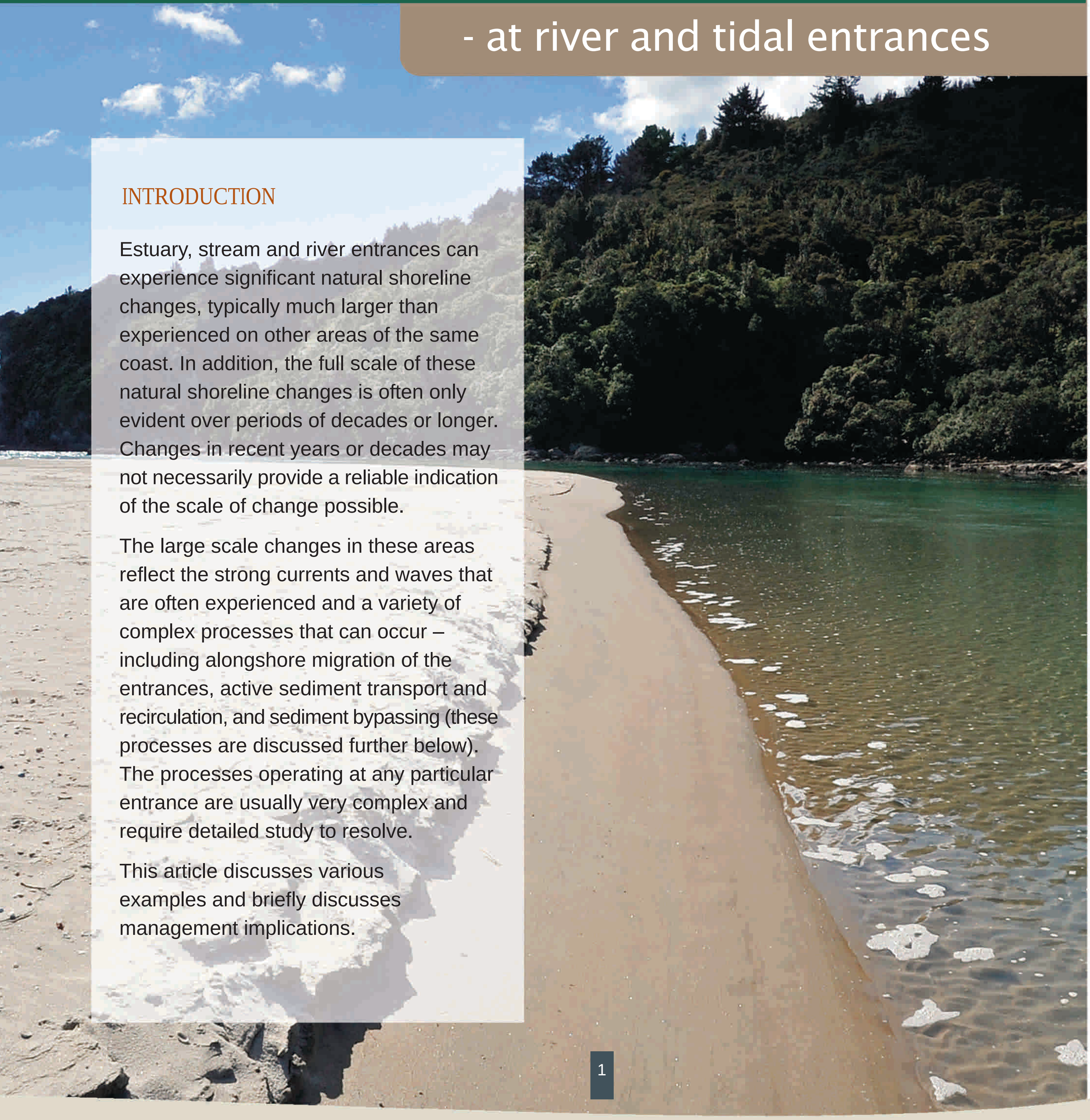
DUNE RESTORATION TRUST OF NEW ZEALAND

Technical Article No. 2.3

# Shoreline changes

## - at river and tidal entrances



### INTRODUCTION

Estuary, stream and river entrances can experience significant natural shoreline changes, typically much larger than experienced on other areas of the same coast. In addition, the full scale of these natural shoreline changes is often only evident over periods of decades or longer. Changes in recent years or decades may not necessarily provide a reliable indication of the scale of change possible.

