Chapter 3: Coastal Characteristics

The coastal environment is the area lying at the interface between land and the sea. The area includes both the zone of shallow water within which waves are able to move sediment and the area landward of this zone including beaches, cliffs and coastal dunes. The landward zones are also affected to some degree by waves, tides and currents.

Most coastline landforms are in dynamic equilibrium with prevailing processes. Whether or not a coastline will exhibit erosion or accretionary characteristics is governed by a combination of sediment supply, weather patterns and the long-term relative change in sea level. A holistic approach is required in relating contemporary land forms to current coastal processes because storm events may obscure features of an accretionary coast for short periods of time.

This section briefly outlines coastal processes and land forms relevant to the Bay of Plenty.

3.1 Winds and wave climate

There are four defined regions around New Zealand based on wave climate (Hume et al. 1992, Pickrill & Mitchell 1979). The Bay of Plenty falls into the “Northern New Zealand” zone and is considered to be a low-energy lee shore (wave height = 0.5 - 1.5 m, wave period = 5 - 7s, from NE) extending between East and North Capes. Wave steepness is variable and Pickrill and Mitchell (1979) considered that northern New Zealand should show weak seasonality. Macky et al. (1995) measured waves in 34m of water in Katikati inlet and found most waves less than 1m 70% of the time with spectral density of 10 - 11s.

Swells originate from the following sources - winds blowing around anticyclones to the east, cyclonic systems retreating eastwards, and mid-latitude depressions which have passed over New Zealand (Harris, 1985).

Data from the Environment Bay of Plenty Triaxys wave buoy located 13km north of Pukehina Beach in 62m of water, for the period September 2003 to December 2006 is summarised in Figure 3.1. Maximum recorded H_{max} = 12.5m, average H_s = 1m and average T_s = 6.3s.

