

3 COASTAL PROCESSES & CAUSES OF EROSION

3.1 General Considerations

An appropriate understanding of the fundamental coastal processes affecting the Redcliffe shoreline is needed in order to make an informed decision on the most reliable management strategy to be adopted.

The Redcliffe shoreline has an extensive history of active shoreline management as shoreline erosion has threatened development and assets in the past and various protection and rehabilitation works have been carried out in response to these threats. Historical protection measures include the construction of revetments and groynes, the use of buffer zones and beach nourishment.

A significant number of studies into the coastal processes and options to mitigate erosion along the Redcliffe shoreline have been undertaken in the past. In order to obtain an understanding of the coastal processes in the study area, existing coastal studies of the Redcliffe Peninsula were collected and reviewed. The coastal processes studies that have been considered in this SEMP include:

- Redcliffe Coastal Process Study (KBR, 2003)
- Eastern Beaches Study (Kinchill et al, 1996)
- Redcliffe Peninsula Foreshore Cliffs Study (GeoEng., 1999)
- Scarborough Cliffs Options Analysis Report (KBR, 2007A)
- Redcliffe Jetty Reconstruction – Wave Modelling report (Cardno, 1998)
- Storm Tide Hazard Study – Moreton Bay Regional Council (Cardno, 2008 – In draft)
- Gayundah Wreck (Picnic Point) Seawall Rectification – Concept Design report (KBR, 2007B)

In addition, limited field measurements were interpreted and aerial photography covering an historical period of 50 years was used to assess the effects of wave, current and sand transport processes occurring at the Redcliffe shoreline and to assess impacts of manmade features. Furthermore, interviews were held with Moreton Bay Regional Council staff to collect information in relation to recent shoreline management operations.

On the basis of the above information, it was possible to obtain reasonable knowledge in relation to the active coastal processes. A brief outline of this knowledge is presented in this Section.

The key issues affecting the most appropriate management action are those of future:

- supply of sand into the beach system;
- sand movements within and through the beach system; and
- possible progressive net loss of sand from the beach system.

A beach system includes not only the beach itself but also:

- the beach ridge that acts as a reservoir of sand for the beach during major erosion events and subsequently rebuilds gradually as the sand is moved onshore by wave and wind action; and

- the nearshore zone where sand movement is related to beach behaviour.

While it is known that there has been a tendency for gradual erosion of Redcliffe beaches superimposed on short term fluctuations of the shoreline location, the nature of progressive long-term erosion has been uncertain and the management actions in response to this erosion have been mostly uncoordinated.

The nature and rate of progressive long-term erosion remains uncertain. The uncertainty lies in the complex interaction of coastal processes affecting the shoreline, the numerous coastal structures that are present on the shoreline and the impact of human interventions on these processes. A comprehensive investigation over some years and involving substantial cost would be needed to gain a full understanding of those processes. However, the review of existing coastal studies have provided a level of understanding sufficient to identify the most suitable engineering and management options for dealing with the erosion, as set out in this report. Within that context, relevant uncertainties and their significance are identified and discussed.

3.2 Previous Reports and Studies

In response to erosion problems at various locations along the Redcliffe Peninsula, numerous studies into the coastal processes and options to mitigate erosion along the shoreline have been undertaken in the past. Most of the studies are focussed on the Eastern Beaches or various cliffs along the Redcliffe Peninsula.

In 1996, a considerable study was undertaken by Kinhill et al. to establish a sediment budget for Redcliffe's eastern beaches, (Kinhill et al, 1996). The study investigated sand sources and sinks and calculated sediment transport rates along Redcliffe's eastern beaches.

A subsequent study was undertaken by KBR in 2002; *The Redcliffe Coastal Process Study* (KBR, 2002). This comprehensive modelling study investigated a range of physical factors that influence coastal processes, including water level variations, waves, storm erosion potentials and longshore sediment transport rates. In addition, the Redcliffe Coastal Process Study assesses shoreline management options for Margate Beach. One component that is not considered in the KBR study, and is now reported as a significant coastal process, is the potential impacts of sea level rise. It has the effect of inducing long-term shoreline recession and the impacts are considered in this study.

In recent years, several studies have been undertaken to investigate the issues related to cliff erosion. The first study was undertaken by Geo-Eng Australia and Coastal Engineering Solutions; *The Redcliffe Peninsula Foreshore Cliffs Study* (Geo-Eng., 1999). This report investigated the issues of cliff erosion at eight precincts and discusses generic solutions to arrest cliff and foreshore erosion at these locations. The eight cliff precincts considered were: Reef Point, Scarborough Point, Drury Point, Queens Beach North, Public Foreshore Reserve between Woody Point and Picnic Point, Picnic Point, Apex Park (Woody Point) and Haymouth Parade. Some of the suggestions by (Geo-Eng., 1999) have been implemented by Council, for example, re-directing drainage away from the top of the cliffs and establishing formal access points to the beach.

Subsequently a more-detailed study into the erosion mechanisms and remediation options for Scarborough Cliffs was undertaken by KBR (Refer to KBR, 2007A).

In order to identify, understand and quantify the risks associated with the possibility of extreme storm tides, Moreton Bay Regional Council has engaged Cardno Lawson Treloar to undertake a Storm Tide Hazard Modelling Study for the Moreton Bay Region, including the Redcliffe shoreline. In September 2008, a draft version of the Final Report was issued for review (Cardno, 2008). The study that investigates the combined effects of astronomical tide, storm surge and wave-induced effects (wave set-up) and the possible impacts of enhanced-Greenhouse climate change was utilized for this SEMP. In the Cardno study storm tide levels in Moreton Bay are assessed through a Monte-Carlo type numerical modelling analysis of wind and pressure fields, tidal forcing, hydrodynamics and waves (using the DELFT-3D modelling package).

Components from the above reports are included throughout this report when discussing coastal processes.

3.3 Geological Framework

A description of the geology of the shoreline of the Redcliffe District is described in the *Redcliffe Peninsula Foreshore Cliffs Study* (Geo-Eng., 1999). A summary of this description is provided below.

Geological maps of the Moreton District indicate that the bedrock underlying and comprising the Redcliffe Peninsula consists of Ecogene Age mudstone, shales and sandstones/mudstones belonging to the Petrie Formation, formed about 65 to 45 million years ago. Petrie formations are formed from deposition of soft sediments in lakes which were formed about 65 to 45 million years ago. At the northern end of the peninsula (at Reef Point) and around Scott's Point, tertiary basalt is noted to be present.

The rock types are generally deeply weathered and after a mottled and ferruginised soil profile is developed, occasionally produce lateritic or bauxitic zones. In some places along the Redcliffe Peninsula (e.g. Reef Point to Scarborough Point) the entire lateritic profile has been developed.

In place where the entire lateritic profile is developed, the usual profile consists of (from top to bottom):

- Zone A: an upper, red ferruginous clay soil, often several metres thick
- Zone B: a zone of pisolitic gravel in red orange brown soil
- Zone C: an indurated, cemented zone comprising mainly iron and aluminium sesquioxides, sometimes with pisolitic texture
- Zone D: a mottled zone comprised of clay and iron oxides, usually orange and gray mottled

Along the shoreline, the geological mapsheets describe quarternary age beach ridges comprising sand and shell grit. These form the beach strips such as the Suttons, Margate, Redcliffe, Queens Beach South, Queens Beach North and Scarborough Beach areas and the coastal zone around Hays Inlet and Deception Bay.

