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Coastal Erosion Hazard In The Waikato Region

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Purpose Of Report

- The report provides an overview of coastal erosion and coastal erosion hazard around the coast of the Waikato Region, as a basis for the development of the coastal erosion risk management strategy for the Region (Environment Waikato Policy Series 1999/03).

Coastal Erosion In The Waikato Region

General Situation

- Overall, coastal erosion along the shoreline of the Waikato Region is primarily associated with natural shoreline changes, particularly dynamic changes associated with shoreline fluctuations and the migration of estuary, river and stream entrances.

- These dynamic changes have probably characterised shoreline behaviour for centuries and are unlikely to have become any more significant in the last 50 to 100 years.

Dynamic Shoreline Fluctuations

- Dynamic shoreline fluctuations (periods of erosion and accretion with little net shoreline change over time) appear to occur at most beaches in the Region.

- The most significant fluctuations occur in the vicinity of estuary and river entrances and their associated flood- and ebb-tidal deltas. Shoreline changes of 50-200 metres have been observed in such areas.

- In areas away from the influence of river and estuary entrances, ocean beaches of the East and West Coasts typically evidence duneline fluctuations of less than 30 and 50 metres, respectively, while shorelines of the Firth of Thames and estuaries typically fluctuate by less than 15 metres.

Progressive Shoreline Erosion

- Trends for progressive (i.e. net) shoreline erosion are also evident in some areas, particularly on the West Coast of the Region and the Firth of Thames. While some of these progressive trends may prove to be dynamic fluctuations over periods of several decades or more, they can essentially be regarded as progressive trends over the time-scales relevant to human activities.

- The most significant erosion trends are associated with the movement of river or estuary entrances and channels. Progressive net erosion ranging from 30 metres to in excess of 200 metres has been observed at some sites, including Mokau, Aotea and Port Waikato on the West Coast and Waikawau, Koputauaki Bay and parts of the Miranda chenier shoreline on the Firth of Thames.

- There is also evidence that some of the sand spits of the West Coast (e.g. Mokau and Port Waikato) and the stream deltas of the Thames Coast (e.g.

Waikawau) may even be extensively destroyed and rebuilt by such changes over periods of centuries.

- In beach areas distant from estuary or river entrances, progressive erosion (shoreline recession) is relatively rare – largely limited to areas on the outside banks of river or estuary meander channels.

- However, there is also evidence of limited beach recession at Whiritoa and Kuaotunu West beaches on the Coromandel east coast. Localised recession has also occurred at some other sites (e.g. eastern end of Cooks Beach).

Aggravation of Coastal Erosion by Human Activities

- Human activities do not yet appear to play a major role in aggravating coastal erosion on the beaches of the Region.

- Nonetheless, there is evidence that some activities have played a role in limited local areas. Sand extraction appears to have caused some net recession at Kuaotunu West and Whiritoa beaches and recovery from historical gravel extraction may have played a role in significant changes noted at Waikawau on the Thames Coast. Localised impacts are also evident, particularly associated with scour around storm-water outlets and the ends of some shoreline armouring structures.

- In the future, there is potential for human-induced global warming to significantly impact on coastal erosion around much of the Region - particularly along the ocean beaches of the East Coast.

- Approximate calculations, based on present "best estimates" of sea-level rise for the next century, suggest this factor alone could result in shoreline recession of 30-50 metres along East and West Coast ocean beaches and 5-10 metres along shorelines of the Firth of Thames and estuarine environments. However, impact along the ocean beaches of the West Coast may be mitigated by the large volumes of littoral drift on this coast.

Coastal Erosion Hazard In The Waikato Region

- In the Waikato Region, most community concerns with regard to coastal erosion relate to threat or perceived threat to private residential property, development (particularly houses or roads) and/or important cultural sites (particularly urupa).

- Risk to these features has been broadly assessed for most of the major settlements in the Region, using a simple classification system to categorise the most serious hazard problems at each site.

- It has been found that most coastal settlements in the Region (38 of the 39 sites assessed) have either existing or potential coastal erosion hazard issues. Existing hazard threat to property or development occurs at 21 of the 39 sites.

- Some major roads also have significant lengths located in areas of existing risk, most notably State Highway 25 along the Thames Coast and at Whitianga.

- Available information also indicates that a number of important cultural and archaeological sites have either been lost to coastal erosion or are presently threatened. These include urupa at Koputauaki Bay and on the Mokau sand spit.

- Calculations undertaken using present “best estimates” of sea level rise suggest there is significant potential for effects accompanying predicted global warming to seriously aggravate coastal erosion hazard over the next century.

- For instance, along the Eastern Coromandel, such changes could result in serious risk to property and development presently valued at $525 million, including approximately 570 dwellings. This compares to the present moderate to serious risk to property and dwellings valued at $150 million, including about 60 dwellings.

- The serious existing and potential hazard problems primarily arise because of past trends to locate subdivision and development in close proximity to the foreshore. For instance, most coastal development along the western Coromandel coast lies within 10-50 metres of the shoreline and most development along the eastern Coromandel beaches within 15-100 metres.

- Present trends for the placement of large and expensive dwellings on beach front lots (particularly along the eastern Coromandel) will also considerably increase potential hazard exposure over time.

Other Hazard Management Issues

- Historically, shoreline armouring structures have been extensively used to manage coastal erosion hazard in the Waikato Region. There is also ongoing pressure from property owners for similar structures at a number of other sites.

- However, there are a number of significant environmental and other concerns associated with the use of shoreline armouring structures. While it is sometimes possible to mitigate these effects with well designed and located structures, this is not common.

- It is unlikely that shoreline armouring structures will provide appropriate and sustainable long-term solutions at many sites.

1 Introduction

1.1 Purpose Of This Report

The purpose of the report is to provide an overview of coastal erosion hazard in the Waikato Region. The report is one of a series of hazard assessments for Environment Waikato's Natural Hazards Programme and provided the basis for development of the coastal erosion risk mitigation strategy. (Environment Waikato Policy Series 1999/03.)

The information in this overview report is based on investigations and advisory work undertaken by staff in the Resource Information Group. Fuller technical reporting of this work is programmed for 1999/2000 as part of documenting recommended hazard set-back arrangements.

1.2 Structure Of The Report

This report is structured as follows:

- ***Section 2*** provides a brief introduction to the natural process of coastal erosion
- ***Section 3*** provides a broad summary of the nature and scale of coastal erosion around the coast of the Waikato Region, focusing on environments where the most significant coastal erosion hazard issues are experienced (typically beaches and other "soft shores")
- ***Section 4*** outlines coastal erosion hazard as a management issue within the Waikato Region

2 Coastal Erosion

2.1 General

Coastal erosion is a normal and expected natural process on virtually all coastlines of the world.

On rocky and cliffed coastlines, coastal erosion results in net landward recession over time.

However, beaches and other cohesionless (e.g. sand, gravel) shorelines are more dynamic and frequently evidence quite complex patterns of shoreline change over time. For management purposes, coastal erosion in these environments can be broadly categorised according to whether it is associated with dynamic shoreline fluctuations or progressive shoreline change:

- ***Dynamic shoreline fluctuations:*** All beach shorelines fluctuate in position over periods of several years to decades, evidencing periods of both erosion (landward movement) and progradation (seaward movement). The fluctuations can be related to a wide variety of controlling processes including episodic storm erosion and subsequent recovery, variations in frequencies of storms, El Nino

Southern Oscillation (ENSO) cycles, episodic sediment supply, and various other factors. These dynamic fluctuations are by far the most common form of shoreline change in evidence on most New Zealand beaches.

Averaged over time these dynamic fluctuations do not in themselves result in permanent shoreline retreat or advance (though the beach will show such trends if there is also an underlying trend for progressive net shoreline change at the site).

The width of shoreline subject to erosion and accretion associated with shoreline fluctuations is frequently referred to as the “dynamic envelope”. As these fluctuations can result in periods of erosion or progradation lasting for several years, they can frequently give the mistaken impression of long-term trends for erosion or progradation.

- ***Progressive shoreline change:*** A few cohesionless shorelines evidence long-term trends for progressive (i.e. net) shoreline change. Where these trends occur, shorelines will show a long-term trend for erosion and/or accretion.

  Where there is a net loss of sediment over time, the beach will show a trend for net erosion - referred to as *shoreline recession*. Where the beach system is slowly gaining sediment over time, there will be trend for the beach to build seaward (prograde).

  As progressive shoreline changes are typically both very slow (e.g. 0.1-0.3 m/yr) and are superimposed on normal dynamic shoreline movements of much greater scale and frequency, they can be very hard to detect. Useful data on shoreline change over periods of several decades or more is usually required to detect such trends.

  Even though these long-term trends are frequently quite slow they can be extremely significant over periods of several decades. Trends for long-term progradation slowly diminish risk to existing subdivision and development while long term shoreline recession can significantly increase risk over time.

  There are also some situations where progressive shoreline change can be associated with river or estuary entrance migration, resulting in significant erosion and rebuilding of adjacent coastal features such as entrance sand spits or deltas. Geologically speaking, many such changes are most properly regarded as dynamic fluctuations. However, on time scales relevant to human activities (i.e. decades), the trends are more appropriately regarded as progressive trends - since they typically evidence a dominant “one-way” trend over periods of many decades.

2.2 Human Influences On Coastal Erosion

There are various human activities which can aggravate coastal erosion, including:

- reduction of sediment supply to coastlines through activities such as dam construction and sediment extraction from rivers

- direct removal of sediment from beaches and coastal systems by activities such as dredging and sand extraction

- interruption of long-shore sediment transport by coastal structures such as groynes, causeways, and solid piers

- local scouring associated with storm-water outlets

- aggravated erosion on unprotected shorelines adjacent to shoreline armouring structures (this aggravated erosion commonly known as "end effects")

- loss or damage of natural protective buffers (e.g. mangroves, coastal wetlands, dunes) associated with human activities.

There is also potential for coastal erosion to be aggravated by changes likely to accompany predicted global warming (Hicks, 1990), including:

- a rise in mean sea level (more accurately, an increase in the rate of rise – since available information tends to suggest sea level around New Zealand has generally been rising at a rate of 1.3-2.3 mm/yr over the past 100 years)

- possible increase in the frequency and intensity of coastal storms on North East exposed coasts of the North Island

- possible reorientation of shorelines in response to changes in littoral drift

The potential impact of predicted global warming is discussed further in Section 3.4 below.

3 Coastal Erosion In The Waikato Region

The coast of the Waikato Region is extremely diverse, including sandy and gravelly beaches, alluvial deltas and plains, river and estuary sand spits, a chenier plain, extensive coastal wetlands and a wide variety of rocky and cliffed shorelines. The coast is also exposed to a wide range of wave energy, including shorelines exposed to ocean waves on both the East and West Coasts, the moderately sheltered shorelines of the Firth of Thames (exposed primarily to local wind-generated waves), and a wide range of sheltered estuarine margins.

Physiographically, the coast of the Waikato Region can be broadly subdivided into the Eastern Coromandel, the Firth of Thames and the West Coast (Figure 1). This section provides an overview of the nature and scale of coastal erosion in each of these areas, based on various data sources (see Appendix A for summary).

All figures given for shoreline changes are with reference to the seaward toe of the dune or bank at the back of the beach, not mean high water mark. (The latter datum is generally the legal boundary but suffers severe deficiencies as a datum for measuring shoreline changes).

As most existing coastal erosion hazard issues in the Region occur along cohesionless shorelines (loosely grouped as "beaches" in this report), coastal erosion along rocky and cliffed coasts are generally not covered in this section - except for parts of the West Coast where cliff erosion is a locally important hazard to existing settlement.

Figure 1 Location Diagram

3.1 Coastal Erosion Along The Eastern Coromandel Coast

The Eastern Coromandel coast consists of ocean beaches separated by rocky and often cliffed shorelines, with several small and medium-sized estuaries also occurring. The most significant coastal erosion hazard issues occur along the ocean beaches, though some locally important issues also occur along estuarine shorelines.

3.1.1 Eastern Coromandel Ocean Beaches

The embayed beaches of the Eastern Coromandel are typically less than 1-2 kilometres in length, with maximum lengths of 4-4.5 kilometres at Opoutere and Matarangi. Available evidence suggests the beaches are relatively discrete sediment systems, though there may be some exchange of sediment around headlands and with offshore shelf areas. Most of the beaches have limited sand reserves, with only one back-beach dune or none, though some (particularly Whangamata, Opoutere, Pauanui, Cooks Beach, Whitianga and Matarangi) are backed by wide Holocene barrier dune systems up to 2800 metres (Whitianga) in width. Morphologic and sediment properties suggest the beach systems typically extend offshore to depths of up to 7 metres below chart datum - though active sediment movement (and probably some sediment exchange) occurs to depths of 20 metres and more.

