tides that are not as extreme as those during spring tides.

As can be seen in Table 3.1, the maximum possible astronomical tidal range at Rowes Bay and Pallarenda is 4.00 metres, with an average range during spring tides of 2.35 metres and 0.63 metres during neap tides.

Spring tides tend to be higher than normal around the time of the Christmas / New Year period (ie. December - February); and also in mid-year (ie. around May - July). The various occurrences of particularly high spring tides are often referred to in lay terms as "*king tides*" - in popular terminology meaning any high tide well above average height.

The widespread notion is that king tides are the very high tides which occur around Christmas or early in the New Year. However, equally high tides occur in the winter months, but these are typically at night and therefore are not as apparent as those during the summer holiday period - which generally occur during daylight hours.

Since tidal predictions are computed on the basis of astronomical influences only, they inherently discount any meteorological effects that can also influence ocean water levels from time to time. When meteorological conditions vary from the average, they can cause a difference between the predicted tide and the actual tide. This occurs at Townsville to varying degrees. The deviations from predicted astronomical tidal heights are primarily caused by strong or prolonged winds, and/or by uncharacteristically high or low barometric pressures.

Differences between the predicted and actual times of low and high water are primarily caused by wind. A strong wind blowing directly onshore will "pile up" the water and cause tides to be higher than predicted, while winds blowing off the land will have the reverse effect. Clearly the occurrence of storm surges associated with tropical cyclones can significantly influence ocean water levels.

3.2.1.2 Storm tide

The level to which ocean water can rise on a foreshore during the passage of a cyclone or an extreme storm event is typically a result of a number of different effects. The combination of these various effects is known as *storm tide*. Figure 3.1 illustrates the primary water level components of a storm tide event. A brief discussion of each of these various components is offered below.

- Astronomical Tide

As discussed earlier, the astronomical tide is the normal day-to-day rising and falling of ocean waters in response to the gravitational influences of the sun and the moon. The astronomical tide can be predicted with considerable accuracy.

Astronomical tide is an important component of the overall storm tide because if the peak of the storm/cyclone were to coincide with a high spring tide for instance, severe flooding of low lying coastal areas can occur and the upper sections of coastal structures can be subjected to severe wave action. The quite high spring tides that typically occur in summer are of particular interest since they occur during the local cyclone season.

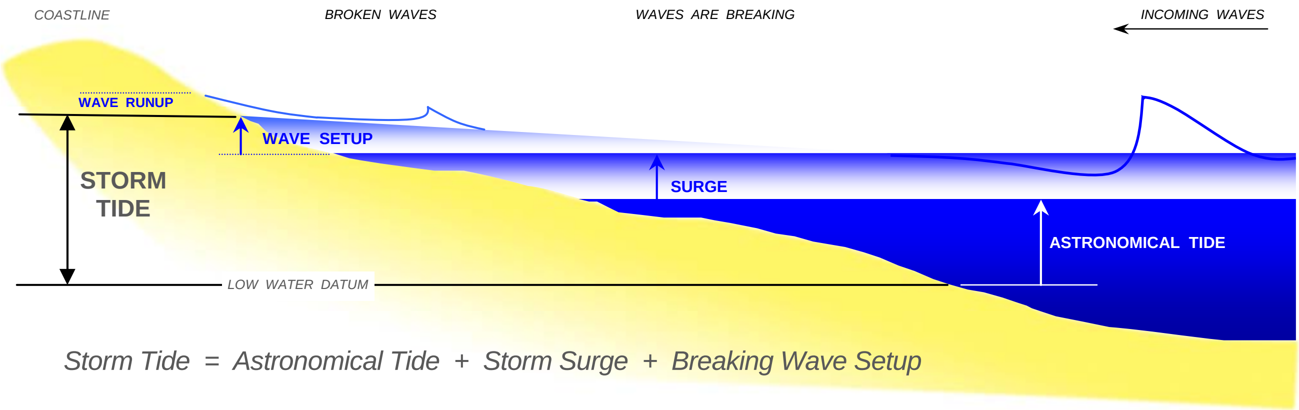


Figure 3.1 : Components of a Storm Tide Event

- Storm Surge

This increase in the ocean water level is caused by the severe atmospheric pressure gradients and the high wind shear induced on the surface of the ocean by a tropical cyclone. The magnitude of the surge is dependent upon a number of factors such as the intensity of the cyclone, its overall physical size, the speed at which it moves, the direction of its approach to the coast, as well as the specific bathymetry of the coastal regions affected.

In order to predict the height of storm surges, these various influences and their complex interaction are typically replicated by numerical modelling techniques using computers.

- Breaking Wave Setup

The strong winds associated with cyclones or severe storms generate waves which themselves can be quite severe. As these waves propagate into shallower coastal waters, they begin to shoal and will break as they encounter the nearshore region. The dissipation of wave energy during the wave breaking process induces a localised increase in the ocean water level shoreward of the breaking point which is called *breaking wave setup*.

Through the continued action of many breaking waves, the setup experienced on a foreshore during a severe wave event can be sustained for a significant timeframe and needs to be considered as an important component of the overall storm tide on a foreshore.

- Wave Runup

Wave runup is the vertical height above the local water level up to which incoming waves will rush when they encounter the land/sea interface. The level to which waves will run up a structure or natural foreshore depends significantly on the nature, slope and extent of the land boundary, as well as the characteristics of the incident waves. For example, the wave runup on a gently sloping beach is quite different to that of say a near-vertical impermeable seawall.

Consequently because this component is very dependent upon the local foreshore type, it is not normally incorporated into the determination of the storm tide height. Nevertheless it needs to be considered separately during the assessment of the storm tide vulnerability of the Rowes Bay and Pallarenda foreshores.

- *Storm Tide Events at Townsville*

A number of studies have previously been undertaken with regard to storm tides that may occur in the Townsville region. The most recently published being the *Townsville - Thuringowa Storm Tide Study* (GHD Pty Ltd, 2007). That study also addresses the effect of future climate change on sea level rise and tropical cyclone occurrences.

The storm tides reported by that regional study have been used in the preparation of this Shoreline Erosion Management Plan and are summarised in Table 3.2 for the present day climate scenario.

Average Recurrence Interval[1]	RL to AHD without Breaking Wave Setup
50 years[2]	2.28 metres
100 years	2.46 metres
200 years	2.52 metres
500 years	3.11 metres
1,000 years	3.60 metres

Table 3.2 : Storm Tide Levels at Rowes Bay / Pallarenda

[1] Average Recurrence Interval (ARI) is a statistical estimate of the average period in years between the occurrences of an event of a particular size. For example, a 100 year ARI event will occur on average once every 100 years. Such an event would have a 1% probability of occurring in any particular year.

[2] For ARI of around 50 years and less, the maximum local storm tide level may not necessarily be associated with tropical cyclones. Other more frequent meteorological or synoptic events may combine with high spring tides to result in potentially greater levels than that listed here.

These levels are without the effects of breaking wave setup, since this particular component varies along the length of the Rowes Bay / Pallarenda foreshore. Its value is determined for this Shoreline Erosion Management Plan in later considerations of storm tide influences.

The duration of the storm tide is also a critical consideration when determining effects on sandy shorelines in Cleveland Bay. The surge component of the storm tide typically builds to a peak over several hours, then drops away over a similar or even shorter timeframe as cyclone influences pass.

3.2.2 Ocean Currents

Ocean currents in Cleveland Bay are predominantly driven by tides and winds. Over the years there have been many studies of ocean circulation in Cleveland Bay. These have typically been numerical modelling studies augmented with some field measurements to assist in verify the modelling predictions.

Most studies have been associated with monitoring and managing the operations of the Port of Townsville, as well as investigations for possible port expansion and other development options in the vicinity of the port precinct.

Whilst these various studies have invariably been comprehensive, they define the structure and magnitude of tidal currents in the deeper waters of Cleveland Bay (or in the immediate vicinity of the port) rather than on the land/sea interface that constitutes the sandy shorelines of Rowes Bay and Pallarenda. Nearshore current speeds are considerably less than those offshore because the wide shallow inter-tidal flats that exist along the shoreline significantly inhibit tidal flows in these areas.

As discussed in Section 3.1, there is a very distinct separation of sediment type between the offshore areas of Cleveland Bay and the sandy beaches of Rowes Bay and Pallarenda. The transport of sand along local shorelines occurs predominantly within the narrow corridor of the beach face rather than across the wide intertidal flats immediately offshore.

However there is no information that can be extracted from earlier hydrodynamic studies of Cleveland Bay that adequately defines ocean currents on the land/sea boundary of Rowes Bay and Pallarenda.

Nevertheless, consideration of the physical characteristics of the sand on these foreshores indicate that bed shear stresses of around 0.2 N/m^2 are required to initiate movement of the sand.

If this was to be achieved by ocean currents alone, then average tidal velocities of around 0.35 m/sec would need to flow against the beach (ie. within nearshore depths less than about 1 metre). However the results of previous studies indicate that even the higher currents in deeper waters further offshore in West Channel (between the mainland and Magnetic Island) rarely exceed this speed.

Nevertheless, some measurements of longshore currents against the beach face were taken as part of the state-wide *Coastal Observation Program, Engineering* (COPE) program that was implemented and managed by the Queensland Beach Protection Authority. The COPE program used volunteers from local coastal communities throughout Queensland to take daily observations and measurements of various parameters including beach profile, wind, waves, and longshore current.

A COPE station was established in March 1992 opposite the RSL retirement village at Rowes Bay (near what is now Beach Access N6) and operated until May 1996 using volunteers from the retirement village.

The COPE data indicates that the direction of the longshore current depends upon the state of the tide and the prevailing wind/weather conditions. However the predominant current direction is northwards towards Cape Pallarenda. Longshore current speeds are quite low, typically being less than 0.1m/sec, and rarely exceed 0.25m/sec. These velocities are less than the 0.35m/sec threshold for initiating sand movement.

Consequently it is evident that tidal currents alone do not contribute to sand movement on the beach face at Rowes Bay and Pallarenda.

3.2.3 Wave Climate

Given that sand is primarily transported by wave action on this coastline, the wave characteristics on the shores of Rowes Bay and Pallarenda are critical considerations to the understanding of local coastal processes. However before describing the local wave climate, it would be informative to firstly outline how waves move sand on shorelines.

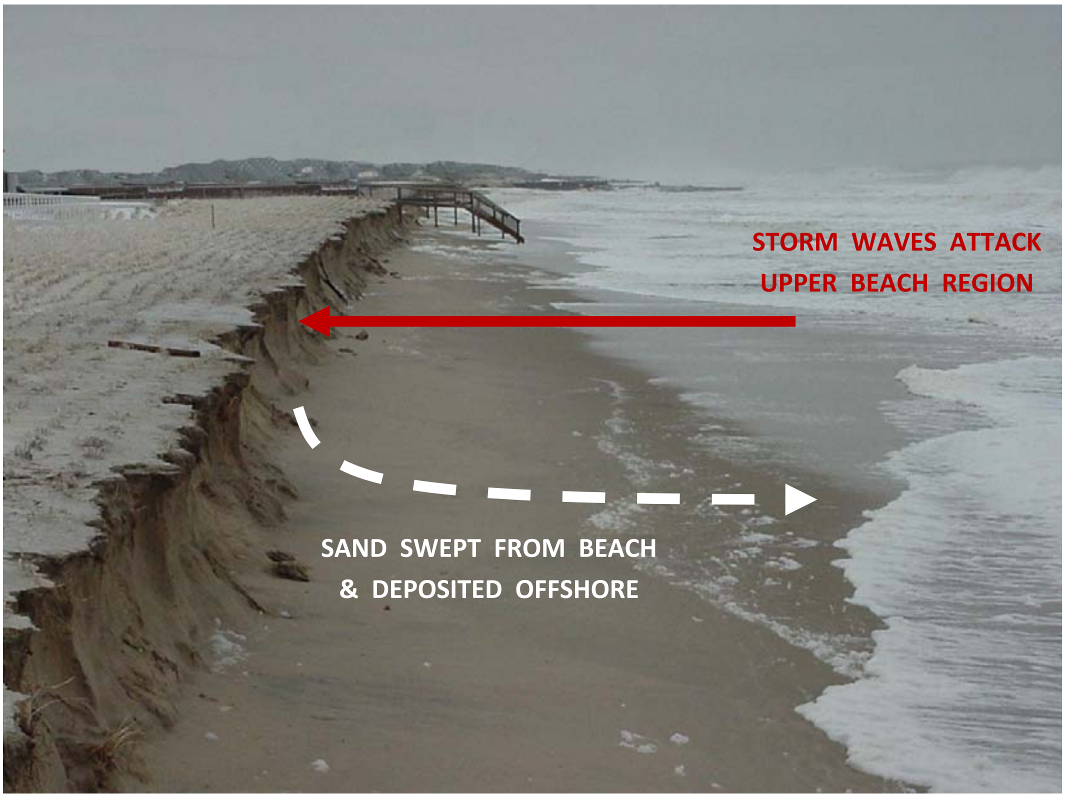
3.2.3.1 Effects of waves on sand transport

Waves move sand in two fundamental ways; by cross-shore transport and by longshore transport. These are illustrated conceptually in Figure 3.2. Both processes can occur simultaneously, but both vary significantly in their intensity and direction in response to prevailing wave conditions.

- Cross-shore transport

This is the movement of sand perpendicular to the beach – in other words, onshore/offshore movement. Whilst this washing of sand up and down the beach profile occurs during ambient conditions (ie. the normal day-to-day conditions), it is during severe storms or cyclones that it becomes most evident and most critical.

Strong wave action and elevated ocean water levels during such events can cause severe erosion of the beach as sand is removed from the dunes and upper regions of the profile. The eroded sand is moved offshore during the storm to create a sand bank near the seaward edge of the surf zone. Subsequent milder wave conditions can return this sand back onto the beach, where waves and onshore winds then re-work it to establish the pre-storm beach condition.



(a) Cross-shore Sand Transport

(b) Longshore Sand Transport

Figure 3.2 : Wave-induced Sand Transport Mechanisms

During particularly severe storms, very significant erosion of sand from the upper beach can occur in only one or two hours; whereas recovery of the beach by onshore transport processes may take many years.

- Longshore transport

This is the movement of sand along the beach and occurs predominantly within the surf zone. Of all the various processes that control beach morphology, longshore sand transport is probably the most influential. It determines in large part whether shorelines erode, accrete or remain stable. Consequently an understanding of longshore sand transport is essential for the determination of sound coastal management practices.

Waves arriving with their crests at an angle to the plan alignment of the shoreline create an alongshore current which initiates and maintains sand transport along the beach.

The angle at which the incoming waves act on the beach face may only be very small (as may be the waves themselves), nevertheless their continual and relentless action is sufficient to account for notable volumes of sand to be moved annually on local shorelines.

On most coasts, waves arrive at the beach from a number of different offshore directions - producing day-to-day and seasonal reversals in transport direction. At a particular beach location, transport may be to the left (looking seaward) during part of the year and to the right during other times of the year. If the volumes of transport are equal in each direction then there is no net change in the beach position over annual timeframes. However this is not often the case.

Typically longshore movement is greater in one direction than the other – which results in a net annual longshore movement. Certainly this is the case for the Rowes Bay and Pallarenda beaches where the net transport rate is towards the north.

Whilst there may be a net longshore transport along a section of foreshore, this does not mean that sand is being lost and therefore the beach is eroding. So long as sand is being supplied at the same rate as it is being transported along the shore at any particular location, then there will be no net change to the beach over annual timeframes. As discussed in Section 3.1.2.4 the supply of sand to the Rowes Bay / Pallarenda coastal reach has been significantly diminished in recent times. Consequently the annual rate of sand supply does not match the longshore transport rate on these foreshores – therefore they are eroding.

The erosion has commenced on the southern shores of this coastal reach (around and immediately north of Mundy Creek) since it is this area that historically received the supply of sand from around Kissing Point. At the present time the foreshores further north of this eroding section are receiving sand at a rate that is similar to the longshore transport rate and are therefore not eroding. However that sand supply is derived from the eroding foreshores near Mundy Creek.

The importance of cross-shore and longshore sand transport by waves to the development and implementation of foreshore management strategies can perhaps best be summarised as:

- Cross-shore transport needs to be understood so that appropriate sand reserves are maintained on a foreshore to act as an erosion buffer during severe storms or tropical cyclones.
- Longshore transport needs to be understood so that the sand supply to a foreshore is maintained at a rate that will continue to naturally sustain the sand reserves acting as the erosion buffer. Where natural supply is deficient, it may need to be augmented with placement of extra sand through beach nourishment works.

3.2.3.2 Types of waves affecting local sand transport mechanisms

Waves arrive in the nearshore waters around Rowes Bay and Pallarenda as a consequence of several phenomena, namely;

- Swell waves - generated by weather systems in the distant waters of the Coral Sea and Pacific Ocean out beyond the Great Barrier Reef. In order to propagate to mainland foreshores in the vicinity of Townsville, these waves must pass thorough and over the extensive reefs and shoals that constitute the Barrier Reef. There is extensive attenuation of swell wave energy during this propagation process.
- Distant Sea waves - generated by winds blowing across the open water fetches between the mainland and the outer Great Barrier Reef system (some 70 kms offshore). This includes the fetches in Halifax Bay to the north-west of Magnetic Island, as well as those south-east of Cape Cleveland (from which waves are then refracted as they propagate shoreward to the project site).
- Local Sea waves - generated by winds blowing across the open waters of Cleveland Bay, as well as those across West Channel between Magnetic Island and the mainland.

Waves from these various sources can occur simultaneously. Given that sand transport processes are primarily driven by waves, a significant focus of the work undertaken for this Shoreline Erosion Management Plan has been the determination of the ambient (ie. the “day-to-day”) wave climate - as well as the extreme wave climate (ie. due to cyclones and severe storms). Because of the complex nature of the wave and sand transport processes, the work has utilised numerical modelling techniques.

Following sections of this report provide some details as to the methodology and the results of that modelling. However some comment is warranted with respect to the various types of waves that can affect sand transport on Rowes Bay and Pallarenda beaches.

- Swell waves

As swell waves generated by weather systems out in the Coral Sea propagate to the mainland, the Great Barrier Reef significantly inhibits the passage of their energy. Nevertheless, whilst inshore swell wave heights are quite low, because of their relatively long wave periods (typically in excess of around 12 seconds) they contribute to local sediment transport processes.

- Distant Seas

The significant distances between the mainland and the Great Barrier Reef means that quite sizeable waves can be generated by winds blowing across these fetches - particularly during cyclones which are a common synoptic event in these waters. To the north-east and east of Cleveland Bay there are very long open water fetches across which winds can generate significant wave energy. It is from this sector that the largest waves can approach the entrance to Cleveland Bay. Magnetic Island affords some protection to the Rowes Bay / Pallarenda foreshores from these waves.

Whilst the project site is sheltered by Cape Cleveland from the direct effects of waves generated out of the south-east quadrant, these waves can nevertheless diffract and refract around the northern tip of the Cape and propagate shoreward to Rowes Bay and Pallarenda. The attenuating effects of diffraction and refraction mean that the energy of these waves is diminished.

However because they are driven by the predominant seasonal weather systems, waves from the south-east and east sectors represent an important component of the ambient wave climate within Cleveland Bay. Their persistent nature and relatively long periods (typically greater than 8 seconds) mean that they strongly influence beach processes in the region.

- Local Seas

The same winds that blow across the open water fetches between the mainland and the Great Barrier Reef (to generate Distant Seas) also blow across the enclosed waters of Cleveland Bay. Consequently they generate waves within the Bay itself – these waves are called Local Seas.

Whilst the fetches are relatively short and shallow (particularly the north-easterly fetches across to Magnetic Island), they still enable substantial wave energy to be generated and propagate to the Rowes Bay and Pallarenda foreshores. They play an important role in the longshore transport of sand on the western shores of Cleveland Bay.

3.2.3.3 Numerical modelling of waves

The generation of the various wave types and how they are modified by wave refraction, diffraction, seabed friction, shoaling and breaking as they propagate from their offshore generation areas to the foreshores of Rowes Bay and Pallarenda is very complex. In the absence of any site specific long-term directional wave measurements, the only way of obtaining an appreciation of the wave climate along the Rowes Bay / Pallarenda coastal reach is to apply numerical modelling techniques.

This approach has been adopted when preparing this Shoreline Erosion Management Plan - so as to obtain the necessary understanding of waves and wave-induced sand transport when determining appropriate foreshore management strategies.

The coastal processes model used to support this Shoreline Erosion Management Plan is the same as that originally used for the investigative studies and engineering designs for the Strand beach and headland system, for which construction was completed in 1999.

Since that time, the regional coastal process model has been progressively but significantly upgraded. This improvement to the model has not only come about by the increased computing power that has developed in recent years, but more significantly due to the model's improved resolution and representation of the seabed and shoreline features throughout Cleveland Bay and offshore regions. The most recent application of the model was for the coastal engineering studies to support the EIS for the Townsville Ocean Terminal Project (Coastal Engineering Solutions, 2007).

A detailed and comprehensive technical discussion of the model and the methodology of its application are not suited for inclusion in this Shoreline Erosion Management Plan, however such information is available from reports pertaining to previous projects and coastal process studies in the Townsville region (Coastal Engineering Solutions, 1998, 2007). The model uses the following data and information:

- wave characteristics recorded by a Waverider station (established in July 1975) which is currently maintained and operated by the Department of Environment and Resource Management;
- hindcasts for waves generated by winds blowing across local Cleveland Bay fetches have been produced using standard mathematical techniques. This requires the use of directional wind data - as measured by the Bureau of Meteorology at local anemometer sites.
- cyclone wave information in the deep waters offshore of Townsville has been extracted from data generated for the *Atlas of Tropical Cyclone Waves in the Great Barrier Reef* (MMU, 2001);
- storm tide levels during extreme events utilises the results of previous modelling of storm tides in the Townsville region (DNRM, 2004) and (GHD Pty Ltd, 2007).

The outcome of the numerical modelling of waves undertaken for the Shoreline Erosion Management Plan consists of time series of wave height, period and direction every hour over timeframes of up to 13 years as well as the cyclone wave characteristics associated with 50, 100, 200, 500 and 1,000 year ARI events.

These various wave time series have been established at thirteen locations along the Rowes Bay and Pallarenda foreshore. These were selected as being at locations where there have been intermittent beach transect surveys undertaken between Kissing Point and Cape Pallarenda since 1982. The locations of these thirteen sites are shown on Figure 3.3, along with the historical survey lines (referred to as TOWN26 to TOWN42).

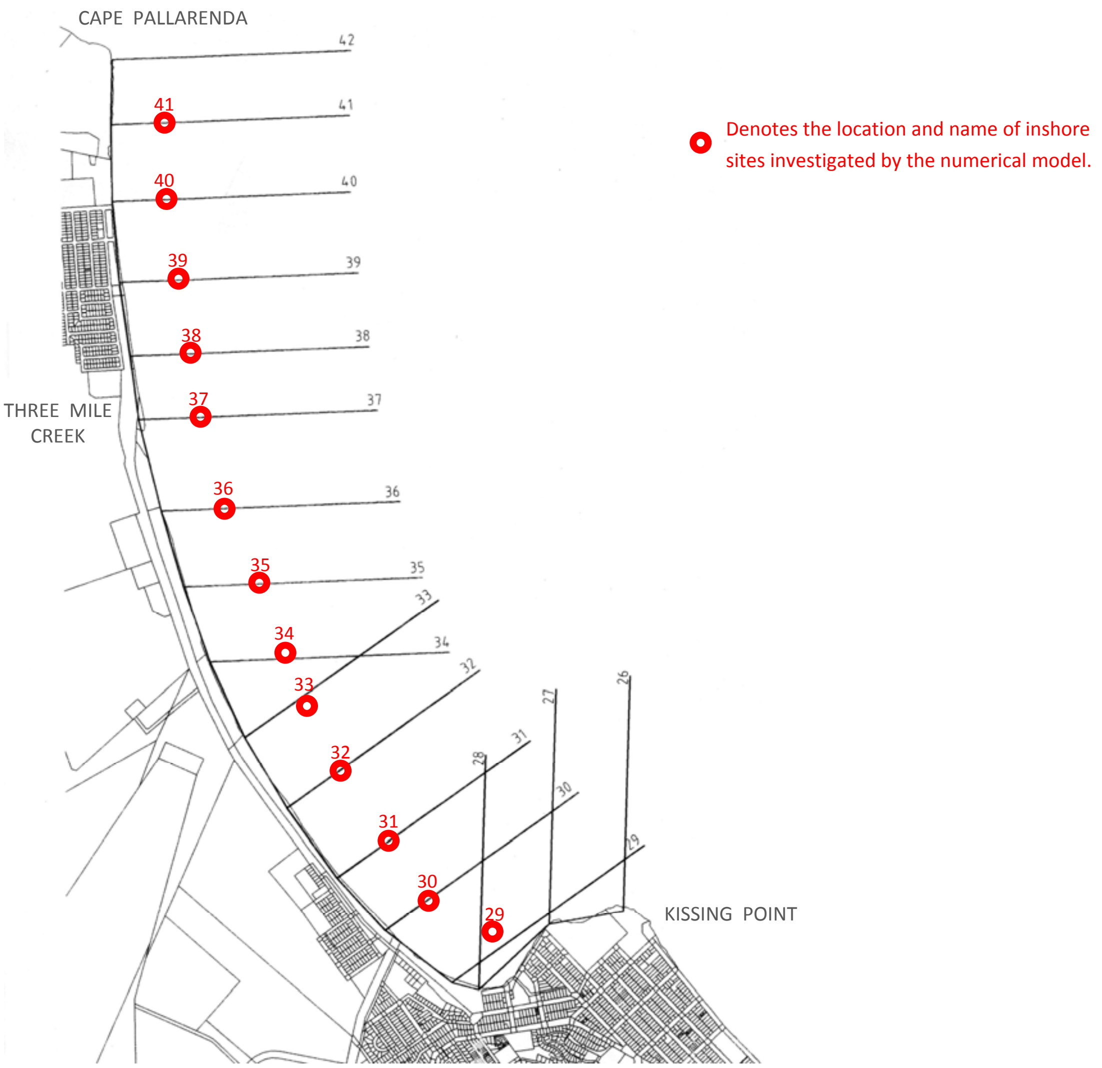


Figure 3.3 : Location of Beach Transect Survey Lines

Initially the surveys were commissioned by the Beach Protection Authority as part of the Authority's initiative to provide repetitive cross-shore surveys at selected coastal locations throughout Queensland. Following closure of the Beach Protection Authority, Townsville City Council has maintained a program of intermittent surveys of the Authority's transect lines.

The numerical modelling of waves provides a comprehensive description of the temporal and spatial variability of the wave climate along the Rowes Bay / Pallarenda coastal reach. This has then been utilised for subsequent numerical modelling of longshore and cross-shore sand transport on these foreshores.

3.2.4 Longshore Sediment Transport

As discussed in the preceding Section 3.1, the primary cause of the erosion problems being experienced in Rowes Bay is the inadequate supply of sand to accommodate the longshore transport rates that are removing sand from this foreshore. Given that the erosion problem has been occurring for many years, there have been a number of previous studies and data collection exercises undertaken that provide useful technical background and insight.

The numerical modelling of waves and sand transport along the Rowes Bay / Pallarenda coastal reach undertaken for this Shoreline Erosion Management Plan, in conjunction with the previously documented work relating to the eroding sections of the foreshore, provides a sound understanding of the local longshore sand transport regime.

3.2.4.1 Existing data and previous studies

As part of a comprehensive state-wide program of surveying cross-shore profiles at coastal locations throughout Queensland, the Beach Protection Authority established a number of transect lines on the shores of Rowes Bay and Pallarenda. The intent being to undertake repeated surveys on these transects to provide quantitative information regarding shoreline change - which could then assist in determining sand transport processes. The locations of the transect lines between Kissing Point and Cape Pallarenda (referred to as TOWN26 to TOWN42) are shown in Figure 3.3.

The first surveys of these profiles were undertaken by the Beach Protection Authority in February 1982, with subsequent surveys undertaken in February 1983, February 1993 and May 1998. Townsville City Council then took on responsibility for surveying the beach transect lines, with these being undertaken at approximately annual intervals in January 2003, March 2004, April 2005, February 2006, March 2007, October 2008 and February 2009

The survey marks identifying TOWN37 were lost in 2003 as a consequence of erosion to the north of Three Mile Creek. This transect line has not been reinstated since that time.

The results of the various surveys of the TOWN transect lines are shown plotted in Appendix C.

Supplementary surveys were also undertaken by staff of JCU's School of Tropical Environment Studies and Geography to monitor and report on the effectiveness of a major beach nourishment exercise undertaken by Council in October / November 1998 (Mabin, 1999a; Mabin, 1999b; and Mabin, 2001). Approximately 16,000 m^3 of sand was initially placed on a 935m long renourishment area north of the Mundy Creek entrance. Additional volumes of sand have since been placed on the beach within this renourishment precinct as well as elsewhere along the Rowes Bay shoreline.

Unfortunately records of the volumes and locations of other sand placement (following completion of the monitoring by JCU in mid-2001) are incomplete. Consequently it is not possible to utilise any surveys after May 2001 to adequately quantify subsequent beach performance on the southern shores of Rowes Bay.

However an analysis of aerial photographs, in conjunction with beach profile surveys undertaken between 1982 and 1998 indicate that in the forty-six years from 1952 to 1998 approximately 153,000 m^3 of sand was lost from the area between the Mundy Creek entrance and transect line TOWN 32 (ie. just to the north of the RSL Villas near Beach Access N7), which equates to an average loss of around 3,300 m^3/year (Mabin, 2002).

The monitoring of the same foreshore in the years following the placement of 16,000 m^3 of sand in the beach nourishment of late-1998 suggests that this was made up of approximately 1,800 m^3/year transported north towards Three Mile Creek and Cape Pallarenda; and 1,500 m^3/year transported towards the entrance of Mundy Creek (Mabin, 2001).

3.2.4.2 Numerical modelling of longshore sediment transport

Numerical modelling of waves and sand transport processes was undertaken specifically for this Shoreline Erosion Management Plan. Time series of longshore sediment transport at one hourly intervals over timeframes of up to 13 years have been established at each of thirteen locations along the Rowes Bay and Pallarenda foreshore. A summary of the modelling results are shown on Figure 3.4.

The rates shown on Figure 3.4 are the net average longshore sand transport rates per year. Figure 3.5 shows how these longshore transport rates typically vary at each location throughout the year.

There are a number of very informative characteristics of the longshore sand transport regime that emerge from this modelling, namely:

- Typically sand is transported northwards during the period of February to September, with southwards drift occurring between October and January.

  The exception to this is in the vicinity of beach transect TOWN31 near Beach Access N5 - where the net monthly movement of sand is towards the north throughout the year. It is in this area and to its immediate north that erosion poses the greatest threat to foreshore infrastructure on Rowes Bay.

- Whilst the net transport is predominantly from south to north on this coastal reach, at a location just to the north of the Mundy Creek entrance (in the vicinity of Beach Transect TOWN30, near Beach Access N3 and N4) there is a "*null point*" where the net longshore transport rate is zero.

This does not imply that there is no sand being moved along the shore at this location, but that the amount being moved northwards each year is balanced by an equal volume of sand being moved southward.

The modelling suggests that on average this is around 1,850 m3/year in each direction, which is verified by the post-nourishment surveys undertaken by James Cook University.

- On the foreshore to the south of this null-point, the local net annual sand transport is towards the south (ie. southward across the Mundy Creek entrance sandbar and along the Soroptimist Park frontage).

  On foreshores to the north of the null-point, the net longshore sand transport is towards the north (ie. northward from around Beach Access N5 all the way up to Cape Pallarenda).

- Immediately north of the null-point (ie. in the vicinity of transect TOWN31, which is near Beach Access N5), the local net annual rate increases quickly and significantly to around 4,000 m^3/year. However further north this steadies to approximately 3,300 m^3/year.

- In the vicinity of the Three Mile Creek entrance, the longshore sand transport rate drops from around 3,300 m^3/year to approximately 1,600 m^3/year. This is due to the influence of Virago Shoal some 1.6kms offshore.

  This significant seabed feature causes waves to be attenuated as they pass over the shoal, thereby diminishing their ability to move sand along the shoreline which is in the lee of the shoal. Virago Shoal effectively throws a “wave shadow” onto the foreshore in the vicinity of the Three Mile Creek entrance.

- North of the Three Mile Creek entrance, longshore transport rates gradually diminish from around 1,600 m^3/year to approximately 1,200 m^3/year near Cape Pallarenda. Because supply rates exceed the rate at which sand can be moved alongshore, this foreshore precinct has been in a long-term accretion phase, interspersed with erosion during cyclones or severe storms.

The local coastal processes in the vicinity of the ocean entrances of Mundy Creek and Three Mile Creek are particularly relevant to this Shoreline Erosion Management Plan. Consequently there is merit in providing further discussion of these two locations.

Figure 3.4 : Summary of Modelling Results for Annual Longshore Sand Transport

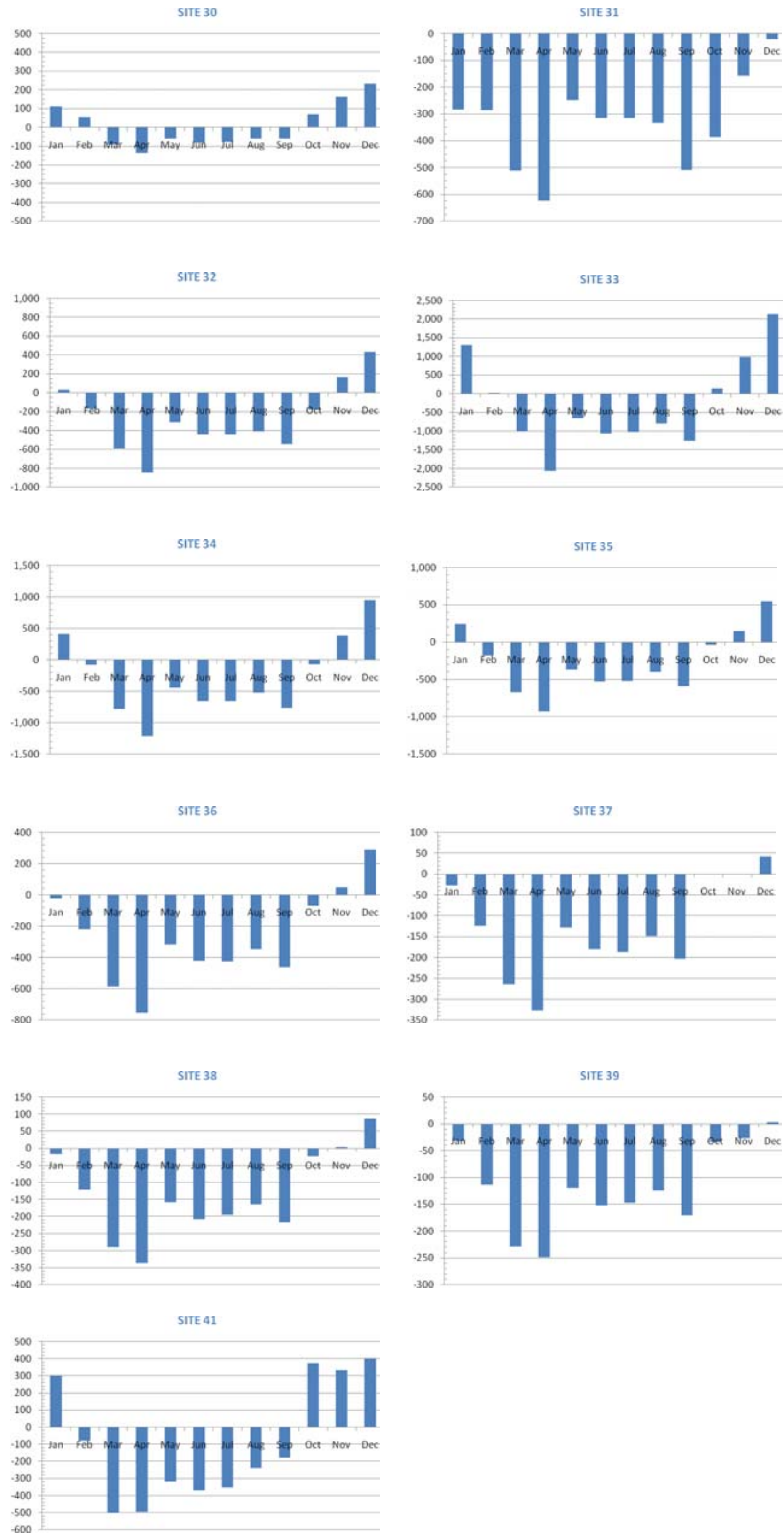


Figure 3.5 : Annual Longshore Sand Transport - Variability Throughout the Year[3]

[3] Negative value is transport northwards, positive value is transport southwards.

The stability and performance of creek entrances on dynamic sandy shorelines rely on the interaction of two competing processes – namely the transport of beach sand along the coast (which is acting to close the entrance) and the flow of water through the mouth of the creek (acting to keep the entrance open by scouring any sand deposited by longshore transport).

Often these two processes are in a state of dynamic equilibrium, whereby the velocity of tidal flows through the entrance is sufficient to prevent infilling by sand which is being transported to the mouth from along the adjacent foreshore. Under such a scenario, sand moving alongshore naturally bypasses the creek entrance by a complex transport pathway that entails the creation of mobile sandbanks and shoals immediately offshore.

During periods of strong wave action and the resulting high rates of longshore sand transport, a creek entrance may be temporarily closed by sand infilling the mouth. However during high rainfall events the entrance may be scoured open again by the discharging flows.

Consequently the nature of such entrances can be dependent on seasonal fluctuations in wave climate and rainfall/runoff on the catchment. Indeed that is the case for Mundy Creek and Three Mile Creek.

3.2.4.3 Processes at Mundy Creek entrance

Originally the mouth of Mundy Creek was further south than it is at present. Figure 3.6 shows that historically the lower reaches of the creek meandered southward through what is now Soroptimist Park, exiting through the foreshore at the western end of The Esplanade, against the northern flank of Kissing Point.

Figure 3.6 : Historical Changes to the Ocean Entrance of Mundy Creek

In late 1961 a wide drainage path was excavated to link the creek more directly with the waters of Rowes Bay, presumably to facilitate improved drainage of the airport and its environs. This artificial waterway replaced the lower 800 metres of the creek at that time.

The newer channel is now known variously as One Mile Creek or Captains Creek and currently forms the lower reaches of Mundy Creek.

Historical aerial photographs indicate that even when at its original location further south, the creek mouth was constantly changing in response to the movement of local sandbanks, spits and shoals. Indeed it was often closed off.

Similar processes are affecting the present relocated entrance, with the new entrance area requiring regular re-opening by earthmoving equipment to ensure that it can efficiently discharge creek flows, particularly during the north Queensland wet season.

As discussed previously, the section of foreshore south of the null-point near Beach Access N3 and N4 experiences a net southerly longshore transport. This southerly transport frequently overwhelms creek flows, causing closure of the entrance.

Originally the net southward transport of sand on this length of the Rowes Bay foreshore caused the Mundy Creek entrance to naturally migrate to its morphologically preferred location at the southern-most end of the Rowes Bay beach – ie. against the Kissing Point headland. This same mechanism is attempting to drive the present re-located entrance southward by filling it in.

Figure 3.7 presents a conceptual representation of sediment transport processes in the vicinity of the existing creek entrance. As discussed, just to the north of the entrance the net longshore transport rate of beach sand is zero – since the wave climate and local shoreline orientation is such that approximately 1,850 m^3/year is moved to the south and an equal quantity is moved northward.

However when wave conditions are such that this quantity of sand is moved southward towards the mouth of Mundy Creek, a significant portion of it is ingested into the entrance or is swept by creek flows onto the shoal and sandbanks just offshore. Consequently when conditions change so as to cause northward sand transport, much of this sand cannot be accessed by waves and therefore cannot be returned to replenish the foreshore immediately north of the creek entrance.

Nevertheless waves can still move 1,850 m^3/year northwards along this foreshore - and in order to do so they make up any deficit of sand that has been ingested into the creek entrance by eroding it from the foreshore and dunes at this location.

In other words, the foreshore north of the Mundy Creek entrance (ie. around Beach Access N3 and N4) is eroding at much the same rate that the creek mouth and entrance shoal are accreting.

Earlier campaigns to re-open the creek entrance entailed excavating the sand and placing it on the eroded beach/dunes immediately north of the creek. However much of this sand was simply swept back into the mouth of the creek during conditions of southerly transport.

Ideally it should be placed north of the null-point - near Beach Access N5 or alternatively on the southern side of the Mundy Creek entrance.

Figure 3.7 : Sand Transport Mechanisms at Mundy Creek Entrance

To be successful, any foreshore management strategy applied to the southern end of Rowes Bay must accommodate the underlying processes causing the migration/closure of the Mundy Creek entrance.

3.2.4.4 Processes at Three Mile Creek entrance

Whilst there has been some accumulation of sand due to supply from the Three Mile Creek catchment itself, the large sand deposits in the nearshore region of the Three Mile Creek entrance have been primarily created by longshore sand transport processes. It is evident from the numerical modelling of wave climate and sand transport mechanisms that Virago Shoal plays an important role in the coastal processes of the Pallarenda foreshore.

As discussed previously, sand is being transported northwards along the Rowes Bay/Pallarenda shoreline towards Three Mile Creek at an average rate of approximately 3,300 m^3/year. However the section of foreshore in the lee of Virago Shoal does not experience the same amount of wave energy due to the attenuating effect of this seabed feature.

Consequently the rate at which waves move sand along this shore is less than that along foreshores just to the south. Numerical modelling indicates that the longshore rate is approximately 1,600 m^3/year within the Virago Shoal wave shadow. In other words, sand is being supplied to the area at a rate which is greater than is being carried through it.

Figure 3.8 presents a conceptual representation of sediment transport processes in the vicinity of the Three Mile Creek entrance.

Figure 3.8 : Sand Transport Mechanisms at Three Mile Creek Entrance

The modelling results indicate that the area has been accreting at a rate of around 1,700 m^3/year (ie. supplied at 3,300 m^3/year less 1,600 m^3/year carried through by longshore processes).

Consideration of historical beach surveys and aerial photographs indicates that there is around 900,000m^3 to 950,000m^3 of sand in the nearshore sandbanks around the Three Mile Creek entrance. This suggests that as the shoreline between Kissing Point and Cape Pallarenda has prograded, sand has been accumulating to form the shoals at the creek entrance for over 500 years.

The 1,600 m^3 of sand which on average moves through the entrance area each year does so by complex sediment pathways that entail sand movement across the various mobile sandbanks and shoals at the entrance, gradually feeding back onto the foreshore further north.

The rate at which the sand moves through the nearshore sandbanks may not always match the longshore rates on the beach face immediately downdrift, there can be a lag in time. Consequently the northern side of the Three Mile Creek entrance is often starved of replenishing sand, making it vulnerable to erosion - particularly during storms.

This area south of Beach Access N15 has historically represented an erosion threat to infrastructure, with the alignment of the Cape Pallarenda Road and the road bridge over the creek being relocated away from the foreshore many years ago.

Some armouring of this foreshore has also occurred in the past, but it has been mostly ineffectual due to the ad hoc nature of the work.

3.2.5 Cross-shore Sediment Transport

In addition to transporting sand along the Rowes Bay / Pallarenda shoreline, waves move sand in a cross-shore direction. It is during storms and cyclones that this type of sand transport becomes critical.

Severe wave conditions in conjunction with elevated ocean water levels enable large waves to access higher levels of the beach profile - resulting in significant erosion of the beach and dunes. Sand is removed from this upper region of the profile and is deposited offshore - resulting in recession of the shoreline and the creation of sandbanks immediately offshore.

If the storm or cyclone is particularly severe, the erosion may threaten or damage foreshore infrastructure.

3.2.5.1 Beach response modelling

Technical work undertaken for this Shoreline Erosion Management Plan included application of the SBEACH proprietary mathematical model to predict the response of the beach to a number of different cyclone scenarios. The 50, 100, 200, 500 and 1,000 year ARI storm conditions were investigated at each of the beach transect lines that exist between Kissing Point and Cape Pallarenda.

The fundamental approach to this beach response modelling has been to:

- utilise cyclone wave information for the deep waters offshore of Cleveland Bay using data generated for the *Atlas of Tropical Cyclone Waves in the Great Barrier Reef* (MMU, 2001);
- utilise storm tide levels for extreme events which has been previously determined by modelling of storm tides in the Townsville region (DNRM, 2004) and (GHD Pty Ltd, 2007);
- transform these offshore cyclone wave and storm tide conditions to each of the thirteen beach transect locations along the Rowes Bay / Pallarenda shoreline using wave transformation modelling; then
- apply the local wave / storm tide conditions and the most recent beach transect surveys as input to the SBEACH model to determine the eroded profile at each location.

Figure 3.9 illustrates a typical outcome of the SBEACH modelling, namely the pre-storm profile and post-storm profiles for a location at transect TOWN31 (ie. near Beach Access N4) for the selected range of cyclone scenarios.

