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West Coast Hazard Project

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REPORT

ENVIRONMENT WAIKATO

West Coast Hazard Project

Report prepared for:
ENVIRONMENT WAIKATO

Report prepared by:
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Executive summary

Tonkin and Taylor Limited (T&T) have been commissioned by Environment Waikato to undertake an assessment of coastal hazard information along the west coast of their region. The west coast region is an area where there is little knowledge of coastal processes and associated hazards. Therefore this assessment consisted of collating available information on coastal hazards and prioritising areas in need of further investigation.

A summary of the 4 district council plans (Franklin, Waikato, Otorohanga and Waitomo) revealed some differences in the way each council treated coastal hazards, even though they occupy similar coastal environments. The disparity is likely to be related to the differing current land use and zoning regimes within the coastal areas of each council and associated lack of information on coastal hazards.

Four major hazard processes (soft shore dynamics, cliff erosion/instability, inundation and mobile dune sand) were assessed along 6 distinct shorelines/environments. The predominant west coast environments are along the open coast and within the three main harbours (Raglan, Aotea and Kawhia). The open coast has been broken down into north of Raglan Harbour, Raglan to Aotea Harbour and south of Kawhia Harbour areas.

Investigations into existing knowledge on coastal hazards along the west coast show varying amounts of information. While some site specific areas have a good to high amount of detail and information, on a regional scale there is very little information.

Based on information from the 4 district councils, priority areas for further information on coastal hazards have been identified and they include:

- Port Waikato
- Raglan Township coastline (inner harbour)
  - The low-lying sandy area from Riria Kereopa Memorial Drive to Kopua Point is the critical area. There have been development plans for the Maori land in this area, which is Pa Zone.
  - The unprotected cliffs in Raglan township.
  - The protected/seawall areas around Raglan. Many seawalls are old and there will be calls for them to be replaced.
- Kawhia Harbour
  - Kawhia township
  - Te Waitere
- Aotea Harbour
- Marakopa

Recommendations for future information gathering include the use of LiDAR information to better assess soft shore dynamics, coastal inundation and cliff instability. Analysis of water levels (particularly storm surge levels and mean level of the sea) along the coast and within harbours, video analysis of open coast sediment fluxes and identification of geological failures should be approached within an integrated methodology.

1 Introduction

Tonkin and Taylor Limited (T&T) have been commissioned by Environment Waikato (EW) to undertake an assessment of coastal hazard information along the west coast of their region. The west coast region is an area where there is little knowledge of coastal processes and associated hazards. Therefore this assessment consisted of collating available information on coastal hazards and prioritising areas in need of further investigation.

The project encompasses all coastal environments along the west coast and incorporates four main areas of coastal hazard processes:

- soft shore
- inundation
- coastal cliff instability
- mobile sand.

The project team was assembled based on their broad collective knowledge and experience of the west coast environment. The project team consists of:

- Bronwen Gibberd (coastal scientist, EW)
- Vernon Pickett (coastal scientist, EW)
- Richard Reinen–Hamill (senior coastal engineer, T&T)
- Bernard Hegan (senior engineering geologist, T&T)
- Rick Liefting (coastal scientist, T&T)
- Jim Dahm (coastal consultant, Eco Nomos Ltd)
- Keith Smith (coastal consultant, Coastal Consultants Ltd).

This project is considered as the first stage in assessing coastal hazard zones along the west coast open coast, harbour/estuary shorelines and river mouths. Once coastal hazard zones are defined in the future, policy can be implemented to guide current and future development.

2 Current planning environment

This section summaries objectives, policies and rules within national, regional and district planning documents that address coastal hazards and development in the coastal zone.

2.1 New Zealand Coastal Policy Statement

On a national level the only guiding policy regarding natural coastal hazards is the New Zealand Coastal Policy Statement (NZCPS). A summary of the provisions within the NZCPS is provided in Table .

Table - New Zealand Coastal Policy Statement (NZCPS) summary of provisions

Plan	Section	Relevance to natural hazard management
New Zealand Coastal Policy Statement (NZCPS)	s8.7	Regard to be had to the susceptibility of the coastal environment to the effects of natural hazards.
	Policy 3.2.1	Policy statements & plans should define what form of subdivision, use and development would be appropriate in the coastal environment, and where it would be appropriate.
	Policy 3.2.2	Avoid adverse effects of subdivision, use or development in the coastal.
	Policy 3.4.1	Identify areas in the coastal environment where natural hazards exist.
	Policy 3.4.2	Recognise the possibility of a rise in sea level.
	Policy 3.4.3	Recognise the ability of natural features to protect subdivision, use, or development.
	Policy 3.4.4	Recognise that in relation to future subdivision, use and development, some natural features may migrate inland.
	Policy 3.4.5	Locate and design new subdivision, use and development to avoid the need for hazard protection works.
	Policy 3.4.6	Coastal protection works permitted only where they are the best option.

2.2 Waikato Regional Coastal Plan

Environment Waikato has an operative Regional Coastal Plan (WRCP) that contains objectives, policies and rules and other implementation methods that specifically address natural hazards within the coastal marine area (CMA).

Section 8.1 of the WRCP sets the objective to avoid and mitigate natural hazard risk to people and property and presents the following policies:

- 8.1.1 – Identification and integrated management of hazard areas.
- 8.1.2 – Adopt a precautionary approach in the assessment of coastal hazard risk.
- 8.1.3 – Promote the protection of natural features that provide a buffer against natural hazards.
- 8.1.4 – Ensure coastal erosion structures are necessary and avoid or mitigate any adverse effect on coastal processes and natural character.

Section 16.4 of the WRCP provides rules for structures designed to mitigate the adverse effects of coastal hazards (Rule 16.4.12, Rule16.4.14, and Rule 16.4.16). These rules set out the following assessment criteria to consider when obtaining resource consent for these works:

- the extent the structure will be designed to withstand coastal processes and predicted sea level rise

- the extent that the structure will adversely affect any conservation value in ASCV areas
- the extent the structure has a functional need for location in the CMA
- other decision-making criteria and considerations set out in Appendix II of the WRCP.

Under the Regional Coastal Plan (Rule 16.7.1) it is a controlled activity for structures to be erected in the CMA to manage hazard risk for a period less than three months. It must be demonstrated that there is a functional need for the structure to be located in the CMA, the structure must not restrict public access to the CMA and the structure must be removed within three months of the issue of a resource consent.

Chapter 17 outlines other methods available to Environment Waikato to facilitate the implementation of the objectives and policies of the WRCP. Section 17.2.14 encourages territorial authorities to adopt a buffer zone along coastal margins of at least 20 m to provide protection for land use and development from erosion and flooding. Section 17.7 provides the following methods to implement the policies presented in the Natural Hazards chapter (section 8.1).

- guidance with hazard assessment methodology
- development of hazard management strategy
- appropriate management options, minimising shoreline armouring works
- identification and protection of natural features (e.g. dune and wetland habitats)
- precautionary approach to take into account our lack of knowledge of the coast and the effects of future sea level rise
- raise awareness of natural coastal hazards and promote community involvement in protecting buffer zones.

Environment Waikato developed two strategies in 1999 to promote integrated management of coastal hazards in the Waikato region – the Coastal Erosion Risk Management Plan and the Coastal Flooding Risk Management Plan. These included a number of implementation methods including inclusion of certain elements in district plans, monitoring programmes and education campaigns.

2.3 Approach of adjacent regional councils

Due to the singular coastal system on the west coast, the Coastal Plan's of adjacent Regional Councils are considered here to compare approaches.

2.3.1 Auckland Regional Council

The Auckland Regional Plan: Coastal has divided the management of the coastal marine area into eleven management areas, including 'Coastal Protection Areas' that are of regional, national or international significance due to their ecological, landform or geological values. It is a comprehensive plan with objectives and policies covering:

- Natural hazards
  - control of the use of land to avoid / mitigate effects of natural coastal hazards
  - avoid interference with natural coastal processes
  - use of non-structural methods for coastal protection
  - accounting for sea level rise.

- Subdivision, use and development
  - appropriate use and development of the coastal marine area
  - regard to the desirability of maintaining or enhancing recreational use of the coastal marine area
  - development in areas already modified by humans
  - where practicable, subdivision, use and development shall be undertaken at times of the day, year or tides where this will avoid adverse effects on the coastal environment
  - avoid, remedy or mitigate cumulative adverse effects
  - adopt a precautionary approach.

There are rules pertaining to coastal protection structures, beach nourishment, planting, and occupation.

2.3.2 Taranaki Regional Council

The Regional Coastal Plan for Taranaki includes four coastal management areas: areas of outstanding coastal value; estuaries; open coast; and Port Taranaki. Regional rules relate to each of these areas, as well as a set of general rules. Natural hazard protection structures are a discretionary activity in all of the coastal management areas.

Objectives for coastal hazards within the Plan include:

- to reduce the susceptibility of people, property and the coastal environment of Taranaki to loss or damage by coastal erosion or flooding
- to avoid as far as practicable, the need for natural hazard protection works in the coastal marine area and to avoid, remedy or mitigate adverse effects on the environment that result from implementation of natural hazard protection works.

Policies on coastal hazards include:

- recognise the ability of natural features and systems to provide defence to hazards and protect their integrity
- recognise the possibility of sea level rise
- coastal hazard protection works only allowed where the positive effects of allowing the works are significantly greater than the adverse effects
- coastal erosion protection works with a duration of less than five years may be allowed (with certain conditions)
- prior to a decision on coastal permits, information will be required on natural hazard risk and alternatives to hazard protection works.

2.4 District Council objectives and policies

There are few objectives in the relevant plans directly related to coastal hazards and development. Those identified are as follows:

- *To avoid conflict between natural coastal processes, including coastal erosion, and activities and development in the coastal environment* - Waitomo District Plan
- *To avoid, remedy or mitigate adverse effects of development on the unique natural character of the coastal environment within the Special Policy Area from Calvert Road Raglan to Papanui Point* - Waikato Operative District Plan

There are a number of policies contained in the Plans which are summarised in Table . Table B1, Appendix A provides a more comprehensive summary.

Table - Summary of Council policies on coastal hazards and development

Policy	FDC	OtDC	WkDC	WtDC	EW
Protect natural buffers	X			X	X
Recognise / protect natural coastal processes	X			X	X
Avoid need for coastal protection structures	X				X
Avoid activity that gives rise to coastal instability / erosion	X				
Avoid development in areas prone to coastal hazards	X			X	X
Identify coastal hazard areas and develop integrated hazard management strategies					X
Account for sea level rise	X		X		X
Account for climate change effect on coastal hazards			X		
Adopt precautionary approach					X

2.5 District council rules

2.5.1 Franklin District Council (FDC)

The Franklin District Plan includes 'Coastal Protection Yards' (open space along the full length of the sea and its bays, inlets and tidal creeks or rivers) which must be unoccupied and unobstructed by buildings.

Buildings and structures must be setback 30 metres from Mean High Water Springs (MHWS) in the residential, rural-residential and business zones, and 60 metres in other zones. In these setback areas, earthworks are restricted to less than 25 cubic metres or an area of 250 square metres.

Urban subdivisions must be clear of coastal protection yards, and Council can require a coastal erosion report in connection with any subdivision application.

2.5.1.1 Plan Change 14 ("Rural Plan Change")

The Rural Plan Change, currently under appeal, is primarily aimed at managing rural and coastal development and growth. Expansion is provided for in villages generally located away from the coast, with structure plans to manage development.

A management area approach has been adopted for the Rural Plan Change, with three management areas proposed in the coastal area - Tasman Coast; Manukau Harbour Fringe; and Seabird Coast.

A coastal zone underlays the management areas and includes a comprehensive set of rules regarding land use and subdivision, and a 60 metre 'coastal protection setback'. A

'special character area' will apply to areas adjacent to the coast with special coastal character particularly sensitive to change.

Under the Plan Change, the area of land between the settlements of Clarks Beach, Waiau Beach and Glenbrook Beach are identified as an area for growth, with development opportunities to be implemented through a structure plan.

2.5.2 Otorohanga District Council (OtDC)

Three distinct coastal environments are recognised in the Otorohanga District Plan (Kawhia Harbour, Aotea Harbour, and the open sea surf beach) however limited planning provisions exist for these areas.

The only coastal planning zone is the 'Urban Limited Services Effects' zone at Aotea Harbour, which comprises an area between the coastline and a hazard line 100 metres inland. Within this zone, buildings must be relocatable and no sea control structures, or other structures designed to control the erosion of land by the sea, are to be erected on the property. Activities are non-complying if they do not meet these requirements.

In areas outside of this zone, if the land is subject to (or likely to be subject to) damage by erosion, subsidence, falling debris, slippage, flooding and/or inundation, any activity on that land is non-complying.

2.5.3 Waikato District Council (WkDC)

Waikato has an operative District Plan (operative September 2002) and a proposed District Plan (notified September 2004). Both of these plans have weight when assessing activities, and are considered separately below.