The large scale changes in these areas reflect the strong currents and waves that are often experienced and a variety of complex processes that can occur – including alongshore migration of the entrances, active sediment transport and recirculation, and sediment bypassing (these processes are discussed further below). The processes operating at any particular entrance are usually very complex and require detailed study to resolve.

This article discusses various examples and briefly discusses management implications.

*Figure 1: Pitoone Stream discharging near centre of Kuaotunu West Beach, eastern Coromandel. In its natural state the stream periodically migrated 300 metres further east (to the left of the photograph).*

## Alongshore migration of small streams

Longshore channel or entrance migration is a very common process observed at stream entrances discharging to open coasts. This periodic longshore migration is typically caused by wave induced longshore transport on the adjacent beach - forcing the entrance or channel alongshore in a particular direction. Upstream channel changes can also be an influencing factor.

For instance, Figure 1 shows Pitoone Stream which discharges near the centre of Kuaotunu West Beach on the eastern Coromandel. Under natural conditions the stream would often migrate 300 metres to discharge adjacent to the headland at the eastern end of the beach (far left of top photo), particularly during low or normal flow conditions. This alongshore migration eroded and reworked beach and dune deposits over a width of more than 50 metres, lowering this area and exposing areas to landward to increased wave action. Floods would often return the entrance to the centre of the beach.

Similar processes operate at many other small streams around the Coromandel and elsewhere around the New Zealand coast. The scale of the alongshore migration can vary from a few tens to hundreds of metres. For instance, historic channels and other evidence indicates that, in its natural state, the Taputaputea Stream at Buffalo Beach on the eastern Coromandel sometimes migrated over 2400 metres alongshore, reworking dunes up to 130-150 metres inland. In some settings, alongshore movement is largely in one direction, as at Kuaotunu West, while at other sites stream entrances can migrate alongshore in either direction at various times according to prevailing waves and other factors.

## Alongshore migration of large river and tidal entrances

In some settings, large river and tidal entrances can also migrate significantly alongshore over time. This is most commonly observed where river or tidal entrances are flanked by sandy erodible shorelines on both sides, with a spit extending in the direction of prevailing longshore transport. As the spit extends the entrance is forced alongshore - eroding the downdrift shoreline over widths of many tens or even hundreds of metres inland. As with small streams, these changes can also be influenced by upstream channel changes.

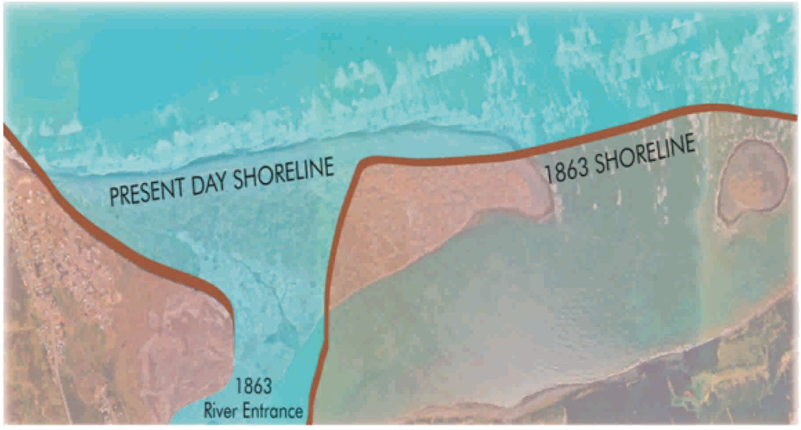



*Figure 2: Changes at Port Waikato showing northwards spit extension since 1863. The main entrance now lies to the right of the island visible in the photograph.*

### Port Waikato

A particularly notable example is the Port Waikato spit at the entrance of the Waikato River. Over the period since 1863, the spit on the southern side of the river entrance has extended significantly northward, moving the main entrance over 4500 metres to the north and eroding the former downdrift shoreline up to 1200-1500 metres inland (Figure 2).