More recently, fluctuating sea levels during the last great ice age, some 120 thousand years ago, deposited clays and silts over the Pine River Lowlands. This has influenced the sandy and clayey soils of the lowland and coastal areas today.

3.4 Coastal Processes

3.4.1 Water Level Variations

Variations in sea level significantly influence coastal behaviour by altering the level at which waves attack the shoreline as well as affecting various wave phenomena such as refraction, shoaling and breaking. Beaches generally obtain an equilibrium profile for given water level and wave conditions. It is therefore important to have an understanding of the ocean water levels which can occur in the area.

This appreciation not only relates to day-to-day tidal influences, but also to storm events that can be experienced along the shoreline. Water levels are likely to be elevated above normal conditions during storm events due the interaction of tide and storm surge.

3.4.1.1 Astronomical Tide

The astronomical tide at the Redcliffe Shoreline is semi-diurnal, typically with significant variation in subsequent high and low tides. The ocean tide propagates to the site predominantly via the northern entrance to Moreton Bay. The pattern of tidal wave propagation and associated tidal currents in the Bay are strongly north-south.

Tide levels within the Bay are amplified relative to the ocean. This is a characteristic of the specific shape and depth of the Bay. At Redcliffe, the tidal range is typically about 28% greater than that in the ocean.

The tides on the Redcliffe Peninsula vary slightly from the southern end to the northern end. The tidal planes relative to Lowest Astronomical Tide (LAT) and Australian Height Datum (AHD) for Woody Point and Scarborough Boat Harbour are as listed in Table 3-1 (From the Tide Tables and Boating Safety Guide (MSQ, 2007)).

Table 3-1 Tidal Planes at Redcliffe Peninsula

	Level at Woody Point (For datum shown)		Level at Scarborough (For datum shown)	
	mLAT	mAHD	mLAT	mAHD
Highest Astronomical Tide	2.58	1.35	2.41	1.24
Mean High Water Springs	2.05	0.82	1.92	0.75
Mean High Water Neaps	1.67	0.44	1.57	0.40
Mean Sea Level	1.15	-0.08	1.11	-0.06
Mean Low Water Neaps	0.71	-0.52	0.67	-0.50
Mean Low Water Springs	0.33	-0.90	0.31	-0.86
Lowest Astronomical Tide	0.00	-1.23	0.00	-1.17

3.4.1.2 Storm Tide Levels

The tidal planes are predictions based on the movements of celestial bodies. Local meteorological conditions, which differ from the average, will cause corresponding differences between the predicted and the actual tide. Variations in tidal heights are mainly caused by strong or prolonged winds and by unusually high or low barometric pressure. The increase in sea level resulting from these effects

during severe storms and cyclones is called the storm surge. The resulting water level combining the surge with the astronomical tide is referred to as the storm tide.

Within Moreton Bay, a storm surge consists of the following components:-

- Oceanographic processes (including coastal trapped waves),
- Regional wave set-up generated by wave breaking along Spitfire Banks,
- Inverse barometer (atmospheric pressure),
- Local wind set-up within Moreton Bay, and
- Local wave set-up generated near the shoreline.

Potential storm tide levels for design purposes have been assessed by a review of existing studies including a recent storm tide study for the Redcliffe District (Moreton Bay Regional Council's Storm Tide Hazard Study (Draft) - Cardno, 2008). Other studies considered in the review are: Impact Assessment Study for Port Expansion at Fisherman Islands, Port of Brisbane (WBM, 2000), Redcliffe Coastal Process Study (KBR, 2002) and Moreton Bay Regional Council internal report (RCC, 1996). A summary of the results of these investigations is presented in Figure 3-1.

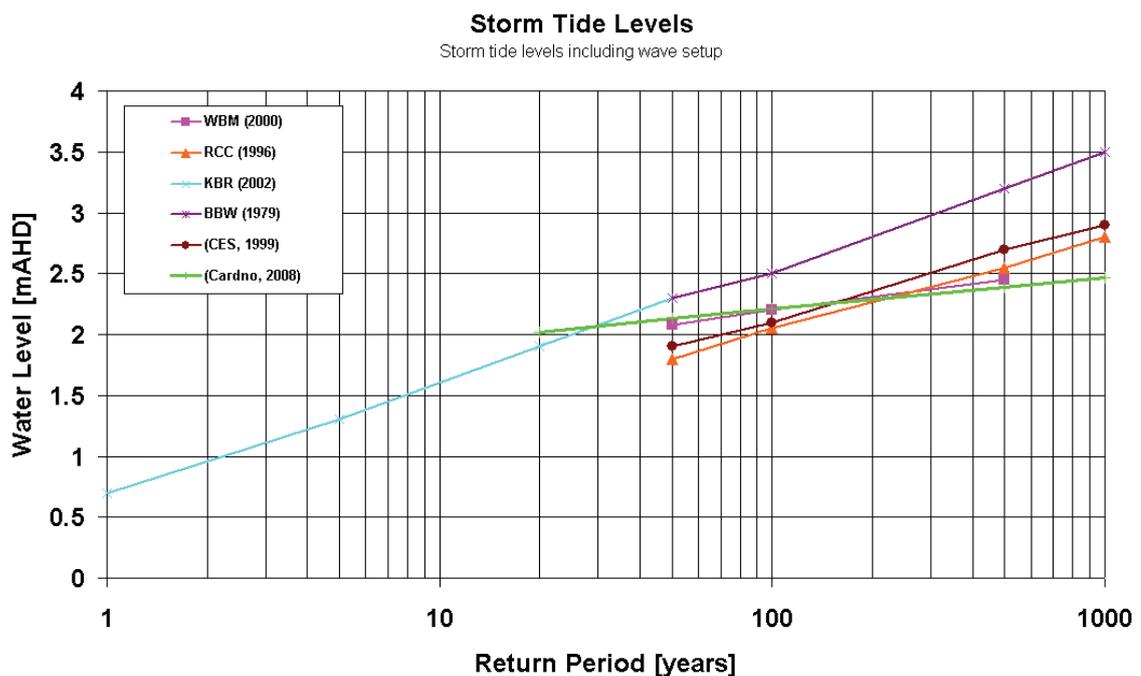


Figure 3-1 Summary of Storm Tide Levels for Redcliffe

3.4.2 Sand Transport Mechanisms

Sand is transported along the Redcliffe beaches by the combined action of waves and currents. The prevailing waves are locally wind-generated "sea" waves from the south-east and north-easterly sea breezes developing on summer afternoons. However, some swell waves of long period (typically 7-12 seconds) and of relatively low height (due to significant refraction and bed friction as they propagate from the deep ocean into Moreton Bay) do reach the beaches. The sea waves are generally generated within the bay and of relatively very short period (generally less than 4 seconds) and are

not substantially affected by the offshore bathymetry prior to breaking at the beach. The locally generated sea waves are present on a day-to-day basis whereas the swell and storm waves are present irregularly.

Waves have three key effects on sand transport in the nearshore zone, namely:

- As wave break they generate so-called radiation stresses, which may drive longshore currents (particularly within the wave breaker zone)
- Their orbital motion may impose shear stresses on the seabed, which may mobilise and put into suspension the seabed sediment. Their asymmetry in shallower water causes a differential in the forcing on the bed sediments, stronger towards the shoreline in the forward direction of a wave, resulting in an onshore mass transport of sand; and
- They cause a bottom return current in the surfzone (undertow), strongest during storms when they typically dominate over the mass transport associated with wave asymmetry.