2.5.3.1 Waikato District Plan (operative)

Under the operative District Plan, buildings within a 20 metre setback from MWHS are discretionary activities.

A Special Policy Area is zoned from Calvert Road (Raglan) to Papanui Point. The Plan highlights that this area has outstanding scenic and recreational value and is under intensive pressure for recreational and residential development. More restrictive conditions are placed on the siting, design and scale of development in this area.

2.5.3.2 Waikato District Plan (proposed)

The proposed Waikato District Plan contains the following relevant provisions and controls that are applicable to activities in the Coastal Zone:

- earthworks within 100m of the mean high water springs (MHWS) are discretionary activities (unless part of an approved subdivision or is necessary for building works authorised by a building consent – in which case the works are permitted.)
- the floor level of any habitable room must be at least 3.7m above Moturiki Datum. This is based on a 2% storm surge of 2.9m, with an allowance of 0.5m for sea level rise and 0.3m freeboard.
- alterations to a building within 100m of MHWS must not increase the building coverage or height.

- new buildings within 100m of MHWS are non-complying activities. The exception is where the allotment is entirely within 100m of the coast and subdivision consent was granted before 25 September 2004, in which case the setback is 32m from MHWS. The building platform on new lots must be at least 100m from MHWS.

There are also conditions for land-use activities within 1,000 metres of MHWS.

There are no controlled subdivisions in the coastal zone, giving Council the ability to decline resource consents.

In the Living Zone and Pa Zone:

- the floor level of any habitable room must be at least 3.7m above Moturiki Datum.
- building within 32m of MHWS is a discretionary activity
- in the Living Zone, subdivision is a controlled activity
- every allotment is capable of containing a building platform set back 100 metres from MHWS
- every allotment has a land-use consent granted for dwellings and a building envelope is specified detailing the floor plate, building height, location of windows and balconies, and elevations and plans (for allotments containing less than 1.6ha within 1,000m of MHWS)
- an esplanade reserve strip 20 metres wide is created from every allotment within 20 metres of MHWS (Mean High Water Springs.

2.5.4 Waitomo District Council (WtDC)

The Waitomo District Plan has a 'Coastal Hazard Area A' which extends inland 50 metres from the open coast and 25 metres from estuaries and harbours. There are two additional zones in Mokau – 'Coastal Hazard Area B' and a 'Prohibited Activity Area'.

Any building is a non-complying activity in Coastal Hazard Area A and the Prohibited Activity Area. However buildings specifically designed to be relocatable are discretionary activities. Any wharf, jetty, boat ramp, carparking area, toilet facility or other utility building associated with the use of the coast is a discretionary activity in Coastal Hazard Area A.

Any existing lawfully established building within Coastal Hazard Area A or the Prohibited Activity Area which is threatened by a hazard may be relocated to a safer position on the same site as a permitted activity.

At Mokau, any building is a discretionary activity in Coastal Hazard Area B.

3 Hazard processes explained

The following sections outline the processes involved with each coastal hazard.

3.1 Soft shore dynamics

Soft shores are comprised (entirely or a proportion) of sand, gravel or mud material. Sediment is transported either along the coastline (alongshore transport) or between the sub tidal and intertidal areas of the beach profile (on/off shore transport). Sand transport above the high tide elevation (mobile dune sands) is discussed in Section 4.4.

Shoreline movement, whether it is erosion or accretion is a function of sediment supply and transport, which is driven primarily by wave action and water level. Tidal or river currents can also influence shorelines in some areas, particularly within estuary or river systems.

These changes in shoreline position occur over differing time scales, from hours during a storm event, daily tidal cycles, monthly/yearly seasonal changes, yearly/decadal climate changes through to geological time scales.

3.2 Cliff erosion and instability

Cliff hazards along the coast range from incremental cliff erosion to episodic sudden failures such as landslips.

Coastal cliff erosion processes are not limited solely to coastal induced mechanisms. Other erosion mechanisms are also occurring. While coastal processes causing the removal of the protective talus slope and/or undercutting the softer cliff material can be the most prevalent erosion mechanism, mass failure caused by falling cliff top trees, rain water run off, storm water discharges, natural weathering, wetting and drying of cliff material and biogenic mechanism's also contribute to erosion.

Sudden landslip events may be due to inherent failures within the geology of the cliff section. While predicting landslips may be difficult, the evidence of previous landslips, and therefore unstable land, can be interpreted from aerial photographs, topography and expert knowledge.

3.3 Coastal inundation

Inundation or flooding of low lying coastal areas can occur due to the effects of storms. The effects are compounded when storms occur over a high tide, particularly a high spring or perigean tide when water levels are near maximum.

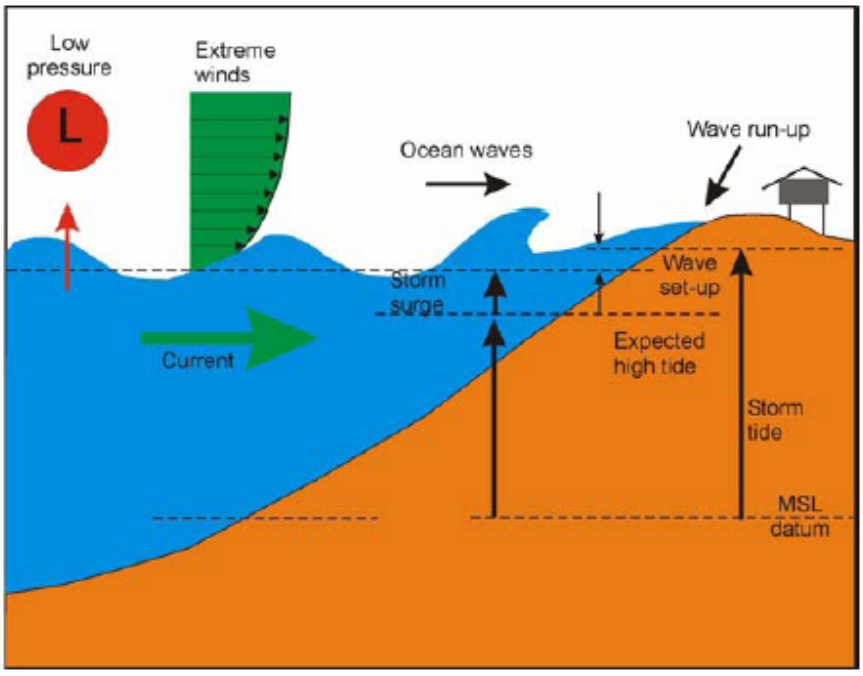

Figure 3- Components of storm surge (source: MfE 2003)

Storms increase water levels along the coast in a number of ways (Figure 3-1). As a storm nears the coast, a rise in local water levels occurs. This increase in local water level (storm surge) is due to the atmospheric drop in pressure associated with a deep low pressure system and by onshore winds causing a build up of water along the coast (wind set up).

Associated with storms is the generation of a wave front which not only produces large waves, but in conjunction with already elevated water levels allows more wave energy to affect the coast. The wave front also creates a localised sea level gradient from a decrease in water level offshore of the breaker zone (wave set down) to progressively higher elevations landward of the breaker zone (wave set up).

As a wave breaks on a beach the water rushes up the sloping beach to an elevation higher than the already increase water level. This is called the swash zone and the elevation a wave can reach is called the wave run up. Wave run up varies from beach to beach as beach characteristics (slope, beach material, infiltration and offshore bathymetry) vary.

Therefore, when assessing water elevation due to tide and storm effects, the sum of the following parameters is used to obtain a theoretical maximum water elevation based on a 2% AEP event.

i. high tide elevation (normally MHWS)
ii. seasonal sea level change (allows for water temp fluctuations causing water expansion/contraction ~0.25m)
iii. sea level rise (0.5 m over next 100 years)
iv. storm surge (~0.9 m maximum rise is estimated along the NZ coast but may vary due to local physical environments)
v. wave set up (can range from 0.6 – 1.3 m)
vi. wave run up (varies depending upon offshore wave height and nearshore slope)

Based on the elevations above, a storm tide level is applied to an area with respect to a reliable elevation datum, usually MSL (Mean Sea Level. MSL is derived from long term tide levels at a particular location. There are currently two elevation datum used on the west coast region, Moturiki (MSL) and Taranaki (MSL).

Moturiki MSL was derived at Moturiki Island, near Mount Maunganui on the east coast of the north island. Taranaki MSL was derived at Port Taranaki, New Plymouth. The MSL at each of these locations and around the New Zealand coastline varies. Therefore, these two datum may not represent a reliable MSL along the west coast open coast or within harbours.

3.3.1 Coastal inundation within estuaries

For estuaries, the affects of wave set up and run up along the open coast are not normally an issue, although they can still contribute to water elevation close to the entrance (inner estuary). Further away from the entrance the effects diminish. Because of the relatively shallow and sheltered nature of estuaries, wave heights generated are relatively low. Therefore, wave set up and run up are also relatively low. However, these small waves can cause serious erosion of softer sediments on estuary margins over a period of time.

In larger estuaries wind set up can cause the build up of water on the down wind side.

Freshwater runoff into the estuary from the same storm event can also cause a rise in water elevation. If peak water flows also coincide with high tide and storm surge, water elevations within the estuary can build significantly.

3.4 Mobile wind blown sands

Dunes may form in areas where there is significant amount of sand above the normal reach of tides and waves. Dunes are formed by wind blown sand accumulating along the coast line. If there is constant supply of sand to the dune system (especially near river/estuary/harbour mouths), the dunes can become very large.

If the sands are not vegetated and are unstable, dunes can become mobile and move landwards (transgressive dunes) by prevailing winds. Unless these mobile dunes become vegetated and are maintained, it is very difficult to halt their progress and can engulf anything in their path.

4 Geographic review of existing information

The west coast of the Environment Waikato region has 749 km of coastline comprising some 199 km of open coast and 550 km of estuary coast. For this project the coastline has been delineated into major harbour/estuary shorelines and the inter-connecting open coast shorelines between them. The delineations closely correspond to those used in the Environment Waikato coastal meta-database.

For this project the Environment Waikato west coast has been split into the following sections (Figure 1 Appendix A):

- Raglan Harbour north, open coast
- Raglan Harbour
- Raglan Harbour to Aotea Harbour, open coast
- Aotea Harbour
- Kawhia Harbour
- Kawhia to Mokau Harbour, open coast.

Each shoreline section includes summaries of information derived from published literature, memorandums, research papers, anecdotal evidence, consent information, historical files and expert knowledge.

4.1 West Coast environmental setting

The West Coast of the North Island from Cape Egmont to Cape Reinga is considered a high energy coastline. This stretch of coast can be generalised as one system due to the relatively uniform orientation of the coast to the prevailing westerly airflow, wave climate and sediment sources. Sand transport is generally northerly and the alongshore transport is sometimes referred to as a river of sand. Knowledge of volumes and rates of sand travelling up the coast is relatively unknown.

However, sand does not travel at a constant rate because of headlands, river and estuary deltas and large harbours. Instead, pulses of sand travel up the coast induced by large wave events that can bypass sand around headlands and displace sand from deltas. The volumes, period and location along the coast these sand pulses occur are unknown.

The west coast is predominantly characterised by black sand.

Sediment sources supplying soft shores along west coast include:

- Mount Taranaki
- Taupo Volcanic Zone (via the Waikato River)
- local catchments (via estuaries/harbours and rivers)
- eroding coastal cliffs
- off shore sand reserves (originally placed by volcanic, catchment or sea level rise processes) .

Net sediment transport for this large system is from south to north, driven by the predominant west to south west wave (swell) climate. However, smaller sediment transport systems (littoral cells) also occur at varying scales along the open coast.

A littoral cell is bounded at the north and south by a control feature such as a headland or large river/harbour mouth. The control feature is a physical feature that limits interaction with adjacent littoral cells. A headland for instance is a physical barrier to sediment transport.

A river or harbour mouth may trap sediment within its ebb and flood deltas and also within the confines of an estuary or harbour. Rivers and harbours can also be sediment sources for the (generally) adjacent northern cell. Waves suspend sediment during large storm events, which may enable bypassing from one cell to the next. The size of a littoral cell depends on the size of the control feature. Sediment supply is locally sourced and distributed within each cell.

Large-scale shoreline changes over periods of several decades to centuries have been reported along the west coast. These include reports of severe erosion on the southern side of Manukau Harbour in the late 1700's (Smith, 1878), extensive seaward progradation at Whatipu on the northern side of Manukau Harbour since the mid 1800's (Williams, 1977), although this area has recently experienced large scale retreat, cliff erosion along west coast of the Awhitu Peninsula (McDonald, 1986), a trend for severe progressive erosion at southern and southern-central areas of Muriwai Beach over the last few decades (Dahm and Spence, 2002) and major shoreline fluctuations near the Aotea Harbour entrance (Willet 1982; Dahm and Riddle, 2000). Dahm and Spence (2002) suggested that these changes might be related to sand storage and transfers, including entrance bypassing, along the littorally-interconnected west coast sand system that extends from Taranaki to North Cape.