Long Term Shoreline Trends

Available information on long-term shoreline trends suggests that most Eastern Coromandel beaches are now experiencing little to no net seaward progradation over time. There is also evidence that some of the small beach systems (e.g. Whiritoa) are no longer receiving any significant net sediment supply, the primary sources of the beach sediment now being buried - either under the beach itself and/or offshore sand deposits. Even beaches which have prograded seaward for significant distances over the last 6500 years typically show evidence of a marked reduction in rates of seaward advance over time, with relatively limited seaward advance (typically less than 0.05 metres per year, except perhaps for Whitianga) generally characteristic of the last few hundred years.

Similarly, available information suggests that few beaches are undergoing any trend for long-term recession. However, there is evidence that some net shoreline recession has been experienced at both Whiritoa and Kuaotunu West beaches.

Shorelines changes evident from historical aerial photos suggests that Whiritoa Beach underwent average duneline recession at a rate of 0.2 to 0.3 metres per year over the over the period between 1948 to 1987. At Kuaotunu West, the dune face has also experienced consistent erosion for at least 3 decades and is now steeply faceted. Older iron-stained dune sands and cultural deposits have been exposed by the dune retreat, suggesting erosion beyond the normal scope of dynamic shoreline fluctuations. Both of these relatively small sand systems have had significant sand extraction operations in the past and the apparent recession may represent shoreline adjustment to these losses. If so, any ongoing recession at these sites is unlikely to continue indefinitely as the sand extraction at both sites has now ceased.

Localised trends for shoreline recession have also been noted over the last 30-40 years, at both the eastern end of Cook's Beach (near the entrance to the Purangi Estuary) and at the southern end of Buffalo Beach (near the entrance to Whitianga Harbour).

At the eastern end of Cooks Beach, historical aerial photos indicate duneline erosion of up to 35 metres since 1944 (Figure 2), with net recession of up to 25 metres. Information from several long-term property owners suggests that most of this erosion has probably occurred since the early 1960's. Available information, suggests little further recession or recovery since the early 1980's.

At the southern end of Buffalo Beach net duneline recession commenced in the early 1960's over a length of approximately 350-400 metres, resulting in the placement of rock armour being required to protect the immediately adjacent State Highway. Evidence from shoreline surveys and available photographs suggests that maximum duneline recession in this area would probably have exceeded 20 metres in the absence of the rock wall. Available shoreline information suggests little further net beach loss since the early 1980's.

While the cause of the recession at these sites is not clear, both sites are near estuary entrances and marked shoreline changes are common in such environments, particularly adjacent to ebb-tidal deltas.

As both periods of erosion appear to have been initiated in the early 1960's, it is also possible they were initiated by offshore changes associated with the tsunami of May 1960. This event resulted in water level fluctuations of about 2 metres, equivalent to a large spring tide, in the upper reaches of Mercury Bay. Water levels typically rose or fell over periods of about 20 minutes, resulting in very strong tidal currents in Whitianga and Purangi estuaries. Significant tidal scour was evident near the Whitianga entrance and the event appears to have initiated other bathymetric change in this area (e.g. aerial photos show formation of a more marked marginal shoal along the landward edge of the main ebb channel discharging from the harbour). Bathymetric changes in areas immediately offshore may have resulted in higher wave energy and increased erosion in the vicinity of both entrances during subsequent storm wave events.

Erosion Associated With Dynamic Shoreline Changes

At present, most episodes of coastal erosion and accretion on beaches of the Eastern Coromandel appear to be associated with dynamic shoreline fluctuations rather than progressive shoreline change. i.e. Most beaches appear to be in a state of dynamic equilibrium, fluctuating backwards and forwards rather than evidencing any long-term trends for erosion or progradation.

However, the full magnitude of these dynamic fluctuations is typically only evident over periods of several decades. Therefore, periods of erosion or progradation can dominate for several years and give the appearance of progressive change. For instance, the period from the late 1960's to about 1978 was typically characterised by erosion, the 1980's and early to mid 1990's generally characterised by accretion, with a general trend for erosion again since about 1995.

While these general decadal trends are not yet well understood, they probably relate at least in part to El Nino and La Nina events (i.e. ENSO cycles). La Nina events are more likely to be characterised by coastal erosion due to a higher frequency of easterly storms and winds and higher sea-levels.

The information on the scale of dynamic shoreline fluctuations is still limited. However, available information suggests that the dynamic envelope defined by duneline changes over periods of several decades is typically less than 30-35 metres – for beach areas removed from the influence of estuary or stream entrances or major storm-water outlets.

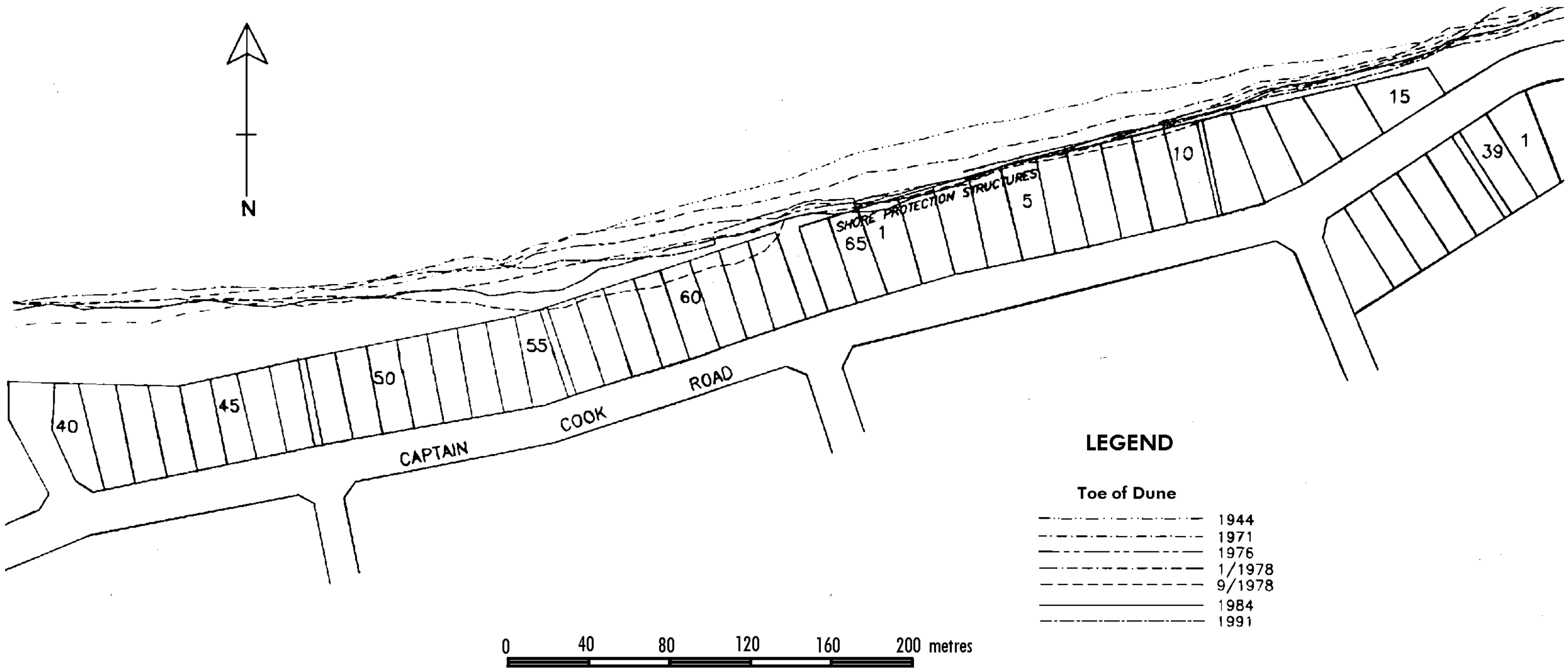

Figure 2: **Duneline changes at Cooks Beach 1944 to 1991.**

The largest scale shoreline fluctuations are observed in the vicinity of estuary entrances. For instance, the shoreline at the northern end of Matarangi Spit (adjacent to the entrance of Whangapoua Harbour, Figure 1) can fluctuate in position by in excess of 200 metres. Shoreline fluctuations of 50 to 70 metres have also been observed along the northern end of the Pauanui foreshore adjacent to the ebb-tidal delta.

Significant dynamic shoreline changes can also occur near stream entrances. For instance, alongshore migration of stream entrances at Buffalo and Kuaotunu West beaches has historically eroded and reworked beach and dune sediments over widths of 100-150 metres. However, alongshore migration of stream entrances is now limited by human intervention at most beach sites. Significant localised erosion can also occur adjacent to stream entrances due to the interaction of storm waves and high stream flows, with subsequent shoreline recovery during quieter periods.

Duneline erosion is also commonly aggravated in the vicinity of storm-water outlets, an extreme example occurring along the foreshore of the main ocean beach at Whangamata in the vicinity of the major Williamson Park storm-water discharge (Figure 3).

3.1.2 Eastern Coromandel Estuaries

Shoreline changes along the margins of Coromandel estuaries are generally minor, with any erosion typically affecting widths of less than 15 metres over periods of up to 50 years.

However, more significant erosion can occur in rare and localised areas - particularly along the outer banks of meander bends in estuary or river channels (particularly in upper estuary areas) and along sandy shorelines in close proximity to estuary entrances. Among the more notable of these changes is the occasional breaching of the sandy spit at Kennedy Bay, due both to river erosion along the landward margin and storm wave over-topping from the ocean side.

Human activities and structures also occasionally influence coastal erosion in estuary areas. For instance, bridge and causeway construction in the upper reaches of the Harataunga River estuary at Kennedy Bay appears to have affected channel alignment and aggravated downstream bank erosion. Historically, there has also been significant shoreline retreat in the vicinity of the Tairua Wharf, due to erosion of a large unprotected reclamation built during periods of timber milling. As with the ocean beaches, aggravated coastal erosion is also commonly noted in the vicinity of storm-water outlets.

3.2 Coastal Erosion Along The Margin Of The Firth Of Thames

3.2.1 General

The coast of the Firth of Thames within the Waikato Region includes the entire eastern and southern shorelines and the western shoreline to just north of Kaiaua (Figure 1).

The shoreline consists largely of sand and gravel beaches and rocky coast, with wide inter-tidal mud flats also fronting the southern and south-western shorelines. Beach sediments are primarily derived from local streams and rivers and from shell. Coastal landslips and cliff erosion also contribute sediment in some areas, though road construction has probably diminished this source in places (eg. Thames Coast).

Most beaches along the eastern margin of the Firth are narrow with limited sediment reserves, though occasional, small stream-mouth deltas prograde into the Firth along the Thames Coast (Figure 4). The western shoreline is a chenier plain up to 2 kilometres in width, composed of shell, sand and gravel ridges overlying inter-tidal muds. Extensive inter-tidal mud flats, up to 2 kilometres wide, also occur along the southern and south-western shorelines – typically backed by mangroves along the southern shoreline.

The Firth is relatively sheltered from ocean swell and the wave environment is generally dominated by local, wind-generated waves. However, strongly refracted swell waves also occasionally penetrate from the north and can cause serious coastal erosion and flooding (e.g. Cyclone Drena, January 1997). Wave action gives rise to a net southwards littoral drift along both the eastern and western shorelines.

3.2.2 Coastal Erosion and Shoreline Change

There is limited information on shoreline movements around the Firth of Thames.

However, available evidence suggests that the most dynamic areas are the gravel delta fans (Figure 4) and parts of the Miranda chenier plain foreshore.

Some of the gravel delta fans of the Thames Coast show evidence of significant shoreline changes over the last 50-75 years, particularly in shoreline areas adjacent to local stream entrances.

At the Waikawau River mouth, the shoreline on the southern side of the river has progressively prograded since at least 1925 (Figure 5), also eroding the limited delta shoreline on the northern side of the river. The changes were probably also influenced by earlier human activities, as the site was extensively dredged for sand and gravel until the 1930’s. Significant shoreline changes have also been evident at Tapu where there has also been quite notable progradation on the true left (i.e. southern) side of the stream entrance over the last 50 years. Shoreline fluctuations in excess of 30 metres have also been noted on shorelines adjacent to the Te Puru Stream mouth.

These changes suggest that the shoreline areas near the stream entrances are quite dynamic areas. Moreover, as the stream channels and entrances change over time, it is probable that the delta fans themselves may be quite extensively reworked over periods of centuries.