Currents generated by the tide, waves and wind provide the primary mechanism for the transport of the sand that has been mobilised and put into suspension by wave/current action. It has been reported (Kinhill et al, 1996) that the currents close to the Redcliffe Beaches are dominated by wave-induced currents.

Generally, at a typical beach location, sand transport may be regarded in simple terms as involving longshore and cross-shore sand movement processes. These act concurrently and interact.

3.4.2.1 Cross-shore Sand Transport

Cross-shore sand transport involves:

- Erosion of sand from the upper beach ridge area during large storm wave events, with the sand being taken offshore where it is commonly deposited as a sand bar located in the vicinity of the wave break zone; and
- Subsequent slow transport of the eroded sand back to the beach, often over many months or several years.

Thus, on dynamically stable beaches, there is balance in the amount of sand that is taken offshore and is subsequently returned to the beach and dune. On artificial beaches where the nearshore consists of significantly finer material (i.e. mud), the transport back to the beach may be complicated and some beach material may be permanently lost offshore.

Longshore sand transport results predominantly from waves breaking at an angle to the shore with an alongshore component of their radiation stress that drives an alongshore current and carries the sand along the coast. The wind and tide may also contribute to generation of alongshore currents near the beach. This longshore sand transport is distributed across the surfzone and is greatest in the area near the wave break point where the wave height, longshore current and bed shear are greatest. That is, it occurs across a limited zone most probably in water depths less than about 5m along the Redcliffe shoreline.

The beach may remain stable (without net recession or accretion) where the longshore sand transport is uniform along the coast. However, where there are differentials in the rates of longshore

transport, such as a structural shortfall in sand supply to a shoreline, the beach will erode or accrete in response.

Wave effects on longshore transport are expected to be complex and variable because of the limited penetration of swell waves to the site, the irregular occurrence of storm tide event with their associated high waves and elevated water levels and effects of the numerous non-erodable shoals and outcrops around the shoreline (i.e. bedrock underlying the Redcliffe Peninsula).

Furthermore, the regional longshore transport is strongly influenced by the various coastal features (natural headlands, revetments, groynes and reclamations) that are present along the Redcliffe shoreline. Several groynes have been built on the Redcliffe shoreline, which have intercepted the northerly sand transport. The most significant of these groynes being at Redcliffe Point, Shields Street, Osbourne Point, Queens Beach North, Drury Point and Scarborough Point. In addition, the breakwater at Scarborough Boat Harbour and the revetments along Pelican Park land reclamation intercept the longshore sediment transport. The effect of these structures has been accumulation of sand on their updrift side (southern edge along the Eastern Beaches) and the initiation of erosion on their downdrift side. It appears that at most groynes sand has accumulated to such an extent that sand bypassing occurs around the groynes.

3.4.2.2 Longshore Sand Transport

Longshore sand transport results predominantly from waves breaking at an angle to the shore. Also tidal currents have the capability to transport sediment along the shoreline. Longshore sediment transport is an important coastal process affecting the Redcliffe shoreline, in particular the beaches exposed to north-easterly to south-easterly waves.

The longshore sediment transport rates at the Redcliffe shoreline have been subject to a number of coastal studies, most notable Eastern Beaches Study (Kinhill et al, 1996) and Redcliffe Coastal Processes Study (KBR, 2002). Based on a review of these studies, the following can be noted:

- On average the net longshore sand transport along the Eastern Beaches (north-south shoreline section between Woody Point and Reef Point) is northward. (Kinhill et al, 1996) suggests an average rate of approximately 5,000 m³ per year along the Eastern Beaches, while (KBR, 2002) suggests a typical average rate in the order of 10,000 m³ per year.
- The magnitude of the net longshore sediment transport varies considerably from year to year. During a strong “northerly” year the net annual longshore transport may be about zero, while during “big south-easterly” years the net transport rate might be double the long-term average.
- Along the Bramble Bay shoreline of the SEMP study area (Clontarf Point to Woody Point), the direction of the longshore sediment transport potential is westwards (towards Clontarf Point). The longshore sediment transport direction along the Deception Bay shoreline (Scarborough Boat Harbour to Albatross Canal) is away from the Boat Harbour (westwards).
- There is significant sediment accumulation in the Reef Point area.
- The sand bypassing around Redcliffe Point is negligible and the northwards longshore sediment transport is accumulating to the south of the Redcliffe Point groyne (most northern section of Sutton Beach).

- The several groynes that have been built on the Redcliffe shoreline have accumulated sand on their southern side (updrift), which has resulted in a stable beach immediately to the south of these structures. Sand appears now to have accumulated to such an extent that during most of the year it is moving past the groynes as it drifts northwards.
- The addition of groynes and revetments on the Redcliffe shoreline has resulted in the concentration of erosion at locations (primarily immediately down drift of these structures). This has led to narrow erosion prone shoreline sections along the Redcliffe Shoreline.

3.4.3 Sediment Supply

Most of the beaches along the eastern side of the Redcliffe Peninsula are artificial with the decreasing supply of natural sand replaced by imported sand. The native beaches prior to nourishment were quite narrow.

The beach material on these native beaches was very low in silica. The dominant portion of the origin beach material is believed to be calcareous in origin (ie. from shell gritt). Based on (Bulman, 1966) and interpretation of petrographic reports, the Eastern Beaches Study report (Kinhill et al, 1996) suggested that 25 to 75 % of the original eastern beaches comprised of shell grit. The remainder of the original beaches would have originated from Moreton Bay and from erosion of local rock (cliff erosion and supply by local creeks on the Peninsula). (Kinhill et al, 1996) concluded that there are no significant quantities of sand move directly from the Pine River to Redcliffe's Eastern Beaches.

"Hardening" of Redcliff's land surface in recent decades has reduced the natural sand supply coming down local creeks.

Nowadays, a large portion of the Redcliffe beaches comprise of imported sands. As a result, the sediment composition of beaches at present differs significantly from the native beaches. Importation has predominantly been from a sand pit at Ningi (Southern Pacific Sands), Moreton Bay and to a smaller extent from the Pine River. Based on indications by Council staff, the average sand volume that has been imported over the last years for beach nourishment onto the beaches of Redcliffe is about 2,500m³ per year¹⁶.

In addition, volumes of sand are being transported from location to location within the Redcliffe Peninsula coastal system. The purpose of these sand relocations is twofold: clearing of stormwater outlets or public beach facilities (eg. boat ramps) and replenishment of the beaches (beach nourishment). These existing internal sand relocations by Council include:

- A sand relocation of about 4,000 m³ per year from the northern end of Suttons Beach (sand that has accumulated behind the Redcliffe Point groyne) to the southern end of Margate Beach;
- A sand relocation of about 1,000 m³ per year from the Crockett Park boat ramp at Woody Point (clearing of the boat ramp) to Scarborough Beach;
- A sand relocation of about 500 m³ per year from beaches around North Reef Point to Queen Beach and Scarborough Beach.

A map indicating the existing average annual beach nourishment and sand relocation quantities is presented in Figure 3-8.

¹⁶ Pers. Comm. Mr. R Hayes, Infrastructure Officer, Moreton Bay Regional Council

3.4.4 Cliff Erosion

The cliffs along the Redcliffe Peninsula form a striking feature of the landscape. The cliffs have a long history of degradation. The relentless weathering over the centuries by wind, rain and wave action has resulted in the undercutting of cliffs and erosion of the cliff faces. Historical sea level rise has an important influence on undercutting of the cliffs as it influences the height that at which the cliff is exposed to wave action. Generally cliff erosion at Redcliffe is occurring at two different elevations; the upper zone of the cliffs are typically being eroded due to rain, storm water runoff and wind (sub-aerial erosion) and the base of the cliffs by waves (wave undercutting). Over the last century, human activity in the form of encroaching urban infrastructure, informal access tracks and vegetation removal has aggravated the natural erosion processes.