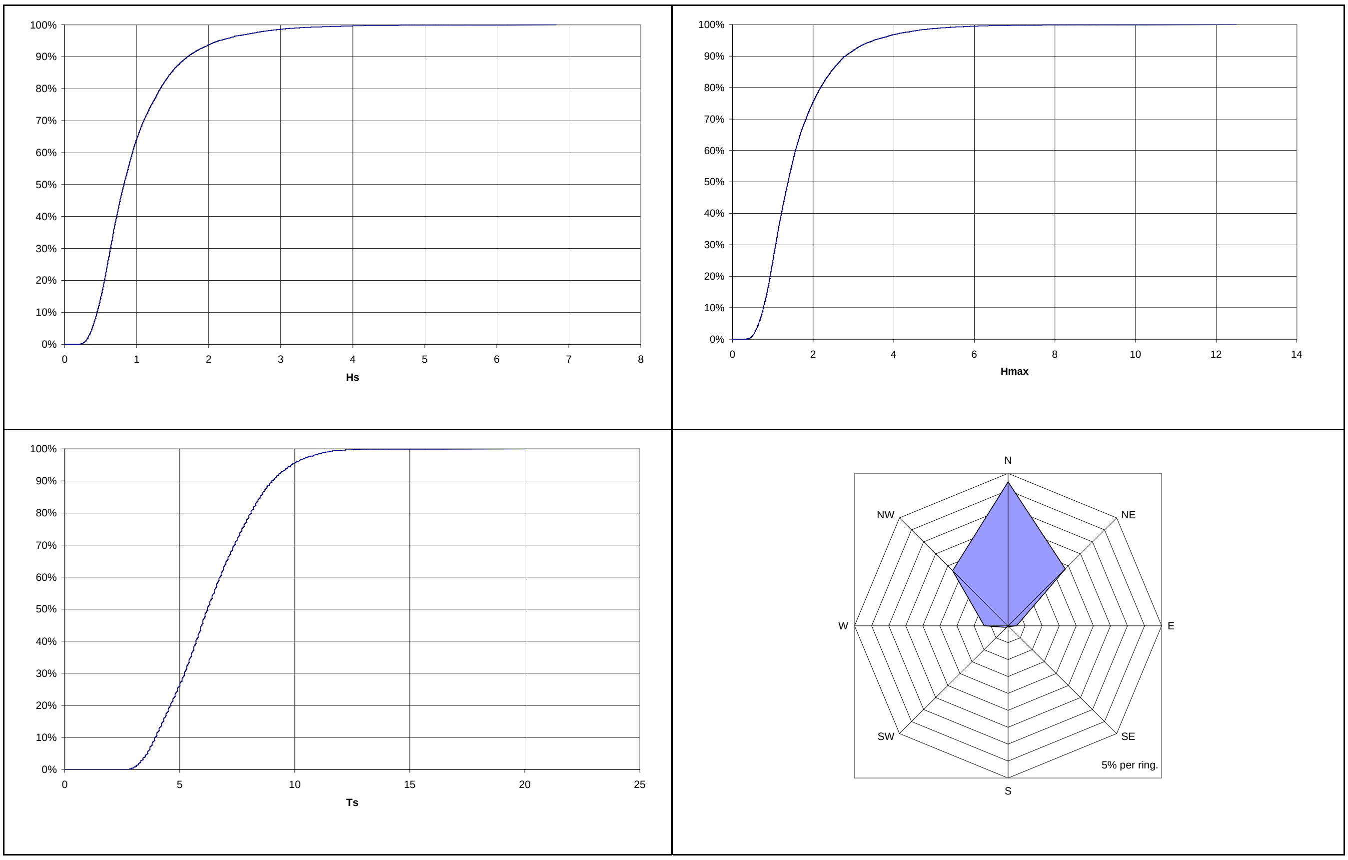

Figure 3.1 Environment Bay of Plenty wave buoy distribution summary graphs, September 2003 to December 2006. Clockwise from top left – H_s, H_{max}, Wave direction (mag.) and T_s.

Due to the prevailing westerly flow over the North Island of New Zealand, approximately 20% of waves reaching shores of the Bay of Plenty approach from the west. However, swells from the east and north predominate due to their long fetches (Harris, 1985; Hay, 1991; Macky et. al., 1995). Offshore swells of medium-energy and wave heights around 1.5m dissipate some of their energy over the 20km of continental shelf arriving in the near shore environment aligned near normal to the shoreline with reduced wave heights of approximately 0.6 - 0.8m (Healy et. al., 1977; Macky et. al., 1995).

Depressions originating in all three of the weather systems discussed in the above section are the most common sources of the winds producing higher waves impinging on the Bay of Plenty (Harris, 1985). These weather events generally produce several days of strong wind and rain from the north-east promoting erosion in exposed areas.

Strong winds are more frequent in winter months and during positive ENSO periods. Therefore persistent waves and storm induced erosion are more persistent during warmer La Nina periods (Hay, 1991)

3.2 Storms

Between 1873 and 1990, 153 storms were recorded in the Bay of Plenty with a mean of a little over 1 storm per year (Hay, 1991). However major storms did not occur every year. Most of the severe storms originated from the east-northeast direction and measured grade 8 - 9 on the Beaufort wind speed scale. A smaller number of storms were derived from the east-southeast. (Hay 1991, Macky *et al.,* 1995)

A summary of the more significant storms that occurred during the period reported in this document are summarised in the Table 3.1.

Table 3.1 Significant storms during this report period.

Event
March 1988 – Cyclone Bola
July 1992
September 1993
24 -25 January 1996
30-31 December 1996 – Cyclone Fergus
10-11 January 1997 – Cyclone Drena
11-13 March 1997 – Cyclone Gavin
July & August 1998
November 1998
12-14 April 2001 – Cyclone Sose
20-21 June 2002
16 April 2003
29 February 2004 – Cyclone Ivy
16 July 2004
25 January 2006

3.3 Coastal Landforms

3.3.1 Cliffs and shore platforms

In some areas of the Bay of Plenty (Matata, Te Kaha) steep vertical cliff slopes formed from rock, rise abruptly above either the sea or a basal shore platform. Shore platforms have formed in some areas of the Te Kaha coast as the cliffs retreat under the effects of abrasion.

3.3.2 Beaches

The profile form of beaches is determined by the size, shape and composition of beach material and the tidal range, type and characteristics of incoming waves. The upper section of most sandy beaches consists of a horizontal to slightly landward sloping surface which is known as the berm. The berm is a zone of accretion formed by backwash deposition. The height of the berm is limited by the upper limit of swash. Berms are present on most Bay of Plenty beaches during periods of accretion. The gradient of the beach slope seaward of the berm is normally low angle, ~2°, on sandy beaches and may be up to 20° where beaches are composed of coarse pebbles. Wave height and steepness are also correlated with the angle of the beach face. (Healy,1978; Phizacklea, 1993; Saunders,1999)

Comparisons of selected average profiles show the variation in beach slope and shape throughout the Bay of Plenty (Figure 3.2).