In areas away from the stream entrances, the shorelines of the deltas have generally been more stable over the last 50 years, typically varying (eroding or prograding) in position by less than 15-20 metres. For instance, up to 15 metres of shoreline erosion has occurred along the frontage of the Te Puru School over the last 8-10 years and there is evidence this shoreline has been eroded back to a similar position at other times over the last 50 years.

The foreshore of the chenier plain is also dynamic in places, particularly near the distal ends of cheniers. Coastal erosion is typically associated with inland migration of chenier ridges due to wave over-wash – this inland migration only ceasing when a new ridge is formed seaward.

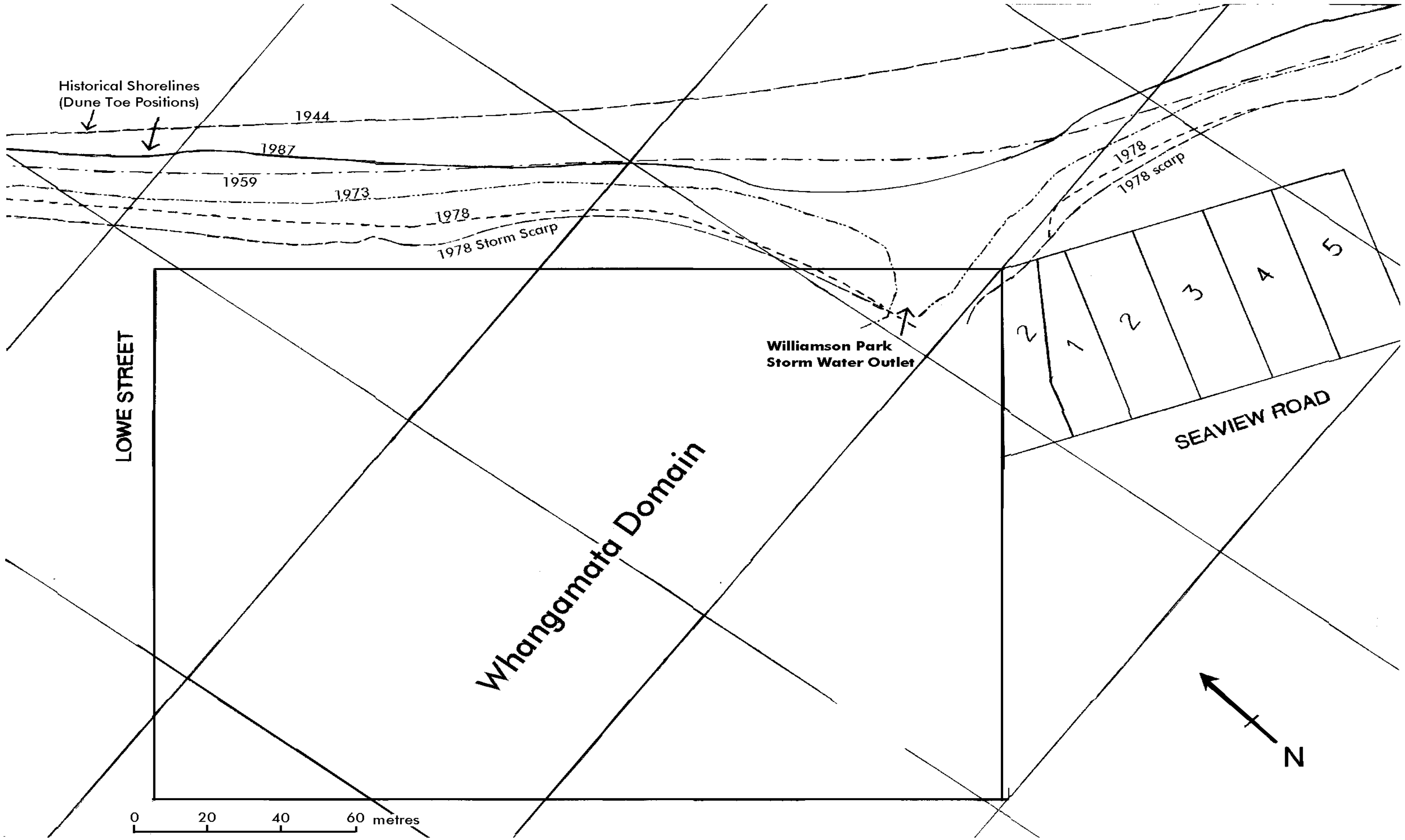

Figure 3: **Duneline changes in the vicinity of the Williamson Park storm-water outlet, Whangamata. Note scour of duneline evident near the storm-water outlet in 1973 and 1978 shorelines.**

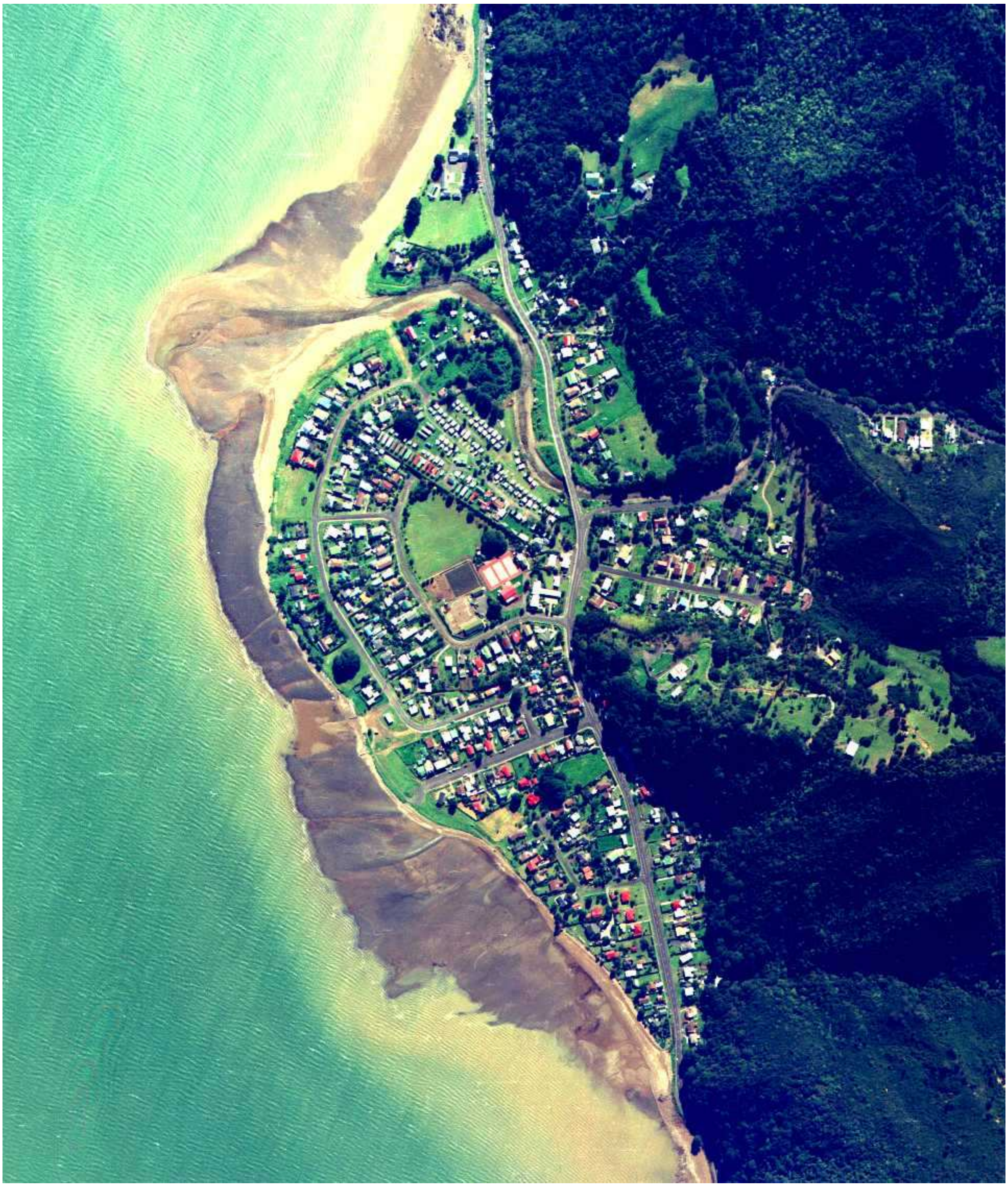

Figure 4: Te Puru Stream delta, western Coromandel coast (Photo: Air Maps, Tauranga)

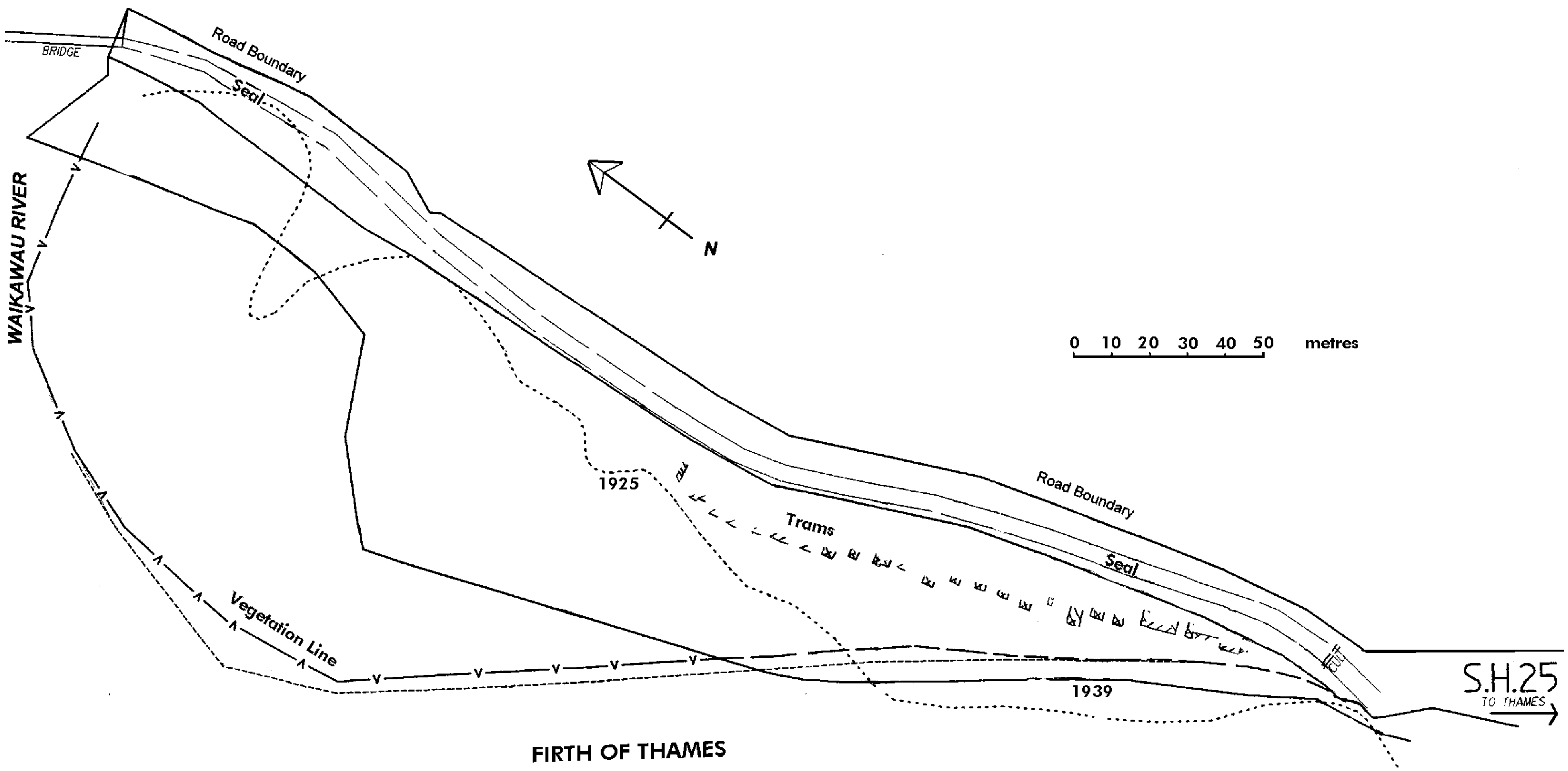

Figure 5: **Surveyed shoreline positions (1925, 1939 and 1998) for the southern portion of the Waikawau Stream Delta, Western Coromandel. The surveys show consistent northward growth of this portion of the delta shoreline. As this change occurred, the delta area on the northern side of the river was progressively eroded.**