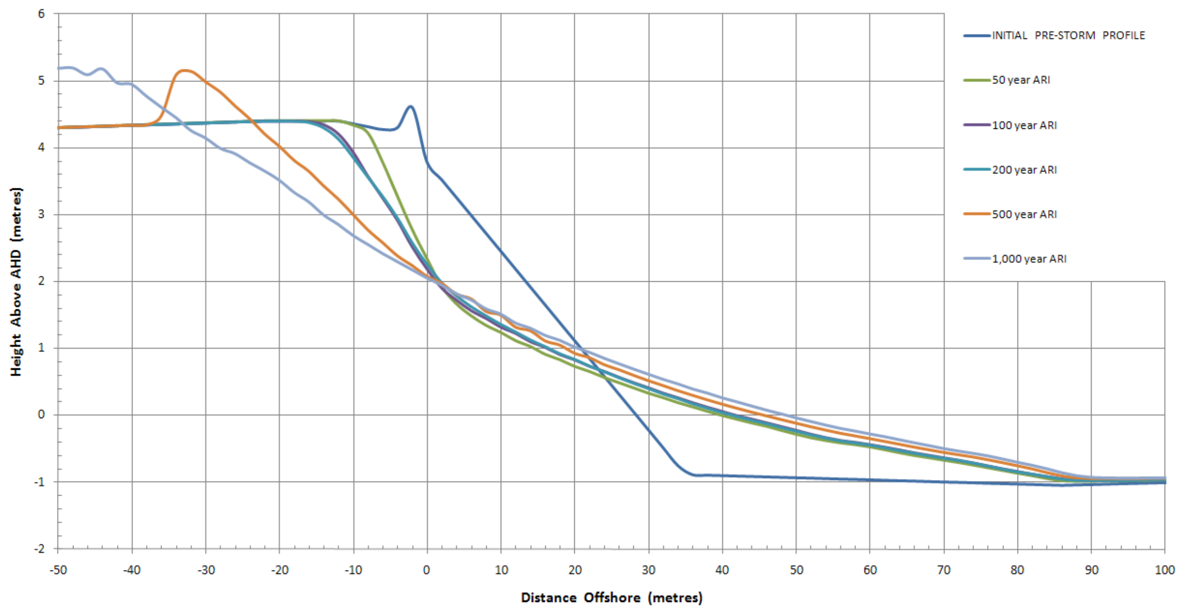


Figure 3.9 : Predicted Beach Response (at TOWN31) for Various Cyclone Events

As can be seen, sand is eroded from the upper beach area, typically from above RL+0.5m AHD. This sand is then deposited offshore of the toe of the beach, thereby flattening the beach slope. This typical cross-shore erosion process occurs along the entire Rowes Bay / Pallarenda shoreline.

The results of the beach response modelling for all transect locations along the Rowes Bay / Pallarenda foreshore are summarised in Figure 3.10 and Figure 3.11.

The volume of sand removed from the upper beach by various cyclone scenarios is presented in Figure 3.10 - whereas the distance that the shoreline recedes as a consequence of these same cyclones is shown in Figure 3.11.

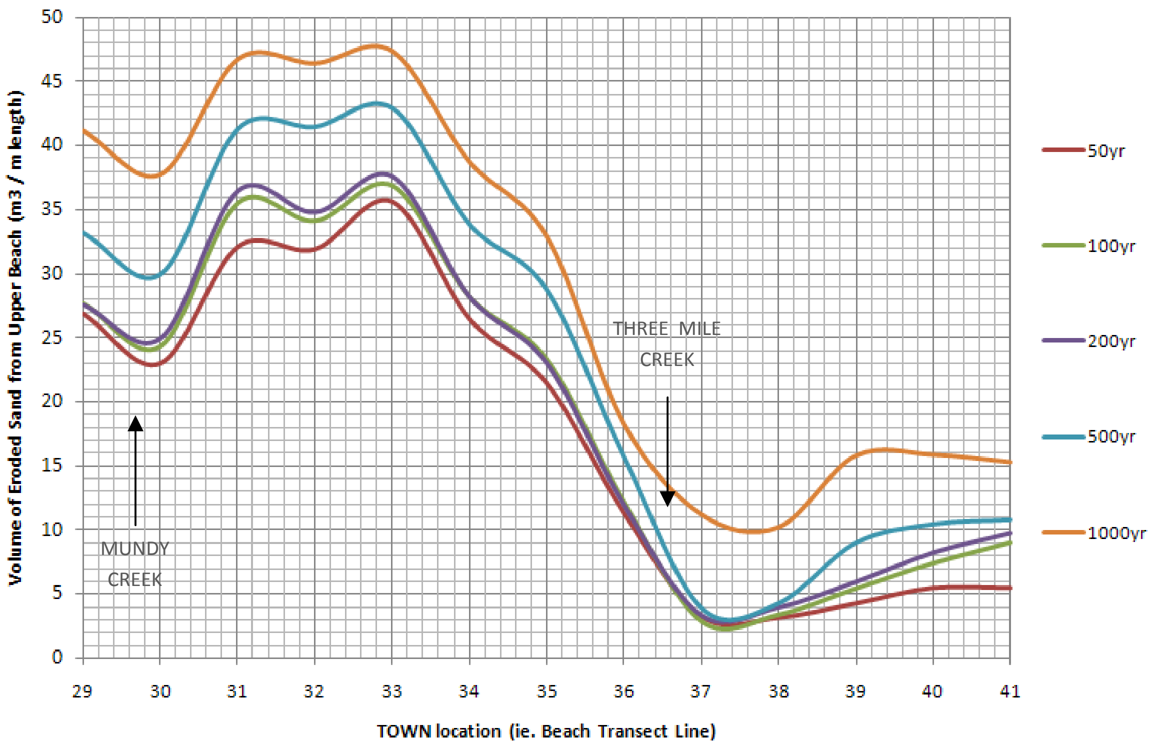


Figure 3.10 : Predicted Cyclone Erosion Volumes for Various ARI Cyclone Events

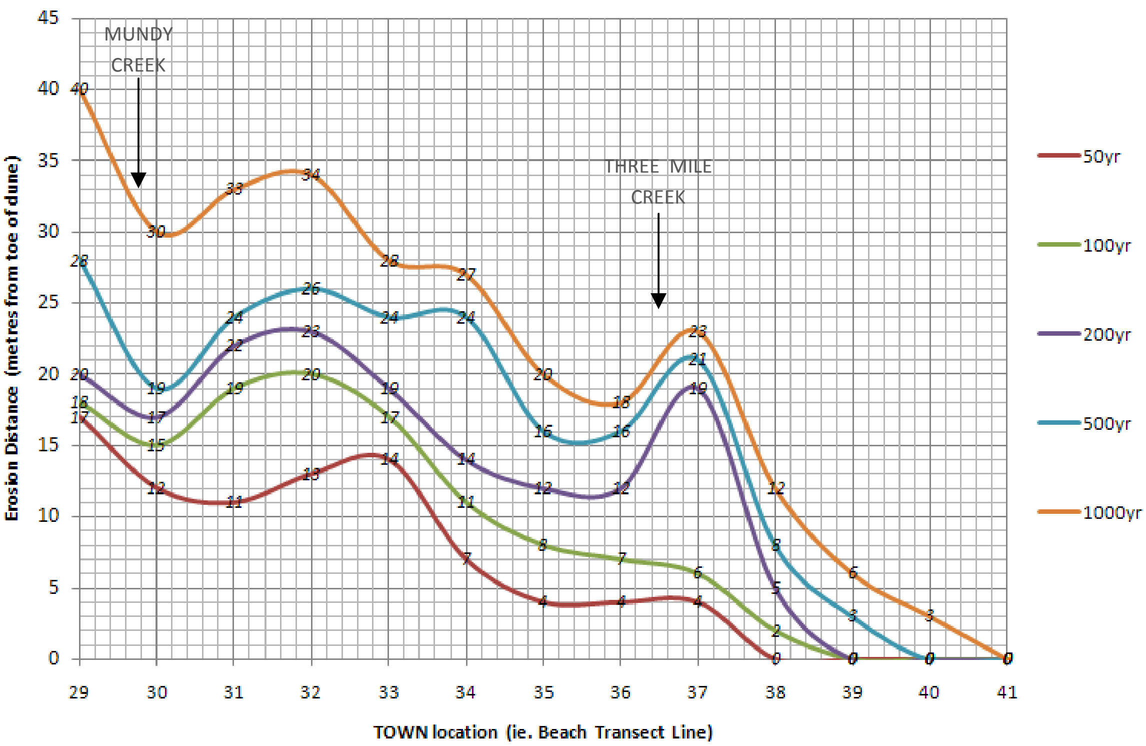


Figure 3.11 : Predicted Cyclone Recession for Various ARI Cyclone Events

Some discussion is offered later regarding the phenomena of *overwash*, which influences the predicted profile response for cyclones greater than approximately 200 years ARI.

It is evident that the southern half of the coastal reach between Mundy Creek and Three Mile Creek experiences the greatest sand loss from the upper beach. For example, the 100 year ARI cyclone event removes around $36m^3$ of sand from each metre length of foreshore between TOWN31 and TOWN 33 (refer Figure 3.10). This equates to a shoreline recession of about 20m at this location (refer Figure 3.11).

The foreshore immediately north of Three Mile Creek experiences significant recession for events more severe than approximately 100 year ARI. This is because the creek alignment meanders as it approaches the ocean entrance, running almost parallel to the shore for 200 metres with a sand barrier between it and the ocean. This barrier is breached by storms having ARI of around 100 years, resulting in significant overwash and erosion of this barrier feature.

3.2.5.2 Overwash

The eroded volumes and shoreline recessions discussed above and shown in Figure 3.10 and Figure 3.11 need to be considered with some caution for events more severe than 200 year ARI. During such storms, there is considerable overwash of the foreshore. This phenomenon occurs when the storm tide builds during the cyclone to be so great that waves no longer dissipate their energy directly on the beach slope or on the dunes - ocean water levels are such that the waves wash over the beach slope since it is substantially submerged.

Once overwash commences, further recession of the foreshore still occurs. However instead of being carried offshore, sand in the upper beach is swept up over the slope and carried inshore. This response can be seen in the predicted beach profile illustrated in Figure 3.9 for storms with ARI greater than 200 years. The consequences of overwash can be devastating to foreshore areas since the foreshore is not only inundated by storm surge, but destructive cyclonic waves can wash over the dunes and penetrate inland.

Unfortunately the extent of profile change and damage caused by overwash cannot be confidently predicted by current mathematical modelling techniques. Consequently the erosion characteristics summarised in Figure 3.10 and Figure 3.11 should be considered as indicative only when overwash occurs.

Nevertheless to assist in obtaining an appreciation of the possible extent of overwash, Figure 3.12 shows the SBEACH model's prediction of the level to which storm tide and wave effects (including wave setup) can occur at each of the thirteen beach transect locations on the Rowes Bay / Pallarenda foreshore.

As can be seen from this figure, the levels vary along the shoreline. This is primarily due to the variation in wave setup that occurs on the slightly different seabed approaches at each location. Typically wave and surge influences have the greatest impact on the southern shores - peaking between approximately TOWN30 and TOWN33 (ie. from the Mundy Creek entrance north to almost Beach Access N8).

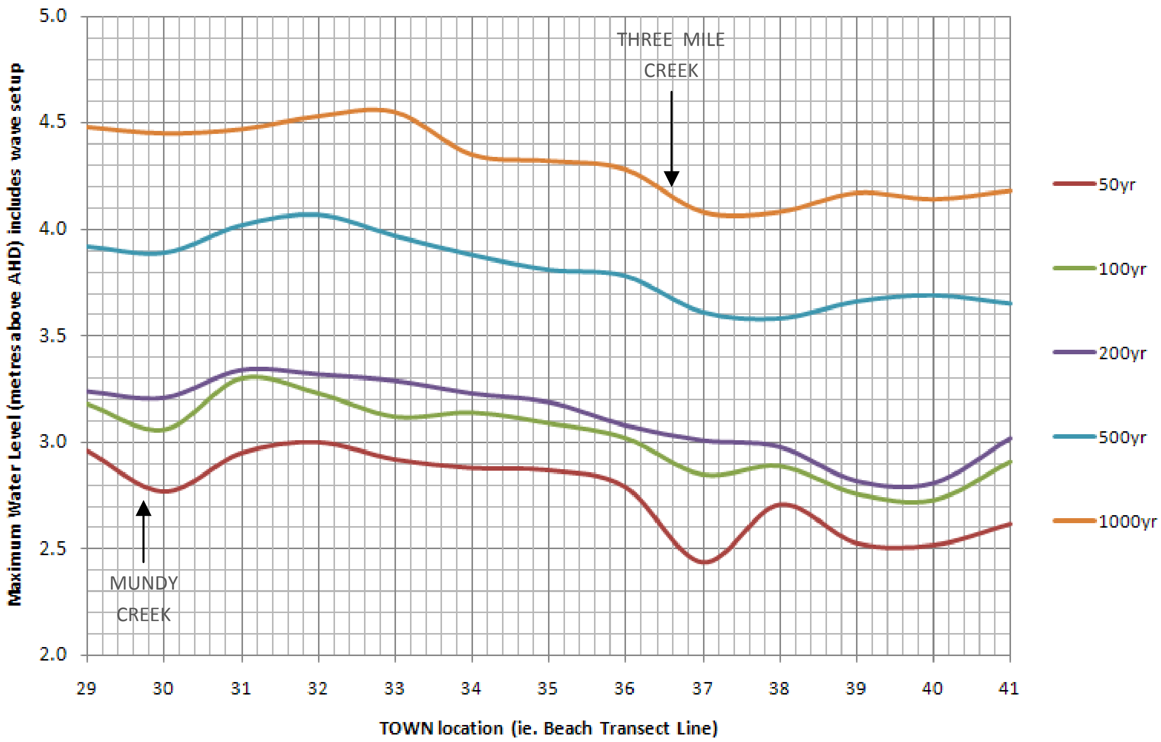


Figure 3.12 : Predicted Wave & Surge Influences for Various ARI Cyclone Events

3.3 Implications to Erosion Buffers

As well as offering considerable environmental and social benefits, the sandy shores of the Rowes Bay / Pallarenda coastal reach serve as erosion buffers, protecting valuable foreshore infrastructure and property. Preceding sections of this Shoreline Erosion Management Plan provided discussion on the longshore and cross-shore sand transport mechanisms that affect these sand reserves.

It is evident that the cross-shore sand transport processes during cyclones and severe storms can cause rapid depletion of the erosion buffers. To ensure that adequate protection is afforded to foreshore infrastructure, the volumes of sand reserves and the minimum buffer widths required are summarised in Figure 3.10 and Figure 3.11.

Maintaining these buffers ensures that such infrastructure is located a sufficient distance inland so as not to be damaged by storm erosion.

Longshore sand transport also plays an important role, since it is the means by which the erosion buffers are kept naturally recharged with sand. Provided the supply of sand from updrift foreshores matches the rate at which sand is moved to downdrift foreshores, then local erosion buffers are not adversely affected by longshore transport processes. As was discussed previously, this is not the case for the Rowes Bay / Pallarenda shoreline since the supply of sand to the beaches has diminished significantly in recent years (refer Section 3.1). Consequently the erosion buffers are diminishing - particularly at the southern end of Rowes Bay.

An analysis of historical photographs dating back to when erosion trends commenced around 1952 indicates that the rate of shoreline recession north of Mundy Creek has been variable, with a slow long-term rate of approximately 0.5 m/yr interspersed by much greater recessions during cyclones (Mabin, 2002).

This, in conjunction with numerical modelling of longshore sand transport, indicates that erosion influences have been migrating northwards at a long-term average rate of around 8 -10 m/yr. Future climate change may result in these recession and migration rates increasing in coming years.

3.4 Future Climate Change

The preceding discussions of sand transport rates are based on a present-day climate scenario. Climate change as a consequence of enhanced Greenhouse gas emissions will cause environmental changes to ocean temperatures, rainfall, sea levels, wind speeds and storm systems. If climate changes develop as predicted, the foreshores of Rowes Bay and Pallarenda will be subjected to potentially greater storm and cyclone energy, higher waves, stronger winds and increased water levels.

In its Fourth Assessment Report released in 2007 the *Intergovernmental Panel on Climate Change* (IPCC, 2007) has presented various scenarios of possible climate change and the resultant sea level rise in the coming century. There is still considerable uncertainty as to which of these various scenarios will occur. The oceanographic and atmospheric processes involved are complex, and numerical modelling of these processes is far from precise.

Because of these complexities, there is a wide range in the predictions of global sea level rise for the coming century. A rise of between 0.18 metres and 0.59 metres by the year 2100 is predicted by the IPCC investigations, with a possible additional contribution of 0.1 to 0.2 metres from melting ice sheets.

At this stage there is no agreed pattern for the longer-term regional distribution of projected sea level rise offered by the IPCC predictions. Nevertheless, in the Australian region a common feature in many model projections of sea level rise is an increase on the east coast of Australia that is potentially higher than the global average. In the Townsville region, this is estimated to be approximately 0.15 metres above global averages (CMAR, 2008).

The projected sea level rise currently adopted for planning purposes by Queensland's *State Coastal Management Plan* is 0.3 metres over 50 years. Whilst this is still within the range of projections in the IPCC Fourth Assessment Report, it is now at the lower end of these recent predictions and is therefore being reviewed. Under the provisions of the Coastal Act, a review of the 2002 *State Coastal Management Plan* was initiated in 2009.

As a consequence of that review, the draft coastal plan has adopted an updated sea level rise of 0.8 metres by the year 2100. This is based on the upper limit of the most recent projections released by the IPCC in its Fourth Assessment Report, in conjunction with the expectation that sea levels along the east coast of Australia will be higher than the global average.

Townsville City Council requires a planning period of 50 years for this Shoreline Erosion Management Plan (ie. to approximately the year 2060). Reference to the upper limit of the range in predictions offered by IPCC (2007) indicates that a 0.4m allowance for Greenhouse-induced sea level rise should therefore be included in current planning for the Shoreline Erosion Management Plan.

In addition to sea level rise, there is speculation that the intensity of tropical cyclones may increase - although it is also acknowledged that there is a possibility that the overall number of cyclones affecting coastal regions may decrease. However estimating any changes to the intensity and occurrence of cyclones is particularly problematic since their formation and subsequent track are dependent upon the complex interaction of a number of natural phenomena (such as the El Nino - Southern Oscillation) which themselves are not yet well understood.

To accommodate any such adverse impacts on future coastal processes when compiling this Shoreline Erosion Management Plan, the effects of a 10% increase in offshore wave heights and a 5% increase in offshore wave periods have been incorporated - along with a 0.4m sea level rise. This increase in wave characteristics equates very approximately to a 10% increase in the intensity of cyclones for any given ARI.

The rate of any sea level rise as a consequence of climate change will be very gradual, and the timescales associated with the coastal processes shaping the nearshore and foreshore regions will keep pace with the slow sea level rise. Consequently the basic form of the beach profile along the Rowes Bay / Pallarenda shoreline will be maintained in relation to the gradually rising sea level in front of it.

Nevertheless, there will be a gradual recession of the position of the shoreline, which will effectively reduce sand buffers in front of existing foreshore infrastructure. The seabed on the wave approaches through Cleveland Bay will likely remain at much the same levels and slopes as they are now - which means that waves will be approaching the shore through slightly deeper water.

Numerical modelling indicates that the combination of predicted sea level rise and increased wave energy results in a 6% to 10% increase in the current longshore sand transport rates reported in Section 3.2.4 for the entire length of the Rowes Bay / Pallarenda shoreline. The recession and northward migration of the long-term erosion influences currently being experienced on the southern shores of Rowes Bay are also likely to increase by this amount.

That is, the long-term rate of recession could increase slightly from around 0.5m/yr to 0.55m/yr; and its migration north could increase slightly to approximately 9 -11 m/yr.

Climate change influences may also increase the cross-shore transport rates associated with cyclones. The erosion and recessions along the project foreshore resulting from predicted climate change are shown in Figure 3.13 and Figure 3.14. These have been determined from application of the SBEACH shoreline response model using the expected increases in sea levels rise and more severe wave conditions. In other words, these two figures represent the data presented in Figure 3.10 and Figure 3.11 modified so as to include the expected effects of future climate change.

The volumes of cross-shore erosion caused by cyclones are generally 10% to 40% higher as a consequence of climate change - with additional shoreline recessions of around 6 metres to 12 metres predicted. The greatest impacts are in the vicinity of the Mundy Creek and Three Mile Creek entrances.

Given the present uncertainties associated with the extent and nature of future climate change, when developing and assessing appropriate erosion mitigation strategies there is considerable merit in applying strategies that are flexible and can be tailored to suit impacts as they gradually evolve.

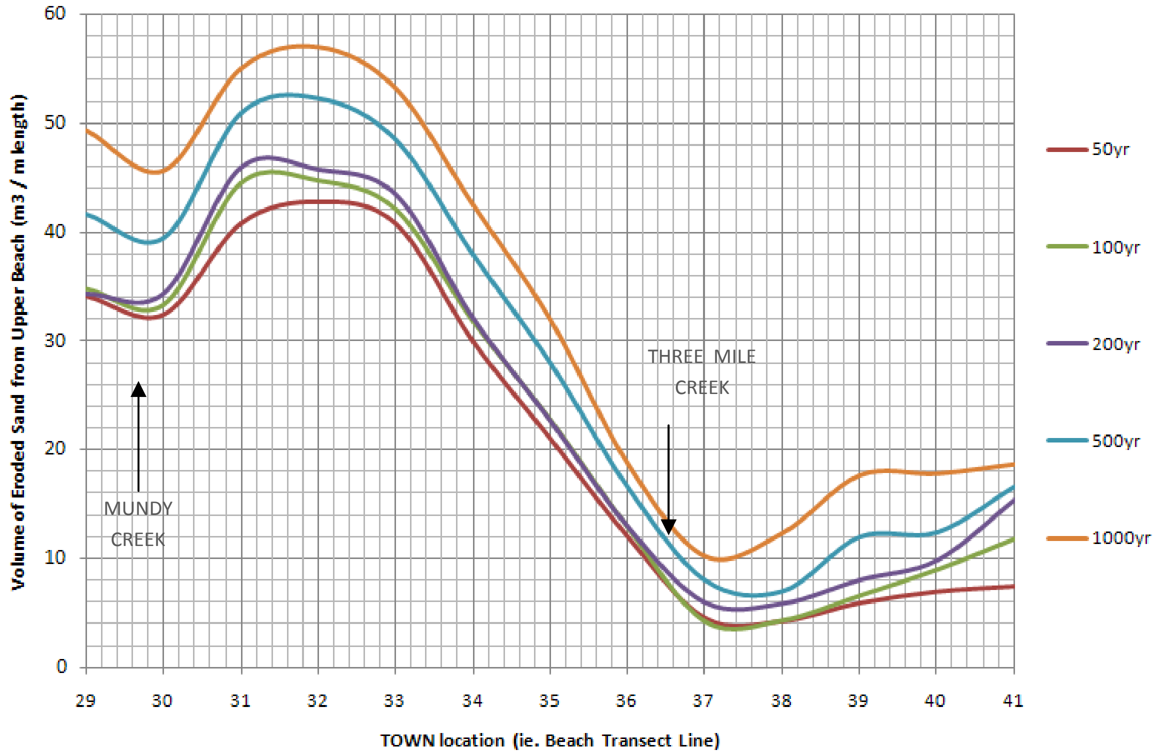


Figure 3.13 : Predicted Cyclone Erosion Volumes - <u>including</u> climate change effects

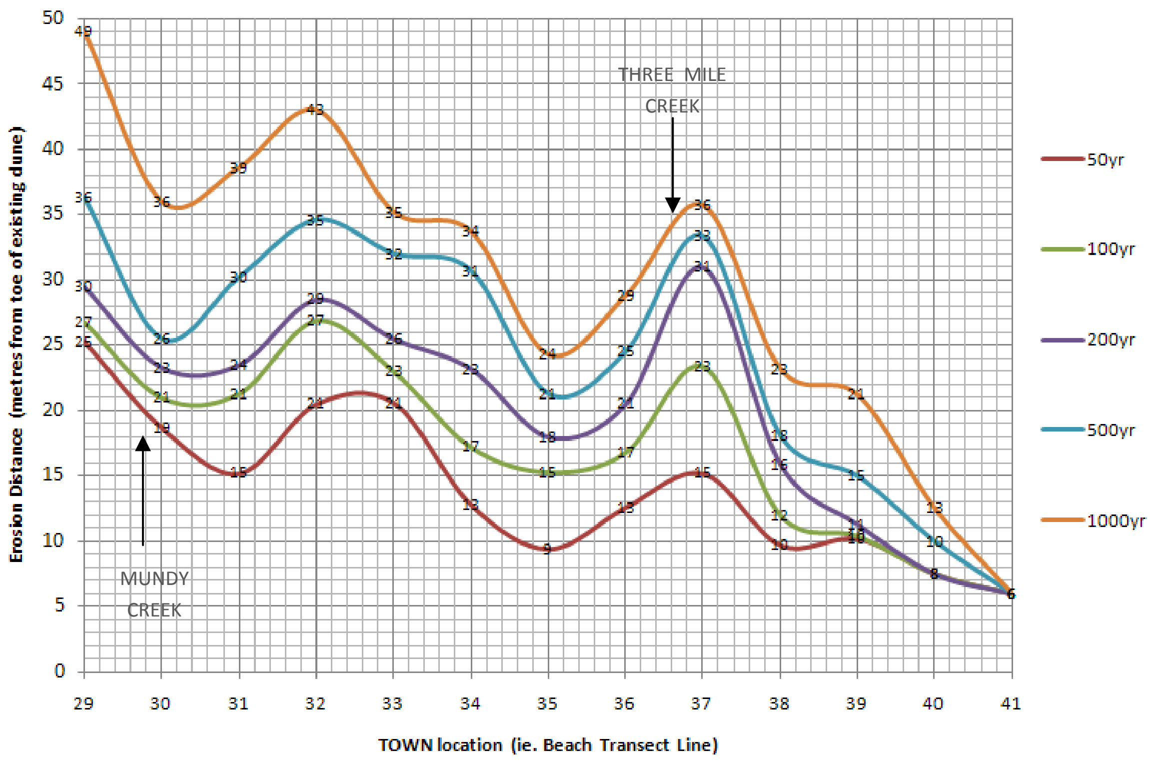


Figure 3.14 : Predicted Cyclone Recession - <u>including</u> climate change effects

4 RISK ASSESSMENT

The preceding sections of this Shoreline Erosion Management Plan quantified long-term foreshore recession (as a consequence of a deficit in the supply of sand) as well as cyclone induced erosion as a consequence of a number of cyclone scenarios.

However it is necessary to relate these shoreline responses to the actual hazard this represents - by considering the extent and nature of "at-risk" property and infrastructure.

4.1 Erosion Threat

4.1.1 Designated Erosion Prone Areas

The establishment of Erosion Prone Areas along Queensland's coastline has been an intrinsic part of the state's coastal management policy since 1968. The concept is to set aside undeveloped buffer zones thereby implementing a philosophy that biophysical coastal processes should be accommodated rather than prevented. The most basic form of accommodation is to avoid locating development and vital infrastructure within dynamic coastal areas affected by the natural processes of shoreline erosion and accretion.

An adequate buffer zone allows for the maintenance of coastal ecosystems (including within littoral and sublittoral zones), visual amenity, public access and the impacts of natural processes - without the high cost and potentially adverse effects of property protection works.

The Department of Environment and Resource Management currently has an Erosion Prone Area Plan for Townsville which was first established by the Beach Protection Authority in December 1984[4]. Its purpose was to define the width of local foreshores that might be susceptible to erosion over the following 50 years. At the time it was prepared, no specific allowances for potential future climate change were directly incorporated into the designated widths, although a 40% factor of safety was applied to the widths calculated by the Beach Protection Authority.

This safety factor was applied in recognition that there are uncertainties and limitations associated with predictions of future foreshore erosion, including those that might arise as a result of what was then identified as emerging Greenhouse effects.

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[4] Plan number SC 3391, titled "*Townsville City Erosion Prone Areas*"; originally dated 04th December 1984. It has subsequently been amended a number of times to the current version, Revision E.

Whilst some amendments have been made to the plan since it was established, the designated erosion prone areas along the Rowes Bay / Pallarenda foreshore remain as follows:

- Around Kissing Point to Cook Street (alongside the Jezzine Military Barracks) = 0 metres (in acknowledgement of the seawall along this foreshore);
- Cook Street northwards to the vicinity of Eclipse Street in the Rowes Bay suburb = 80 metres;
- From around Eclipse Street, north to Cape Pallarenda = 110 metres

The erosion prone area is measured landward from the seaward toe of the frontal dune, or from the line of permanent terrestrial vegetation if a dune feature is not well established or identifiable.

As with designated erosion prone widths along the entire Queensland coastline, these areas have served in the past as planning and legislative tools when considering development on the state's foreshores.

4.1.2 Planning Period

When preparing a Shoreline Erosion Management Plan it is necessary to select the timeframe (or planning period) over which erosion influences are to be considered. The threat of erosion to most foreshores can be summarised as being a result of:

- long-term erosion – due to a shortfall in sediment supply over time;
- short-term erosion – due to the direct effects of severe cyclone events; and
- future climate change – primarily sea level rise and increased severity of tropical cyclones.

The selection of a planning period determines the effects of these phenomena when considering foreshore management options.

- Long-term erosion

Long-term erosion manifests itself as a gradual recession of the average position of the shoreline due to a deficit in the supply of sand from updrift foreshores – such as is happening along the southern shores of Rowes Bay. When considering the threat that this poses and the measures required to mitigate the threat, it is necessary to select a planning period.

For example, the average long-term recession of 0.5m / year that has been occurring on the shoreline to the north of Mundy Creek (refer discussions in Section 3.3) represents a potential recession of 25m over a 50 year planning period. A different planning period represents a different recession. The effect of this long-term deficit is also gradually migrating northward along the foreshore at a rate of 8 to 10 m/yr.

It is therefore necessary to have a planning period established in order to quantify the extent of future long-term erosion and an appropriate strategy to address it.

- Short-term erosion

The selection of a planning period also has an effect on the threat posed by short-term cyclone induced erosion. For example, the likelihood of a 100 year ARI cyclone occurring in (say) a 50 year planning period is quite different to that for shorter or longer timeframes. Consequently when determining risk, the implications of a 100 year ARI cyclone could be considered unlikely for short planning periods – or alternatively, very likely for longer periods.

- Future climate change

The nominated planning period also has implications to the effects of climate change that are to be incorporated into each Shoreline Erosion Management Plan. Current projections of sea level rise and the severity / frequency of cyclones and storm tides vary - depending upon when in the future such issues are considered. Clearly such effects are different in 20 years time as opposed to 50 or 100 years into the future.

The Department of Environment and Resource Management currently uses a planning period of 50 years when considering the requirement for coastal setbacks (ie. erosion prone area widths) under the current State Coastal Management Plan. Indeed this planning period has been the State Government's policy since the establishment of the Beach Protection Authority in 1968. A 50 year planning period was considered appropriate given the practical life of coastal management projects and the maximum reasonable forward projections of present and past erosion trends.

Townsville City Council has nominated a 50 year planning period for this Shoreline Erosion Management Plan.

4.1.3 Probability of Occurrence

The probability of events having various Average Recurrence Intervals occurring or being exceeded within a 50 year planning period can be predicted using established mathematical techniques, thereby quantifying the risk associated with each such event.

Table 4.1 presents these various probabilities of occurrence for cyclones of varying intensities (ie. for various ARI).

When preparing designs for the implementation of the preferred erosion management strategy, it will be necessary for Council to consider these probabilities and nominate an Average Recurrence Interval as the design standard. This then establishes the Design Event when implementing the Shoreline Erosion Management Plan.

Should an event occur that is more severe than the selected Design Event, then the strategies and engineering works implemented in accordance with this Shoreline Erosion Management Plan may be compromised and coastal infrastructure could be damaged or destroyed as a consequence. The selection of an appropriate Design Event is therefore an important consideration.

ARI of the event	probability of being equalled or exceeded	probability of occurring in any single year
10 years	99.3%	9.5%
20 years	91.8%	4.9%
50 years	63.2%	2.0%
100 years	39.3%	1.0%
200 years	22.1%	0.5%
500 years	9.5%	0.2%
1,000 years	4.9%	0.1%

Table 4.1 : Probability of Occurrence of ARI events in a 50 year Period

4.1.4 Long-term Erosion

As discussed previously, the southern shores of Rowes Bay are experiencing long-term erosion as a result of inadequate supply of sand from around Kissing Point.

In recent years a number of beach renourishment campaigns have been undertaken on the affected shoreline. Such remedial works have been necessary along the shoreline extending from the Soroptimist Park foreshore (ie. south of Mundy Creek entrance), northwards to approximately transect TOWN32 - which is some 200 metres north of Beach Access N7.

This section of foreshore is expected to continue to experience long-term erosion - requiring foreshore management to address adverse effects. The predicted recession rate of 0.55 m/yr (including climate change effects) over the 50 year planning period suggests that if left unchecked, the foreshore south of TOWN32 will recede an additional 27.5m (say 28m) inland.

Furthermore, the effects of long-term erosion at Rowes Bay is expected to extend northwards at a rate of around 11 m/yr which over the same planning period indicates that erosion influences will reach some 550m further north than at present - ie. up to transect line TOWN33, some 250m south of Beach Access N8.

The Rowes Bay / Pallarenda shoreline between that location and Cape Pallarenda is not expected to experience any significant long-term erosion since the supply of sand to these foreshores will be sufficient to match the local longshore transport rates that are moving sand onwards. The sand supplying this northern section of shoreline would be derived from the eroding foreshore south of TOWN33.

4.1.5 Short-term Erosion

Sections 3.2.5 and 3.4 provided discussions on cyclone induced erosion under present day and future climate change scenarios respectively. This resulted in predicted shoreline recessions that are summarised in the preceding Figure 3.14 for a range of cyclone ARI

4.1.6 Overall Erosion Threat

When combining long-term, short-term and climate change influences along the Rowes Bay / Pallarenda foreshore for a planning period of 50 years, the following potential shoreline erosion emerge:

Location	TOWN transect	Cyclone ARI				
		50yr	100yr	200yr	500yr	1000yr
Cape Pallarenda	41	6	6	6	6	6
	40	8	9	9	10	13
	39	10	10	11	15	21
	38	10	12	16	18	23
Three Mile Creek	37	15	23	31	33	36
	36	13	17	21	25	29
	35	9	15	18	21	24
	34	13	17	23	31	34
	33	48	51	53	60	63
	32	48	54	56	62	71
	31	43	49	51	58	66
Mundy Creek	30	46	49	51	53	64
Soroptimist Park	29	53	54	57	64	77

Table 4.2 : Predicted Foreshore Recession *(metres)* for a 50 Year Planning Period - includes climate change

As can be seen, erosion is anticipated to be most acute south of transect TOWN33, which is near Beach Access N8.

The distances are measured inland from the toe of the frontal dune where such a feature is evident; otherwise it is measured from a line defining the seaward limit of terrestrial vegetation along the shoreline.

As discussed previously (in Section 3.2.5.2), the shoreline recessions in Table 4.2 and Figure 4.1 need to be considered with some caution for events more severe than 200 year ARI. During such storms, there is considerable overwash of the foreshore.

This phenomenon occurs when the storm tide builds during the cyclone to be so great that waves no longer dissipate their energy directly on the beach slope or on the dunes - ocean water levels are such that the waves wash over the beach slope since it is substantially submerged. The numerical modelling of erosion mechanisms during such complex overwash processes is unfortunately not particularly reliable at this point in time.

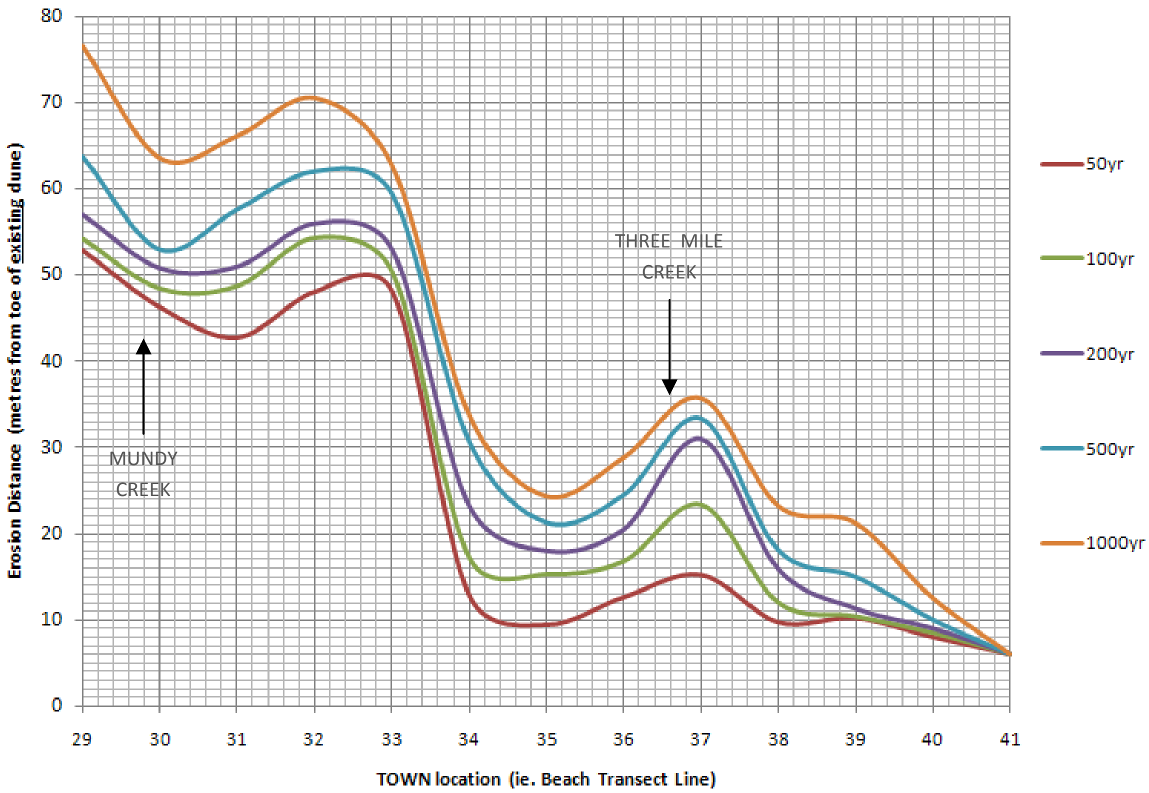

Figure 4.1 : Erosion in the 50 Year Planning Period (includes climate change)

4.2 Threatened Assets

The predicted shoreline recessions under a range of storm conditions over the 50 year planning period have been plotted on recent aerial photographs. These are presented in Appendix D and include the effects of future climate change at the end of the planning period.

4.2.1 South of Mundy Creek

It is evident from the predicted shoreline recession plots that Soroptimist Park will be vulnerable to erosion even for 50 year ARI events. For cyclone events greater than approximately 100 year ARI, Heatleys Parade itself is expected to be significantly eroded.

4.2.2 Mundy Creek to Three Mile Creek

The erosion threat is most severe immediately north of Mundy Creek. In particular the foreshore north of Eclipse Street is expected to be significantly eroded - with cyclones of just 50 year ARI predicted to completely remove Cape Pallarenda Road over a length of some 700m. Erosion by cyclones of around 1,00 year ARI would threaten the oceanside infrastructure of the RSL Retirement Villas near Havana Street.

North of Beach Access N8 the existing erosion buffers are adequate to protect Cape Pallarenda Road for severe events up to 1,000 year ARI during the entire 50 year planning period.

4.2.3 Three Mile Creek to Cape Pallarenda

The erosion threat is most severe immediately north of the Three Mile Creek entrance. The meandering nature of the creek as it approaches the entrance is such that there is a narrow sand spit between the waters of Cleveland Bay and the lower reaches of the creek.

The shoreline recession plots indicate that this spit may in fact be breached by storms greater than 100 year ARI. In such circumstances it is likely that a new entrance would be created almost directly east of the road bridge over the creek. Infrastructure such as the paths and power lines located on this spit would be lost. Indeed the power lines immediately north of the Three Mile Creek entrance would be lost for events of approximately 50 year to 100 year ARI.

Further north towards the suburb of Pallarenda it is evident that the existing erosion buffers are able to accommodate events of 1,000 year ARI. The exception to this is the foreshore infrastructure associated with the swimming enclosure located between Shelley and Marlow Streets.

The toilet and change rooms are located immediately behind the beach slope - and are at risk of damage/loss by erosion for events of around 50 year ARI or greater towards the end of the planning period. The public boat ramp and its associated hardstand areas are similarly at risk of damage or loss during 50 year ARI events.

5 SHORELINE EROSION MANAGEMENT OPTIONS

5.1 Guiding Principles

When preparing a Shoreline Erosion Management Plan there are a number of generic solutions and strategies which can be considered for erosion mitigation of shorelines. The *State Coastal Management Plan* provides a logically sound and robust approach to the problem by requiring all planning for Queensland's coastal areas to address potential impacts through the following hierarchy of approaches[5]:

- avoid — focus on locating new development in areas that are not vulnerable to the impacts of coastal processes and future climate change;
- planned retreat — focus on systematic abandonment of land, ecosystems and structures in vulnerable areas;
- accommodate — focus on continued occupation of near-coastal areas but with adjustments such as altered building design; and
- protect — focus on the defence of vulnerable areas, population centres, economic activities and coastal resources.

5.2 Coastal Defence Line

When considering foreshore protection measures, it is necessary to define a Coastal Defence Line which represents the landward limit of acceptable erosion. In other words, it forms the landward boundary of any erosion buffers to protect the Rowes Bay / Pallarenda shoreline, or alternatively the alignment of any protection structure such as a seawall. Property and infrastructure landward of the Coastal Defence Line remains protected throughout the 50 year planning period, whereas foreshore areas seaward of the line lie within the active beach system (ie. within the erosion buffers).

Defining the position of the Coastal Defence Line therefore entails consideration by Council as to what assets are to be defended. Options could include a Coastal Defence Line on an alignment alongside the seaward edge of Cape Pallarenda Road, or along the seaward edge of the coastal pathway, or even along the toe of the existing dune. For example, this later option is likely to be the case for a Coastal Defence Line along the ocean frontage of Soroptimist Park, and to preserve the iconic trees along the southern shores of Rowes Bay.

5.3 Generic Erosion Management Options

In essence, erosion mitigation options can be considered as "soft" non-structural solutions, or "hard" structural solutions.

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[5] Required under the current State Coastal Planning Policy 2.2.1 (Adaptation to climate change).

Soft (or non-structural) solutions would typically include:

- Do nothing - allowing coastal processes to take their natural course while accepting the resulting losses;
- Avoiding development - by implementing regulatory controls with regard to building in undeveloped areas;
- Planned retreat - removing the erosion threat by relocating existing development away from the vulnerable area;
- Beach nourishment - rehabilitate eroding foreshores by direct placement of sand onto the beach, thereby providing an adequate erosion buffer;
- Beach scrapping - by using earthmoving plant and equipment to mechanically relocate sand from the inter-tidal zone or nearshore sandbanks into the upper beach or dune, thereby improving erosion buffers on the beach;
- Channel relocation - relocate dynamic river or creek entrances that may be contributing to shoreline erosion so that they have a lesser impact.

Hard (or structural) solutions that can be utilised to mitigate the threat of erosion include:

- Seawalls - which act as physical barriers to prevent shoreline recession;
- Seawalls with beach nourishment - where the seawall defines the inland extent of erosion, whilst sand is intermittently placed in front of the wall for improved beach amenity;
- Groynes / offshore breakwaters - used to inhibit the natural longshore movement of sand, thereby retaining sand on the eroding foreshore for longer periods;
- Groynes / offshore breakwaters with beach nourishment - where the structure assists in maintaining sand on the beach, and beach nourishment reduces the downdrift erosion caused by the groyne's interruption to longshore sand supply.

Given the variability of local coastal processes along the Rowes Bay / Pallarenda shoreline, there is a possibility that the optimum management strategy may include "soft" or "hard" solutions, or a combination of both.

An appraisal of each generic erosion management option and its potential application to the Rowes Bay / Pallarenda shoreline is set out below. This is followed by a summary of the advantages and disadvantages of each.

5.3.1 Non-structural Management Options

5.3.1.1 Do nothing

A "do nothing" strategy of coastal management can be appropriate where foreshore land is undeveloped, or assets and property are of only limited value. It is well suited to situations where available erosion buffers are sufficient to accommodate long-term and short-term erosion over the nominated planning period. However on foreshores where existing development and infrastructure is threatened by erosion, the high social and financial costs associated with their loss are generally unacceptable.

Indeed it is the threat of such loss along the southern shores of Rowes Bay that has necessitated intervention in recent years - by way of Council's beach nourishment campaigns and emergency foreshore stabilisation works.

As stated previously, it is the foreshore south of approximately Beach Access N8 which is threatened by erosion over a 50 year planning period. A Do Nothing strategy on this shoreline would potentially lead to the loss of some 1200m of the Cape Pallarenda Road north of Mundy Creek; and a significant loss of the foreshore up to Beach Access N8, including Soroptimist Park south of the creek.

This scenario would therefore lead to considerable social trauma and substantial economic loss. Consequently it is not a desirable management option for this erosion prone foreshore.

However north of Beach Access N8, the available buffer zone remains sufficient to accommodate erosion and climate change influences over the next 50 years. Consequently a Do Nothing strategy has potential application on these northern shores, since any action can be deferred until such time as the slowly diminishing erosion buffers can no longer adequately accommodate the potential threat of cyclone erosion events.

5.3.1.2 Avoid development

Along sections of the foreshore that remain substantially undeveloped, a key objective would be to prevent an erosion problem from occurring by allowing the natural beach processes of erosion and accretion to occur unimpeded. This would also preserve the natural ecosystem, amenity and character of the beach.

There is scope to implement this option along the foreshore north of Beach Access N8 since the foreshore prone to erosion influences over the next 50 years primarily constitutes undeveloped land - which in some locations includes public parklands.

The implementation of such a strategy would require appropriate planning controls to prevent future development and infrastructure occurring in these areas. However such instruments are already in place, through the current designation of these northern areas of the Rowes Bay / Pallarenda foreshore as being within a 110m wide Erosion Prone Area (refer discussions in Section 4.1.1). Presently any foreshore protection works or re-zoning applications within designated Erosion Prone Areas trigger an approval requirement from the Department of Environment and Resource Management.

5.3.1.3 Planned retreat

The intent of a planned retreat strategy is to relocate existing development outside of the area considered vulnerable to erosion, allowing this previously developed land to function as a future erosion buffer. This approach accommodates natural beach processes without attempting to influence them.

Virtually all of the threatened foreshore along the Rowes Bay / Pallarenda coastline constitutes public property - the exception being private property in the vicinity of Palm Street and Havana Street which is threatened towards the end of the 50 year planning period by cyclones of 1,000 year ARI or greater.

A planned retreat strategy would require:

- inland relocation of a significant length of Heatleys Parade at Soroptimist Park;
- relocating approximately 700 metres of the Cape Pallarenda Road alignment between Mundy Creek and Beach Access N8; and
- the construction a new road bridge across Mundy Creek on the new road alignment.