### Ohope Spit

Ohope Spit enclosing Ohiwa Harbour in the southern Bay of Plenty is another example (Figure 3). Gibb (1977) estimated that the Ohiwa Harbour entrance migrated 346 metres eastwards between 1867 and 1976 in response to longshore extension of the Ohope Spit. Ohiwa Spit on the southern side of the entrance eroded as the spit advanced (Smith, 1976; Gibb, 1977). The entrance to Opotiki Harbour (the river mouth of Waioeka and Otara Rivers) is presently 900-1100 metres west of its position in 1866, with upstream channel changes contributing to this alongshore movement (Dahm and Kench, 2002). Many other similar changes have been observed around the New Zealand coast over the last century.

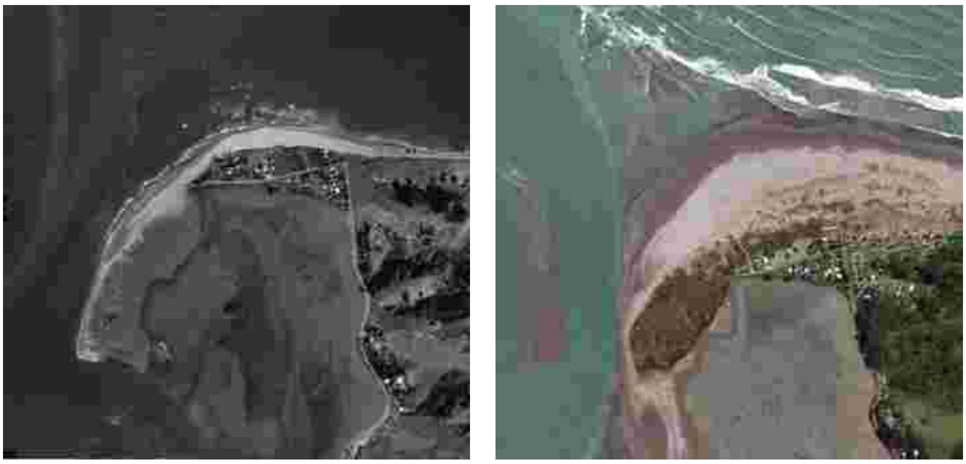


*Figure 3: Aerial photos of Ohiwa Spit (southern side of Ohiwa Harbour entrance, Bay of Plenty) showing the large-scale shoreline fluctuations which can occur in these near entrance locations. The black and white photo dates from 1979 and shows the spit during an erosion period – with the shoreline having eroded back into the township affecting several properties. In 2011 (colour photo), the shoreline in front of the township was in an accretionary state - having advanced by 150-180 m. At this site, these large scale shoreline fluctuations have a period of about 50-70 years (i.e. the time from severe erosion to an accreted state and back to severe erosion). These large scale fluctuations will continue over time and in the future the shoreline will erode back into the township as it did in the*