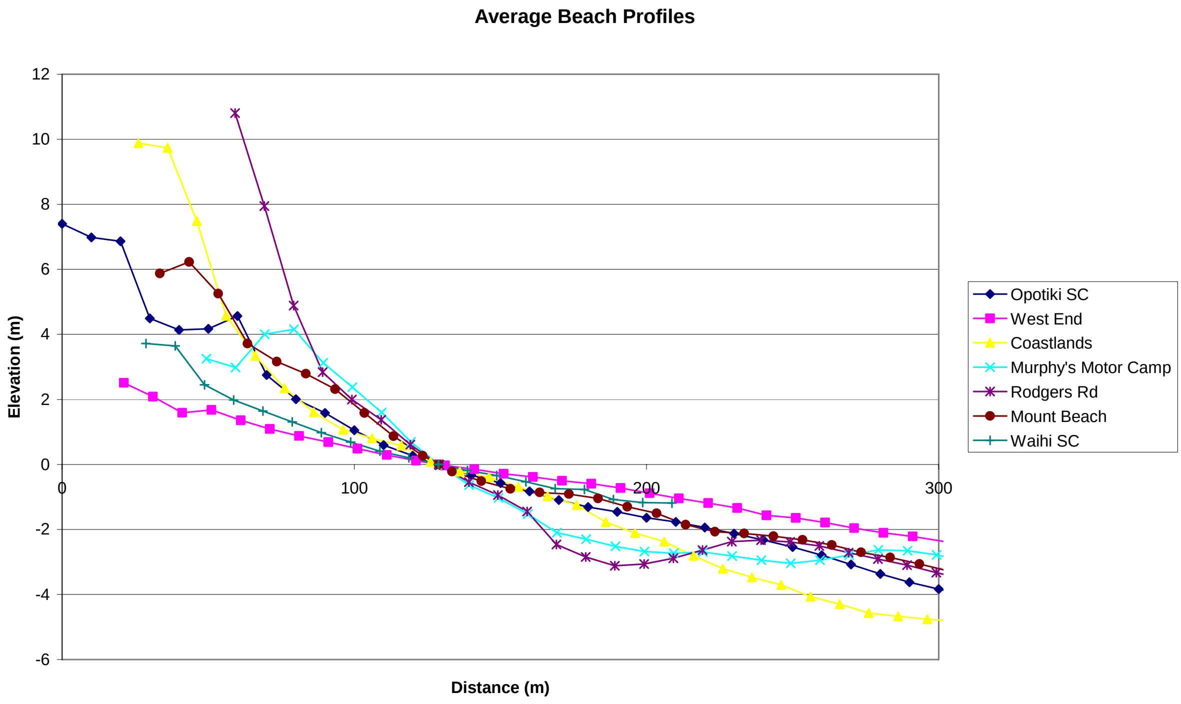

Figure 3.2 Average beach profile variation throughout the region.

Where the beach slope is shallow to moderate, there is typically one or several submerged longshore bars running parallel to shore and separated from the beach by a trough. Such bars develop in response to the action of breaking waves migrating backwards and forward normal to the shoreline (Pickett, 2004).

Bay of Plenty beaches build up in strong westerlies (typical of El Niño weather conditions) when long period waves carry sediment onto beaches and build up berm slopes and dunes.

It is important to note that beach profiles are not static, but rather change their forms over a range of time scales. Bay of Plenty beaches undergo a seasonal cycle of erosion and deposition. The predominance of swell waves in summer is associated with deposition from swash and a phase of beach construction involving the development of a berm just above high water mark. During winter, storm waves either cut back or completely destroy the berm. The eroded sediment is transported just offshore and deposited in longshore bars and also travels eastwards with littoral drift to be deposited along the beach. Such bars are eroded in summer to supply sediment to rebuild berms that were eroded in winter. This process is known as the cut and fill cycle (Komar, 1976). However during the summer, storms that generally move through the Bay of Plenty as a result of tropical cyclones and subtropical depressions, beach berms are destroyed by storm waves which temporarily magnify the rate of erosion of the beaches. This can lead to wave attack on backing cliffs (such as on the northern side of Whale Island), dunes (on beaches such as Ohope) and developed areas where dunes are absent (such as West End Ohope).

