COASTAL ENGINEERING SOLUTIONS

SAUNDERS BEACH

ASSESSMENT OF COASTAL EROSION MITIGATION OPTIONS

prepared for

Townsville City Council

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SUMMARY

Background

- Saunders Beach is a coastal community located approximately 25kms west-north-west of Townsville's CBD. An approximately 1.4km long foreshore near the northern end of the coastal reach between the Black River entrance and Althaus Creek forms the ocean frontage to the settlement.

- Recent erosion events have heightened concerns by the local community regarding the threat of erosion. Very high tides accompanied by moderately rough sea conditions in early 2009 and again in early 2010 caused foreshore erosion. These erosion events were then followed by TC Yasi in February 2011 - which caused considerable damage to the Saunders Beach foreshore.

- In response to these concerns, Townsville City Council has commissioned an *Assessment of Coastal Erosion Mitigation Options* for Saunders Beach. The objective is to identify potentially viable mitigation strategies that can be considered for the foreshore fronting the coastal community. This report presents the findings of those investigations.

- The nature of land tenure fronting the township Saunders Beach is an important consideration when assessing appropriate erosion mitigation options. The foreshore between private property boundaries and the beach consists of an Esplanade on Unallocated State Land (USL) for which Council is the trustee for management purposes.

- The width of buffer between the beach and private property boundaries is not constant along the Saunders Beach foreshore - due to the slight crescent shape of the shoreline itself, as well as the castellated planform of the seaward property boundaries (particularly along the northern section).

Prevailing Coastal Processes

- There is a net transport of approximately 10,000m^3 to 14,000m^3 of sand northwards along Saunders Beach each year.

- The primary source of sand supply to Saunders Beach is the nearby Black River. However rather than a steady annual rate, the supply of this sand to Saunders Beach is somewhat episodic and heavily reliant on processes affecting the sand delta at the river entrance.

- The supply of sand to the coast from the Black River relies on infrequent major floods to flush sediments off the catchment and through the lower reaches of the river, in conjunction with the need to have storms or sustained periods of strong south-easterly wave conditions to sweep sand northwards off the submerged delta onto Saunders Beach.

- Consequently there are inevitably periods where actual sand supply does not match the ongoing average north-westerly sand transport of 10,000m^3 to 14,000m^3 each year, nor are buffers naturally recharged prior to the onset of adverse northerly sea conditions – resulting in periods of erosion on Saunders Beach. However these erosion phases are typically followed by periods of beach recovery when greater sand supply is initiated during years of more energetic south-easterly wave activity.

- Whilst there are these cycles of beach erosion and accretion, over time a steady-state has prevailed whereby the shoreline between the Black River and Althaus Creek is supplied with sand at a long-term rate that matches the sand moved off the shoreline. However strong cycles of erosion and accretion mean that there are appreciable fluctuations from year to year around the average shoreline position.
- The relatively low foreshore along Saunders Beach makes it particularly susceptible to overwash. This phenomenon occurs when the storm tide builds during a 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 the storm causing overwash abates, the actual position of the intertidal beach slope may not have retreated inland much further than its pre-storm location.
- When considering erosion mitigation measures, it is important to appreciate the specific vulnerability of the Saunders Beach foreshore to storm events. Because of the low level of this foreshore, the local community and foreshore infrastructure are particularly susceptible to the damage that can be inflicted by the elevated ocean water levels and waves that can wash over the beach during severe cyclone occurrences. Such storm tide inundation and simultaneous wave action can cause extensive damage.
- However in terms of shoreline recession, such severe events on their own are not as damaging as less severe but more frequent storm events.
- During less severe events, waves can directly attack the beach itself (rather than wash over it), thereby causing recession of the beach face. If such events occur in relatively quick succession, their accumulating effect can be considerable before natural beach processes can act to restore beach profiles as part of the typical erosion / accretion cycles that occur on Saunders Beach. The elevated tides and simultaneous rough sea conditions that occurred in early 2009 and early 2010 were indicative of such phenomena.
- The high rates of shoreline recession in recent years have coincided with a period of increased ocean water levels and wave activity.

Recommended Erosion Mitigation Strategy

- When considering foreshore protection measures on any shoreline, 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 Saunders Beach shoreline, or alternatively the alignment of any protection structure such as a seawall. Property and infrastructure landward of the Coastal Defence Line remain protected, whereas foreshore areas seaward of the line lie within the active beach system (ie. within the erosion buffers).

- When considering appropriate erosion mitigation options along the suburban foreshore of Saunders Beach it is necessary to consider the entire coastal reach between the Black River and Althaus Creek. In doing so it is evident that the shoreline can be considered as three coastal precincts, namely:
    - Southern Precinct : from the entrance of the Black River to approximately the southern-most end of Cay Street. It is approximately 4.2kms in length.
    - Central Precinct : from the southern end of Cay Street to Saunders Beach Road, which is almost the entire ocean frontage of the developed community of Saunders Beach. It is approximately 1.4kms in length.
    - Northern Precinct : from approximately Saunders Beach Road northwards to the ocean entrance of Althaus Creek. It is approximately 400 metres in length.
- This separation into coastal precincts does not imply that the coastal processes within each are in any way compartmentalised. They are not isolated or discrete sections of shoreline, since the processes affecting each have significant influences on the others. However this partitioning lends itself to the development of viable erosion management strategies that integrate well over the entire Saunders Beach coastal reach.
- The recommended erosion mitigation strategy for the Saunders Beach coastal reach requires consideration of different strategies for the three precincts along the entire foreshore.

Southern Precinct : Between the Black River and the Southern End of Cay Street

- No direct intervention, since this Southern Precinct is currently in a phase of accretion.
- Given the episodic nature of sand supply; and that it does not necessarily coincide with northerly storm events, there will invariably be periods of short-term erosion of the foreshore and front dune. It is therefore also recommended that no future development should occur on the foreshore along this Southern Precinct.
- The foreshore should be monitored by regular surveys. Appropriate transect lines need to be established at regular intervals along this southern precinct.

Central Precinct : Between Southern End of Cay Street and Saunders Beach Road

- Two viable options are available for consideration by Townsville City Council and other stakeholders for the long-term protection of this 1400 metre long Central Precinct. These options being:

    Option 1 : Beach Nourishment only

    - initial placement of approximately 120,000 m^3 of sand to reinstate the position of the shoreline that existed in 1941. This initial sand placement could be undertaken over 3 to 4 consecutive years;
    - on-going placement of an average of between 5,000m^3 and 10,000m^3 of sand per year to keep the reinstated buffer charged with sand.

Option 2 : Seawall and Beach Nourishment

- o select an alignment for the seawall (ie. a Coastal Defence Line).
- o complete a detailed structural design of a buried seawall; which at this stage is estimated to require the placement of either approximately 15,000m^3 of armour rocks within the size range of 1 tonne to 5 tonne, or alternatively constructed of sand-filled geotextile containers.
- o placing an initial volume of sand in the existing buffer in front of the seawall to provide improved beach and foreshore amenity. The volume of any imported sand will depend upon the chosen alignment of the Coastal Defence Line; however as a guide there should be at least a sand volume of 35m^3 / metre length of foreshore available at all times to serve as a buffer in front of the seawall.
- o on-going placement of an average of between 5,000m^3 and 10,000m^3 of sand per year to keep the buffer in front of the seawall charged with sand.

Recommended interim strategy

- o Either of these long-term measures will invariably be expensive and require time to be appropriately designed and for the necessary approvals to be obtained. In the interim, it is recommended that the strategy recently implemented by Townsville City Council of mechanically redistributing sand on the beach profile should be continued. Under this strategy, mechanical plant and equipment are used to move sand up the beach slope into the depleted foredune area - thereby hastening the natural rehabilitation of the upper beach area.

- Irrespective of the option adopted, the foreshore should continue to be monitored through regular surveys on previously established beach transect lines.

Northern Precinct : Between Saunders Beach Road and Althaus Creek

- No direct intervention, since this Northern Precinct is currently in a phase of accretion.
- However given the dynamic nature of the Althaus Creek entrance area, there will invariably be periods of short-term erosion of this foreshore. It is therefore also recommended that no intensification of development should occur in future on this northern foreshore precinct.
- Continue to monitor the foreshore through annual surveys of established beach transect lines.

1 INTRODUCTION

1.1 General

Saunders Beach is a coastal community located approximately 25kms west-north-west of Townsville's CBD. An approximately 1.4km long foreshore near the northern end of the coastal reach between the Black River Entrance and Althaus Creek forms the ocean frontage to the settlement.

In recent years this foreshore has been experiencing variable rates of erosion which have been threatening private and public assets.

Townsville City Council has therefore commissioned an *Assessment of Coastal Erosion Mitigation Options* for Saunders Beach. The objective is to identify potentially viable mitigation strategies that can be considered for the foreshore fronting the coastal community. This report presents the findings of those assessments.

This report has been structured as follows:

- This Section 1, which consists of an introduction and provides some background regarding the Saunders Beach foreshore.
- Section 2 provides a broad overview of the coastal processes that are shaping the foreshore and nearshore regions of the Saunders Beach coastal reach.
- Then in Section 3, a number of generic strategies to mitigate erosion are offered.
- This is followed in Section 4 by an assessment of specific strategies in the context of the Saunders Beach coastal reach.
- Section 5 then summarises the recommended erosion mitigation strategy.
- Technical references are listed in Section 6.
- Appendices to support the technical content of the assessment are then included.

1.2 Regional Setting

As shown on Figure 1, Saunders Beach is located on the southern shores of Halifax Bay. The Bay is a wide crescent-shaped embayment between Cape Pallarenda and Lucinda Point. It faces approximately north-east onto the broad open waters between the mainland and the Great Barrier Reef.

The gradient of the seabed approaches onto the local foreshores of Saunders Beach are quite flat, providing some natural protection due to the attenuating effect on incoming wave energy.

Nevertheless, the fetches to the north-east of Halifax Bay are quite long, with the main Great Barrier Reef system being some 75kms offshore. It is from across these open north-east fetches that the largest waves can propagate across Halifax Bay and onto the Saunders Beach foreshore.

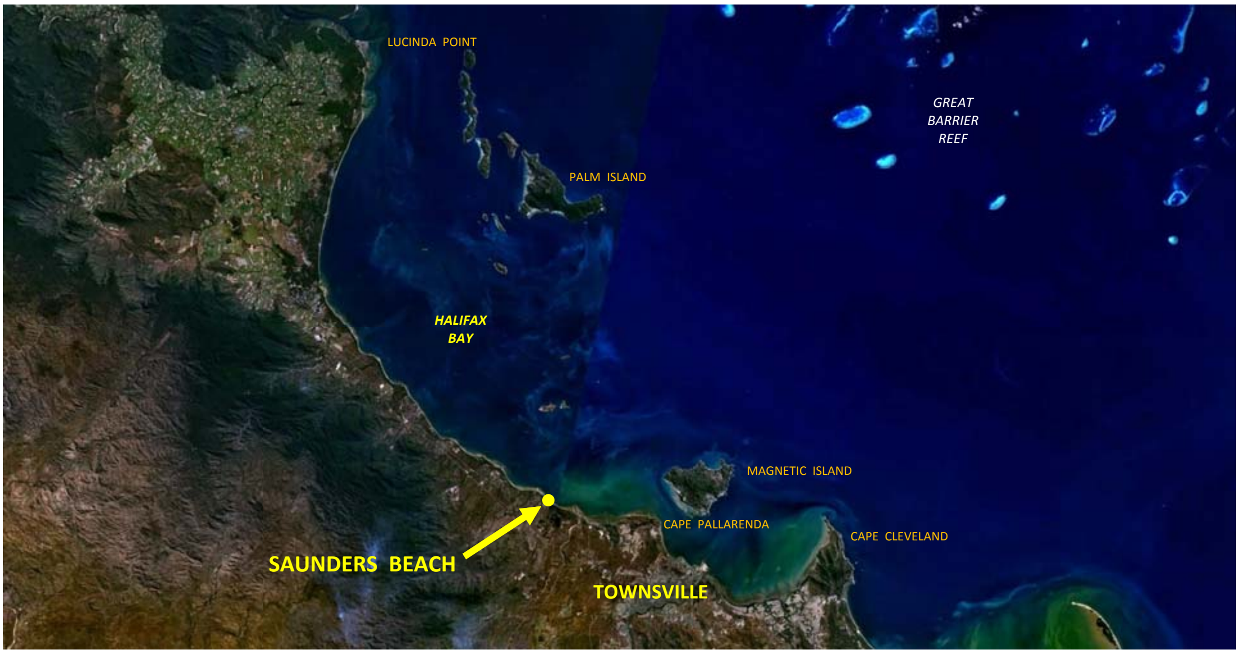


Figure 1 : Location of Saunders Beach in a regional context

1.3 Local Setting

Figure 2 shows the setting of Saunders Beach within a more local context. There are a number of features evident in this figure which are referred to in later discussions throughout this report. The most relevant of these being:

- the developed area that constitutes the community of Saunders Beach;
- the entrance and delta of the Black River, which forms the southern boundary of the Saunders Beach coastal reach;
- Althaus Creek, which forms the northern boundary of the reach; and
- an un-named creek that discharges across the foreshore to the south of the Saunders Beach suburb.

Throughout this report the term *Saunders Beach* is used to define the approximately 1.4km long ocean frontage of the developed suburban community of Saunders Beach.

There have been intermittent beach transect surveys undertaken along Saunders Beach in recent years; and the results of these surveys have been made available for this assessment. The locations of these transect lines and the survey results are summarised in Appendix A.