4.2 Open coast North Raglan

This section covers the shoreline and cliffed area from the Raglan Harbour mouth north to the Environment Waikato regional boundary with Auckland Regional Council at about Kariotahi Beach. This coastline is generally characterised by ancient and modern sea cliffs

4.2.1 Soft shore dynamics

4.2.1.1 Port Waikato sand spit

The Port Waikato sand spit has evidenced major changes over the past 150 years – extending northwards by over 1.5km since the earliest survey in 1863 (Dahm, 1999) (Figure 4-). The northward extension of the spit and river entrance has also resulted in severe erosion of the shoreline immediately north. The northern side of the entrance now

lies more than 2km north of the 1863 position and the inland extent of erosion exceeds 600m in places.

The changes experienced may represent a dominance of longshore drift in relation to river discharge.

Figure 4- Comparison of shoreline position between 1863 and 1996. Source: Dahm 1999

Future changes in the Port Waikato sand spit are uncertain and further investigation would be required to better understand past changes. However, given the scale of change over the last century, considerable caution is warranted - it is possible that the site may experience cycles of spit extension and breaching/erosion over periods of centuries. For instance, Whatipu on the northern side of Manukau Harbour is now experiencing retreat after large scale shoreline advance for over a century.

Any breaching of the spit could potentially pose a serious hazard to the existing settlement – though any such change is likely to occur relatively slowly given the scale of the spit. Nonetheless, given the implications of a breach for the present township, a simple ongoing monitoring programme is warranted to monitor and provide early warning of any trends that could ultimately lead to breaching.

4.2.1.2 Other soft shores

Other soft shores north of Raglan are generally limited to thin widths of beach and dunes at the base of cliffs/bluffs (e.g. Karioitahi) or to intertidal sand beaches at the base of cliffed shorelines.

There is little information on shoreline changes along these beaches, though there is some evidence of significant changes in the past. For instance, McKelvey (1999) noted that work by Gibb (1984) suggested a trend for erosion at 1-2 m/yr in the period between 1880 and 1980. In addition, Smith (1878) noted that local Maori recalled serious erosion just south of Manukau Harbour in the 1700's, eliminating a wide low-lying sandy shoreline that previously existed in this area. On the other hand, some beaches on this coast (e.g. Karioitahi) generally appear to have been reasonably stable over the last 1-2 decades – apart from periods of storm erosion and recovery. Therefore, further work would be required to confirm erosion trends.

Nonetheless, given the limited width of the beach systems, the potential for major shoreline movements along this coast and the presence of historic sea cliffs behind the beaches, caution is appropriate. It is possible the beaches are occasionally eroded back to the cliffs behind.

4.2.2 Coastal cliff instability

Soft weak Tertiary aged sedimentary rocks form sea cliffs in this section. Generally north of Otangaroa Stream cliff slopes are standing at 1V : 2H with little observed instability. However south between Otangaroa and Kaawa Stream the coastline is characterised by a number of large active earthflows that extend inland with slope angles of 10° (1V : 6H) or less. South of Kaawa Stream the calcareous sandstone and siltstone form the sea cliff are standing at 1V: 3H.

The main hazard identified is regression of the head scarp associated with each earthflow and the earthflow mass becoming a rapid debris flow following a heavy rainfall event.

4.2.3 Wind erosion and mobile dune sands

Surficial loose sands overlying older materials are common on cliffs and hill slopes along this coast – particularly the western margin of the Awhitu Peninsula and the area to the immediate north of the Waikato River (e.g. Maioro).

Historically, there has been considerable sand instability of cliff and hill slopes in these areas arising from disruption of stabilising vegetation by human activities, particularly stock; leading to migrating sand sheets encroaching over adjacent land. Most of the severe sand instability has been stabilised in recent decades. McKelvey (1999) notes that stabilisation works were commenced in 1936 to halt the incursion of sand onto farmland. The Waiuku Forest now covers a large area of these sands. Sand mining also occurs over a significant area – with the land rehabilitated after the iron sands are extracted.

However, notwithstanding the extensive stabilisation works, occasional localised problems are still experienced – primarily associated with disruption of stabilising vegetation by poor stock management.

In recent decades, there have also been problems with wind erosion arising from inappropriate use of off-road vehicles on dunes – particularly motorbikes. This issue is becoming a particular problem in the area around Karioitahi and southwards to the Waikato River. Council staff at both Franklin District and Environment Waikato are working with local landowners and communities in an attempt to improve management of this escalating problem.

There were also problems with dune damage and wind erosion at Port Waikato associated with poorly managed pedestrian and vehicle use until the early 1990's – with quite severe wind erosion and dune damage experienced at the southern end of the spit near the main car parking and residential area (Dahm, 1994).

In recent years, the community based Beachcare programme operating at this site has significantly restored damaged dunes (Dahm and Spence, 1997; Spence et al., 1998) and there is currently a high level of community awareness of the issue, with little damage to dune plantings in recent years (Mr Greg Lowe, Franklin District Council, pers. comm., May 2006).

Use of off-road vehicles at this site has also reduced, with very little off-road "honing" over the dunes compared to the widespread activities that characterised the 1960's-early

1990's. There is still quite extensive vehicle use on the spit but largely limited to access for fishing. These users generally keep to established tracks. However, there is potential for these problems to re-emerge given the escalating problems with off-road vehicles (particularly motorbikes) along the west coast.

There has been some evidence of increasing pressure at this site over the last year and this will need to be addressed early to avoid a recurrence of past problems.

Mobile sand appears to be a lesser hazard along the coast south of Port Waikato until the area close to Raglan Harbour (discussed further below), with only isolated and limited pockets of sand dunes in this area (e.g. at the entrance of the Waikorea and Waimai Streams).

4.2.4 Coastal inundation

Due to the topography of the open coast area being comprised of a beach backed by steep cliffs, inundation is generally not considered to be an issue. However, there may be localised areas of low lying land that may be susceptible to coastal inundation during storm events. Low lying areas of Port Waikato are prone to both coastal inundation and river flooding events.

An Environment Waikato water level recorder located at Hoods Landing, approximately 10 km up stream from Port Waikato has been recording since 1962. Table B2 appendix B shows maximum recorded water levels for Hoods landing above 2.0 m RL.

The highest elevation recorded to date is 2.51 m RL, reflecting the combined influence of astronomical tides and storm surge – though extreme river levels probably also influence water level elevations at this site. The return period of this elevation is unknown. Coastal inundation levels are likely to be higher on the open coast where wave set up and wave runup are additional factors not relevant at the sheltered Hoods Landing site.

4.3 Raglan Harbour

4.3.1 Soft shore dynamics

4.3.1.1 Harbour entrance

The main ocean beach at Raglan consists of beach and dune sediments overlying a rock platform formed by landward retreat of the cliffs while sea levels have been at present levels. The width of the dunes between the sea and the cliffs varies, but is generally 50-100m. The former sea cliffs landward of the beach are now typically well vegetated and the only active sea cliffs occur over a limited length towards the northern end of the beach. The dunes fronting the historic sea cliffs are generally undeveloped, except in the area near the entrance where there are a number of houses towards the end of Riria Kereopa Memorial Drive.

To date, there has been little work on the shoreline dynamics of the ocean beach. The ocean shoreline lies adjacent to the large ebb tide delta formed seaward of the Raglan Harbour entrance and shoreline movements are likely to be significantly influenced by this feature. Shorelines adjacent to ebb tide delta systems and harbour entrances often experience significant shoreline fluctuations associated with changes on the adjacent delta and with sediment bypassing.

Dahm (2002) assessed shoreline changes in the vicinity of the entrance near the former surf club (at the end of Riria Kereopa Memorial Drive) using 1:5000 enlargements from

vertical aerial photos flown in 1944, 1957, 1979, 1999 and 2001. The most significant shoreline changes noted occurred in the periods from 1957 to 1979 and from 1979-1999. The dunes eroded by up to 30-50m between the photos of 1957 and 1979 and then accreted seaward by up to 20-30m between 1979 and 1999. The changes were interpreted as indicating that the shoreline is subject to dynamic fluctuations – characterised by alternating periods of erosion and accretion.

This interpretation appears to be supported by subsequent changes – with a period of severe erosion in the period 2000-2004 in which the duneline retreated at least 15-20m in places. A historic shipwreck (barge) on the beach was uncovered and washed away during this period. The barge was last uncovered in the 1960s and previously some 40 years before (file notes Smith 2004) indicating the periodic nature of sand supply and transport on the west coast.

The dunes in some areas are now recovering (e.g. in front of the parking area at the end of Riria Kereopa Memorial Drive, Photo 4-), though erosion continues on the margins of the entrance channel.

Photo 4- Early stages of dune recovery (November 2006) at seaward end to Riria Kereopa Memorial Drive - following severe coastal erosion in early 2000's. Source: J.Dahm.

Dynamic changes of this nature, occurring over periods of several years or even decades, are extremely common along beaches located close to the entrance of major harbours.

Dahm (2002) conducted field examinations of dune morphology and sediments at the northern end of the beach, including various test pits landward of the carpark and Riria Kereopa Memorial Drive. He noted airfall and voluminous wave rafted pumice materials, in this area together with older dune soils and midden materials. He considered this suggested that the dunes in that area may not have been disturbed by sea erosion for many centuries. Therefore, it is possible that the dunes on the landward side of Riria Kereopa Memorial Drive may be far less vulnerable to erosion than areas further seaward, despite the relatively narrow width of dunes in the near entrance area. However, the work by Dahm (2002) was undertaken in a limited area and he cautioned that further more detailed work would be required to comment definitively on hazard risk areas.

Overall, the limited available data suggests the ocean beach experiences duneline fluctuations of up to 20-40m over periods of decades, these shoreline movements probably closely related to changes on the adjacent ebb tide delta. The limited available data suggests that more extreme erosion, capable of seriously affecting houses landward of Riria Kereopa Memorial Drive, may be very rare. However, more detailed investigation would be required to confirm this.

Ongoing erosion along the margins of the harbour entrance potentially threatens a public parking area and toilet block located on the seaward side of the road.

Photo 4-1 Toilet block threatened by erosion along southern side of harbour entrance adjacent to Riria Kereopa Memorial Drive (November 2006). Source: J.Dahm

Work by Gibberd et al (in prep) suggests that this erosion is the most serious experienced in this area in recent decades, though they note that the Te Kopua shoreline further into

the harbour is also very dynamic (see discussion further below). Further investigation would be required to assess the threat posed to the toilet block and the road by the presently ongoing erosion.

4.3.1.2 Harbour beaches

The lower harbour from the entrance to the camping ground inclusive (an area known as Te Kopua) consists of sandy beaches backed by dunes.

Gibberd et al (in prep) investigated shoreline changes in this area using historical surveys dating from 1885 and aerial photos dating from the 1940's. They found that the shoreline is very dynamic over periods of decades, with changes over the last century commonly in excess of 60 m, and up to 105 m. Some parts of the shoreline have shown a consistent trend for either accretion or erosion since the earliest survey in 1885, while other areas appear to have fluctuated in position.

Gibberd et al (in prep) note that such large-scale shoreline changes are typical near high-energy entrance areas subject to high velocity tidal currents, swell waves propagating through the entrance, and the influence of the adjacent flood tidal delta. They suggest that the shoreline changes are probably related primarily to sub-tidal changes in banks and channels - associated with both sediment bypassing of the Raglan Entrance and with the large volumes of sediment re-circulating between the outer and inner entrance areas.

The significant shoreline changes experienced in the Te Kopua area over long periods of time indicate a need for caution in planning future use and development in this area.

Most of the beaches around the rest of Raglan Harbour are largely thin veneers or envelopes of sand over rock, typically backed by cliffs, low banks, seawalls or rocky shorelines rather than dunes.

Photo 4-2 Typical harbour beach composed of veneer of sand over rock platform.

In general, these harbour beaches have very limited volumes of sand. While beach levels fluctuate over time, erosion hazard is primarily determined by the rate of cliff or bank retreat or by cliff instability (see discussion in next section) rather than beach changes.

However, the small harbour beaches often do play a useful role in public access and amenity at higher stages of the tide and careful management of the shoreline is required to protect these narrow beaches. In some areas, placement of seawalls has significantly narrowed or limited these beaches.

4.3.2 Coastal cliff instability

Rock falls and soil/debris falls and flows have occurred at Cliff Street in Raglan (Cooper L; 2004: "Cliff Street Raglan Engineering Geology Erosion Assessment" Environment Waikato Document 930568) within the Tauranga Group sediments and Hamilton Ash Formation. Localised major cliff failure has also occurred in areas between the wharf and Lorenzen Bay in recent decades and, while rare, this erosion does warrant more detailed consideration in order to ensure existing and future development is appropriately managed.