The extent of erosion varies along the length of the cliffs. *The Scarborough Cliffs Options Analysis Study* by KBR (KBR, 2007A) estimated that the current erosion rate of the cliffs at Scarborough is about 3 to 10mm per year. Many of the cliff profiles at present exhibit an over-steep cliff face between the upper zone (root overhang zone) and the lateritic/cemented base. These over-steep cliff faces have the potential to slide or slump.

While the immediate threats of damaging development and infrastructure are generally low, cliff erosion may form a risk to endanger people walking along the base or tops of the cliffs (e.g. potential rock falls of unstable material).

The erosion threat of the cliffs along the Redcliffe shoreline and the primary erosion mechanisms have been assessed as part of the *Redcliffe Peninsula Foreshore Cliffs Study* (Geo Eng., 1999). This study also assessed protective needs that would be required at the individual cliff sections. The study concluded that one of the main causes of the cliff erosion experienced at the Redcliffe Peninsula is undercutting of the base of the cliffs by wave action. For specific details on the erosion mechanisms and protective needs for each cliff section, reference should be made to (Geo Eng., 1999).

In response to recommendations from the Redcliffe Peninsula Foreshore Cliffs Study, in recent years Council has implemented several measures to minimise further sub-aerial cliff erosion, including measures to re-direct drainage away from the top of the cliffs and establishing formal access points to the beach by fencing.

3.4.5 Storm Erosion Potential

Storm erosion is short-term erosion due to severe wave and elevated sea water levels (surge conditions). The potential for short-term erosion at Margate Beach was assessed by KBR as part of the *Redcliffe Coastal Process Study* using the cross-shore equilibrium profile model of Vellinga (1983). This method uses the storm tide level, wave height, an initial beach profile and sediment characteristics to establish the post-storm beach profile.

The recession calculations were undertaken with a median grain size of 0.5mm, a significant breaking wave height of 2.5m and a storm tide level of 2.3m AHD. The study found that a shoreline recession of 13m to 16m may be experienced during a 50 year ARI storm event.

The value given is based on recession that would occur if the profile consisted of sand only. At locations where outcropping bedrock is present (eg. cliffs) or the shoreline benefits from shoreline

protection structures, such as revetment, the extent to which shoreline recession can occur may be significantly smaller. For example, the northern end of Margate Beach and Suttons Beach has a stepped seawall at the top of the beach profile, which limits the extent of the short-term storm erosion to the position of the seawall.

It is noted that the median grain size adopted in the KBR study are consistent with sand that is currently present on Margate Beach. However, on beaches where the median grain size is smaller, the short-term dune erosion may be substantially larger.

3.4.6 Coastal Inundation

The main coastal inundation mechanism, which may cause coastal flooding along the Redcliffe Peninsula, is dune overtopping at low-lying areas.

The storm tide conditions at the Redcliffe Peninsula have been assessed by Cardno Lawson Treloar as part of the Storm Tide Hazard Study (Cardno, 2009). For the consideration of coastal inundation in the Shoreline Erosion Management Plan, the storm tide levels and associated wave conditions as reported in the Storm Tide Hazard Study have been used.

It is noted that the Storm Tide Hazard Study suggests that for storm tide events with an annual exceedence probability of 5% to 0.5%, the offshore wave height is independent from the magnitude of the storm tide event (i.e. Offshore Significant Storm Wave Height = 1.84m for storm tide events ranging between 5% and 0.5% AEP). Furthermore, it is noted that the significant wave height associated with the 2% AEP storm event is significantly smaller than significant wave height as reported in the *Redcliffe Coastal Processes Study* (KBR, 2002). The *Redcliffe Coastal Processes Study* suggests a 2% AEP significant breaking wave height of 2.5 m.

The extreme wave and storm surge conditions for Redcliffe Point, from *the Storm Tide Hazard Study*, are summarised in Table 3-2 , along with peak wave runup levels for two different edge treatments, namely sandy beaches (beach slope of 1:15) and revetments (slope 1:1.5). The peak wave runup levels represent the potential height exceeded by 2% of wave runup events. For situations where the frontal dune is overtopped the presented levels will be conservative (upper-bound) estimates of the runup height.

At areas where the foreshore is backed by cliffs, ground elevations are generally above the design storm wave run-up levels. As a result the likelihood of coastal inundation in these areas is generally low. However, lower lying areas, specifically the areas adjacent to Bramble Bay and Deception Bay may be below wave run-up levels. Consequently these areas may be subject to coastal inundation.

Table 3-2 Extreme Storm Tide Conditions at Redcliffe Point – From (Cardno, 2009)

Condition at Redcliffe Point	Annual Exceedance Probability of Storm Event			
	5% AEP	2% AEP	1% AEP	0.5% AEP
Offshore Significant Storm Wave Height [m]	1.84	1.84	1.84	1.84
Peak Inundation Levels (Including Wave Setup) [mAHD]	1.92	2.00	2.06	2.12
Peak Wave Runup Potential Levels at Beaches [mAHD]	2.58	2.66	2.72	2.78
Peak Wave Runup Potential Levels at Revetments [mAHD]	4.64	4.72	4.78	4.84

Dune Breach Assessment

A potential threat to low-lying areas with a coastline consisting of dune systems is the development of breaches in the dune system during coastal inundation events. These breaches in the dune system may develop as a consequence of hydrodynamic loading during or directly following storm surge events. The hydrodynamic loading may be caused by wave loading during elevated water levels and/or still water overtopping (currents over the dune tops). The assessment of the potential dune erosion width due to severe waves during elevated water levels (storm surge event) is discussed in Section 3.4.5.

The flooding hazards associated with breaching of the dune system are largely dependent on the significance of flood protection of the dune system and the elevation of land behind the dune. Along most of the Eastern Beaches, the foreshore is backed by cliffs with ground elevations above wave run-up levels. As a result the potential for coastal inundation and dune breaching in this area is considered to be small. At the most southern and northern sections of the study area (areas adjacent to Bramble Bay and Deception Bay, the dunes are approximately at the same level as the land behind dunes. Therefore, the potential for impoundment of water behind the dune is limited and the potential for this to breach the dune system following a storm event (when floodwater drains back into sea) is small.

3.4.7 Erosion Prone Areas

For the study area of this SEMP, the Environmental Protection Agency (EPA) has adopted erosion prone areas as defined by Beach Protection Authority (BPA) in 1994 (Plan SC4006B). These Erosion Prone Areas are defined as a zone measured 40m landward of the mean high water springs line except where approved revetments exist, in which case the zone is 10m landward of the upper edge of the revetment alignment.

BPA's Erosion Prone Areas width represents a nominal value for the Moreton Bay region and includes allowances for the erosion likely to be experienced by erosion in the event of a major storm or series of storms (short-term erosion), long-term progressive recession if long-term erosion was allowed to occur and shoreline retreat associated with climate change impacts (i.e. mean sea level rise).

For the Redcliffe shoreline, where there is a commitment to “hold the line”, the Erosion Prone Area width defined by the BPA is likely to represent a conservative value for the area prone to erosion and the more important width is the short term storm erosion value of 16m (see Section 3.4.5).