The altered road and bridge alignments would require either the resumption of private property within the developed residential suburb of Rowes Bay, or the construction of new road and associated drainage works through low-lying land between the Belgian Gardens Cemetery and the existing Rowes Bay residential area.

The social and financial costs involved in such relocations and any associated resumption of land would be considerable given current property values in the suburbs of Rowes Bay and Belgian Gardens. Strong adverse community response to this strategy is very likely. This, along with the very high cost, is a considerable disadvantage of this option.

However where there are only small scale and non-essential Council assets being threatened by erosion, planned relocation may be the most viable and cost effective option.

For example, the toilets and change rooms alongside the swimming enclosure at Pallarenda could possibly be relocated within the adjoining foreshore parkland under a planned retreat strategy.

Given that the foreshore north of approximately Beach Access N8 is not expected to experience long-term erosion over a 50 year planning period, any planned retreat along this northern length of shoreline would be primarily aimed at accommodating short-term erosion associated with severe cyclones and climate change.

Consequently a more appropriate implementation of a retreat strategy in this area would be to consider the cost of any relocation of non-essential infrastructure given the probability/risk that such severe cyclone events might occur within the planning period, in conjunction with monitoring foreshore response as climate change influences unfold.

As stated, such retreat would not affect any private property along the Pallarenda foreshore.

Another aspect of planned retreat which could be implemented relates to existing power and telecommunications infrastructure that is located within erosion prone areas. For example power lines immediately north of Three Mile Creek are vulnerable to erosion associated with cyclone events of approximately 50 year ARI or greater.

During such events it is conceivable that power poles would be undermined and swept away, requiring rectification works to subsequently reinstate the electrical power infrastructure servicing the Pallarenda community further north. However such emergency works could be averted if a strategy of retreat was able to be implemented by power supply agencies as part of planned relocation works.

5.3.1.4 Beach nourishment

In recent years Townsville City Council has undertaken a number of successful beach nourishment campaigns on the eroding shoreline north of Mundy Creek.

A strategy of beach nourishment entails the placement of sand directly onto the beach - either by using conventional earthmoving techniques or by pumping - so as to restore an adequate buffer width on the foreshore. The advantages of beach nourishment as an erosion management strategy are that it has no adverse impacts on adjacent foreshores, and it maintains the beach amenity.

It is generally regarded as being the most desirable solution to erosion problems on foreshores where a suitable and economic source of sand is available.

A frequent community criticism of beach nourishment projects is that it does not provide a permanent solution to persistent long-term erosion problems since it requires an on-going commitment to further renourishment. Nevertheless most other forms of direct intervention (even those of a “hard” structural nature) also require maintenance and a commitment to future costs. When all impacts and costs are taken into account, the requirement for future nourishment campaigns typically does not detract from the cost/benefit advantage of a beach nourishment strategy.

However the ability to immediately replace sand lost in a storm so as to provide continual protection by an adequate buffer is often a challenging issue under this strategy. This is particularly the case given that there can be several storms or cyclones in any one season; and means that sand may need to be placed on the beach more than once in any cyclone season so as to be completely effective.

Sand used for nourishment is typically sourced from outside of the active beach system to offset any possibility that the benefit to the nourished foreshore is achieved at the expense of beach erosion elsewhere. This places a constraint on prompt restoration of buffers depleted by storm/cyclone events if such sources are not readily to hand.

The requirements for an effective beach nourishment strategy are determined by the local sediment transport regime. The objectives of such a strategy are to establish and maintain adequate erosion buffers. Local cross-shore sand transport processes dictate the overall volume of sand required in the buffer so as to accommodate a particular cyclone ARI. On the other hand, longshore transport processes determine the average rate at which sand needs to be added periodically to the buffers so that they are maintained in the long-term.

The buffer characteristics of sand volume and width are basically the volumes and widths that would be removed by short-term erosion processes. These characteristics were presented earlier for present-day climate conditions in Figure 3.10 and Figure 3.11.

An appropriate beach nourishment strategy would be to initially create the buffers required for present-day conditions and to then continually monitor foreshore performance - increasing buffer volumes/widths as actual climate change conditions manifest themselves.

The risk assessment applied to the Rowes Bay / Pallarenda shoreline (refer to the findings in Section 4.2) indicate that the foreshore north of approximately Beach Access N8 does not require additional buffer widths - beach fluctuations do not threaten essential community infrastructure or compromise environmental values.

Therefore a Beach Nourishment strategy would really only be applied to the shoreline south of approximately Beach Access N8.

As discussed in Section 5.2, it is necessary to define a Coastal Defence Line which under a Beach Nourishment strategy represents the landward limit of acceptable beach fluctuations. In other words, it forms the landward boundary of the sand buffer which is to protect the Rowes Bay / Pallarenda shoreline. Property and infrastructure landward of the Coastal Defence Line will remain protected throughout the 50 year planning period, whereas foreshore areas seawards of the line fall within the dynamic erosion buffer.

Clearly such determinations will affect the volume of sand that needs to be initially imported to create the required buffer widths. For example, if the line was to lie immediately alongside the Cape Pallarenda Road, then much of the existing foreshore between the road and the beach can be considered as being part of the required buffer. This would need much less sand to be placed than an option that had the line along the toe of the existing dune, which would then require importing a greater volume of sand to effectively create a completely new buffer area.

Reference to discussions in Section 3.2.4 indicates that the average net longshore sand transport rates along this section of foreshore are typically between 3,300 m^3/year and 4,000 m^3/year. Since there is negligible supply of sand from around Kissing Point to meet this demand, renourishment of the shoreline at these annual rates would be required to maintain the necessary erosion buffers.

5.3.1.5 Beach scrapping

The concept of beach scrapping entails moving sand from lower levels of the cross-shore beach profile (typically from tidal flats immediately in front of a beach) up onto the beach slope or into the dune system. In essence it is simply redistributing sand that is already within the active beach profile and as such does not provide a net long-term benefit - particularly on foreshores that are experiencing long-term recession, such as those on the southern shores of Rowes Bay.

Beach scrapping can be beneficial in reinstating or reshaping the dune following a storm event, thereby assisting and accelerating natural processes that would otherwise rebuild the eroded dune system over much longer timeframes. However since scrapping lowers the seabed in front of the beach, it allows slightly greater wave energy to reach shore, offsetting to some degree the benefits achieved by reinforcing the beach face and/or dune.

Intensive scrapping activities would need to be undertaken on the nearshore intertidal flats of Rose Bay on a regular basis - to ensure adequate sand was placed to create and maintain the necessary erosion buffers. However the large volumes of sand that need to be initially placed by scrapping to form the buffers are unlikely to be economically viable or physically achievable within reasonable timeframes. Adverse impacts on intertidal flora and fauna communities are likely to be considerable under such works.

Nevertheless there is potentially a viable application for minor beach scrapping on the sand shoal at the Mundy Creek entrance to supplement or enhance other more appropriate primary strategies in this area.

5.3.1.6 Channel relocation

In some cases foreshore erosion can be attributed in varying degrees to the dynamic nature of river or creek entrances. The sandbanks and shoals at the mouth of these natural waterways can affect tidal currents and wave patterns which can have an adverse effect on nearby shorelines. In some of those instances the problem can be alleviated somewhat by the planned relocation of the entrance or main channel flow.

Mundy Creek and Three Mile Creek are the main waterways discharging across the Rowes Bay / Pallarenda foreshore. Whilst both entrances have an influence on local coastal processes, neither contributes significantly to local erosion problems over the 50 year planning period. Consequently there is no merit in considering any relocation of these creek entrances.

5.3.2 Structural Management Options

5.3.2.1 Seawalls

Seawalls are commonly used to provide a physical barrier to continuing shoreline recession. Properly designed and constructed seawalls can be very effective in protecting foreshore assets by stopping any further recession. Consequently if such a strategy was to be implemented along the Rowes Bay / Pallarenda foreshore, it would be constructed along the alignment of a nominated Coastal Defence Line.

However seawalls significantly interfere with natural beach processes by separating the active beach from sand reserves stored in beach ridges and dunes. In other words, seawalls can protect property behind the wall, but they do not prevent in any way the erosion processes continuing on the beach in front of them. In fact they very often exacerbate and accelerate the erosion.

Typically the effect of seawall construction on actively eroding shores is for the level of the beach in front of it to steadily lower - until the beach reaches a new equilibrium profile.

This lowering is primarily caused by wave action washing against the wall causing a high degree of turbulence in front of the structure - which scours the beach material. Wave energy reflected from the seawall also contributes to these scour and beach lowering processes. In many cases this lowering continues until the level of the beach is below prevailing tide levels, in which case the ocean simply washes against the face of the seawall and there is no beach for part (or possibly for all) of the tide cycle. The amenity of the beach and foreshore is therefore significantly degraded in order for the seawall to protect the area behind it.

This lowering of the sand level in front of seawalls can also present problems for the overall stability of the structure. Unless appropriate foundation and toe arrangements are constructed, the seawall can fail by undermining. Even if only damaged, it is extremely difficult and very expensive to repair existing seawalls that have been damaged by undermining. Indeed frequently the most cost effective solution is to demolish the structure and rebuild it with deeper and more robust foundations.

Such adverse effects on beach amenity and structural collapse occurred along the seawall frontage of The Strand foreshore prior to its rehabilitation by beach nourishment in the late 1990's. That rehabilitation work was triggered in part by the undermining collapse of the seawall during storm conditions that were historically quite mild.

Another typically adverse impact of seawalls is that the original erosion problem that they were meant to solve is simply relocated further along the shore. Natural beach processes can no longer access the sand reserves in the upper part of the active beach that are behind the seawall. Consequently this sand cannot be moved downdrift by longshore sand transport processes to replenish the sand that these same processes are moving along the shoreline beyond the end of the seawall.

The deficit in sand supply to these downdrift sections initiates greater erosion, ultimately requiring extension of the seawall along the entire downdrift shoreline in order to protect it.

Seawalls have an effect on the visual amenity of a shoreline, and this can be quite adverse if the wall is high - or if it becomes so as a consequence of natural beach lowering in front of it. Such walls also inhibit easy public access across the foreshore onto the beach. Typically access stairways or ramps need to be provided on seawalls to ensure the safety of beach access by pedestrians.

Along urban foreshores, seawalls can offer sheltered habitats for vermin such as feral cats and rodents. This can adversely affect natural coastal flora and fauna values.

Appropriately designed and constructed seawalls are relatively expensive and they do not always compare favourably with the cost of other alternatives. However many seawalls constructed in Queensland have been built of rock during or immediately following severe sea conditions and significant cyclone erosion events. Under such circumstances appropriate design and construction of these walls may not have been implemented. Consequently most of the rock walls constructed in this manner require significant maintenance to prevent structural failure and the re-establishment of the original erosion problem.

Despite their disadvantages, rock seawalls are probably the most commonly used method in Queensland for protecting foreshore assets against the threat of erosion. This can probably be attributed to their versatility. They are relatively easy to construct using conventional earthmoving plant and equipment; and this is often accomplished by simply dumping rock on a prepared slope rather than applying more appropriate construction practises to create a robust structure.

Such adhoc methods can be used to not only protect long sections of foreshore, but also individual private properties. The substantial and solid appearance of rock walls can provide owners of foreshore assets with a sense of security - which unfortunately is frequently misguided given the often inadequate design and construction of these structures. Their subsequent failure or damage can not only lead to the re-establishment of the original erosion problem, but the scattering of removed rocks can adversely affect foreshore use and visual amenity.

The rock placed on the foreshore immediately north of the Three Mile Creek entrance is an example of an ineffectual adhoc seawall.

If a rock seawall was to be constructed on a Coastal Defence Line along the at-risk section of the Rowes Bay / Pallarenda foreshore, it would need to be constructed of two layers of approximately 3tonne rocks overlying two layers of smaller rocks of around 0.25 tonne each. This armoured slope should be no steeper than 1 vertical to 1.5 horizontal; and founded no higher than approximately RL-2m AHD.

The rock seawall could initially be constructed along the southern shores of Rowes Bay which are immediately threatened by erosion. However the accelerated erosion processes would soon require the wall to be extended further north. The location of the Coastal Defence Line with respect to the active beach would determine when this extension would be required. However eventually it will be necessary to construct the seawall along the entire foreshore from Soroptimist Park to at least Beach Access N8, or possibly further.

This 2.3km long seawall would require some 90,000 to 100,000 tonnes of armour rock and cost more than $7million to build.

5.3.2.2 Seawalls with beach nourishment

To mitigate some of the disadvantages of seawalls, beach nourishment can also be undertaken to create a beach amenity in front of the structure. This sand placement also provides a reservoir of sand to feed the downdrift foreshore which would otherwise be starved of sand by the wall.

The seawall structure still serves as the primary defence against erosion so must be designed and constructed accordingly. The amount of sand initially placed as beach nourishment will depend on both where the Coastal Defence Line is located within the active beach profile and the extent of the amenity to be provided.

For example, if the Coastal Defence Line was located some distance inland (say, along the seaward kerb of Cape Pallarenda Road) then the existing foreshore between the seawall and the beach could be considered as the beach nourishment. Nevertheless, regular sand placement would be required to maintain the beach amenity, as well as prevent migration of the initial erosion problem northward along the shore. This intermittent renourishment would need to at least match the average net longshore sand transport rate of around 4,000 m^3 /yr.

Assuming that no initial sand placement is required (due to an inland Coastal Defence Line), then costs would therefore be the approximately $7million to construct the wall and approximately 4,000 m^3 annually (at present day rates) for renourishing the beach in front of it.

5.3.2.3 Groynes

The longshore transport of sand on an eroding shoreline can be impeded by constructing groynes across the active beach. A groyne functions as a physical barrier by intercepting sand moving along the shore. Sand is gradually trapped against the updrift side of the structure, resulting in a wider beach on this “supply-side” of the structure. However the downdrift beach is deprived of the sand trapped by the groyne and therefore it erodes.

This process of updrift entrapment and downdrift erosion continues until such time as sand has accumulated on the updrift side of the groyne to the extent that it starts to feed around its seaward end. Sand supply is then reinstated to the downdrift foreshore; however this then simply maintains the shoreline on its eroded alignment.

Groynes cannot prevent the significant cross-shore erosion that typically occurs during cyclones. Nevertheless they have an indirect effect in that by having trapped sand on their updrift side, they have created a wider beach and an enhanced erosion buffer on that section of foreshore. However on the depleted downdrift side, the foreshore is more susceptible to cyclone erosion due to the depleted beach/buffer width.

Consequently the construction of a groyne does not in itself resolve the erosion problem, but merely transfers it further along the beach.

The same effect of impeding the longshore transport of sand by a groyne can also be achieved by a structure built offshore of the beach, but not connected to it. Such structures a called *offshore breakwaters* and function by casting a "wave shadow" onto the shoreline in its lee.

The reduced wave energy landward of the offshore breakwater means that the ability of the waves to keep moving sand along the shoreline is reduced. Consequently the supply of sand from the updrift shoreline is greater than that at which it can be moved out of the wave shadow. Sand therefore accumulates in the lee of the structure. However, as is the case with a conventional groyne, the shoreline downdrift of the wave shadow is deprived of sand and therefore erodes.

This wave shadow effect occurs naturally on a much larger scale in the vicinity of Three Mile Creek entrance as a consequence of Virago Shoal - which acts much like an offshore breakwater. However local processes on the foreshore north of Virago Shoal are such that this accumulation does not have an adverse effect.

5.3.2.4 Groynes with beach nourishment

The downdrift erosion caused by groynes can be compensated to a large extent by incorporating beach nourishment into the strategy. This is achieved by placing sand against the updrift side of the groyne immediately after it is constructed so that it is "filled". Any additional sand moved against this side of the structure by natural processes can therefore be carried around the end of the groyne to supply the downdrift shoreline.

The length of updrift shoreline that benefits from such groyne and beach nourishment is somewhat limited. Therefore if long sections of shoreline require protection then a number of groynes can be built at intervals along the shoreline. This is typically called a *groyne field*.

The length and spacing of such groynes depend to a large degree on the local longshore sand transport regime; and in particular the naturally preferred stable orientation of the beach. Their length and spacing are also somewhat dependent upon each other. Under any given longshore transport regime, it is possible to achieve a similar degree of protection by using short closely spaced groynes, or longer more widely spaced structures. Such issues can only be resolved by further detailed study and design.

Nevertheless such intervention will have a significant impact on the visual amenity of the Rowes Bay / Pallarenda foreshore. Structures such as groynes that cross the shore can also have an adverse impact on beach use since walking along the beach will entail crossing over the groynes. This experience is also potentially marred by the different beach levels on the updrift and downdrift sides.

It is for these reasons alone that a management strategy that entails a groyne field is unlikely to have appeal.

5.3.3 Advantages and Disadvantages of Generic Options

As discussed above, there are a number of generic erosion management strategies which could be implemented under this Shoreline Erosion Management Plan. Some options are better suited than others. To assist in evaluating these in the context of the Rowes Bay / Pallarenda coastal reach, a summary of the advantages and disadvantages of the various strategies has been prepared in Table 5.1 (for non-structural options) and Table 5.2 (for structural options).

5.4 Assessment of Shoreline Management Options

When considering appropriate erosion management options along the Rowes Bay / Pallarenda foreshore it is evident that the shoreline can be considered in three coastal precincts, namely

- Southern Reach : south of Mundy Creek entrance;
- Central Reach : from Mundy Creek to Three Mile Creek; and
- Northern Reach : north of Three Mile Creek entrance.

This separation into coastal reaches does not imply that the coastal processes within each are in any way compartmentalised. They are by no means isolated or discrete sections of shoreline, since the processes affecting each have considerable influence on the others. However this partitioning lends itself to the development of viable erosion management strategies that integrate well over the entire Rowes Bay / Pallarenda coastal reach. Indeed as will be seen, there is scope to further refine the partitioning within each precinct due to various intensities of existing development and infrastructure close to the beach.

An assessment of potential management strategies for each of these three coastal precincts is presented in the following sections. In order to rate the various options, a score is intuitively assigned to each option using a numerical scale ranging from 1 (exceptionally poor) to 10 (excellent). Therefore the higher the score, the more appropriate or desirable is the option's outcome.

Erosion Management Option	Advantages	Disadvantages
Do Nothing	Maintains existing undeveloped foreshores in their natural state.	Considerable loss of essential community infrastructure, including recreational reserves, stormwater drainage system, telecommunications and power distribution networks.
	Coastal processes proceed unimpeded by erosion mitigation works.	Loss of approximately 1.2km of Cape Pallarenda Road and substantial damage to Heatleys Parade (at Soroptimist Park).
	Could be applied to existing foreshore north of approximately Beach Access N8.	Significant loss of land in Soroptimist Park.
		Significant adverse impact on visual amenity.
		Expected erosion of foreshore will result in considerable loss of important terrestrial values.
		Will cause significant social trauma.
Avoid Development	Maintains existing undeveloped foreshores in their natural state.	Does not resolve current erosion problems at the southern end of Rowes Bay where existing development and assets are located within foreshore areas prone to erosion.
	Coastal processes proceed unimpeded by erosion mitigation works.	
	Planning controls to achieve outcomes are substantially in place.	
Planned Retreat	Maintains existing undeveloped foreshores in their natural state.	Does not ensure that existing terrestrial values are protected. Loss of existing foreshore flora and fauna habitats.
	Coastal processes proceed unimpeded by erosion mitigation works.	Requires relocation of Cape Pallarenda Road along approximately 1,200 metres in suburb of Rowes Bay.
	Can be implemented with limited costs in areas north of around Beach Access N8.	Requires relocation of Heatleys Parade near Soroptimist Park.
	Maintains existing beach amenity and public access.	Requires new road bridge over Mundy Creek.
	Minimal disturbance to visual amenity.	Substantial social and financial costs to implement on the foreshores under most imediate threa (ie. on ocean frontage of Rowes Bay suburb).
Beach Nourishment	Coastal processes can proceed unhindered, with no adverse impacts on adjacent foreshores.	Requires on-going commitment to annual sand re-nourishment to recharge erosion buffers.
	Maintains existing beach amenity and public access.	Cost of initial sand placement and renourishment can be medium/high if appropriate sand sources are a long way away.
	Minimal disturbance to visual amenity.	
	Cost of initial sand placement and renourishment can be low if appropriate sand sources are close-by.	
	Successfully and cost-effectively implemented previously on the southern shores of Rowes Bay.	
	A flexible solution that can be tailored to suit the currently uncertain effects of future climate change as they actually emerge.	
Beach Scrapping	Can supplement and enhance other strategies, particularly in the vicinity of Mundy Creek entrance.	Does not resolve long-term erosion problems at southern end of Rowes Bay where existing assets are located within foreshore areas prone to erosion.
		Unlikely to achieve the volumes of sand required to create and maintain buffers without significant and intensive earthmoving activity on the intertidal flats.
		Adverse impacts likely on intertidal flora and fauna.
		Adverse impacts on visual amenity during scrapping activities.
		Adverse impact on beach amenity during scrapping activities.
Channel Relocation	None	Does not resolve long-term erosion problems at southern end of Rowes Bay where existing assets are located within foreshore areas prone to erosion.

Table 5.1 : Non-structural Erosion Management Options

Erosion Management Option	Advantages	Disadvantages
Seawalls	Provides robust physical barrier to halt shoreline recession.	High construction cost. Adverse affect on local coastal processes - causing loss of beach in front of the structure. Does not solve the existing erosion problem at the southern end of Rowes Bay, it simply transfers the problem further north. Will need to continually extend the seawall along the shore to accommodate the ongoing northward migration of the erosion. To accomodate expected erosion influences over the entire planning period, it will be necessary to extend the seawall up to approximately Beach Access N8. Significant impact on visual amenity. Adversely affects beach amenity by inhibiting easy access across the foreshore onto the beach. May require stairways/ramps to provide safe access onto the beach.
Seawalls and Beach Nourishment	Provides robust physical barrier to halt shoreline recession. Under most ambient conditions, coastal processes proceed unimpeded by erosion mitigation works. Maintains existing beach amenity and public access. Minimal disturbance to visual amenity. A flexible solution that can be tailored to suit the currently uncertain effects of future climate change as they actually emerge.	High construction cost. Requires ongoing financial and works commitment to future sand placements in order to assure beach amenity.
Groynes	Retains sand on presently eroding foreshores for longer periods.	Medium / High construction cost. Does not solve the existing erosion problem at the southern end of Rowes Bay, it simply transfers the problem further north. Will need to continually extend the number of groynes along the shore to accommodate the ongoing northward migration of the erosion. To accomodate expected erosion influences over the entire planning period, it will be necessary to construct several groynes at locations up to approximately Beach Access N8. Significant impact on visual amenity. Adversely affects beach amenity by inhibiting access along the shore.
Groynes and Beach Nourishment	Retains sand on presently eroding foreshores.	High construction cost. Requires ongoing financial and works commitment to future sand placements in order to assure beach amenity.

Table 5.2 : Structural Erosion Management Options

It is acknowledged that there is a degree of subjectivity in such an approach, and that even amongst experienced coastal management practitioners there is likely to be some differing opinions as to overall and relative scores. As will be seen, preferred strategies nevertheless strongly emerge from this process.

Whilst the strategy of Avoid Development is offered as a generic solution, it is really not a viable application to the Rowes Bay / Pallarenda shoreline on its own. It cannot solve erosion problems on sections of foreshore that are already developed or that have infrastructure located in areas prone to erosion. However it can be used to supplement other management options that can be applied to undeveloped foreshores. For example, under Do Nothing or Planned Retreat scenarios the future integrity of these solutions can be secured by a supplementary strategy of Avoid Development within the erosion buffers that such strategies provide.

This is relatively easy to implement given that the width of the Rowes Bay / Pallarenda foreshore at risk of erosion over a 50 year planning period is already nominated under the State Coastal Plan as being within a designated Erosion Prone Area. Future rezoning or development of the foreshore covered by Do Nothing and Planned Retreat options can be controlled by application of appropriate coastal management principles that are already in place under the State Plan.

5.4.1 Southern Reach

The southern reach of the Rowes Bay / Pallarenda shoreline nominated for inclusion in this Shoreline Erosion Management Plan extends from the seaward tip of Kissing Point to the Mundy Creek entrance. As shown in Figure 5.1, this can be further subdivided into two smaller precincts:

- along the northern flank of Kissing Point; and
- along the ocean frontage of Soroptimist Park.

5.4.1.1 Northern flank of Kissing Point

This section of the shoreline is adequately protected from erosion by an existing rock armoured seawall. Inspections of this structure indicate that it is of apparently sound structural integrity and is expected to fulfil its function of mitigating erosion - both in the short-term and long-term.

Consequently it is evident that a Do Nothing strategy is appropriate as it represents the most cost effective erosion management strategy along this sub-reach.

Figure 5.1 : Southern Reach of Rowes Bay / Pallarenda Shoreline

5.4.1.2 Ocean frontage of Soroptimist Park

The ocean frontage of Soroptimist Park can be considered as being a "developed foreshore" since it consists of an intensely managed and highly utilised public park. The road pavement and associated drainage of Heatleys Parade is also included in the area prone to erosion and therefore requires protection.

Consequently whilst a Do Nothing strategy might have negligible direct cost, the indirect financial cost associated with the loss of this asset is considerable. Likewise the cost of a Planned Retreat strategy that requires property resumptions, along with the relocation of road and other infrastructure, would be considerable.

These and other options have been subjectively assessed in Table 5.3 from which it is evident that a Beach Nourishment strategy is the most effective.

Structural management options (such as a seawall or groynes - with/without supplementary beach nourishment) rate poorly. This is due to their adverse impacts on prevailing coastal processes and coastal values, along with their high financial costs. Other non-structural options such as Do Nothing and Planned Retreat would have adverse social impacts and significant indirect financial costs.

Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
	Generic Management Options								
Compliance with State Coastal Policy	7	NOT APLICABLE	10	8	4	2	5	2	5
Maintaining coastal processes	8		9	9	5	4	7	4	7
Maintenance of Marine Values	8		8	8	3	4	5	3	4
Maintenance of Terrestrial Values	4		7	8	8	5	5	6	6
Maintenance of Social Values	1		2	9	3	3	7	3	6
Visual amenity	4		6	9	4	2	6	2	4
Beach access and amenity	3		6	9	5	3	6	3	5
Initial financial cost (direct & indirect)	6		1	6	8	4	2	4	3
Ongoing financial cost (direct & indirect)	2		7	4	6	4	2	3	3
TOTAL SCORE	**43**		**56**	**70**	**46**	**31**	**45**	**30**	**43**

Table 5.3 : Option Assessment - Southern Reach

5.4.2 Central Reach

The central reach of the Rowes Bay / Pallarenda shoreline extends from the entrance of Mundy Creek northward to the Three Mile Creek entrance. For the purposes of developing an appropriate management strategy, the entrances of these waterways are included within this central coastal precinct. As shown in Figure 5.2, this central reach can be further subdivided into two smaller precincts:

- along the predominantly developed foreshore south of Beach Access N8; and
- along the predominantly undeveloped foreshore north of Beach Access N8.

5.4.2.1 South of Beach Access N8

It is along this section of shoreline that the erosion problem is most acute. Previous beach nourishment campaigns by Townsville City Council have been effective in addressing the threat posed to local infrastructure - particularly the potential damage or loss of Cape Pallarenda Road which is located quite close to the beach at its southern end.

However it is evident (from historical surveys in conjunction with the modelling of local coastal processes) that during periods of southerly transport, sand can be ingested into the Mundy Creek entrance and swept onto the creek's entrance shoals. This has the dual effect of inhibiting creek flows and removing a significant volume of sand from the active beach face. Consequently whilst being effective, previous beach nourishment activities have had to be supplemented with more frequent renourishment than might otherwise be the case.

Likewise, regular clearance of sand from the mouth of the creek has been necessary to ensure adequate discharge of flows and appropriate water quality in the creek's lower reaches.

Figure 5.2 : Central Reach of Rowes Bay / Pallarenda Shoreline

It is because of these shortcomings that the recently implemented strategy of Beach Nourishment has been reappraised by this Shoreline Erosion Management Plan. This and other options have been subjectively assessed in Table 5.4. It is evident that a Beach Nourishment strategy is nevertheless the most effective solution.

However to optimise the benefits of this preferred solution, it will be necessary to incorporate considerations of its influence on the entrance to Mundy Creek. These aspects are discussed in more detail in the following Section 6.

	Generic Management Options								
Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
Compliance with State Coastal Policy	7	NOT APLICABLE	10	8	4	2	5	2	5
Maintaining coastal processes	8		9	9	5	4	7	4	7
Maintenance of Marine Values	8		8	8	3	4	5	3	4
Maintenance of Terrestrial Values	2		3	8	8	5	5	6	6
Maintenance of Social Values	1		2	9	3	3	7	3	6
Visual amenity	2		4	9	4	2	6	2	4
Beach access and amenity	3		4	9	5	3	6	3	5
Initial financial cost (direct & indirect)	1		1	6	8	3	2	3	3
Ongoing financial cost (direct & indirect)	5		7	4	6	4	2	3	3
TOTAL SCORE	**37**		**48**	**70**	**46**	**30**	**45**	**29**	**43**

Table 5.4 : Option Assessment - Central Reach (South of Access N8)

Again structural management options (such as a seawall or groynes - with/without supplementary beach nourishment) rate poorly. As is the case for the developed shoreline south of Mundy Creek, this is due to adverse impacts on prevailing coastal processes and coastal values, along with their high financial costs.

Likewise other non-structural options such as Do Nothing and Planned Retreat would have adverse social impacts and significant indirect financial costs on this developed section of the Rowes Bay suburb.

5.4.2.2 North of Beach Access N8

The foreshore north of Beach Access N8 is primarily undeveloped and the alignment of Cape Pallarenda Road is set back from erosion influences that are expected to manifest themselves over a 50 year planning period. Consequently whilst there will be some short-term erosion and subsequent recovery along this section of foreshore in the next 50 years, there is no essential infrastructure at risk. Even the shoreline buffers to Robertson Park at the northern end of this sub-reach are sufficient to ensure that there is no adverse loss of park amenity or infrastructure.

The preferred strategy is therefore Do Nothing. Nevertheless, to ensure the future integrity of this solution, a supplementary strategy of Avoid Development is also warranted. As discussed, there is already means in place to implement this supplementary strategy under the State Coastal Plan.

5.4.3 Northern Reach

For the purposes of this Shoreline Erosion Management Plan, the northern reach of the Rowes Bay / Pallarenda shoreline extends from the entrance of Three Mile Creek northward to Cape Pallarenda. As shown in Figure 5.3, this can be further subdivided into two smaller precincts:

- along the predominantly developed foreshore south of Beach Access N22; and
- along the predominantly undeveloped foreshore north of Beach Access N22.

5.4.3.1 South of Beach Access N22

This sub-reach includes the ocean frontage of the Pallarenda suburb (which is primarily public parkland) as well as the infrastructure associated with:

- power lines immediately north of Three Mile Creek entrance;
- the swimming enclosure just to the north of Shelley Street;
- the public boat ramp and its hardstand/parking area; and
- the ring road and car-park facilities servicing Beach Access N20, N21 and N22.

Management options have been subjectively assessed in Table 5.5, from which it is evident that a Planned Retreat strategy is the most effective. It is important to appreciate that this strategy does not affect any private property or residences. The implications of such a solution to the above foreshore infrastructure require specific applications that are discussed in greater detail in Section 6.

	Generic Management Options								
Assessment Criteria	Do Nothing	Avoid Development	Planned Retreat	Beach Nourishment	Beach Scrapping	Seawalls	Seawalls & Nourishment	Groynes	Groynes & Nourishment
Compliance with State Coastal Policy	7	NOT APLICABLE	10	8	4	2	5	2	5
Maintaining coastal processes	8		9	9	5	4	7	4	7
Maintenance of Marine Values	8		9	8	3	4	5	3	4
Maintenance of Terrestrial Values	6		8	8	8	5	5	6	6
Maintenance of Social Values	3		8	6	3	3	7	3	6
Visual amenity	4		8	8	4	2	6	2	4
Beach access and amenity	8		9	9	5	3	6	3	5
Initial financial cost (direct & indirect)	7		7	6	8	3	2	3	3
Ongoing financial cost (direct & indirect)	8		6	4	6	4	2	3	3
TOTAL SCORE	**59**		**74**	**66**	**46**	**30**	**45**	**29**	**43**

Table 5.5 : Option Assessment - Northern Reach (South of N22)

Figure 5.3 : Northern Reach of Rowes Bay / Pallarenda Shoreline

5.4.3.2 North of Beach Access N22

The foreshore north of Beach Access N22 is primarily undeveloped. The access road into the old Quarantine Station is setback beyond the width of foreshore that is prone to erosion influences over a 50 year planning period. Consequently whilst some short-term erosion and subsequent recovery is expected along this foreshore in the next 50 years, there is no essential infrastructure at risk.

Therefore the preferred strategy is Do Nothing.

Nevertheless, as recommended for other undeveloped sections of the Rowes Bay / Pallarenda foreshore, to ensure the future integrity of this solution a supplementary strategy of Avoid Development is also warranted. This is relatively easy to implement by application of appropriate coastal management principles under the existing State Coastal Plan.

6 RECOMMENDED SHORELINE EROSION MANAGEMENT

6.1 Recommended Management Strategies

The recommended future management of the Rowes Bay / Pallarenda shoreline incorporates a number of strategies along specific lengths of the foreshore. They constitute:

- Beach Nourishment
- Do Nothing
- Planned Retreat

Direct intervention by Beach Nourishment is only proposed on sections of the Rowes Bay / Pallarenda shoreline that have development or environmental and social values that are at risk of damage or loss as a consequence of erosion processes over a future planning period of 50 years.

In other locations, erosion processes will primarily be associated with short-term recessions induced by cyclonic events and with climate change. However no marine, terrestrial and social values or essential infrastructure (apart from a short length of power lines) will be compromised by such recession. Therefore strategies of Do Nothing and Planned Retreat are proposed in those areas.

6.2 Beach Nourishment

Beach nourishment is recommended along the southern shores of Rowes Bay which are threatened by erosion within the next 50 years. This is the shoreline south of Beach Access N8. The strategy basically consists of:

- Initial Nourishment - through the placement of a sufficient volume of sand to establish the sand buffers that are necessary to accommodate erosion caused by a nominated Design Event.
- On-going Renourishment - given that the nourished foreshore experiences long-term erosion processes, it will be necessary to recharge these erosion buffers by periodic placement of additional sand.

It is evident from the understanding of local coastal processes that has emerged from previous nourishment campaigns and from numerical modelling, that a successful beach nourishment solution will also need to address natural coastal processes at the Mundy Creek entrance.

6.2.1 Initial Nourishment

The extent of buffers required to accommodate various Design Events along the southern shores of Rowes Bay have been discussed previously. From which it is evident that the foreshore as far north as Beach Access N8 will require management by beach nourishment over the coming 50 years.

Under the present day climate scenario, the shoreline most at risk extends only as far north as approximately transect TOWN32 - which is some 200 metres north of Beach Access N7. The required buffer widths seaward of a designated Coastal Defence Line along this section of shoreline are presented in Table 6.1.

As climate change influences manifest themselves, additional widths will be required and the northern extent of nourishment may need to be extended to around Beach Access N8. The additional widths to accommodate climate change are shown in brackets in Table 6.1.

The recommended strategy for initial beach nourishment is to establish the necessary buffers for current conditions; and to gradually increase these widths and the distance northwards (towards Beach Access N8) as actual climate change effects become apparent. Such effects would be identified by regularly survey and monitoring of buffer performance.

Transect Location	Average Recurrence Interval (ARI)				
	50 year	100 year	200 year	500 year	1000 year
TOWN 29	17 (+8)	18 (+9)	20 (+10)	28 (+8)	40 (+9)
TOWN 30	12 (+5)	15 (+6)	17 (+6)	19 (+7)	30 (+6)
TOWN 31	11 (+4)	19 (+2)	22 (+2)	24 (+6)	33 (+6)
TOWN 32	13 (+8)	20 (+7)	23 (+6)	26 (+9)	34 (+9)
TOWN 33	14 (+7)	17 (+6)	19 (+7)	24 (+8)	28 (+7)

Table 6.1 : Overall Buffer Widths Required by Beach Nourishment[6] (*metres*)

When establishing sand buffers, the primary objective is to ensure that there is a sufficient volume of sand available to accommodate the expected erosion. Simply stating a buffer width does not guarantee that the required volumes are achieved. To do so requires that the crest level to which the sand buffer is placed is also defined.

The level of the buffer should be no lower than the foreshore area immediately behind the beach slope. In fact a slightly elevated dune would best be created where such a feature no longer naturally exists. Typically the dune crest should be 0.5m to 1.0m higher than the foreshore behind - thereby creating a swale that can

[6] The figures shown in brackets are the additional buffer widths (in metres) to accommodate climate change projections for a 50 year planning period.

intercept and disperse any shoreward flow of runoff during severe rainfall events. A typical nourishment profile is shown conceptually on Figure 6.1.

It is evident by reference to this figure that the location of the Coastal Defence Line will have a significant bearing on the volume of sand that needs to be initially placed to form the required erosion buffer. A more seaward location will require more imported sand than a more landward location - since sand already on the foreshore can be considered as being part of the buffer.

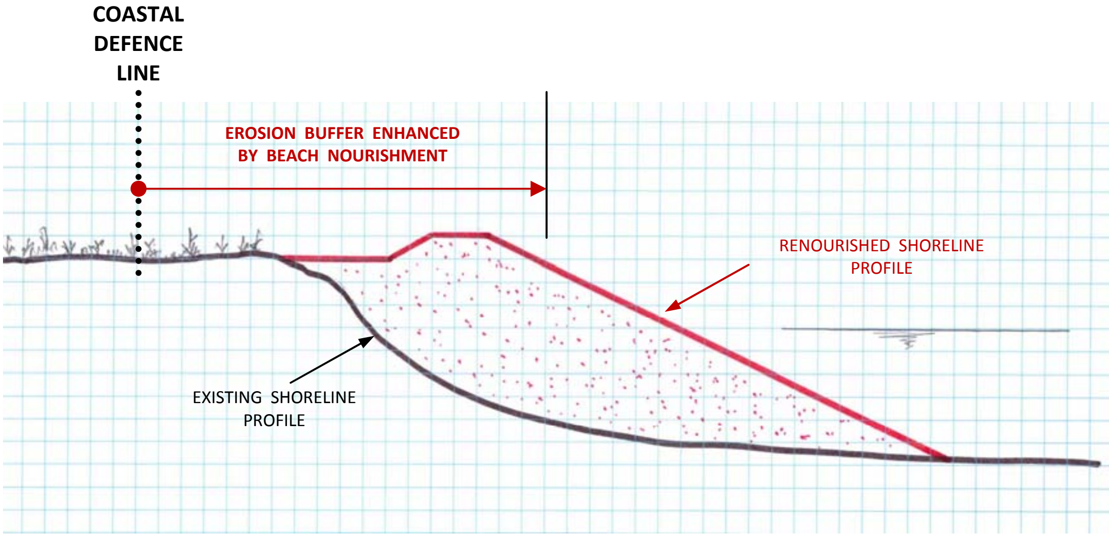

Figure 6.1 : Typical Initial Nourishment Profile

Whilst it is acknowledged that the location of the Coastal Defence Line is a matter for Council and other stakeholders, for the purposes of illustrating and quantifying works under this Shoreline Erosion Management Plan a location along the existing fence between the path and the beach on the shoreline north of Mundy Creek is selected.

An alignment along the existing seaward extent of terrestrial vegetation on the Soroptimist Park ocean frontage is selected along the shoreline south of Mundy Creek. The assumed location of the Coastal Defence Line is shown in Figure 6.2.

6.2.2 On-going Renourishment

As discussed, the long-term erosion on the southern shores of Rowes Bay caused by the deficit in sand being supplied from the south is expected to continue. This means that the erosion buffers created by the initial sand nourishment will gradually be depleted - thereby diminishing the protection that they afford.

Figure 6.2 : Assumed Location of the Coastal Defence Line at Rowes Bay

The proposed extent of initial sand placement for the recommended Beach Nourishment strategy on the Rowes Bay / Pallarenda shoreline is shown conceptually on Figure 6.1. It requires the initial placement of the sand volumes shown in Table 6.2

Foreshore	Required Buffer Volumes for Various ARI Storms				
Precinct	50 year	100 year	200 year	500 year	1000 year
TOWN 29	34,500	36,000	39,000	51,000	69,500
TOWN 30	22,500	27,000	29,500	32,500	48,500
TOWN 31	52,500	74,500	82,500	88,000	113,000
TOWN 32	18,000	36,000	43,500	51,500	72,000
TOWN 33	0	4,500	7,000	14,000	19,500
subtotals	*127,500*	*178,000*	*201,500*	*237,000*	*322,500*

Table 6.2 : Sand Volumes Required for Initial Beach Nourishment *(m^3)*

On-going renourishment will therefore be required to recharge the buffers with sand. This should not be construed as a "failure" of beach nourishment, as it is typically an integral component of successful beach nourishment strategies throughout the world.

Renourishment rates should at least match the net longshore transport rates along the nourished foreshore. To the north of Mundy Creek the historical surveys and numerical modelling indicate that currently this should be at around 4,000 m^3/year.

South of Mundy Creek, the predicted rates are less certain - since there have been only a few historical surveys and the resolution of the previously established coastal processes model that has been referenced for this Shoreline Erosion Management Plan does not have particularly good resolution in this area. Nevertheless, it is estimated that recharging the initially established sand buffer on the foreshore south of Mundy Creek is likely to require approximately 500 m^3/year.

In summary then, the on-going renourishment of the initially created buffers along the Rowes Bay foreshore will require 4,500 m^3/year of sand to be placed on the shoreline. Of this amount 4,000 m^3/year is to be placed north of Mundy Creek and 500 m^3/year placed on the ocean frontage to the south of the creek.

As discussed in Section 3.2.4, sand is typically transported northwards during the period of February to September, with southwards drift occurring between October and January. The exception to this is in the vicinity of beach transect TOWN31 near Beach Access N5 - where the net monthly movement of sand is towards the north throughout the year. It is in this area and to its immediate north that erosion poses the greatest threat to foreshore infrastructure on Rowes Bay.

Given the requirement to also ensure that erosion buffers are fully recharged prior to the likelihood of any cyclone erosion, it is recommended that the renourishment should be completed prior to the onset of each cyclone season - that is, it should be completed by November.

6.2.3 Mundy Creek Entrance

The local longshore sand transport regime in the vicinity of the Mundy Creek entrance is such that there are periods when waves move sand southwards. This results in sand moving off the beach and across the mouth of the creek. Tidal flows cause this sand to be ingested into the lower reaches of the creek and to be swept offshore onto the entrance shoals.

This sand is therefore not available to be moved back onto the adjacent beach when longshore transport processes see a resumption of the more dominant northerly littoral drift. This exacerbates the erosion problem north of Mundy Creek and causes infilling of the creek entrance.

Previous beach nourishment carried out to the north of the creek has experienced these problems, compromising the effectiveness of these earlier nourishment campaigns.

It is therefore recommended that the entrance to Mundy Creek should be better controlled through the construction of training walls. The concept is illustrated in Figure 6.3.

Figure 6.3 : Conceptual Layout of Entrance Training Works at Mundy Creek

The northern training wall would prevent southward moving sand from infilling the entrance area, keeping the creek entrance open for longer. Sand captured against the northern flank of this wall would accumulate so as to form a fillet of sand (as shown conceptually in Figure 6.3). The wall needs to be of a sufficient length that the naturally occurring equilibrium plan alignment of the beach in this fillet results in no sand being able to be swept by waves around its end (and into the mouth of the creek) during periods of southerly sand transport.

When the prevailing conditions change to the more dominant northerly sand transport, sand is swept northwards off the fillet to feed back onto the nourished foreshore to the north. In other words, the northern training wall acts as a physical barrier to hold sand on the northern side of the creek entrance, rather than have it swept into the mouth of the creek or onto the entrance shoals by tides and creek flows.

It is estimated that the northern training wall would need to extend approximately 80 metres beyond the toe of the existing beach to achieve this outcome.

A southern training wall is also likely to be required to prevent sand moving off the nourished frontage of Soroptimist Park and into the creek entrance area. However the longshore transport processes are such that a shorter wall is required - extending some 35 metres beyond the toe of the beach on the southern side of the creek.

The construction of training walls at the entrance to Mundy Creek provides the added benefit of confining the creek flows between physical barriers through the dynamic foreshore area. This means that the main flow channel is more likely to be naturally maintained by the scouring effect of flood and tidal flows.

Rather than allow natural processes to fill the fillet against each of the shore-side flanks of the training walls (and thereby depleting the sand reserves of adjacent beaches to do so) it is more appropriate to use sand excavated from the main flow channel through the mouth of the creek to create these sand fillets.

Detailed coastal processes modelling could be undertaken prior to the implementation phase of the project to more accurately determine the length of the training walls. The particularly complex natural processes at the creek entrance are such that any predicted outcomes of the modelling would nevertheless have to be treated with some caution. Greater confidence in outcomes would be achieved by application of a prototype trial for the entrance training works.

It is recommended that temporary sand filled geotextile bags be placed so as to create the training walls on either side of the Mundy Creek entrance. These would be placed on their estimated optimum alignments and lengths; then their effectiveness monitored. A trial period of two years is envisaged, although this would depend upon the results of the trial itself.

Sand to form the beach fillets against the outside flanks of each training wall must be constructed at the same time as the training walls. Otherwise these features will form by natural processes, using sand derived from the adjacent shoreline to do so. This sand will therefore be permanently removed from future beach processes and significant erosion of adjacent beaches would therefore result. Forming the fillets in conjunction with the training walls averts this scenario.

Sand for filling the geotextile bags and creating the sand fillets can be sourced from the main channel of the Mundy Creek entrance.

Should funding constraints require staged construction of the training walls, it is recommended that the northern wall and its associated beach fillet be constructed first. This is because the prevailing coastal processes are such that the predominant infilling of the creek (and loss of beach sand from the adjacent foreshore) occurs as a consequence of the southerly longshore sand transport in this region. Constructing the northern wall and beach fillet provides a greater initial benefit than a southern wall and beach fillet.