3.3.3 Barrier Island

A barrier island (barrier bar) is an elongated offshore ridge of sand running parallel with a mainland coast and separated from it for almost its entire length by a lagoon or harbour. Matakana Island, which separates Tauranga Harbour, from the sea is the only barrier island in the Bay of Plenty. It is 5 km wide at its widest point and 20 km in length.

3.3.4 Spits

Spits are elongated depositional forms attached at one end to the mainland and usually developed where the coast changes direction. The largest spits in the Bay of Plenty separate Ohiwa Harbour, Whakatane River mouth estuary, Maketu Estuary and Waihi Estuary from the sea. A feature of many spits in the Bay of Plenty (such as Ohope and Ohiwa) is their landward curvature at their accreting ends. The curved forms are generated by refraction of incoming waves around the accreting spit hooks and landward movement of sediment supplied by longshore drift. Occasional periods of incident waves from a different direction than normal will also modify the characteristic of the spit.

3.3.5 Dunes

Dunes form when sand is blown landward from beaches. Aeolian transport is favoured by high onshore wind speeds moving sand from thick beach deposits. Larger beaches generally supply greater quantities of sand to dunes than smaller beach surfaces. Coastal areas (such as Coastlands near Whakatane) which receive abundant supplies of sand from rivers generally have the largest coastal dunes complexes. Dunes develop in rows parallel to the coast. The row closest to the coast is the primary dune set which receives sand from the beach. The secondary more inland dunes are maintained as sand is blown inland from the more coastal dunes.

A recent study of 10 sites along the Bay of Plenty coastline (McNutt et. al., 2006) showed on the whole the vegetation structure and species composition are relatively simple which is not unusual for a duneland. Sand fields are the most common vegetation structure, present in all 10 selected sites. They are situated in the foredune with sand binding plants such as spinifex (*Spinifex sericeus*), pingao (*Desmoschoenus spiralis*) and native shore convolvulus (*Calystegia solandri*).

Chapter 4: Climate Change

The beach profiles have been surveyed at all sites on at least and annual basis since 1990. This 16 year record of annual or near annual beach change includes the effects of three periods of persistent La Nina (positive SOI) weather pattern, three periods of persistent El Nino (negative SOI) patterns (Figure 4.1) and 15 storm events which are highlighted in Chapter 3 and deemed significant in the Bay of Plenty. However all the records were taken during a positive period of the Interdecadal Pacific Oscillation (IPO).