4.3.3 Coastal inundation

Raglan Harbour (as with all estuaries) is prone to both coastal inundation from storm surge and flooding from rain events. The storm event (April 1998) which produced maximum water level elevation at Hoods Landing (section 4.2.4) produced elevated levels within Raglan Harbour. Areas near the entrance (inner harbour) are more prone to coastal inundation while upper harbour areas are more prone to flooding events (over the high tide period).

A WDC (1999) memo details the event and notes a water elevation of 2.85 m RL (Moturiki Datum) recorded at Wallis Street at the tip of the Aroaro estuary. This is the highest known flood level for Raglan Harbour. The WDC engineer at the time suggested that a 1% AEP level could be *estimated* at 3.0 RL. Adding to this an estimated 0.5 m rise in sea level over the next 100 years a Design Level of at least 3.5 m RL was proposed for the inner Raglan Harbour.

Another extreme sea level event occurred in September 2005. In this event the elevation at Hoods Landing was 2.47m RL, while anecdotal evidence suggests very similar levels to the April 1998 event within Raglan Harbour.

There was no reported damage due to these events, though low lying areas within the inner and upper harbour were subject to flooding/inundation.

Note that the proposed Waikato District Plan adopts a Design Level of 3.7 m RL which comprises of a 2% AEP elevation of 2.9m, sea level rise (to 2100) of 0.5 m and freeboard of 0.3 m.

4.3.4 Wind erosion and mobile sand

The headland on the northern side of Raglan Harbour entrance is covered by extensive sheets of mobile sand which have historically migrated nearly 2km inland from the shoreline (Kear, 1960). Historically, there have been extensive problems with wind erosion and sand instability in this area due to disruption of stabilising vegetation – particularly by stock. Smith (2004) reports historical files noting landward advance of up to 20m/yr in the mid 1940's, with the area of unstable sands given as approximately 101 ha. In recent history, the area has been relatively stabilised by marram plantings, though the present

cover is limited and the potential for renewed sand instability remains if this cover is disrupted.

Recently, there has also been an increasing problem with sand instability in dunes along the back of Ngaranui Beach, south of the harbour entrance, due largely to vehicle use (particularly motorbikes) and, to a lesser extent, poor management of pedestrian use. Pedestrian beach access is now generally well managed and improving. A beachcare group now operates in Raglan, supported by Environment Waikato and the Waikato District Council. However, local reports suggest that problems with motorcycles on the beach and dunes are continuing to escalate.

4.4 Open coast Raglan to Aotea

4.4.1 Soft shore dynamics

4.4.1.1 Whale Bay boulder beach

This site is composed of a boulder beach and barrier, backed by a small area of sand flats and a lagoon (Dahm, 2006). The boulder barrier is relatively resistant to erosion but does appear to experience some damage associated with wave overtopping towards the distal end (Dahm, 2006).

The sand flats that have accumulated in the shelter behind the barrier are relatively low lying (generally a lesser elevation than the boulder barrier, apart from isolated dune hummocks) and subject to erosion around the margins of the lagoon (Dahm, 2006; Shand, 2006). However, investigations of shoreline change using historic aerial photographs indicates that erosion over the past few decades has been limited to shoreline fluctuations adjacent to the lagoon, with most of the sand flats unaffected (Shand, 2006).

Similarly, geotechnical investigations indicate that some areas of the sand flats are underlain by peats and that the sands in these areas evidence some iron and organic staining, both of which are factors that could indicate the materials have not been affected by erosion for some time, possibly centuries. Therefore, while extensive erosion of the sand flats may occur from time to time, it would appear to be relatively rare – possibly over centuries rather than decades.

4.4.1.2 Ruapuke Beach

This sand system consists of a beach and dune overlying a rock platform. Beach profiling has been conducted at the site since 1995 and is the only beach profile data available for west coast beaches within the Waikato Region. Profiles showing the maximum erosion and accretion noted to date are shown in Figure 4-1

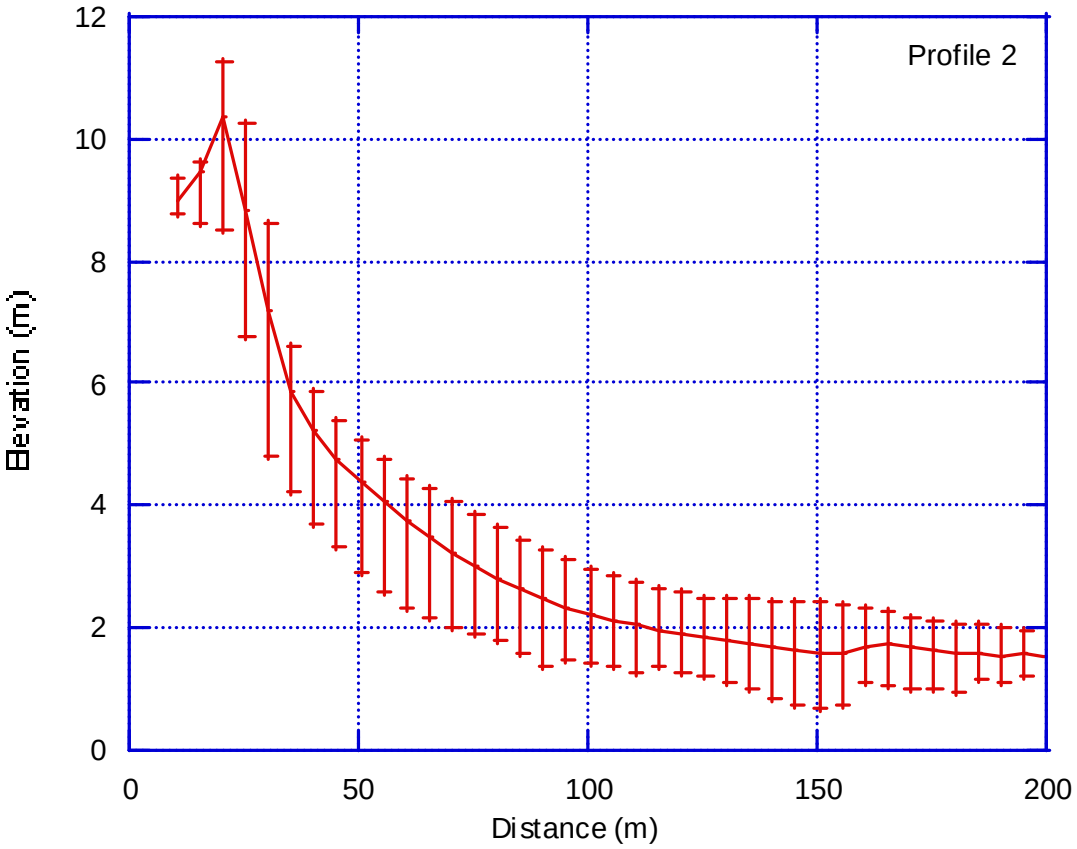

Figure 4-1 Showing beach profile envelope for Ruapuke beach along Profile 2 from 1995 to 2006. Profile shown represents average beach profile, error bars denote maximum and minimum beach elevation. (Source: Keith Smith)

At times, the underlying rock platform has been extensively exposed after coastal storms and it is possible that the beach and dune areas are occasionally completely eroded after extreme storm events.

4.4.2 Coastal cliff instability

The northern section of sea cliffs between Raglan and Aotea Harbour are formed by hard strong volcanic rocks with Tertiary aged limestone and Pleistocene aged weakly cemented dune sands outcropping to the south. Generally slope angles appear stable at 1V: 2H. No significant hazards are identified on the basis of the present study.

4.4.3 Coastal inundation

4.4.3.1 Whale Bay boulder beach

The boulder barrier enclosing the sand flats and lagoon is a wave built feature and therefore maximum wave runup exceeds the height of this feature. This was borne out by observations after the major storm in September 2005, which indicated that waves overtopped the seaward margin of the boulder barrier and flowed landward onto the seaward edge of the sand flats (Dahm, 2006). Similarly, wave effects resulted in overtopping of the sand flats in a limited area adjacent to the lagoon (Dahm, 2006).

Shand (2006) subsequently completed a detailed assessment of coastal inundation, including evaluation of the September 2005 and April 1999 storm events. He argued that

the coastal flooding of September 2005 was the worst event in at least the last 20 years and that complete inundation of the sand flats was probably rare, with limited depths likely even with rare and extreme events.

At present (June 2006) further investigations of coastal inundation in this area are being undertaken in association with a proposal for a dwelling on the sand flats. Work presently in preparation suggests that the September 2005 flooding may have had a return period of approximately 100 years and that a 1%AEP coastal flooding event would not result in inundation of a proposed house site (Dr R Shand, pers. comm., June 2006).

Therefore, while there is still some uncertainty as to the frequency and severity of coastal flooding at this site, serious flooding of the sand flats appears to be relatively rare.

4.4.4 Wind erosion and mobile sand

Mobile sand is not a significant issue along this coast, with the only sand dune areas occurring along the back of Ruapuke Beach and the mouth of the Toreparu Stream. However, there is potential for wind erosion damage to these dunes with increasing vehicle and pedestrian use and a Beachcare group may eventually need to be established at this site.

4.5 Aotea Harbour

4.5.1 Soft shore dynamics

4.5.1.1 Harbour Entrance

The open coast in the vicinity of Aotea Harbour consists of a large sand spit extending southwards across the harbour entrance, with sandy beaches backed by dunes to both the north and south of the entrance.

While there is little to no published information on the ocean beaches, they are likely to be very dynamic given their proximity to the tidal entrances at Aotea and Kawhia. For instance, very considerable shoreline fluctuations may occur in response to sediment bypassing at these entrances. Similarly, the shoreline areas directly adjacent to the ebb tide delta (i.e. the sub-tidal spit on the northern side of the entrance and the shorelines to the south) are likely to experience significant shoreline changes.

These changes are in response to bar and channel changes as a result of the large volumes of sediment re-circulating over the inlet-delta complex. The distal end of the sand spit across the harbour entrance, primarily intertidal, is known to be very dynamic and often significantly overtopped by waves.

The separation of ocean and harbour beaches at this site is a little artificial, as similar to Raglan, the lower harbour beaches are dynamically interconnected with the ocean beaches by tidal currents, waves and sediment transfers. Changes along the lower harbour shorelines are undoubtedly intimately connected with changes at the entrance and with sediment bypassing - as discussed in the following section.

4.5.1.2 Harbour beaches

The only significant beaches occur in the lower harbour, particularly along the southern side of the harbour entrance channel near Pourewa Point where the township of Aotea is located on low sand flats. Further up the harbour, beaches are relatively rare and where they do occur, primarily consist of thin veneers of sand over firmer materials.

The shoreline along the front of the township is extremely dynamic and shoreline surveys dating from 1889 compiled by Environment Waikato reveal major shoreline fluctuations and changes. The most recent significant shoreline changes occurred in the 1960's and 1970's when the shoreline retreated by up to 125m over a distance of several hundred metres (Whiting, 1979; Willet, 1981; Dahm and Riddle, 2001).

A survey of residents conducted by Whiting (1979) indicates that coastal erosion started to affect the initial subdivision about 3-5 years after development in 1963. Residents were divided as to whether the erosion commenced with a storm in May 1966 or during the "Wahine" storm of April 1968. However, the most severe erosion occurred during the 1970's. In 1977, a particularly large storm caused erosion of more than 60m of shoreline over a distance of several hundred metres (Willet, 1982).

Earlier reports suggested that approximately 180 m of shoreline retreat occurred in the period from the late 1960's to 1979 (Whiting, 1979; Willet, 1981). However, the survey work commissioned by Environment Waikato in 1995 indicates that the maximum shoreline retreat between 1963 and 1995 was approximately 125m. This figure incorporates the additional (relatively minor) erosion between 1979 and 1995.

The shoreline erosion between 1963 and 1995 resulted in the complete loss of 20-22 private sections, and partial or significant loss of a further 12. Significant areas of reserve were also lost. This severe erosion appears to have been associated with complex changes both on the adjacent flood tide delta and at the harbour entrance. In particular:

- Changes to the entrance spit, which appear to have allowed increased penetration of swell waves into the harbour (Whiting, 1979). Swell waves entering the harbour appear to have played a major role in most erosion noted to date.
- Increased tidal flows through the area immediately offshore from the settlement (Whiting, 1979; Willet, 1982). The deeper channels and increased tidal flows in these areas probably increased the susceptibility of the shoreline to erosion during periods of swell wave attack. Studies of shoreline changes in other near-entrance locations have indicated that changes in tidal flow patterns and bathymetry can result in very significant shoreline changes.

The underlying causes of the bathymetric and shoreline changes are not well understood but could be associated with (largely northward) bypassing of beach sands across the harbour entrance and/or complex subtidal changes associated with the large volumes of sediment re-circulating between the flood and ebb tide deltas and the adjacent shorelines (Dahm and Riddle, 2001).