As the performance of the temporary walls become evident, changes to their length, height and even their location can be implemented with reasonable ease during the trial. The results obtained from monitoring an actual prototype scenario are likely to provide greater certainty than any numerical modelling.

Once the optimum training wall arrangement has been determined by the trial, the temporary walls can be made more permanent by placing armour rock over them. If for some unforseen reason, the trial indicated that training of the creek entrance was not appropriate, then the temporary training walls can be readily removed. An excavator fitted with a ripping tyne can easily tear open and remove the geotextile bags, allowing the filling sand to spill back into the active littoral system.

6.2.4 Existing Emergency Foreshore Protection Works

In response to short-term erosion induced by storms and cyclones in recent years, Townsville City Council has implemented emergency protection works on the foreshore north of Mundy Creek. This has primarily entailed the installation of sand-filled geotextile tubes and bags that were buried at the rear of the upper beach slope. These works reputedly extend to a location just north of Beach Access N7.

Due to the need to have emergency foreshore protection implemented quickly, precise details as to founding levels and other such physical characteristics of the geotextile elements are not precisely recorded. This inhibits the ability to currently undertake a detailed appraisal of the degree of protection that the works can accommodate (ie. the storm/cyclone ARI that the works can withstand). This information could be obtained by undertaking exploratory excavations to expose the existing works.

Approval for these geotextile structures was forthcoming on the basis that they were emergency and temporary works only. Under existing approval conditions, they are to be removed at some time in the future. However until the proposed Beach Nourishment strategy is implemented, it is recommended that the emergency works remain in place.

If during implementation of the Shoreline Erosion Management Plan, the selection of the Coastal Defence Line should be such that the emergency works are located either along or inland of the Line, then they will not be adversely exposed by the selected Design Event at any time during the 50 year planning period. Consequently the emergency works need not be removed.

If it eventuates that the works are seaward of the selected Coastal Defence Line, then future short-term erosion events could expose the geotextile containers and even cause their failure. The extent that the emergency works might interfere with natural beach processes during such extreme events cannot be determined until such time as the location of the Coastal Defence Line is established - since this will also determine the extent of the newly created buffer in front of the existing works.

Consequently it is recommended that:

- since the emergency protection works are currently protecting essential infrastructure (ie. Cape Pallarenda Road) and the iconic banyan trees, they should remain in place until the beach nourishment proposed by this Shoreline Erosion Management Plan is implemented along the affected foreshore; and
- when preparing designs and approvals for the recommended beach nourishment, (following selection of the Coastal Defence Line and the ARI Design Event by project stakeholders) a detailed assessment of the impact of the existing emergency works on beach processes should be undertaken. This

would then enable a decision to be made as to whether or not the works need to be removed.

- If it is appropriate to leave them in place, then the emergency works should be included in the approval applications for the beach nourishment works recommended by this Shoreline Erosion Management Plan.

6.2.5 Management of Sand Dunes

The dune system established by beach nourishment needs to be effectively managed in a manner consistent with natural processes. Appropriate management will assist in maintaining their natural ecosystem and ensure their structural integrity as erosion buffers. Dune vegetation traps wind-blown sand on foreshore dunes which might otherwise be blown inland. Therefore rather than being permanently lost from erosion buffers (and potentially creating a nuisance to road and stormwater drainage systems), such trapped sand remains within the natural beach system.

Appropriate dune management will include the planting and protection of native dune vegetation, the clearing of weeds and other noxious species from the area, and the provision of controlled access through the dunes onto the beach.

The system of controlled access which has already been implemented by Council along the Rowes Bay / Pallarenda foreshore is expected to continue to provide benefits to the proposed nourished foreshore north of Mundy Creek.

The Department of Environment and Resource Management offers valuable information and recommendations regarding the stabilisation of coastal dunes which should be applied to local foreshores enhanced by beach nourishment.

Likewise such management practices should be implemented on other reaches where the Do Nothing and Planned Retreat strategies are proposed. Where foredunes are naturally created by sand transport processes, stabilisation of these important features with primary vegetation species and controlled access is recommended.

6.2.6 Recommended Source of Sand for Nourishment Works

Most of the sand supplied for previous beach nourishment works in Rowes Bay has been sourced from the Haughton and/or the Star Rivers. Indications are that such commercial sources are likely to be available for some time yet. Nevertheless the implications and sustainability of hauling large volumes of sand such long distances on public roads and highways over the next 50 years raises a range of problems.

Apart from traffic disruption and road safety issues, the direct cost of sand extraction and haulage are already quite high and are likely to increase in the future. Indirect costs such as road repairs and the environmental implications of heavy vehicle emissions make such a source less attractive in the future.

It is for these reasons that back-passing of sand on the Rowes Bay / Pallarenda foreshore is recommended.

6.2.6.1 Sand Back-passing

Sand backpassing operations redistribute sand within the littoral system. It involves the mechanical transport of sand from a wide stable foreshore back onto an updrift sediment-starved beach. This method is often utilised in locations where coastal processes are such that sand from an eroding foreshore moves alongshore and is deposited in a more sheltered area.

Backpassing essentially "recycles" the sand back onto the eroding beach. If the sand volumes are moderate and the haul distances are short, the practice can provide a very cost-effective scheme for mitigating the erosion problems on the updrift beach.

It is recommended that sand on the foreshore and in nearshore sandbanks near the entrance to Three Mile Creek be back-passed to the eroding shores of Rowes Bay.

As discussed in Section 3.2.4, sand is moving northward along the Rowes Bay / Pallarenda foreshore under the influences of longshore transport mechanisms. In the vicinity of the Three Mile Creek entrance the longshore transport rates reduce due to the wave shadow of Virago Shoal offshore, causing sand to accumulate in this area. It is from this accreting foreshore and nearshore area that sand can be obtained for recycling back onto the eroding Rowes Bay foreshore to the south.

In other words, instead of importing sand from distant sources and accepting the adverse implications and costs, it is proposed to better manage the sand that is already within the Rowes Bay / Pallarenda coastal reach by implementing sand backpassing.

6.2.6.2 Potential constraints

The intertidal shoals and sand banks that have accumulated in the lee of Virago Shoal provide large areas that are exposed at low tide, creating an extensive intertidal environment. This diversity of habitats is home to a high species richness of invertebrates, which in turn provide food for fish and marine reptiles at high tide, and for birds and terrestrial vertebrates at low tide. Extensive sand extraction across a wide area of these intertidal shoals will likely have an adverse impact on these environmental values.

Therefore the extraction of sand from this area for the initial nourishment of the eroding foreshore at Rowes Bay may not be viable. This initial nourishment may need to be implemented by using sand from external sources. However this needs to be investigated further prior to committing to sourcing sand from distant locations. This would require surveys of the entrance area and adjacent foreshores.

Nevertheless, judicious selection of an extraction locale and appropriate methodology will enable the 4,500 m^3/year required for on-going renourishment to be provided by backpassing from the vicinity of the Three Mile Creek entrance.

For example, rather than source this entire amount each year from a wide area, a smaller area that uses a deeper extraction would be implemented, thereby limiting the area directly affected by the activity. This is in accordance with guidelines provided by the State Government's *Fish Habitat Management Operational Policy FHMOP 010*.

Also, rather than locate the extraction point within the shoals themselves, it is proposed that this be on the updrift side of the entrance area where the northerly littoral drift will readily recharge the extraction site.

Another constraint on the sourcing of sand from the Three Mile Creek entrance area is that such activities need to be located beyond the boundaries of the Great Barrier Reef Marine Park (GBRMP). Under *Great Barrier Reef Marine Park Act 1975* this activity is regarded as mining and is a prohibited activity in the Park.

The Great Barrier Reef Marine Park Authority has further advised that the landward boundary in this area is defined by the line of Mean Low Water. This is implied to be the average of Mean Low Water Springs and Mean Low Water Neaps at Pallarenda.

Reference to published tidal planes for the region (reproduced as Table 3.1 herein) suggests that this is the line defined by the RL-0.74m AHD contour. The beach transect surveys undertaken in this area show that this boundary lies some 175 metres offshore of the foreshore vegetation line. Therefore in order not to encroach within the Great Barrier Reef Marine Park, sand for back-passing must be sourced from within this 175 metre wide foreshore area.

Given these various environmental constraints, the proposed general area for sourcing sand for on-going renourishment of southern Rowes Bay foreshores is shown in Figure 6.4 as being just to the south of Beach Access N12. Investigations including surveys are required to optimise the location within this general area.

6.2.6.3 Implications to downdrift foreshores

The investigations and numerical modelling undertaken for this Shoreline Erosion Management Plan indicate that the foreshore and nearshore shoals at Three Mile Creek have been accreting at a rate of around 1,700 m^3/year (ie. 3,300 m^3/year supplied by sand transport from the south less 1,600 m^3/year which is carried through by longshore processes).

Consideration of historical beach surveys and aerial photographs indicates that there is around 900,000m^3 to 950,000m^3 of sand in the nearshore sandbanks around the creek entrance. This suggests that as the shoreline between Kissing Point and Cape Pallarenda has prograded, sand has been accumulating at the Three Mile Creek entrance for over 500 years.

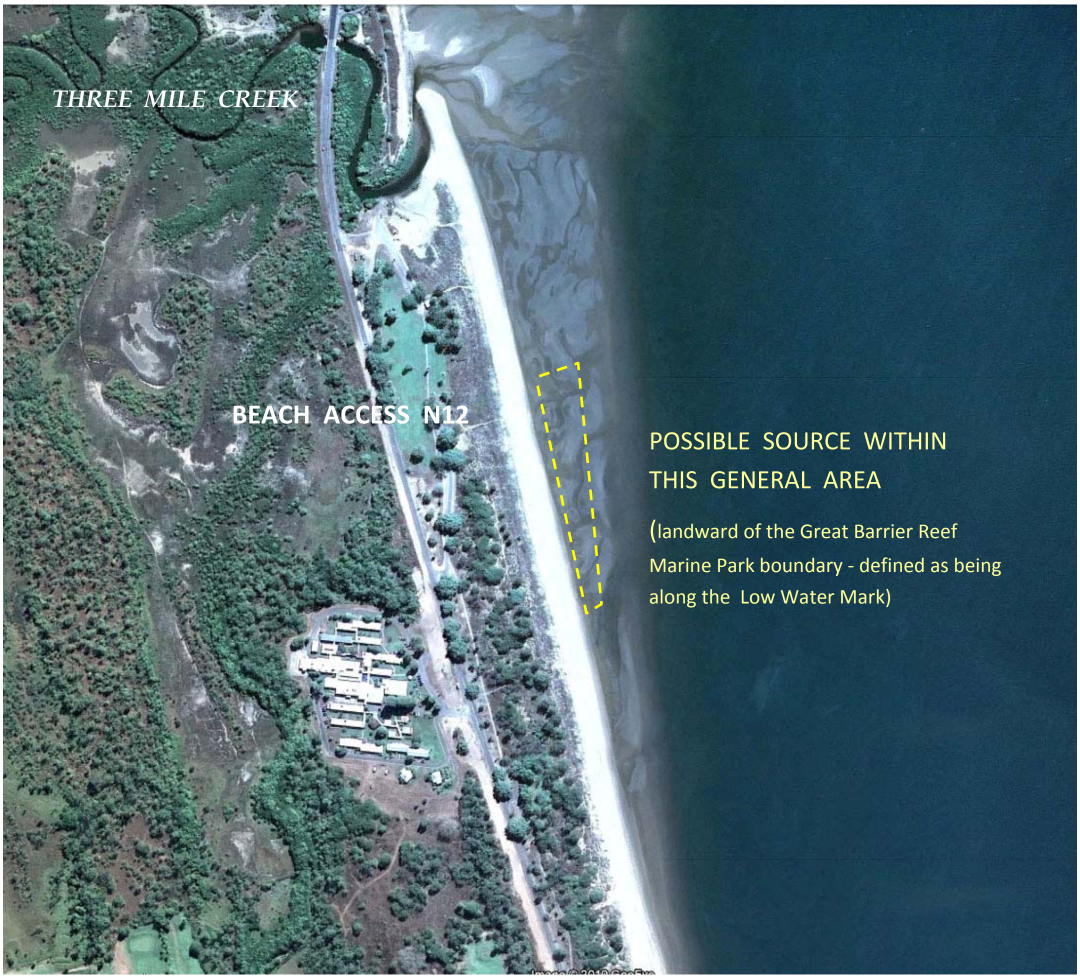

Figure 6.4 : Possible Source for Sand Backpassing

The 1,600 m^3 of sand which on average moves through the entrance area each year does so by complex sediment pathways that entail sand movement across the various sandbanks and shoals at the entrance, feeding back onto the foreshore further north.

On these northern foreshores of the Pallarenda suburb, longshore transport rates are around 1,600 m^3/year; dropping to some 1,200 m^3/year at Cape Pallarenda. These rates are lower than they are to the south primarily because of the increased protection afforded by Magnetic Island. Also the more easterly orientation of the shoreline means that the predominant south-easterly waves arrive on this foreshore with very little down-coast littoral component.

In summary then,

- waves supply approximately 3,300 m^3 /year of sand to the entrance area of Three Mile Creek;
- of this amount approximately 1,700 m^3 /year is retained within the entrance shoals and the balance of 1,600 m^3/year is moved through the entrance area to feed onto the shoreline north of the creek.

Implementation of the recommended backpassing from the entrance area will result in the following changes to this process:

- waves will continue to supply approximately 3,300 m^3/year of sand to the entrance area of Three Mile Creek;
- again approximately 1,700 m^3/year is retained within the entrance shoals and the balance of 1,600 m^3/year is moved through the entrance area to feed onto the shoreline north of the creek;
- however, backpassing operations will remove approximately 4,500 m^3/year from the area (so that 4,000m^3 is delivered as re-nourishment north of Mundy Creek entrance and 500 m^3 is used to re-nourish south of that entrance).
- Therefore instead of the entrance area and its various shoals and sandbanks accumulating sand at an ongoing rate of 1,700 m^3/year, the area will be gradually diminished at a rate of 2,800 m^3/year (ie. 1,700 m^3/year natural accretion less 4,500 m^3/year removed by sand backpassing activities).

Nevertheless the 1,600 m^3/year supply of sand to the Pallarenda foreshores north of Three Mile Creek will continue despite extraction by backpassing operations, since this sand movement is due to waves transporting sand out of the entrance area. The approximately 900,000m^3 to 950,000m^3 of sand in these shoals and sandbanks represents an enormous reservoir to supply this 1,600 m^3/year. The impacts of their gradual depletion at a rate of around of 2,800 m^3/year will only begin to be felt on downdrift beaches when these reservoirs approach depletion in some 300 years' time.

At that point, a strategy of backpassing from Cape Pallarenda to the northern side of Three Mile Creek could be implemented.

In other words, there are negligible implications to downdrift shorelines by the proposed sand backpassing from the Three Mile Creek entrance area.

6.2.7 Back-passing Techniques and Operations

The mechanical back-passing of sand from Three Mile Creek to just north of Mundy Creek can be achieved by using either:

- conventional earthmoving equipment; or
- a hydraulic "sand shifter".

6.2.7.1 Conventional earthmoving equipment

This technique would entail use of equipment such as an excavator and front-end loader removing sand from the extraction site and loading trucks - which then haul the sand approximately 3km along Cape Pallarenda Road for placement and spreading by a loader on the target shoreline north of Mundy Creek.

Typically trucks would be around 10 m^3 capacity - or alternatively approximately 20 m^3 if truck and dog-trailer combinations were used. The annual placement of 4,500 m^3/year on the southern shores of Rowes Bay could be achieved in timeframes of only a few weeks (since it represents approximately 200 to 250 return trips per campaign).

Nevertheless it requires fairly intensive construction traffic on the Cape Pallarenda Road during this time. The adverse implications are not dissimilar to those experienced by renourishment using sand sourced from distant sources - except of course that it is confined to a much shorter haulage route.

Such an exercise would likely cost around $\$12/m^3$ to $\$14/m^3$ - resulting in an annual back-passing cost of approximately $60,000.

6.2.7.2 Sand shifter

An alternative to earthmoving equipment is the application of a sand shifter. Such equipment has been successfully used for sand bypassing and back-passing operations to manage eroding coastlines elsewhere in Australia.

However given the relatively small annual volumes of sand back-passing, it is more expensive than the option of using conventional earthmoving equipment - but will have somewhat less social and environmental impacts.

The sand shifter is based on a fluidising principle which enables sand to be recovered from below the seabed over a distance equivalent to the length of the sand shifter unit. This unit is essentially a submerged sand pump mounted on a frame. When operating, pressurised sea water is delivered to the unit through three pipelines:

- a temporary pipe to fluidise the seabed beneath the legs of the support frame, enabling it to bury itself in the seabed at the commencement of operations;
- a permanent pipe to fluidise the sand under the buried sand shifter unit; and
- another permanent pipeline to transfer the fluidised sand to shore.

Sand is drawn down towards the sand shifter unit, creating a hole in the beach which is replenished by the natural longshore transport of sand. When the hole is refilled with sand, pumping recommences.

Once onshore, the sand slurry is then pumped through a pipeline to the discharge point on the foreshore where sand renourishment is required. Therefore the sand shifter unit is supplemented by shore-based facilities such as:

- a pump that supplies the pressurised seawater;
- pumps, trash rack and hopper to ensure the consistency of the sand slurry and to boost the sand discharge through the pipeline to the delivery point; and
- delivery pipelines.

A permanent installation would utilise solar and/or electrical power to operate the pumps - which could also be run automatically at night to use off-peak power.

The onshore facilities can be housed in a permanent pump station and operated automatically or remotely. The delivery pipeline from the supply point to the target foreshore on the southern shores of Rowes Bay can be buried within the foreshore reserve.

The self-burying sand shifter unit would be placed parallel to the shore between the high water and low water line off the beach. The concept is illustrated in the images presented in Figure 6.5 - which are of existing backpassing operations larger than would be required for Rowes Bay / Pallarenda.

Because the recovery of sand at the extraction point relies on the prevailing coastal processes to bring sand to the unit, the rate at which sand is extracted and delivered to the eroding shoreline matches the natural rate that sand is moved off the eroding foreshore by these processes.

In other words, there is no large single annual placement of sand for renourishment purposes. Instead sand can be delivered steadily throughout the year to the foreshore that requires it.

A potential shortcoming of the system relates to recharging the erosion buffers on the southern shores of Rowes Bay following a severe cyclone event. The system can only supply sand that is brought alongshore to recharge the hole created by the sand shifter. This may not necessarily be at a rate that enables the system to quickly recharge the southern erosion buffers. Extra sand shifter unit(s) might be required during these periods to create a larger sink for capturing sand. Such unit(s) would be dormant during normal conditions.

Rather than commit to a permanent installation, a trial of the sand shifter system could be implemented. The purpose of the trial would be to tailor the equipment and operations to suit the local longshore transport regime.

For the trial, the pumps might be diesel operated with subsequent conversion to solar/electric once the trail has confirmed the arrangements and operations of a permanent system. In which case, the location of the onshore facilities would need to consider the potentially adverse effects that noise generated by diesel pumps might have on nearby residents.

The recommended location for the deployment of the trial sand shifter is in the vicinity of Beach Access N12 at Robertson Park (refer to Figure 6.4).

The cost of on-going renourishment by a sand shifter arrangement is related to the establishment of the back-passing system and its subsequent running costs. The implementation costs for on-going renourishment by this method can therefore be considered to entail:

- establishment of the trial program;
- operation of the trial, with amendments and refinements as necessary;
- adapt/convert trial arrangements to a permanent system; and
- operation of the permanent system.

sand shifter unit:
on the beach prior to deployment at the extraction site

sand shifter unit:
in the process of self submerging at the selected sourcing site

temporary onshore pump and slurry systems for transfer of extracted sand to the foreshore requiring renourishment.

Figure 6.5 : Images of Sand Shifters Used for Sand Backpassing Operations

These costs are summarised below in Table 6.3. Assuming a two year long trial, the cost would be approximately $525,000 (ie. around $58/m^3) - with costs reducing to around $120,000 per year (ie. at approximately $27/m^3) and an initial one-off conversion cost of around $150.000 should a permanent system be subsequently installed.

Activity	Capital Cost	Annual Cost
Establish Trial Program	$225,000	-
Operation of the Trial	-	$150,000
Convert to a Permanent System	$150,000	-
Operation of the Permanent System	-	$120,000

Table 6.3 : Estimated Costs for Renourishment by Sand Shifter

Clearly these costs are much higher than those for sand back-passing using conventional earthmoving plant and equipment. However the system would be mostly automated, and would not require truck movements on Cape Pallarenda Road, nor require extensive operation of machinery on local beaches.

6.2.8 Estimated Costs of Beach Nourishment Activities

The costs associated with a beach nourishment option relate primarily to the initial beach nourishment to create the necessary erosion buffers; and the on-going renourishment to recharge these buffers. Estimates of these costs are provided below.

6.2.8.1 Initial beach nourishment

As discussed previously, there are a number of aspects which determine the extent of sand to be provided to create the necessary erosion buffers. Firstly there is the degree of protection required by Council and other stakeholders (ie. what Average Recurrence Interval is to be adopted as the Design Event). Secondly there is the location of the Coastal Defence Line. The more seaward is the location, the more sand that is required to create the necessary buffer.

For the purposes of preparing cost estimates, a range of ARI events are considered. However the location of the Coastal Defence Line is assumed to be as shown earlier in Figure 6.2

As discussed previously, it is possible that the large volumes of sand required to initially create the erosion buffers might not be obtained from the Three Mile Creek entrance area without adverse impacts. However this assumption needs to be investigated further prior to committing to obtaining sand from other more distant sources.

The cost estimates in Table 6.4 are therefore based on the unit rates for the supply and placement of sand for the nourishment campaign undertaken by Council in late 2009. That exercise provided some 28,000 m^3 of sand to the foreshore north of Mundy Creek, of which approximately 13,000 m^3 was imported from the Star River and the balance obtained from clearing the creek entrance area.

The estimates are based on importing all of the required sand from commercial extraction operations at the Star River.

ARI	Volume of Sand	Estimated Cost
50 years	127,500 m^3	$3.47 million
100 years	178,000 m^3	$4.84 million
200 years	201,500 m^3	$5.48 million
500 years	237,000 m^3	$6.45 million
1,000 years	322,500 m^3	$8.77 million

Table 6.4 : Estimated Costs for Initial Beach Nourishment

6.2.8.2 On-going renourishment

As noted in the preceding Section 6.2.7, backpassing of sand from Three Mile Creek using conventional earthmoving equipment is approximately half the cost of using a sand shifter arrangement. However the adverse implications of heavy vehicle movements on Cape Pallarenda Road and the operation of excavators and loaders on the beaches at the extraction and delivery points need to be considered.

In summary, the costs of backpassing 4,500 m^3 of sand each year by the two options are shown below in Table 6.5:

Conventional earthmoving equipment

- $12/$m^3$ to $14/$m^3$ = say, approximately $60,000/year

Sand Shifter

- 2 year trial = $58/$m^3$ = approximately $262,500/year
- permanent installation = $27/$m^3$ = approximately $120,000/year

Table 6.5 : Estimated Current Costs for Sand Back-passing

6.2.8.3 Mundy Creek Training Walls

It is recommended that a trial of the training walls is implemented prior to them being permanently constructed. A trial period of two years is envisaged, although this would depend upon the results of the trial itself.

The training walls would initially be constructed from sand-filled geotextile bags, using sand from within the main Mundy Creek entrance channel to fill the bags. Once the specific details as to their optimum length, location and orientation is determined by the trial, then the walls would be permanently armoured with rock or other appropriate material.

Consequently the implementation costs can be considered to entail:

- establishment of the trial program;
- operation of the trial, with amendments and refinements as necessary;
- adapt/convert trial arrangements to a permanent system; and
- operation of the permanent system.

These costs are summarised below in Table 6.6.

Activity	Capital Cost	Annual Cost
Establish Trial Program	$175,000	
Operation of the Trial		$15,000
Convert to a Permanent System	$230,000	
Operation of the Permanent System		$15,000

Table 6.6 : Estimated Current Costs for Training Walls at Mundy Creek

6.3 Do Nothing

A strategy of Do Nothing is recommended on the shores of the Rowes Bay / Pallarenda coastal reach where erosion will not threaten essential community infrastructure or compromise environmental and social values within the next 50 years.

This consists of the shoreline:

- along the northern flank of Kissing Point which is currently protected by a rock armoured seawall; and
- along the undeveloped sandy foreshore north of Beach Access N8; up to the entrance of Three Mile Creek.

The long-term erosion processes currently contributing to the erosion problems further south at the Rowes Bay suburb will not migrate to this section of shoreline within the 50 year planning period. The short-term erosion associated with even the most severe cyclone events will not cause damage or loss to infrastructure, nor will the additional shoreline recession expected as a consequence of future climate change.

There are no identifiable costs associated with this aspect of the overall management strategy for the Rowes Bay / Pallarenda coastal reach.

6.4 Planned Retreat

The strategy of Planned Retreat is recommended on the foreshore north of Three Mile Creek. It includes the ocean frontage of the Pallarenda suburb - which is public parkland behind quite a wide natural dune system.

Consequently the strategy does not incorporate any private property or residences in Pallarenda.

A Do Nothing strategy would be appropriate except that some non-essential community infrastructure is located within the area that can be affected by short-term erosion events. Future climate change is likely to increase the existing vulnerability of this infrastructure, which includes the following:

- power lines immediately north of Three Mile Creek entrance;
- the swimming enclosure between Shelley and Marlow Streets in Pallarenda;
- the public boat ramp and its hardstand/parking area; and
- the ring road servicing Beach Access N20, N21 and N22 at the end of Cape Pallarenda Road.

6.4.1 Electrical Power Lines

The power lines immediately north of Three Mile Creek are vulnerable to erosion by cyclone events of approximately 50 year ARI or greater. Reference to Table 4.1 indicates that such an event has a 63% chance of occurring within a 50 year planning period.

Numerical modelling of cross-shore erosion shows that during such events, the power poles would be completely undermined - to the extent that they would likely collapse and even be swept away. This would cut electricity supply to the Pallarenda community during the cyclone and require reinstatement of the lost infrastructure after the event.

However such post-disaster emergency works could be averted if a strategy of retreat was able to be implemented by Ergon as part of a planned relocation program.

There is a failed seawall on the foreshore immediately north of the Three Mile Creek entrance which is opposite the power lines at risk. Anecdotal reports suggest that rocks were placed on the foreshore in an attempt to offer protection to the power lines. However the resulting adhoc placement of insufficient and significantly undersized rocks by what appears to have simply been dumping (rather than consolidation into a properly designed and constructed seawall) provides no effective erosion protection whatsoever during severe events.

Unless there are legal instruments in place that preclude Power and Telecommunications Authorities from such responses to immediate erosion threat, then this response to erosion threat by future rock placement is in breach of environmental and planning legislation.

A seawall to protect the power lines could be properly designed and constructed, however it would be very expensive and have an adverse erosion impact on foreshores to the north. It is for this reason that a strategy of planned retreat is more appropriate for safeguarding the power distribution infrastructure at this particular location. Consequently it is recommended that Council develops a consultation plan with Ergon as a step towards implementing this strategy.

6.4.2 Swimming Enclosure

The swimming enclosure and associated amenities to the north of Shelley Street in Pallarenda are located within the area vulnerable to erosion by cyclone events. Clearly a strategy of retreat for the enclosure itself is not viable as it needs to remain in the nearshore area. However the risk to the adjoining amenities block can be alleviated by relocating it further inshore. Since this foreshore is public parkland, there is land available for such relocation.

Given that a significant component of the risk to the amenities block relates to the recession associated with future climate change, an appropriate implementation strategy for its Planned Retreat is to monitor the effects of climate change and undertake the planned retreat if and when necessary.

6.4.3 Public Boat Ramp

The existing boat ramp and associated onshore hardstand and parking facilities by necessity are currently located within the area vulnerable to cyclone-induced erosion. This threat is expected to increase in future years as a consequence of climate change.

It is acknowledged that a Planned Retreat strategy is not strictly a viable means of mitigating the threat to this particular asset. However it would be prudent for Queensland Department of Main Roads and Transport, and Townsville City Council to be aware that there is likely to be a requirement for increased maintenance of the ramp itself; and possible relocation of the hardstand areas in coming years.

An appropriate management approach would be to maintain the ramp in its current location, but in the event of damage to onshore hardstand areas a strategy of retreat be implemented - rather than simply reinstate hardstand areas damaged by short-term erosion events.

The vacated width between the hardstand area and the beach could be reformed and revegetated into a small coastal dune system to act as a buffer and allow coastal processes to continue unaffected along this section of foreshore.

6.4.4 Ring Road at Beach Access N20, N21 and N22

Part of the ring road and car-park facility at the northern-most end of Cape Pallarenda Road (servicing Beach Accesses N20, N21 and N22) is within the area currently prone to erosion by cyclones. Shoreline recession as a consequence of future climate change also threatens the seaward edge of the road pavement.

In the event of such damage, Council should implement a strategy of retreat - rather than simply reinstate the ring road and the car-park areas damaged by short-term erosion events.

As recommended for the boat ramp further south, the vacated width between the ring road / car-park and the beach should be reformed and revegetated into a small coastal dune system to act as a buffer and allow coastal processes to continue unaffected.

6.5 Monitoring Surveys

Once implemented, monitoring of the performance of the Shoreline Erosion Management Plan ensures that potential threats to project outcomes can be addressed in a proactive manner.

Given that a primary objective of the Shoreline Erosion Management Plan is to manage erosion along the Rowes Bay / Pallarenda shoreline, regular surveys of the foreshore should be undertaken as part of the Plan.

Beach transect lines were first established on this shoreline many years ago by the Beach Protection Authority. The first cross-shore surveys were undertaken in February 1982 with others taken at irregular intervals since that time. Since 2003 Council has commissioned surveys on almost an annual basis. It is strongly recommended that this annual survey campaign be maintained and extended as follows:

- reinstate the TOWN37 transect line at Three Mile Creek.
- the TOWN transects (numbered TOWN29 to TOWN42) continue to be surveyed annually. This should occur at the same time every year, ideally in late-October or early-November (immediately prior to the cyclone season);
- the foreshore south of Beach Access N8 should be surveyed more intensely, particularly on the section of foreshore where beach nourishment has occurred. This would entail monitoring transect lines established at approximately 250 metre spacings. This will require the establishment of three new transect lines on this section of foreshore. Surveys should be conducted twice annually in this priority area - both at the same time each year. Ideally this would be in late-October or early-November (immediately prior to the cyclone season), then again in late-March or early-April (immediately following the cyclone season).
- all beach transect surveys should extend well beyond the toe of the beach to ensure that the entire littoral system is captured by the survey. This has not always happened in the past. Typically the surveys should extend at least 500 metres offshore. This is likely to require some bathymetric survey from a boat so as to profile the transects in deeper water.
- the monitoring surveys should commence prior to implementation of any activities recommended by this Shoreline Erosion Management Plan, thereby providing a pre-project foreshore condition as a baseline reference.

As discussed in Section 3.4, in coming decades the foreshores of Rowes Bay / Pallarenda are likely to experience the effects of climate change - which may see gradual increases in sea level and the volumes of sand being transported by natural processes. There remains considerable uncertainty about the scale and effect of such processes.

The monitoring of future shoreline response by a regular program of foreshore surveys therefore serves an important role in assessing the effectiveness of the recommended erosion management strategies in coming years and to guide future action.

6.6 Recommended Shoreline Erosion Management Plan

Following a review of the prevailing coastal processes, risks and values of the Rowes Bay / Pallarenda foreshores the following activities are recommended by this Shoreline Erosion Management Plan:

Project Design and Approvals

- Townsville City Council (in consultation with other stakeholders) to select the Design Event for which the erosion mitigation strategies recommended by this Shoreline Erosion Management Plan are to accommodate. This requires consideration and acceptance of the risk that such an event will occur (or be exceeded) within a 50 year planning period. Guidance on risk is offered in Section 4.1.3 of this Shoreline Erosion Management Plan. Nominating the Design Event requires selecting the Average Recurrence Interval (ARI) cyclone for which immunity is required.
- Should an event occur that is more severe than the selected Design Event, then the strategies and engineering works implemented in accordance with this Shoreline Erosion Management Plan may be compromised and coastal infrastructure could be damaged or destroyed as a consequence. The selection of an appropriate Design Event is therefore an important consideration.
- Townsville City Council (in consultation with other stakeholders) to select the alignment of an appropriate Coastal Defence Line along the Rowes Bay / Pallarenda shoreline. Throughout the 50 year planning period, property and infrastructure landward of the Coastal Defence Line remain protected from long-term erosion effects; short-term erosion caused by the Design Event; and recession as a consequence of future climate change. Foreshore areas seaward of the Coastal Defence Line lie within the active beach system (ie. within the erosion buffers).
- Undertake engineering designs for works associated with the trial of training walls at the Mundy Creek entrance; and for the initial beach nourishment to the north and south of Mundy Creek.
- Prepare and submit appropriate approval applications based on designs for the proposed works.

Project Monitoring

- Establish and undertake pre-project monitoring survey on beach transects at 250 metre intervals along the 2.5km long shoreline between the southern end of Soroptimist Park and Beach Access N8. This will require the establishment of three new transect lines in addition to those transects already located in this priority area.
- Reinstate transect line TOWN37 at Three Mile Creek.
- Include surveys of all Beach Transects between TOWN29 and TOWN42 in a pre-project monitoring survey.
- Undertake beach transect surveys annually on all of these TOWN Beach Transect Lines.
- However on the shoreline south of Beach Access N8, beach transect surveys to be undertaken twice annually - with additional surveys on these transects immediately after major erosion events.
- All surveys are to extend offshore for a minimum distance of 500m from the line of mean sea level on the beach.

Beach Nourishment

- The extent of the recommended Beach Nourishment is shown conceptually on Figure 6.6.
- Implement a trial of entrance training works at the mouth of Mundy Creek. This is to be implemented by using sand-filled geotextile bags to initially construct two training walls (approximately 80m long on the northern side of the entrance and 35m long on its southern side).
- At the same time as the training walls are constructed, sand must be placed on the outside flanks of each wall to create the beach fillets that would otherwise form naturally. This is necessary to avoid instigating erosion on the shoreline adjacent to the training walls if these fillets were allowed to be created naturally.
- Should funding constraints require the staged construction of the training walls, it is recommended that the northern wall and its associated beach fillet be constructed first.
- Place sand as initial nourishment on the shoreline north of Mundy Creek and along the Soroptimist Park ocean frontage. The sand quantities required will depend upon the location of a Coastal Defence Line nominated by Council; and the degree of protection required (ie. the selected Design Event). Some guidance on the quantities of sand required in erosion buffers is provided in Table 6.2 of this Shoreline Erosion Management Plan.
- The sand for this initial nourishment is likely to be from sources previously utilised by Council for earlier beach nourishment campaigns at Rowes Bay. This supply could be supplemented by clearing deposited sand from the main channel of the Mundy Creek entrance (between the new training walls) and from the creek's lower reaches downstream of the Cape Pallarenda Road bridge.

- It is possible that this initial supply of sand could be obtained from the entrance shoals at Three Mile Creek; however this option would need to be explored further through surveys and appropriate sampling / testing.
- Implement appropriate dune management practices on newly nourished foreshores. As a minimum, this entails the planting and protection of native dune vegetation, the on-going clearing of noxious weed species and ensuring adequate controlled access is maintained through new dune areas.
- Undertake annual sand back-passing campaigns to take 4,500 m^3 /year of sand from the vicinity of the Three Mile Creek entrance area (between mean sea level and low tide) and transport it to the renourishment areas north of Mundy Creek (4,000 m^3/year) and the ocean frontage of Soroptimist Park (500 m^3/year). Impacts on foreshores downdrift of the extraction point are negligible.
- This back-passing can be achieved in one of two ways - either by using conventional earthmoving equipment, or by a "sand shifter" arrangement. The most appropriate application will be determined by costs and considerations of operational impacts on local communities. Guidance on these issues is offered in Section 6.2.7 of this Shoreline Erosion Management Plan.
- Monitor the effectiveness of training works at Mundy Creek entrance, making any alterations to the length and height of walls if appropriate. Upon successful completion of the trial, armour the temporary training walls for a more permanent arrangement. Alternatively completely remove the sand-filled geotextile bags that constitute the walls, returning sand to the beach system.
- Monitor the effectiveness of the sand back-passing arrangements, making alterations to equipment and operations as appropriate.

Do Nothing

- The extent of the recommended Do Nothing strategy is shown conceptually on Figure 6.6.
- Allow natural coastal processes to continue to shape the shoreline in those areas where no essential community infrastructure is threatened by erosion processes and where environmental values are not compromised by such processes. This applies to the following coastal reaches:
    - the northern flank of Kissing Point (where an existing seawall exists as far west as Soroptimist Park);
    - north of Beach Access N8, up to the southern side of the Three Mile Creek entrance; and
    - north of Beach Access N22, up to Cape Pallarenda.
- To ensure the future integrity of this management option, a supplementary strategy of Avoid Development is also recommended. This is relatively easy to implement by application of appropriate coastal management principles and policies under the existing State Coastal Plan.

Planned Retreat - Relocate Non-essential Infrastructure

- The extent of the recommended Planned Retreat strategy is shown in Figure 6.6. It does not affect any private property.
- Relocate non-essential community amenities so as to allow natural coastal processes to shape the shoreline unimpeded. This applies to the shoreline north of the Three Mile Creek entrance, up to Beach Access N22, and therefore includes the ocean frontage of the Pallarenda suburb.
- To ensure the future integrity of this management option, a supplementary strategy of Avoid Development is also recommended. Again, this is relatively easy to implement by application of appropriate coastal management principles and policies under the existing State Coastal Plan.
- A section of the power lines that provide electrical services to the suburb of Pallarenda is at risk of loss by erosion. Consideration needs to be given to relocating this section of the local power distribution network to a location further inland beyond erosion influences.

Existing Emergency Foreshore Protection Works

- In response to major storm erosion in recent years, emergency protection works have been implemented on the foreshore north of Mundy Creek. This entailed the installation of sand-filled geotextile tubes and bags that were buried at the rear of the upper beach slope.
- Approvals for these geotextile structures was forthcoming on the basis that they were temporary works, undertaken as emergency measures only and were to be removed at some time in the future.
- In relation to these emergency foreshore protection works, it is recommended as follows:
    - since the works are currently protecting essential infrastructure (ie. Cape Pallarenda Road) and the iconic banyan trees, they should remain in place until the beach nourishment proposed by this Shoreline Erosion Management Plan is implemented along the affected foreshore; and
    - when preparing designs and approvals for the recommended beach nourishment, (following selection of the Coastal Defence Line and the ARI Design Event by project stakeholders) a detailed assessment of the impact of the existing emergency works on beach processes should be undertaken. This would then enable a decision to be made as to whether or not the works need to be removed.
    - If it is appropriate to leave them in place, then the emergency works should be included in the approval applications for the beach nourishment works recommended by this Shoreline Erosion Management Plan.

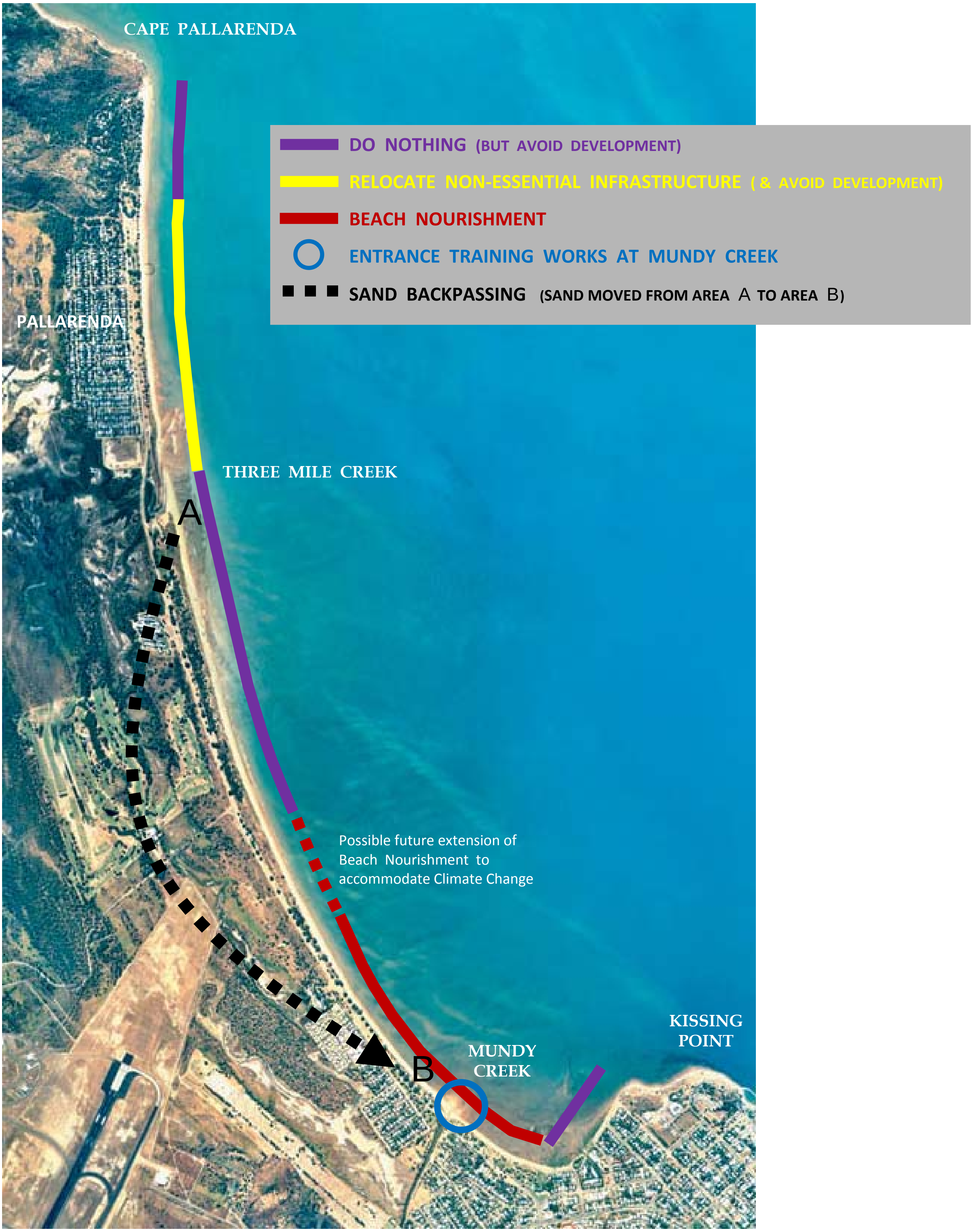

Figure 6.6 : Recommended Shoreline Erosion Management Strategy

6.7 Estimated Costs

The estimated costs associated with the recommended strategies under this Shoreline Erosion Management Plan are summarised below.

At this early stage these estimates must be considered as indicative only since no detailed design has been undertaken. They have been based on an approximation of sand volumes for initial beach nourishment to provide a buffer to a Coastal Defence Line on the general alignment previously shown in Figure 6.2.

SEMP component	Cost	Annual Cost
Project Design and Approvals		
Design of trial training walls at Mundy Creek entrance	$15,000	
Design of initial beach nourishment	$5,000	
Obtain appropriate approvals	$20,000	
Project Monitoring		
Establish & undertake initial pre-project surveys	$18,000	
Annual survey of all beach transects		$12,000
Additional bi-annual survey of priority area		$8,000
Beach Nourishment		
Implementation of trial training walls at Mundy Creek	$175,000	
Operation of trial for training walls (assume 2 years duration)	$30,000	
Implementation of initial beach nourishment :		
for 50 year ARI immunity	*$3,470,000*	
for 100 year ARI immunity	*$4,870,000*	
for 200 year ARI immunity	*$5,470,000*	
for 500 year ARI immunity	*$6,470,000*	
for 1,000 year ARI immunity	*$8,770,000*	
Implementation / maintenance of dune management program	$50,000	$10,000
On-going renourishment by conventional earthmoving equipment		$60,000
Convert to permanent training walls at Mundy Creek	$230,000	
Maintenance of training walls		$10,000
Totals (for various initial beach nourishment options)		
for 50 year ARI immunity	**$4,013,000**	**$100,000**
for 100 year ARI immunity	**$5,413,000**	**$100,000**
for 200 year ARI immunity	**$6,013,000**	**$100,000**
for 500 year ARI immunity	**$7,013,000**	**$100,000**
for 1,000 year ARI immunity	**$9,313,000**	**$100,000**

7 IMPLEMENTATION OF THE STRATEGY

7.1 Approvals Process

The planning and legislative framework associated with coastal protection on Queensland's shorelines is discussed in Appendix A of this Shoreline Erosion Management Plan. The specific approvals that are likely to be required under the recommended strategies of this Shoreline Erosion Management Plan are shown below.

LEGISLATIVE / PLANNING INSTRUMENT	LIKELY	POSSIBLE	UNLIKELY
State Coastal Management Plan	✓		
Great Barrier Reef Marine Park Act 1975		✓	
Queensland Marine Parks Act 2004	✓		
Queensland Environmental Protection Act 1994	✓		
Sustainable Planning Act 1997	✓		
Townsville Planning Scheme	✓		
Aboriginal Cultural Heritage Act 2003		✓	
Nature Conservation Act 1992	✓		
Fisheries Act 1994	✓		
Vegetation Management Act 1999			✓
Local Government Act 1993		✓	
Environmental Protection and Biodiversity Conservation Act 1999	✓		
Land Act 1994	✓		

7.2 Implementation Plan

As noted in Section 6, the recommended future management of the Rowes Bay / Pallarenda shoreline incorporates a number of strategies along specific lengths of the foreshore, these being:

- Beach Nourishment
- Do Nothing
- Planned Retreat

Direct intervention by Beach Nourishment represents the only management strategy requiring comment with regard to timeframes for implementation. As the name implies, the Do Nothing strategy requires no timeframe.

7.2.1 Planned Retreat

The Planned Retreat strategy applies to relocating non-essential community amenities located north of Three Mile Creek further inland beyond the threat of erosion - it does not affect any private property in Pallarenda. This relocation of non-essential infrastructure is recommended once climate change influences become more apparent in coming decades.