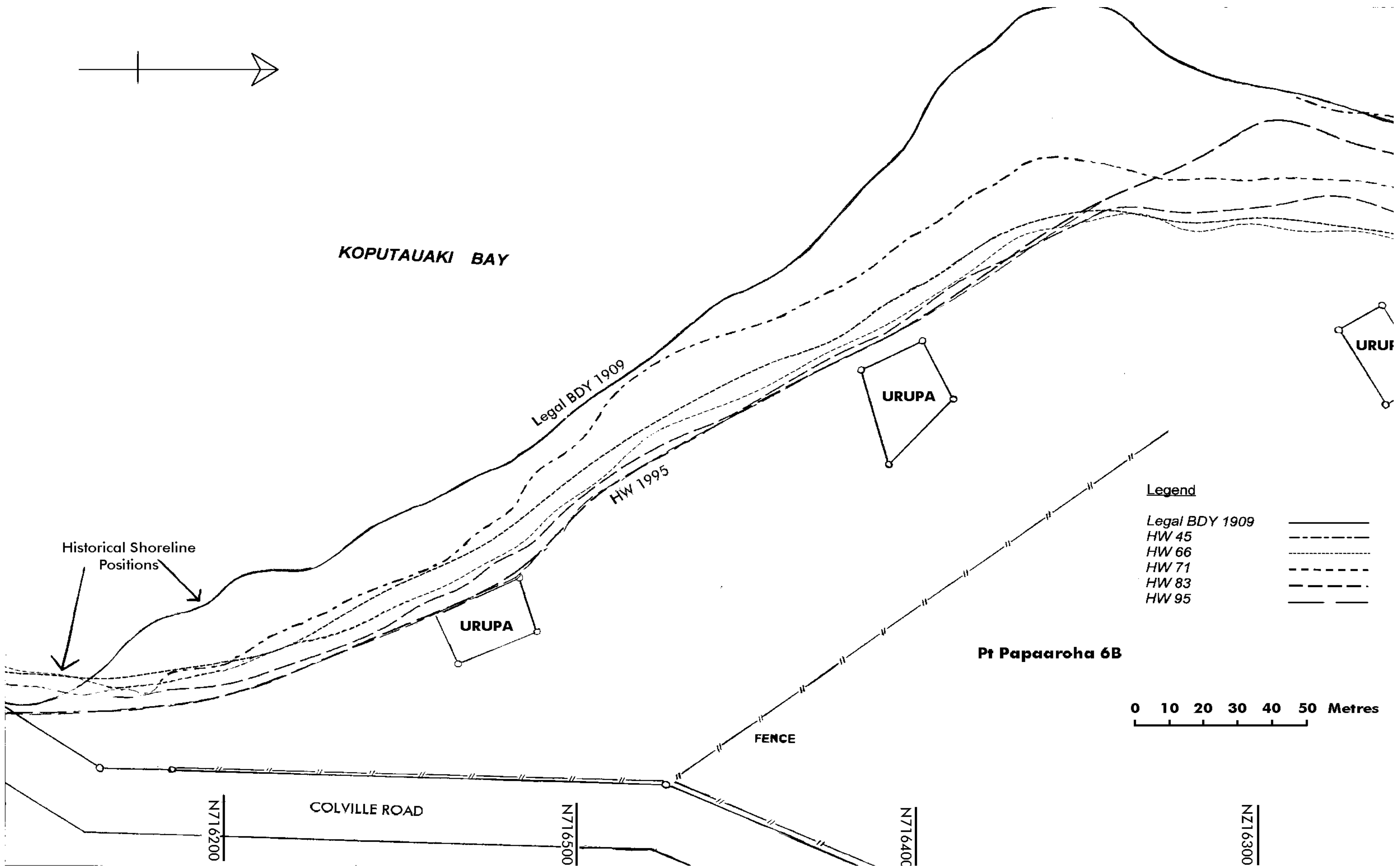

Figure 6: Shoreline changes at Koputauaki Bay, western Coromandel, 1909 to 1995. Note the consistent trend for landward retreat along most of this length of shoreline.

The most dynamic areas are the distal ends of the chenier ridges where movements of 95 metres have been reported over a period of 7 months, with as much as 10 metres movement observed over 7 days in response to an individual storm.

However, in older and more stable parts of this shoreline, shoreline changes (erosion and/or accretion) are typically less than 15-20 metres over periods of several decades.

Few sites around the Firth of Thames show any present evidence of long-term trends for erosion, most erosion appearing to be associated with dynamic changes such as those discussed above. However, a notable exception occurs at Koputauaki Bay (Figure 1) where much of the coastal margin has experienced relatively consistent net shoreline retreat (averaging about 0.3 to 0.4 metres per year) over at least the last 90 years (Figure 6).

3.3 West Coast

The West Coast of the Region stretches from the mouth of the Mokau River to just north of Port Waikato heads. The ocean shoreline consists of sandy beaches, composed largely of iron sand, separated by cliffed shorelines. The coast also includes three moderately-sized tidal estuaries (Raglan, Aotea and Kawhia) and four river estuaries (the largest at Port Waikato, with others at Marokopa, Awakino and Mokau) (Figure 1).

The ocean beaches are part of a littorally interconnected sand system, with a predominant net northward littoral drift. Most of the beaches along the coast are backed by cliffs and have only limited back-beach or sand dune reserves. However, large dune systems occur on some parts of the coast, particularly at Taharoa, the shorelines immediately north and south of Kawhia and Aotea Harbours, on the northern side of Raglan Harbour and on various estuary entrance spits. Some of the larger dune systems (e.g. those near Kawhia, Aotea and Raglan Harbours) consist of dunes migrating inland over older pre-existent topography.

The coast is only sparsely settled with the main coastal communities (Port Waikato, Raglan, Aotea, Kawhia, Marokopa, Awakino and Mokau) occurring in the lower reaches of tidal and river estuaries. However, some of these settlements also border the ocean coast (e.g. Mokau and Port Waikato).

3.3.1 Coastal Erosion along Beaches and Sandy Shorelines

There is presently little detailed information on shoreline change along the beaches of the West Coast.

However, available information suggests that the most significant shoreline changes occur along ocean and estuarine shorelines in the vicinity of estuary and river entrances.

For instance, parts of the sandy spit on the northern side of the Mokau River entrance have fluctuated in position by more than 200 metres over the 40 years between 1956 and 1995 (Figure 7), these fluctuations decreasing with distance from the entrance. Large-scale shoreline changes have also occurred along the margins of the estuarine shoreline over the last 115 years, exceeding 300 metres in places (Figure 8).

Similar large-scale shoreline changes have also occurred in other near entrance locations along the West Coast. Particularly notable is the erosion along the foreshore of Aotea township, with shoreline retreat of up to 180 metres between 1968 and 1979.

In beach areas away from the influence of estuary and river or stream entrances, the scale of dynamic shoreline fluctuations generally decreases significantly. The limited available information suggests that beaches along the ocean coast are generally characterised by dynamic shoreline fluctuations of less than 50 metres, while estuarine shorelines typically vary by less than 15-20 metres.

In addition to the changes noted above, there is some evidence that many of the sand spits extending across West Coast river and estuary entrances may undergo significant erosion associated with estuary entrance changes over periods of several decades to centuries.

The most notable example occurs at Port Waikato where the main river entrance has progressively migrated northward over at least the last 136 years, moving approximately 1500 metres between 1863 and 1961 (Figure 9). This change has been accompanied by significant northward extension of the present entrance spit (on the South side of the entrance) and equally significant erosion of a previous sand pit on the Northern side of the entrance.

Unpublished geological investigations conducted by Environment Waikato also suggest that the entrance sand spit at Mokau may be extensively destroyed and rebuilt by entrance movements over periods of centuries.

Other entrance sand spits along this coast also exhibit a high level of dynamic instability. For instance, the spit at Aotea entrance was substantially eroded in the 1960’s and 1970’s, allowing oceanic swell to penetrate into the estuary and probably playing a significant role in the erosion along the foreshore of Aotea township. Similarly, the spit at the entrance to Awakino River has been eroded on the landward side by river erosion and was also recently over-topped by wave action in the coastal storm of 17 April 1999.

The large-scale shoreline fluctuations noted near estuary entrances reflect the complex dynamics of these areas, with very high tidal and wave energy, river and estuarine channel changes and the bypassing of large volumes of sediment in transport along the ocean coast. River floods and erosion are also an added complication in river estuaries. While further investigation is required to better understand the dynamics of these areas, it is clear that near-entrance areas along the West Coast are potentially very unstable and should be avoided for further subdivision and development.

3.3.2 Cliff Erosion

Cliffed and rocky coastlines are common along the West Coast on both ocean and estuarine shorelines. For the most part, these shorelines are undeveloped - adjacent land typically covered with indigenous coastal vegetation or used for pastoral agriculture. However, coastal settlement does occur in some cliffed areas - notably at Raglan, Te Waitere on Kawhia Harbour and along the coast from Awakino to Mokau.

The cliffs between Awakino and Mokau typically have a narrow strip of Holocene beach and dune deposits at their base, protecting the cliffs from coastal erosion. However, these features may still be subject to failure from subaerial denudation (e.g. falls, sliding).

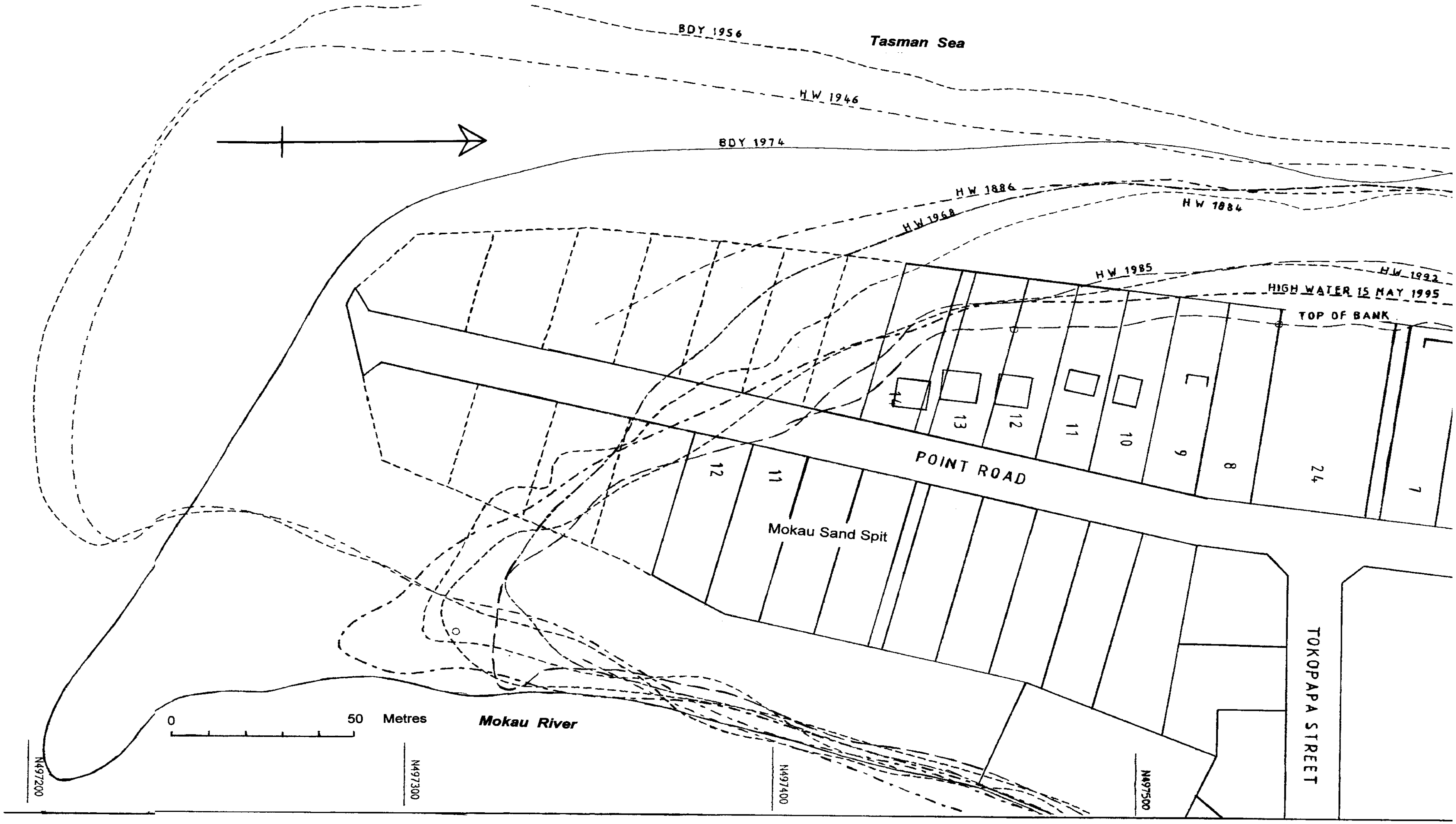

Figure 7: **Shoreline changes in the period 1884 to 1995 along the sand spit located on the northern side of the Mokau River entrance. It can be seen that the shoreline at the river end of the spit has fluctuated by up to at least 150 metres over this period.**