Interestingly, the shoreline change data compiled by Environment Waikato suggests that the recent erosion may be part of complex shoreline fluctuations that occur over long periods. For instance, a short length of the shoreline surveyed in 1912 was located 50-100m landward of the position shown in a more extensive survey conducted in 1955 – suggesting a period of shoreline advance between these surveys similar in scale to the erosion of the 1960's and 1970's. Similarly, a shoreline survey from 1889 lay 200-300m seaward of the 1955 and 1963 surveys in places (towards the western end of the present township) but 50-100m landward towards the eastern end.

The maximum extent of shoreline changes that can occur over long periods of time is unknown but a precautionary approach is warranted for all areas on sand given the significant shoreline changes that have occurred historically.

The shoreline of the township was armoured in 2003 and this consented seawall should limit landward shoreline retreat in the near future - provided the wall is adequately maintained. However, the seawall is having significant adverse effects on the beach along the shoreline, including loss of high tide beach along significant lengths. Over time other options such as wall removal may be considered and current landward development may affect such options viability. Therefore, caution is required in regard to managing development in hazard risk areas behind the wall.

4.5.2 Coastal cliff instability

The Aotea Harbour coastline is formed by both Early Pleistocene to Holocene mobile sand dunes and Late Pliocene to Early Pleistocene weakly cemented dune sands on the seaward side and Tertiary aged limestone and calcareous sandstone inland. There are no obvious areas of instability on the aerial photographs viewed. However there have been claims lodged with the Earthquake Commission for land slippage on the old sea cliff behind Aotea Township. These landslips occurred within the Late Pliocene to Early Pleistocene fixed weakly cemented dune sands.

In addition to slope instability, there is also active wave erosion of some shorelines in the harbour. For instance, the bluffed foreshore fronting Te Papatapu Marae (located in the north-eastern area of the upper harbour) has experienced moderately severe erosion over the past few decades – though the exact retreat in this area has not yet been quantified.

The main hazard identified is with regard to regression of the coastline. This hazard may be better managed if the rates for the various areas were established by using geo-referenced aerial photography flown at regular intervals.

4.5.3 Coastal inundation

There are no known issues associated with coastal flooding of developed areas around Aotea Harbour. However any future development of low lying areas would need further investigation. Extreme water levels recorded in Raglan Harbour may be used as a guide to design flood levels in Aotea Harbour.

4.5.4 Wind erosion and mobile sand

There is a large area of mobile dunes on the northern headland (Oioroa) of Aotea Harbour extending nearly 3km inland (Kear, 1960), most of which lies within the Aotea Heads Scientific Reserve. Historical files note approximately 500 ha of dunes in this area (Smith, 2004).

The active dune system (known as the Nukimiti dunes) was originally a major factor in the area being designated as a scientific reserve and at the time of designation it was referred to as "..the last Crown block of sand dunes in an almost completely unmodified state on this part of the west coast" (Dahm, 2001).

However, Dahm (2001) argues that it is not strictly correct to regard these dunes as a natural landscape – as archaeological and geological evidence suggests that the migrating dunes arose from the disruption of stabilising vegetation and soils by human use associated with both Maori and early European settlement. He notes that well formed soils on the older Holocene sands (known as the Paparoa dunes) suggest the dunes were stabilised and well vegetated prior to human settlement. The reserve and surrounding areas have a long history of Maori use and occupation, dating back to the oldest period of

human occupation in New Zealand – with the oral history and traditions of local Maori recording the harbour as the landing place of the Aotea canoe. Archaeological investigations by various workers have also identified numerous sites in the area dating back 700-800 years (Dahm, 2001).

Dahm (2001) notes that present sand supply for the active dunes is derived almost entirely from erosion of the old Paparoa fossil dune system, with little direct sand supply from the beach – with the area of mobile dunes separated from the sea by a wide zone of reasonably well-vegetated dunes. At present there does not appear to be a significant issue with motorcycles on these dunes due to the isolated nature and the difficult access. The Department of Conservation and local Maori have also agreed on a co-management approach for the Oioroa area, including limited access to this culturally very significant area. This should help preclude ongoing damage to the dunes.

Historically, the coastline between Aotea and Kawhia Harbours was also covered in actively migrating dunes – extending 2.5-3km inland. These sands were stabilised in the late 1960's, with extensive pine planting on Maori-owned areas undertaken from 1970 (McKelvey, 1999). Most unstable sands on private farms (typical of the area nearest Aotea Harbour) have also been stabilised and are now in pastoral use. However, the local Maori incorporations and the private landowners both report increasing difficulties with unauthorised use of motorcycles in this area and note increasing areas of sand being destabilised by such activities. As noted earlier, this appears to be a slowly escalating problem along most areas of the west coast.

4.6 Kawhia

4.6.1 Soft shore dynamics

4.6.1.1 Harbour entrance

The open coast on the northern side of the Kawhia entrance consists of beaches backed by a wide vegetated dune system. To the immediate south of the harbour, the beaches are largely backed by rock, with only isolated and limited dunes.

There is little published material on the dynamics of the local coast. McKelvey (1999, p129) records that Gibb (1984) reported the beaches in this area as experiencing a long-term trend for recession of 1-2 metres per year over the period from 1880-1980, but the data on which this conclusion is based was not discussed.

Regardless of long-term trends, it is likely that significant shoreline fluctuations occur over periods of decades - in response to sediment bypassing of the entrance and offshore changes on the ebb tide delta. Until existing uncertainties in regard to erosion are investigated, it is probably best to assume that all areas where sand extends below high tide may be vulnerable to erosion over periods of decades to centuries.

4.6.1.2 Harbour beaches

The main sandy beaches occur in the lower area of the harbour, particularly the northern side of the entrance channel, the shoreline adjacent to Maketu Marae (much of the marae area appears to be on sand) and the beach backed by a single dune at Te Maika. In other areas of the harbour, beaches tend to be more limited veneers of sand over firmer materials.

The shoreline along the northern side of the entrance has experienced significant periods of erosion in the past, including the early 1990's when the shoreline was littered with pine trees undermined by the erosion. However, there is no development in the area likely to be threatened by such erosion.

Historically, the shoreline adjacent to Maketu Marae has experienced periods of erosion which apparently threatened Te Ruruhi, the oldest standing building on the marae. Smith (2004) notes reports of erosion in the vicinity of the marae as early as1943 in historical files. A seawall was built by the local people in 1971 to protect the marae and has since been reinforced in 2004. The seawall was located relatively close to the shore to protect both the building and the access road along the seaward margin. The nearshore location of the seawall precludes a high tide beach forming on many, if not most, occasions. In the longer term, if Te Ruruhi is ever relocated or removed and the existing seawall eventually replaced, a slightly more landward location for the new seawall could be considered to enable a high tide beach to re-establish.

The beach at Te Maika is relatively sheltered and the old baches located on the foredune close to the shore have apparently not experienced severe erosion threat since being placed over 50 years ago – though some active dune erosion is evident towards the northern end of the dune (beyond the area of development). However, given the very close proximity of development to the shore, problems may arise in the longer term with sea level rise.

The foreshore of Kawhia township was originally characterised by a narrow veneer beach fronting bluffs that were subject to erosion. Historical files contain a wide range of reports of erosion (Smith, 2004) and over the years a wide variety of erosion protection structures have been built along this shoreline. The rate of erosion is likely to have been very slow and this was also the conclusion of an April 1949 report noted by Smith (2004) in historical Ministry of Works files.

That report noted little immediate need for erosion protection works at that time apart from the stone wall protecting culturally significant Pohutukawa. Many of the existing erosion control structures are poorly designed and constructed and some also adversely impact on coastal values. Many of these structures are also now near the end of their useful life. Therefore, in the near future, it could be timely to review the threat posed by erosion along this foreshore and to develop a comprehensive and integrated coastal management strategy for the area.

The road to Kawhia is also close to the shoreline in places and has experienced some minor issues with erosion.

4.6.2 Coastal cliff instability

The short stretch of coastline between Aotea Harbour and Kawhia Harbour is characterised by Early Pleistocene to Holocene mobile sand dunes. These sands are constantly shifting and reshaping the local topography.

As with Aotea harbour the main hazard identified is with regard to regression of the coastline and this hazard may be better managed if the rates for the various areas were established by using geo-referenced aerial photography flown at regular intervals.

There have been problems with erosion at Te Waitere with some houses and properties threatened in the 1990's. These problems related to instability of an over-steepened slope that has developed from slow toe erosion over many centuries. Investigations by Environment Waikato in the 1990's, including comparison of historical surveys, indicated

that the rate of erosion at the toe of the slope was very slow (averaging <0.03m/yr) and that protection of this area would not significantly reduce risk to the houses and properties at the top of the high slope. Planting and relocation of houses to a safe distance from the top of the slope were recommended. It is important that the risk to the houses in this area is effectively managed to reduce the risk of serious slope instability damage during a storm event.

4.6.3 Coastal flooding

There has been periodic inundation of low lying areas around Kawhia Harbour including an old cemetery. Design flood water levels derived for Raglan inner harbour could be used in the inner harbour areas of Kawhia Harbour. However, low lying areas require investigations into coastal inundation/flooding hazard if they are to be developed.

4.6.4 Wind erosion and mobile sand

Historically, as noted in section 3.4, there have been serious problems with sand instability between Aotea and Kawhia harbours, with mobile sands extending up to 2.5-3km inland up to the 1960's. The area of unstable dunes was very large, estimated at 1906 ha in historical files investigated by Smith (2004). A 1915 report on historic files noted that the problem arose largely from stock grazing right to the coastline (Smith, 2004). It also suggested that the migrating dunes then posed some threat to Kawhia township.

These sands are now largely stabilised (see earlier discussion in 3.4.4) – though there are steadily increasing problems with isolated and localised sand instability arising from unauthorised motorcycle use on the dunes.

The shoreline south of the entrance has only limited areas of dunes. Nonetheless, there are localised problems with sand instability at Te Maika - arising largely from stock and, possibly, motorcycle damage to stabilising vegetation. Fortunately, the mobile sands involve relatively limited volumes, though the problem does appear to be getting steadily worse. The areas will need to be fenced off and planted if the mobile sand problems are to be successfully addressed. Early surveys dating from 1911 and 1925 also reported some sand blows south of Te Maika extending over a Maori settlement named Parawai and into Kawhia Harbour (Smith, 2004).

4.7 Open coast South Kawhia

4.7.1 Soft shore dynamics

Extensive lengths of beach and dunes occur in places along this shoreline - particularly at Taharoa, Marakopa, Kiritehere, and from Awakino south to Mokau

4.7.1.1 Taharoa

The beach at this site is approximately 7.5km long and was originally backed by extensive dunes and by mobile sands extending up to 2-2.5km inland. The dynamics of the ocean beach, including shoreline changes, have not yet been investigated.

4.7.1.2 Marokopa

The estuarine reaches of the Marokopa River are bordered on the seaward margin by a large sand spit approximately 2.5km long – with the river entrance at the southern end of this spit. The sand spit is Maori owned land with significant wahi tapu values and is currently being restored by the local Beachcare group. It is very unlikely to ever be

developed. The township of Marokopa is located on the landward side of the estuary, with a significant portion of the township lying within a meander loop in the lower river.

Little is known about shoreline change along the ocean side of the sand spit, though it does not appear to currently be an issue. However, the landward edge of the spit has been subject to some erosion, particularly during flood events. This erosion, combined with lowering of the spit by wind erosion (see section 3.6.4) led to some concerns with the longer term potential for the spit to be breached by erosion and wave overtopping – especially following high sea levels in the storm of 17 April 1999. However, this risk has now been substantially lowered with extensive dune restoration work. The risk of spit breaching in the foreseeable future would appear to be low, though the landward shoreline continues to experience periods of erosion.

The near entrance shoreline on the landward side of the river has also been subject to erosion in the past, leading to construction of various seawalls and other erosion protection devices fronting properties and baches in this area. Many of the erosion protection structures in this area are now in a relatively dilapidated condition. Investigation of the erosion hazard and the most appropriate management should be given consideration as many existing baches will be replaced or upgraded in the near future.

There have been no investigations of the erosion in the lower harbour to date, though the erosion mechanism appears to be a combination of factors – including wave surges entering the entrance and running along the shore, river floods and dynamic changes within intertidal and subtidal regions of the lower estuary (probably associated with sediment recirculation over the inlet delta system and with sediment bypassing of the entrance).

The shoreline of the main township further upstream also experiences occasional periods of erosion, especially where the river channel directly impinges on the shore, and some areas may ultimately require protection though, on average, the rate of erosion appears to be relatively slow. Areas of the shoreline on the inside of the meander loop show evidence of recent dune advance in places. However, periods of erosion are also experienced along these shorelines – probably related to subtidal changes and to river floods.