3.5 Present and Future Shoreline Erosion

3.5.1 Assessment of Coastal Segments

Based on the assessment of the regional coastal processes at the Redcliffe shoreline, the SEMP study area can be divided into five coastal segments, namely:

- Princess Terrace to Clontarf Point
- Clontarf Point to Woody Point
- Woody Point to Redcliffe Point
- Redcliffe Point to North Reef Spit
- Scarborough Boat Harbour to Albatross Canal

The sections below discuss the erosion issues and primary coastal processes that may cause these issues for each of these coastal segments. The extent of the five coastal segments is shown in Figure 3-9. The shoreline type and existing coastal structures within each segment are presented in Appendix N.

3.5.1.1 Princess Terrace to Clontarf Point

This coastal segment extends from the Houghton Highway Bridge at Clontarf Point to the golf course of Redcliffe Golf Club (western end of Princess Terrace, Clontarf). This coastal segment is located within Hays Inlet, an estuary of the Pine River. Some parts of the shoreline have well-established mangrove areas. Due to its location within Hays Inlet, it has limited exposure to wave action and sediment transport at this shoreline is expected to be low.

Historically, there was a sandy beach along this coastal segment as evident on aerial photography from 1957 (Refer to Appendix O). However, nowadays most sand has disappeared. The beach erosion experienced at the Princess Terrace to Clontarf Point shoreline is caused by a change in the sand supply to this shoreline. Historically, this shoreline was supplied with sand from Bramble Bay. The various land reclamations that have been built around Hornibrook Esplanade have interfered with the natural sediment transport along the shoreline. This has reduced the sand supply to the Princess Terrace to Clontarf Point segment.

Appendix O presents historical aerial photography of the coastal segment from 1957 to 2007. From the historical aerial photography it is evident that the beach width has been reduced since the construction of the land reclamations at Hornibrook Esplanade.

In an attempt to arrest erosion of the shoreline along a state-owned parcel of land behind Princess Terrace, adjacent property owners have dumped rubble onto the foreshore. This ad hoc attempt is unlikely to be an effective measure to prevent further shoreline erosion.

3.5.1.2 *Clontarf Point to Woody Point*

This coastal segment is adjacent to Bramble Bay and extends from Woody Point to the Houghton Highway Bridge at Clontarf Point. Most of the shoreline along this coastal segment is armoured, either in the form of rock walls or concrete seawall.

There are three substantial land reclamations in this coastal segment, namely around Pelican Park, around Bicentennial Park/Crockett Park and the slip road to the Houghton Highway Bridge. All three land reclamations are surrounded by revetments and have a significant influence on the adjacent shoreline. The direction of the net longshore sediment transport in this coastal segment is generally westwards (away from Woody Point).

There are three short sandy beaches in this coastal segment, namely in front of Crockett Park, Bells Beach (between Bells Creek and Pelican Park) and Clontarf Beach (between Pelican Park and the Houghton Highway Bridge).

Bells Beach has a groyne at its eastern extremity (near the outlet of Bells Creek) and a revetment wall, associated with the Pelican Park land reclamation, at its western extremity. This beach appears to be a stable pocket beach. The dune front is generally located at least about 25m from the Hornibrook Esplanade.

Clontarf Beach is enclosed between a substantial groyne (western edge) and the revetment of the Pelican Park land reclamation (eastern end) and is a pocket beach. The dune front is located at least 22m from the Hornibrook Esplanade.

The small sandy beach in front of Crockett Park is backed by a concrete seawall and is stabilised by a short groyne at the western edge of the park. The groyne at this beach appears to be full and sand has now accumulated on the eastern side of the groyne to such an extent that substantial sand bypassing occurs around the groyne. Evidence of the fact that sand bypassing occurs around the groyne is found in the accumulation of sand on the boat ramp, which is located immediately to the west of the groyne.

Because accumulation of sand on the boat ramp adversely impacts on the usability of the boat ramp, Council regularly removes sand from the boat ramp at Crockett Park. The removed sand is transported to Scarborough, where it is placed as beach nourishment sand onto the beaches. Based on indications of MBRC staff, the volume of sand that is being removed from the boat ramp equates to about 1,000 m³ per year. The removal of sand from the boat ramp and the transportation to Scarborough Beach acts as a sediment sink for this coastal segment.

Another sediment sink for this coastal segment is maintenance dredging around the Pelican Park boat ramp. The maintenance dredging of the access channel (areas below low water mark) is undertaken by Queensland Transport and the boat ramp and adjacent beaches by Council. The dredged material that is removed by Queensland Transport is transported to an offshore spoil ground, while the material that is being removed by Council is transported to a nearby landfill site for disposal. Although no information in relation to the composition of the dredged material or quantities could be made available for this study, it is believed that the dredged material predominantly consists of mud.

3.5.1.3 Woody Point to Redcliffe Point

The coastal segment comprises of two distinct shoreline sections; the southern shoreline section extends from Woody Point to Scott's Point and the northern section extends from Scott's Point Beach to the Redcliffe Point groyne. The foreshore of the southern section consists of cliffs and the northern section encompasses the sandy beaches of Scott's Point Beach, Margate Beach and Suttons Beach.

Woody Point to Scott's Point

The foreshore between Woody Point and Scott's Point consists predominantly of cliffs and along most of this shoreline armouring has been used to resist erosion.

Between Woody Point and Picnic Point, the shoreline is located directly adjacent to private property at most locations. In response to shoreline erosion, property owners have implemented a wide range of shoreline protection measures including vertical concrete seawalls, rock armoured revetments and uncoordinated placements of rubble on the foreshore. The responsibility for the maintenance of the existing shoreline protection structures that are protecting private property lies with the adjacent property owners.

In the vicinity of the "Gayundah" wreck, there have been several uncoordinated efforts by adjacent property owners to arrest the foreshore erosion by dumping materials onto the foreshore. The armouring material consists mostly of rubble and broken concrete slabs. A photograph of the foreshore near the "Gayundah" wreck is presented in *Figure 3-2*. The resulting foreshore is not only aesthetically unattractive, but also likely to be of limited value in protecting the shoreline during significant storm events.



Figure 3-2 Uncoordinated armoring of the foreshore near "Gayundah" wreck

Further to the north, around Picnic Point, there is a vertical concrete seawall. This 80m long seawall extends around Picnic Point Park and protects a public park and a pathway linking the Coastal Arboretum with the "Gayundah" wreck. The structural capacity of the seawall was analysed as part of the Redcliffe Peninsula Cliff Study (Geo-Eng& CEM, 1999) and concluded that rehabilitation or replacement of the structure was required. Rehabilitation options for this seawall were subsequently

investigated by KBR in the 'Gayundah Wreck (Picnic Point) Seawall Rectification – Concept Design Report' (KBR, 2007B). The (KBR, 2007B) report recommends a rehabilitation option where a rock revetment is placed in front of the existing wall. The recommended option has not been implemented to date.

Between Picnic Point and Scott's Point, there is a 700m long rock seawall with a narrow beach. This approved rock wall protects parkland and is maintained by Council.

Scott's Point Beach, Margate Beach and Suttons Beach

The northern section is a mostly straight shoreline with slight fillets at its extremities and a minor rocky outcrop around Mabel Street, which locally affects the shoreline alignment. The beaches of Scott's Point Beach and Margate Beach are generally narrow, while Suttons Beach widens to the north. The slope of the beaches is typically around 1 in 12 and consists of imported sand with a median grain size of 0.5mm.

The average net longshore sand transport along this coastal segment is northward. (Kinhill et al, 1996) estimated that the average net longshore sand transport rate along the beach is approximately 5,000 m³ per year. (KBR, 2002) suggested a somewhat greater average rate of about 10,000 m³ per year.