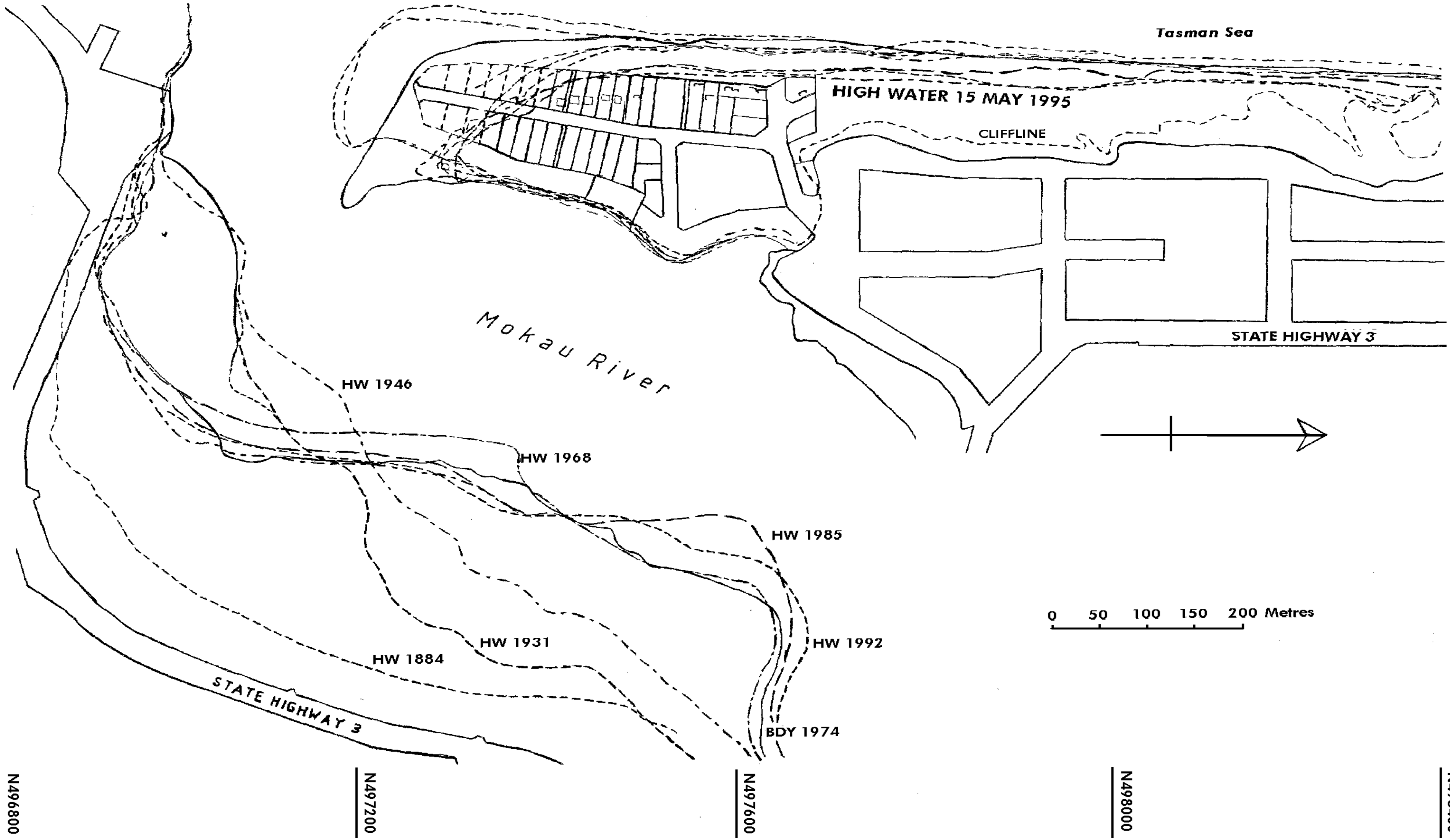

Figure 8: **Shoreline changes along the southeastern margin of the Mokau River estuary, 1884 to 1992. This area of shoreline probably undergoes extensive erosion and rebuilding over time in response to river changes.**

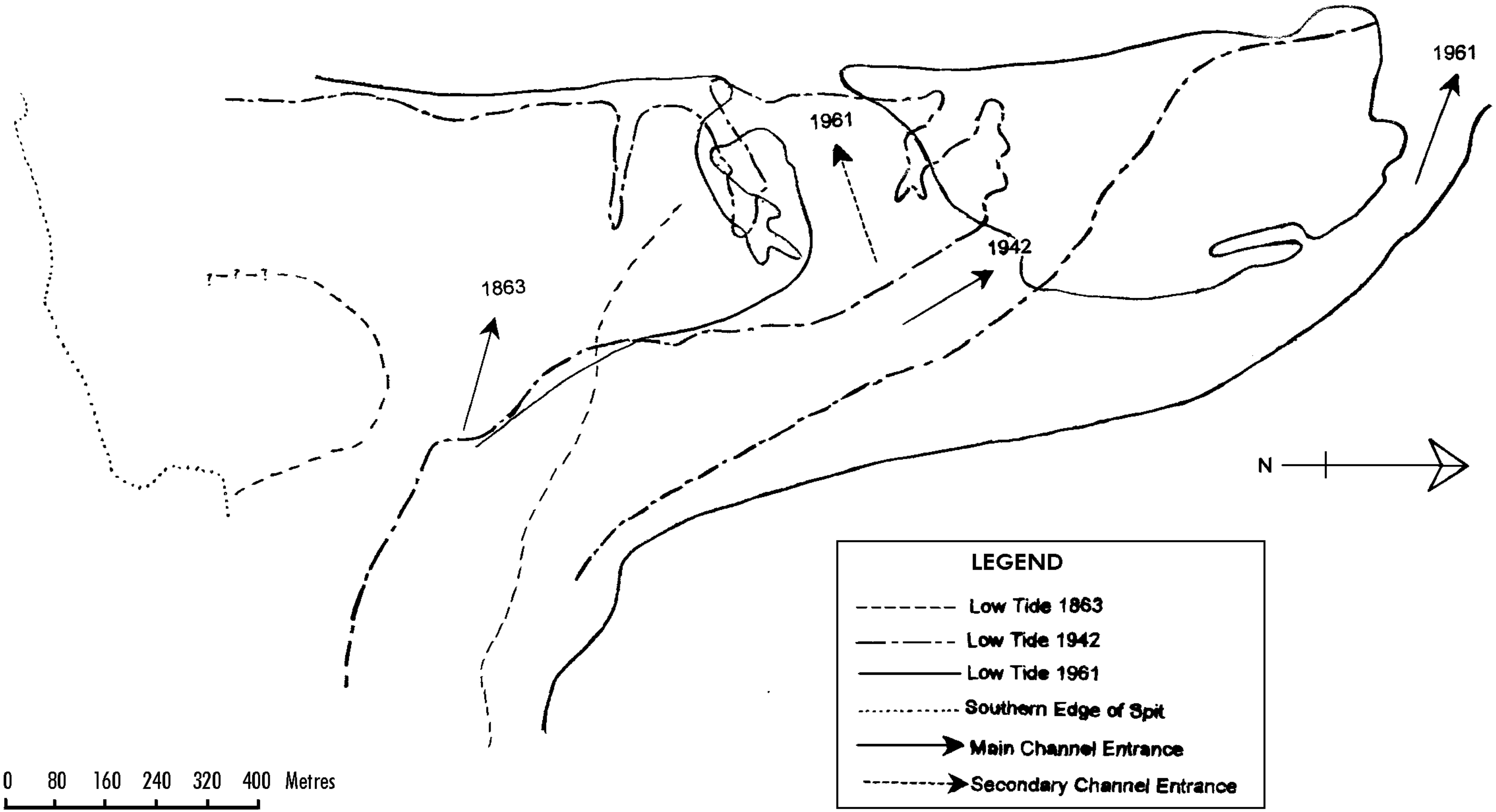

Figure 9: **Northward migration of the Port Waikato sand spit and main river entrance in the period since 1863. (A secondary channel has also developed as the spit has grown northward). Over periods of centuries it is possible the spit is completely eroded and rebuilt by river entrance changes.**

However, at Raglan and Te Waitere the cliff areas typically experience wave erosion along their seaward margins. At both sites, cliffed shorelines have experienced significant localised cliff failures which have seriously threatened adjacent property and development. The rates of erosion at the seaward base of the cliffs is presently unknown but appears to be slow in most areas. A recent thesis study of cliff erosion along the foreshore of Raglan Harbour (Blair, 1998) has indicated that wave action is not the main controlling factor in cliff erosion but contributes by removing toe buttressing and debris.

Further work is required on cliff erosion, particularly in the area of Raglan township, to better understand cliff failure and quantify associated hazard.

3.4 Potential Impact Of Global Warming

In the future, coastal erosion may be exacerbated by effects likely to accompany predicted global warming. In particular, these effects include an acceleration in the rate of sea-level rise, increased frequency and severity of cyclonic storms (for the Eastern Coromandel) and complex changes in the patterns of waves and currents.

The scale of any such effects and their timing are, like global warming, matters of considerable uncertainty and ongoing debate. Nonetheless, there is presently a broad scientific consensus that global warming is likely to occur and to be accompanied by effects such as an acceleration in the rate of rise of mean sea-level (IPCC, 1996). There is also a requirement in the New Zealand Coastal Policy Statement (NZCPS, 1994) for policy statements and plans to ".. *recognise the possibility of a rise in sea level, and .. identify areas which would as a consequence be subject to erosion or inundation …* " (Policy 3.4.2, NZCPS).

Therefore, it is important to estimate the potential impact of global warming in considering the risk posed by coastal erosion. However, apart from sea level rise, it is not presently possible to make any useful quantitative estimates of the effects likely to accompany global warming or their impact on coastal erosion. Therefore, in this report comment on the possible effect of predicted global warming is restricted to the potential impact of associated sea level rise.

Sea level rise projections developed by the Intergovernmental Panel on Climate Change (IPCC) are probably the most appropriate to use for planning purposes, being the closest thing we have to an international consensus at this time (Warrick et al., 1993). The IPCC have recently reviewed their sea level projections for a variety of greenhouse gas emission scenarios and these revised figures (IPCC, 1996) are probably the most appropriate data for planning purposes at this time. Using "best estimate" model parameters, sea level rise is projected to be about 0.2 m higher by 2050 A.D., and 0.49 m higher by 2100 A.D. (Warrick et al., 1996).

The latter figure has been used to estimate the potential impact of global warming for the purposes of this report.

Approximate estimates of the effect of the predicted sea level rise were made for this report using the simple Bruun rule (Bruun, 1962; 1983). This rule argues that as sea-level rises against a shore profile in equilibrium, beach erosion takes place to provide sediments to the nearshore so that the seabed can be elevated in direct proportion to the rise in sea-level (Bruun, 1962). The following simple equation can be used to estimate the extent of shoreline retreat:

$$X = al/h$$

where X is the shoreline retreat, a is the rise in mean sea level, l is the horizontal distance between the foredune crest and the seaward limit of profile adjustment (the depth at the latter point, known as the closure depth, is a critical factor in the calculations and not always easy to determine), and h is the elevation between these two points.

Estimates for the ocean beaches along the eastern Coromandel and the West Coast of the Region, using available information to estimate parameters l and h, suggest predicted shoreline retreat of 30 to 50 metres for these coasts, depending particularly on estimates of closure depth. Therefore, there is potential for accelerated sea level rise to result in quite significant shoreline retreat on both of these coasts – though the high rates of longshore drift on the West Coast might also mitigate such effects on that coast.

Estimates for the coast of the Firth of Thames and for estuarine environments typically range from 5-10 metres (adopting the base of the present beaches, generally at or above low tide, as the effective closure depth for calculations).

The estimates for the open ocean coasts suggest that there is potential for global warming to considerably aggravate coastal erosion in these environments. While the effect is likely to be considerably less in estuarine environments and the Firth of Thames, it has the potential to be significant in terms of risk given the limited set-back of coastal development along this coast.