4.7.1.3 Kiritehere

This beach is backed by a single large foredune and is underlain by a gravel deposit, with the Kiritehere Stream discharging towards the northern end of the beach.

Coastal erosion has not been investigated but to date has not been a significant issue, with shoreline fluctuations associated with storm cut and fill cycles generally only affecting the seaward face of the dune. The dune has also been subject to stream erosion, particularly along the northern bank, though this natural erosion does not pose a significant hazard.

A Beachcare group involving a local hapu is involved in coastal dune restoration at this site.

4.7.1.4 Waikawau

There is currently little information on Waikawau, however further examination of historic county council files may provide more information and should be carried out as an initial phase of any more site specific assessment at this location.

The estuary is surrounded by low lying land that is prone to flooding from storm surges and rainfall events. The southern side of the estuary is cut off from the sea by a narrow sand spit. Historically, a tunnel was cut through northern cliff/headland to provide stock access to the open coast.

4.7.1.5 Awakino to Mokau

This shoreline is typically characterised by sandy beaches backed by a narrow zone of dunes fronting fossil sea cliffs, though actively erosing bluffs occur over limited lengths of the coast.

The spit along the seaward side of the lower Awakino River extends southward over a distance of 1.8 km to the river entrance. The spit is generally quite narrow, typically 120 to 200m, and is subject to periods of erosion along the landward margin – particularly associated with river floods and extreme sea levels. Dahm (1999) notes that the spit was overtopped by wave action over a short length during the coastal storm of April 1999. The entire length of the narrow spit is likely to be vulnerable to erosion and breaching over periods of decades.

South of Awakino River, the widest area of dunes, typically 60-80m occur in the vicinity of the Seaview Motor Camp. McComb and Govier (2005) investigated shoreline changes in this area using aerial photographs dating back to 1946. They found that the shoreline was dynamic over the 41-year period from 1964 to 2005, exhibiting periods of erosion and accretion but no long-term trend for erosion. The average positional variability of the foredune was only 14.2m, with a maximum change of 25m.

Qualitative comparison with the earliest aerial photo (1946) also suggested little significant change in the period from 1946-64.They concluded that the shoreline is generally relatively stable over periods of decades, but noted that the potential for more serious erosion will always exist.

Drilling work conducted in this area by Environment Waikato in the mid 1990's found that the dune sands at the Seaview Motor Camp were a relatively thin veneer over an old shore platform formed by cliff retreat. There was no evidence of significant sub-soil development or other staining of the sands that might indicate they had been there for some centuries. This limited data, together with the geomorphic setting (a narrow band of dunes backed by formerly active sea cliffs), reinforces the need for caution in use and development of these areas.

The potential for larger scale erosion over longer periods, including erosion back to the old sea cliffs further landward, cannot presently be ruled out and is a major source of uncertainty in respect to use of the narrow dune areas seaward of the cliffs along this coast. Further investigation of this aspect and the potential response to projected sea level rise is warranted prior to any significant subdivision or development of these areas. However, given the relative stability noted over periods of decades, the areas are well suited to uses that can be readily relocated.

4.7.1.6 Mokau Spit, river entrance

The sand spit on the northern side of the Mokau River entrance was subdivided in the mid-to-late 1950's and has subsequently experienced at least 4 periods of severe coastal erosion – in the early 1960's, the mid-1970's, the early-mid 90's, and the recent erosion dating since about April/May 2004 (Dahm et al., 2004).

In the three earliest periods of erosion a total of 11 sections were lost and several houses had to be relocated – some further landward on their sections and others completely off site (Dahm et al, 2004). The most recent period of erosion has severely threatened at least 4 homes.

Shoreline changes to 1995 were mapped by Environment Waikato (Figure 4-2) from available aerial photos (dating from the 1940's) and historic surveys (dating from 1884 and 1886), covering just over 100 years. This data indicates that the spit experiences very significant shoreline changes, as common on sandy shorelines close to river entrances, with the distal end of the spit fluctuating by more than 200m.

Figure 4-2 Mokau Spit shoreline change. Source: Environment Waikato

Dahm et al (2004) noted that the most severe erosion is primarily associated with shoreline fluctuations and tends to be followed by a period of beach (cf dune) recovery. They also note evidence of a long-term trend for erosion superimposed on the shoreline fluctuations – with each of the successive periods of erosion over the past 40-50 years having been more severe than the preceding, affecting properties and dwellings not threatened in preceding phases. In addition, there was little to no dune recovery between the two recent phases of erosion, despite a period of significant beach recovery.

If, as it appears, the erosion is becoming progressively more severe over time, this has serious implications for beachfront properties.

The causes of the shoreline changes are complex and not yet fully understood but are likely to be associated with changes on the offshore bar at the river entrance – particularly changes associated with the large volumes of sediment being moved northwards past the

harbour entrance (Dahm et al, 2004). Complex bar and shoreline changes are associated with the movement of this sand across river and estuary entrances. River floods, storm waves and changes in the river channel also influence shoreline changes (Dahm, et al, 2004; Needham, 2005). Dahm et al (2004) note that the apparent trend for erosion to become increasingly serious over time may be associated with the significant progressive geomorphic changes that have occurred in the lower river over the last 100 years (see discussion of these changes in section 3.6.1.7 below).

It is difficult to predict with certainty how much property might be affected by erosion over the next 50-100 years. However, as noted above, there appears to be an ongoing underlying erosion trend superimposed on the large-scale shoreline fluctuations. In the longer-term, climate change effects include the potential for increased westerly winds and higher sea levels, both of which could also increase erosion potential at this location. Therefore, on balance, progressive worsening of the situation over time is likely (Dahm et al, 2004).

Environment Waikato has made approximate estimates of the level of risk to different properties, identifying 3 different risk areas (Figure 4-3).

Figure 4-3 Mokau Spit Hazard areas. Source:Environment Waikato

The high-risk area shown on this map is most at risk and property within this area could be lost to erosion within the next 50 years if the apparent trend for long term erosion superimposed continues (Dahm et al., 2004). The medium and low risk areas might also be affected but that the nature and scale of erosion would have to change significantly for these properties to be affected within the next few decades (Dahm et al., 2004).

Dating of shell from river gravels underlying the spit was undertaken by Environment Waikato in the mid 1990's based on four widely spaced boreholes over the entire area of the spit to collect these materials. The shell samples exhibited ages of 1100-2000 years, suggesting that the present spit has been in place for some time but may have been the site of the river channel within the last 1-2000 years. Therefore, it is possible that over long periods of time, the spit is completely removed by erosion associated with river changes.

4.7.1.7 Mokau Harbour shoreline

Shoreline change maps compiled by Environment Waikato in the mid 1990's indicate significant shoreline change in the lower harbour along the southern side of the river over the past century.

In particular, most of the present low-lying coastal flats on the seaward side of the State Highway (including the Domain) have developed over this time. Ancient sea cliffs on the landward side of the road indicate that the river once flowed around the landward side of this area. Therefore, it appears that the shoreline in this area may come and go with river channel changes over periods of centuries.

Consequently, some caution should be exercised in regard to use and development of this area. For instance, the area is probably unsuitable for subdivision – though very well suited to existing uses such as the recreational uses associated with the Domain.

The progressive changes in the lower estuary may also be having some influence on the ocean foreshore of the spit. As noted in section 3.6.1.6, there is some evidence of a longer-term trend for net erosion along the ocean foreshore of the spit - superimposed on the larger dynamic shoreline fluctuations.

While the dynamic shoreline fluctuations are probably associated largely with changes on the ebb tide delta and in turn probably related to sediment bypassing and to sediment recirculation, the trend for erosion to worsen over time may arise from influence of the lower river changes on discharge patterns at the harbour entrance. Further work would be required to confirm this.

In recent decades, there has also been some erosion along the seaward edge of the Domain, including extensive erosion of a small area of private property that once existed just inside the entrance on the southern side of the river.

4.7.2 Cliff instability

From Albatross Point to Tirua Point hard strong indurated greywacke sandstone and argillite dominate the coastline forming erosion resistant sea cliffs. A small area of both Early Pleistocene to Holocene mobile sand dunes and Late Pliocene to Early Pleistocene weakly cemented dune sands are mined at Taharoa. Exploratory drilling shows these deposits along with pumiceous volcanic tephra and swamp deposits overlie the basement rocks.

South of Tirua Point Tertiary aged weak to moderately strong volcaniclastic sandstone with minor calcareous sandstone and limestone crop out along the coastline. These sedimentary rocks while subject to fretting due to wetting and drying are generally stabile at slope angle of 1V: 2H or less.

No significant cliff hazards are identified on the basis of the present study for these areas.

4.7.3 Coastal inundation

Coastal inundation along this coastline is only deemed an issue in low lying areas close to the coast. Marakopa has experienced inundation in low lying areas during the April 1998 and September 2005 event. While no water elevation levels are known at Marakopa for these events, they are possibly similar to those recorded at Raglan Harbour. Again, Design Flood levels derived at Raglan Harbour could be utilised here, but with further investigation of any proposed development of low lying lands.

4.7.4 Mobile sand and wind erosion

The only significant areas of sand dunes extending inland on this section of coast occur at Taharoa, with migrating dunes once extending up to 2km inland (Kear, 1960). Historic files report serious problems with wind blown sand in this area in the past due to disruption of stabilising vegetation by stock (Smith, 2004). The total area of dunelands was estimated at about 1566 ha in historical files, with surveys conducted by the former Department of Lands and Survey in 1911 and 1925 reporting that about 800ha of this area was mobile dune lands (Smith, 2004).

However, since the establishment of sand mining operations in this area, the dunes have been extensively mined for iron sands, with mined areas rehabilitated with marram and ultimately pine forests. Therefore, serious issues with wind erosion are unlikely to arise over the next few decades.

The mining area excludes the frontal dune and beach and once ore has been extracted other sands are returned to the coastal system. Therefore, the mining does not affect the active coastal system and large dune sand reserves are also maintained behind the beach.

The large spit on the northern side of the Marokopa River entrance is the only other relatively large area of dunes along this coast. These dunes suffered from severe wind erosion up until about 2000, due to disruption of stabilising vegetation by stock and extensive human access and use (motorbikes, horse-riding, pedestrians, etc). However, since 2000, the Maori landowners have been involved in active restoration of this area with native species (largely spinifex and pingao) in partnership with the Environment Waikato Beachcare programme – presently the single largest dune restoration project using native species in the North Island. This work is now significantly advanced with over half the dunes re-vegetated. In addition, the Maori landowners are maintaining very strict control on access and use which should ensure that the restoration plantings are not disrupted.

Lesser dune widths occur at some river entrances (e.g. Kiritehere, Awakino and Mokau – discussed earlier) and while disruption of stabilising vegetation and consequent wind erosion occurs in isolated areas at these sites, it is not yet a widespread or serious issue -– though there are reportedly increasing problems with motorbike use. Some of these sites are already working on dune restoration as part of the Environment Waikato Beachcare programme and others are likely to become involved in the future.

There are also apparently some isolated and limited areas of dunes on farms, including some areas of instability near Awakino (Te Pare Joseph, *pers. comm.,* June 2006), probably relating to stock damage.

5 Priority areas for hazards assessments

While a more detailed assessment of coastal hazards along the entire Environment Waikato west coast region would be desirable, costs for such an assessment could be prohibitive and may not address issues associated with the scale and timing of a regional approach. Therefore, smaller scale priority areas are recommended as a starting point for more detailed coastal hazard assessments.

Areas are deemed to be of priority if they have current or future development pressures (as identified by District Councils) and are potentially prone to coastal hazards (i.e. on or near soft shore/dune material, low lying land or cliffed area).

Based on this approached the following areas have been identified as priority areas:

- Port Waikato
- Raglan Township coastline (inner harbour)
  - The low-lying sandy area from Riria Kereopa Memorial Drive to Kopua Point is the critical area. There have been development plans for the Maori land in this area, which is Pa Zone.
  - The unprotected cliffs in Raglan township, particularly some of the higher cliffs upstream of the wharf.
  - The protected/seawall areas around Raglan. Many seawalls are old and there will be calls for them to be replaced.
- Kawhia Harbour
  - Kawhia township
  - Te Waitere
- Aotea Harbour
- Marakopa

6 Future information recommendations

Based on information in Sections 4 and 5, a strategy for future information needs has been undertaken. The strategy is based around the uniformity and consistency of coastal processes along the west coast system both on the open coast and within estuaries. To enable a cost and time effective approach to data gathering and analysis the strategy has taken into account latest advances in information gathering techniques and analysis.

This approach allows for information to be applied to both different coastal hazard processes but also different scales of analysis. While the emphasis is on a regional context, some information can be applied to site specific applications.

The following sections describe each information source and how it can be applied to each coastal hazard and to what scale. Table B3 appendix B summarises the information strategy.