Figure 2 : Saunders Beach coastal reach

The survey results (supplemented by on-site observations) indicate that the foreshore level is somewhat variable. The foredune along the northern part of Saunders Beach is typically the highest - with levels generally around RL+5m AHD. The foreshore immediately behind this crest also tends to be around this level.

South of the sealed pavement of the Esplanade, the foreshore tends to be lower, being around RL+3.5m to RL+5.0m AHD. Along the southern-most end of Cay Street, there has typically been a distinct foredune in recent years with a crest around RL+4.0m to RL4.5m AHD.

1.4 Local Foreshore Land Tenure

The nature of land tenure along the foreshore of Saunders Beach is an important consideration when assessing appropriate erosion mitigation options. As evident in Figure 3, Figure 4 and Figure 5, the foreshore between private property boundaries and the beach consists of an Esplanade on Unallocated State Land (USL) for which Council is the trustee for management purposes. These figures have been provided by Townsville City Council and use aerial photographs taken in late 2009.

The width of buffer between the beach and private property boundaries is not constant along the Saunders Beach foreshore - due to the slight crescent shape of the foreshore and the castellated planform of the seaward property boundaries (particularly along the northern section).

Property boundaries overlain on the aerial photographs of 2009 show the residual buffer widths following significant erosion earlier that year which was caused by high tides and rough sea conditions in the period of January to March. Minimum buffer widths of around 14m to 25m metres existed along most of the foreshore. These buffer widths have been further diminished since that time due to additional high tides and adverse sea conditions in January 2010; and as a consequence of TC Yasi in February 2011.

In recent years an informal survey of the position of a section of the beach opposite Cay Street has been undertaken by Integrated Sustainability Services of Townsville City Council (refer to Figure 6). The results indicate that since 2009 when the aerial photographs for the property overlays were prepared, foreshore buffers have been further reduced by some 5m to 6m.

These recent erosion events have heightened concerns by the local community regarding the threat of shoreline recession. TC Yasi in early February 2011 also caused considerable damage to the foreshore.

Figure 3 : Foreshore Properties & Survey Transects - northern Saunders Beach
(superimposed on a 2009 aerial photograph)

Figure 4 : Foreshore Properties - central section of Saunders Beach
(superimposed on a 2009 aerial photograph)

Figure 5 : Foreshore Properties - southern section of Saunders Beach
(superimposed on a 2009 aerial photograph)

Figure 6 : Indicative buffer widths - Cay Street, Saunders Beach
(provided by Integrated Sustainability Services of Townsville City Council)

2 LOCAL COASTAL PROCESSES

2.1 Background

The coastal processes in Halifax Bay result in the transport of sand from the south-east towards the north-west along the foreshore of Saunders Beach. Consequently natural processes shaping the beach are strongly influenced by the presence of the Black River Entrance immediately to the south-east. This river system has provided sediments to the coast via the extensive shoals within the entrance delta - which have then been worked by waves and currents onto local beaches. Other smaller local creeks and streams also have sandy deltas indicating their supply of sediments to the coast.

Previous detailed analysis of shoreline position of Saunders Beach (Smithers, 2009) reveals a history of erosion and accretion cycles since at least 1941. That comprehensive earlier study utilised mathematical modelling, surveys and historical aerial photographs (dating back to 1941) to identify and measure historical realignments of the local shoreline. It provides a sound technical basis to support the determination of an appropriate erosion mitigation strategy for this foreshore. Given the importance of that earlier work by Dr. Smithers and its direct relevance to this assessment of erosion mitigation options, it is included herein as Appendix B.

Particularly relevant findings of that earlier study are summarised below. It is important to appreciate that these findings were determined prior to the adverse sea and tide conditions of January 2010 and the devastating effects of TC Yasi in February 2011. However these subsequent severe events do not alter the conclusions or overall findings of that study.

- There is a net transport of approximately 10,000m^3 to 14,000m^3 of sand northwards along Saunders Beach each year.
- The shoreline can be very dynamic. Significant changes in the shoreline position occur rapidly during high-energy wave events. There is no particular location that has consistently shown either uniform on-going erosion or accretion - "*fluctuations are the norm*".
- Nevertheless since 1941 there have been some net changes to the shoreline, namely
  - significant accretion of the shoreline to the south of the developed suburban community of Saunders Beach;
  - the foreshore south-east of Saunders Beach Road has receded by up to 15m (as at 2009) since 1941;
  - the foreshore north-east of Saunders Beach Road (to the entrance of Althaus Creek) has accreted since 1941, but is particularly dynamic with significant fluctuations over seasonal timeframes.
- Although some sections of Saunders Beach have clearly retreated in recent decades, the average trend over the entire coastal precinct from the Black River up to Althaus Creek has been one of small net accretion.

- In recent years, the increased erosion experienced on Saunders Beach is more directly attributed to higher than normal tides occurring in conjunction with rough sea conditions. The elevated ocean water levels during such events resulted in substantial erosion of the upper beach area.
- It is postulated that since the higher and more frequent tides that occurred in recent years have been part of the 18.6 year tidal epoch, in coming years as the cycle wanes extreme high tides will not be as high or as frequent.

2.2 Overview of Sand Transport Processes

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

2.2.1 Longshore transport

Longshore transport is the movement of sand along the beach. 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 successful erosion 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 Saunders Beach shoreline, where the net transport rate is towards the north-west despite there being sand movement in both longshore directions throughout a typical year. Earlier investigations estimated an average net north-westerly rate of 10,000m^3 to 14,000m^3 each year.

Whilst there may be a net longshore transport along Saunders Beach, 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. The primary source of sand supply to Saunders Beach is the nearby Black River. Certainly other rivers and creeks that discharge into Halifax Bay further to the south contribute sand to Saunders Beach, but it is the Black

River which overwhelmingly provides the greater volume of sand to the immediate downdrift coastal reach of Saunders Beach.

However rather than a steady annual rate, the supply of sand to Saunders Beach is somewhat episodic and heavily reliant on processes affecting the sand delta at the Black River Entrance. The supply of sand to the coast by the Black River relies on infrequent major floods to flush sediments off the catchment and through the lower reaches of the river, in conjunction with the need to have storms or sustained periods of strong south-easterly wave conditions to sweep sand northwards off the submerged delta onto Saunders Beach.

Consequently there are inevitably periods where actual sand supply does not match the ongoing average north-westerly sand transport of 10,000m^3 to 14,000m^3 each year – resulting in periods of erosion on Saunders Beach. However these erosion phases are typically followed by periods of beach recovery when greater sand supply is initiated during years of more energetic south-easterly wave activity.

Whilst there are these cycles of beach erosion and accretion, over time a steady-state has prevailed whereby the shoreline between the Black River and Althaus Creek is supplied with sand at a long-term rate that matches the sand moved off the shoreline. This behaviour is reflected in the findings of Dr. Smither's earlier study, which concluded that there has been only a minor change to the net volume of sand on the downdrift Saunders Beach coastal reach since 1941.

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 north-westerly longshore sand transport was matched by the long-term net supply of sand from the south-east.

It is pertinent to note that this is quite a different scenario to other foreshores in the Townsville region that are experiencing erosion problems. For example at Rowes Bay, Nelly Bay, Cungulla and Bushlands Beach, the longshore sand transport rates are greater than the rate that sand is now being supplied to these foreshores. Consequently these beaches have been steadily eroding. However this diminished longshore supply of sand is not the primary cause of erosion at Saunders Beach.

2.2.2 Cross-shore transport

Cross-shore transport 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 dune system 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.

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.

There is another processes affecting cross-shore sand transport. During particularly severe storms or cyclones, there can be considerable "*overwash*" of some foreshores. This phenomenon occurs when the storm tide builds during a 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 but is significantly curtailed. Instead of being moved offshore, sand in the upper beach is swept up over the slope and carried inshore. 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.

Nevertheless since waves are not actively attacking the submerged beach slope during overwash, the beach itself does not retreat significantly. Once the storm causing overwash abates, the actual position of the intertidal beach slope may not have retreated inland much further than its pre-storm location. It is the severity and nature of the conditions during the early part of the storm prior to overwash (when ocean levels are such that waves actually break directly on the beach) which has a greater effect on shoreline recession.

Nevertheless when overwash occurs, it flattens the beach slope - particularly in the upper part of the profile. Natural features such as a low foredune, scarp and/or berm that are typical of the upper beach profile are wiped out by the overtopping water levels and wave action.

2.2.3 Vulnerability of Saunders Beach foreshore to storm events

The relatively low foreshore along Saunders Beach makes it particularly susceptible to overwash. Recent cyclone events offer testimony to this vulnerability and illustrate the response of the Saunders Beach to overwash events.

More than 10 metres erosion of Saunders Beach is reported to have occurred as a consequence of TC Althea when it crossed the coast near Balgal Beach in December 1971 (Hopley, 1974). However in February 2011 the more severe TC Yasi caused much less shoreline recession along the Cay Street ocean frontage despite the higher storm tide and greater wave energy. It is evident that overwash of the Saunders Beach foreshore during this more recent event resulted in shoreline recession being much less than might intuitively be expected following such a severe event.

The images presented in Figure 7 show the extensive amount of beach sand that was swept off the beach face and deposited inshore by waves as they washed over the crest of the beach. The upper beach profile is seen to be devoid of any foredune, berm or erosion scarp due to such natural features being flattened by overwash.

When considering erosion mitigation measures, it is important to appreciate the specific vulnerability of the Saunders Beach foreshore to storm events. Because of the low level of this foreshore, the local community and foreshore infrastructure are particularly susceptible to the damage that can be inflicted by the elevated ocean water levels and waves that can wash over the beach during severe cyclone occurrences.

Such storm tide inundation and simultaneous wave action can cause extensive damage - particularly to foreshore vegetation. Indeed considerable damage to the Saunders Beach foreshore occurred during TC Yasi as a result of overwash.

Figure 7 : Evidence of overwash during TC Yasi

However in terms of shoreline recession, such severe events on their own are not as damaging as less severe but more frequent storm events. During less severe events, waves can directly attack the beach itself (rather than wash over it), thereby causing recession of the beach face.

If such events occur in relatively quick succession, their accumulating effect can be considerable before natural beach processes can act to restore beach profiles as part of the typical erosion / accretion cycles that occur on Saunders Beach. The erosion threat is perceived by local residents and Council to have been increasing somewhat in recent years. Given the particular vulnerability of the Saunders Beach foreshore to erosion by moderate events, this increased erosion has been due primarily to the increased occurrence and intensity of such events in recent years. The elevated tides and simultaneous rough sea conditions that occurred in early 2009 and early 2010 were indicative of such phenomena.

2.3 Summary of Coastal Processes

The important aspects of the local coastal processes that are shaping the shoreline of Saunders Beach can be summarised as follows:

- There is a net transport of approximately 10,000m^3 to 14,000m^3 of sand northwards along Saunders Beach each year.

- The primary source of sand supply to Saunders Beach is the nearby Black River. However rather than a steady annual rate, the supply of this sand to Saunders Beach is somewhat episodic and heavily reliant on processes affecting the sand delta at the Black River Entrance.

  The supply of sand to the coast from the Black River relies on infrequent major floods to flush sediments off the catchment and through the lower reaches of the river, in conjunction with the need to have storms or sustained periods of strong south-easterly wave conditions to sweep sand northwards off the submerged delta onto Saunders Beach.

- Consequently there are inevitably periods where actual sand supply does not match the ongoing average north-westerly sand transport of 10,000m^3 to 14,000m^3 each year, nor are buffers naturally recharged prior to the onset of adverse northerly sea conditions – resulting in periods of erosion on Saunders Beach. However these erosion phases are typically followed by periods of beach recovery when greater sand supply is initiated during years of more energetic south-easterly wave activity.

- Whilst there are these cycles of beach erosion and accretion, over time a steady-state has prevailed whereby the shoreline between the Black River and Althaus Creek is supplied with sand at a long-term rate that matches the sand moved off the shoreline. However strong cycles of erosion and accretion mean that there are appreciable fluctuations from year to year around the average shoreline position.

- The relatively low foreshore along Saunders Beach makes it particularly susceptible to overwash. This phenomenon occurs when the storm tide builds during a 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 the storm causing overwash abates, the actual position of the intertidal beach slope may not have retreated inland much further than its pre-storm location.

- When considering erosion mitigation measures, it is important to appreciate the specific vulnerability of the Saunders Beach foreshore to storm events. Because of the low level of this foreshore, the local community and foreshore infrastructure are particularly susceptible to the damage that can be inflicted by the elevated ocean water levels and waves that can wash over the beach during severe cyclone occurrences. Such storm tide inundation and simultaneous wave action can cause extensive damage.

- However in terms of shoreline recession, such severe events on their own are not as damaging as less severe but more frequent storm events.

- During less severe events, waves can directly attack the beach itself (rather than wash over it), thereby causing recession of the beach face. If such events occur in relatively quick succession, their accumulating effect can be considerable before natural beach processes can act to restore beach profiles as part of the typical erosion / accretion cycles that occur on Saunders Beach. The elevated tides and simultaneous rough sea conditions that occurred in early 2009 and early 2010 were indicative of such phenomena.

- The high rates of shoreline recession in recent years have coincided with a period of increased ocean water levels and wave activity.

3 EROSION MITIGATION OPTIONS

3.1 Coastal Defence Line

When considering foreshore protection measures on any shoreline, 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 Saunders Beach shoreline, or alternatively the alignment of any protection structure such as a seawall.