The effects may also be more significant than the above calculations suggest as other effects which could aggravate coastal erosion are also likely to accompany predicted global warming (Hicks, 1990). Moreover, IPCC (1996) model simulations suggest that sea level will continue to rise over many centuries, even after concentrations of greenhouse gases have stabilised. Therefore, aggravation of coastal erosion by sea level rise and other changes could continue well beyond the year 2100

4 Coastal Erosion Hazard In The Waikato Region

Coastal erosion is a significant management issue for many communities around the coast of the Region. Over the last 8 years, staff have been called on to provide management advice at over 100 separate sites.

Management issues generally relate to:

- actual or perceived risk to development (particularly houses and roads), important cultural sites and residential property; and,
- environmental and other issues associated with the use of coastal structures to manage actual or perceived coastal erosion risk.

This section provides an overview of coastal erosion hazard as a coastal management issue in the Waikato Region, looking particularly at these two aspects.

4.1 Coastal Erosion Hazard

This sub-section provides a brief overview of the risk posed by coastal erosion to property and development around the coast of the Waikato Region. A simple classification system is developed and used to rank sites according to risk. A short discussion of hazard issues is also provided.

4.1.1 Background

Fundamentally, a hazard can be defined as a threat to people or what people value. Coastal erosion does not normally pose serious threat to human life and safety and is generally only regarded as a natural hazard when it threatens what people value. Therefore, identifying and ranking coastal erosion hazard issues inevitably involves a degree of subjective judgement, as to what is valued.

This introduces considerable difficulty in classifying or ranking coastal hazard issues. For instance, there is often considerable difference between “expert” and property owner perceptions and assessments – both in terms of the nature and degree of the risk and the seriousness of the issue.

There is also an added difficulty in regard to classification of risk to land or property. As the legal seaward boundary in New Zealand is generally either mean high water mark (MHWM) or (more recently) mean high water spring (MHWS), datums that are well out on the “wet” active Region of the beach, there is a sense in which most coastal erosion affects property (either public or private). Consequently, as coastal erosion is a part of the fundamental character of virtually all shorelines of the Region (see sections 2 and 3), there is potential for the entire coastal margin of the Region to be regarded as subject to erosion hazard.

In this report, the above issues are addressed by adopting a classification system focusing on areas of *common community concern,* based on Council experience over the last 8 years.

In the Waikato Region, experience to date indicates that most community concerns with regard to coastal erosion can be broadly grouped as threat or perceived threat to:

- private residential property;
- development, including houses, roads and other infrastructure; and/or
- important cultural sites, such as urupa.

There is also commonly a difference in the threat posed to development or cultural sites as opposed to land. The threat to development or important cultural sites is generally of severe damage or total loss. However, the threat to land varies. In most situations, the coast is presently in dynamic equilibrium and merely undergoing dynamic shoreline fluctuations – so that the loss of land is generally temporary (i.e. the land comes and goes). Therefore, it is useful for management purposes to distinguish between the risk to land as opposed to development or cultural sites.

The usefulness of this pragmatic distinction is also reinforced by the fact that most present coastal erosion in the Region is natural and part of the fundamental character of the relevant land. To mitigate the risk posed by coastal erosion to such land, it is necessary to change the nature and behaviour of the shoreline (e.g. by beach nourishment, shoreline armouring or offshore reefs). In contrast, the threat to development can be avoided or mitigated by other means (e.g. avoiding the placement of development in such areas or relocating existing development).

It is also important for management purposes to distinguish between the risk associated with existing coastal processes and that which could be associated with changes likely to accompany predicted global warming. While it is appropriate and important to attempt to identify any additional threat that could be associated with predicted global warming (see section 3.4 above), this potential risk is clearly not as certain as the risk associated with existing coastal processes. Therefore, in some circumstances (particularly where there is existing subdivision or development), different management approaches may be appropriate.

4.1.2 Coastal Erosion Hazard Classification used in this Report

The system used in this report for broadly categorising coastal erosion hazard issues in the Waikato Region is outlined below and shown schematically in Figure 10.

Category 1	Little to no existing or potential threat to residential property, development or important cultural sites.
Category 2	Potential threat to residential property as a consequence of predicted global warming
Category 3	Potential threat to development or important cultural sites as a consequence of predicted global warming
Category 4	Existing threat to residential property
Category 5	Existing threat to development or to important cultural sites

These categories provide a simple measure of the nature of risk at any particular site. They also provide a useful grouping of hazard problems for management - with similar hazard management options and strategies likely to be relevant for sites within the same category.

The categories also provide a crude measure of the seriousness of risk at each site, with category 5 sites generally being the most serious and also the most difficult to manage effectively. However, additional information may be required to prioritise or rank sites, particularly within each category.

4.1.3 Assessment of Hazard

To classify a particular site using the above procedure requires an assessment of both the existing hazard from coastal erosion and the potential additional hazard that may arise as a consequence of predicted global warming.

Preliminary assessments of hazard for this report were based on the information in section 3 and estimated as follows:

- ***Existing hazard:*** The assessment of *existing* hazard attempted to define for each site the landward limit of the area likely to be affected by coastal erosion within a hundred year period – *given the continuation of existing coastal processes and shoreline behaviour*. The estimates are the author's best judgements based on existing information for each site or, where absent, similar beaches. For all sites except Koputauaki Bay, it was also assumed that there is no *presently ongoing* trend for long-term recession (in line with available information, though some net recession has historically occurred at a few other sites, as noted in section 3).

  Overall, it is judged that the estimates of existing hazard are reasonably accurate, but err slightly on the side of under-stating the level of hazard. Therefore, some sites may rank in a more serious category once more detailed work is undertaken.

  The estimates of existing hazard used at the various sites were always less than the areas defined by existing coastal erosion hazard set-backs. The uncertainties inherent in estimating coastal erosion are such that hazard set-backs must incorporate various factors of safety - to ensure the set-back reasonably exceeds the area likely to be vulnerable to erosion. This ensures that a protective buffer still remains between development and the sea at all times, including the estimated worst case erosion.

- ***Potential hazard associated with predicted global warming:*** For the purposes of this report, the lower of the broad estimates of shoreline retreat outlined in section 3.4 were used - i.e. 30 metres for the Eastern Coromandel and the West Coast, and 5 metres for estuarine environments and the Firth of Thames.

More detailed site specific assessments of hazard will be undertaken for priority sites as part of the implementation of the coastal erosion hazard mitigation strategy.

The estimation of hazard at most sites ignored any existing protection works (e.g. shoreline armouring) - the hazard being assessed as if these works were not present. This reflects the fact that many of these works are inappropriate as long-term solutions in view of associated environmental issues or other concerns (see Section 4.2 below). The only sites where existing protection works were taken into account were those sites where properly designed and built structures have been designed and consented as long-term hazard management measures (e.g. Moanatairi Reclamation on the Thames foreshore).

4.1.4 Erosion Hazard In The Waikato Region

The classification system outlined above has been used to group the major coastal settlements of the Region according to the most serious coastal erosion hazard problem at each locality (Tables 1 and 2). Some significant hazard problems outside of major coastal settlements (generally sites where roads or cultural sites are threatened) have also been listed in these tables.

The hazard issues have been grouped both according to physiographic regions (Table 1) and district council areas (Table 2).

The only major settlement not included in Tables 1 and 2 is Thames. Here the existing foreshore generally fronts wide, legal reclamations. The full width of these reclaimed areas is potentially vulnerable to erosion over time if not properly protected. Therefore, these areas could in theory be regarded as being in categories 4 or 5 (depending on existing land use) until fully protected. However, the areas are not at serious risk and are likely to be appropriately protected as required. Some areas (e.g. Moanatairi Reclamation) already have adequate protection works. The only natural foreshore occurs at Kuranui Bay at the Northern limit of the township and even this beach has prograded over time due to the groyne effect of the Moanatairi Reclamation to the immediate south. The width of natural shoreline in this area is such that there is no existing or potential erosion risk to the areas behind.

Coastal Settlements

Tables 1 and 2 indicate that exposure to erosion hazard (i.e. categories 2 to 5) is widespread. Of the 39 different settlements listed, only 1 site (Opoutere) does not have some existing or potential coastal erosion hazard to residential property or development along either its ocean or harbour margins.

Existing coastal hazard problems (i.e. categories 4 and 5) are also widespread, occurring in all major coastal physiographic areas and in all coastal district councils (Tables 1 and 2). Moreover, 21 of the 39 (54%) settlements listed have relatively serious (i.e. category 5) existing hazard problems along parts of either their ocean and/or estuarine margins (Table 1).

Most of the hazard problems appear to have arisen because coastal development has been placed too close to the sea to accommodate natural shoreline movements. As discussed in section 3, there is little to no evidence of any significant changes in natural shoreline behaviour at most of these sites – though predicted global warming may lead to such changes in the future.

The tendency of coastal development to be placed very close to the shoreline is well illustrated by Figures 11 and 12. These diagrams show the set-back of all foreshore development (roads and houses) at settlements along both the western (Figure 11) and eastern (Figure 12) coasts of the Coromandel – as scaled from colour aerial photographs taken in 1995 and 1996. Each data point on these graphs represents a length of foreshore, showing the minimum, average and maximum set-backs occurring in that area.

It can be seen that the vast majority of development on the Western Coromandel lies closer than 50 metres to the sea, with much of this set-back less than 25 metres and some as little as 5-10 metres (Figure 11). Similarly, most coastal development along the Eastern Coromandel lies within 100 metres of the foreshore, with much of this set back less than 50 metres and some less than 15-25 metres (Figure 12). Seaward property boundaries are of course even closer.

As noted in section 3, shoreline changes of 10-15 metres can occur fairly widely along the Western Coromandel coast, with changes of 20-30 metres common along the ocean beaches of the Eastern Coromandel. Larger shoreline changes can also occur in some areas along both coasts, particularly in areas close to stream or estuary entrances. Therefore, with the limited set-backs evident in Figures 11 and 12, the potential for erosion hazard problems is clearly evident.

The close proximity of coastal development to the sea (Figures 11 and 12) also results in the potential for very significant hazard problems to arise in the future, given the potential impact of predicted global warming over the next 100 years and beyond (section 3.4). Such changes would aggravate existing hazard problems (categories 4 and 5, Tables 1 and 2) as well as giving rise to additional problems (categories 2 and 3, Tables 1 and 2).

For instance, an average of 30 metres net recession along the Eastern Coromandel beaches (section 3.4) could result in coastal erosion extending at least 50-60 metres inland at some sites (taking into account natural shoreline fluctuations of 20-30 metres). It is quite evident from Figure 12 that this would result in serious and widespread coastal erosion hazard problems along this coast. Approximate estimates (based on existing development set-backs) suggest that such erosion would result in serious hazard to existing property and development presently worth about $525 million, including nearly 570 existing dwellings. This compares to the present moderate hazard to property and development worth approximately $150 million, including about 60 dwellings.

The potential for global warming to seriously aggravate coastal erosion hazard problems emphasizes the need to effectively manage risk at all coastal settlements, rather than simply focus on existing issues.