The exception to this is the more immediate threat to important power transmission lines just to the north of Three Mile Creek. Given that its loss is likely during cyclones of 50 year ARI or more, there is considerable merit in power distribution authorities relocating this section of power lines further inland beyond such erosion influences. Deferring this relocation only increases the likelihood of loss as climate change influences evolve. Consequently it is recommended that Council develops a consultation plan with Ergon as a step towards implementing this strategy of Planned Retreat at this particular location.

7.2.2 Beach Nourishment

The implementation of the Beach Nourishment strategy can be tailored to suit available funding. Ideally the initial nourishment to provide the erosion buffers necessary to provide immunity for the Design Event would be undertaken in a single campaign as soon as possible.

However a staged approach whereby the buffers are created over a number of (possibly annual) nourishment campaigns might offer a more financially viable implementation. Under such an approach, the annual renourishment requirement of 4,500 m^3/year would need to be included in the volumes of each progressive sand placement.

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APPENDIX A

- **PLANNING & LEGISLATIVE FRAMEWORK**

A. PLANNING AND LEGISLATIVE FRAMEWORK

To ensure that the proposed management options are consistent with planning and legislative requirements of Commonwealth, State and Local governments it is necessary to have appropriate regard for the full range of legislation that controls activities in the coastal zone.

This appendix of the Shoreline Erosion Management Plan outlines the relevant planning and legislative framework that will influence the development, assessment and implementation of appropriate erosion mitigation measures on the Rowes Bay / Pallarenda shoreline. The specific requirements for the recommended strategy developed by this Shoreline Erosion Management Plan are discussed in Section 7 relating to the implementation of that strategy.

A.1 Queensland Coastal Legislation and Planning Instruments

The Queensland Government has developed a coastal management framework which includes specific legislation, policies and support tools to direct sustainable planning, development and management decisions. The *Coastal Protection and Management Act 1995 (Qld)* (hereafter referred to as, the Coastal Act) provides a comprehensive framework for the coordinated management of a diverse range of coastal resources and values in the coastal zone.

Fundamental tools to implement the Coastal Act are the State Coastal Management Plan and regional coastal management plans. The *Coastal Protection and Management Act 1995 (Qld)* provides for the appropriate management of Queensland's coastal zone. The Act recognises the diverse range of resources and values of:

"*coastal waters and all foreshore areas in which there are physical features, ecological or natural processes or human activities that affect, or potentially affect, the coast or coastal resources.*"[7]

In 2001 the State Coastal Management Plan was developed in accordance with the requirements of the Coastal Act and serves as a statutory instrument under that Act.

[7] s3 Coastal Protection and Management Act 1995 (Qld)

A.1.1 State Coastal Management Plan

The *State Coastal Management Plan* was reviewed in 2009 and at the time of preparing this Shoreline Erosion Management Plan, that review has been completed and a *Draft State Coastal Management Plan* is currently in the public domain for review and comment. Until such time as the public review and subsequent drafting of a new Queensland Coastal Plan is completed, the existing State Coastal Management Plan remains in force. Once the new Queensland Coastal Plan has been finalised and approved, the current State Coastal Management Plan will be repealed.

This Shoreline Erosion Management Plan will provide strategic direction for the sustainable management of the Rowes Bay / Pallarenda shoreline, and ensure shoreline protection management actions are consistent with the State Coastal Management Plan. A 50 year planning horizon is applied to such considerations.

In particular, the Shoreline Erosion Management Plan will provide a non-statutory shoreline erosion management strategy that will detail the existing and likely future sediment transport processes, erosion trends and geomorphological processes. It will describe and compare management options for coastal erosion - in terms of environmental sustainability, community priorities and cost effectiveness.

Queensland's State Coastal Management Plan (SCMP) aims to protect and manage the state's coastal resources and values by providing an overarching framework for coastal management. It is founded on the following ten management topics:

- coastal use and development
- physical coastal processes
- public access to the coast
- water quality
- indigenous traditional owner cultural resources
- cultural heritage
- coastal landscapes
- conserving nature
- coordinated management
- research and information

Specific principles and policies have been developed within each of these issues so as to achieve defined coastal management outcomes. These topics are considered by the Shoreline Erosion Management Plan for Rowes Bay / Pallarenda when assessing appropriate erosion management options.

The State Coastal Management Plan provides five policies under the topic *"Physical Coastal Processes"* that relate to the management of coastal erosion. These being:

Policy 2.2.1 Adaptation to climate change;
Policy 2.2.2 Erosion prone areas;
Policy 2.2.3 Shoreline erosion management;
Policy 2.2.4 Coastal hazards; and
Policy 2.2.5 Beach protection structures.

Comment on these policies and their relevance to the preparation of this Shoreline Erosion Management Plan are offered below.

A.1.1.1 Policy 2.2.1 Adaptation to climate change

Consideration must be given to the local implications of possible future climate change, including sea level rise and increased climatic variability. When developing the Shoreline Erosion Management Plan for Rowes Bay / Pallarenda a hierarchical approach must be applied as follows:

- *Avoid* - to focus on locating new development in areas not vulnerable to the impacts of climate change;
- *Planned retreat* - to focus on systematic abandonment of land, structures and ecosystems in vulnerable areas;
- *Accommodate* - to focus on continued occupation of coastal areas but with adjustments such as altered building design;
- *Protect* - to focus on the defence of vulnerable areas, population centres, economic activities and coastal resources.

When assessing potential erosion mitigation options for the Rowes Bay / Pallarenda foreshore this ranking of preferred approaches to future climate change is applied.

A.1.1.2 Policy 2.2.2 Erosion prone areas

Under this policy the State Coastal Management Plan recognises the important role of erosion prone areas as natural coastal buffers. Wherever practical, erosion prone areas are to remain undeveloped - except for temporary or relocatable structures.

In areas that have already been developed and are now in designated erosion prone areas, future use should not be at a scale or intensity greater than the existing development. Nor should such future development extend further seaward than the current alignment of buildings or services.

Retreat from the erosion prone area is the preferred strategy, but it is acknowledged that coastal protection works may be necessary to defend existing land uses and infrastructure. In such circumstances intervention by way of physical barriers (such as seawalls) should only be considered as a last resort where the threat to public safety or property is immediate and the infrastructure is not expendable. Coastal defence works are not to adversely affect coastal processes and environmental values.

Where erosion mitigation measures are required, the State Coastal Management Plan specifies the following hierarchy of actions (in order of decreasing preference):

- Remove, relocate or resume development from the threatened location; or
- Undertake beach nourishment to increase the width of the erosion buffer; or
- Push sand up from the intertidal zone onto the beach so as to provide short-term protection from erosion influences, provided such work will have only minor and temporary impacts on intertidal ecology; or
- Construct groynes or offshore breakwaters to impede longshore sand transport and increase the accumulation of sand on the eroding coast - subject to acceptable impacts on downdrift shoreline; or

- Construct a revetment / seawall as a physical barrier to permanently stop erosion and protect development; provided that such works are located as far landward as possible so as not to isolate important sand reserves from the active beach system - again subject to acceptable impacts on downdrift shoreline.

When assessing potential erosion mitigation options for the Rowes Bay / Pallarenda foreshore this ranking of preferred measures is applied.

A.1.1.3 Policy 2.2.3 Shoreline erosion management

Areas that are to be considered as priorities for erosion management must be taken into account when considering:

- applications for renewal or conversion of leases for leasehold land on the coast;
- issuing approvals for coastal protection works; and
- assessing proposals for funding proposals for coastal management programs.

A.1.1.4 Policy 2.2.4 Coastal hazards

Coastal hazards on the Rowes Bay / Pallarenda foreshore not only include the threat of erosion but also damage and inundation by storm tides. Under the State Coastal Management Plan wherever possible areas identified as being at risk of coastal hazards should remain undeveloped. In developed areas that are vulnerable to coastal hazards, further development must address vulnerability to storm tide inundation - including protection of evacuation routes.

Areas within the Rowes Bay / Pallarenda coastal precinct that are vulnerable to storm tide effects have been identified in the *Townsville - Thuringowa Storm Tide Study* (GHD, 2007). Appropriate erosion mitigation options in these inundation prone areas will be considered when preparing this Shoreline Erosion Management Plan.

A.1.1.5 Policy 2.2.5 Beach protection structures

The State Coastal Management Plan states under this policy that the construction of beach protection structures (such as seawalls) will only be approved where:

- there is a demonstrated need in the public interest; and
- comprehensive investigation has been carried out and it can be demonstrated that:
    - there would not be any significant adverse impact on longshore transport of sediments; and
    - there would be no increase in coastal hazards for neighbouring foreshores.

A.1.2 Regional Coastal Management Plan

A requirement under Section 2.2.3 of the State Coastal Management Plan is that *Regional Coastal Management Plans* (RCMP) identify any priority areas for erosion management. Regional plans are required to be consistent with and/or set more detailed requirements compared with the State Coastal Management Plan (SCMP). RCMP's implement the SCMP at the regional level and also identify key coastal sites at the regional level that require specific management interventions.

The SCMP identifies eleven coastal regions in Queensland. The Rowes Bay / Pallarenda shoreline is included in Dry Tropical Coast Region. However work on the preparation of a RCMP for this area has halted whilst the review of the SCMP has been underway. However it is now understood that the regional plan will no longer be prepared (Queensland Department for Premier and Cabinet, 2009; Webbe & Weller, 2009).

A.2 Great Barrier Reef Marine Park Act

The Great Barrier Reef Marine Park Act 1975 is the primary Act in respect of the Great Barrier Reef Marine Park. It includes provisions which:

- Establish the Great Barrier Reef Marine Park itself;
- Establish the Great Barrier Reef Marine Park Authority (GBRMPA), a Commonwealth authority responsible for the management of the Marine Park;
- Provide a framework for planning and management of the Marine Park, including through zoning plans, plans of management and a system of permissions ;
- Prohibit mining operations (which includes prospecting or exploration for, as well as recovery of, minerals) in the Great Barrier Reef Region (unless authorised to carry out the operations by a permission granted under the Regulations, for the purpose of research or investigations relevant to the conservation of the Marine Park);
- Require compulsory pilotage for certain ships in prescribed areas of the Great Barrier Reef Region;
- Provide for regulations, collection of Environmental Management Charge, enforcement etc.

As a consequence of the findings of a review of the Act in 2006, amendments to the Act were made by the Australian Government in 2008, which came into force in two stages in 2008 and 2009. The purpose of the amendments was to update the Act, and better integrate it with other legislation in order to provide an effective framework for the protection and management of the Marine Park.

Within the study area of this Shoreline Erosion Management Plan, the Park's landward boundary is along the low water mark.

Zoning plans prepared in accordance with the *Great Barrier Reef Marine Park Act* define activities that may be undertaken within specific zones. In the vicinity of Rowes Bay / Pallarenda the adjoining area of the Park is predominantly Conservation Park (Yellow) Zone.

When assessing erosion management strategies for this Shoreline Erosion Management Plan, the permissible activities within this zone must be taken into account. Consideration of other zones in the Park may be required if sand sourcing or other activities associated with erosion mitigation for Rowes Bay / Pallarenda are undertaken within those zones.

A permit for certain activities within the Park is required under the Act and its regulations; *Great Barrier Reef Marine Park Regulations 1983* and the *Great Barrier Reef Marine Park Zoning Plan 2003*.

A.3 Queensland Marine Parks Act

In Queensland, the State's main legislation and regulation pertaining to marine parks are the *Marine Parks Act 2004 (Act)* and the *Marine Parks Regulation 2006 (Regulation)*. These are designed to complement the Commonwealth's *Great Barrier Reef Marine Park Act 1975*, indeed the zoning plan for the State Marine Park is the same as the zoning plan for the Great Barrier Reef Marine Park.

The *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 (Zoning Plan)* defines the zoning arrangements, including the objectives for each zone, the allowable and prohibited activities, and those that require a marine park permit.

Whereas the landward boundary of the Great Barrier Reef Marine Park is low water mark, the landward boundary of the State Marine Park is the high water mark. The Department of Environment and Resource Management defines high water as:

"…high water means the mean height of the highest high water at spring tide." [8]

When considering erosion mitigation strategies for this Shoreline Erosion Management Plan, it is likely that any works or activities below the high water line (and therefore within the State Marine Park) will require approval under the State *Marine Parks Act 2004*.

A.4 Queensland Environmental Protection Act

The primary objective of the *Environmental Protection Act 1994* is to safeguard Queensland's natural environment whilst allowing for development in an ecologically sustainable manner. It is administered by the Department of Environment and Resource Management.

The Act establishes a general environmental duty that requires any erosion mitigation works on foreshores to be undertaken such that all reasonable and practical steps are taken to prevent or minimise environmental harm.

Environmentally relevant activities (ERAs) are authorised by an administering authority. Schedule 2 of the *Environmental Protection Regulation 2008* lists all ERAs. Included in that schedule are "Extractive and screening activities" of which ERA 16 (relating to extracting material from the bed of any State waters) may be relevant to strategies developed by the Shoreline Erosion Management Plan.

Specific environmental protection policies (EPPs) currently exist and others may be prepared under the Act to protect or enhance the environment. The EPP most relevant to considerations of erosion mitigation measures under this Shoreline Erosion Management Plan is the *Environmental Protection (Water) Policy 2009*.

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[8] Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004 "*Schedule 11 Dictionary*" p 132.

The intent of this policy is to achieve ecologically sustainable development with regard to Queensland waters - including those of coastal ecosystems. It provides a framework for appropriate management of environmental impacts by identifying environmental values and presents guidelines to protect and maintain the State's water environment.

A.5 Sustainable Planning Act

New planning and development laws recently came into effect in Queensland with *the Sustainable Planning Act 2009* replacing the *Integrated Planning Act 1997*. This new legislation seeks to achieve sustainable planning outcomes through:

- managing the process by which development takes place;
- managing the effects of development on the environment;
- continuing the coordination and integration of local, regional and state planning.

Development approval of foreshore protection works may be required under the Integrated Development Assessment System (IDAS). Specifically the instruments may include but not be limited to:

- *Coastal Protection and Management Act*
- *Fisheries Act*
- State Planning Policy 2/02 (SPP 2/02) - *Planning and Managing Development Involving Acid Sulfate Soils*.
- *Vegetation Management Act 1999*.

A.6 Townsville City Plan 2005

The *Townsville City Plan* aims to implement the vision for the City to achieve ecologically sustainable development. It provides a robust, responsive and transparent environment for simplified development assessment reflecting the aspirations of the local community.

At the time of preparing this Shoreline Erosion Management Plan, a new planning scheme for the entire local government area is in the process of being created. This will be in line with information provided by Queensland's Department of Infrastructure and Planning on how new planning schemes are to be formatted and what they are to include. Areas that have been identified by Council as needing to be addressed include climate change and impacts of natural hazards - and in particular how they relate to existing coastal communities, infrastructure and future development in coastal areas.

Until such time as that new scheme is finalised, the current planning scheme remains in force.

The erosion mitigation strategies recommended in this Shoreline Erosion Management Plan will need to be appropriately designed during subsequent implementation phases to ensure that the proposed works comply with the relevant assessment criteria in the Specific Outcomes of relevant codes.

A.7 Land Act

The Land Act applies to all land in Queensland - including that below high-water mark. Its administration requires that land to which this Act applies must be managed for the benefit of the people of Queensland by having regard to the following principles:

- Sustainability - Requires sustainable resource use and development so as to ensure that existing needs are met, and the State's resources are conserved for the benefit of future generations.
- Evaluation - Requires that land evaluation is based on the appraisal of land capability and the consideration and balancing of the different economic, environmental, cultural and social opportunities and values of the land.
- Development - Requires allocation of land for development in the context of the State's planning framework, and applying contemporary best practice in design and land management. When land is made available for development, it is allocated to persons who will facilitate its most appropriate use; and that use supports the economic, social and physical wellbeing of the people of Queensland.
- Community purpose - If land is needed for community purposes, the retention of such land is to be in a way that protects and facilitates the community purpose.
- Protection - Requires the protection of environmentally and culturally valuable and sensitive areas and features.
- Consultation - Requires consultation with community groups, industry associations and authorities as an important part of any decision making process.
- Administration - Requires that administration of the Act is consistent, impartial, efficient, open and accountable. A market approach is applied in land dealings, adjusted when appropriate for any community benefits arising from the dealing.

Erosion mitigation measures proposed by this Shoreline Erosion Management Plan on Unallocated State Land and other State Land will require a resource entitlement permit where there are direct implications (such as sand extraction activities) or indirect implications (e.g. impact on access). These provisions are also covered through the IDAS process.

A.8 Indigenous Cultural Heritage Act

Legislation exists under a number of Commonwealth and State Acts to protect Aboriginal and Torres Strait Islander cultural heritage. To ensure compliance with the *Aboriginal Cultural Heritage Act 2003*, when implementing erosion mitigation works Council must take all reasonable and practical measures to ensure that such works do not harm Aboriginal cultural heritage. This may include:

- following the statutory "duty of care" guidelines, which may require consultation with the relevant Aboriginal party; or
- development and approval of a Cultural Heritage Management Plan.
- The State's *Native Title (Queensland) Act 1993* and the Commonwealth's *Native Title Act 1993* should both be considered when planning foreshore protection works.

A.9 Nature Conservation Act

The *Nature Conservation Act 1992* maintains biological diversity and ecologically sustainable development within areas established and managed under the Act. The Regulations under the Act that are of relevance to the Shoreline Erosion Management Plan are as follows:

- *Nature Conservation (Protected Areas) Regulation 1994* : which nominates declared protected areas such as National Parks and conservation parks - such as the Townsville Town Common Conservation Park which is in the study area covered by this Shoreline Erosion Management Plan;
- *Nature Conservation (Wildlife) Regulation 2006* : which identifies management intent and principles associated with certain significant species. It is read in conjunction with:
- Nature Conservation (Administration) Regulation 2006.

Any disturbance of areas so as to provide access for implementing erosion mitigation works will require assessment as to whether the area is an “essential habitat” for fauna species listed under the Act. For example, such species may include nesting habitats for listed sea turtle species if these are found to be in the area.

A.10 Fisheries Act

The *Fisheries Act 1994* provides for the management, use, development and protection of fisheries resources and fish habitats throughout Queensland. Approvals are required for marine plant disturbance, works in a declared fish habitat area or constructing or raising a waterway barrier.

Mangroves & Marine Plants

Tidal inundation of a coastal area generally indicates the presence of marine plants on a site protected under Section 8 of the *Fisheries Act 1994*. The definition of the term Marine Plant includes the following:

- A plant (a tidal plant) that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing, or fallen. Material of a tidal plant, or other plant material on tidal land.

- A plant, or material of a plant, prescribed under a regulation or management plan to be a marine plant.

Areas within and adjoining the area covered by this Shoreline Erosion Management Plan contain vegetation that are protected in accordance with Section 123 of the *Fisheries Act*; and as such any disturbance (trimming or removal) to these areas would require approval from the Department of Employment, Economic Development and Innovation (DEEDI).

Limited removal or trimming works on mangroves and associated marine plants may be undertaken for maintenance works on existing lawful structures or works on farm drains as per Marine Plant Code 02 and 03. However, any removal or trimming required for new construction works directly related to a development will require a development approval.

Any activities associated with the implementation of the Shoreline Erosion Management Plan that may require the removal or harm to marine plants will require an approval from the DEEDI.

A.11 Local Government Act

The high water mark is the seaward extent of Townsville City Council's jurisdiction under the *Local Government Act 2009*. Nevertheless the Act enables local government authorities to obtain specific jurisdiction from the State with regard to the beach between the high and low water lines for special purposes - typically for beach nourishment.

Local government authorities control land use and activities under the local planning scheme (via the *Sustainable Planning Act 2009*) and Local Laws (via the *Local Government Act 2009*).

With regard to coastal management, local government has responsibilities relating to:

- land use control;
- recreational planning;
- management of local reserves;
- environmental protection and rehabilitation;
- monitoring.

A.12 Vegetation Management Act

The purpose of the *Vegetation Management Act* 1999 (VMA) is to regulate clearing of remnant vegetation on freehold and leasehold land by:

- Preserving remnant endangered, of concern and not of concern Regional Ecosystems and vegetation in areas of high nature conservation value; and
- Considering the preservation of vegetation in areas vulnerable to land degradation.

The definition of the term *Vegetation* under the Act includes the following:

- Native tree; or
- Native plant, other than a grass or mangrove.

Since the remnant vegetation identified within the study area of the Shoreline Erosion Management Plan comprises marine plants and tidal grasses it is not consistent with the definition of vegetation under the Act. Consequently no approvals are likely to be required under the VMA.

A.13 Environment Protection and Biodiversity Conservation Act

The Commonwealth Department of the Environment, Water, Heritage and Arts administers the *Environment Protection and Biodiversity Conservation Act 1999.* Referral to the Department is required for actions that have (or are likely to have) a significant impact on a matter of national environmental significance.

These include;

- World Heritage properties
- National Heritage places
- Wetlands of international importance
- Migratory species
- Nationally threatened species and ecological communities
- The Commonwealth marine area
- Nuclear matters.

The issues potentially relevant to activities prescribed by the Shoreline Erosion Management Plan include the world and national heritage values of the Great Barrier Reef World Heritage Area; migratory species such as bird species listed under international agreements (JAMBA and CAMBA); and nationally threatened species and ecological communities.

If erosion mitigation works recommended by this Shoreline Erosion Management Plan are declared a "*controlled action*", approval will be required under the Act before works can commence. The Commonwealth and Queensland governments have a bilateral agreement under the Act that controlled actions requiring environmental impact assessment (EIA) may be assessed in accordance to the EIA processes under Queensland law.

APPENDIX B

- ASSESSMENT OF THE LOCAL MARINE ENVIRONMENT BY C&R CONSULTING

Rowes Bay

Much of Cleveland Bay (85%) is composed of soft-bottom benthic communities, and despite the large volume of work conducted on these communities, very little has been published and most is unavailable to the public (Kettle et al. 2002). Rowes Bay itself is also primarily characterised by soft-bottom environments, with a small seagrass bed and unconsolidated coral and sponge aggregations. Rowes Bay may have been affected by dredging sediment plumes over the past 20 years (Kettle et al. 2002).

The Rowes Bay intertidal and marine environment includes a small mangrove forest, a rocky shoreline, an estuarine creek, sandy flats and several rubbly reef areas (Figure 1), one of which includes a sponge garden on the seaward edge (TCC 2003). The area is shallow, with a very gentle gradient, and large areas are exposed at low tide, creating an extensive intertidal environment. This diversity of habitats is home to a high species richness of invertebrates, which in turn provide food for fish and marine reptiles at high tide, and birds and terrestrial vertebrates at low tide.

The small mangrove forest in Rowes Bay is composed of approximately 75 individual trees of the genera *Avicennia*, *Rhizophora* and *Ceriops* (Mabin 2002). A number of invertebrate species utilise this habitat, including a range of crustaceans and gastropods. The commercially important mud crab (*Scylla serrata*) is present in low abundance (TCC 2003). Extending seaward from the mangroves is a rocky / rubble shore. The rocky shore areas of Rowes Bay provide a complex habitat and shelter for a variety of organisms. Algal biomass is removed by a multitude of herbivorous mollusks, and the rocks themselves provide attachment points for sessile invertebrates such as barnacles and oysters (TCC 2003). The intertidal soft-sediment area follows the rocky zone and is characterised by a range of sediment sizes, from fine silt to coarse-grained sand. Invertebrate communities living within the sediments change according to their sediment type preferences. A small seagrass meadow was documented in the intertidal and subtidal areas of Rowes Bay and Pallarenda in 1996 and 2007, composed primarily of the species *Halophila spinulosa* and *H. ovalis* (Lee Long et al. 1996; Coles et al. 2007). A more recent survey differentiated three types of seagrass meadow: a small meadow off Rowes Bay composed of a dense stand of thin *Halodule uninervis* (~72 ha), a narrow band of moderate density thin *H. uninervis* extending along two-thirds of the Pallarenda foreshore (~56 ha), and a larger meadow of low density *Halophila spinulosa* and wide *H. uninervis* further offshore (~2538 ha)(Figure 2).

A sand spit has formed at the mouth of Three Mile Creek, along the Pallarenda foreshore. The ecological values of this sand spit are unknown. The three primary creeks in this area, namely Mundy Creek within Rowes Bay, three Mile Creek, and an unnamed creek at Cape Pallarenda are lined with mangroves. They are therefore of habitat value to estuarine organisms and of potential nursery value to fish and crustacean species that are commercially caught in the area. Any disturbance of these areas is likely to require a permit for the specific removal or disturbance of marine plants.

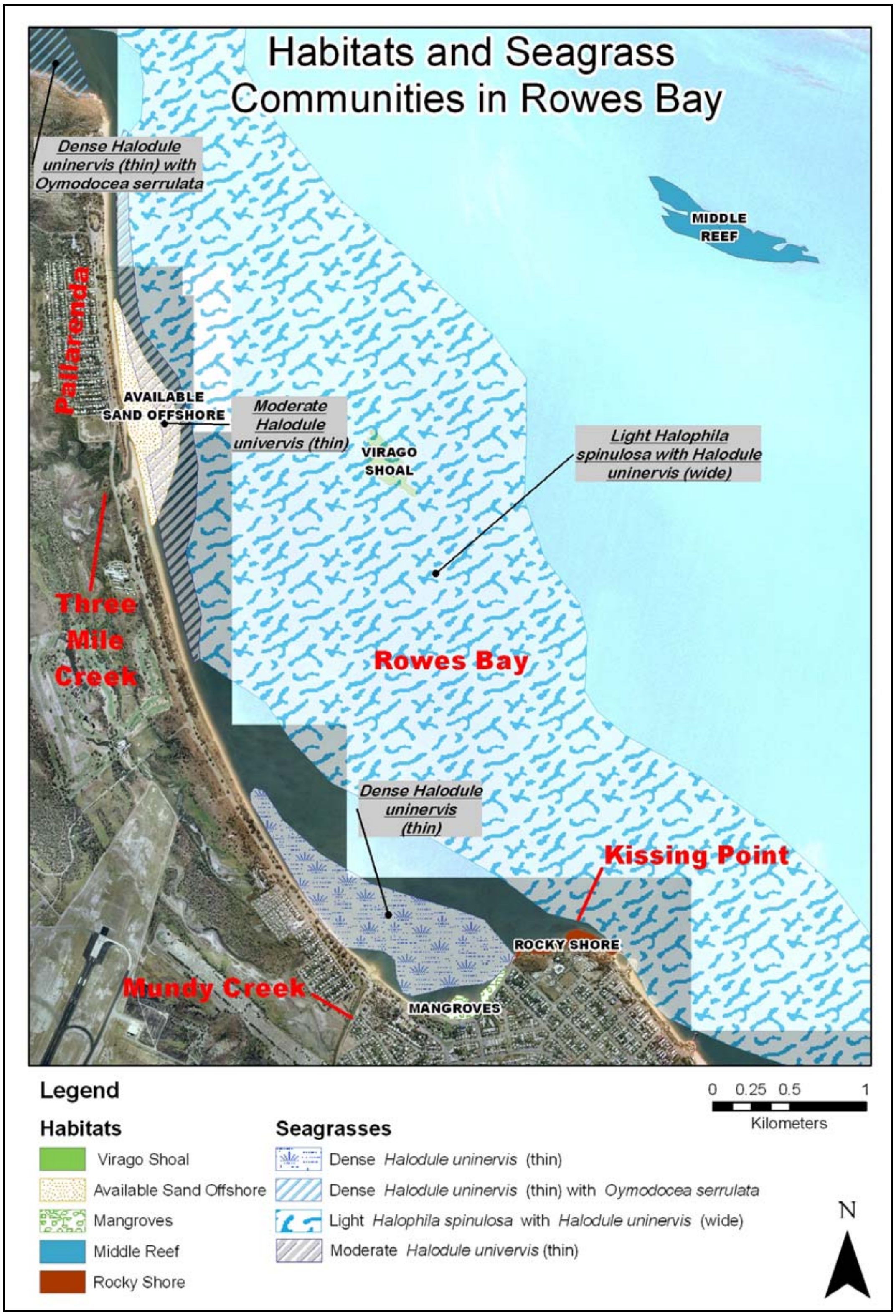

Figure 1. Distribution of major habitats in Rowes Bay and along the nearshore areas from Kissing Point to Cape Pallarenda.

Subtidal habitats off Rowes Bay are characterised by a patchwork of unconsolidated coral reef, sponge gardens, seagrass beds, algal beds and other aggregations of sessile benthic organisms such as ascidians and soft corals. These aggregations occur in scattered patches surrounding Virago Shoal and Middle Reef over a wide area. These habitats are home to a range of juvenile fish of commercial importance, including trout, snappers, trevallies and emperors. These benthic biota and the mobile animals that utilise them have never been systematically quantified in a publically available format. Estuarine crocodiles transit through the Cleveland Bay area on an irregular basis (QPWS 2007), and are occasionally sighted from Townsville beaches, including Rowes Bay (Johnson 2009). However, it is expected that crocodiles observed in Cleveland Bay are transient, and are unlikely to regularly use habitats around Townsville. There is anecdotal evidence of low numbers (1-2 per year) of sea turtles nesting in the area (QPWS, pers. comm.). Dolphins have also been recorded in waters off Rowes Bay (Parra et al. 2006).

The seagrass beds in the area are considered a very important food resource for juvenile and adult turtles, and for dugongs (Taylor & Rasheed 2008). Seagrasses are sensitive to changes in turbidity (especially to light attenuation resulting from increased dissolved particulate matter in the water column), sedimentation rates and hydrodynamics (Collier & Waycott 2009). Disturbances listed as affecting Cleveland Bay seagrass meadows include sediment deposition, reduced light, reduced salinity and increased nutrients. Possible causes of these changes include natural events such as river run-off and storms, and human-related such as dredging for ports and marinas (Collier & Waycott 2009). The Rowes Bay / Pallarenda seagrass meadows are also considered at high risk from a number of impacts and are likely to be vulnerable to any additional pressures, such as erosion (Grech et al. 2008), and is considered one of the key areas for continued monitoring (Rasheed et al. 2007). The landward extent of seagrasses along the Pallarenda foreshore is likely to be limited by the sediment types present. Seagrass growth is likely to be restricted to the finer marine sediments, whereby the landward extent is probably limited by the 'toe' of the beach where coarser sediments of terrestrial origin prevail. All seagrasses on this side of Cleveland Bay (as opposed to those growing adjacent to Cape Cleveland) are likely to be highly ephemeral, responding to changes in water chemistry and water quality brought about by the wet and dry seasons.

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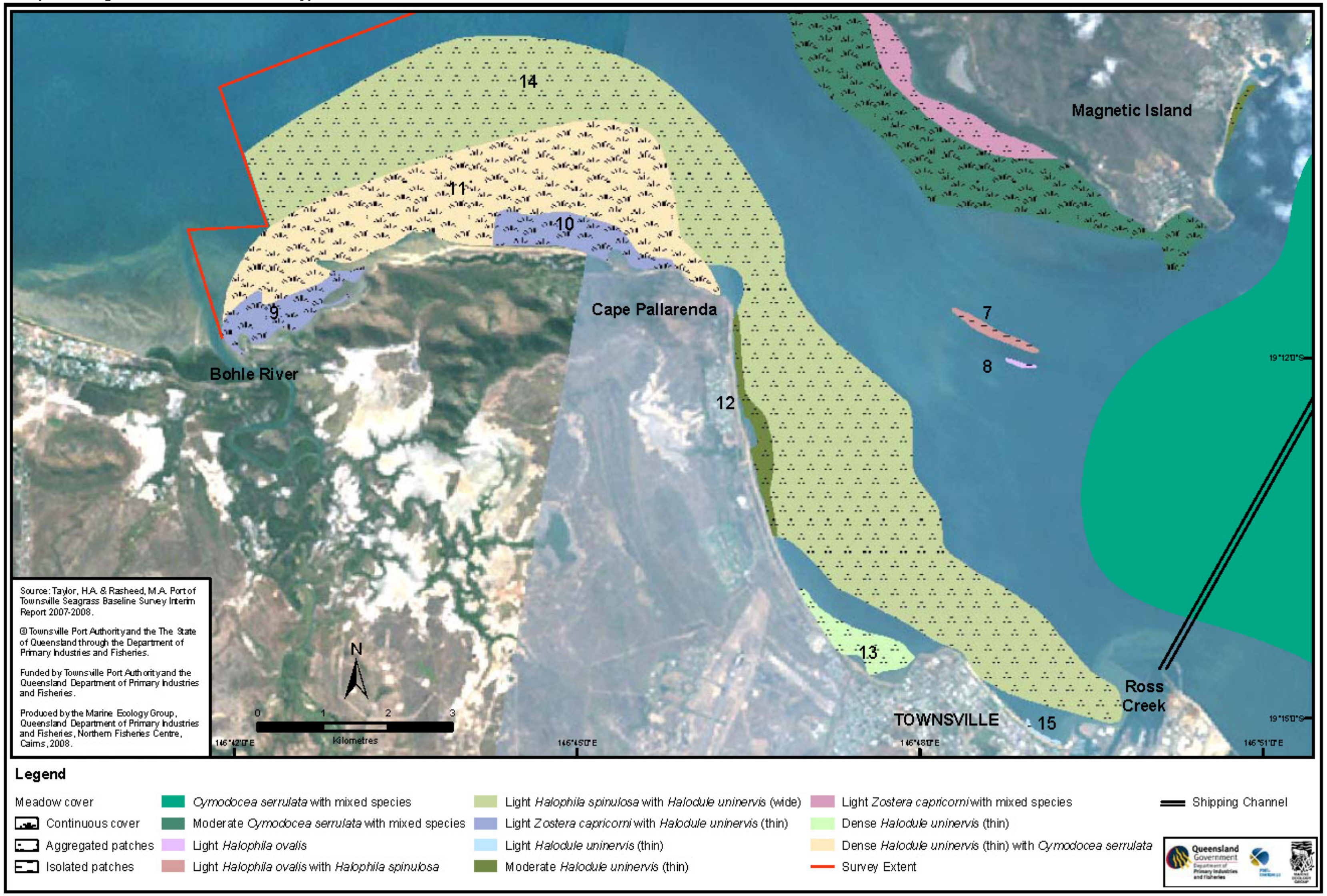

Figure 2. Extent and types of seagrass recorded off Rowes Bay and the Pallarenda foreshore in 2007-2008. Rowes Bay is identified with the number '13'. From Taylor and Rasheed (2008).

Coastal Zoning and Management Arrangements

Jurisdictionally, the Great Barrier Reef Marine Park (GBRMP) extends seaward from the mean low water mark. Most of the Pallarenda foreshore is zoned as a Conservation Park (Yellow) Zone (Figure 3). Recreational fishing is restricted to one line or rod with one hook per person. Extractive activities are generally permitted to a limited extent (see below: Beach Replenishment).

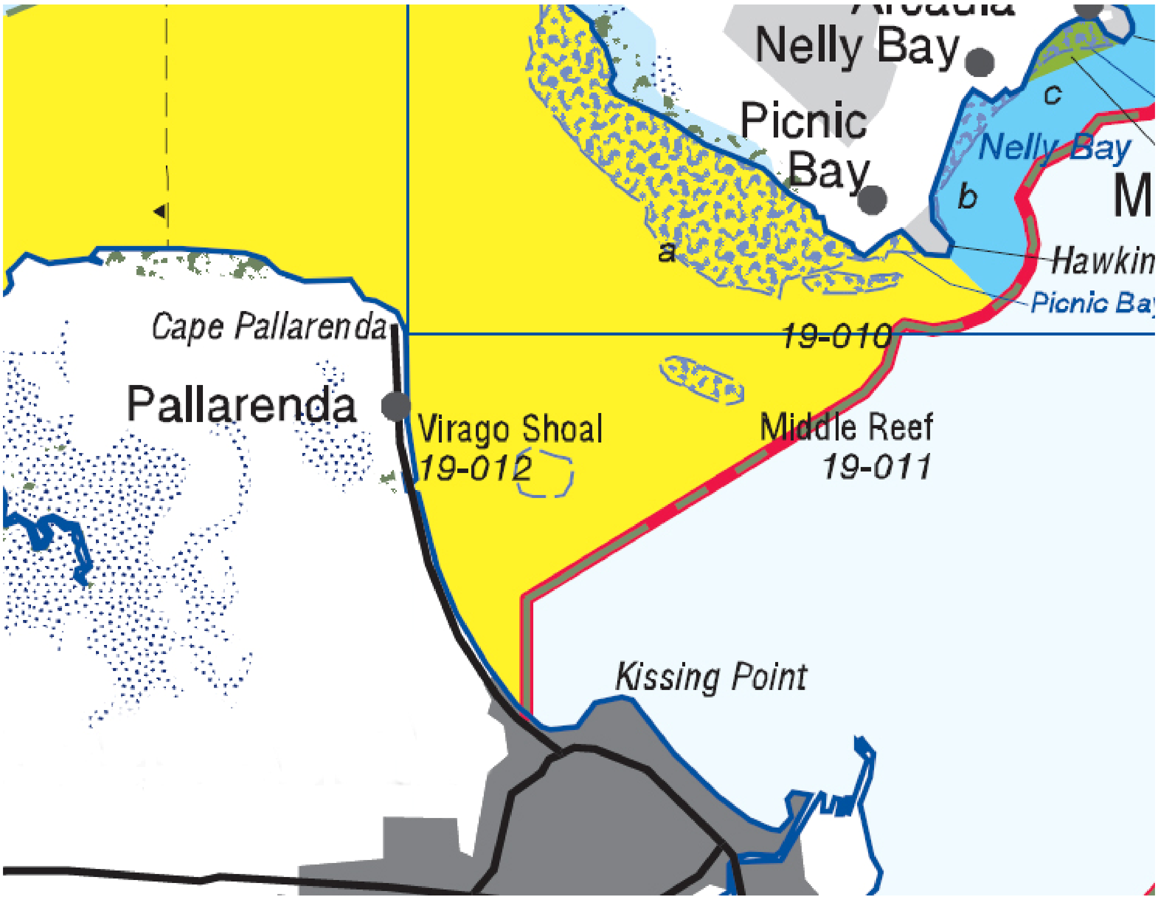

Figure 3. Excerpt of Townsville Zoning Map (GBRMPA) focusing on the Kissing Point – Cape Pallarenda foreshore. Most of this area is zoned Conservation Park (Yellow).

The Great Barrier Reef Coast Marine Park boundaries relevant to the Rowes Bay study area are defined by the *Marine Parks (Declaration) Regulation 2006* (the Regulation). The Regulation defines the landward boundary of the marine park as (Figure 4):

From where longitude 146°47.465' east intersects the coastal 20m line around the mainland

then northerly along the coastal 20m line around the mainland to where it intersects latitude 19°12.107' south

then west along latitude 19°12.107' south to where it intersects the mainland at high water

then generally northerly and westerly along the mainland at high water to where it intersects longitude 146°45.465' east

The Regulation defines the coastal 20m line as '*around the mainland, means the line every point of which is 20m seaward from the mainland at high water*'.

Figure 4. Landward boundary of Great Barrier Reef Coast Marine Park as defined under the *Marine Parks (Declaration) Regulation 2006*.

Potential impacts of proposed mitigating devices – sandshifter, seawalls, groynes, beach replenishment

Sandshifter – The description of the sandshifter used in Noosa claims that the system does not represent a net removal of sand or disturb marine life (Nankervis 2005). Its application on the Pallarenda foreshore is unlikely to cause any widespread damage to marine communities at the intake end. However, the discharge of sediment in Rowes Bay is likely to cause elevated turbidity levels within the embayment. Previous documents describing the system maintain that the sand emitted by the pump is clean and well sorted to avoid the generation of silt plumes (Nankervis 2005). A sandshifter is unlikely to impact significantly on dugongs or turtles in the area.

Seawalls and groynes – Constructing seawalls and groynes to capture longshore sand drift is unlikely to cause widespread ecological damage. While some studies exist on the sediment and fauna characteristics around established structures, no data exist for the immediate impact of constructing the structures and how these effects may change over time (Walker et al. 2008). Seawalls and groynes built perpendicular to the beach will cause accumulation on one side and some erosion on the other. Localised burial of nearshore seagrasses, macroalgae and infauna may result through the accumulation of sediment, and the structure is likely to cause changes in the benthic communities within a localised area (Walker et al. 2008). Given the low incidence of turtle nesting on this beach, seawalls and groynes are unlikely to have a large impact on nesting turtles. The expected footprint of sediment accumulation is likely to be small and therefore should not significantly affect food resources (seagrasses) of dugongs.

Beach replenishment – Widespread burial of nearshore benthic invertebrates and seagrasses near the beach is likely to result from beach replenishment. Construction equipment can crush beach invertebrates and disturb nesting turtles. The extent of this damage depends on the extent of the beach to be replenished. However, replenishment will need to be repeated periodically, as its benefits are temporary. The ability of the affected nearshore benthic communities to return to their pre-impact state is unknown, but the impact footprint is likely to be small.

Under the *Great Barrier Reef Marine Park Act 1975*, the Great Barrier Reef Marine Park Authority (GBRMPA) has no powers to grant permission for the extraction of minerals from the GBRMP. Due to the quantities of sand required for beach renourishment, the activity is classified as minerals extraction. A study on the availability of suitable sand directly outside the GBRMP found none in the vicinity of Cleveland Bay (Mabin 1991).

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APPENDIX C

- ASSESSMENT OF THE LOCAL TERRESTRIAL ENVIRONMENT BY C&R CONSULTING

Rowes Bay

For the purpose of this study, the extent of the terrestrial, coastal environment of Rowes Bay has been limited to areas of Land zones 1 and 2 and small areas of Land zone 3 that may be directly influenced by coastal erosion processes along Rowes Bay beach.

A Land Zone is a simplified geology/substrate landform classification for Queensland. Land Zones are used in Regional Ecosystem Classification, and are combined with details of different vegetation types within a particular bioregion to give a Regional Ecosystem description to a particular patch of vegetation, on a particular substrate in that bioregion. Regional ecosystems are defined by Sattler and Williams (1999) as 'vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil'.

The terrestrial values study area has been expanded to include terrestrial environments which may be impacted by coastal erosion processes (Figure 3). Land zones 1 and 2 include mangroves, saltpans, tidal flats and tidal beaches, coastal dunes and beach ridges, sand plains and swales, lakes and swamps enclosed by dunes. Land zone 3 comprises alluvial systems, including floodplains, alluvial plains, alluvial fans, terraces, levees, swamps, channels, closed depressions and fine textured palaeo-estuarine deposits. The terrestrial environment extends approximately 2km inland from the Rowes Bay foreshore. A total of seven regional ecosystems occur within this area (Table 4).

Figure 3: Rowes Bay terrestrial values study area, overlaid onto the original Rowes Bay study area plan.

The foreshore of Rowes Bay, subject to salt-laden winds, comprises a moderately sloping, highly modified foredune mapped as non-remnant vegetation, with elements of remnant herbland and grassland that are quite dense in areas. Some *Casuarina* open-forest to woodland remnants consistent with the 'of concern' Regional Ecosystem 11.2.2 occur along the 10km stretch of foreshore, and along the eastern side of Cape Pallarenda. Other scattered trees or shrubs also occur along the foreshore. Several large Banyan Figs (*Ficus benghalensis*) occur along the foreshore parkland (Figure 4). These historical trees hold aesthetic and social value, and must be protected from coastal processes including beach erosion. A number of introduced and invasive plant species have also established along the foredune.

Figure 4: Location of Banyan Figs along the Rowes Bay / Pallarenda foreshore parkland.

Anecdotal evidence suggests that marine turtles, including the green turtle (*Chelonia mydas*) nest above high water mark along Rowes Bay beach (Refer Marine Biodiversity Values), and a number of sea birds and shorebirds, including some threatened species such as the little tern (*Sterna albifrons*) and the beach stone curlew (*Esacus neglectus*) are known to occur along the beach (Table 5). A number of migratory species listed under various international treaties, including JAMBA and CAMBA are also known to occur or likely to occur in the area (Table 6).

In addition to the environmental value of Rowes Bay, the foreshore holds much social value for Townsville residents and visitors alike. A number of public parklands and associated infrastructure have been established along the foreshore, including car parks, barbeque areas and picnic facilities. Rowes Bay also provides one of a limited number of dog-friendly beaches in Townsville, and is frequented by many people on a daily basis.

Directly behind the foredune, a bitumen bicycle path runs parallel to Heatleys Parade and Cape Pallarenda Road, traversing the coastal dune from Kissing Point to Cape Pallarenda. This road and related infrastructure provide sole access to the suburb of Pallarenda, the Rowes Bay Golf Course, Rowes Bay Caravan Park and the Townsville Town Common Conservation Park. This infrastructure currently serves as a linear disturbance affecting the zonation of coastal vegetation, preventing tertiary successional species from gaining any foothold on areas to the east of the road.

A highly modified urban environment occurs on the coastal dune system immediately to the west of Rowes Bay foreshore. Residential development is expanding in this area, and an appealing mix of seaside (Rowes Bay) and mountainside (Cape Pallarenda) residential offerings has been described as the catalyst for accelerating and affluent residential development in the suburbs of both Rowes Bay and Pallarenda (http://en.wikipedia.org/wiki/Rowes_Bay,_Queensland).

Immediately to the west of the coastal fore dune a series of mangrove forests, saltpans and wetlands occur (Figure 5). These areas comprise the Regional Ecosystems 11.1.1, 11.1.2, 11.1.4 and 11.2.5 which are listed as not of concern under the *Vegetation Management Act 1999*, and small areas of Regional Ecosystem 11.2.2 listed as of concern. Marine couch wetlands dominated by almost pure stands of *Sporobolus virginicus* with a wide range of other species present as scattered individuals occur on supratidal flats which are often only inundated by highest spring tides. These wetland areas are in places dissected by small tidal channels. Small areas of mangrove forest also occur along or in close proximity to the small tidal creeks and channels.

Samphire forbland, bare mud-flats and saltpans also occur throughout this section. Similarly, these ares are only inundated during the highest spring tides.

A series of dunes and swales occur at the western extent of the Rowes Bay environment, comprising old beach ridge open-woodland, with *Melaleuca dealbata* dominating swale vegetation. This community is mapped as the Regional Ecosystem 11.2.5, listed as not of concern under the *Vegetation Management Act 1999*.