Property and infrastructure landward of the Coastal Defence Line remains protected, 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 for a Coastal Defence Line along the Saunders Beach foreshore include:

- an alignment along the landward boundary of the USL and Esplanade (ie. on the seaward boundaries of private properties); or
- an alignment along the seaward boundary of the USL and Council Esplanade; or
- an alignment notionally seaward of the existing foreshore - say along the 1941 alignment on the central section of Saunders Beach (where the shoreline has retreated since that time).

3.2 Design Storm Conditions

When considering foreshore protection measures on any shoreline, as well as defining a Coastal Defence Line it is also necessary to define a *Design Event* for which immunity is required. The *Queensland Coastal Plan* nominates the 100-year average recurrence interval extreme storm event for such purposes

However whilst the characteristics of such an event can be determined by a detailed study of storm tides and waves (typically by applying numerical modelling techniques), for Saunders Beach such an event may not be the most critical from the viewpoint of providing erosion mitigation. As discussed in the preceding Section 2.2.3, shoreline recession is likely to be more severe following successive storms of moderate severity rather than a single major event.

This represents a significant technical challenge to any detailed design of an erosion mitigation strategy - but particularly for one that incorporates beach nourishment as an element. Such determinations of critical combinations of moderate, yet more frequent events are beyond the scope of this assessment of erosion mitigation options. Nevertheless broad strategies for mitigating erosion can still be evaluated, with their detailed design being deferred to later stages of implementation.

3.3 Generic Erosion Mitigation Options

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

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.

In many locations the optimum management strategy may include a combination of both "soft" and "hard" solutions.

A more detailed description of each generic erosion management option is provided in Appendix C. To assist in evaluating these various options in the context of the Saunders Beach coastal reach, a summary of the advantages and disadvantages of each type are presented overleaf in Table 3.1 (for non-structural options) and in Table 3.2 (for structural solutions).

Erosion Management Option	Advantages	Disadvantages
Do Nothing	Maintains existing undeveloped foreshores in their natural state.	Erosion of foreshore may encroach onto some private landholdings and threaten dwellings.
	Coastal processes on natural foreshores proceed unimpeded by erosion mitigation works.	Potential loss of essential community infrastructure, including recreational reserves, stormwater drainage system, telecommunications and power distribution networks.
		Loss of Council controlled foreshore Esplanade.
		Significant adverse impact on visual amenity.
		Will cause significant social trauma.
Avoid Development	Maintains existing undeveloped foreshores in their natural state.	Does not resolve current erosion threat along Saunders Beach suburban foreshore, since 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.	Substantial social and financial costs to implement.
	Coastal processes proceed unimpeded by erosion mitigation works.	Requires relocation or accepted loss of the Esplanade .
	Improves existing beach amenity and public access.	Requires removal of illegal & ad hoc foreshore armouring works.
	Minimal disturbance to visual amenity.	Will cause significant social trauma.
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.
	Improves 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.
	Improves visual amenity.	
	Cost of initial sand placement and renourishment can be low if appropriate sand sources are close-by.	
	A flexible solution that can be tailored to suit the currently uncertain effects of future climate change as they actually emerge.	
Beach Scrapping	Improves existing beach amenity and public access.	Unlikely to achieve the volumes of sand required to create and maintain buffers without significant and intensive earthmoving activity on the intertidal flats and/or the shoals at the Black River Entrance.
	Improves visual amenity.	Adverse impacts likely on intertidal flora and fauna.
	Cost of initial sand placement and renourishment is low since sand source is close-by.	Temporary adverse impacts on visual amenity during scrapping activities.
	A flexible solution that can be tailored to suit the currently uncertain effects of future climate change as they actually emerge.	Temporary adverse impact on beach amenity during scrapping activities.
Channel Relocation	None	Does not resolve long-term erosion problems.

Table 3.1 : Non-structural Erosion Mitigation Options

Erosion Management Option	Advantages	Disadvantages
Seawalls	Provides robust physical barrier to halt shoreline recession.	Significantly inhibit natural shoreline fluctuations & initiate erosion elsewhere on the foreshore. 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. Maintains existing 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 threatened foreshores for longer periods.	Does not solve the existing erosion problem, it simply transfers the problem further south. To accomodate expected erosion influences, it will be necessary to construct many groynes, as far Significant impact on visual amenity. Adversely affects beach amenity by inhibiting access along the shore.
Groynes and Beach Nourishment	Retains sand on presently threatened foreshores.	Requires ongoing financial and works commitment to future sand placements in order to assure beach amenity.

Table 3.2 : Structural Erosion Mitigation Options

4 ASSESSMENT OF EROSION MITIGATION OPTIONS

4.1 The Saunders Beach Coastal Reach

When considering appropriate erosion mitigation options along the suburban foreshore of Saunders Beach it is necessary to consider the entire coastal reach between the Black River and Althaus Creek. In doing so it is evident that the shoreline can be considered as three coastal precincts, namely:

- Southern Precinct : from the entrance of the Black River to approximately the southern-most end of Cay Street.
- Central Precinct : from the southern end of Cay Street to Saunders Beach Road, which is almost the entire ocean frontage of the developed community of Saunders Beach.
- Northern Precinct : from approximately Saunders Beach Road northwards to the ocean entrance of Althaus Creek.

This separation into coastal precincts does not imply that the coastal processes within each are in any way compartmentalised. They are not isolated or discrete sections of shoreline, since the processes affecting each have significant influences on the others. However this partitioning lends itself to the development of viable erosion management strategies that integrate well over the entire Saunders Beach coastal reach.

4.2 Southern Precinct

The Southern Precinct of the Saunders Beach coastal reach is the 4.2kms long section of the shoreline north of the Black River Entrance. The foreshore immediately alongside the suburb of Saunders Beach comprises a broad ridge with a vegetated primary dune. Whilst experiencing short-term episodic erosion, this area has accreted substantially in recent decades. Comparisons with aerial photography of 1941 suggest that the foreshore south of the Saunders Beach township has prograded variably by 50m to 80m since that time.

This accretion is predominantly due to the onshore transport of sand from the shoals and sand banks that form the delta of the Black River. Sand is delivered into Halifax Bay by the Black River during major flood events when substantial flows flush the accumulated deposits from the lower reaches of the river.

Any material finer than sand tends to be distributed widely as the flood waters dispersed through Halifax Bay and beyond. Whereas the coarser sand fractions that are swept out by floods are deposited closer to the Black River entrance - resulting in substantial sand shoals near the river mouth. Waves then work these sand deposits onto and along adjacent foreshores. Similar processes deliver smaller volumes of sand onto Saunders Beach from the un-named creek that enters Halifax Bay some 450 metres south of Cay Street.

These natural processes will continue to supply sand to the Saunders Beach coastal reach. However significant supply rates will be the result of episodic high-energy waves from the south-east - typically during north Queensland's dry season.

4.2.1 Recommended Strategy

Given this on-going trend of sand supply and general accretionary trend on the Southern Precinct, there appears little need to implement any erosion protection measures along this foreshore in the future. A strategy of Do Nothing is therefore appropriate.

However given the episodic nature of sand supply; and that it does not necessarily coincide with northerly storm events, there will invariably be periods of short-term erosion of the foreshore and front dune. It is therefore also recommended that no future development should occur on the foreshore along this Southern Precinct.

The foreshore should be monitored by regular surveys. Appropriate transect lines need to be established at regular intervals along this southern precinct.

4.3 Central Precinct

The Central Precinct is the approximately 1400 metre long section of the foreshore which constitutes almost the entire ocean frontage of the Saunders Beach suburban community. It extends from the southern-most end of Cay Street northward to around Saunders Beach Road. It is the section of foreshore that is most at risk of erosion. The shoreline has encroached into the foreshore Esplanade, with private property boundaries within metres of the shoreline.

The greatest threat of erosion to this foreshore is recurring periods of adverse sea conditions from across the open fetches to the north-east. Whilst there appears to be an adequate supply of sand to this precinct from the south, this supply is provided by high energy south-easterly wave events (typically during the dry season) moving sand from the Black River Entrance area - which may not match the demand on local foreshore buffers during north-easterly events (which typically occur during the wet season).

As discussed earlier, this foreshore therefore experiences cycles of erosion and accretion. At the present time it is in an erosion phase, primarily as a result of high tides and coexisting northerly wave energy both being greater than normal. Whilst it is possible that these cyclic processes causing increased erosion may diminish somewhat in coming years, there is no real certainty to this premise. Any erosion mitigation strategy needs to accommodate the likelihood of a continuing erosion trend on this foreshore.

4.3.1 Possible Erosion Mitigation Strategies

Possible erosion mitigation strategies for the Central Precinct include:

- Beach Nourishment - to establish a wide natural buffer of sand in front of the eroded foreshore. This will require on-going beach re-nourishment on an annual basis to maintain the buffer.
- Seawall - a properly designed structural seawall to provide a physical barrier to shoreline recession. Should the seawall be located within the zone of natural beach fluctuations

(remembering that this foreshore experiences erosion and accretion cycles) then this will result in the removal of sand from the foreshore in front of the structure by natural sand transport processes. In other words, no sandy beach would form in front of the seawall.

- Seawall with beach nourishment - under this scenario the structural benefits of a properly designed seawall would be available during severe events. However the placement of sand to form a narrow beach in front of the seawall offers the amenity of a beach during ambient conditions. Nevertheless, frequent sand re-nourishment would be required to maintain the beach.

The overall and relative effectiveness of each of these three options, as well as their individual costs, will be very much dependent upon the location of the preferred Coastal Defence Line. It will be the cost of implementation that will invariably determine the preferred option.

As discussed, the Saunders Beach foreshore is quite low - making it susceptible to storm tide inundation and the possible simultaneous damaging effects of waves washing over the beach and accessing property and infrastructure close to the shore. It is important to appreciate that the erosion mitigation strategies discussed below relate to the mitigation of shoreline *recession* - not the effects of overwash during severe cyclone events. That is quite a different coastal hazard and one that requires different mitigation measures which relate primarily to habitable floor levels and the structural design of nearshore properties.

During particularly severe cyclones, little can be done to prevent storm tide inundation of the Saunders Beach foreshore. However some mitigation of overtopping waves could be achieved through the provision of a wider foreshore buffer to attenuate overwash during the peak of the storm tide, and this consideration can be applied to the assessment of erosion mitigation options.

Some comment on technical aspects of each of the three possible strategies is offered below to support the recommendations presented in following sections of this report.

4.3.2 Beach Nourishment

This strategy basically consists of:

- Initial Nourishment - through the placement of a sufficient volume of sand to establish a sand buffer in front of the selected Coastal Defence Line that can accommodate the erosion caused by the nominated Design Event. Figure 8 illustrates the concept.

- On-going Renourishment - given that the nourished foreshore will experience cycles of erosion, it will be necessary to recharge these erosion buffers by periodic placement of additional sand.

The determination of the parameters associated with a nominated Design Event and the subsequent determinations of foreshore response and buffer requirements (for current and future climate scenarios) is beyond the scope of this assessment of erosion mitigation options.

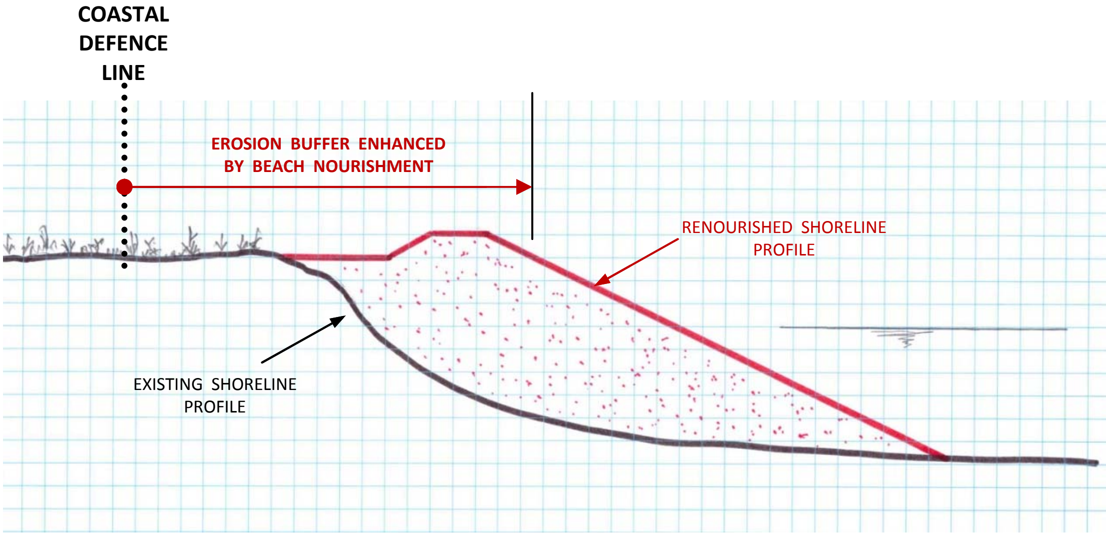


Figure 8 : Typical initial beach nourishment profile

Initial Nourishment

It is evident by reference to Figure 8 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 landward location - since sand already on the foreshore can be considered as being part of the buffer. Clearly the position of the Coastal Defence Line determines just how much sand needs to be imported from external sources to create or supplement this buffer requirement.

In the absence of a determination of the Coastal Defence Line by Council, the local community and other stakeholders, an initial nourishment to reinstate the position of eroded sections of the Central Precinct to that which existed in 1941 is offered as a point of reference.

The volume of required sand has been estimated on the basis of the net shoreline change between 1941 and 2007 that was derived from geo-rectified aerial photography (Smithers, 2009); along with the subsequent change to the shoreline opposite Cay Street that has been measured by Townsville City Council (refer to Figure 6).