6.1 LiDAR

LiDAR (Light Detection And Ranging) is an airborne system that measures large areas of land topography at a relatively high resolution. This method of topographic survey is becoming more main stream and is effective at capturing data at a regional scale while also providing data at smaller scales. While an initial survey will address a number of information gaps, subsequent periodic surveys will provide more data. We recommend high resolution aerial photography be carried out concurrently with any LiDAR survey to facilitate mapping and analysis.

LiDAR is seen as a priority in terms of future information requirements; the following sections explain how the data can be applied to a number of coastal applications. However, to be useful for coastal applications, surveys must be undertaken at or near low tide.

The use of LiDAR data is not limited to coastal processes or hazards and can be used by councils for a range of assessment purposes. It is important to ground truth levels

derived from LiDAR to improve level accuracy, particularly when comparative assessments of this data may become more practicable in future.

Future consideration of water penetrating LiDAR such as LADS and SHOALS should also be investigated. These systems are still in development, however they maybe become more viable in the near future.

Any large scale elevation survey will require comprehensive ground control or geoid-spheroid separation to produce accurate elevations. However, there is currently no reliable elevation datum or geoid model along the west coat EW region (Section 3.3).

6.1.1 Soft shore dynamics

In our opinion, the beach profile data gathered at Ruapuke is valuable, given the otherwise total absence of such data on west coast beaches of the Waikato Region. It would be useful for Councils to consider purchase this data and to investigate options to fund ongoing monitoring of this site or an alternative site on the west coast to provide improved information on dynamic fluctuations and long term trends.

LiDAR flown at low tide will be able to help identify sand deposits along the open coast. Subsequent surveys will then be able to assess sand fluctuation and assist investigations to determine timing and size of sediment pulses as they travel along the coast.

Shoreline fluctuations will be able to be quantified in a similar manner.

6.1.2 Coastal inundation

Low lying areas, especially around estuaries will be able to be identified at a much better resolution that is currently available. Topographic elevation data can also be used for hydrological models when modelling flood events.

6.1.3 Cliff instability

Analysis of topography determined from LiDAR data can be used to better identify land slips and slope angle. This will again provide more accurate assessments of cliff/slope instability. Better delineation of coastal cliff top positions by LiDAR will also enable cliff retreat rates to be calculated via subsequent surveys.

6.2 Water level analysis

While a preliminary assessment of tidal levels was undertaken for this project there is scope to better refine the assessment using the existing water level recorders at Hoods Landing and Anawhata. Because the tidal record at Hoods Landing is limited, correlation with data recorded at Anawhata will enable analysis of a longer tidal record to better determine storm surge water elevation. This storm surge analysis can then be applied to much of the Environment Waikato west coast open coast area.

The propagation of storm surge effects into the larger estuaries of Raglan, Aotea and Kawhia is not well understood. The establishment of water level recorders, one near the mouth and at least one other in the upper reaches will provide information of storm surge propagation.

Research is being undertaken within Raglan Harbour on a sediment transport project - Raglan Fine Sediment Study. Included within this project is the establishment of a

hydrodynamic model of the estuary. This model is likely to produce information on extreme water levels within Raglan Harbour. The results from Raglan Harbour could be applied to Kawhia and Aotea Harbours.

6.2.1 Elevation datum

Water level analysis is also required to better define a consistent and reliable elevation datum along the west coast. A permanent tide gauge is recommended along the west coast, probably at Raglan wharf. In conjunction with this permanent tide gauge, temporary tide gauges are also recommended along the coast and within the major harbours to provide reliable:

- mean level of the sea
- inundation levels
- sea level trends

A reliable geoid model for the west coast EW region is also recommended to provide accurate elevation surveys.

6.3 Video analysis (Cam Era)

A video camera installation has been operating at Mokau since 1997. This system consist of two cameras, one looking north along Mokau spit and one looking west over the river mouth. Images from these two cameras are saved every daylight hour. These images are stored for later analysis. The cameras were initially sited at Mokau to provide information to help understand erosion events that have occurred periodically.

This installation has been the only monitoring site along the Environment Waikato west coast for some time (apart from beach profiling at Ruapuke) and provides a valuable data set for future analysis. There have been some short-comings with the installation that has limited available analysis techniques. These have been primarily due to image quality and camera view angle.

Video analysis of the images from the cameras can be used to detect geomorphologic changes of the river mouth, beach and offshore bar over time. The Mokau installation has collected sufficient data for future analysis and continuation of the installation is unlikely to provide any further benefit for future analysis (pers comm Dr Karin Bryan University of Waikato 2006). So while the Mokau video installation has probably come to the end of its life, a video monitoring site should still remain on the west coast. However the installation should be set up to focus on quantifying movement of sand pulses along the coast.

Video analysis of shoreline change between two adjacent littoral cells (one camera for each cell) would provide information on sediment movement (sand pulses) for the entire west coast system.

As the system focuses on the larger west coast system, the installation need not be in the Environment Waikato area and funding of this installation could be shared between councils.

6.4 Geology failure mechanisms

Further engineering geological investigations are required. These consist of aerial photographic interpretation and field recognizance mapping to produce geo-referenced maps showing the extent of earth flows.

Investigation into controlling mechanisms of failures within weak geology types will also provide information to enable better classification of cliff/geology hazards.

For instance, a coast-wide analysis looking at failure mechanisms and hazards for different geology along the coast would be useful to classify the coast and identify the management measures (e.g. setbacks) appropriate for development in different areas. There are also some cliffed regions with existing development that appear to warrant more detailed attention in the near future – such as the high cliffs upstream of the wharf in Raglan Harbour.

6.5 Integrated approach

Because the west coast system incorporates multiple regional and district councils a strategic approach to geomorphic process should be advocated. This is particularly relevant to the open sandy coast.

Approaches to the Foundation for Research Science and Technology (FRST) and NIWA are recommended to advocate improved understanding of this coast – including longer term sand storage and transfer along the coast and associated hazard.

In the absence of this information, a precautionary approach is strongly recommended in respect of any development on sandy shorelines.

7 Applicability

This report has been prepared for the benefit of Environment Waikato with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

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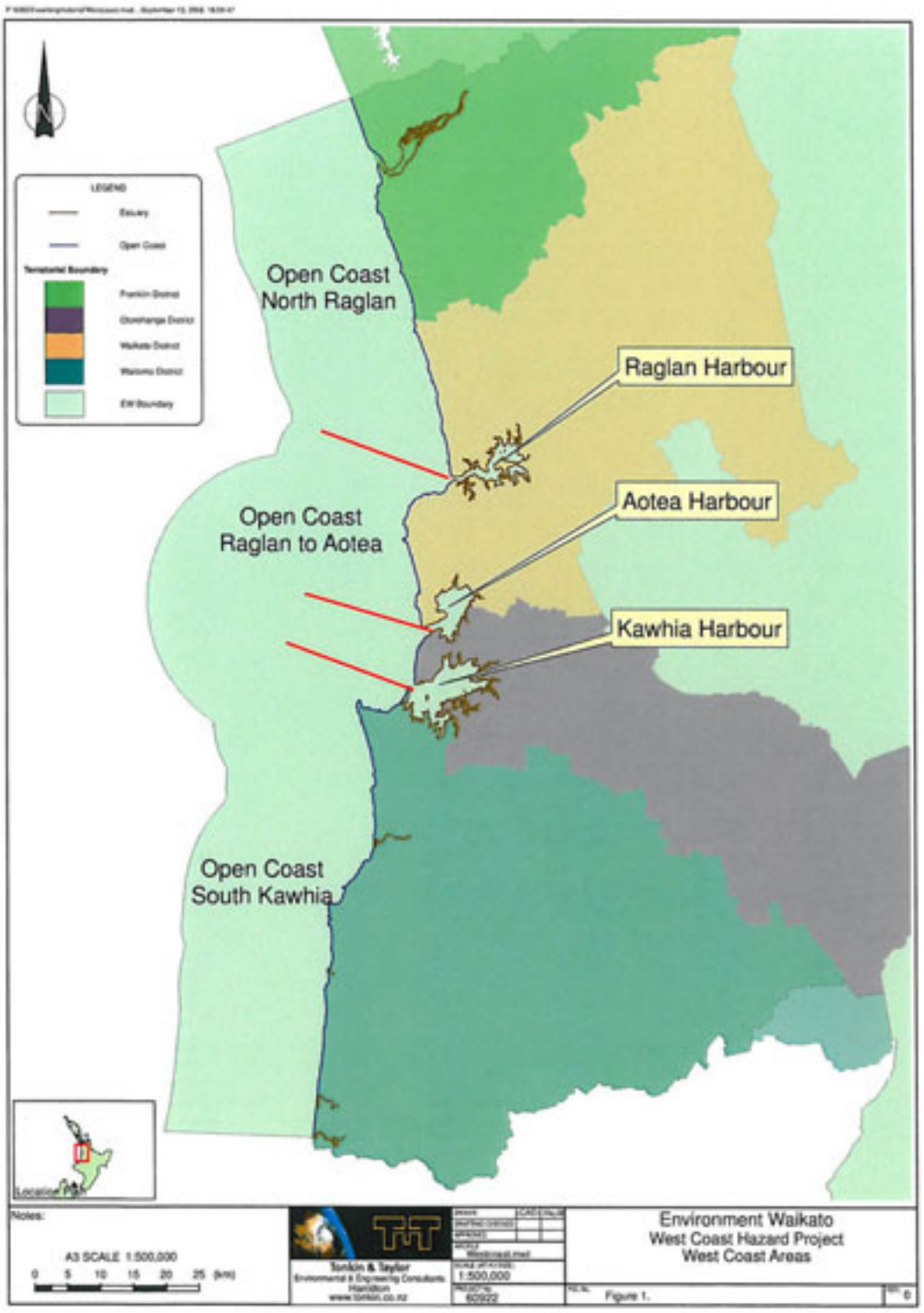
Appendix A: West Coast Areas



Appendix B: Tables

- **Summary of district and regional policies**
- **Hoods landing water elevations**
- **Summary of future information strategy**

Table B1 Summary of Planning Provisions

Franklin District Plan	<u>Coastal zones / protected areas</u> • Coastal Protection Yards along full length of the coast • *Proposed Rural Plan Change - 3 Coastal Management Areas: Tasman Coast; Manukau Harbour Fringe; and Seabird Coast - 2 underlying zones: Coastal Zone; and Coastal Village Zone*
	<u>Policies</u> • Land disturbance activity in coastal and riparian margins shall not give rise to instability or erosion. • New subdivision, use, and development should be located and designed to avoid interference with natural coastal processes, so that the need for coastal protection measures is avoided. • Where existing subdivision, use, and development in the coastal environment is adversely affected by coastal hazards, including mean sea level rise, further subdivision, use, and development that exacerbates the risk, or creates a new risk should be avoided. • Natural features such as beaches (sand dunes and longshore bars), mangroves, and wetlands, which may buffer subdivision, use, and development from coastal hazards, shall be protected. <u>Rules</u> • 7.3.5 - Except for in the residential, rural-residential and business zone, all buildings and structures shall be sited a minimum of 60 metres from mean high water springs. • 27 & 29 - In residential, rural-residential and business zones no building shall be sited within 30 metres of mean high water springs • 7.3.6 - Earthworks in the development setbacks adjoining the coastal marine area shall not exceed a total volume of 25 cubic metres or a total area of 250 square metres. • 22 & 26 - Council may require a coastal erosion report in connection with any subdivision application. • 26.6.1.3 - Urban subdivisions must be clear of coastal protection yards • 50 - coastal protection yards must be unoccupied and unobstructed by buildings

Otorohanga District Plan	Coastal zones / protected areas • *Urban Limited Services Effects* zone at Aotea Harbour, including a hazard line 100 metres from the coastline. • Three distinct coastal environments recognised (no planning zones for these areas): Kawhia Harbour; Aotea Harbour; and the open sea surf beach

	Standards
	• 17A -The property is located within the Urban Limited Services Effects area at Aotea and is situated in the area between the coastline and the 100 metre hazard line depicted on Planning Map A, and
	  ○ Any building to be erected is relocatable, and
	  ○ Any approved sewerage disposal field is located on the landward side of any building, and
	  ○ No sea control structures or other structures designed to control the erosion of land by the sea are to be erected on the property.
	• 17B - The property is not subject to, or not likely to be subject to, damage by erosion, subsidence, falling debris, slippage, flooding and/or inundation.
	
	Rules
	• 17.1 - Any activity that complies with one of the standards is a permitted activity.
	• 17.2 - Any activity that does not comply with either of the standards will be considered as a non-complying activity.

Waikato District Plan (operative)	Coastal zones / protected areas • Special Policy Area: Calvert Road (Raglan) to Papanui Point
	Objectives ▪ 22.1.1 - To avoid, remedy or mitigate adverse effects of development on the unique natural character of the coastal environment within the Special Policy Area from Calvert Road Raglan to Papanui Point. Rules • Any building within 20m of mean high water springs is a discretionary activity (excluding those principally built for the purpose of housing equipment to pump water).