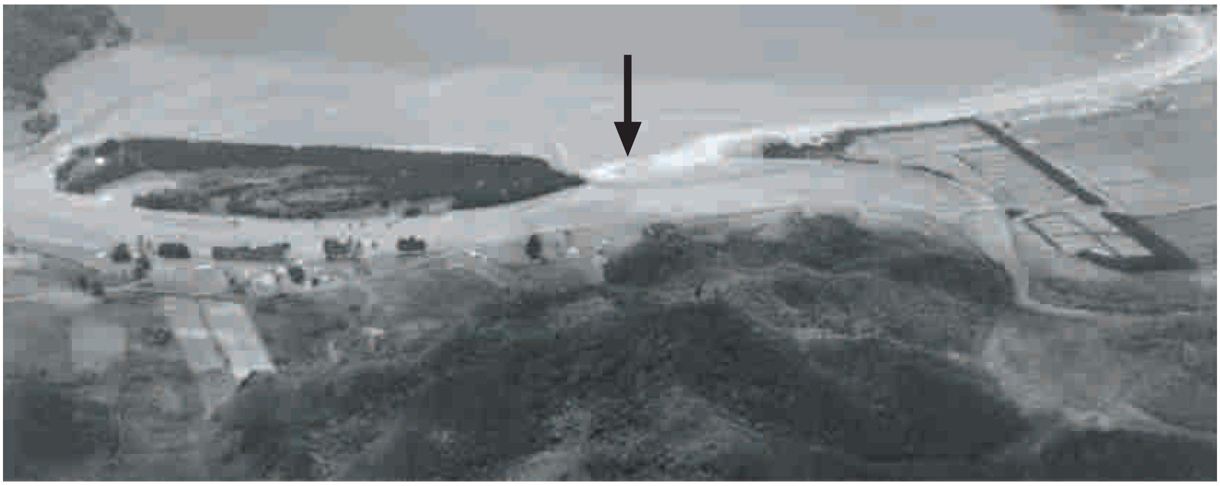


*Figure 4: Example of spit breach. Aerial view of Kennedy Bay sand spit taken in 1982 – showing a second entrance (arrow) formed by a spit breach. The normal entrance is further north (far left of photo). The breach was eventually closed by human action. Left to natural processes, the second entrance may have gradually migrated northwards eroding the forested land between or it may have closed naturally.*

## Spit breaching

Spits enclosing tidal or river estuaries can sometimes be breached, opening up a new or second entrance. The breaching often occurs as a consequence of narrowing by erosion on the landward or lagoon side of the spit, leading to the spit being overtopped and breached by waves during significant coastal storms. The new entrance is normally only temporary and will typically either close or migrate alongshore to the original entrance location – eroding the downdrift dunes as it migrates. The natural process of alongshore migration to the original entrance can however be slow and left to nature with the second entrance sometimes persisting for several years or longer.

### Mangawhai, Northland

For instance, Mangawhai Spit on the east coast north of Auckland was breached in the coastal storm of July 1978, forming a second entrance south of the original entrance. The new entrance slowly migrated northwards but was eventually closed by human action as the natural process was occurring too slowly.

### Coromandel and Bay of Plenty

Other examples of significant spit breaches over the past century include Maketu Estuary on the Bay of Plenty coast (Rutherford et al., 1989) and Kennedy Bay (Figure 4) on the northern Corormandel (Dahm and Munro, 2002). Historically, the Kaituna River discharged through the Maketu Estuary and erosion on the outside of river bends occasionally breached the spit enclosing this estuary. Following diversion of the Kaituna River from the estuary, the flood tide delta in the lower estuary expanded rapidly – pushing a tidal channel into the back of the spit and leading to another breach to the north of the main entrance (Rutherford et al., 1989).

## Sediment circulation at river and estuary entrances

River and tidal entrances on open coasts are characterised by active sediment transport over the bar (ebb tide delta) formed to seaward (Oertel, 1975; Hayes, 1975; Fitzgerald, 1988). This reflects the significant wave and current action which typically characterizes these areas. The pattern of net sediment transport is usually closely related to the gross morphology of the delta (Oertel, 1975; Hayes, 1975).

At tidal entrances, the active sediment transport can result in very significant volumes of sediment re-circulating between the ebb tide delta seaward of the entrance and the flood tide delta formed within the estuary. In Northland, the Kaipara Sand Study estimated that 2.4 million cubic metres of sand per year were deposited on the Tapora Banks flood tide delta within the entrance of Kaipara Harbour.

Large volumes of sediment also recirculate over the bars seaward of even relatively small river entrances. For instance, surveying by Dahm and Kench (2004) reported that currents entering the Opotiki harbour entrance deposited over 28 000 cubic metres of sand on the eastern side of the entrance over a period of only six weeks – despite relatively minor wave action during this period.

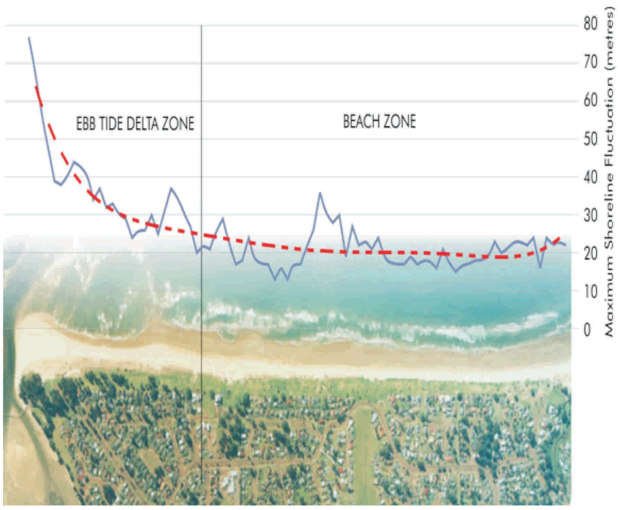



*Figure 5: Maximum shoreline change recorded along Pauanui Beach between 1895 and 1995, Coromandel. Shoreline change is greatest nearer the harbour entrance.*