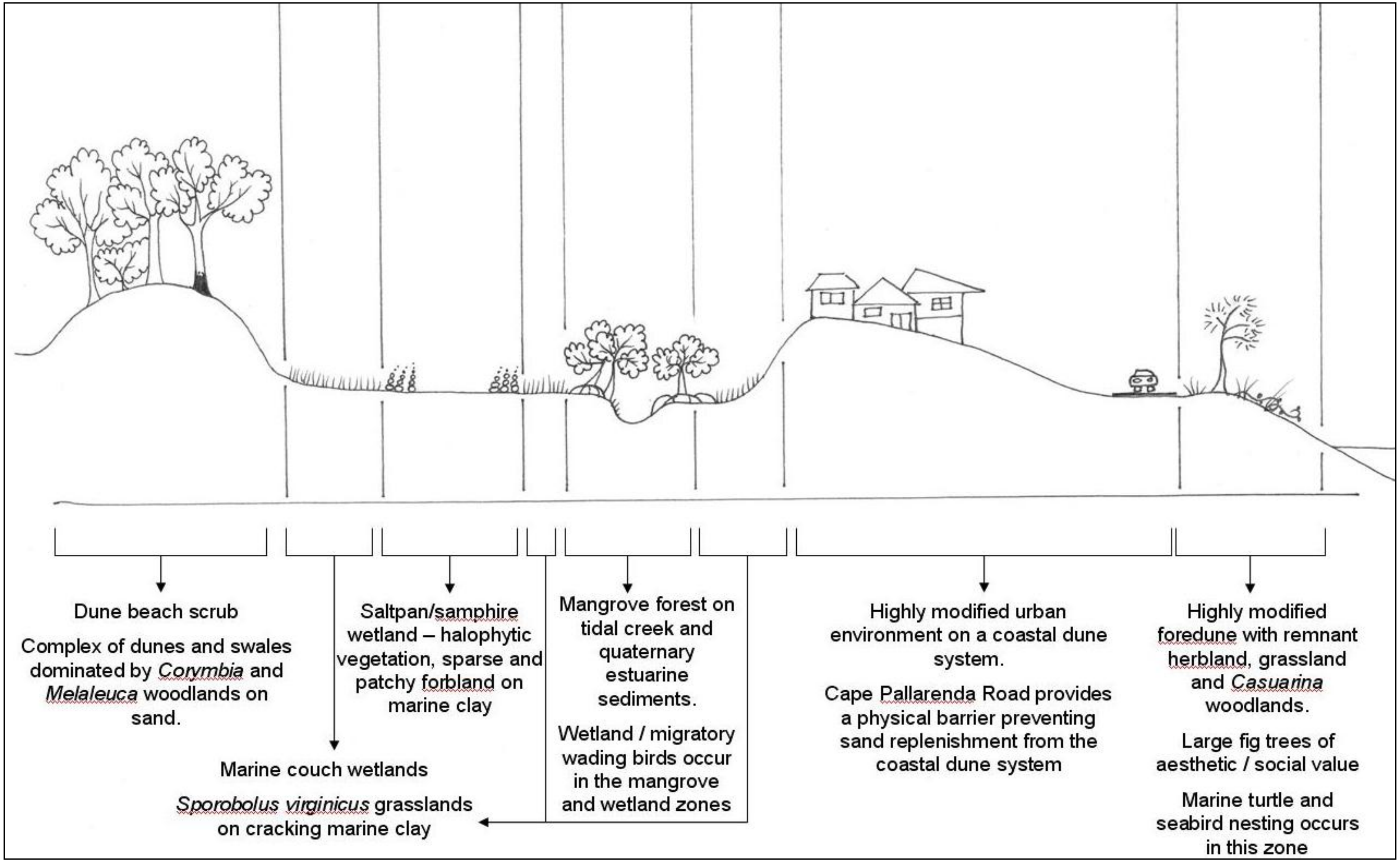

Figure 5: Simplified cross-section diagram of the terrestrial environment of Rowes Bay.

Table 1: Regional Ecosystems occurring in Rowes Bay

Regional Ecosystem No.	Status under the VMA 1999	Description
11.2.5	Not of concern	Corymbia-Melaleuca woodland complex of beach ridges and swales. Beach ridge woodland with *Melaleuca dealbata* in swales and *Corymbia tessellaris* woodland on Quaternary dune systems. Ridges: Usually a woodland to open forest of *Corymbia tessellaris* with occasional *Acacia crassicarpa*, *Cupaniopsis anacardioides*, *Pleiogynium timorense* and *Terminalia muelleri*. A sparse to dense shrublayer may include Acacia oraria, A. crassicarpa, *Planchonia careya*, *Alphitonia excelsa*, *Exocarpos latifolius*, *Senna surattensis* and *Dodonaea viscosa*. Groundlayer includes *Aphyllodium biarticulatum*, *Themeda triandra*, *Heteropogon contortus*, *Elionurus citreus*, *Aristida holathera*, *Cymbopogon refractus* and *Perotis rara*. Swales: Open forest of *Melaleuca dealbata*, (sometimes *M. leucadendra* or *M. viridiflora*), *Livistona drudei* or *L. decora*, with shrubs of *Pandanus spiralis*. Groundlayer of *Chrysopogon filipes*, *Imperata cylindrica*, *Sporobolus virginicus* and *Lepturus repens*. In some areas sedges are common, including *Cyperus javanicus*, *Fimbristylis dichotoma*, *F. polytrichoides*. Small vines are commonly present including *Cynanchum carnosum*, *Abrus precatorius*, and *Jasminum didymum*. Occurs on Quaternary undulating stabalised dunes with narrow linear depressions. Associated soils are generally well drained siliceous sands, swales with humic hydrosols Major vegetation communities include: 11.2.5a: Woodland to open forest of *E. tereticornis* x *platyphylla* with *Corymbia tessellaris* and occasional *M viridiflora* 11.2.5b: Palustrine wetland (e.g. vegetated swamp). Swales: Open forest of *Melaleuca dealbata*, (sometimes *M. leucadendra* or *M. viridiflora*), *Livistona drudei* or *L. decora*, with shrubs of *Pandanus spiralis*. Groundlayer of *Chrysopogon filipes*, *Imperata cylindrica*, *Sporobolus virginicus* and *Lepturus repens*. In some areas sedges are common, including *Cyperus javanicus*, *Fimbristylis dichotoma*, *F. polytrichoides*. Small vines are commonly present including *Cynanchum carnosum*, *Abrus precatorius* and *Jasminum didymum.*
11.2.2	Of concern	*Ipomoea pes-caprae* and *Spinifex sericeus* grassland ± *Casuarina equisetifolia*. *Casuarina equisetifolia* varies from clumps of open-forest, to woodland, to isolated trees. Other scattered trees or shrubs may be present including *Pandanus tectorius*, *Hibiscus tiliaceus*, *Terminalia muelleri*, *Alphitonia excelsa*, *Caesalpinia bonduc* and *Cupaniopsis anacardioides*. The ground layer is quite dense, and includes *Ipomoea pes-caprae*, *Cyperus pedunculatus*, *Bulbostylis barbata*, *Aphyllodium biarticulatum* (prostrate form), and *Spinifex sericeus*. Several species are prostrate, but the only climbing vine is *Cassytha pubescens*. Occurs on Quaternary coastal fore dunes and beaches. Major vegetation communities include: 11.2.2a: Grassland with *Heteropogon triticeus*, various other grasses and herbaceous spp. Includes narrow prostrate strandline vegetation. 11.2.2b: Complex of vegetation on Quaternary coastal dunes and beaches. Characterised by *Casuarina equisetifolia*, which varies in structure from clumps of open-forest, to woodland, to isolated trees. Other scattered trees

Regional Ecosystem No.	Status under the VMA 1999	Description
		may be present including *Pandanus tectorius*, *Hibiscus tiliaceus*, *Terminalia muelleri*, *Alphitonia excelsa*, and *Cupaniopsis anacardioides*. There may be a shrublayer of *Clerodendrum spp*., *Caesalpinia bonduc*, *Vitex trifolia* and/or *Scaevola taccada*. The ground layer usually includes *Eragrostis interrupta*, *Thuarea involuta*, *Eriachne triodioides*, *Spinifex sericeus*, Ip*omoea pes-caprae*, *Canavalia rosea* and *Cyperus pedunculatus*. There is usually a distinct zonation along the strandline. On gentle to moderately sloping foredunes and immediate swales, usually within 200 m of the high tide mark. Occurs in environments subject to salt-laden winds. Associated with exposed and loose aeolian (wind-transported) pale siliceous sands.
11.1.1	Not of concern	*Sporobolus virginicus* grassland on Quaternary estuarine deposits. *Sporobolus spp*. usually dominates pure stands although a wide range of other species may be present as scattered individuals including *Fimbristylis ferruginea*, *Cyperus victoriensis*, *C. scariosus*, and sometimes *Eleocharis spiralis*, *Mnesithea rottboellioides*, *Marsilea mutica*, *Cynanchum carnosum*, *Ischaemum australe*, *Cyperus polystachyos*, *Ceratopteris thalictroides* and *Leptochloa fusca*. Occasional emergent stunted mangroves, usually *Avicennia marina* or *Ceriops tagal*, may occur as isolated individuals or along small channels. There may also be a minor presence of salt-tolerant forbs such as *Suaeda australis*, *S. arbusculoides*, *Sarcocornia quinqueflora subsp. quinqueflora* or *Tecticornia australasica*. Occurs on supratidal flats which are often only inundated by highest spring tides. Often occurs on the landward side of intertidal flats; seaward margins irregularly inundated with tidal waters and dissected by small tidal channels. Formed from Quaternary estuarine sediments with deep grey or black and grey saline cracking clays with occasional mottling, minor gilgai occasionally present.
11.1.2	Not of concern	Samphire forbland or bare mud-flats on Quaternary estuarine deposits. Mainly saltpans and mudflats with clumps of saltbush including one or several of the following species; *Halosarcia spp*. (e.g. *Halosarcia indica subsp. julacea*, *Halosarcia indica subsp*. l*eiostachya*), *Sesuvium portulacastrum*, *Sarcocornia quinqueflora subsp. quinqueflora*, *Suaeda australis*, *S. arbusculoides*, *Tecticornia australasica*, *Salsola kali*, algal crusts and the grass *Sporobolus virginicus*. Sedges are also common. Occurs on supratidal flats with deep saline clay soils and formed from Quaternary estuarine sediments. Occurs along the landward edge of the intertidal zone in a hypersaline environment that is only inundated by the highest spring tides. Soils are grey mottled clays with a crusting surface, and are highly saline. Major vegetation communities include: 11.1.2a: Estuarine wetlands (e.g. mangroves). Bare mud flats on Quaternary estuarine deposits, with very isolated individual stunted mangroves such as *Avicennia marina* and/or *Ceriops tagal*. May have obvious salt crusts on the soil surface. 11.1.2b: Estuarine wetlands (e.g. mangroves). Samphire forbland on Quaternary estuarine deposits. Mainly saltpans and mudflats with clumps of saltbush including one or several of the following species; *Halosarcia spp*. (e.g. *Halosarcia indica subsp. julacea*, *Halosarcia indica subsp. leiostachya*),

Regional Ecosystem No.	Status under the VMA 1999	Description
		Sesuvium portulacastrum, *Sarcocornia quinqueflora subsp. quinqueflora, Suaeda australis, S. arbusculoides, Tecticornia australasica*, *Scleria ciliaris*, *Marsilea mutica*, *Salsola kali*, algal crusts and the grass *Sporobolus virginicus*. Sedges may be common.
11.1.4	Not of concern	Mangrove low forest on Quaternary estuarine deposits. Low open-shrubland to closed forest of mangrove species forming a variety of associations, depending on position in relation to salt water inundation. *Avicennia marina* is the most common dominant but also other trees such as *Aegiceras corniculatum*, *Rhizophora spp*. and *Ceriops tagal* dominate often in pure stands. There is often a shrub layer consisting of juvenile plants of the above species. Other species such as *Excoecaria agallocha*, *Bruguiera spp*., *Lumnitzera racemosa* and *Alchornea ilicifolia* may also occur. Occurs on intertidal flats which are often dissected by tidal streams. Soils are usually deep saline clays. Major vegetation communities include: 11.1.4a: Estuarine wetlands (e.g. mangroves). *Rhizophora spp*. open-forest on Quaternary estuarine deposits. This may include *Rhizophora stylosa* or *R. apiculata* as dominants, with occasional *Avicennia marina* as emergents, and subdominant *Bruguiera gymnorhiza* and/or *Ceriops tagal*. In northern areas, occasional *Xylocarpus moluccensis* may also occur. A shrub layer is usually not present. Occurs on fringing waterways low in intertidal zone, with roots submerged during high tides (Danaher 1995) 11.1.4b: Estuarine wetlands (e.g. mangroves). *Avicennia marina* low open-shrubland to closed forest on Quaternary estuarine deposits. There may be occasional *Ceriops tagal*, *Rhizophora spp*., *Bruguiera spp*., *Excoecaria agallocha* or *Lumnitzera spp*. An occasional presence of species such as *Aegialitis annulata* and/or *Aegiceras corniculatum* may occur. Open-shrublands of *Avicennia marina* may have a sparse presence of samphires such as *Suaeda spp*., *Tecticornia australasica* and *Sarcocornia spp*. Occurs in all intertidal environments from the seaward edge (as a pioneer) to accreting banks (as a fringe), to the landward edge adjacent to claypans (Bruinsma 2000; Danaher 1995) 11.1.4c: Estuarine wetlands (e.g. mangroves). *Ceriops tagal*, +/- *Avicennia marina* open forest on Quaternary estuarine deposits. Other mangrove species may be present as occasional individuals including *Rhizophora spp*., *Bruguiera spp*., *Lumnitzera spp*., and *Sonneratia spp*. A shrub layer is not usually present. Occurs on upstream creek edges, and toward the landward edge of the upper intertidal limit. Only inundated by spring tides (Bruinsma 2000). 11.1.4d: Estuarine wetlands (e.g. mangroves). Dominated by a range of species from genera such as from *Avicennia sp., Ceriops sp., Rhizophora sp.* and *Bruguiera sp*. which form a closed forest. A low shrub layer composed of species such as *Acanthus ilicifolius*, *Acrostichum speciosum*, *Crinum pedunculatum* or juvenile canopy species is often present. Epiphytes on the canopy are common. Occurs on the landward edge of the tidal flats and in the upper tidal reaches of creeks and rivers where there is a high freshwater influence. 11.1.4e: Estuarine wetlands (e.g. mangroves). *Avicennia marina* usually dominates the canopy which forms an open-forest

Regional Ecosystem No.	Status under the VMA 1999	Description
		although may vary from a low open-forest to a woodland or shrubland. *Ceriops tagal* sometimes occurs as a codominant. Occurs on intertidal flats which are often dissected by tidal streams. Occurs on the seaward edge of the tidal flats as a pioneer and on landward edge in areas bordering saltpans and that are inundated by the highest spring tides.
11.3.27	Not of concern	Freshwater wetlands. Vegetation is variable including open water with or without aquatic species and fringing sedgelands and eucalypt woodlands. Occurs in a variety of situations including lakes, billabongs, oxbows and depressions on floodplains. Major vegetation communities include: 11.3.27a: Lacustrine wetland (e.g. lake). Vegetation ranges from open water ± aquatics and emergents such as *Chara spp*. *Nitella spp*., *Myriophyllum verrucosum*, *Nymphaea violacea*, *Potamogeton javanicus*, *P. crispus, P. tricarinatus*, *Ottelia ovalifolia*, *Vallisneria caulescens* and *Nymphoides indica*, A narrow fringing woodland commonly dominated by *E. camaldulensis* or *E. coolabah* but also a range of other tree species may be present. Larger ephemeral - permanent water bodies (lakes). 11.3.27b: Palustrine wetland (e.g. vegetated swamp). Vegetation ranges from open water ± aquatics and emergents such as *Potamogeton crispus*, *Myriophyllum verrucosum*, *Chara spp*., *Nitella spp*, *Nymphaea violacea*, *Ottelia ovalifolia*, *Nymphoides indica*, *N. crenata*, *Potamogeton tricarinatus*, *Cyperus difformis*, *Vallisneria caulescens* and *Hydrilla verticillata*. Often with fringing woodland, commonly *Eucalyptus camaldulensis* or *E. coolabah* but also a wide range of other species including *Eucalyptus platyphylla*, *E. tereticornis*, *Melaleuca spp., Acacia holosericea* or other *Acacia spp*. Occurs on billabongs no longer connected to the channel flow. 11.3.27c: Palustrine wetland (e.g. vegetated swamp). Mixed grassland or sedgeland with areas of open water +/- aquatic species. Dominated by a range of species including *Eleocharis spp*., *Nymphoides spp*. and sometimes *Phragmites australis*. Occurs on closed depressions on alluvial plains that are intermittently flooded in inlands parts of the bioregion. 11.3.27d: Palustrine wetland (e.g. vegetated swamp). *Eucalyptus camaldulensis* and/or *E. tereticornis* woodland. A range of sedges and grasses occur in the ground layer including *Fimbristylis vagans*, *Myriophyllum striatum*, *Nitella pseudoflabellata* and *Pseudoraphis sp.* Occurs fringing larger lakes and billabongs. 11.3.27e: Palustrine wetland (e.g. vegetated swamp). Vegetation ranges from open water ± aquatics sometimes with fringing trees and shrubs. Fringing tree species include *Melaleuca dealbata*, *Nauclea orientalis*, *M. leucadendra*, *Lophostemon suaveolens* and *Corymbia tessellaris*. Shrub layers are usually absent although scattered *Pandanus spp.* may be present. The ground layer is often open water with emergent aquatic species or sedges and grasses including *Leersia hexandra, Cyperus dactylotes*, *Cyperus lucidus*, *Nymphaea spp*. and *Gymnanthera oblonga*. Occurs on billabongs and oxbows with permanent to ephemeral water regime. 11.3.27f: Palustrine wetland (e.g. vegetated swamp). *Eucalyptus coolabah* and/or *E. tereticornis* open woodland to woodland fringing swamps. Ground layer and treeless areas range from open water ± aquatics and

Regional Ecosystem No.	Status under the VMA 1999	Description
		emergents such as *Potamogeton crispus*, *Myriophyllum verrucosum*, *Chara spp*., *Eleocharis spp*., *Nitella spp*, *Cyperus difformis*, *Hydrilla verticillata*. Occurs on closed depressions on floodplains associated with old drainage courses that are intermittently flooded. 11.3.27g: Palustrine wetland (e.g. vegetated swamp). *Eucalyptus coolabah* fringing lakes with open water. Occurs on closed depressions on floodplains associated with old drainage courses. 11.3.27h: Lacustrine wetland (e.g. lake). Lakes with mainly open water or bare lake bed. May be *Muehlenbeckia florulenta* low shrubland ± scattered *E. coolabah* trees fringing or scattered across the area. Occurs on floodplains. Seasonally dry. 11.3.27i: Palustrine wetland (e.g. vegetated swamp). *Eucalyptus camaldulensis* woodland to open-woodland with sedgeland ground layer. Other tree species such as *E, coolabah, E. tereticornis* and *E. largiflorens* may be present or locally dominant. Ground layer dominated by *Eleocharis spp*, *Juncus spp*., *Marsilea spp*. etc Occurs in depressions on floodplains. 11.3.27j: Palustrine wetland (e.g. vegetated swamp). *Acacia stenophylla* and other shrubby species Occurs in frequently flooded depression on floodplains. 11.3.27x1a: Palustrine wetland (e.g. vegetated swamp). Sedgelands to grasslands on old marine planes. Often occurs as an *Eleocharis spp*. (*E. dulcis*, *E. sphacelata*) sedgeland but a variety of other species dominate in local areas including *Typha orientalis*, *Cyperus alopecuroides*, *Phragmites australis* and *Ludwigia octovalvis*. A range of other sedges, grasses small shrubs and herbs (<40 cm) are abundant, and include *Ammannia multiflora*, *Cyperus polystachyos*, *Sporobolus virginicus*, *Chloris virgata*, *Fimbristylis ferruginea*, *Ceratopteris thalictroides*, *Phyla nodiflora var. nodiflora* and *Persicaria attenuata.* The vines *Passiflora foetida* may occur in some areas. Trees and large shrubs are generally absent. Occurs in depressions on Quaternary estuarine deposits which are seasonally inundated with fresh water. 11.3.27x1b: Palustrine wetland (e.g. vegetated swamp). Sedgelands to grasslands on Quaternary deposits. Often occurs as an *Eleocharis dulcis* sedgeland but a variety of other species dominate in local areas including *Typha orientalis* and *Phragmites australis*. Trees and large shrubs are generally absent. Occurs on broad drainage depressions situated on old alluvial plains. 11.3.27x1c: Palustrine wetland (e.g. vegetated swamp). Sedgelands to grasslands on Quaternary deposits. Sedgeland areas typically dominated by *Schoenoplectus litoralis* although a range of other sedges and grasses may also dominate localised areas. Other dominant species include the sedges *Eleocharis philippinensis, Cyperus alopecuroides*, *C. scariosus* and *C. iria* and the grasses *Phragmites australis*, *Sporobolus virginicus* and *Paspalum vaginatum*. Other typical species in shallower margins include *Fimbristylis ferruginea*, *Phyla nodiflora* and *Cyperus polystachyos*. Occasional twiners such as *Cynanchum carnosum* may be present. Occurs in depressions on old Quaternary estuarine deposits. These are seasonally inundated with fresh water but become more brackish as they dry. Dry out completely before the next season's rain.

Table 2: Rare and threatened species, listed under the Environmental Protection and Biodiversity (EPBC) Act 1999 and the Nature Conservation (Wildlife) Regulation 2006 of the Nature Conservation Act 1992, occurring or potentially occurring in Rowes Bay (E: Endangered; V: Vulnerable; R: Rare). Likelihood of occurrence is based on EPBC protected matters search tool data and records obtained through the Wildlife Online database. Likelihood of direct impact from coastal processes is based local knowledge and expertise of the consultant.

Group	Common name	Species name	Status EPBC	Status NCWR	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
Birds	Red goshawk	*Erythrotriorchis radiatus*	V	E	One confirmed sighting within the area; Species or species habitat likely to occur within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Grey goshawk	*Accipiter novaehollandiae*		R	Three confirmed sightings within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Grey falcon	*Falco hypoleucos*		R	One confirmed sighting within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Star finch (eastern), Star finch (southern)	*Neochmia ruficauda ruficauda*	E		Species or species habitat likely to occur within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Black-throated finch (southern)	*Poephila cincta cincta*	E		Species or species habitat likely to occur within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Crimson finch	*Neochmia phaeton*		V	Five confirmed sightings within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Australian painted snipe	*Rostratula australis*	V		Species or species habitat may occur within the area	Species or species habitat may be impacted as a result of coastal erosion processes, particularly processes potentially impacting the mangrove forests, saltpans and mud

Group	Common name	Species name	Status EPBC	Status NCWR	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
						flats to the west of the fore dune
	Square-tailed kite	*Lophoictinia isura*		R	Two confirmed sightings within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Cotton pygmy-goose	*Nettapus coromandelianus*		R	Five confirmed sightings within the area	Species or species habitat may be impacted as a result of coastal erosion processes, particularly processes potentially impacting the mangrove forests, saltpans and mud flats to the west of the fore dune
	Major Mitchell's cockatoo	*Lophochroa leadbeateri*		V	One confirmed sighting within this area. *Note: This sighting is considered likely to be an aviary escapee, as the species is not known to occur within this area.*	Species or species habitat considered very unlikely to be significantly impacted coastal erosion processes along Rowes Bay. This species does not occur naturally within this area
	Black-necked stork	*Ephippiorhynchus asiaticus*		R	Forty-six confirmed sightings within the area	Species or species habitat may be impacted as a result of coastal erosion processes, particularly processes potentially impacting the mangrove forests, saltpans and mud flats to the west of the fore dune
	Little tern	*Sterna albifrons*		E	Two confirmed sightings within the area	Species or species habitat likely to be impacted as a result of coastal erosion processes along Rowes Bay foreshore. Confirmed sightings of this species have been made in this area
	Southern giant petrel	*Macronectes giganteus*	E	E	One confirmed sighting within the area	Species or species habitat considered very unlikely to be significantly impacted coastal erosion processes along Rowes Bay. This species is very uncommon in the tropics

Group	Common name	Species name	Status EPBC	Status NCWR	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
	Eastern curlew	*Numenius madagascariensis*		R	Six confirmed sightings within the area	Species or species habitat likely to be impacted as a result of coastal erosion processes along Rowes Bay foreshore
	Macleay's fig-parrot	*Cyclopsitta diophthalma macleayana*		V	One confirmed sighting within the area	Species or species habitat may be impacted by coastal erosion processes along Rowes Bay, where habitat trees such as figs and *Elaeocarpus* trees occur.
	Rufous owl (southern)	*Ninox rufa queenslandica*		V	One confirmed sighting within the area	Species or species habitat considered very unlikely to be significantly impacted coastal erosion processes along Rowes Bay. This species prefers dense woodland, river margins and rainforest habitat.
Mammals	Northern quoll	*Dasyurus hallucatus*	E		Species or species habitat likely to occur within the area; One confirmed sighting within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay
	Semon's leaf-nosed bat	*Hipposideros semoni*	E		Species or species habitat may occur within the area	Species or species habitat considered unlikely to be significantly impacted coastal erosion processes along Rowes Bay. This species prefers tropical rainforest, monsoon forest and wet sclerophyll forest.
	Greater large-eared horseshoe bat	*Rhinolophus philippinensis*	E		Species or species habitat may occur within the area	Species or species habitat considered very unlikely to be significantly impacted coastal erosion processes along Rowes Bay. No confirmed sightings of this species have been recorded within this area. This species prefers rainforest habitats.
	Spectacled flying	*Pteropus*	V		Species or species habitat may	Species or species habitat

Group	Common name	Species name	Status EPBC	Status NCWR	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
	fox	*conspicillatus*			occur within the area	considered very unlikely to be significantly impacted coastal erosion processes along Rowes Bay. No confirmed sightings of this species have been recorded within this area. This species prefers rainforest habitats.
	Water mouse	*Xeromys myoides*	V		Species or species habitat may occur within the area	Species or species habitat considered very unlikely to be significantly impacted coastal erosion processes along Rowes Bay. No confirmed sightings of this species have been recorded within 100km of this area.
Reptiles	Loggerhead turtle	*Caretta caretta*	E		Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat may be impacted as a result of coastal erosion processes
	Green turtle	*Chelonia mydas*	V	V	Species or species habitat may occur within the area; One confirmed sighting within the area	Species or species terrestrial (breeding) habitat may be impacted as a result of coastal erosion processes
	Leatherback turtle	*Dermochelys coriacea*	E		Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat unlikely to be impacted as a result of coastal erosion processes. No confirmed breeding records occur in this area
	Hawksbill turtle	*Eretmochelys imbricata*	V		Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat unlikely to be impacted as a result of coastal erosion processes. No confirmed breeding records occur in this area
	Olive Ridley turtle	*Lepidochelys olivacea*	E		Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat unlikely to be impacted as a result of coastal

Group	Common name	Species name	Status EPBC	Status NCWR	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
						erosion processes. No confirmed breeding records occur in this area
	Flatback turtle	*Natator depressus*	V		Breeding likely to occur within the area.	Species or species terrestrial (breeding) habitat may be impacted as a result of coastal erosion processes
	Striped-tailed delma	*Delma labialis*	V	V	Species or species habitat likely to occur within the area; One confirmed sighting within this area	Species or species habitat unlikely to be directly impacted by coastal erosion processes
	Yakka skink	*Egernia rugosa*	V		Species or species habitat likely to occur within the area	Species or species habitat unlikely to be directly impacted by coastal erosion processes
	Yellow-naped snake	*Furina barnardi*		R	One confirmed sighting within this area	Species or species habitat unlikely to be directly impacted by coastal erosion processes
	Rusty monitor	*Varanus semiremex*		R	One confirmed sighting within the area	Species or species habitat unlikely to be directly impacted by coastal erosion processes
Plants	Frogbit	*Hydrocharis dubia*	V		Species or species habitat likely to occur within the area	Species or species habitat unlikely to be directly impacted by coastal erosion processes. There are no confirmed records of this species within the area.
		Leucopogon cuspidatus	V		Species or species habitat likely to occur within the area	Species or species habitat unlikely to be directly impacted by coastal erosion processes. There are no confirmed records of this species within the area.

Table 3: Migratory species, listed under the Environmental Protection and Biodiversity (EPBC) Act 1999, occurring or potentially occurring in Rowes Bay. Likelihood of occurrence is based on EPBC protected matters search tool data and records obtained through the Wildlife Online database. Likelihood of direct impact from coastal processes is based local knowledge and expertise of the consultant.

Group	Common name	Species name	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
Terrestrial Birds	White-bellied sea-eagle	*Haliaeetus leucogaster*	Species or species habitat likely to occur within the area	Species or species habitat may be directly impacted by coastal erosion processes in Rowes Bay, particularly if habitat (nesting) trees are disturbed. This species is also known to occasionally nest on the ground. The white-bellied sea-eagle returns to the same nest site each breeding season, and will therefore suffer direct impacts if nesting sites are damaged or destroyed as a result of coastal erosion processes.
	White-throated needletail	*Hirundapus caudacutus*	Species or species habitat may occur within the area	Species of species habitat unlikely to be significantly impacted coastal erosion processes in Rowes Bay.
	Barn swallow	*Hirundo rustica*	Species or species habitat may occur within the area	Species of species habitat unlikely to be significantly impacted coastal erosion processes in Rowes Bay.
	Rainbow bee-eater	*Merops ornatus*	Species or species habitat may occur within the area	Species or species habitat may be directly impacted by coastal erosion processes in Rowes Bay, particularly where nesting tunnels may be disturbed.
	Black-faced monarch	*Monarcha melanopsis*	Breeding may occur within the area	Species or species habitat unlikely to be directly impacted by coastal erosion processes in Rowes bay. This species nests above ground and prefers rainforest and other similar habitats.
	Spectacled monarch	*Monarcha trivirgatus*	Breeding likely to occur within the area	Species or species habitat unlikely to be directly impacted by coastal erosion processes in Rowes bay. This species nests above ground and prefers rainforest and other similar habitats.

Group	Common name	Species name	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
	Satin flycatcher	*Myiagra cyanoleuca*	Species or species habitat likely to occur within the area	Species of species habitat unlikely to be significantly impacted coastal erosion processes in Rowes Bay
	Rufous fantail	*Rhipidura rufifrons*	Breeding may occur within the area	Species or species habitat unlikely to be directly impacted by coastal erosion processes in Rowes bay. This species nests above ground and prefers rainforest, woodland and other similar habitats.
Wetland birds	Great egret	*Ardea alba*	Species or species habitat may occur within the area	Species or species habitat may be impacted by coastal processes in Rowes bay, particularly where wetland and creek habitats are disturbed.
	Cattle egret	*Ardea ibis*	Species or species habitat may occur within the area	Species or species habitat may be impacted by coastal processes in Rowes bay, particularly where wetland and creek habitats are disturbed.
	Latham's snipe, Japanese snipe	*Gallinago hardwickii*	Species or species habitat may occur within the area	Species or species habitat may be impacted by coastal erosion processes in Rowes Bay
	Australian cotton pygmy-goose	*Nettapus coromandelianus albipennis*	Species or species habitat may occur within the area	Species or species habitat may be impacted as a result of coastal erosion processes, particularly processes potentially impacting the mangrove forests, wetlands, saltpans and mud flats to the west of the fore dune
	Painted snipe	*Rostratula benghalensis s. lat*	Species or species habitat may occur within the area	Species or species habitat may be impacted as a result of coastal erosion processes, particularly processes potentially impacting the mangrove forests, wetlands, saltpans and mud flats to the west of the fore dune
Marine birds	Little tern	*Sterna albifrons*	Species or species habitat may occur within the area	Species or species habitat likely to be impacted as a result of coastal erosion processes along Rowes Bay foreshore. Confirmed sightings of this species have been made in this area
Reptiles	Loggerhead turtle	*Caretta caretta*	Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat unlikely to be impacted as a result of

Group	Common name	Species name	Likelihood of occurrence	Likelihood of direct impact from coastal erosion processes
				coastal erosion processes. However, no confirmed breeding records occur in this area
	Green turtle	*Chelonia mydas*	Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat likely to be impacted as a result of coastal erosion processes. Nesting occurs in the area.
	Estuarine crocodile	*Crocodylus porosus*	Species or species habitat likely to occur within the area	Species or species habitat likely to be impacted by coastal erosion processes in Rowes Bay. This species is known to occur in this area. However, no confirmed nesting has been recorded.
	Leatherback turtle	*Dermochelys coriacea*	Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat unlikely to be impacted as a result of coastal erosion processes. However, no confirmed breeding records occur in this area
	Hawksbill turtle	*Eretmochelys imbricata*	Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat unlikely to be impacted as a result of coastal erosion processes. However, no confirmed breeding records occur in this area
	Olive Ridley turtle	*Lepidochelys olivacea*	Species or species habitat may occur within the area	Species or species terrestrial (breeding) habitat may be impacted as a result of coastal erosion processes. However, no confirmed breeding records exist for this area
	Flatback turtle	*Natator depressus*	Breeding likely to occur within the area	Species or species terrestrial (breeding) habitat likely to be impacted as a result of coastal erosion processes. Nesting is known to occur in Rowes Bay

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http://www.epa.qld.gov.au/nature_conservation/wildlife/wildlife_online/, 2 October 2009

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Mapping of Regional Ecosystems and Vegetation Communities in Queensland. Version 3.1. Updated September 2005. Queensland Herbarium, Environmental Protection Agency, Brisbane

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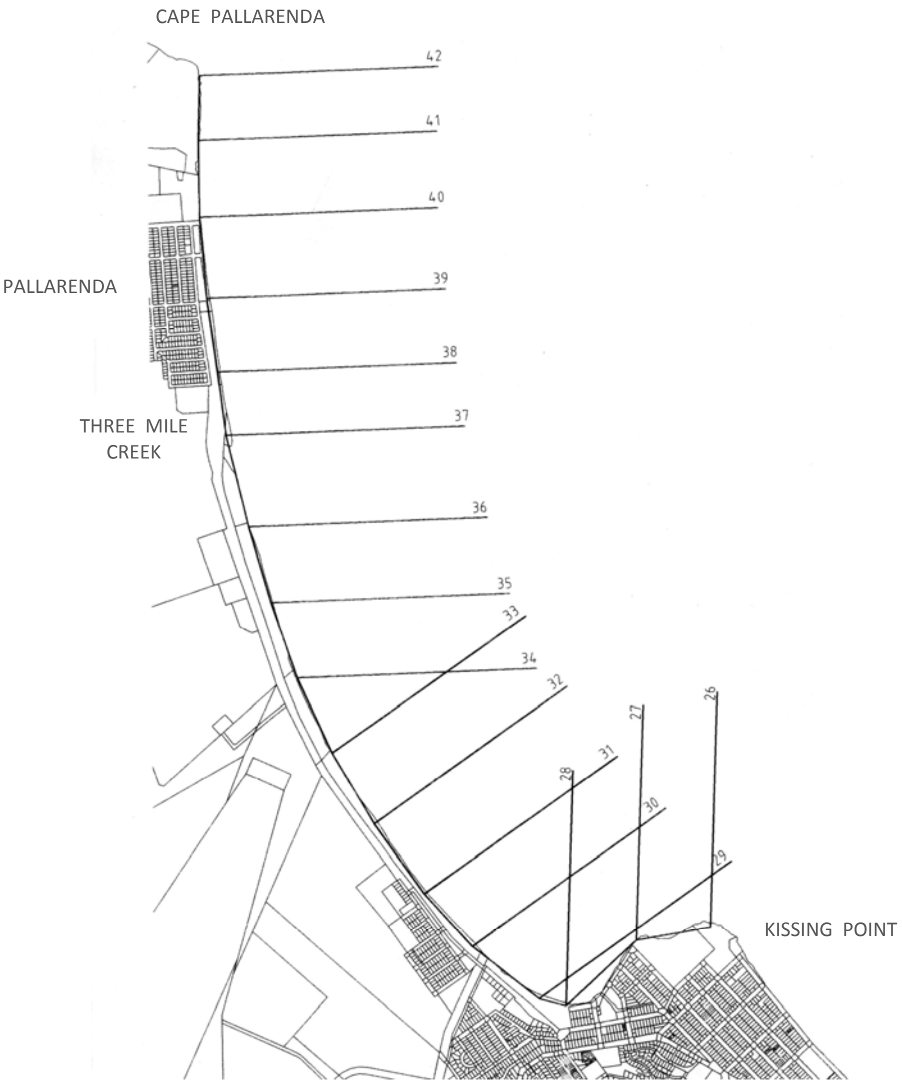
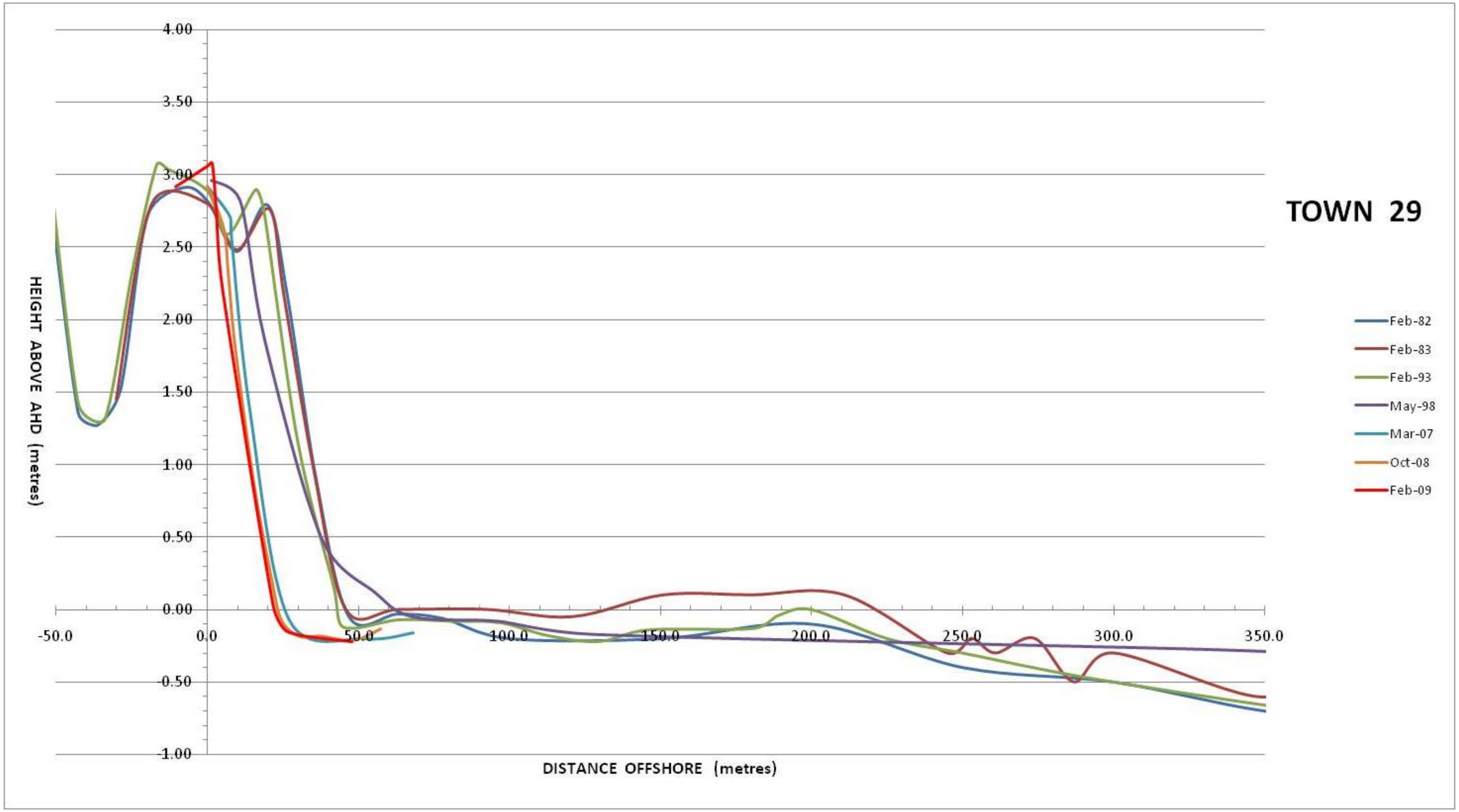
http://apps.townsville.qld.gov.au/nad/, 2 October 2009