Approximately 120,000 m^3 of sand would need to be imported and placed along the foreshore between the southern-most end of Cay Street northwards to Saunders Beach Road in order to reinstate the shoreline to its 1941 position.

Given this significant volume of sand, it is unlikely that it could be supplied in any single year, since it is likely to exceed most commercial sand supply allocations - particularly if those sources are to maintain sand supplies to other stakeholders. The 120,000m^3 could instead be supplied over a wider timeframe of say 3 to 4 consecutive years.

As discussed previously, the episodic erosion processes affecting the Central Precinct are expected to continue into the future. This means that the erosion buffer created by the initial nourishment through sand placement will gradually be depleted - thereby diminishing the protection that it affords.

On-going renourishment will therefore be required to recharge the buffer 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.

On-going Renourishment

It is difficult to determine the renourishment requirement, since natural sand supply processes are closely matching the rates of longshore transport out of the buffers over long timeframes. The problem of short-term buffer depletion (due to only sporadic supply from the reserves of the Black River delta) is one that needs better understanding. As an alternative to nominating a predetermined annual re-nourishment rate, regular monitoring of buffer condition could be undertaken through regular beach transect surveys that trigger a sand re-nourishment campaign should buffer volumes fall to critically low levels.

Given the requirement to also ensure that the erosion buffer is fully recharged prior to the likelihood of any cyclone erosion, it is recommended that the foreshore should be monitored by surveys at least twice yearly - and that any renourishment should be completed prior to the onset of each cyclone season.

For budgeting purposes it is suggested that an allowance be made for between 5,000m^3 and 10,000m^3 of sand to be placed as annual renourishment along the Saunders Beach foreshore.

In summary, a beach nourishment strategy for the Central Precinct of Saunders Beach would require the following:

- initial placement of approximately 120,000 m^3 of sand to reinstate the position of the shoreline that existed in 1941. This initial sand placement could be undertaken over 3 to 4 consecutive years;
- on-going placement of an average of between 5,000m^3 and 10,000m^3 of sand per year to keep the reinstated buffer charged with sand.

4.3.3 Seawall

A seawall appropriately designed to accommodate severe storms and cyclones can be constructed along the alignment of a nominated Coastal Defence Line on Saunders Beach. If it was located such that it was exposed regularly to the effects of wave action, it would need to be a very robust structure to accommodate the local wave climate, the significant overtopping during severe events, and the expected scour at the toe.

However more importantly, such a structure would be built within the dynamic zone of natural foreshore fluctuations. It would therefore have significantly adverse effects on local beach processes - with the erosion problem simply being transferred to the downdrift foreshore. Waves washing directly against the seawall during ambient and storm conditions will remove any sand from in front of the structure, lowering the beach to the extent that during some (or all) tides, waves may wash against the seawall - leaving no beach at all in front of it. A seawall strategy on its own will inevitably lead to the degradation of the beach.

Consequently a seawall option cannot be considered a viable mitigation strategy for Saunders Beach.

4.3.4 Seawall with Beach Nourishment

To counter the adverse effect of an exposed seawall on foreshore amenity, sand nourishment could be undertaken to create a sand buffer in front of the seawall - albeit with a width less than that required for a full beach nourishment strategy.

Alternatively the selection of a Coastal Defence Line could be made such that the seawall was buried well back from the existing shoreline (say along the seaward property boundaries). The foreshore between the buried seawall alignment and the existing shoreline could serve as the erosion buffer - or could be enhanced through the placement of additional sand.

The purpose of any smaller scale beach nourishment would be to place only sufficient sand in front of the buried seawall to accommodate moderate storm events - not the 100 year ARI storm required of a full beach nourishment option. However should the seawall become directly exposed to waves (either by a severe storm season or by the gradual removal of sand by the net northerly longshore transport) then the turbulence and reflected wave energy generated by waves against the seawall face will very rapidly remove any remaining sand.

It is suggested that a sand buffer of some 35m^3 / metre length of foreshore would be necessary in front of the seawall. Depending upon the selected location of the Coastal Defence Line, some or all of this might be available in the exiting foreshore reserve. Under such a scenario, the foreshore in front of the seawall alignment would need to be considered as sacrificial and likely to be significantly damaged or removed during a major storm event.

Furthermore this initial buffer creation would need to be supplemented with an average annual placement of between 5,000m^3 and 10,000m^3 to recharge the buffer.

The seawall would need to be designed appropriately. Simply dumping rocks or other such armouring material onto a foreshore does not constitute a viable seawall structure. Engineering designs need to incorporate structural elements and details that mitigate all of the fundamental modes of seawall failure. It is estimated that the 1.4km long seawall will require two layers of interlocking rock armour overlying geotextile fabric. Approximately 15,000m^3 of rocks within the size range of 1tonne to 5 tonne would be required, along with approximately 10,000m^2 of heavy geotextile as the underlying filter.

Alternatively sand filled geotextile containers (such as the Elcorock proprietary system) could be used to construct the cut-off seawall buried at the back of the beach.

In summary, a strategy of a seawall and beach nourishment for the 1.4km long Central Precinct of Saunders Beach would entail the following:

- selecting an alignment for the seawall (ie. a Coastal Defence Line).
- complete a detailed structural design of a buried seawall; which at this stage is estimated to require the placement of either approximately 15,000m^3 of rocks within the size range of 1tonne to 5 tonne, or alternatively constructed of sand-filled geotextile containers.
- placing an initial volume of sand in the existing buffer in front of the seawall to provide improved beach and foreshore amenity. The volume of any imported sand will depend upon the chosen alignment of the Coastal Defence Line; however as a guide there should be at least a sand volume of 35m^3 / metre length of foreshore available at all times to serve as a buffer in front of the seawall.

- on-going placement of an average of between 5,000m^3 and 10,000m^3 of sand per year to keep the buffer in front of the seawall charged with sand.

4.3.5 Recommended Interim Strategy

Consideration of the above discussions regarding erosion mitigation strategies indicates that the most technically viable is either beach nourishment alone, or in conjunction with a buried seawall. Both of these measures will invariably be expensive and require time to be appropriately designed and for the necessary approvals to be obtained.

In the interim it is recommended that the strategy recently implemented by Townsville City Council of mechanically redistributing sand on the beach profile should be continued. Under this strategy, mechanical plant and equipment are used to move sand up the beach slope into the depleted foredune area.

This optimises the available sand resources on the beach to enhance its capacity to accommodate moderate storm events and reduce somewhat the damage to the upper beach area.

Following erosion events, natural recovery of the upper beach area typically occurs through the deposition of sand to create a low berm in front of any erosion scarp cut into the foreshore. This berm establishment occurs relatively rapidly - typically within two to four weeks of the erosion event. Subsequent onshore winds and high tides gradually work sand from this berm back into the upper beach profile and the foredune area. However the timescales associated with this natural rehabilitation of the upper beach and foredune region are quite long - typically many years.

The current practice of mechanically moving sand from the berm into the upper beach area is in effect hastening this natural rebuilding process.

4.4 Northern Precinct

The Northern Precinct is the approximately 400 metre long section of the Saunders Beach foreshore which extends northwards from approximately Saunders Beach Road to the entrance of Althaus Creek. It forms the ocean frontage to the eight northern-most private properties in Reef Street, as well as public open space (with picnic facilities and an amenities block) immediately adjacent to the creek entrance.

An analysis of geo-rectified aerial photography (Smithers, 2009) indicated that between 1941 and 2007 this foreshore had experienced net accretion. However it was noted that the position of the beach was highly variable over short timeframes and is significantly affected by the natural processes that occur at the entrance to Althaus Creek.

Since 2007 the foreshore has experienced a number of high energy erosion events - in January to March 2009, January 2010 and TC Yasi in February 2011. These erosion events are typical of the natural variability that affects this precinct, albeit somewhat more adversely than has occurred in recent times. Although in 1961 the shoreline was some 30 metres further inland than it is at present.

4.4.1 Recommended Strategy

Given this general accretionary trend on the Northern Precinct, there appears little need to implement any erosion protection measures along this foreshore in the future. A strategy of Do Nothing is therefore appropriate.

However given the dynamic nature of the Althaus Creek entrance area, there will invariably be periods of short-term erosion of this foreshore. It is therefore also recommended that no intensification of development should occur in future on the foreshore along this Northern Precinct.

The foreshore should continue to be monitored by regular surveys of transect lines already established for this purpose.

5 RECOMMENDED EROSION MITIGATION STRATEGY

The recommended erosion mitigation strategy for the Saunders Beach coastal reach requires consideration of different strategies for the three precincts along the foreshore. These are outlined below.

5.1 Between the Black River and Southern End of Cay Street

- No direct intervention.
- No intensification of development should occur in future.
- Establish new transect lines to be surveyed on a regular basis.

5.2 Between Southern End of Cay Street and Saunders Beach Road

- Two viable options are available for consideration by Townsville City Council and other stakeholders for the long-term protection of this 1400 metre long section of foreshore. These options being:

  Option 1 : Beach Nourishment only

  - initial placement of approximately 120,000 m^3 of sand to reinstate the position of the shoreline that existed in 1941. This initial sand placement could be undertaken over 3 to 4 consecutive years;
  - on-going placement of an average of between 5,000m^3 and 10,000m^3 of sand per year to keep the reinstated buffer charged with sand.

  Option 2 : Seawall and Beach Nourishment

  - select an alignment for the seawall (ie. a Coastal Defence Line).
  - complete a detailed structural design of a buried seawall; which at this stage is estimated to require the placement of either approximately 15,000m^3 of armour rocks within the size range of 1 tonne to 5 tonne, or alternatively constructed of sand-filled geotextile containers.
  - placing an initial volume of sand in the existing buffer in front of the seawall to provide improved beach and foreshore amenity. The volume of any imported sand will depend upon the chosen alignment of the Coastal Defence Line; however as a guide there should be at least a sand volume of 35m^3 / metre length of foreshore available at all times to serve as a buffer in front of the seawall.
  - on-going placement of an average of between 5,000m^3 and 10,000m^3 of sand per year to keep the buffer in front of the seawall charged with sand.

Recommended interim strategy

- o Either of these long-term measures will invariably be expensive and require time to be appropriately designed and for the necessary approvals to be obtained. In the interim it is recommended that the strategy recently implemented by Townsville City Council of mechanically redistributing sand on the beach profile should be continued. Under this strategy, mechanical plant and equipment are used to move sand up the beach slope into the depleted foredune area - thereby hastening the natural rehabilitation of the upper beach area.

- Irrespective of the option adopted, the foreshore should continue to be monitored through annual surveys on previously established beach transect lines.

5.3 Between Saunders Beach Road and Althaus Creek

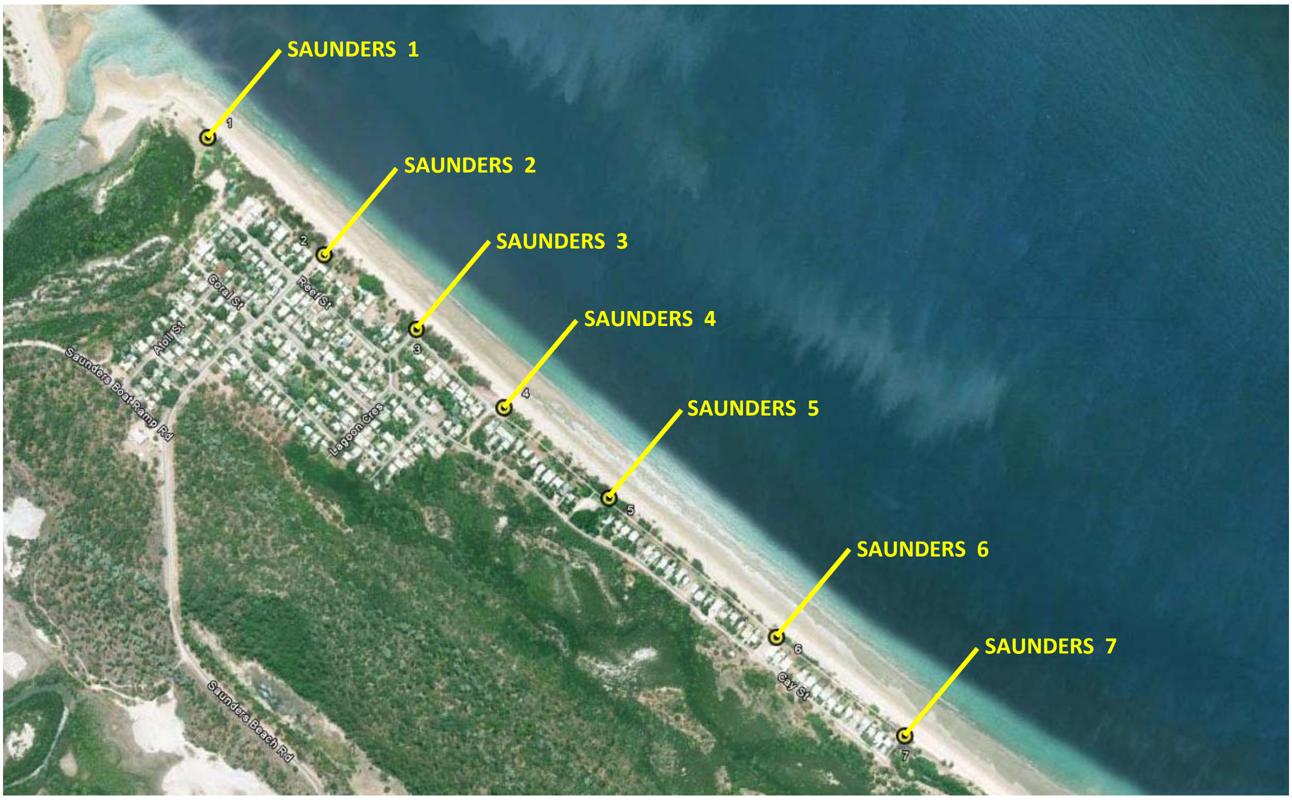
- No direct intervention.
- No intensification of development should occur in future.
- Monitor this foreshore through annual surveys of previously established beach transect lines.