The active sediment exchange between flood and ebb tide deltas and adjacent shorelines results in significant shoreline fluctuations close to tidal entrances. Figure 5 shows the maximum shoreline changes recorded along Pauanui Beach using historic surveys dating from 1895 to 1995 – based on data from Dahm and Munro (2002). It can be seen that the maximum change near the harbour entrance (over 75 metres) is over three times the typical values (20-25 metres) noted in beach areas further removed from the entrance. The occasional higher spikes away from the entrance coincide with stormwater outlets.

## Sediment Bypassing

On sandy coastlines connected by wave-driven longshore sediment transport, river and estuary entrances are barriers which the longshore moving sediment has to pass. The process by which the sediment is exchanged across the entrance is known as bypassing. Bypassing can occur by several mechanisms (Bruun and Gerritsen, 1959; Fitzgerald, 1988) but these usually involve significant bar and channel changes over time, and together with the sediment volumes bypassed, these can result in significant changes being experienced on adjacent shorelines.

At small river entrances, significant clumps of sediment can be bypassed on a fairly regular basis often evidenced by dynamic fluctuations of the adjacent shorelines. An example is the Mokau river entrance on the northern Taranaki coast. Bypassing of sediment across this entrance results in significant shoreline fluctuations of the spit on the northern side of the entrance. As a clump of sediment is bypassing the entrance, nearshore depths initially increase close to the spit together with wave action and nearshore current velocities – as the marginal flood tide channel is pushed closer to the shoreline. This results in aggravated erosion during storm events. Conversely, when a clump of bypassed sediment arrives at the shoreline, the beach widens considerably.

## Examples of Sediment Bypassing

### Mokau River Entrance

Sediment bypassing results in significant fluctuations of the shoreline over time as shown in Figure 6, for the Mokau river entrance, West Coast, North Island. Unfortunately, the spit was in an accreted state when originally subdivided in the late 1950s and experienced severe erosion shortly thereafter in the early 1960s with loss of some sections at that time.

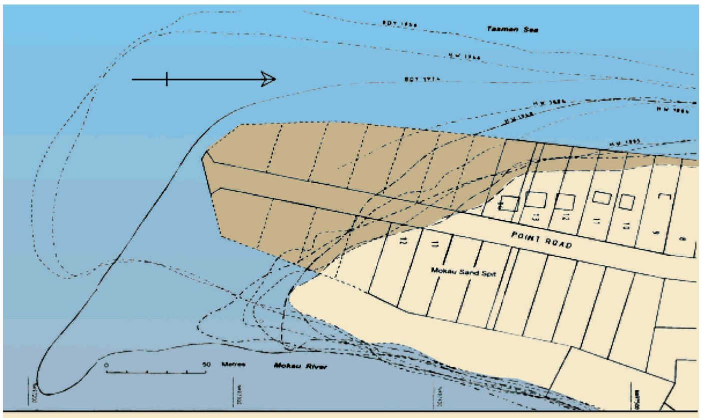



*Figure 6: Shoreline changes at Mokau River entrance showing scale of dynamic variation (from Dahm et al., 2004).*

The situation is further complicated at this site in that there appears to be a trend for long term erosion superimposed on the dynamic shoreline fluctuations (Dahm et al., 2004), possibly related to large scale changes occurring in the lower estuary (Dahm, 1999). Accordingly, each erosion phase accompanying bypassing events has proved more serious than the preceding one, with the result that more houses and properties are affected over time (Figure 7). The super-position of dynamic changes and a long term trend for net erosion illustrates the complexity that can occur at such sites. Drilling and dating indicates that the spit has even been entirely eroded in the past (Dahm, 1999) though it is not at all clear that this is a likely outcome of the present ongoing erosion.