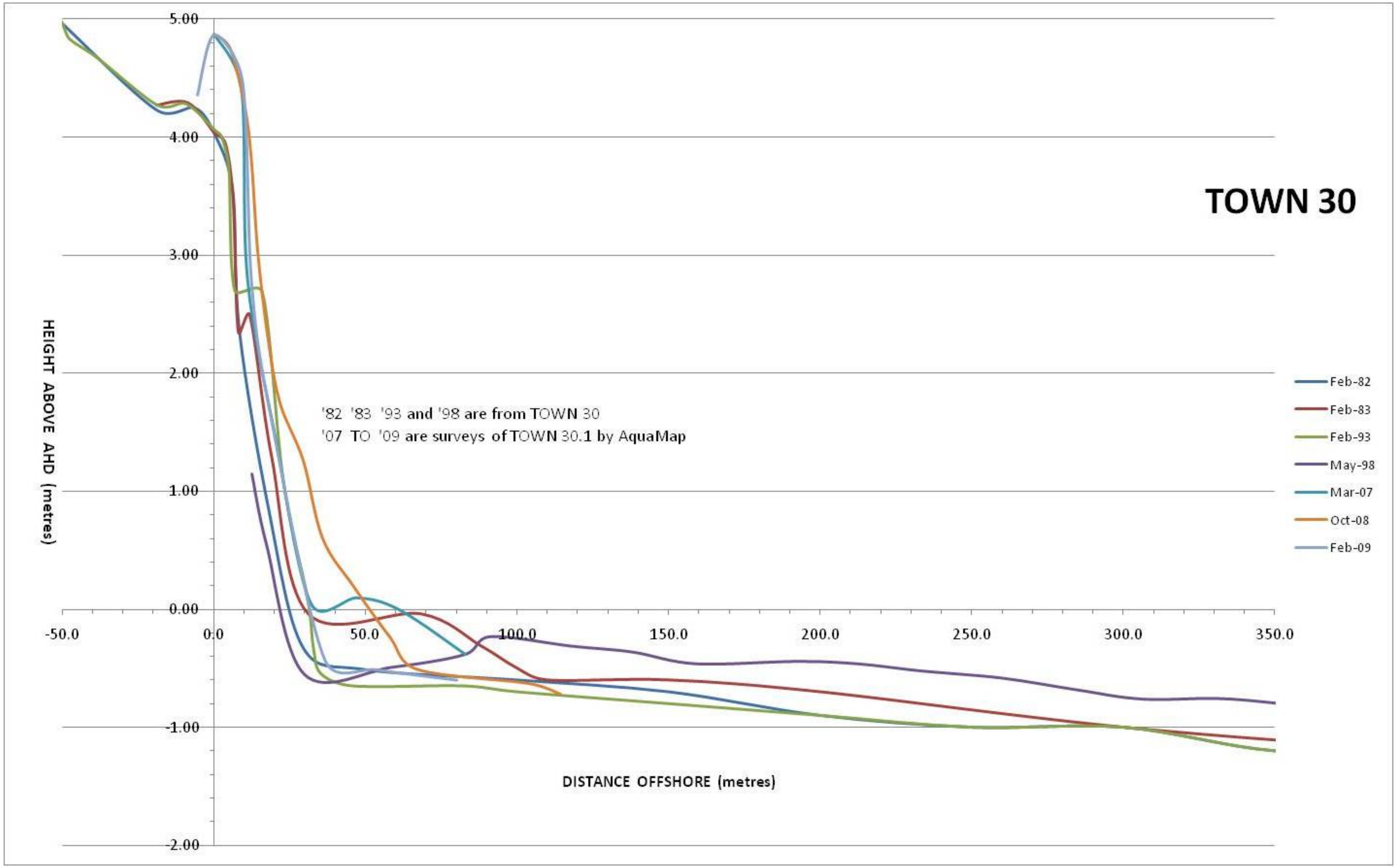
APPENDIX D

- RESULTS OF BEACH TRANSECT SURVEYS

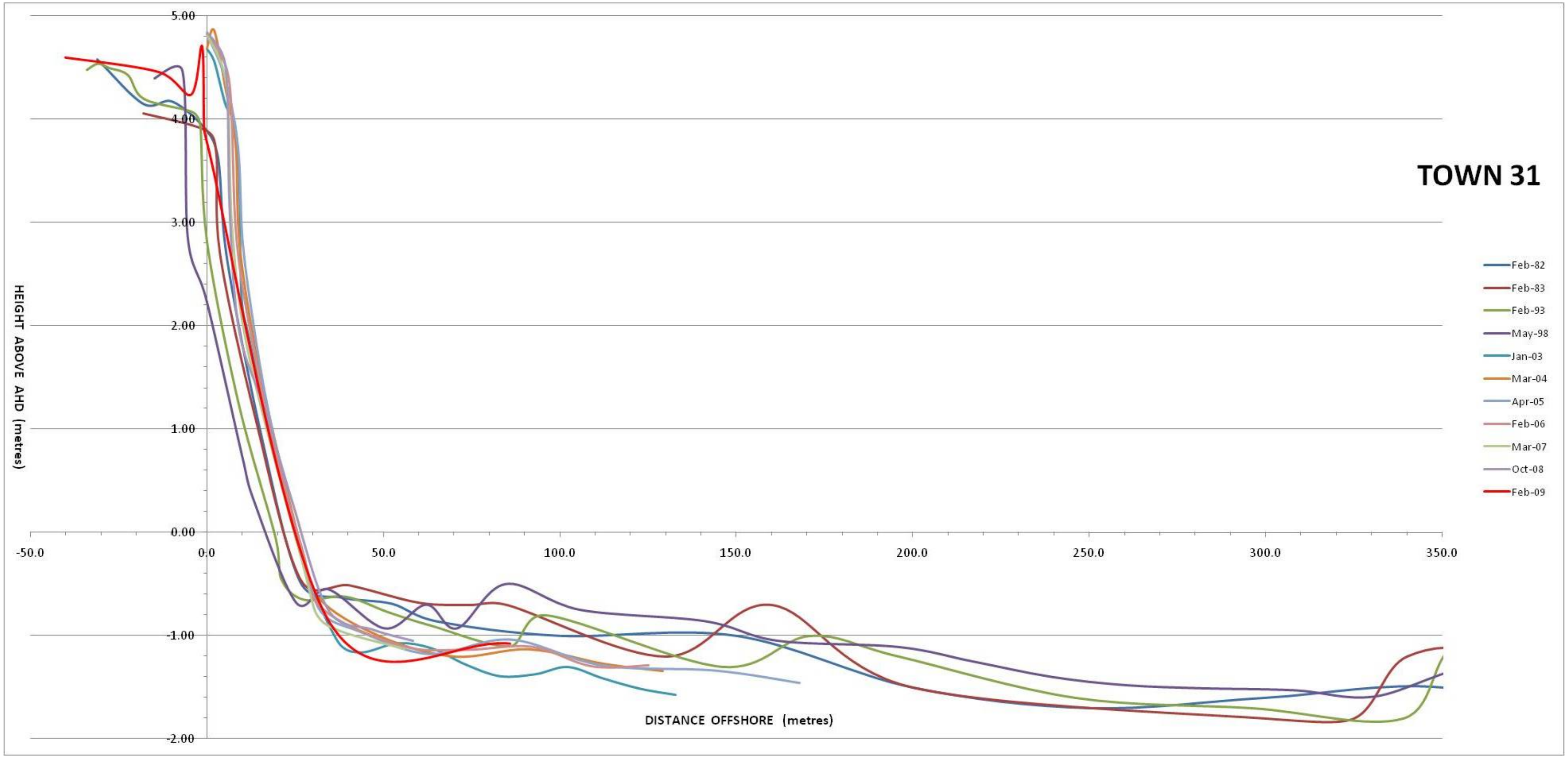


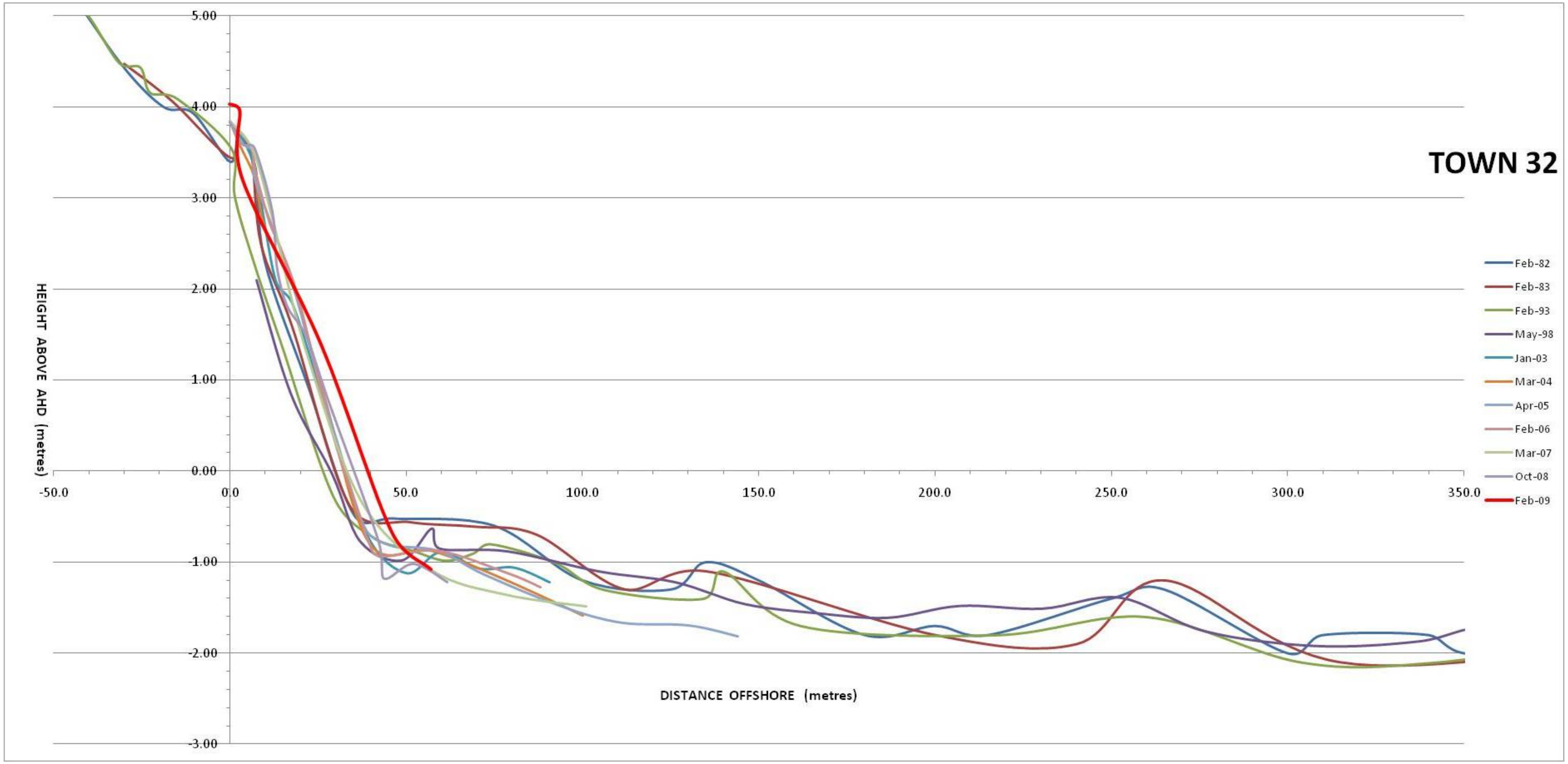
LOCATIONS OF BEACH TRANSECT LINES


TOWN 29
HEIGHT ABOVE AHD (metres)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
DISTANCE OFFSHORE (metres)
Feb-82
Feb-83
Feb-93
May-98
Mar-07
Oct-08
Feb-09



TOWN 30
'82 '83 '93 and '98 are from TOWN 30
'07 TO '09 are surveys of TOWN 30.1 by AquaMap
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Mar-07
Oct-08
Feb-09


TOWN 31
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
Apr-05
Feb-06
Mar-07
Oct-08
Feb-09
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0



TOWN 32
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
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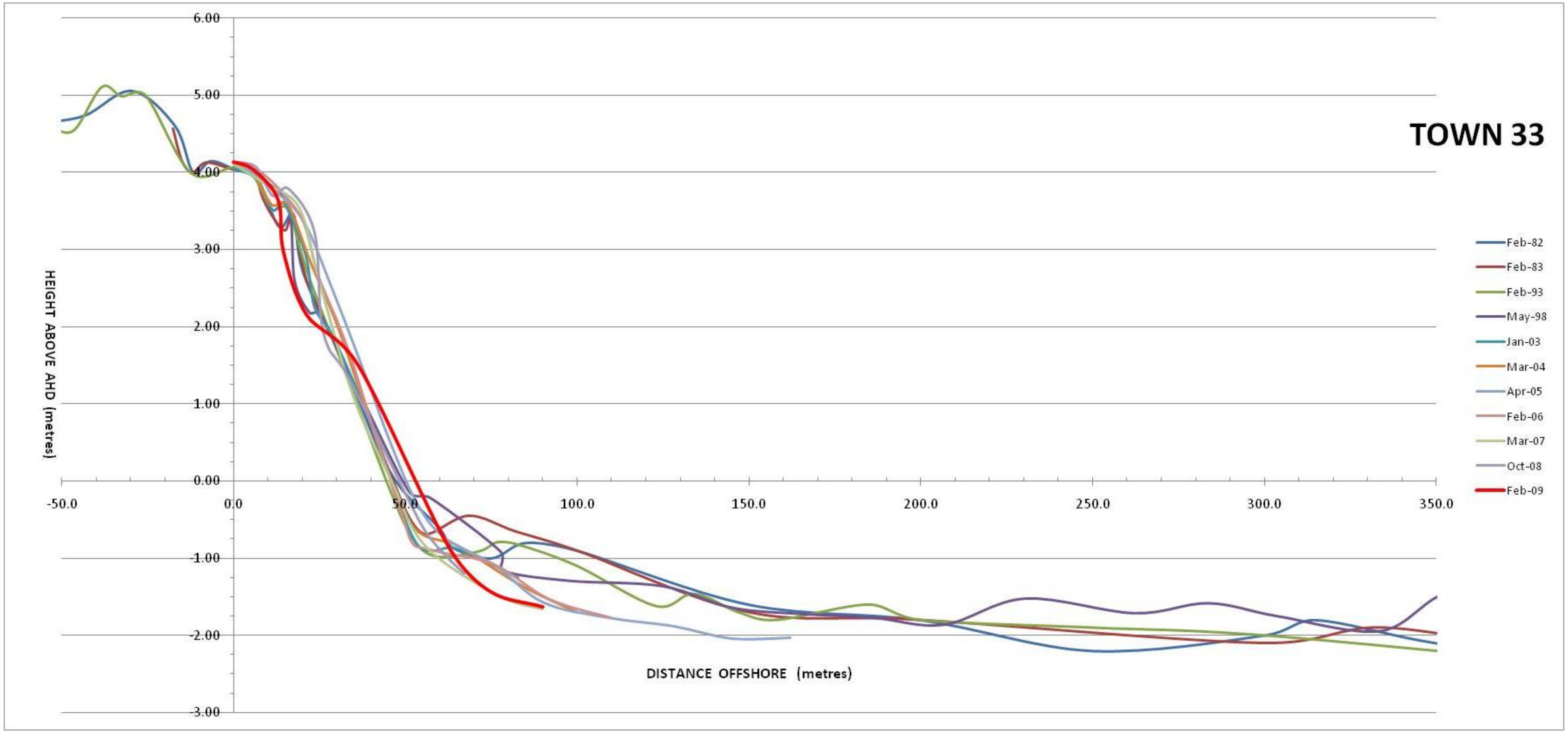
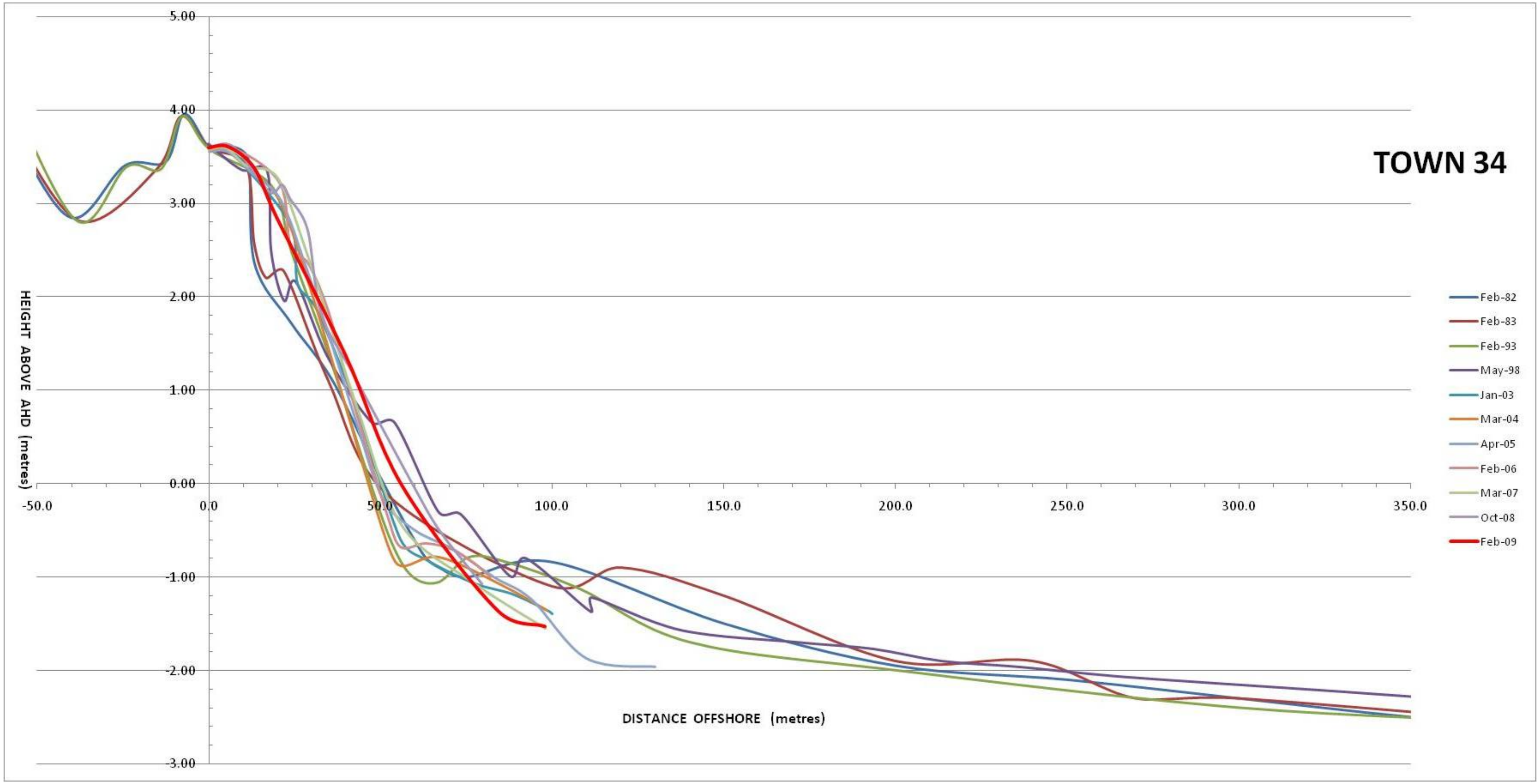
Feb-06
Mar-07
Oct-08
Feb-09


TOWN 33
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
Apr-05
Feb-06
Mar-07
Oct-08
Feb-09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HEIGHT ABOVE AHD (metres)
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3.00
2.00
1.00
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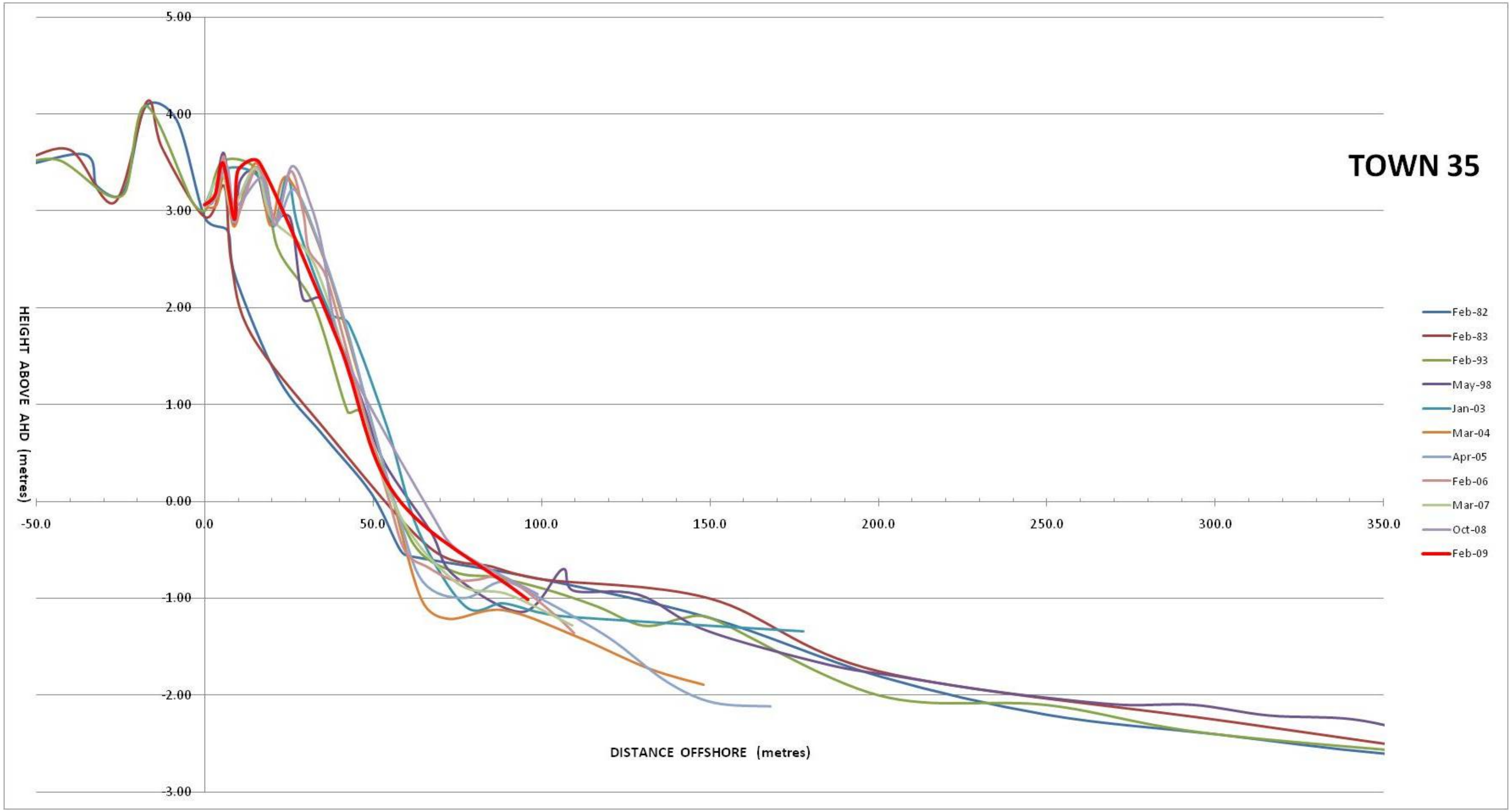
-1.00
-2.00
-3.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
DISTANCE OFFSHORE (metres)
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
Apr-05
Feb-06
Mar-07
Oct-08
Feb-09



TOWN 35
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
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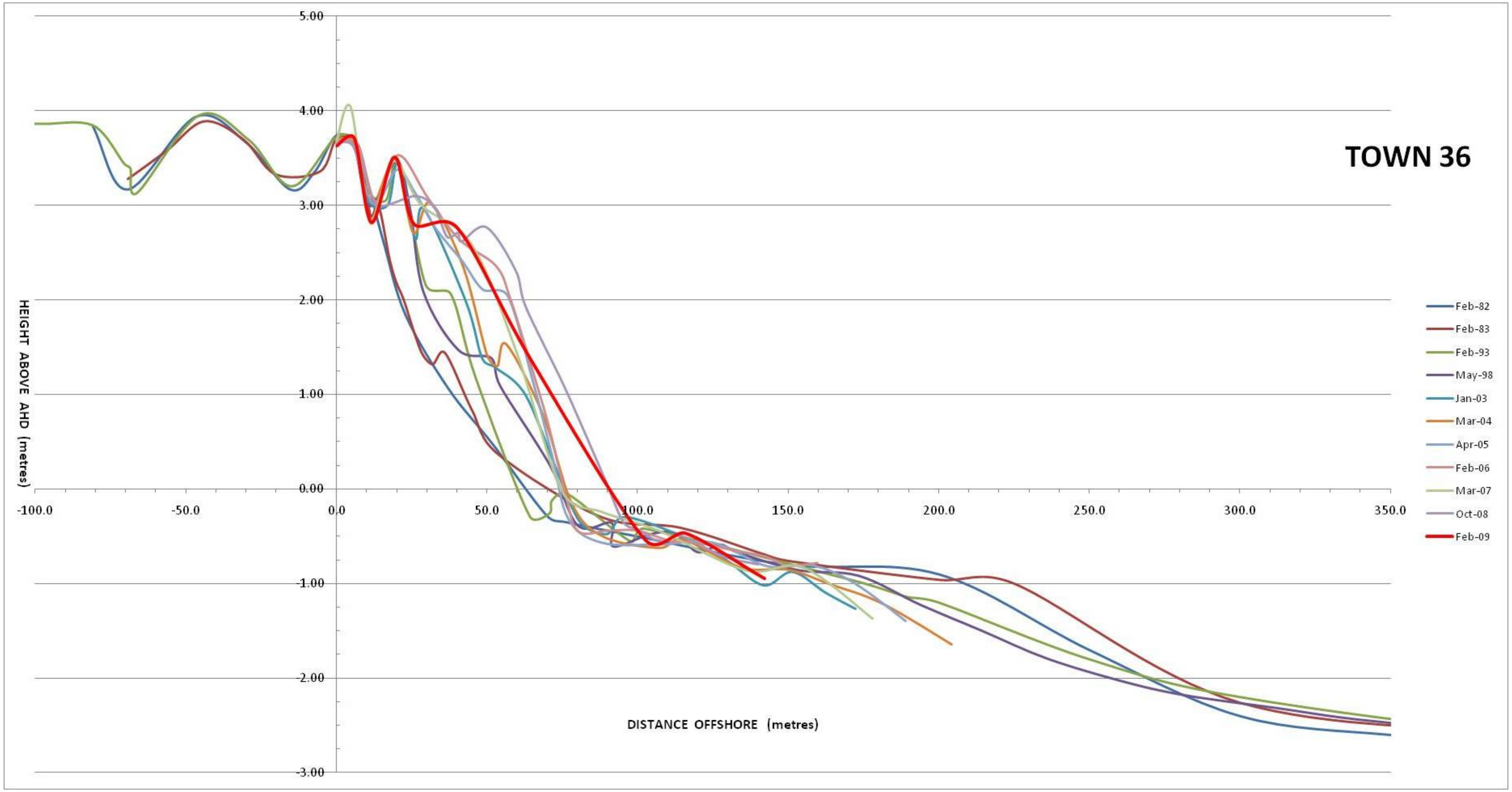
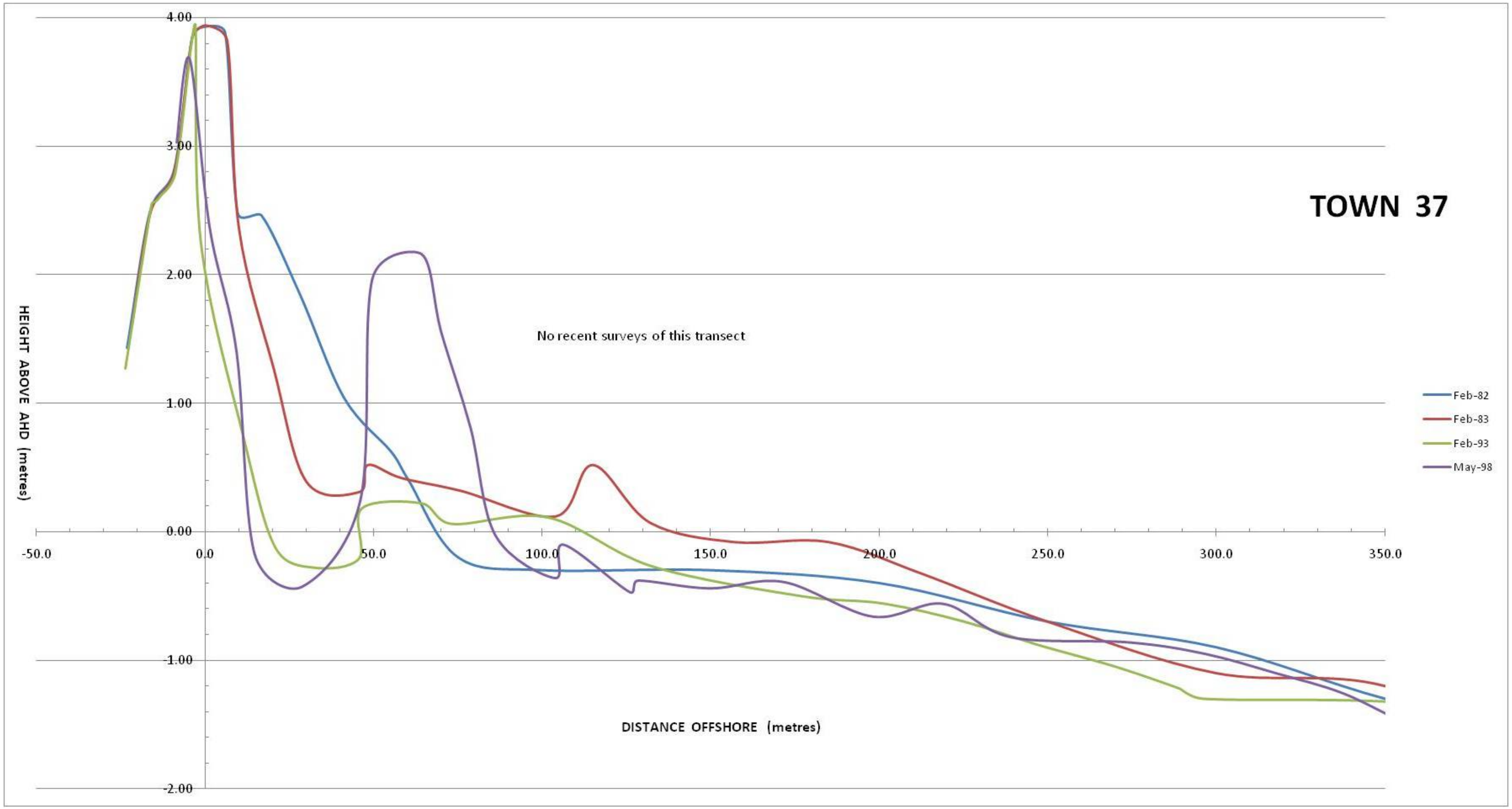
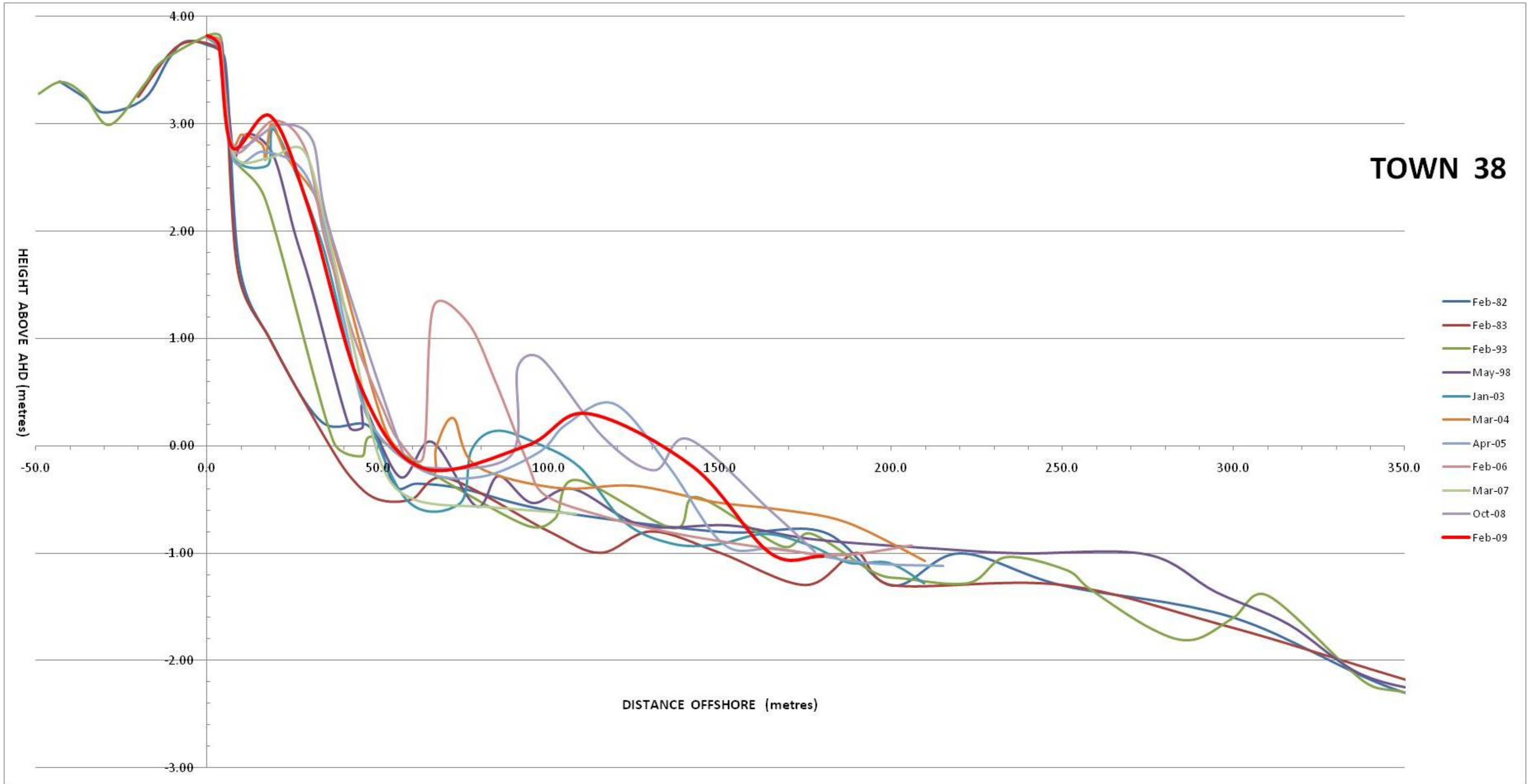
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
Apr-05
Feb-06
Mar-07
Oct-08
Feb-09


TOWN 36
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-100.0
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
Apr-05
Feb-06
Mar-07
Oct-08
Feb-09


TOWN 37
No recent surveys of this transect
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
Feb-82
Feb-83
Feb-93
May-98
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0


TOWN 38
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
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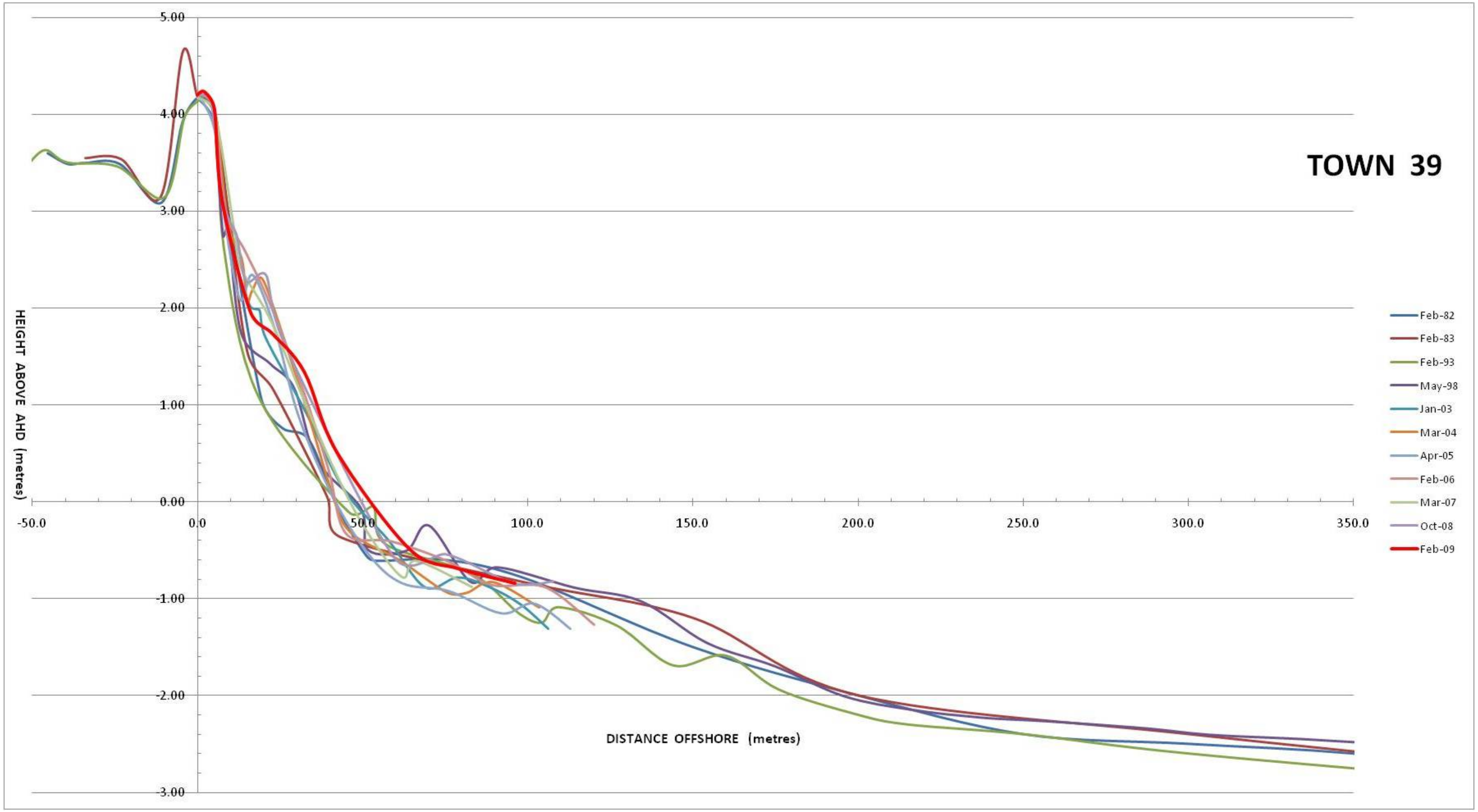
Mar-07
Oct-08
Feb-09


TOWN 39
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
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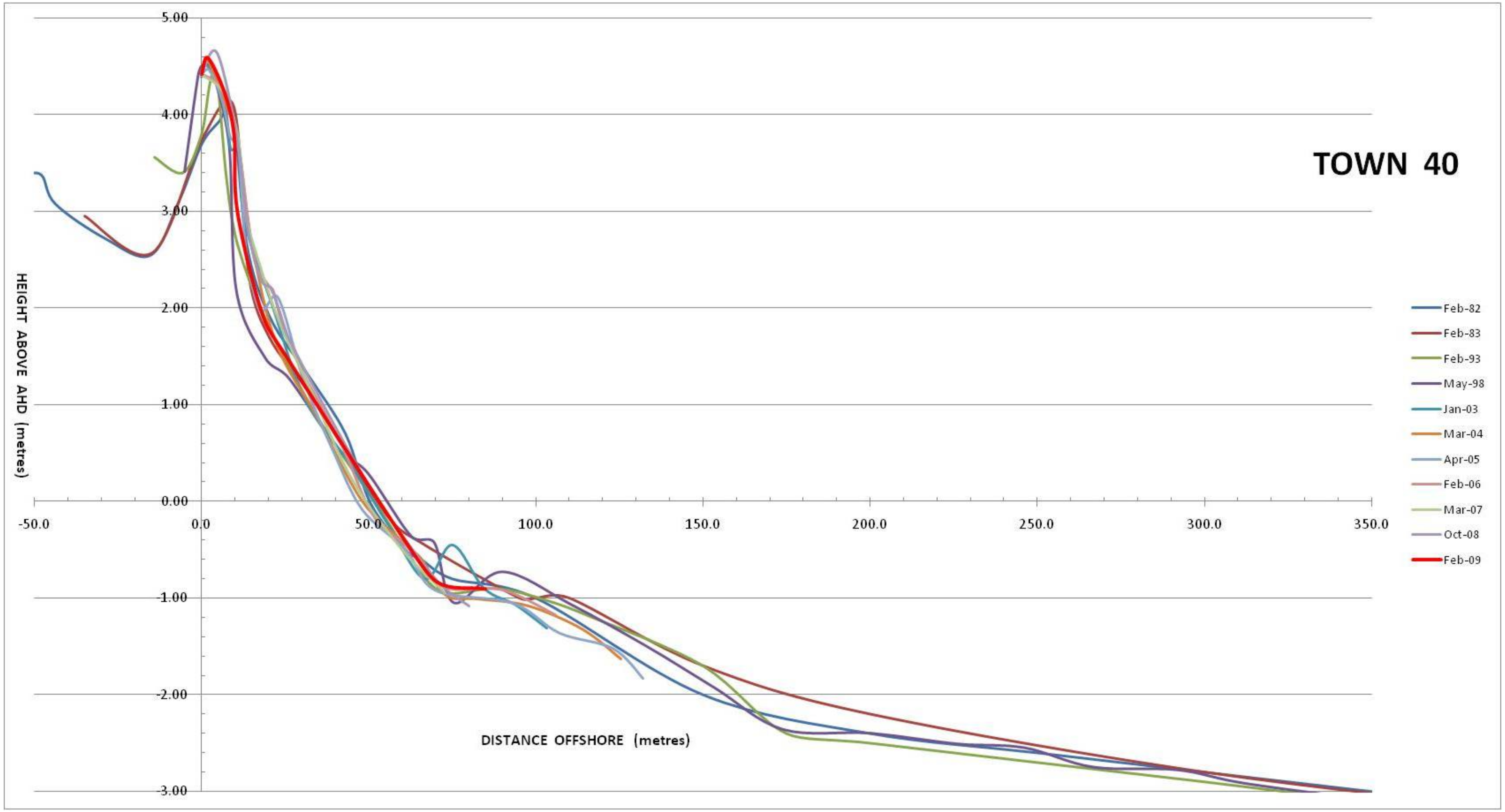
Mar-07
Oct-08
Feb-09



TOWN 40
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
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4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
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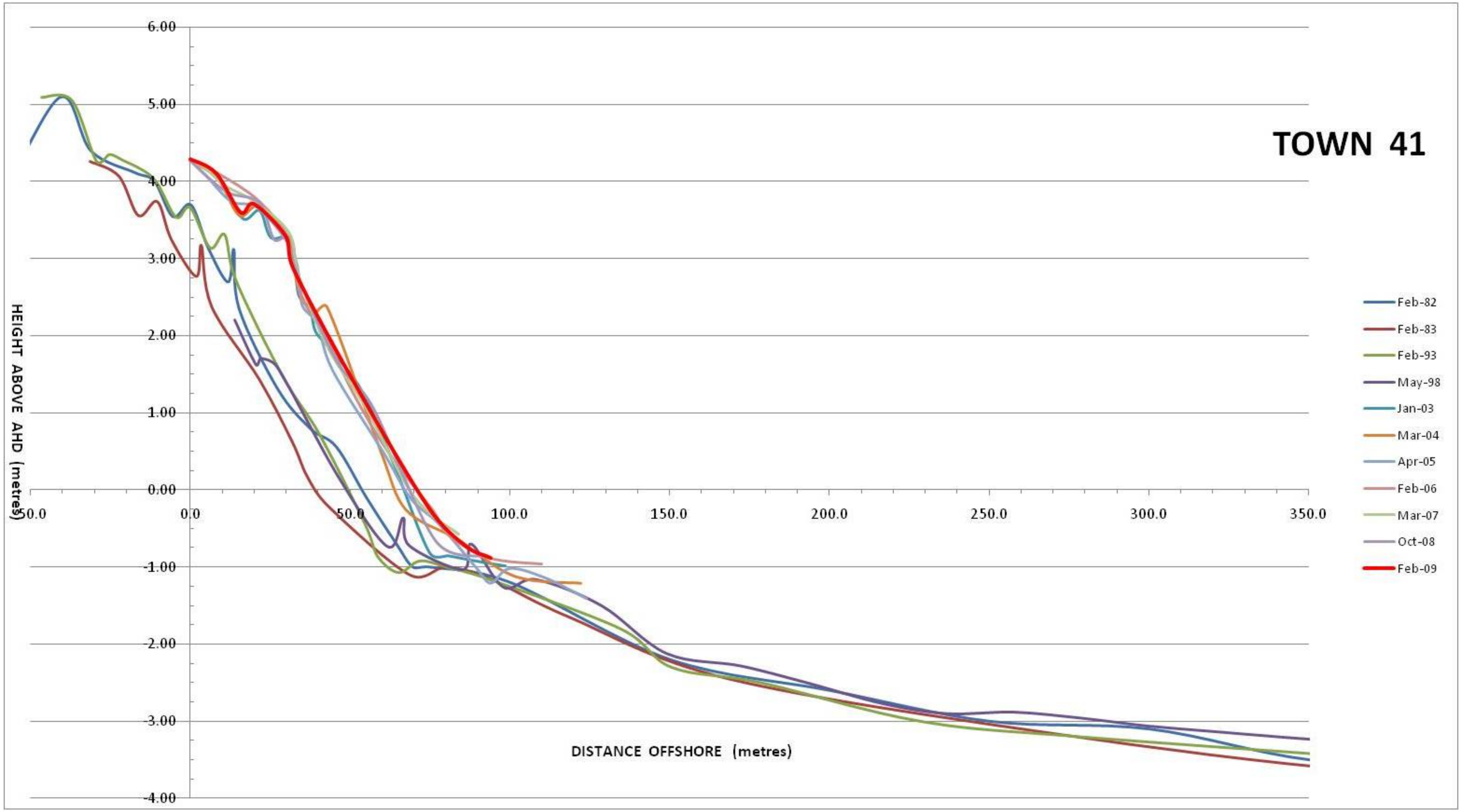
Mar-07
Oct-08
Feb-09


TOWN 41
HEIGHT ABOVE AHD (metres)
DISTANCE OFFSHORE (metres)
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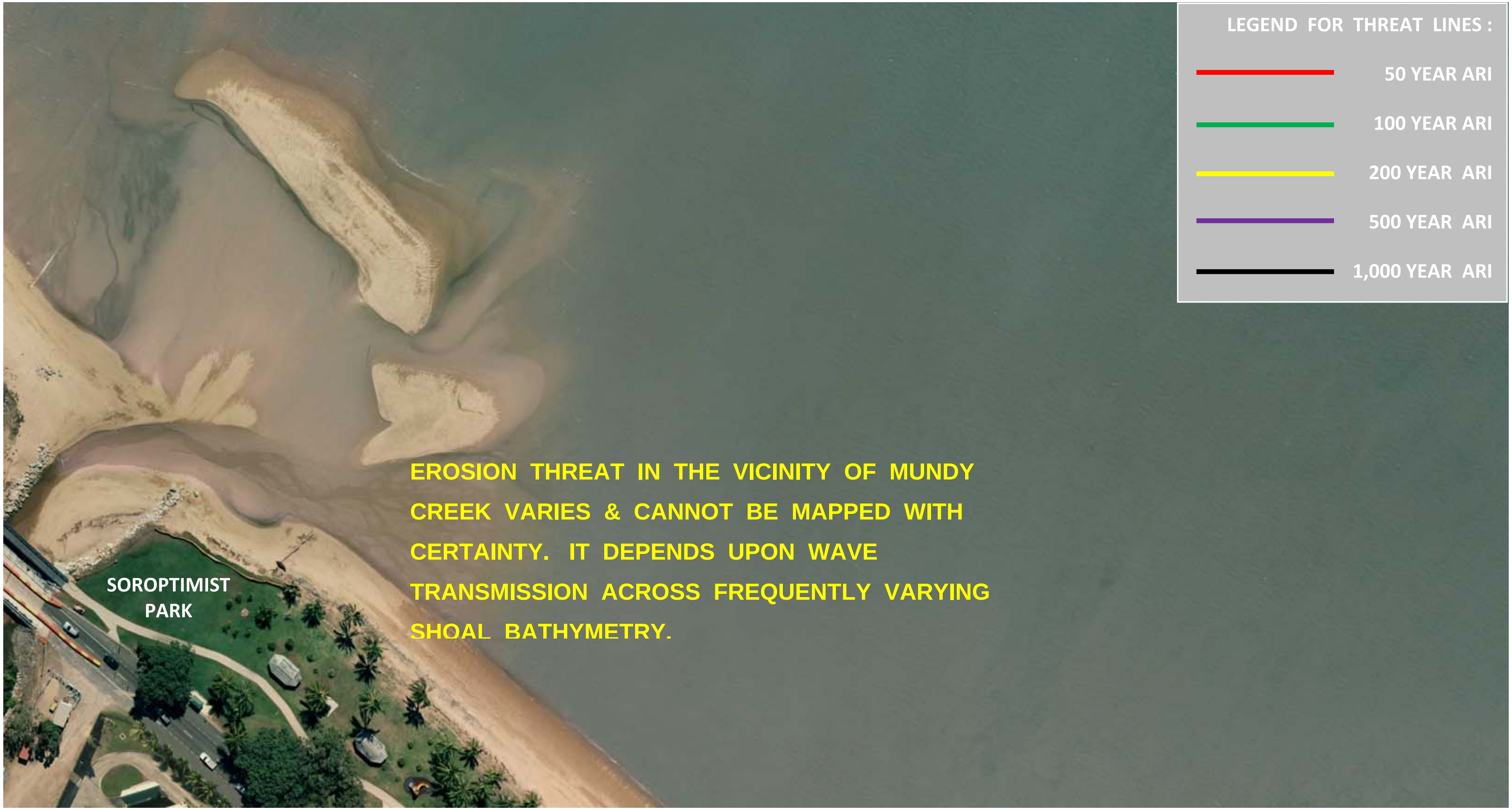
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-50.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
Feb-82
Feb-83
Feb-93
May-98
Jan-03
Mar-04
Apr-05
Feb-06
Mar-07
Oct-08
Feb-09