6 REFERENCES

Hopely, D. 1974. *Coastal changes produced by Tropical Cyclone Althea in Queensland*; *December 1971.* Australian Geographer, 12(5): 445-456.

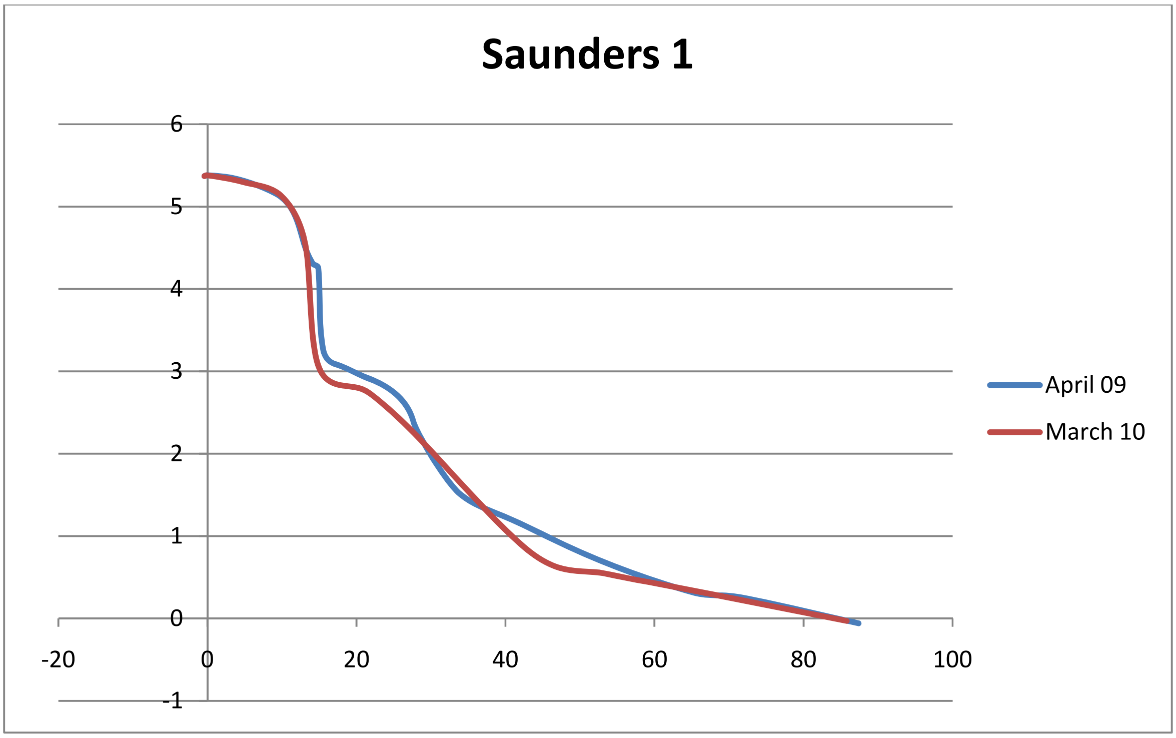
Smither, S.G. 2009. *Coastal Erosion at Saunders Beach - Background Briefing.* School of Earth and Environmental Sciences, James Cook University, Townsville. 2009. Prepared for Townsville City Council.

Appendix A - Results of Beach Transect Surveys



Location of the Beach Transect Survey Lines plotted overleaf in Appendix A

SAUNDERS 1	***POST***		
458353			
7882156			
6.22m AHD			
Brg 40			
Chainage	April 09	Chainage	March 10
-0.4	5.37	-0.4	5.37
0.1	5.38	0	5.38
4.2	5.33	4.7	5.3
9.5	5.14	9.9	5.13
11.7	4.9	13.1	4.56
13.1	4.51	15	3.04
14.2	4.3	21.5	2.75
14.9	4.25	27.4	2.28
15.6	3.24	43.7	0.78
18.8	3.03	53.7	0.54
24.2	2.8	62.8	0.38
26.9	2.55	85.8	-0.03
28.2	2.27		
31.3	1.8		
34.8	1.45		
41.8	1.16		
52.5	0.71		
65	0.32		
72	0.25		
87.4	-0.06		



SAUNDERS 2 ***POST***

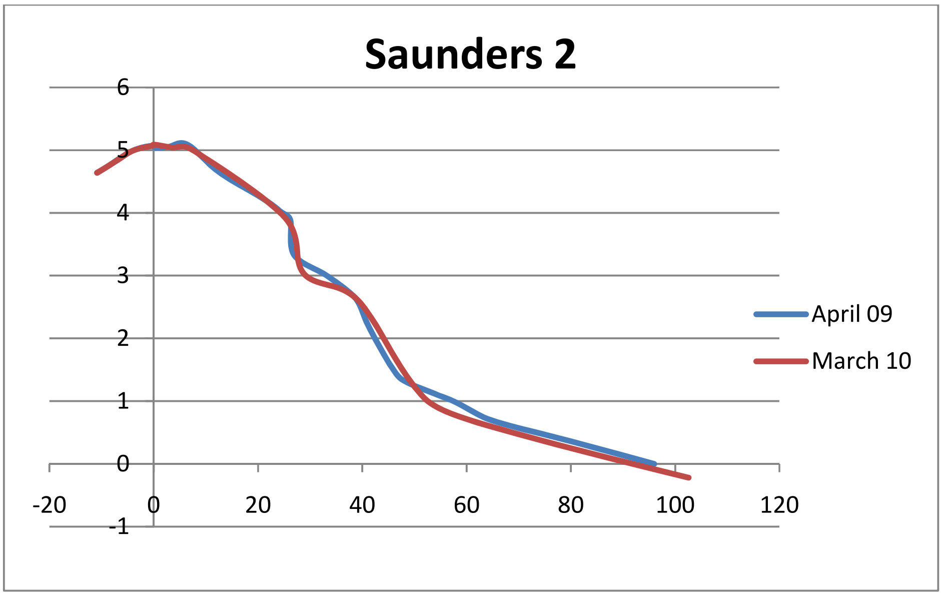
458567

7881942

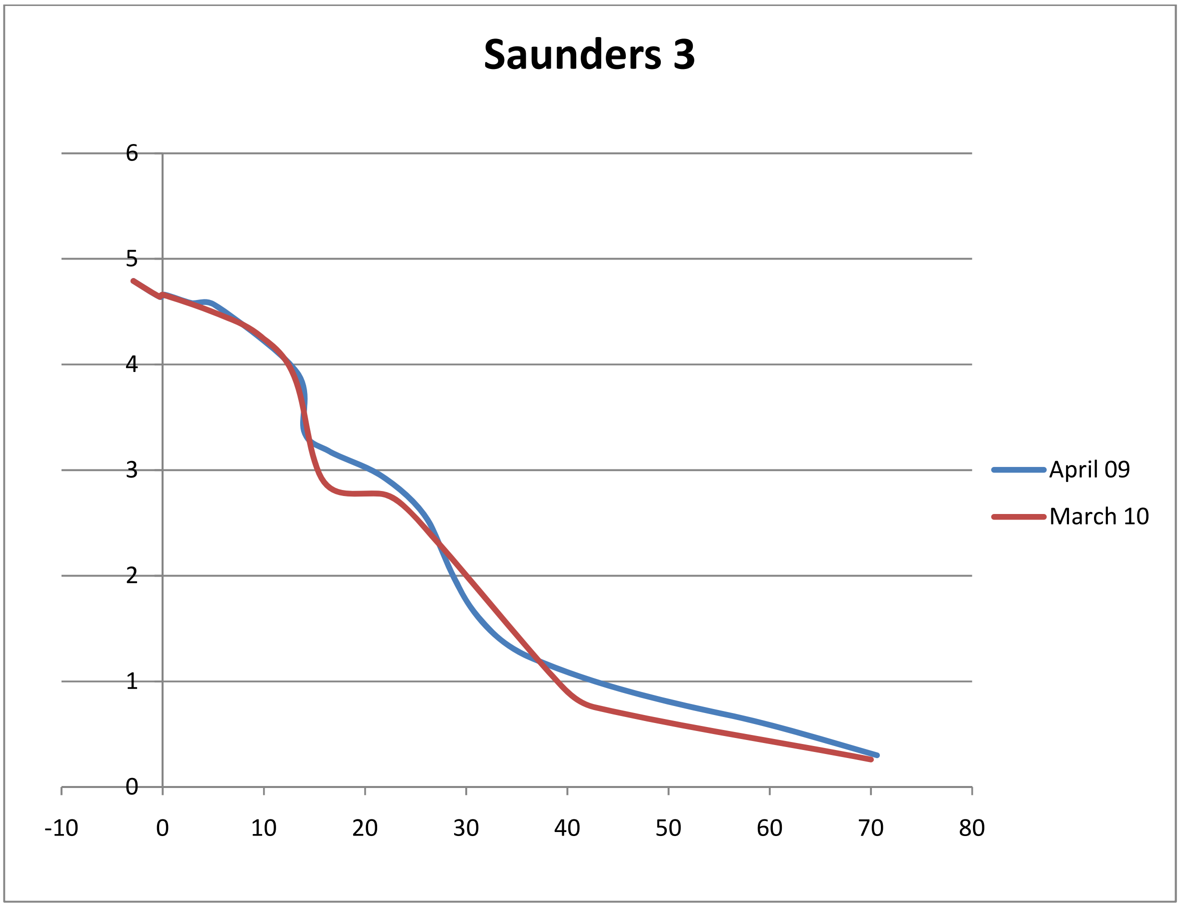
5.99m AHD

Brg 40

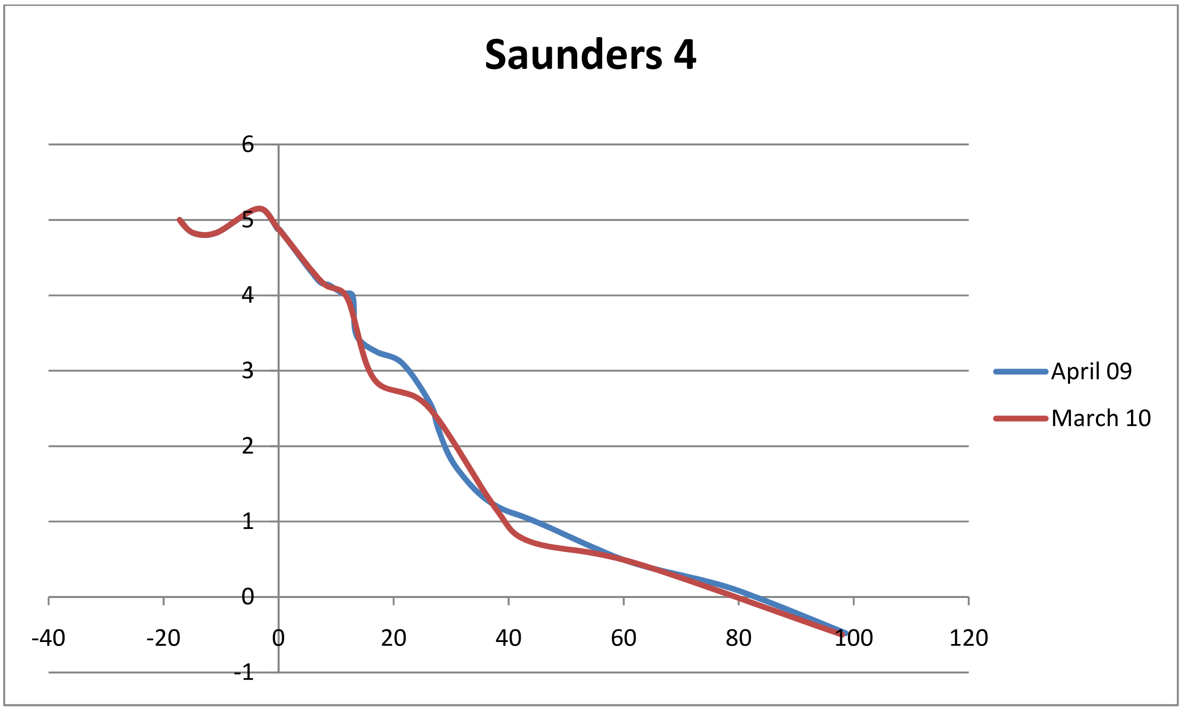
Chainage	April 09	Chainage	March 10
-10.9	4.64	-10.9	4.64
-8.1	4.78	-8.1	4.78
-4.1	4.99	-4.1	4.99
-0.3	5.07	-0.3	5.07
0.2	5.04	0	5.09
2.7	5.05	3.7	5.04
6.4	5.09	7.1	5.02
12.5	4.65	25.1	3.93
20.9	4.23	28.8	3.03
24.5	4.01	39	2.62
26.2	3.88	49.1	1.33
26.9	3.33	56.2	0.83
33.2	3	78.6	0.28
38	2.7	102.6	-0.22
39.5	2.53		
40.6	2.3		
42.6	1.97		
45.8	1.52		
47.9	1.33		
52.6	1.16		
58.5	0.96		
65	0.69		
81	0.34		
96	0		