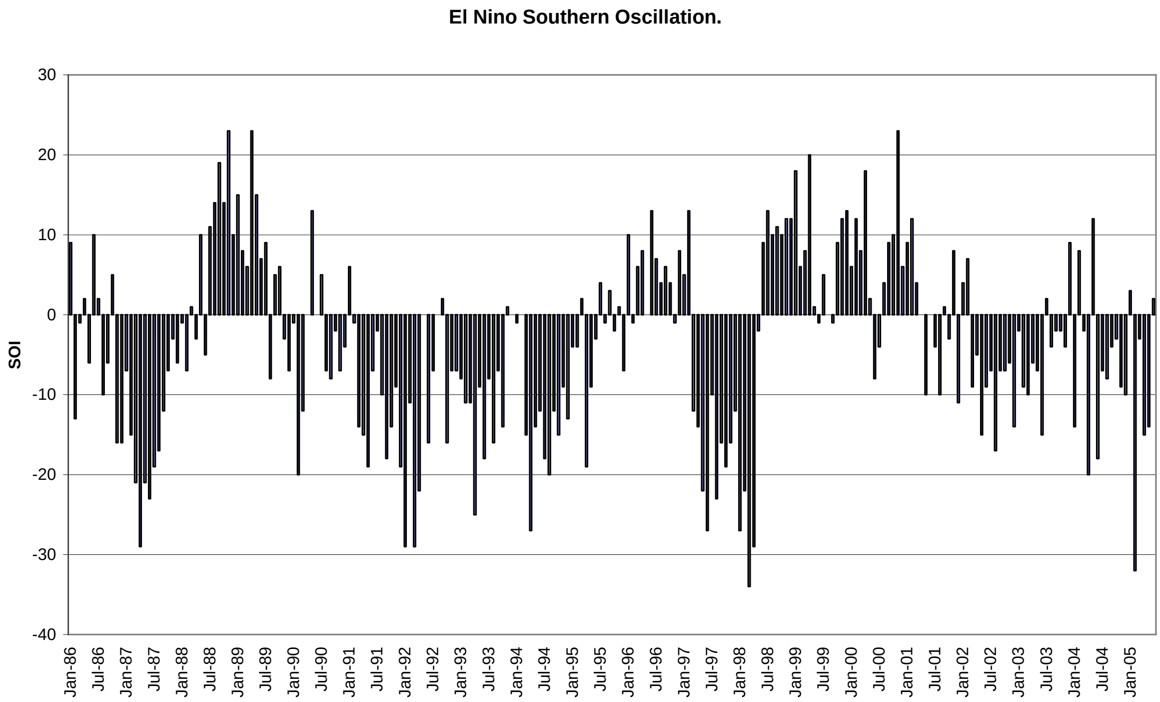

Figure 4.1 El Nino Southern Oscillation timeseries (source: NIWA)

4.1 Climate Change

The Intergovernmental Panel on Climate Change in its Fourth Assessment Report (2006) concluded that there was new and strong evidence that most of the global warming observed over the last 50 years could be attributed to increased greenhouse gas concentrations in the atmosphere due to human activities. Whilst there are still many uncertainties associated with predicting future climatic changes, the broad pattern of change over New Zealand related to coastal areas is expected to consist of:

- floods and storm surges that are very likely to become more frequent and intense,
- sea level is virtually certain to rise.
- by 2050, there is very likely to be degraded beaches.

By 2050, vulnerability is likely to be high in a few identified hotspots. In New Zealand, one of the recognised hotspots is the Bay of Plenty where ongoing coastal development is very likely to exacerbate the future risk to lives and property from sea-level rise and storms (NIWA, 2007)

A recent study undertaken by Bell et. al. (2006) for Environment Bay of Plenty to access how potential climate changes may affect the drivers of coastal erosion and inundation hazards. The study specifically summarises the present knowledge of the impacts of potential climate change on:

- tides, storm surges and sea levels within the Bay of Plenty;
- wave conditions along the Bay of Plenty coastline;
- sediment supply from rivers in the Bay of Plenty to the coastline;
- the potential movements of beach sediment and hence impact on the patterns of coastal erosion or accretion along the Bay of Plenty coastline.

The following sections are excerpts from the Bell et. al. (2006) report.

4.2 Tides, storm surges and sea-levels

Sea levels are important along the Bay of Plenty coastline for two primary reasons: a) the tide height governs the likelihood of coastal inundation, especially when combined with storm surge; and b) sea-levels also determine the degree to which waves may become depth limited at the coastline and hence is important in determining factors such as the magnitude of wave run-up, or storm induced beach and dune erosion.

The main component of sea level is the astronomical tide but sea level at any location can be elevated (or lowered) due to:

- climatic fluctuations operating over annual to decadal timescales (for example the 2 – 4 year El Niño Southern Oscillation and the 20 – 30 year Interdecadal Pacific Oscillation);
- storm surge due to atmospheric pressure and wind effects;
- wave breaking and ensuing set-up and run-up at the shoreline.

Storm surge in the eastern Bay of Plenty tends to be higher than that in the western Bay of Plenty. However, storm surge heights measured at sea-level gauges within the Whakatane River and Ohiwa Harbour do not always provide a true indication of storm surge conditions on the open coast in the eastern Bay of Plenty. In Tauranga Harbour, extreme storm-tide levels are generally lower than those recorded at Moturiki.

Sea levels have been rising around New Zealand since the early to mid part of the 1800s. The Port of Auckland sea-level gauge operating since 1899 (the closest long-term tide gauge record to the Bay of Plenty) provides a reasonable indication of how sea levels have risen in the Bay of Plenty (Figure 4.2). This rise in the mean level of the sea has been around 0.14 m over the last 100 years, which is slightly less than the average for New Zealand of 0.16 m, but within the global range of 0.1 to 0.2 m. It is expected that this rate of sea-level rise will accelerate in the future due largely to thermal expansion of the world's oceans and the melting of many of worlds glaciers due to a warmer climate. The general effect of sea level rise on a variety of coastal margins can be seen in Figure 4.3.