The magnitude of the net longshore sediment transport will vary considerably from year to year. During a strong "northerly" year the net annual longshore transport may be about zero, while during "big south-easterly" years the net transport rate may be double the long-term average.

Due to the northern longshore sand transport and the lack of adequate supply of sand from around Scott's Point, both Scott's Point Beach and Margate Beach experience ongoing erosion.

Redcliffe Point with its substantial groyne and rocky headland forms a significant coastal feature, which completely intercepts the northern longshore sediment transport. As a result, the sand transport around Redcliffe Point is approximately nil and significant amounts of sand are being stored at the northern end of Suttons Beach, which has created a wide beach with substantial dunes (i.e. the park fronting the cliffs). The continued accretion causes sand to deposit against the concrete steps from where it can be transported into the park by wind. In recent years, Council has undertaken sand relocations (recycling), where sand has been removed from the northern section of Sutton Beach and transported to Margate Beach (primarily the area immediately updrift of the outcrop at Mabel Street). The volume of sand that is being transported as part of these sand relocation operations is about 4,000 m³ per year (one major maintenance operation of about 10,000 m³ every three years plus numerous small ad hoc maintenance operations during the year).

In addition, Council replenishes Margate Beach with sand imported from a sand pit at Ningi. These beach replenishments occur in the form of occasional larger beach fill operations and frequent top ups of the dune front. Based on indications of MBRC staff, the volume of sand that is imported from Ningi and placed onto Margate Beach as beach replenishment sand is estimated to be on average about 1,000m³ per year.

At various locations, private property, public spaces and Council infrastructure is located in close proximity to the shoreline. Several coastal structures have been built along most of this shoreline, including:

- A rock seawall along Scott's Point Beach
- A buried, stepped concrete seawall between Duffield Road and Redcliffe Point

A map showing the locations of these coastal structures is presented in Appendix N.

The vulnerability of the beaches to storm erosion has been investigated by KBR as part of the Redcliffe Coastal Processes Study. The study found that, for a 50 year ARI storm event, shoreline recession of up to 16m may be experienced. At locations where the beach is backed by coastal structures, the extent to which shoreline recession can occur is limited by the structures. For example, the northern end of Margate Beach and Suttons Beach has a stepped seawall at the top of the beach profile, which limits the extent of the short-term storm erosion to the position of the seawall.

Between Woody Point Park and Mabel Street (Margate Parade) a boardwalk/footpath, the Margate Bathing Pavilion (a place of cultural significant) and some other Council buildings (eg. toilet blocks) and parts of the road on Margate Parade are located within the 16m short term erosion zone.

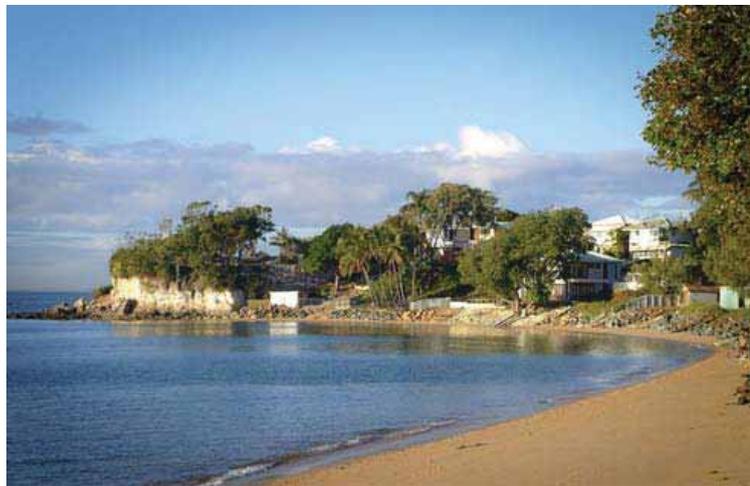


Figure 3-3 Scott's Point and Scott's Point Beach



Figure 3-4 Suttons Beach



Figure 3-5 Recent dune top-up at Margate Beach

3.5.1.4 Redcliffe Point to North Reef Spit

This coastal segment extends from Redcliffe Point in the south to North Reef Spit in the North. A map showing the shoreline types along the coastal segment is presented in Appendix N.

The shoreline consists of a number of curved embayments, which are formed between headlands (cliffs) and the several groynes that have been built in this coastal segment. The most significant of these groynes being at Redcliffe Point (southern edge of the coastal segment), Shields Street, Osborne Point, Donkin Street, Drury Point and Scarborough Point. The effect of these structures has been the accumulation of sand on their southern side. It appears that most of these groynes are now full (i.e. sand has accumulated to the extent that it is naturally moving around the groyne as it drift northward).

An exception is the groyne at Shield Street (Northern end of Queens Beach South). The shoreline of Queens Beach South seems to have re-aligned itself in recent years in response to the construction of the Redcliffe Jetty offshore breakwater. This has resulted in shoreline erosion at the northern end of the bay and accumulation of sand near the jetty (in the lee of the offshore breakwater). At the moment, significant Norfolk Pines, a foreshore bike path and some recreational facilities are at risk of erosion. The shoreline re-alignment process is evident from aerial photography of the beach before construction of the offshore breakwater (1997) and after (2002) as presented in Figure 3-6. The accumulation of sand behind the offshore breakwater is causing siltation of the creek outlet near Anzac Place and the outlet is cleared frequently by Council. Sediment that is removed from the outlet area by Council is placed onto the northern section of Queens Beach South.

In recent years, the shoreline at northern end of Queens Beach South has experienced retreat. To protect the esplanade and a cycle path, Council has implemented in 2007 a rock wall at the northern most 120m of Queens Beach South. The beach in front of Captain Cook Park continues to erode and is regularly replenished with beach nourishment sand.



Figure 3-6 Accretion at Redcliffe Pier since construction of offshore breakwater

The average net longshore sand transport along this coastal segment is northward. (Kinhill et al, 1996) estimated that the net annual longshore sand transport rate along this shoreline is typically about 5,000 m³ per year. (KBR, 2002) suggested a somewhat greater rate of about 10,000 m³ per year. The average longshore sand transport rate is not constant along the shoreline of this segment and will vary considerably from year to year.

Due to the shape of the embayments, the longshore transport rate tends to be greater at the northern end of the beach and smaller at the southern end. The southern ends of the beaches therefore experience continued erosion, necessitating seawall construction and beach nourishment at these locations.

If there was an adequate volume of sand and sufficient space, the beach would eventually form a pocket beach, a stable embayment with deep crenulated shape and hook at its southern end. There are several locations along the Queensland coast where such a pocket beach has formed (eg. southern beaches of the Gold Coast and Rainbow Beach). At Redcliffe, pocket beaches cannot form because there is insufficient sand, a lack of large projecting headlands and insufficient space for the required indentation depth between the headlands.

The sand transport around Redcliffe Point groyne is approximately nil, which means that there is a lack of sand supply at the shoreline around the Redcliffe Point land reclamation. This has resulted in the beach in front of the reclamation almost completely disappearing.

Presently Council conducts beach nourishment at the beaches between Redcliffe Point and North Reef Spit. The beach nourishment works consists of the importation of sand from outside the coastal system and sand relocations within the system.

Sand is imported from various sources including a sand pit at Ningi and dredge sites at Bribie Island. In addition, sand is being imported from Bramble Bay, around Crockett Park (clearing of the boat ramp). The sand volume that is sourced from the Crockett Park boat ramp is about 1,000 m³ per year and is placed onto Scarborough Beach.