SAUNDERS 3	***POST***		
458737			
7881806			
5.60m AHD			
Brg 40			
Chainage	April 09	Chainage	March 10
-2.9	4.79	-2.9	4.79
-0.3	4.64	-0.3	4.64
0.2	4.66	0	4.66
2.9	4.58	5.4	4.48
5.2	4.56	9.5	4.28
13.3	3.92	13	3.89
14	3.36	16	2.88
16.4	3.18	22.5	2.75
21.7	2.94	26.6	2.38
25.9	2.57	39.4	0.96
28.5	2.04	43.3	0.74
31.1	1.62	70	0.26
35.8	1.25		
46.6	0.89		
59.5	0.6		
70.6	0.3		



SAUNDERS 4	***POST***		
458898			
7881663			
5.76mAHD			
Brg 40			
Chainage	April 09	Chainage	March 10
-17.2	5	-17.2	5
-14.9	4.83	-14.9	4.83
-10.8	4.83	-10.8	4.83
-3.5	5.15	-3.5	5.15
-0.2	4.88	0	4.88
0.2	4.87	7.6	4.17
7	4.19	11.9	3.97
8.7	4.14	16.6	2.89
11.1	4.03	25.9	2.53
12.9	3.99	37.6	1.19
13.5	3.48	43.5	0.74
16.8	3.26	62	0.45
21.5	3.1	98	-0.5
26.4	2.56		
27.9	2.2		
30.7	1.74		
36.7	1.26		
45	0.99		
61.3	0.46		
78.5	0.12		
98.6	-0.48		



SAUNDERS 5 ***POST***

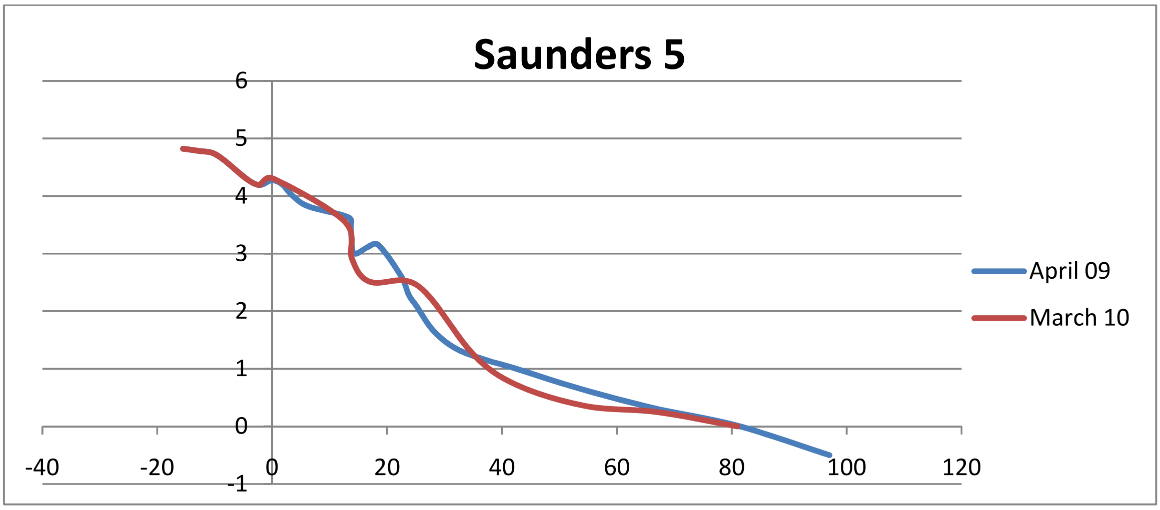
459092

7881498

5.20mAHD

Brg 40

Chainage	April 09	Chainage	March 10
-15.5	4.82	-15.5	4.82
-12.6	4.78	-12.6	4.78
-9.6	4.71	-9.6	4.71
-4.2	4.28	-4.2	4.28
-2.2	4.19	-2.2	4.19
-0.3	4.27	0	4.31
0.4	4.27	12.6	3.56
1.8	4.2	13.9	2.91
3.5	4.01	17	2.51
6.3	3.82	25.4	2.44
13.3	3.63	35.2	1.23
13.7	3.44	43	0.7
14.2	3.01	54.8	0.35
16.6	3.11	67	0.25
18.5	3.15	81	0
22.4	2.62		
23.8	2.28		
25	2.11		
28	1.67		
32	1.35		
37.3	1.15		
42.2	1.01		
53	0.67		
66.7	0.31		
80.7	0.02		
97	-0.5		



SAUNDERS 6 ***POST***

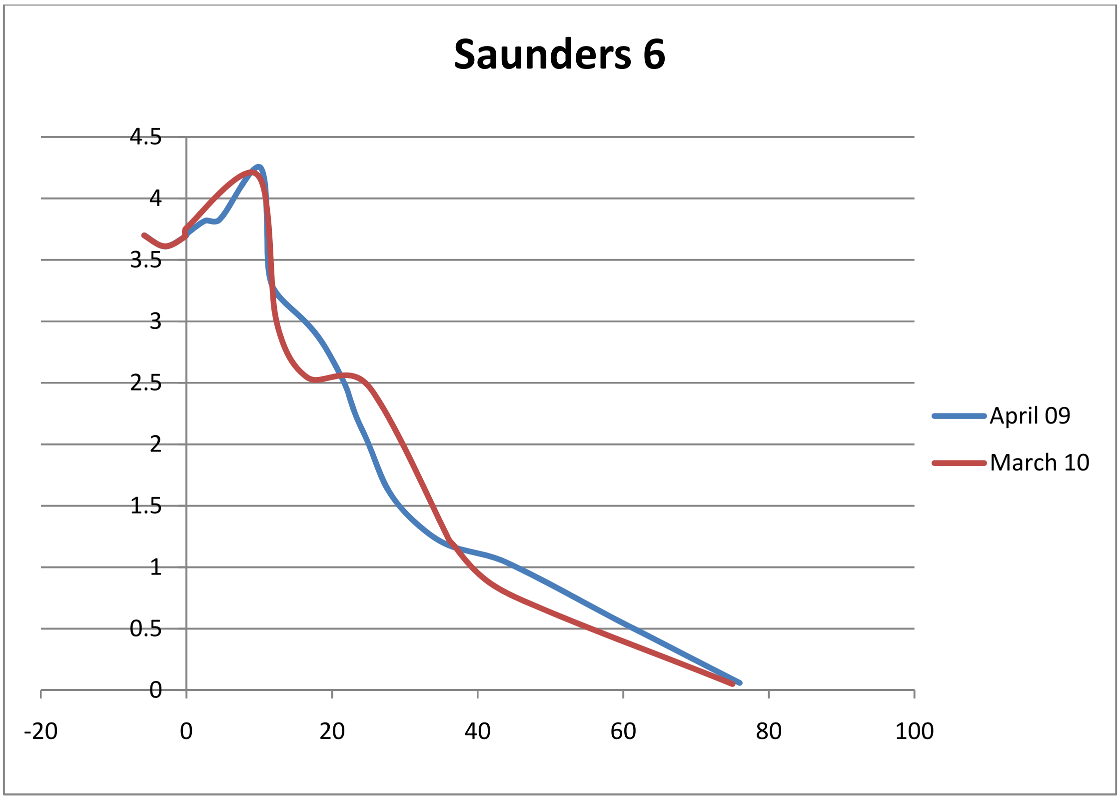
459400

7881244

4.63mAHD

Brg 40

Chainage	April 09	Chainage	March 10
-5.8	3.7	-5.8	3.7
-3	3.61	-3	3.61
-0.2	3.69	-0.2	3.69
0.2	3.72	0	3.76
2.6	3.82	9.8	4.19
4.6	3.83	12.4	2.99
10.2	4.25	16.7	2.54
11.3	3.41	24.9	2.48
12.5	3.22	36.1	1.22
17.8	2.9	36.4	1.2
21.6	2.51	43.7	0.8
23.1	2.26	75	0.05
25.2	1.98		
27.5	1.65		
31	1.39		
36	1.18		
44	1.04		
57.3	0.63		
76	0.06		



SAUNDERS 7 **_POST_**

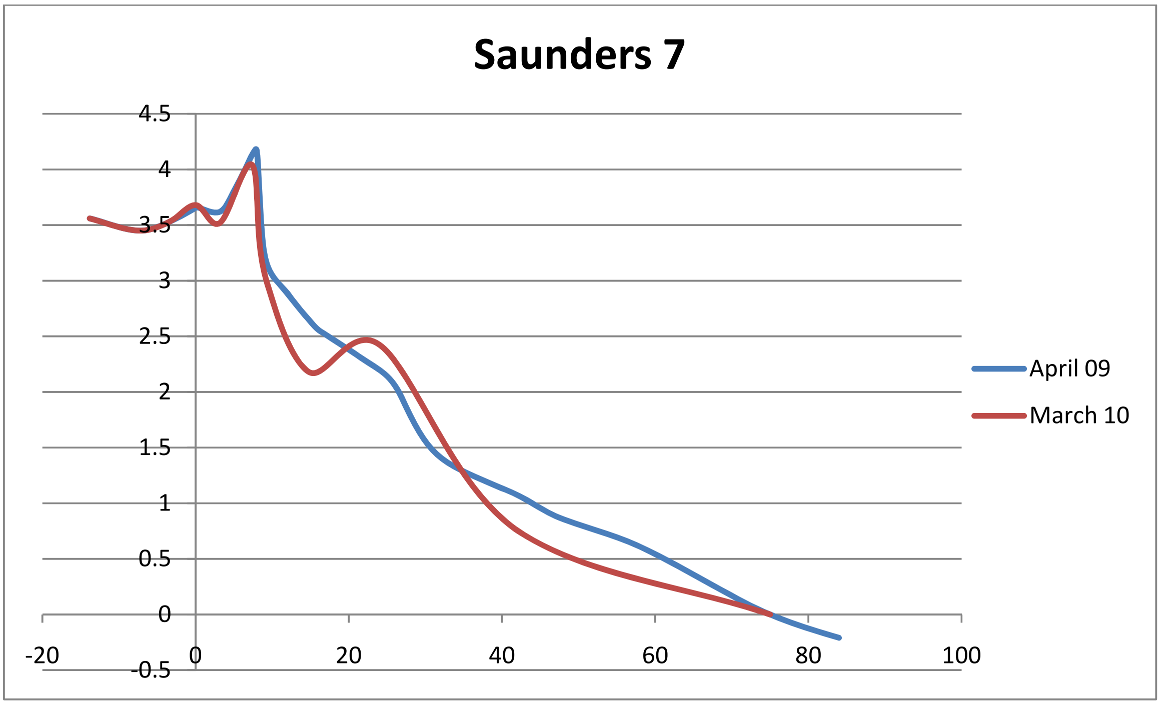
459636

7881064

4.66mAHD

Brg 40

Chainage	April 09	Chainage	March 10
-13.8	3.56	-13.8	3.56
-7.5	3.45	-7.5	3.45
-3.4	3.53	-3.4	3.53
-0.1	3.65	0	3.68
0.2	3.66	3.2	3.52
3.2	3.62	7.4	4.04
5.2	3.83	9	3.07
7.1	4.09	14.8	2.18
8	4.17	24.1	2.42
9.1	3.21	41.9	0.76
12.2	2.87	75	0
15.7	2.58		
16.9	2.52		
22.4	2.27		
25.8	2.08		
31.5	1.44		
42.4	1.06		
47.5	0.87		
58.3	0.6		
74	0.03		
84	-0.21		



Appendix B - Reference Document

COASTAL EROSION AT SAUNDERS BEACH - BACKGROUND BRIEFING

by

Dr. Scott Smithers

School of Earth And Environmental Sciences

James Cook University

COASTAL EROSION AT SAUNDERS BEACH

BACKGROUND BRIEFING

Dr Scott Smithers
School of Earth and Environmental Sciences James Cook University

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Introduction

Saunders Beach is an approximately 2.4 km long beach segment located to the north of Black River at the southern end of Halifax Bay (Figure 1). Saunders Beach is characterised by a broad (>80 m wide) low-tide bench composed of fine sand that extends seaward from a relatively narrow (10-20 m) and steep upper beach composed of coarser sediments. A sharp break in slope typically separates the upper beach and the low tide terrace at a level between Mean Low Water Spring (MLWS) tide and Mean Sea Level (MSL) position.

The settlement at Saunders Beach is developed over a narrow beach ridge plain composed of successive ridges and relatively low-lying swales; however at the eastern end of Saunders Beach this is reduced to just a single narrow ridge.

Erosion of the upper foreshore opposite houses at the southern and central end of the settlement has reduced the distance between the upper beach and property boundaries.

Recent recession of the shoreline and loss of established trees has increased concerns about possible future shifts in the shoreline and the possibility that coastal assets and environments may be damaged by any such shifts.

Coastal processes and shoreline behaviour have been investigated at Saunders Beach as part of a broader coastal erosion study of the Northern Beaches. Information from this study provides important background data within which to consider the driving variables and significance of recent shoreline changes.

Recent changes in shoreline position at Saunders Beach must be viewed within the context of broader patterns of sediment supply and redistribution within Halifax Bay, and natural variability in the processes that deliver sediment to the coast and onto and off the beaches.

Physical Setting and Processes

The shoreline in Halifax Bay is predominately sandy, and is largely composed of coastal landforms such as beach ridges, dunes, tidal inlets, estuaries, and salt flats formed within the last 6000 years by coastal processes. These landforms typically form a narrow (up to 1.5 km wide but generally narrower) fringe of geologically recent sediment deposits and landforms at the coast (Figure 2).