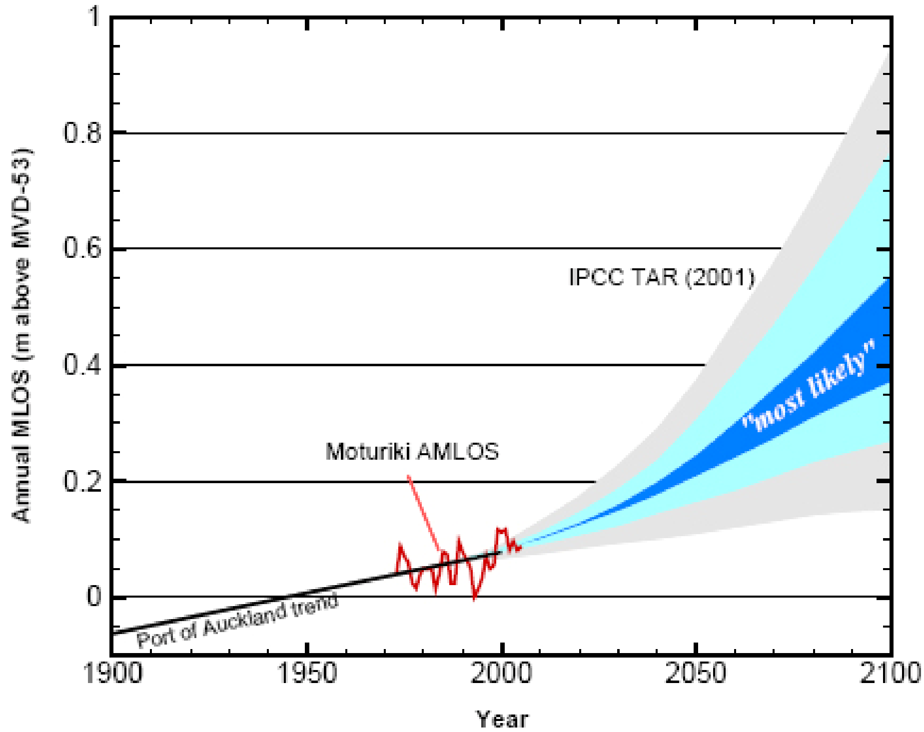

Figure 4.2 *Sea level rise projections (Bell et. al., 2006), MLOS = mean level of sea.*

Future sea-level rise in the Bay of Plenty region also needs to account for any potential vertical movements in the landmass. For example if the land is subsiding, the relative rate of sea-level rise could be greater, or if tectonic uplift occurs, relative sea-level rise will reduce. Vertical land movements are an important consideration in the Bay of Plenty which has a history of tectonic movements. Over geological timescales, the area between Waihi and Papamoa has been relatively stable. Between Whakatane and East Cape land has been uplifted (hence potentially reducing the relative impact of long-term sea-level rise). The Whakatane Graben region between Maketu and the Whakatane River entrance, (within the Taupo Volcanic Zone), has been subsiding over geological time. However, this tends to occur episodically during seismic events rather than necessarily at a continuous rate.

Until a longer record of continuous vertical land movements is available it is recommended that future rates of sea level rise within the Bay of Plenty be considered similar to the current absolute global estimates. Whilst there is still uncertainty as to the likely magnitude of these estimates, it is recommended for planning purposes that allowance be made for a rise of 0.2 m by 2050 (relative to 1990) and of 0.5 m for 2100 which is in keeping with present guidance from the Ministry of the Environment. This corresponds to a mean level of the sea of 0.26 m relative to Moturiki Vertical Datum-53 by 2050 and 0.56 m Moturiki Vertical Datum-53 by 2100.