APPENDIX E

- EROSION VULNERABILITY

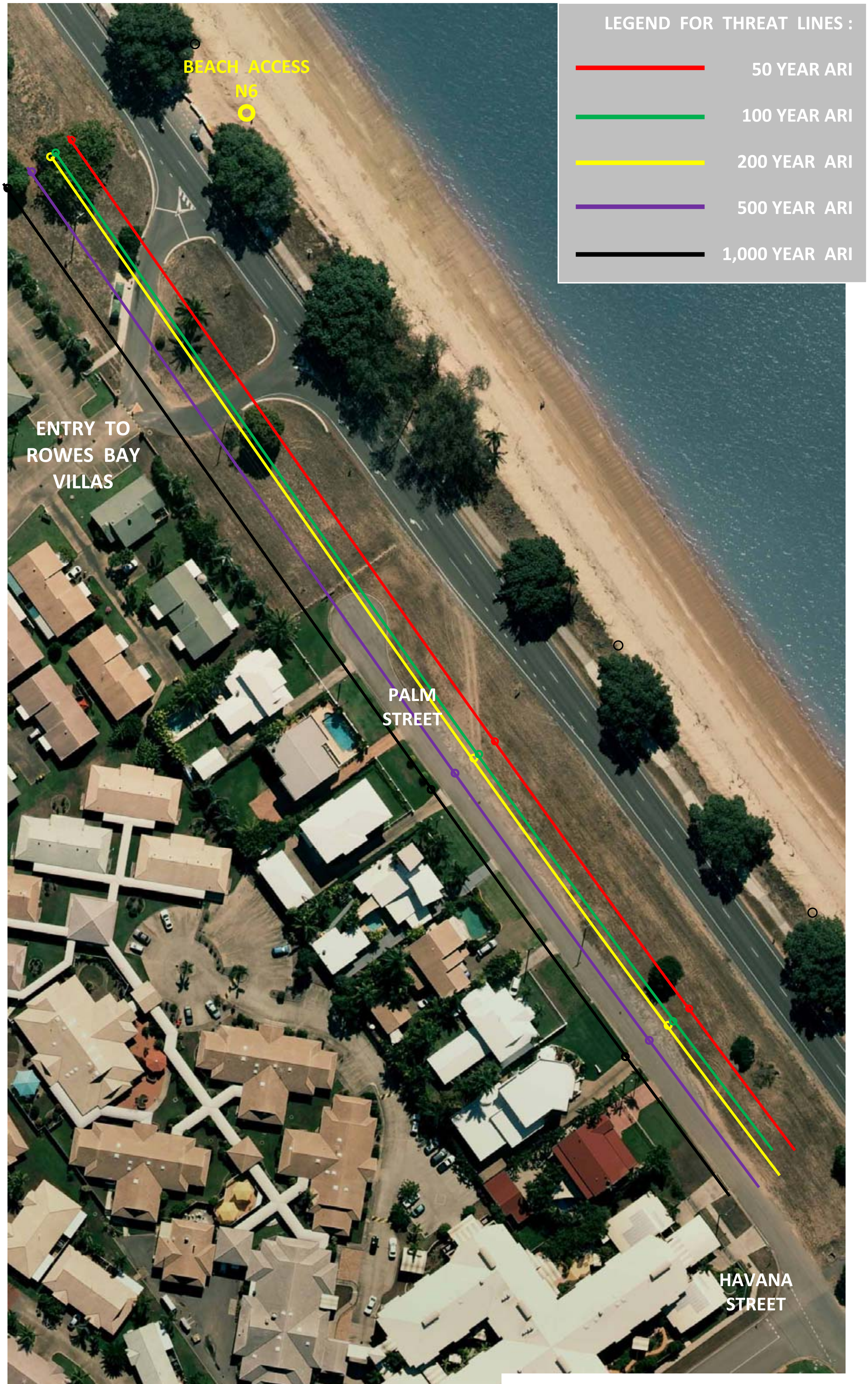
EROSION VULNERABILITY : **MAP 1**



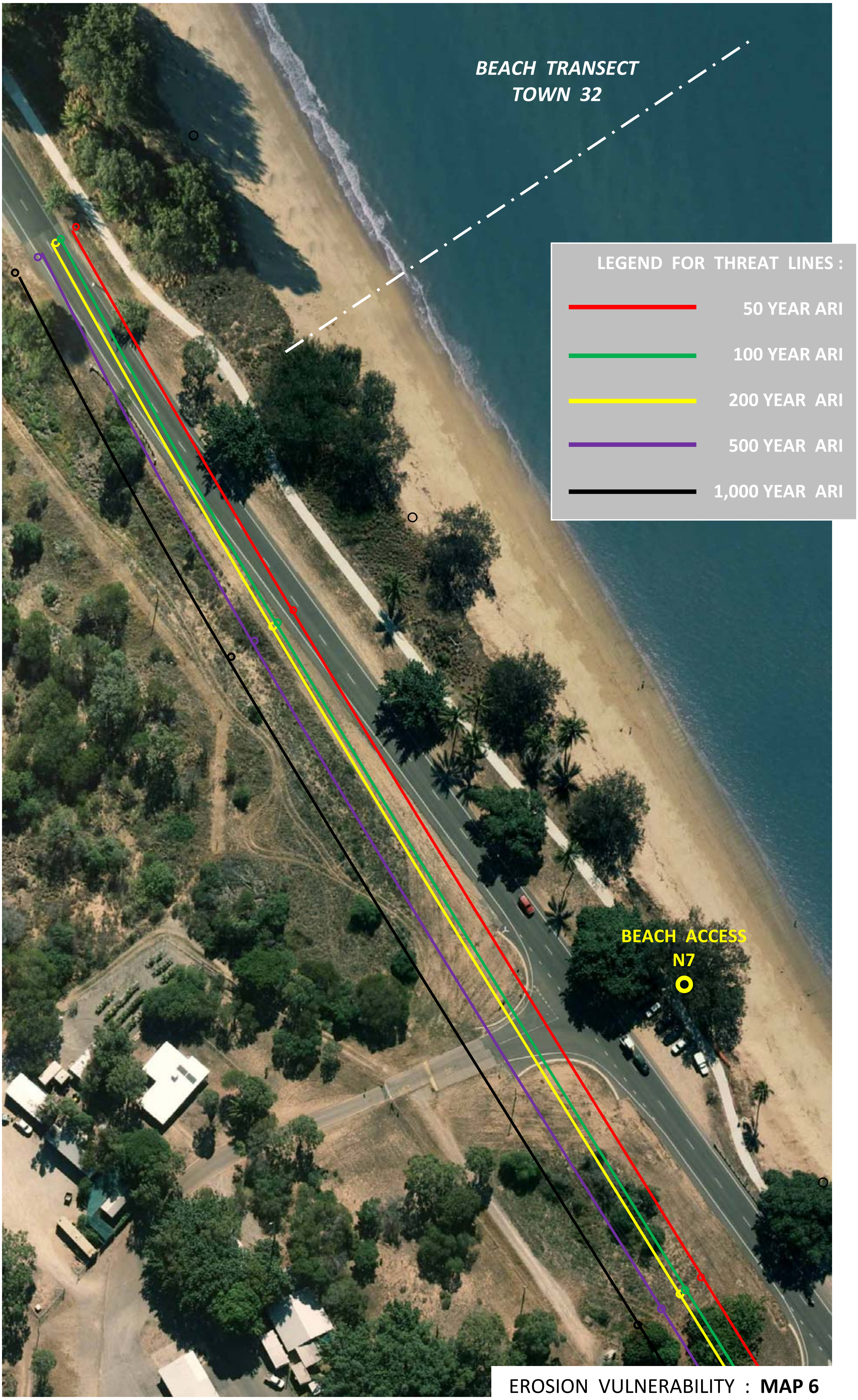
EROSION VULNERABILITY : **MAP 2**


LEGEND FOR THREAT LINES :
50 YEAR ARI
100 YEAR ARI
200 YEAR ARI
500 YEAR ARI
1,000 YEAR ARI
BEACH TRANSECT TOWN 30
BEACH ACCESS N3
BEACH ACCESS N2
PALM STREET
ESK STREET
EROSION THREAT IN THE VICINITY OF MUNDY CREEK VARIES & CANNOT BE MAPPED WITH CERTAINTY. IT DEPENDS UPON WAVE TRANSMISSION ACROSS FREQUENTLY VARYING SHOAL BATHYMETRY.
EROSION VULNERABILITY : MAP 3

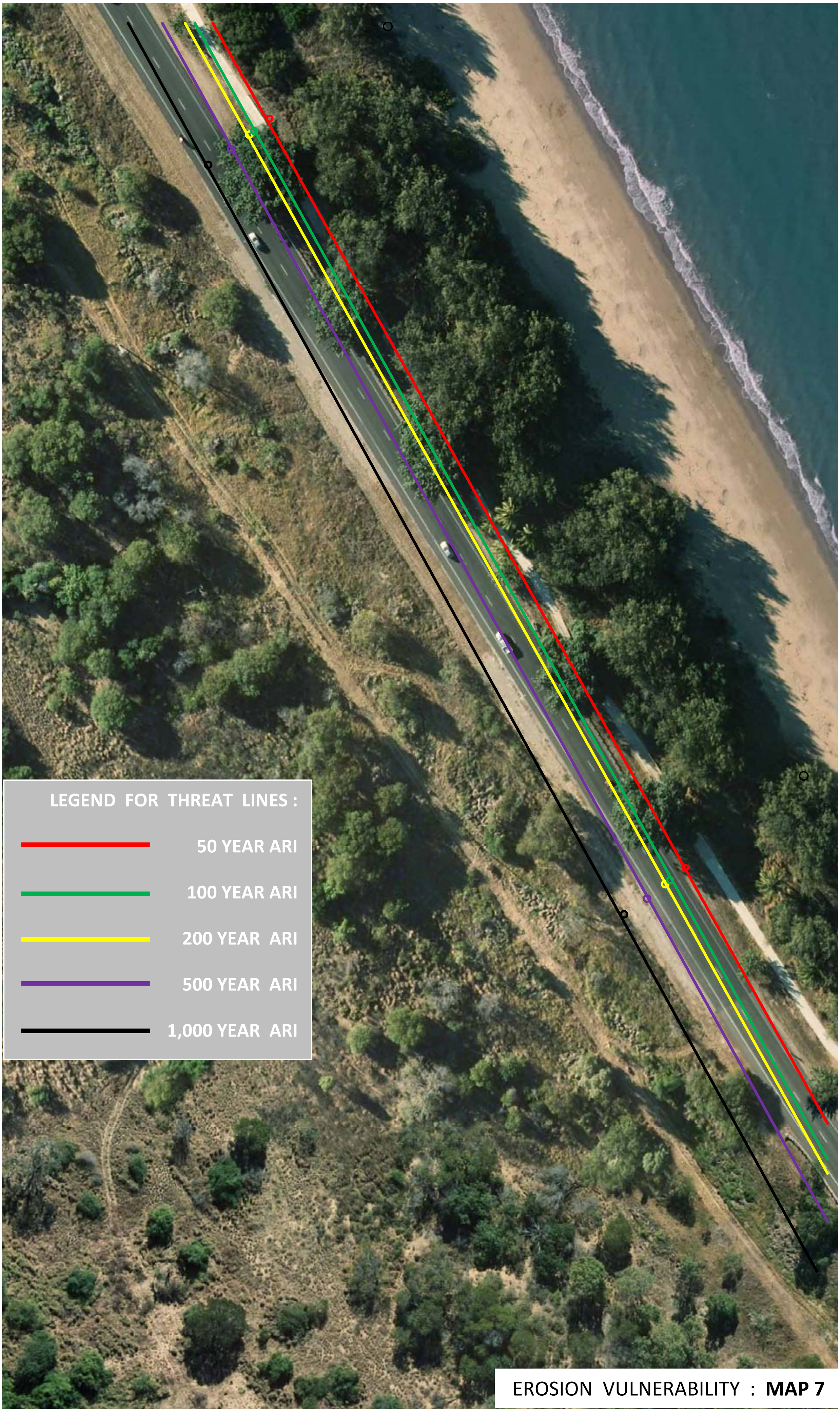
EROSION VULNERABILITY : **MAP 4**

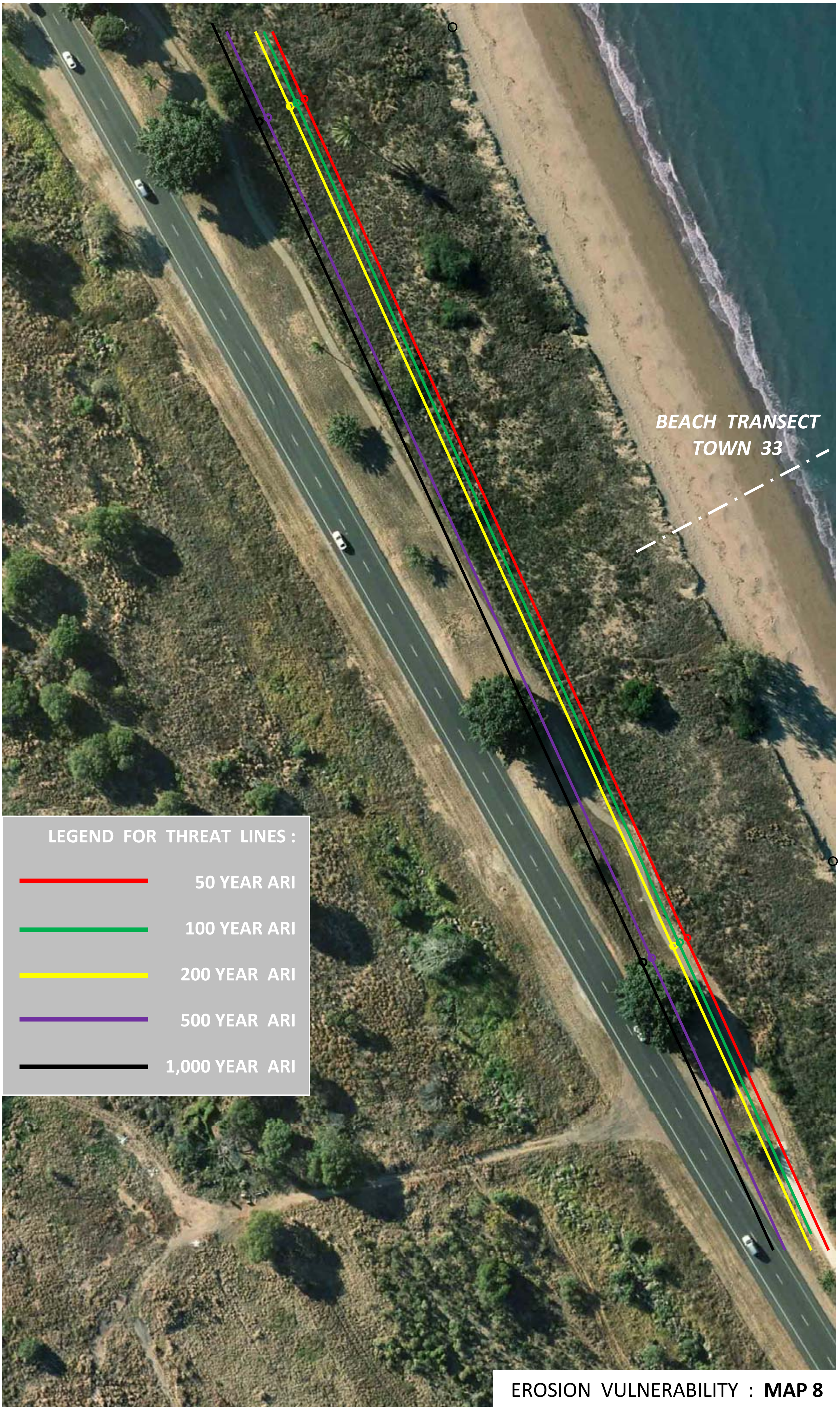


EROSION VULNERABILITY : **MAP 5**

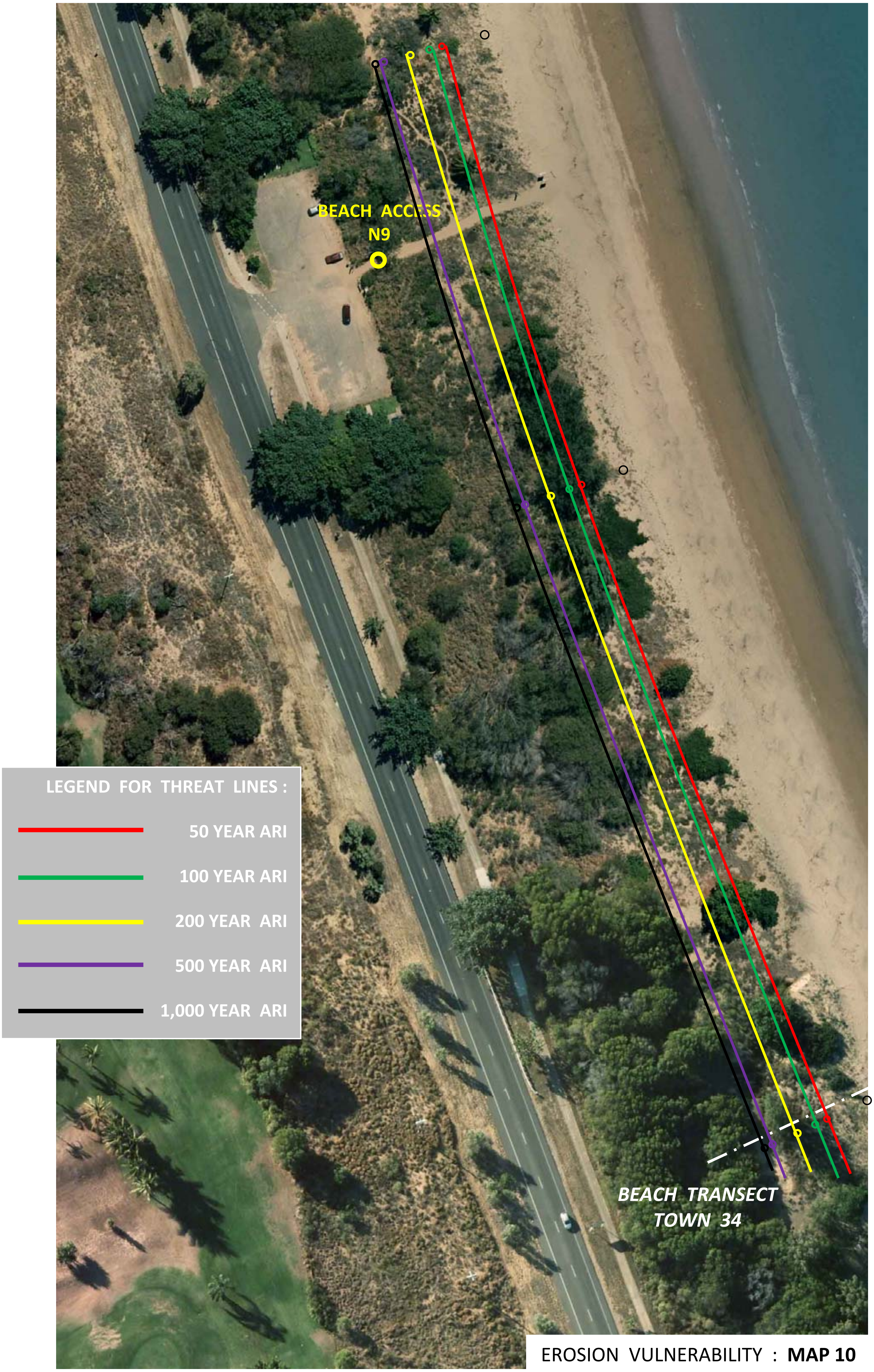


EROSION VULNERABILITY : **MAP 6**

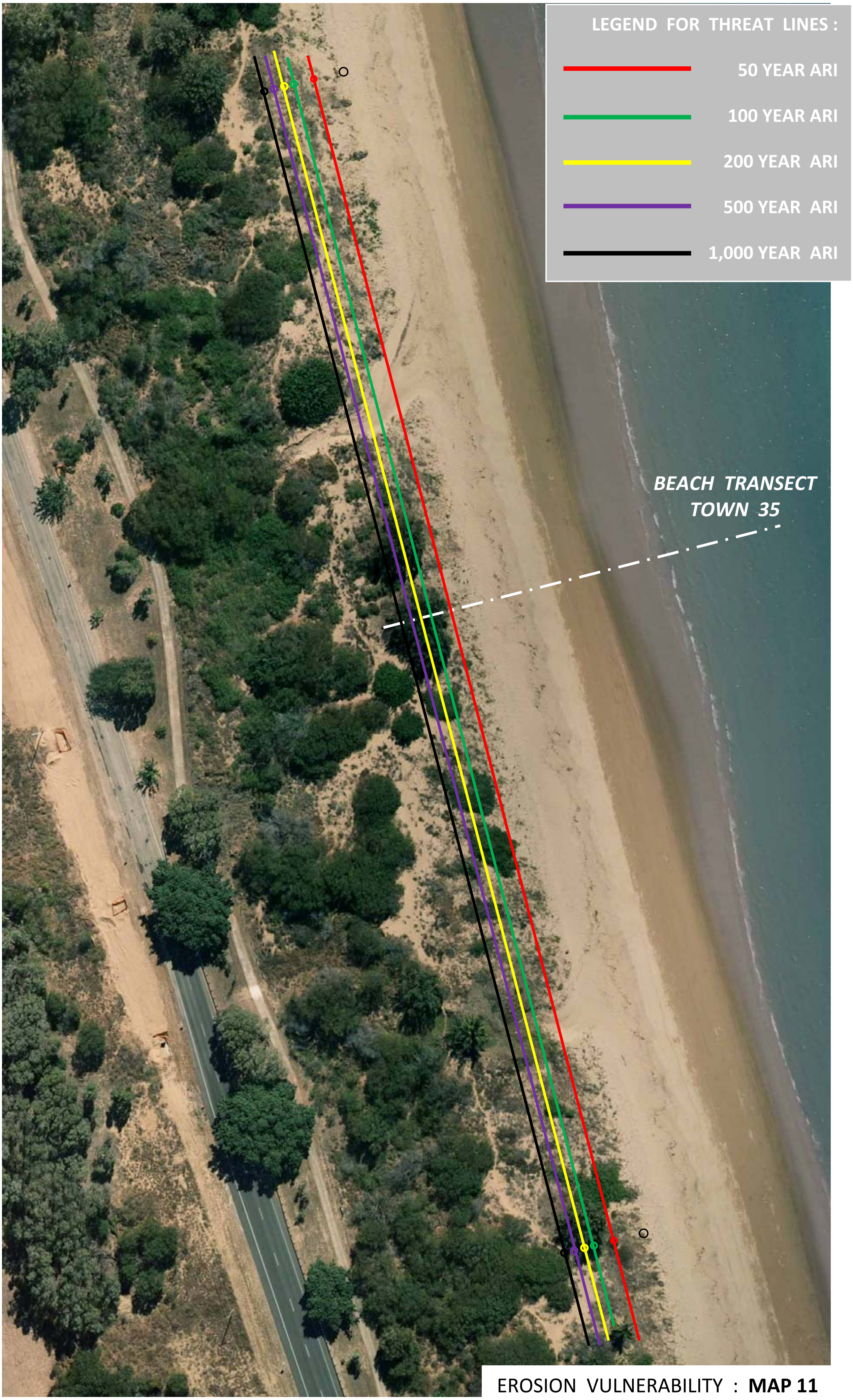

LEGEND FOR THREAT LINES :
50 YEAR ARI
100 YEAR ARI
200 YEAR ARI
500 YEAR ARI
1,000 YEAR ARI
EROSION VULNERABILITY : MAP 7


BEACH TRANSECT
TOWN 33
LEGEND FOR THREAT LINES :
50 YEAR ARI
100 YEAR ARI
200 YEAR ARI
500 YEAR ARI
1,000 YEAR ARI
EROSION VULNERABILITY : MAP 8


ACCESS TO
ROWES BAY
GOLF CLUB
BEACH ACCESS
N8
LEGEND FOR THREAT LINES :
50 YEAR ARI
100 YEAR ARI
200 YEAR ARI
500 YEAR ARI
1,000 YEAR ARI
EROSION VULNERABILITY : MAP 9

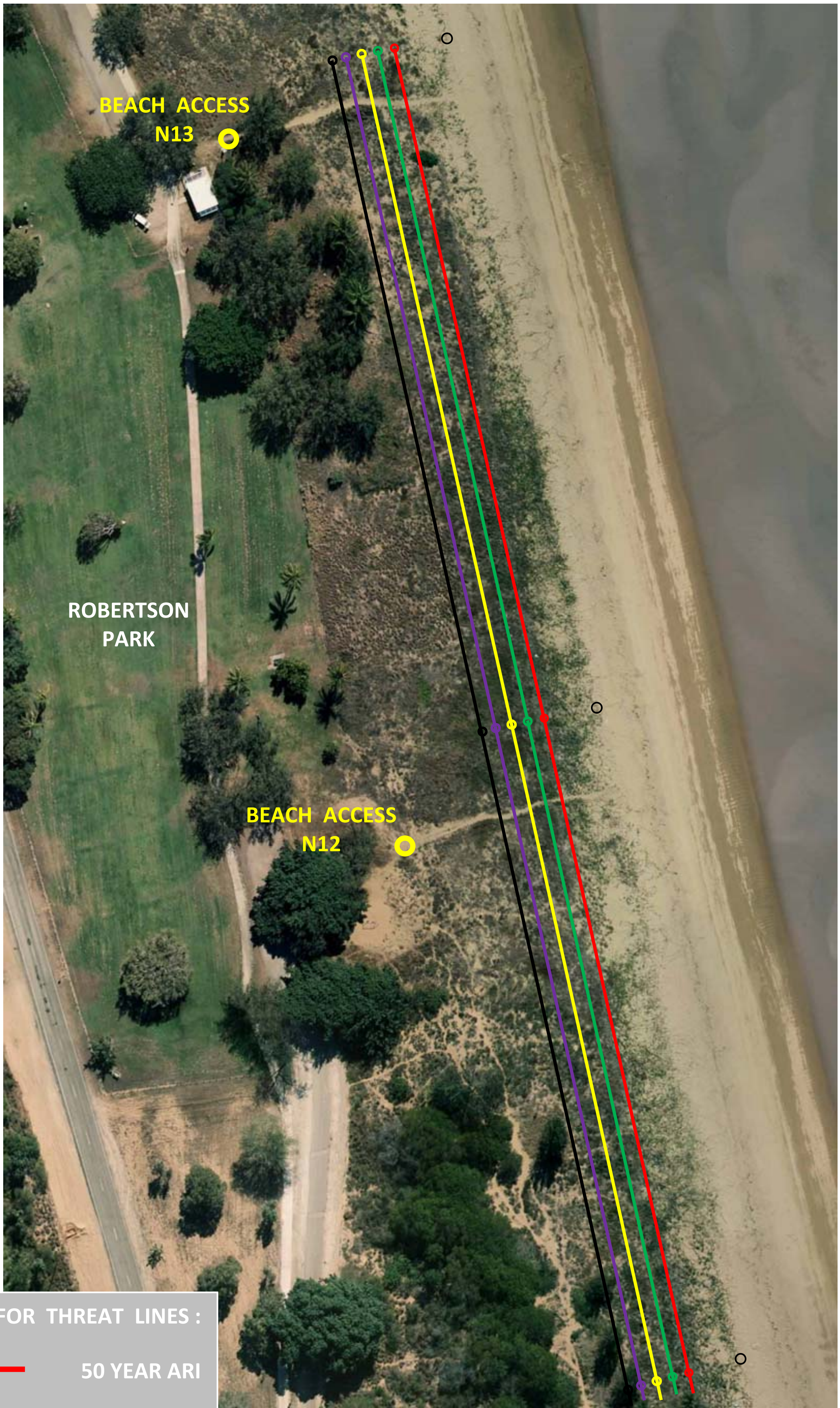


EROSION VULNERABILITY : **MAP 10**



EROSION VULNERABILITY : **MAP 11**

EROSION VULNERABILITY : **MAP 12**



LEGEND FOR THREAT LINES :

50 YEAR ARI

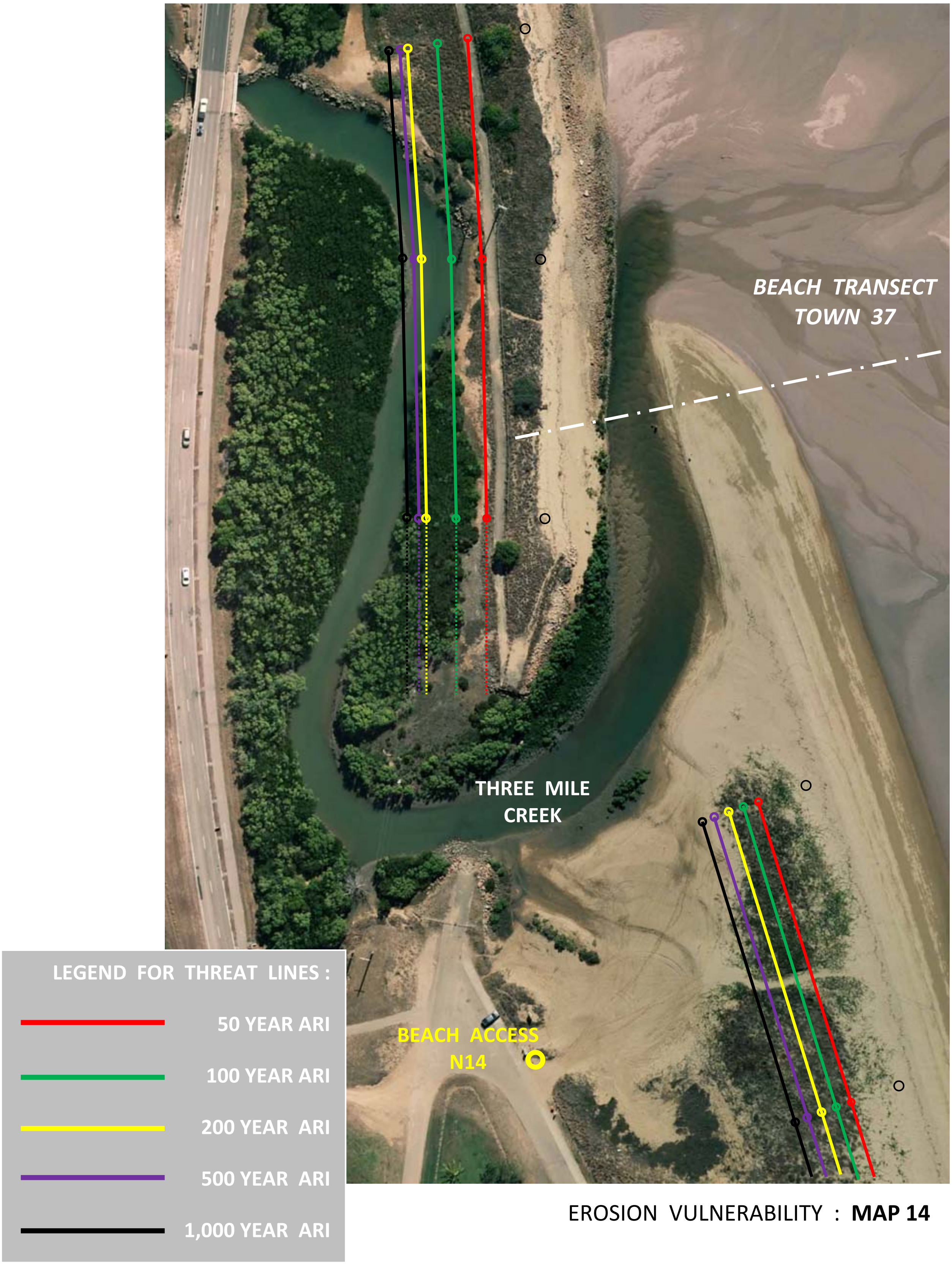
100 YEAR ARI

200 YEAR ARI

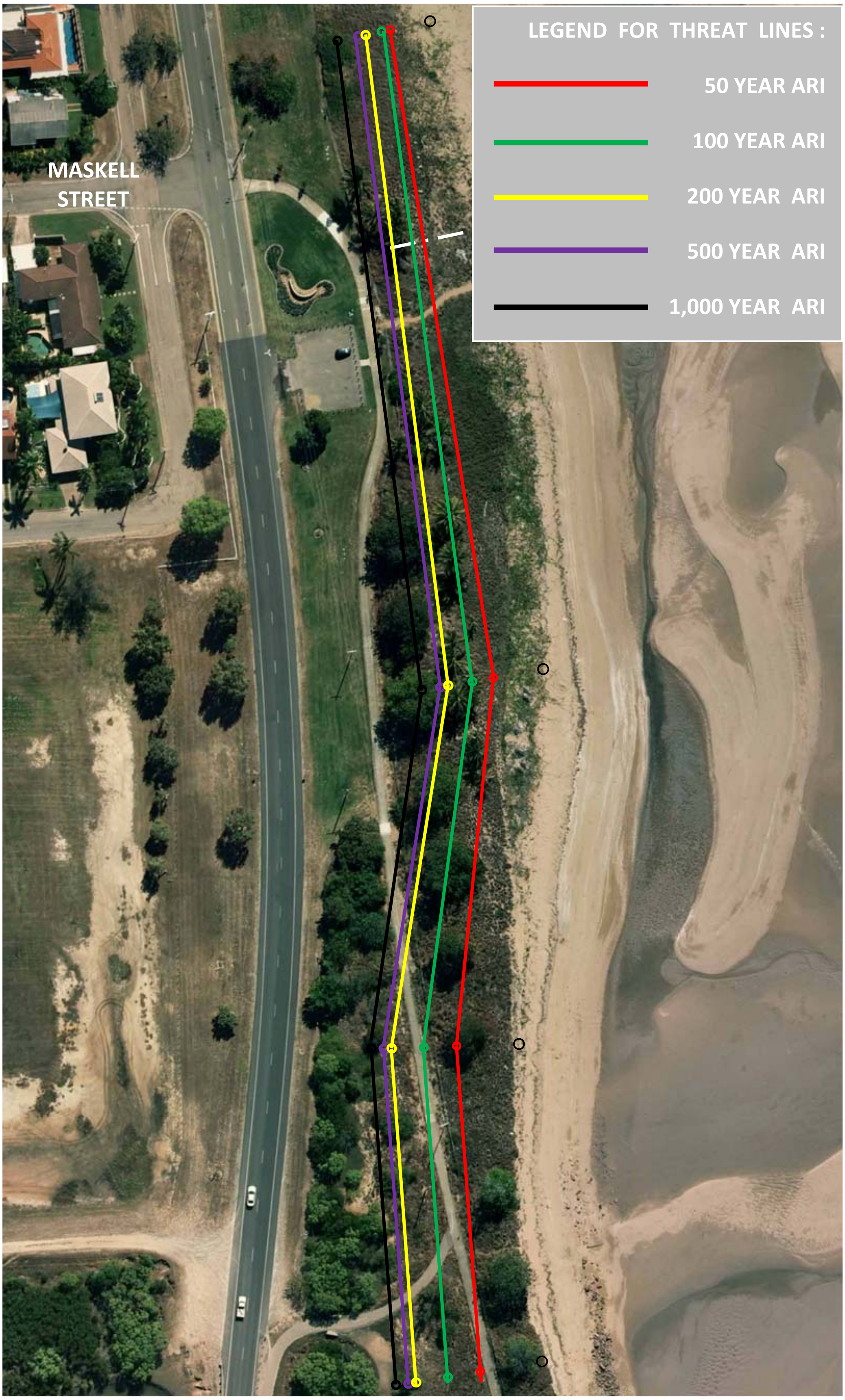
500 YEAR ARI

1,000 YEAR ARI

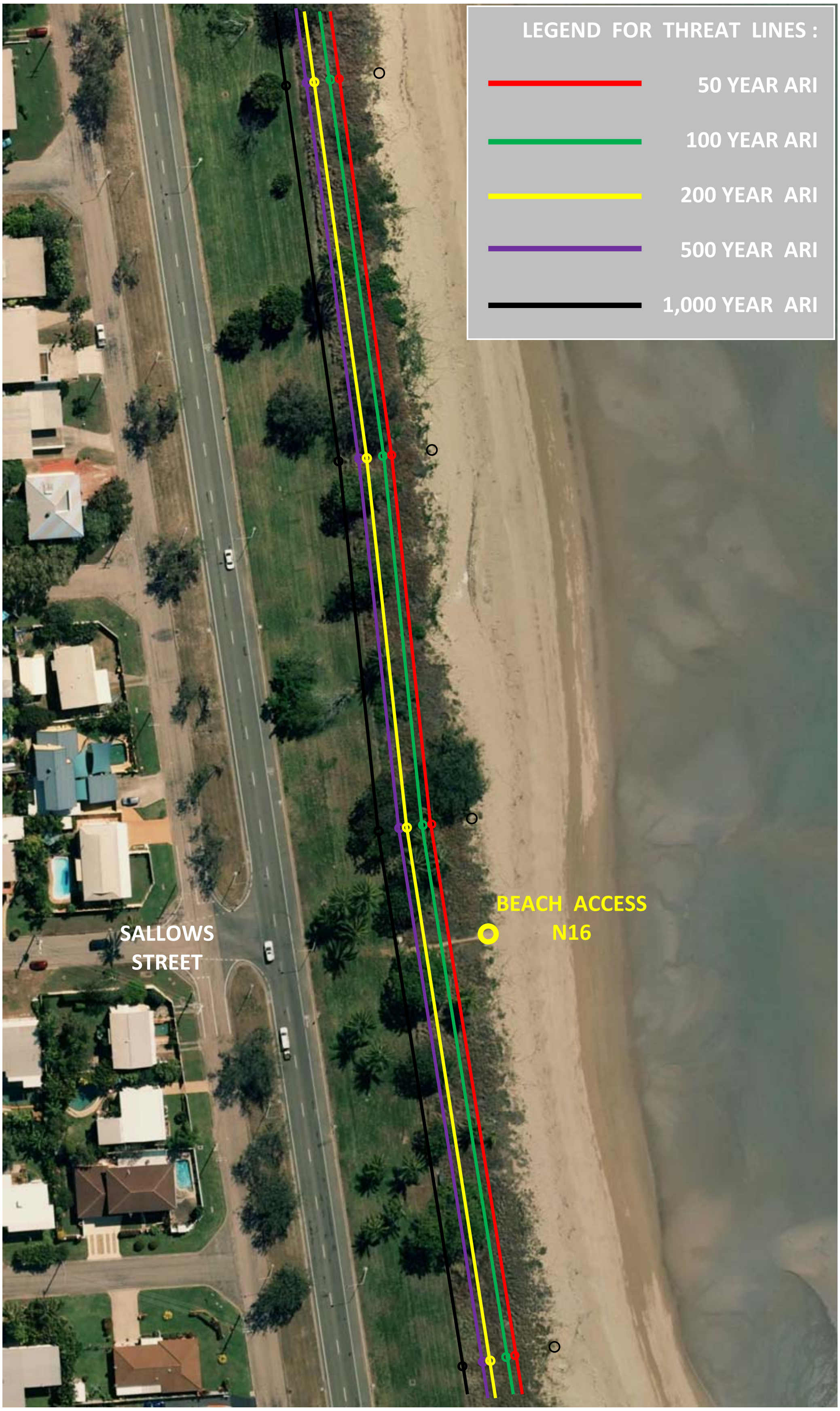
EROSION VULNERABILITY : **MAP 13**



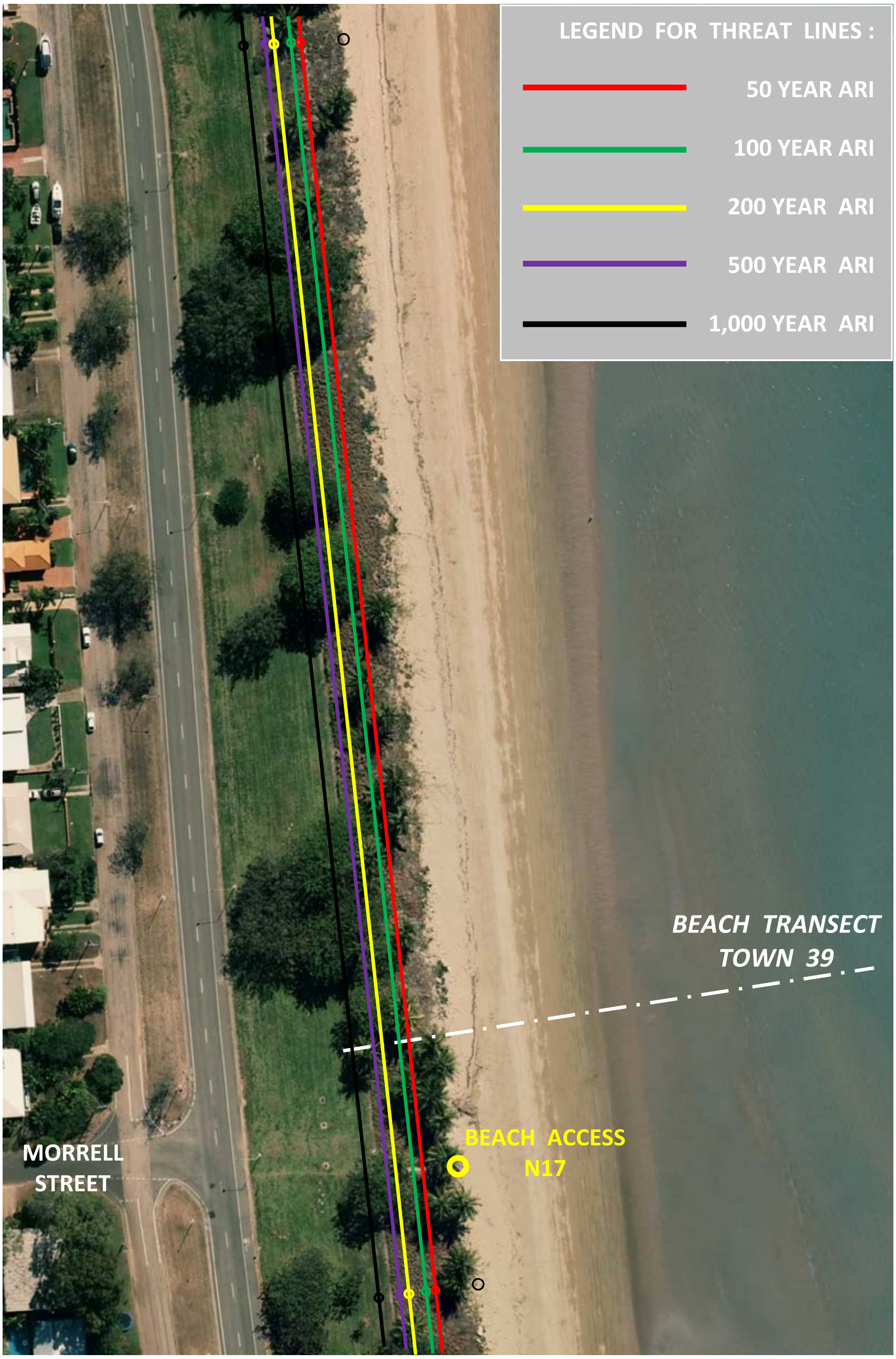
EROSION VULNERABILITY : **MAP 14**



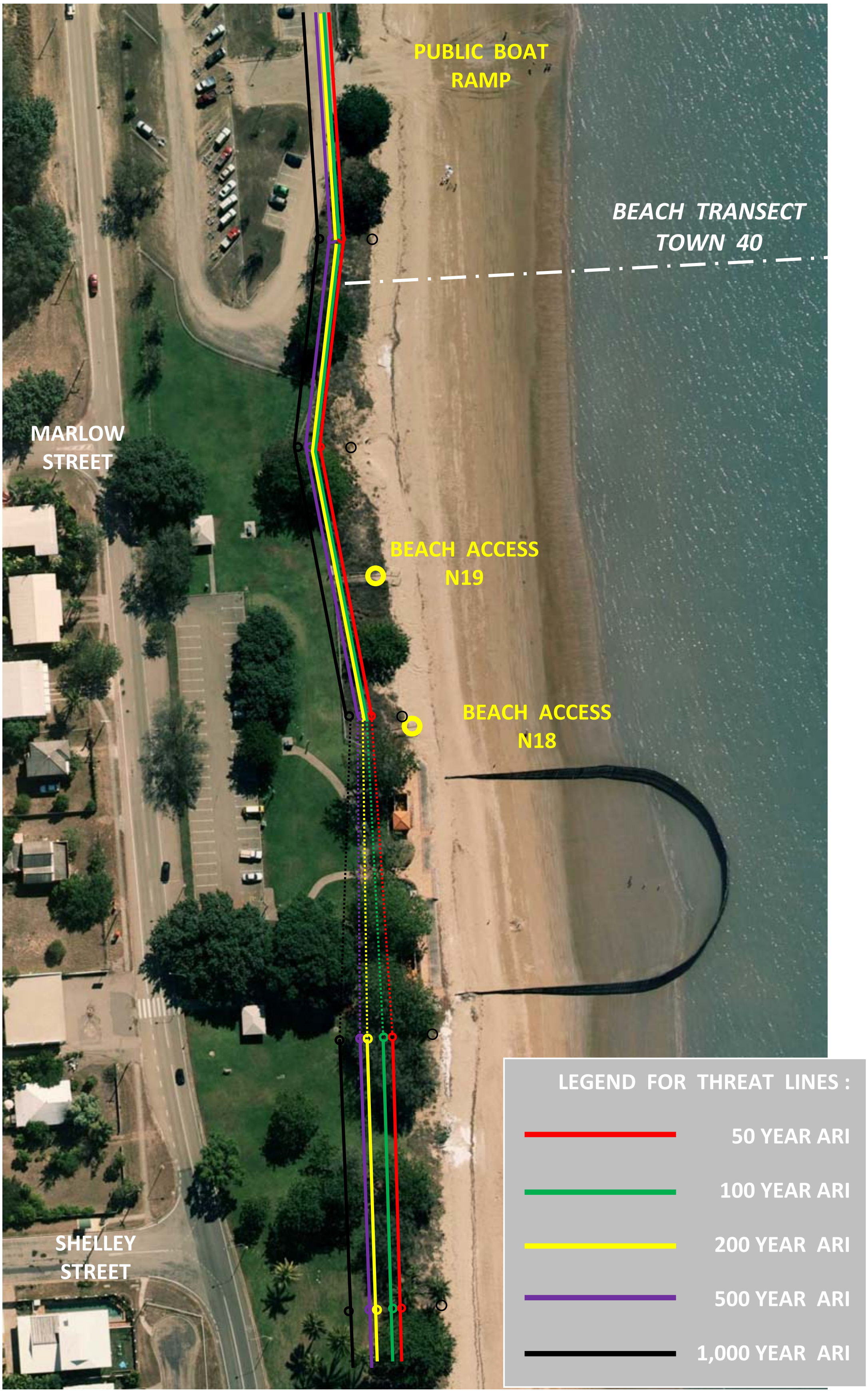
EROSION VULNERABILITY : **MAP 15**



EROSION VULNERABILITY : **MAP 16**



EROSION VULNERABILITY : **MAP 17**



EROSION VULNERABILITY : **MAP 18**

EROSION VULNERABILITY : **MAP 19**