Because coastal processes built the landforms, their elevation is closely constrained by sea-level history since around 6000 years ago; only rocky outcrops extend more than six or so metres above the Highest Astronomical Tide (HAT) mark. Sea level was 130 m lower than now at the peak of the ice age 18000 years ago, exposing the entire continental shelf. As the ice subsequently melted, sea level rose to around 1-1.5 m above present by around 6000 years ago, before falling to its current level (Figure 3).

The shoreline began to build out after sea level reached this higher level around 6000 years ago and as it fell to present. The mineralogy and sedimentology of coastal sands in Halifax Bay indicates they are mostly weathered from local rocks and delivered to the coast by local rivers and creeks.

The extent to which the shoreline built out in Halifax Bay varies according to factors such as the sediment supply, exposure to waves and currents, and coastal alignment. Generally, however, the shore prograded as an upper sandy beach ridge unit built out and over a lower unit of finer intertidal and subtidal sands (like those on the broad lower intertidal flats today). Where inlets and estuaries were sufficiently sheltered from high-energy waves, muddier deposits dominated by mangrove materials developed. These deposits are now exposed on the foreshore at several locations within Halifax Bay, indicating localised retreat of the shoreline since they were emplaced. In some locations this shoreline retreat has opened a corridor where wave action can entrain and suspend fine sediments but sedimentation is relatively low, allowing nearshore reefs, such as Paluma Shoals to establish and thrive. Larcombe et al. (2001) presented a schematic model that depicts these interactions (Figure 4). From the age of the exposed mangrove deposits and inshore reefs we know that this phase of coastal recession may have begun several thousand years ago at some locations within Halifax Bay.

Following the ice age sea level rose quickly and flooded the low gradient continental shelf. As inundation progressed the shoreline retreated rapidly westward, and reworked unconsolidated sediments. Residual gravels and coarser deposits (marking earlier channel positions) now form pavements where fine sediments were winnowed away. The general shape of the coastline in Halifax Bay is a legacy of this process. The irregular occurrence of pavements of residual coarse sediments at the shore separate embayments formed where finer sediments were eroded, and define the broader scale changes in coastal alignment within Halifax Bay.

Net littoral drift is to the north and sediments are exchanged between the embayments described above. A series of small to moderate size streams traverse the coastal plain to discharge at the coast, with the larger rivers (The Bohle and Black Rivers, and Bluewater Creek) occurring toward the south of the study area (Figures 1 & 5). Most of these coastal streams flow only seasonally following wet season rains, when extreme flows associated with cyclonic and monsoonal deluges can cause major flooding, significant erosion and reconfiguration of coastal morphology. Some streams have developed sandy deltas indicative of sediment delivery to the coast, where prevailing longshore currents tend to move materials progressively north. The delta at the mouth of the Black River is the most conspicuous of these features.

During the dry season, or when wet season flows are not competent, coastal processes (waves and currents) may significantly modify coastal morphology at stream and inlet mouths. The shoreline can be very dynamic, with substantial changes in shoreline position and character known to occur quickly during episodic high-energy events. For example, more than 10 m of beach retreat occurred at both Saunders Beach and at the Black River settlement when Tropical Cyclone Althea (category 3: estimated central pressure 952 mb) crossed the coast near Balgal Beach in December 1971 (Hopley, 1974). Longer-term changes associated with prevailing wind and wave conditions also affect this coast; complex and truncated beach ridge sequences have been interpreted as evidence of ‘natural’ changes in coastal configuration along the northern beaches (Hopley and Murtha, 1975).

Historical and Recent Change at Saunders Beach

The general pattern of shoreline change at Saunders Beach can be established through the analysis of geo-rectified aerial photographs that have been taken at the appropriate scale at an irregular interval since 1941 (1941, 1961, 1974, 1983, 1987. 1991, 1996, 2000, 2004, 2005) together with shoreline positions accurately mapped with GPS (Figure 6).

These analyses indicate that:

1. Sections of Saunders Beach have shown net accretion and others have shown net erosion since 1941 – there is no universal erosion or accretion trend. This is the case along the entire Halifax Bay shoreline. These variations appear to result from variations in alongshore sediment transport, with eroded beach segments commonly updrift of sites of significant accretion. It is important to note that erosion and accretion zones on the beach can change through time (both seasonally, inter-annually, and at longer (decadal and millennial) timescales).

2. Fluctuations in shoreline position at a site – phases of accretion and erosion – are demonstrated by the fact that changes in shoreline position to both seaward and shoreward are identified at all 18 transects along Saunders Beach from the geo-rectified photos. In summary, at no transect has the shoreline consistently either eroded or built out – fluctuations are the norm.

3. Based on the total data set of shoreline changes for all transects (including those at Bluewater) an average accretion rate for the entire shoreline for the period was calculated at 0.24 m (n = 272). This is in good accord with the longer-term rate of accretion established for this segment of Halifax Bay by looking at the age of onshore coastal sediment deposits (Holmes, 1992). In summary, although some sections of Saunders Beach have clearly retreated in recent decades, the average net trend over the entire beach is has been one of average net accretion, and is very similar to the longer term rate.

4. The shoreline to the immediate south of Saunders Beach settlement significantly accreted and became vegetated between 1941 and 2007. This area comprises a broad vegetated ridge with a vegetated dune to seaward. The vegetated dune was eroded severely during the high tides and moderate seas of early 2009.

5. The shoreline in front of the settlement from its southern end to a point near Saunders Beach Road has retreated by as much as 15 m from its 1941 position (transect 18 (near the turning bay at the eastern end of the Esplanade) and transect 22 (opposite 105 Cay Street)). The upper beach along this section is now markedly scarped, and held in sections by mature *Casuarina* trees, with scalloped embayments between. Many of these trees were lost during the erosion events of early 2009, with further retreat of the upper beach in these areas. Some recovery of the beach has occurred since, with infill of the upper beach below the scarp and progradation of a new berm.

6. Between 1941 and 2007 the beach between Saunders Beach Road and the mouth of Deep Creek has shown net accretion, but this end of the beach is highly variable over shorter periods (including seasonal), and is significantly affected by processes near the creek mouth.

Observations of recent changes include:

7. The upper beach between the southern end of the settlement and Saunders Beach Road is now (and has been for some time) marked by a conspicuous scarp, in places exceeding 1 m high, which locally retreated several metres during the 2009 January - March high tides. Typically the eroded sediment was redeposited relatively rapidly (within two to three weeks) on the upper shoreline further north along the beach.

8. Erosion in early 2009 coincided with very high tides and moderately rough weather. It is pertinent to note that the very high tides occurred as part of the broader 18.6 year lunar tidal cycle, which effectively meant that the high tides this year were the highest over this multi-decadal cycle, and that there were a greater number tides high enough for waves to affect the upper beach. The combination of higher tides and rough weather increased the erosion of the upper beach. As this cycle wanes over the next decade the elevation and frequency of very high tides will reduce.

9. The eroded scarp cut into an older vegetated beach ridge dominates the upper beach long most of the settlement. As indicated above, in places the top of this scarp separates the active beach by more than a metre, and waves at high tide swirl at its base. However, elsewhere on the beach a broad berm of recently deposited sand has been deposited in front of the eroded scarp. At these locations the beach exhibits both erosionary and accretionary traits.

10. New sediment can only be added to the beach ridge on which the settlement is

located when waves swash on to it and deliver sediment from the beach below. The scarp effectively separates the active beach from the beach ridge surface, and impedes the deposition of new material on top of the ridge.

11. The *Casuarina* trees have been very effective at holding the upper beach position, and mediating further retreat of the upper beach. Where they have recently failed it is likely that they would have performed better if they were located in thicker plantings and not as a single row. Many fallen trees appear to have been outflanked by erosion concentrated in bare areas.

Other points for consideration:

12. Saunders Beach is a location where coastal erosion during the last major cyclone to affect the region (TC Althea) was accurately measured. During that event the shoreline retreated by 12 m and waves broke over the first beach ridge and onto the road (Hopley 1974). This event generated a storm surge estimated to be 3.66 m at nearby Toolakea, but luckily the peak coincided with the low tide raising water levels to near the high tide level only. On the northern beaches some recovery from this erosion occurred quite rapidly, with as much as 2.5 m accretion noted within 6 months.

13. The Black River is the nearest and most significant sediment source for the Saunders Beach. Approximately 1 million cubic metres of sand were extracted from this river between 1970 and 2001. Extractive activities have now ceased. Although the impacts of extraction would be expected to only be modest due to other contributions and the redistribution of existing delta sediments (see Figure 5), it is possible that these activities have contributed to the local erosion experienced at Saunders Beach, either directly as a result of disruption to sediment supply, or indirectly as a consequence of reconfiguration of the delta. Given the irregular nature of both events that deliver sediments and redistribute them along the coastline, the significance of these processes is hard to determine. Nonetheless, the termination of extraction removes the possibility of any ongoing negative effects.

14. Both modelling and measurement confirm the transport of sediment north along the beach. Estimates of littoral drift indicate that around 10-14 000 m^3 of sand is transported north along this section of shoreline on average each year. Observations of sediments redistributed during high-energy events indicate that sediments can be quickly redistributed on this shoreline. The implications are that any discontinuities in alongshore sediment supply might be expected to manifest relatively quickly, and that sediment introduced to the upper beach may be redistributed relatively rapidly. Where sediments are temporarily stored in the system, such as the ridge to the south of the settlement a deficit may develop updrift and contribute to shoreline retreat. However, recent erosion on Saunders Beach can be more directly attributed to higher water levels and wave energy conditions acting on an already destabilised and upper beach.

Conclusions

The shoreline at Saunders Beach is dynamic, with all sections of the beach showing phases of erosion and accretion since 1941. When the entire data set for the entire beach is examined an average rate of accretion of 0.24 m per year is calculated.

The pattern of shoreline change between 1941 and 2007 is, however, spatially variable along the beach. The differences can be summarised as:

- Significant accretion to the immediate south of the settlement (where the broad vegetated ridge and dune have developed).
- Retreat of as much as 15 m and significant scarping of the upper beach in front of the settlement from Saunders Beach Road south.
- Highly variable but net accretion between Saunders Beach Road and Deep Creek.

The entire shoreline was affected by the combination of moderate seas and very high tides on several occasions in early 2009, during which the upper beach was significantly eroded (reports of several metres retreat in just a few days). The high tides that focused the wave action on the vulnerable upper beach were associated with the peak of the 18.6-year tidal cycle that is now on the wane.

Although sediment extraction from the Black River may have disrupted sediment supply to Saunders Beach it is more likely that variations in sediment deposition and transfer together with wave erosion during the higher tides have been responsible for shoreline retreat along the shoreline at both decadal and event timescales.

Sediment is actively transported north alongshore on this beach as indicated by modelling, measurement and observations of sediment redistribution following erosive events. If renourishment is considered as a treatment option the mobility of 'natural' sediments on this shoreline will need to be considered and strategies to mediate this be included in the renourishment plan (sediment size, positioning, time of emplacement and augmentative stabilisation).

Casuarinas can effectively hold the shoreline position against erosion events, and more contiguous and wider plantings should be considered.

References

Holmes, K.H., 1992. Townsville-Rollingstone coastal sector. MA50/2, Department of Environment and Heritage, Brisbane.

Hopley, D., 1974. Coastal changes produced by Tropical Cyclone Althea in Queensland; December 1971. Australian Geographer, 12(5): 445-456.

Hopley, D. and Murtha, G.G., 1975. The Quaternary Deposits of the Townsville Coastal Plain. Monograph Series, 8. Department of Geography, James Cook University of North Queensland, Townsville, 30 pp.

Hopley, D., Smithers, S.G. and Parnell, K.E., 2007. Geomorphology of the Great Barrier Reef: evolution, diversity and change. Cambridge University Press, Cambridge.

Larcombe, P., Costen, A. and Woolfe, K.J., 2001. The hydrodynamic and sedimentary setting of nearshore coral reefs, central Great Barrier Reef shelf, Australia: Paluma Shoals, a case study. Sedimentology, 48(4): 811-835.

Lewis, S.E., Wust, R.A.J., Webster, J.M. and Shields, G.A., 2008. Mid-late holocene sea-level variability in eastern Australia. Terra Nova, 20: 74-81.

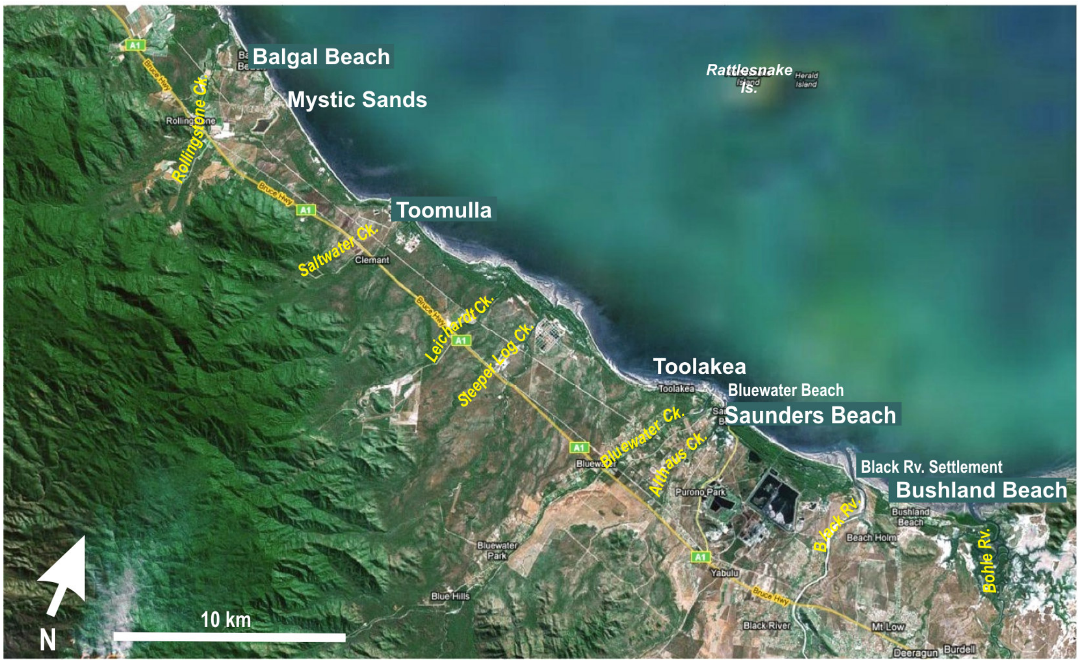

Figure 1 Satellite image showing coastal zone features and major settlements Halifax Bay (Google, 2008).