In addition Council has regularly removes sand from the northerly beaches around North Reef Spit and relocated it to southern beaches of this coastal segment. The purpose of these sand relocations is twofold: to replenish the beaches to the south and to prevent infilling of stormwater drains that drain out onto the beach around North Reef Spit. The sand volume of these sand relocation works is estimated to about 500 m³ per year. It is noted that the North Reef Spit area has recently been declared a Marine Park Conservation Zone, which could constrain the possibilities to continue these sand relocation works in the future.

Furthermore, sand is imported from outside the Redcliffe Peninsula. In recent years, Council has placed about 1,500 m³ per year of imported sand onto the beaches between Redcliffe Point and North Reef Spit as beach nourishment sand.

The primary sink for the sand that moves through the coastal segment is believed to be an area of deeper water to the south of North Reef (offshore of Castlereagh Point).

3.5.1.5 Scarborough Boat Harbour to Albatross Canal

This coastal segment is located along Deception Bay and extends from the Scarborough Boat Harbour to the Albatross Canal. The shoreline of this coastal segment has a northeast-southwest alignment and with the exception of the 300m immediately to the west of the Scarborough Boat Harbour (along Oyster Point Esplanade) the shoreline consists of a rock wall. A map showing the shoreline types along the coastal segment is presented in Appendix N.

Most of the shoreline along Oyster Point Esplanade is fronted by mangroves. There is evidence of erosion along the 300m of shoreline immediately to the west of the Scarborough Boat Harbour and near Michel Road and rubble and broken concrete slabs have been dumped onto the dune front in an effort to prevent further erosion at a public toilet block. A photograph of the shoreline near Michel Road is presented in Figure 3-7.

The erosion at this shoreline is due to the lack of sediment supply caused by the presence of the Scarborough Boat Harbour breakwaters and the ongoing maintenance dredging that is undertaken at the marina by Queensland Transport. Consequently, the transport of sediment from around Oyster Point has stopped. This has reduced the sand supply to the Scarborough Boat Harbour to Albatross Canal shoreline resulting in persistent erosion. The rate of erosion is relatively low because the sediment transport processes along this shoreline are expected to be low as the wave exposure of the shoreline is limited.



Figure 3-7 Dumped Rubble on Dune Front at a public toilet block near Michel Road

3.5.2 Climate Change Impacts

Research on likely climate change impacts indicates that two fundamental impacts may affect the shoreline, namely:

- Changes to storm occurrences and storm winds together with their effects on storm surges; and
- Sea level rise.

3.5.2.1 Changes to Storm Occurrences

Little is known about likely changes to prevailing winds or extreme storm behaviour, although it is likely that cyclones would extend further south under warmer sea temperatures. The effect of changed storm occurrences on storm surges has been investigated by Cardno as part of Storm Tide Hazard Study (Cardno, 2008). The Cardno study suggests that the 1% AEP storm tide levels at Redcliffe may increase by 0.16m (excludes any mean sea-level rise) and there may be a slight increase in design wave conditions.

3.5.2.2 Future Sea Level Rise

Global-average temperatures increased at about 0.7 degrees Celsius since 1900 and the global-average sea-level has risen 1.7 mm per year since 1900 (Church and White, 2006). Due to anthropogenic greenhouse gas emissions the rates of both temperature increase and Sea Level Rise (SLR) are likely to be presently increasing and are expected to further accelerate in the future (IPCC, 2001; IPCC, 2007).

There are uncertainties as to the actual magnitude and rate of future sea level rise. This has led to various scenarios being adopted by the Intergovernmental Panel on Climate Change (IPCC), based

on the range of model results available and dependent upon the amount of future emissions assumed.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) reports that global sea level rise is projected to be 18–59 cm by year 2100 relative to 1990 levels. These projections do not include a contribution from ice flow rates, however if these were to continue to grow linearly with global warming, then the upper ranges of sea level rise would increase by a further 10 to 20 cm (by year 2100 relative to 1990) (IPCC, 2007). There is an acknowledged risk that the contribution of ice sheets to sea level rise this century may be substantially higher than this.

The climate models predict that there will be a not-insignificant regional variation in future sea level rise, predominantly due to spatial variations in the contribution made by ocean thermal expansion. Predictions reported by the CSIRO (2007) indicate that future sea level rise along the eastern Australian coastline may be up to 12 cm greater than the global average due to the greater efficiency in South Pacific Ocean currents (such as the East Australian Current) to disperse thermal energy.

In summary the total mean sea level rise along the eastern Australian coastline is estimated to be in the range 28–91 cm to the year 2100. This will occur gradually at first as we continue to accelerate from the historic rate of 1.7 mm per year and then more rapidly as the year 2100 is approached.

For planning purposes in developed areas (planning horizon of 50 years), an allowance of 0.28 m for global warming induced mean sea level rise is recommended. This is based on the mid-range projection of the 50-year sea level rise. This increase is consistent with other studies along the Queensland and NSW coastlines and EPA recommendations for shoreline erosion assessments.

Thus, planning for a sea level rise of the order of 0.3m over the planning timeframe of 50 years for the Redcliffe SEMP appears appropriate in the context of the present understanding of these processes. Furthermore, the potential change in storm occurrences may slightly increase the extent of future storm erosion of the beaches and dunes.

3.5.2.3 Beach Profile Response due to Climate Change

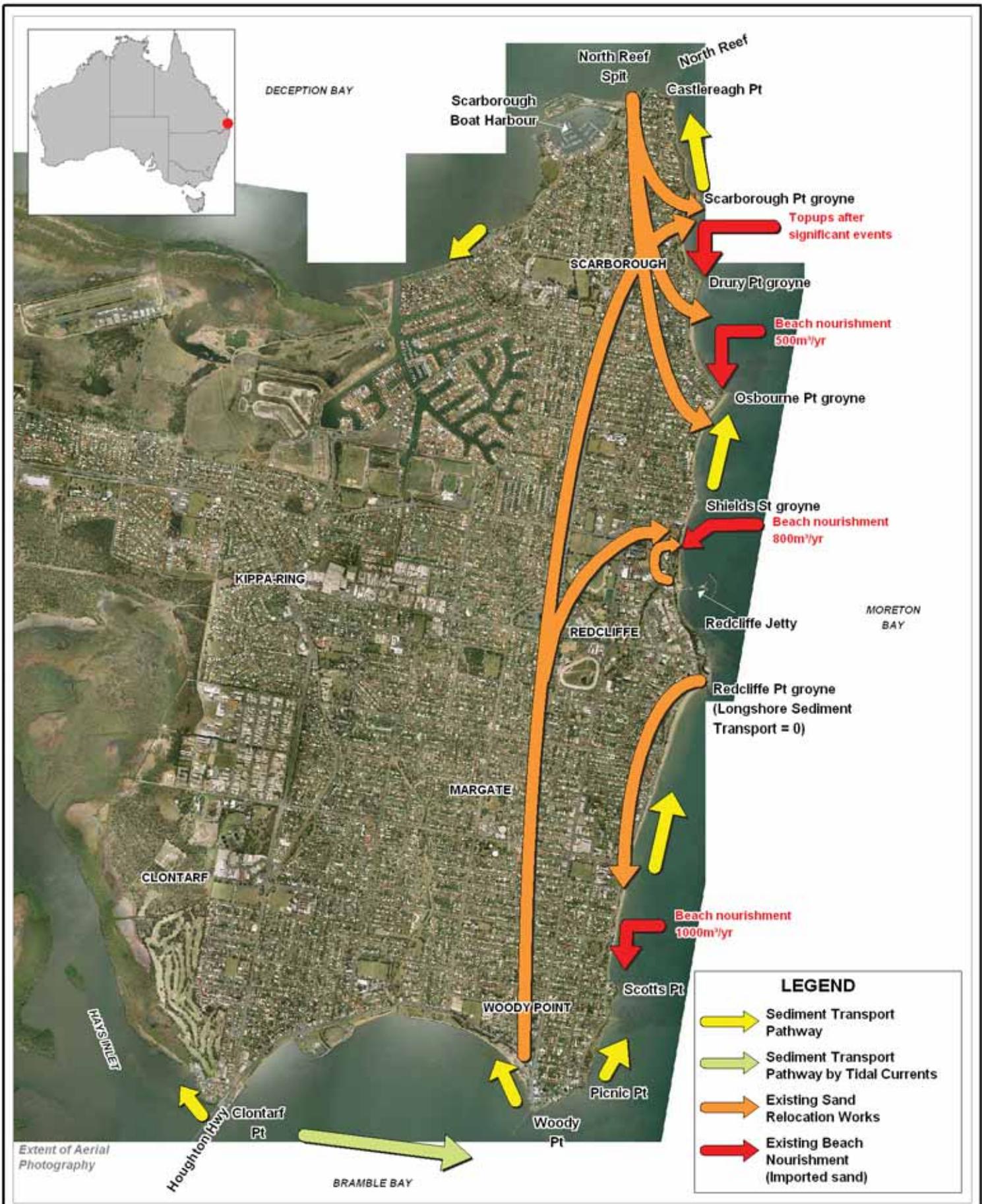
Both mean sea level rise and intensification of the storm occurrences are likely to have an impact on the maintenance requirements of Redcliffe shoreline. For the development of this SEMP, as a minimum, recognition is therefore required that this may affect the shoreline and any shoreline management action will need to cater for these potential changes.