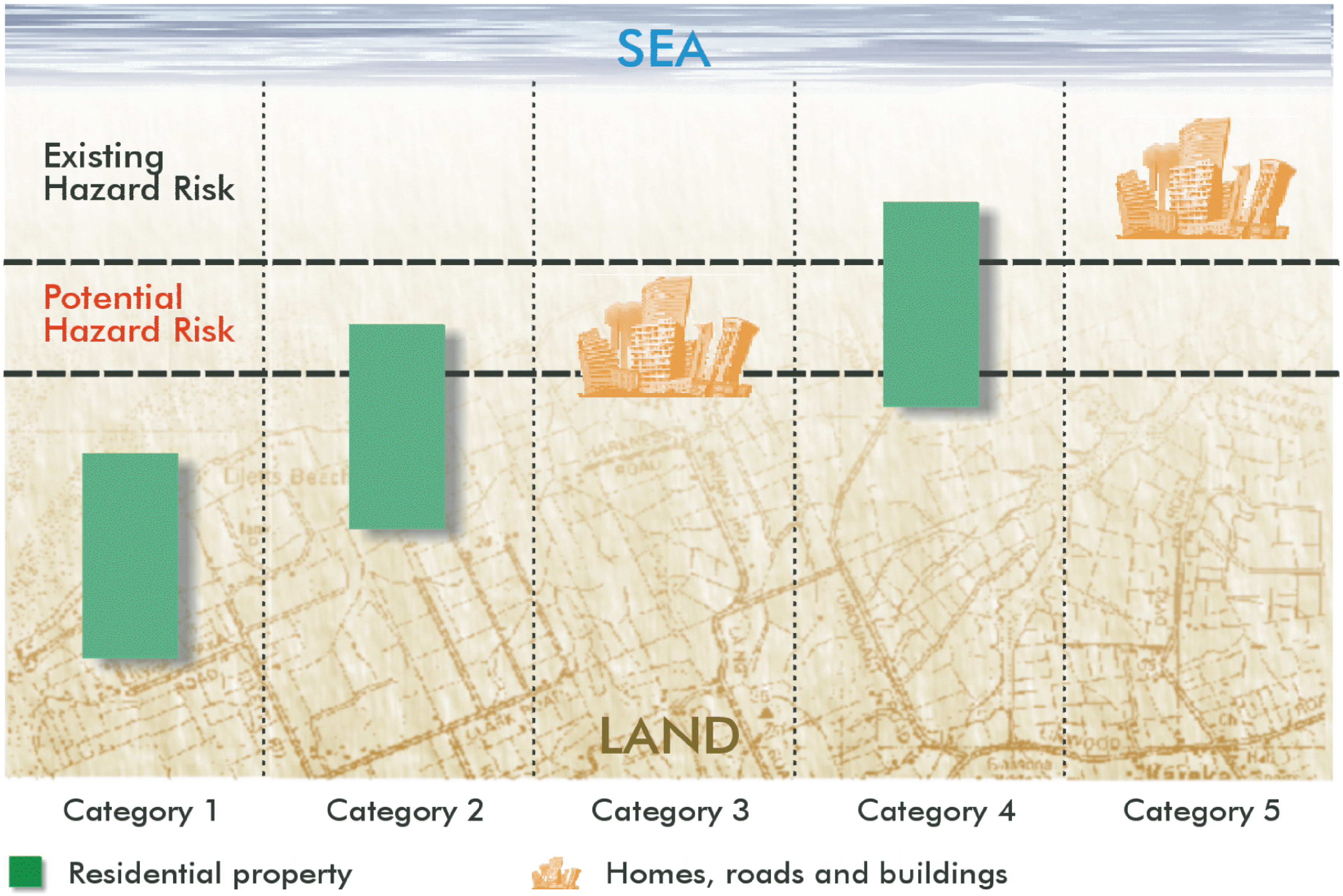

Figure 10: Categories used to classify coastal erosion risk in the Waikato Region.

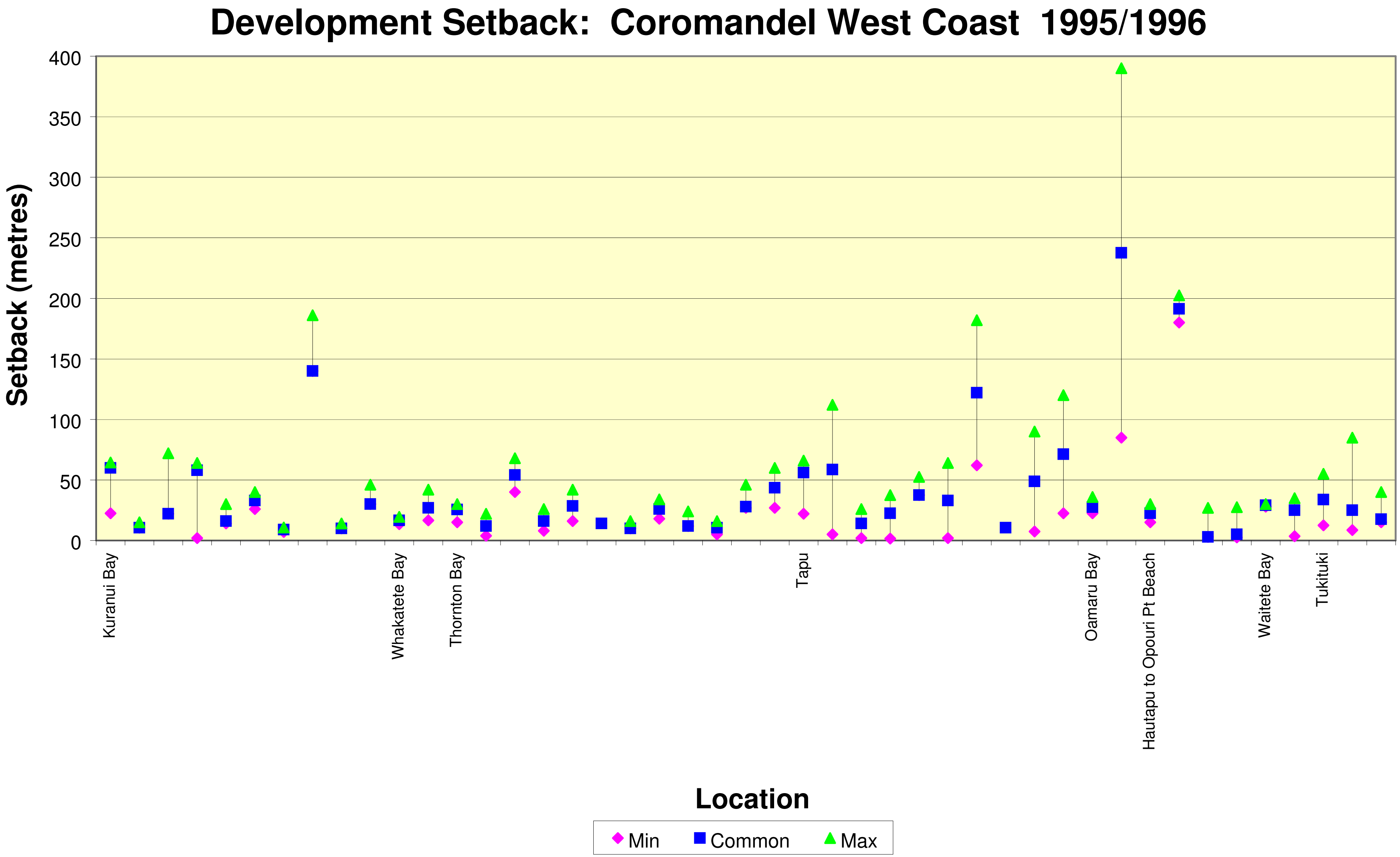

Figure 11: Development Setback – Coromandel West Coast 1995/96

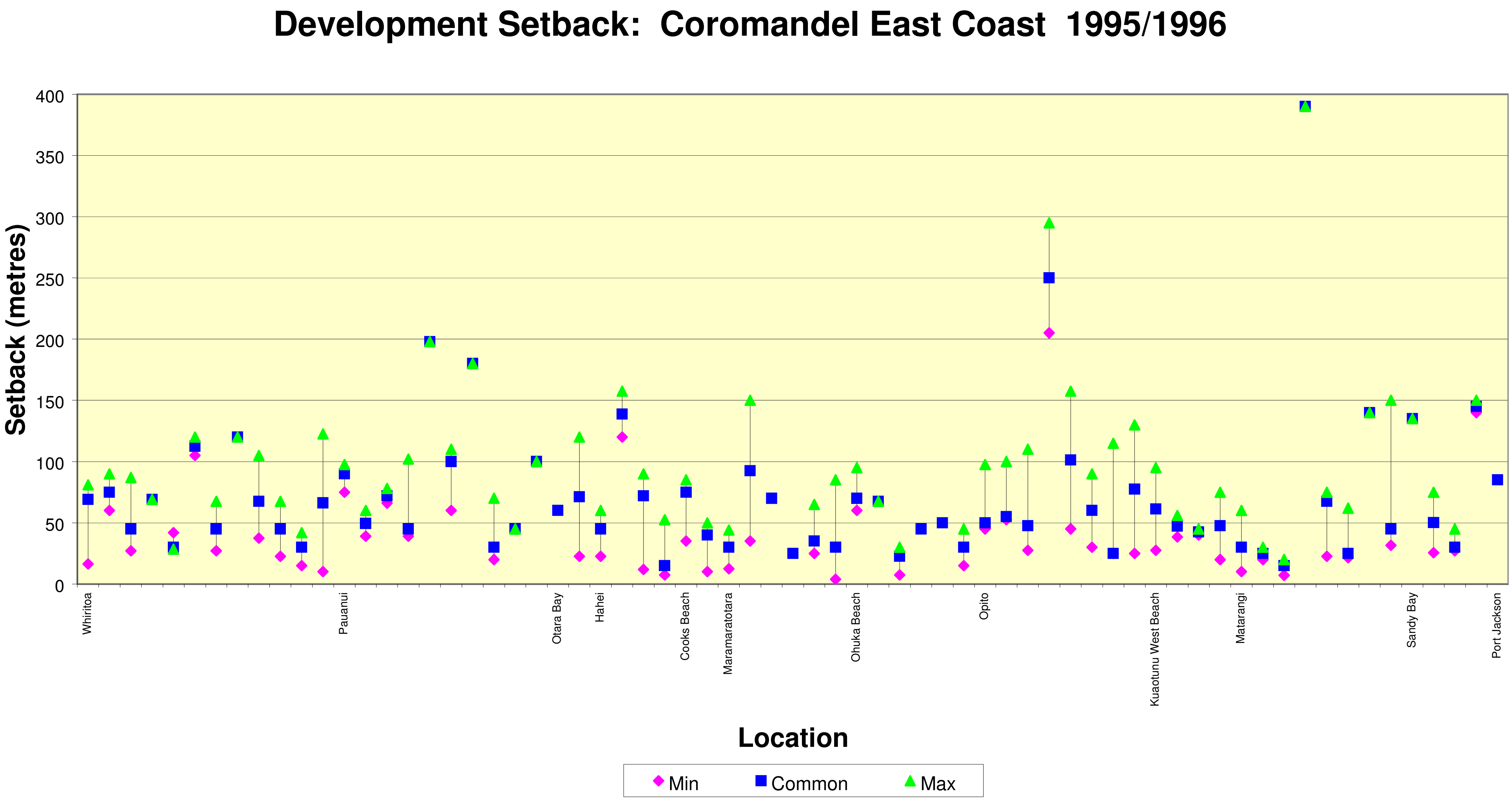

Figure 12: Development Setback: Coromandel East Coast 1995/96

PHYSIOGRAPHIC AREA	RISK CATEGORY				
	Category 5	***Category 4***	***Category 3***	***Category 2***	***Category 1***
Eastern Coromandel Ocean Beaches	Whiritoa, Tairua, Hahei, Cooks, Buffalo, Wharekaho, Whangapoua	Whangamata, Kuaotunu E Matarangi, Little Bay	Onemana, Pauanui, Opito, Kuaotunu West, Rings, Sandy		Opoutere, Kennedy Bay
Eastern Coromandel Estuary Margins	Whangamata, Whitianga, Tairua, Kennedy Bay				Opoutere, Pauanui, Matarangi
Firth of Thames	SH25, Tararu, Te Puru, Waiomu, Koputauaki Bay, Kaiaua, Seabird Coast Rd.	Waikawau, Coromandel	Ngarimu Bay, Thorntons Bay, Te Mata, Tapu		
West Coast Estuaries	Raglan, Aotea, Kawhia, Te Waitere, Marokopa, Mokau	Awakino			Port Waikato
West Coast Ocean Beaches	Seaview, Mokau	Raglan	Port Waikato		

Table 1: Distribution of coastal erosion hazard problems by physiographic area

DISTRICT COUNCIL	RISK CATEGORY				
	Category 5	***Category 4***	***Category 3***	***Category 2***	***Category 1***
Thames Coromandel District Council	Tairua, Hahei, Cooks, Buffalo, Wharekaho and Whangapoua beaches; Whangamata, Whitianga and Kennedy Bay estuaries; SH25, Tararu, Te Puru, Waiomu and Koputauaki Bay.	Whangamata, Kuaotunu East, Matarangi and Little Bay beaches; Waikawau (west coast) and Coromandel.	Onemana, Pauanui, Mahinapua, Opito Kuaotunu West and Rings beaches; Sandy Bay, Ngarimu Bay, Thorntons Bay, Te Mata. Tapu		Opoutere (ocean and harbour margins); harbour margins of Pauanui, Tairua, Cooks and Matarangi; ocean margin of Kennedy Bay
Hauraki District	Whiritoa				
Franklin District	Kaiaua; Seabird Coast Road		Port Waikato (ocean coast)		Port Waikato (harbour)
Waikato District	Raglan (harbour margins)	Raglan (ocean coast)			
Otorohanga District	Aotea and Kawhia				
Waitomo District	Te Waitere, Marokopa, Seaview, Mokau (ocean and estuary coast)		Te Maika, Awakino		

Table 2: Distribution of coastal erosion hazard problems by District Council

Other Hazard Issues

There are a number of roads in the Region that are vulnerable to coastal erosion hazard - most notably State Highway 25 (particularly along the Thames Coast, but also at Whitianga). Many other roads in the Region also have isolated but significant coastal erosion hazard issues, including coastal roads along the Western Coromandel north of Coromandel township and the Seabird Coast road along the western margin of the Firth of Thames. Lesser problems also occur along a number of additional coastal roads. Erosion hazard at these sites can also be accentuated by road widening and realignment activities which extend roads further seaward.