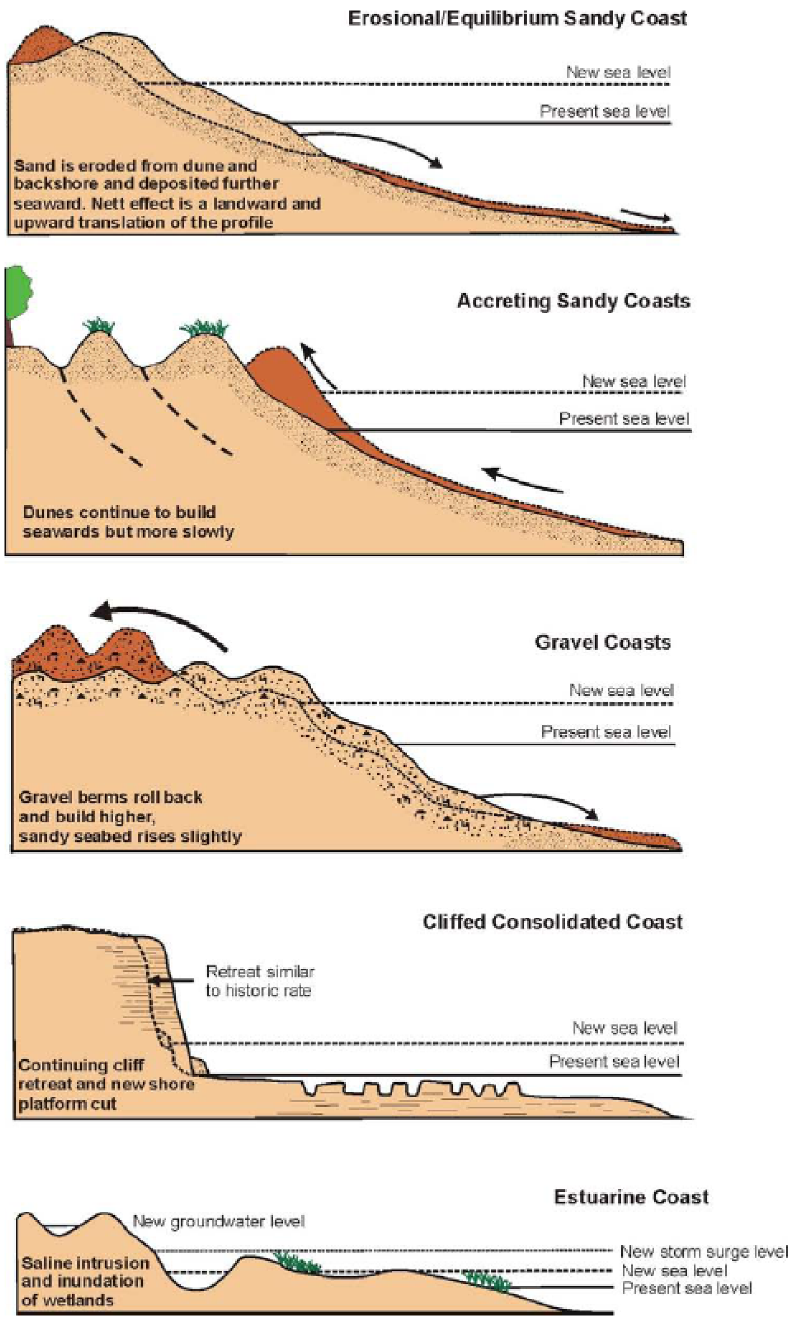

Figure 4.3 Generalised shoreline impacts of sea-level rise and coastal "drivers" on different types of coasts. Indicative only as local conditions and "sand supply" may produce different responses (MfE, 2001).

A window on how the New Zealand coastline might behave with a rise in sea level can be cautiously appraised from examples where the land has subsided suddenly in an earthquake, effectively causing a relative rise in sea level. The Edgecumbe earthquake on 2 March 1987 caused the 9 km coastal margin between the mouth of the Rangitaiki and Tarawera Rivers to subside by about 0.4m (equivalent to an instantaneous rise in sea level). Sea floor sediments adjacent to the Rangitaiki Plains are sand and silty-sand. Historically the trend has been a coastline advancing seaward (Healy et al., 1977), although the beach was relatively stable from 1977 to 1987. The retreat likely to be caused by the 0.4m subsidence was 45m using the Bruun (1962) rule.

What took place was quite different, with the lower foreshore (below 2m elevation above mean sea level) showing a loss of material for the first five years after the earthquake, as expected, followed by accretion to the present, as shown in Figure 4.4 (Smith, NIWA unpublished data). Above 4m elevation the dune deposit maintained a steady accretion rate throughout. In this case, even though the lower foreshore initially eroded in response to the sea-level change, it appears that sufficient sediment supply was available from offshore and alongshore drift to satisfy the sediment demand of what was effectively a localised rise in sea level, and thereby rectify the perturbation (MfE, 2001).