As water levels change, the beach profile will respond toward a new equilibrium, which causes a redistribution of sand over the active beach profile with erosion of the foreshore and deposition of sand offshore. The active beach profile runs from the dune front to the depth of closure and is typically 200 to 300m wide at Redcliffe (depth of closure at Redcliffe's eastern beaches is at approximately -4m AHD, (Hallermeier, 1978)).

With a historical mean sea level rise of 1.7mm per year since 1900, the annual sand volume that is transported from the upper beach offshore due to mean sea level rise would have been about 0.3 to 0.5 m³ per year per linear metre. This means that along the "Scott's Point to Redcliffe Point" coastal segment a beach nourishment volume of about 900 to 1,300 m³ per year would have been lost to

accommodate beach profile changes as a result of mean sea level rise and about 1,500 to 2,200 m³ per year for the “Redcliffe Point to North Reef Point” segment.

With a mean sea level rise allowance of 0.28m over the planning timeframe of 50 years, the average loss of beach material from the upper beach (i.e. beach nourishment requirement to mitigate shoreline recession due to mean sea level rise) may increase to about 2,900 to 4,400m³ per year for the “Scott’s Point to Redcliffe Point” coastal segment and about 4,800 to 7,200m³ per year for the “Redcliffe Point to North Reef Point” segment.

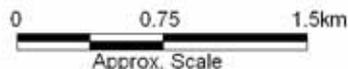


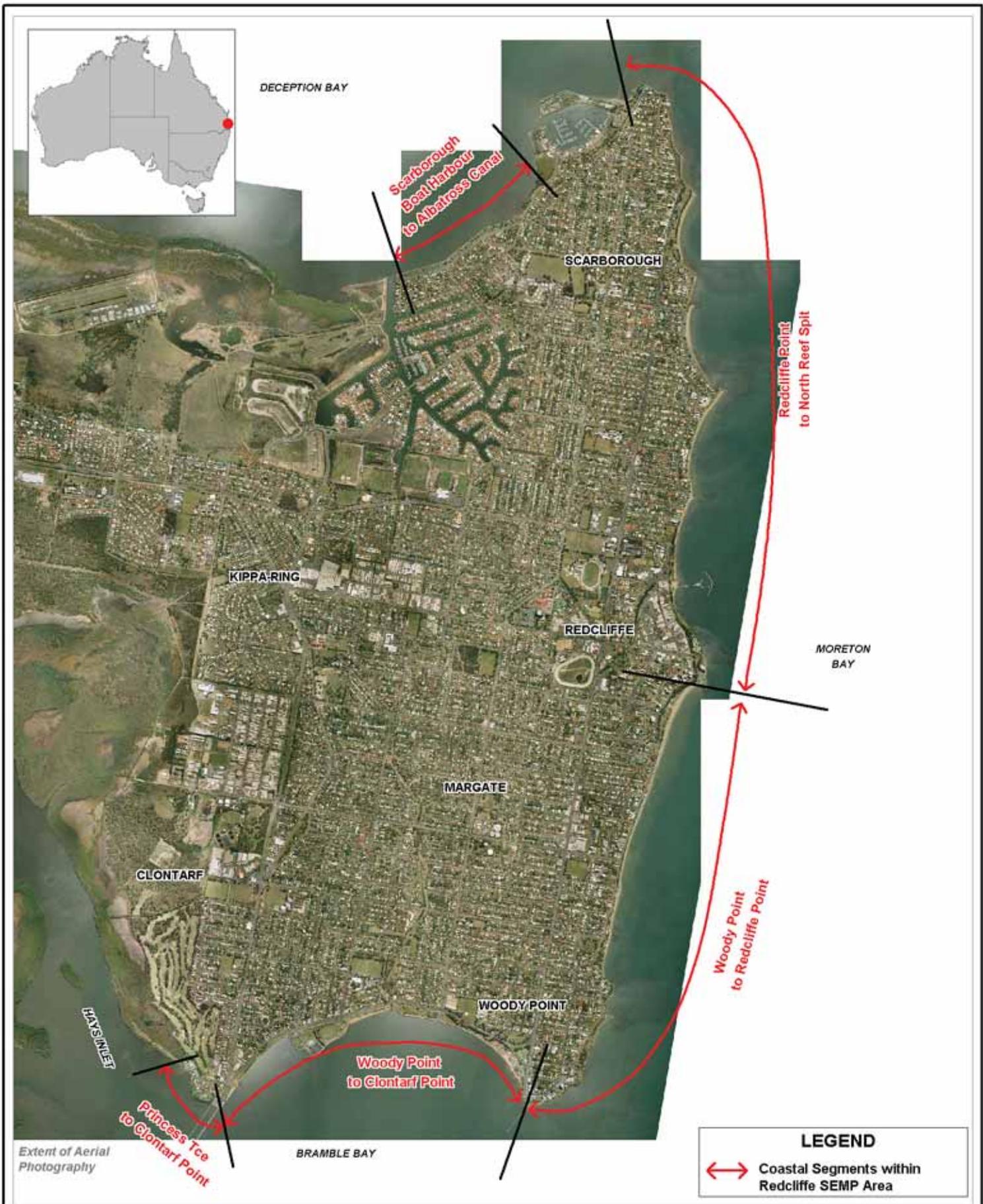
Title:
Sediment Transport Pathways, Existing Beach Nourishment and Sand Relocation Operations at the Redcliffe Shoreline

Figure:
3-8

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Title:
Coastal Segments within Redcliffe SEMP Area

Figure:
3-9

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0 0.75 1.5km
Approx. Scale



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