Significant cultural sites are also threatened by erosion at a number of sites. Most notably, these include urupa at Koputauaki Bay and on Mokau spit. However, there are also a large number of cultural and archaeological sites at risk, including some of the oldest settlements sites in New Zealand - particularly along the Coromandel coastline (Furey, 1998).

Community concerns are also rising in regard to erosion hazard issues in other areas. These sites include erosion of public reserve land, particularly when the reserves are relatively narrow (e.g. road reserve at Te Mata and parts of the reserves bordering residential property at Te Puru).

The extensive nature of unauthorised shoreline protection devices, including rural shorelines and other locations removed from existing settlements, also illustrates that coastal erosion is viewed as a “problem” by communities and property owners. A recent survey of foreshore structures in the Region noted in excess of 450 shoreline protection devices (e.g. sea-walls, dumped rock, groynes), the majority of which have only either existing use rights or no present authorisation. The proliferation of these coastal structures raises many significant environmental and other issues (see section 4.2 below).

For the majority of the coastal areas of the Region, existing shoreline movements and associated coastal erosion are part of the fundamental nature or character of the land. However, this does not appear to well understood by coastal communities or by present and prospective owners of coastal real estate. Therefore, there appears to be a significant need for increased attention to community information and education in regard to coastal erosion.

4.2 Issues Associated with the use of Coastal Structures

Historically, coastal structures such as shoreline armouring and groynes have been widely used to mitigate erosion hazard (or perceived hazard) to property and development around the coast of the Region.

Particular emphasis has been given to the use of shoreline armouring. A survey of coastal structures around the coast of the Region conducted in 1994/95 identified 401 shoreline armouring structures.

However, experience with these devices indicates that there are a number of significant issues commonly associated with the use of these measures. This section briefly outlines and discusses these issues.

4.2.1 Adverse Environmental Effects

The adverse environmental effects associated with coastal structures particularly (though not exclusively) relate to the loss of high-tide and inter-tidal beach along the seaward face of the structures. The greater the loss of high tide and inter-tidal beach, the more severe the adverse environmental effects become.

The beach loss typically arises from two effects – loss of beach behind and beneath the placed structure, and/or “passive erosion” effects. While aggravation of erosion has also been cited as a contributing factor, the available information suggests this effect has probably been over-stated.

Passive erosion effects refer to the process whereby a retreating beach is “pinched out” in front of a shoreline armouring structure. Without the presence of a shoreline armouring device, coastal erosion (associated with either net recession or dynamic fluctuations) simply results in a beach being displaced landward, provided there is adequate back-beach sand reserves. However, if the shoreline is held artificially seaward by shoreline armouring, the retreating beach gradually becomes pinched out in front of the structure.

Unfortunately, passive erosion effects are very difficult to avoid - since they are an inevitable consequence of holding the shoreline seawards of where it would otherwise naturally occur. This is inevitably a key objective for shoreline armouring works. Therefore, the most significant adverse environmental effects typically occur where the structures have been most effective as property protection devices - i.e. sufficiently rigorous to hold the coast seaward of where it would naturally occur.

The most significant adverse effects associated with shoreline armouring tend to relate to:

- **Loss of natural character:** The natural character of the coast is that character that derives from natural features (e.g. landforms, vegetation) and patterns and the underlying physical and biological processes that maintain these features and patterns. Case law has defined it as that character that derives from products of nature as opposed to human built structures.

  The placement of human built shoreline armouring structures on beaches tends to significantly degrade the natural character of these landforms – particularly when exposed on the foreshore. Invariably, these structures are markedly different in character from the natural beach landforms. Natural shoreline processes can also be significantly modified by such structures, particularly when they extend seaward of the high water mark or the limit of normal wave upwash. When the structures extend sufficiently seaward to result in loss of a high tide dry beach, the natural process of dune building and repair can also be significantly and adversely affected.

- **Interference with public access along the coastal marine area (CMA):** When shoreline armouring structures extend sufficiently seaward to limit a high tide dry beach, they can have a significant adverse effect on public access along the CMA. The further seaward the structure extends, the greater the period that public access is restricted. Some rare structures that extend to below low water, can effectively eliminate public access along the CMA entirely.

- **Loss of beach amenity:** Beach loss in front of a shoreline armouring structure can significantly reduce beach amenity. Such adverse effects can include the loss of a dry, high tide beach popular for sun-bathing and other recreation, the replacement of sandy beach with rocks or other elements that make it less suitable and safe for swimming, and loss of the aesthetic values of the beach.

The preservation of the natural character of the coast and the protection of public access to and along the CMA and of amenity values are matters that are central to the purpose and principles (i.e. Part II) of the Resource Management Act (RMA) and to the principles of the New Zealand Coastal Policy Statement. Therefore, significant adverse effects on these values are not compatible with sustainable coastal management and tend to mitigate against the use of shoreline armouring works for the management of coastal erosion hazard.

Adverse environmental effects associated with shoreline armouring structures also raise wider equity issues. The adverse effects of such structures can essentially be viewed as negative externalities, effectively cross-subsidising nearshore development at the expense of values important to the wider community. I.e. Effective shoreline armouring structures enable those who enjoy the benefits of a nearshore hazardous location to externalise some of the disbenefits of that location to other parties.

The severity of the adverse effects associated with shoreline armouring largely depend on the extent of beach loss associated with the structure. For any given site, beach loss increases the further seaward the armouring structure is located, since this increases the losses associated both with direct burial and with “passive erosion”. Sloping structures (e.g. dumped rock or rip-rap) also result in greater beach loss than vertical structures, largely because of the increased loss by direct burial beneath the structure (though passive erosion effects are also increased with a sloping structure because it protrudes further seaward).

Therefore, adverse effects of shoreline armouring structures can sometimes be significantly reduced by locating the structure as far landward as possible and by using structures that are as near vertical as practical and appropriate for the site.

For instance, on shorelines that are in dynamic equilibrium, adverse effects can be mitigated by locating the structure as far as possible towards the landward margin of the dynamic envelope (i.e. the width of shoreline affected by dynamic shoreline changes). Preferably, sufficiently landward to ensure that the structure is buried on most occasions and is only exposed on the foreshore for short periods after extreme erosion events. Such a location can also have the additional benefit of requiring a less rigorous and expensive structure than locations further seaward However, in practice this is rarely done. Most structures are placed directly on the foreshore and are partially or wholly exposed for most of the time – maximising both property protection benefits and adverse environmental effects.

Where a shoreline is undergoing net recession, adverse environmental effects are very hard to avoid or mitigate. On such a shoreline, any effective shoreline armouring structure will over time become more frequently and extensively exposed on the foreshore, with increasing loss of beach width. This will inevitably result in increasingly severe adverse effects on natural character, public access and beach amenity. Therefore, coastal structures are not well suited as long-term hazard management solutions for such sites.

4.2.2 Ineffective Structures

Commonly, many shoreline armouring structures are poorly designed and constructed and serve little useful purpose in terms of mitigating coastal erosion. Most frequently, these are measures placed by individual property owners along their own frontage utilising materials readily available to them. Such structures are frequently comprised of concrete slabs, rubble or dumped rock of inadequate size and without an underlying filter. Poorly constructed wooden or concreted stone walls are also common. Such measures are usually placed following erosion events and the inadequacy of the structures may not be exposed for several years. The measures are usually vulnerable to failure through a number of mechanisms, including undermining, out-flanking, direct destruction or removal by wave action, and collapse due to removal of materials from behind or underneath the structure.

It is also not uncommon for a “patchwork quilt” of largely ineffective structures to slowly expand along a foreshore as individual owners take independent action.

The measures appear to meet a psychological need to “do something” and it is not uncommon for property owners to have considerable confidence in these devices, even when it is reasonably evident that they serve little to no useful purpose. This is particularly so for those structures that have been in place for some time.

The false sense of security engendered by such structures can result in inappropriate activities – commonly including placement of structures (e.g. concrete barbecues, garden sheds, fences) or section development (e.g. top-soiling and grassing, planting of feature trees) too close to the sea. The risk to these assets tends in turn to drive further placement of rubble or other materials on the foreshore when the earlier armouring structure is damaged or destroyed.

These structures frequently result in beach loss by direct burial and can have quite significant adverse effects on natural character, beach amenity and public access. The devices are generally not sufficiently robust to cause beach loss due to passive erosion, typically being damaged or destroyed by severe wave action. However, the dispersal of the materials over the adjacent beach and foreshore following damage or failure can aggravate adverse effects, particularly on beach amenity.

4.2.3 Aggravation of Coastal Erosion:

It was once widely argued that shoreline armouring structures aggravate erosion along the seaward face of the structure. However, available evidence suggests that such effects are minimal on most occasions – with bed levels in front of a structure much as they would be at that point in space in the absence of the structure. Direct burial and passive erosion effects are now the processes believed to be primarily responsible for the loss of beach width commonly noted along the face of shoreline armouring works.

However, there is some evidence that additional scour of bed levels may occur along the face of shoreline armouring structures during coastal storms. While such effects are likely to be short lived (i.e. not evident after the storm), they could cause undermining of poorly designed or constructed devices.

There is also fairly compelling evidence that shoreline armouring structures can give rise to “end effects” – aggravated erosion of unprotected shorelines at one or both ends of the structure. There is some evidence that such effects may have been partially responsible for the severe damage incurred by properties and development at Cooks Beach on the eastern Coromandel during the major coastal storm of July 1978.

4.2.4 Concentration of Development in Hazard Areas

A significant concern with regard to the use of measures like shoreline armouring which manage coastal erosion hazard by modifying shoreline behaviour, is that they tend to send the wrong signals to nearshore development. By providing protection (or apparent protection) to hazardous areas, such measures can encourage further subdivision and development in these areas. In this manner, structures have the potential to reinforce the inappropriate patterns of coastal use and development that led to the measures being required in the first instance. This can very considerably complicate erosion hazard problems over time, making it extremely difficult and expensive to resolve such problems in an appropriate manner. Rather, such trends tend to “lock in” the requirement for shoreline modification options, together with associated ongoing (maintenance and eventual replacement) costs and adverse environmental effects.

4.2.5 Global Warming

The above difficulties with coastal structures will be considerably complicated by any trend for aggravation of coastal erosion associated with predicted global warming. Moreover, many existing structures may prove to be inadequate and require replacement with structures built to more rigorous standards - increasing both associated costs and adverse effects.

4.2.6 Discussion

Overall, the above issues raise serious concerns with the historical emphasis on the use of shoreline armouring structures for the management of coastal erosion hazard. Therefore, while armouring structures may continue to be required at a number of existing problem sites for the short to medium term future, they are unlikely to prove appropriate, long term, sustainable solutions at many sites. Rather, where such measures are required, they will generally need to be accompanied by other hazard management approaches (e.g. development controls) that will act to reduce community vulnerability over time. The limited role of shoreline armouring structures is further discussed in the Coastal Erosion Risk Mitigation Strategy (Environment Waikato Policy Series 1999/03).

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Appendix A: Information Sources Used to Assess Coastal Erosion

The preliminary assessment of coastal erosion presented in this report is based on various data sources, including:

- newspaper reports, including a storm data base compiled for the east coast for the period dating from 1868
- investigations of Holocene beach development at various east coast sites and at Mokau on the West Coast
- analysis of historical shoreline changes at Whiritoa, Whangamata, Pauanui, Cooks Beach, Whitianga, Koputauaki Bay, Te Puru, Aotea, and Mokau using available survey and/or photographic data.
- previous reports and papers
- inspection of historical vertical and oblique aerial photography dating from the 1940's (for about 45 sites distributed around the coast of the region);
- site inspections (all sites)
- inspection of old maps, bathymetric charts, historical photographs (from a variety of sources), and historical survey plans
- shoreline monitoring (largely restricted to Coromandel east coast beaches - but also included more limited monitoring along the Thames Coast and in Tairua Harbour)
- information from files of various central, regional and local government bodies
- information from residents and property owners.