In the1990s, the Regional Council prepared hazard lines to raise awareness of risk - but these have largely been ignored in the many subsequent property purchases.

### Manakau Harbour Entrance

At larger river and tidal entrances, bypassing can result in very large scale shoreline changes. An example is the Manukau Harbour entrance.

*In the 1860s, local Maori advised Percy Smith that "many generations ago" the coastline south of the harbour extended further seaward, projecting in a curved line from Manukau Heads to the Waikato River (Smith, 1878). The area was described as low sandy country with numerous sand dunes, freshwater lakes and clumps of tall manuka. It appears the area eroded in the 1600s or 1700s.*

In the 1900s, large scale shoreline advance occurred at Whatipu on the northern side of the harbour entrance, the shoreline advancing seaward by more than 1 km in places by 1976 (Williams, 1977).

*The sandy expanse created is very similar to that which previously existed on the southern side of the harbour entrance – as described by local Maori to Percy Smith in the 1860s. It appears to have taken at least 200-300 years for the sand eroded from the southern side of the entrance to have bypassed the harbour entrance.*

The sand feature at Whatipu is now eroding as the sand moves further northwards alongshore. Work by NIWA noted that the northern end of Piha has advanced seaward significantly since the 1940s suggesting the sand is already reaching this area.

Interestingly, there is some evidence that this "clumping" of sand associated with bypassing of large entrances can affect shorelines considerably downdrift from the entrance. For instance, the southern end of Muriwai Beach some 22 km north of Whatipu began to seriously erode in the 1960's and has continued to retreat at an average rate of 12-15 metres per decade since. Dahm and Spence, (2002) hypothesized that this is related to the clumping of sand by bypassing – with a previous clump of sand presently being moved from southern Muriwai to northern Muriwai (where the shoreline is advancing). They suggested the erosion trend at the southern end of Muriwai will eventually reverse once the clump of sand at Whatipu and Piha eventually moves further alongshore.

*Figure 7: Mokau spit - properties and dwellings threatened by erosion in mid 1990s as a result of significant fluctuations of the shoreline near the Mokau River entrance. (Photo: J Dahm).*

## SUMMARY AND MANAGEMENT IMPLICATIONS

In summary, large scale natural shoreline changes commonly occur near tidal and river entrances over periods of decades to centuries. These natural changes are driven by a wide range of natural processes and can be very complex. Climate change may well exacerbate many of these processes.

### Intervention

In the period since WWII, marked by considerable expansion of coastal subdivision, there has been increasing demand for human intervention with natural processes at river and tidal entrances. Almost without exception, this need for intervention arises from inappropriate placement of human development. Such intervention generally involves significant social, economic and environmental costs and can be very difficult on high energy coasts – exemplified by the serious problems experienced by unfortunate property owners on the Mokau Spit.

### Adapting to the coast

The development of sustainable and resilient coastal communities requires improved control of human use in near entrance areas and improved public awareness of the very dynamic nature of these environments – enabling communities to better live with and adapt to natural coastal processes.

In general, the best approach is to avoid permanent occupation in areas that could be affected. Hazard risk areas can however be quite suitable for temporary or relocatable uses such as camping grounds or car parks provided the risk is well understood and the features are designed to be removed when threatened. For instance, car parks, camping grounds and other facilities exist on land potentially at risk at Muriwai - but a strategy of managed retreat has been adopted and assets are retreated as threatened.

### Dune restoration

Dune management and restoration will not prevent the dynamic natural changes that occur in these areas and dune management should never be seen as a means of preventing natural erosion processes. Hazard avoidance or managed retreat are generally the preferred responses.

Dune restoration can however be useful where dunes or native sand trapping vegetation have been damaged by human activities. For instance, at Muriwai, the eroding dunes are being actively planted with spinifex on the landward side. The spinifex does not slow the wave erosion but helps avoid serious wind erosion. In addition, experience has shown that the spinifex grows landward with the eroding dune - maintaining a good cover of sand trapping vegetation. Once the existing erosion trend ceases, the spinifex cover will facilitate rapid seaward advance of the dune as the beach advances.

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Author: Jim Dahm, Eco Nomos

Dune Restoration Trust of New Zealand
Email: info@dunestrust.org.nz
www.dunestrust.org.nz

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