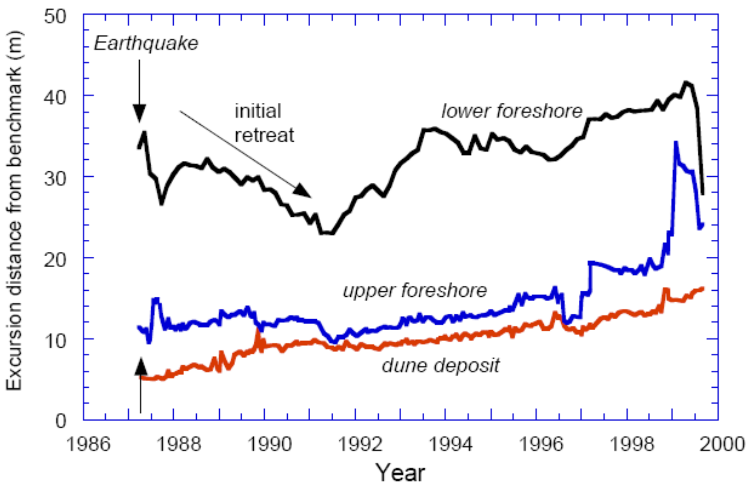

Figure 4.4 *Response of a beach profile near Thornton (Bay of Plenty) following the March 2, 1987 Edgecumbe earthquake when the coastal margin subsided by 0.4 m. The upper foreshore and dune deposit lines are 1.5m and 2m respectively above the lower foreshore datum.*

4.3 Wave conditions

Wave action is the dominant forcing process causing changes in erosion and accretion patterns along the Bay of Plenty coastline. It also contributes to coastal inundation through locally raising water levels (set-up) at the shoreline and wave run-up on to the land. The potential effects of climate change on wave conditions experienced at the coastline of the Bay of Plenty is complex, depending on the interaction between both changes in regional conditions around New Zealand and in the wider South Pacific (e.g., changes in local and regional winds, storm and cyclone tracks and intensity).

Wave conditions in the Bay of Plenty are moderately influenced by the El Niño Southern Oscillation. More stormy conditions than average tend to occur during La Niña periods, which are associated with an increase in northeasterlies in the New Zealand region. During El Niño years, where a higher occurrence of southwesterlies occurs, wave conditions in the Bay of Plenty are somewhat reduced although episodic extra-tropical cyclones still occur. Given that since 1998 we have entered a negative phase of the Interdecadal Pacific Oscillation where neutral or La Niña conditions may be more likely to occur, it is possible that the Bay of Plenty region may experience increased rates of erosion over the next 20 to 30 years, similar to that experienced in the late 1960s and early to mid 1970s.

Potential changes to swell wave conditions reaching the Bay of Plenty have a considerable influence on wave induced set-up and run-up which, although highly variable along the coastline, could result in increases in annual maximum set-up and run-up of up to around 1 m due to climate change effects.

4.4 Sediment supply and beach erosion and accretion

Remotely generated swell waves are also the dominant factor moving sediment along the Bay of Plenty coast, particularly between Waihi and Opape. The climate change scenarios suggest in general that changes in longshore movements of beach and nearshore sediments will be relatively uniform within the region and relatively small compared to typical present day inter-annual variability.

A further factor influencing coastal-erosion patterns within the Bay of Plenty region are changes to the input of sand and gravel from river sources to the coast. Rainfall is the main climatic driver that affects the amount of sediment transported down rivers, since it affects both the rates of erosion on hillslopes and the transport capacity of runoff down river channels. Bay of Plenty rivers show large inter-annual variability in sediment yields, with annual yields ranging over at least a factor-of-ten. However, in general, there does not appear to be a significant correlation between annual sediment yield and El Niño Southern Oscillation or the Interdecadal Pacific Oscillation index. The exception is the Tarawera River, which tends to have higher yields during La Niña phases.

Projections of future annual average rainfall in the region vary widely, ranging from a 15% decrease to a 2% increase by the 2080s. This translates to anywhere from a 25% reduction in average annual sediment yields to a 3% increase which is small compared to the existing inter-annual variability. Taking this, and the likelihood that changes to the general longshore movement of beach material is also likely to a have relatively small effect at a regionwide scale, suggests that the patterns of erosion experienced along the open coast of the Bay of Plenty region are unlikely to change substantially relative to that occurring at present and over the last few decades. The most susceptible areas to coastal changes will still occur at locations such as estuary and river mouths, adjacent to promontories and along spit features. However, areas that have traditionally been relatively stable, such as to the south of Papamoa, in the lee of Motiti Island, may begin to show a greater tendency to erode.