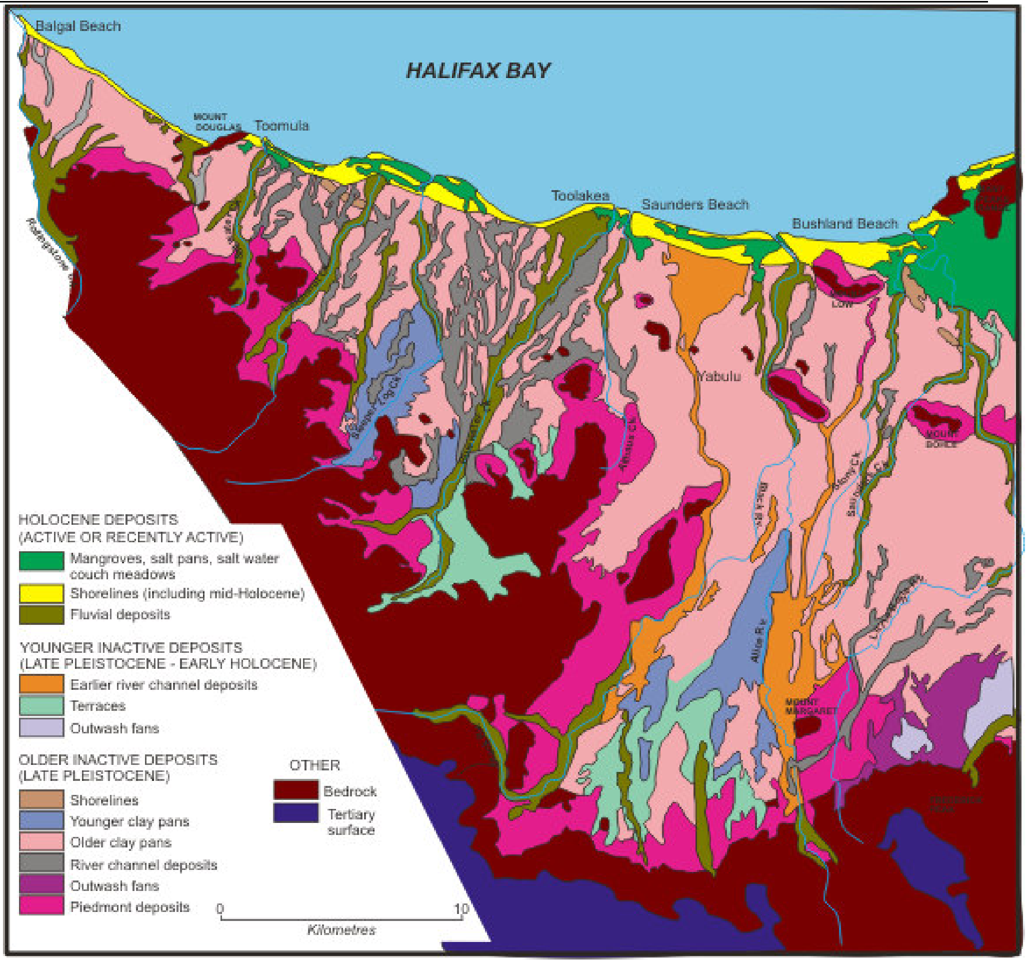

Figure 2 *Map of surface deposits and landforms within the study area (redrawn from Hopley and Murtha, 1975).*

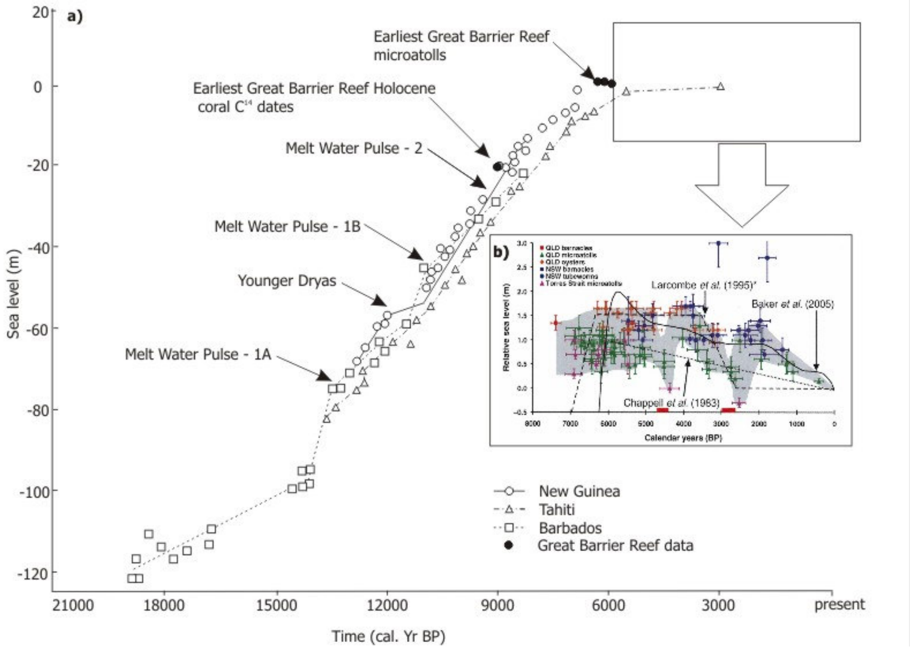

Figure 3 *a) Global postglacial sea-level history from reef records (Hopley et al., 2007); b) data and various interpretations of sea level fall since around 6000 years ago on inshore Great Barrier Reef (from Lewis et al., 2008).*

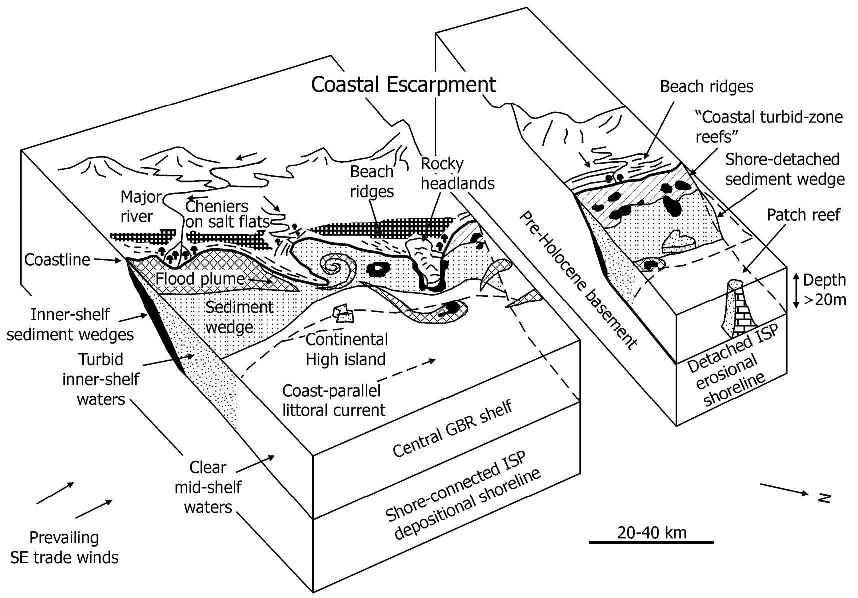

Figure 4 *Coastal sediment transport and development in depositional shoreline settings such as Cleveland Bay (left) and in erosional shoreline settings such as Halifax Bay (right). (Larcombe et al., 2001).*

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Figure 5 *Coastal sediment budget for southern end of Halifax Bay estimated from several sources including Boral 1998, DallaPozza 2005 and Holmes 1992.*

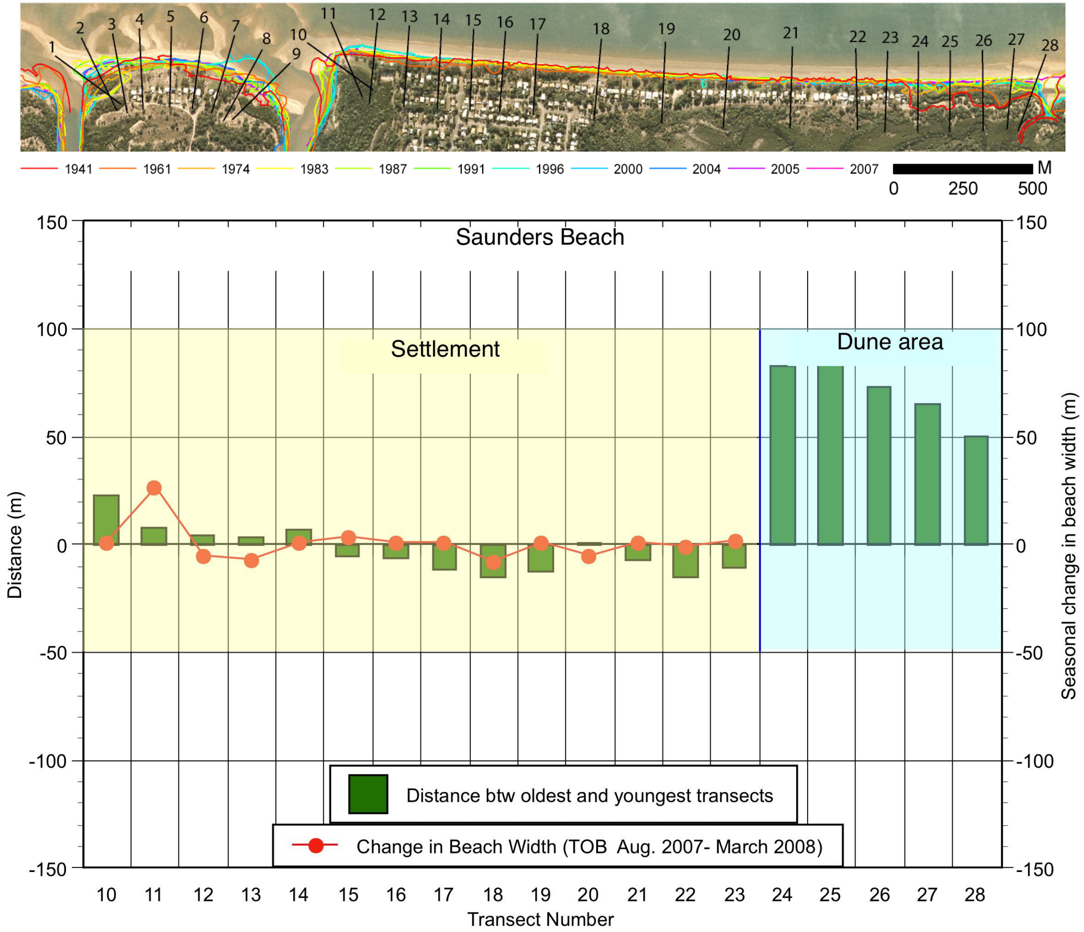

Figure 6 Net shoreline change between 1941 and 2007 derived from geo-rectified aerial photography along Saunders Beach

Appendix C - Generic Erosion Mitigation Options

Overview

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

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.

Some discussion on each of these various options is offered in the following pages.

Non-structural Management Options

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 a 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. This scenario could therefore lead to considerable social trauma and substantial economic loss. Consequently it is rarely a desirable management option for a significantly developed foreshore.

Avoid development

Along sections of the foreshore that remain substantially undeveloped, a key objective can 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.

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 designation of foreshores within state-wide Erosion Prone Areas under Queensland’s State Coastal Plan. 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.

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.

This can require the relocation of essential and non-essential infrastructure and/or the resumption of private land and dwellings. The social and financial costs involved in such relocations and any associated resumption of land can be considerable given current property values along the coast.

However where there are isolated and small scale public assets threatened by erosion, planned relocation can be a viable and cost effective option.

Beach nourishment

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 establish or 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 may 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 the short-term erosion processes associated with a severe storm / cyclone that is nominated as the Design Event.

The strategy is flexible in its implementation and is therefore well suited to accommodating the uncertain impacts of future climate change of local foreshores. For example, 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 through the annual renourishment campaigns as actual climate change conditions manifest themselves.

Beach scrapping

The concept of beach scrapping entails moving sand from lower levels of the cross-shore beach profile (typically from intertidal 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 may not necessarily provide a net long-term benefit - particularly on foreshores that are experiencing long-term recession.

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.

The large volumes of sand that need to be initially placed by scrapping to form the buffers against significantly eroding foreshores are unlikely to be economically viable or physically achievable within reasonable timeframes. Adverse impacts on intertidal flora and fauna communities can also be considerable under such works.

Channel relocation

In some cases foreshore erosion can be attributed in varying degrees to the dynamic nature of local 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.

Structural Management Options

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. Typically seawalls are constructed on 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.

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.

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 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 along the shore.

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.

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 can have a significant impact on the visual amenity of local foreshores. 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.