Waikato District Plan (proposed)	<u>Coastal zones / protected areas</u> ▪ Coastal Zone
	<u>Policies</u> • 5.2.4 - Construction or alteration of a building should not take place on land that in the event of a 0.5 metre sea-level rise would be: (a) below mean high water springs, or (b) subject to inundation by storm surges, or (c) subject to coastal erosion. • 5.2.9 - Development should be designed and located to avoid or mitigate the predicted effects of global climate change on natural hazards, especially increased flooding, erosion, fire, and storms. Where there is incomplete information, a precautionary approach should be taken. <u>Rules</u> • 26.5 – prohibited activities: o an extractive industry within 1,000m of mean high water springs o activities within 100m of mean high water springs that involve earthworks or indigenous vegetation clearance, other than activities on public roads and public recreational facilities o construction of a building within 100m of mean high water springs ▪ 32m if building is wholly within 100m of mean high water springs and has a certificate of title issued prior to 25 Sep 2004 • controlled activities (become discretionary if these conditions not complied with): o 26.44.1 - alterations to a building within 100m of mean high water springs that does not increase the building coverage or height o 26.49.1 – construction / alteration of building if set back at least 32m if building is wholly within 100m of mean high water springs and has a certificate of title issued prior to 25 Sep 2004 • non-complying activities: o 26.10 - land use activity within 1,000m of mean high water springs that does not comply with all effects and building rules • No controlled activity subdivisions in the coastal zone, certain criteria for restricted discretionary (rule 26.70) and discretionary (rule 26.70.2), and becomes non-complying if these cannot be met (rule 26.70.3)

	• 26.76.1 - Subdivision is a restricted discretionary activity if every allotment is capable of containing a building platform set back at least 100m from mean high water springs (becomes non-complying if this cannot be met). • 26.77.1 - Subdivision is a restricted discretionary activity if, for every allotment containing less than 1.6ha within 1,000m of mean high water springs: (a) a building envelope is specified for a dwelling for which land use consent has been granted, including details of the: (i) floor plate, and (ii) building height, and (iii) location of windows and balconies (iv) elevations and plans. • 26.81.1 - Subdivision is a restricted discretionary activity if an esplanade reserve or strip 20m wide is created from every allotment within 20m of mean high water springs
Waitomo District Plan	<u>Coastal zones / protected areas</u> • Coastal Hazard Area A – 50m from open coast, 25m from estuaries and harbours • Coastal Hazard Area B (Mokau) • Prohibited Activity Area (Mokau)
	<u>Objectives</u> • 27.3.3 - To avoid conflict between natural coastal processes, including coastal erosion, and activities and development in the coastal environment. <u>Policies</u> • 8.4.1 - To avoid, remedy or mitigate the adverse effects of residential development encroaching on significant landforms or other sensitive parts of the coastal environment. • 27.4.1 - To avoid the siting of new development on land that is subject to flooding, coastal erosion or slope instability. • 27.4.2 - To ensure that where development is to take place within areas of potential suspect stability, and within coastal areas where there is some risk of hazards that each such proposal and its implications is individually assessed. • 27.4.5 -To recognise and maintain, and where appropriate enhance, the ability of natural features such as beaches, sand dunes, and wetlands to protect subdivision, use and development. • 27.4.6 - To recognise that some natural features may migrate inland as the result of natural coastal processes. <u>Rules</u> • 27.5.2.1a) – any building in Prohibited Activity Area at Mokau is a prohibited activity. • 27.5.2.1b) – any building in Coastal Hazard Area A is a non-complying activity. • 27.5.2.1c) – any building in Coastal Hazard Area B at Mokau is a discretionary activity.

	• 27.5.2.2 – in the Coastal Hazard Area A: a) No building shall be erected within 25 metres of any estuary or harbour. b) No building shall be erected within 50 metres of the open coast. c) Where a river meets the open coast no building shall be erected within 25 metres of the river upstream to the boundary of the Coastal Marine Area • 27.5.2.3 a) - Any existing lawfully established building within the Prohibited Activity Area at Mokau, or Coastal Hazard Area A, which is threatened by the identified hazard may be relocated to a safer position on the same site as a permitted activity. • 27.5.2.3 b) - Any wharf, jetty, boat ramp, carparking area, toilet facility or other utility building associated with the use of the coast shall be a Discretionary Activity in Coastal Hazard Area A. • 27.5.2.3 c) - Any building which is specifically designed to be able to be readily relocated shall be a Discretionary Activity in the Prohibited Activity Area at Mokau, or Coastal Hazard Area A.
Waikato Regional Policy Statement (Environment Waikato)	<u>Policies</u> ▪ s3.5.4 Policy 2 - Ensure that the subdivision, use and/or development of the coastal environment are undertaken in a way, or at a rate which recognises and provides for the unique processes operating in this environment. ▪ s3.5.4 Policy 3 - Adopt a precautionary approach when managing the coastal environment which recognises the likely occurrence of events in the coastal environment of high potential impact and low probability. ▪ s3.5.4 Policy 4 - Promote the use of 'soft-engineering' or non-engineering solutions to avoid or mitigate the adverse effects of natural hazards in the coastal environment.
Waikato Regional Coastal Plan (Environment Waikato)	<u>Objectives</u> ▪ 8.1 - Coastal hazard risk to people and property avoided or mitigated <u>Policies</u> ▪ 8.1.1 - Identify areas of coastal hazard risk and develop integrated hazard management strategies for these areas. ▪ 8.1.2 - Adopt a precautionary approach in the assessment of coastal hazard risk and in the assessment of potential risks for coastal permit applications. ▪ 8.1.3 - Promote the protection of natural features that provide a buffer against natural hazards. ▪ 8.1.4 - Ensure that any use of structures to control coastal erosion is necessary and avoids or remedies any adverse effects on other coastal processes and on natural character.

	Rules ▪ 16.7.1 - The erection or placement of any structure in the CMA, for a period of time less than three months, for the sole purpose of managing hazard risk is a controlled activity provided it complies with the following standards and terms: o It shall be demonstrated that there is a functional need for the structure to be located in the CMA. o The structure shall not restrict public access to the CMA. o The structure shall be totally removed from the CMA within three months of the issue of a Resource Consent under this Rule.

Table B2 Hoods landing water elevations

Table B2 Hoods Landing water levels above 2.0 m RL

Event Date/Time	Elevation (m)
17/04/1999 @ 11:30:00	2.514
18/09/2005 @ 23:10:00	2.470
02/05/1965 @ 10:52:53	2.441
29/07/1976 @ 21:16:21	2.430
17/03/1980 @ 11:00:00	2.347
05/06/2000 @ 00:20:00	2.319
29/09/2003 @ 12:40:00	2.308
14/04/1968 @ 11:33:39	2.304
16/06/1999 @ 00:00:00	2.300
18/01/1980 @ 11:21:37	2.295
21/07/1974 @ 23:45:00	2.288
08/09/1994 @ 12:00:00	2.286
20/07/1978 @ 22:45:43	2.281
20/07/2001 @ 22:15:00	2.281
15/09/1962 @ 23:49:15	2.280
15/07/1995 @ 00:15:00	2.277
03/07/2004 @ 23:20:00	2.270
28/09/1984 @ 00:30:00	2.268
11/01/1997 @ 12:15:00	2.267
02/08/1984 @ 01:59:17	2.262
02/05/1984 @ 00:00:00	2.255
10/03/1962 @ 13:22:47	2.254
05/09/1975 @ 22:52:49	2.254
13/09/1976 @ 01:00:00	2.251
19/08/2001 @ 23:00:00	2.250
09/07/1980 @ 20:15:31	2.247
08/04/1982 @ 10:59:59	2.238
09/08/1979 @ 23:44:04	2.236
25/07/1978 @ 02:15:56	2.227
21/02/2004 @ 11:30:00	2.224
06/09/1971 @ 23:45:00	2.222
28/02/1975 @ 13:02:27	2.222
18/03/1972 @ 13:00:00	2.219
02/07/1977 @ 23:23:01	2.219
03/08/1996 @ 01:00:00	2.219
28/08/1996 @ 22:00:00	2.218
17/06/2003 @ 00:15:00	2.207
16/10/1989 @ 11:45:00	2.203
15/05/1984 @ 23:29:46	2.199
06/04/1985 @ 12:00:00	2.196
01/09/2000 @ 00:15:00	2.196
02/07/1969 @ 00:00:00	2.194
26/02/1971 @ 11:45:00	2.185

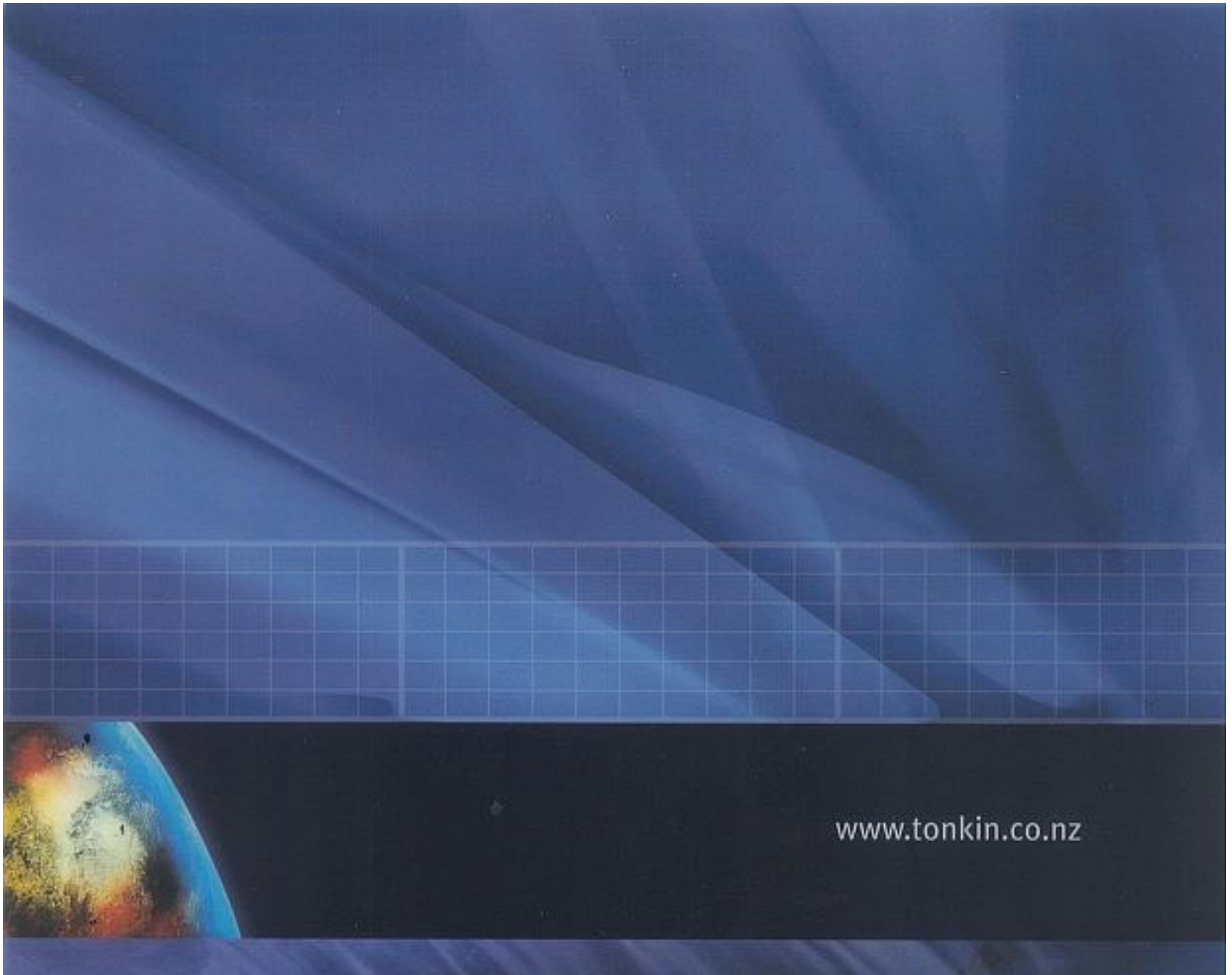
Event Date/Time	Elevation (m)
22/08/1970 @ 01:29:00	2.183
18/04/1972 @ 03:00:00	2.182
12/07/1986 @ 01:30:00	2.177
15/05/1979 @ 12:36:57	2.176
15/06/1975 @ 14:45:00	2.175
02/05/1977 @ 21:34:15	2.173
02/03/1980 @ 11:15:00	2.171
28/07/1988 @ 22:00:00	2.169
24/10/1976 @ 11:00:00	2.164
16/06/1995 @ 00:30:00	2.164
18/03/1984 @ 11:30:00	2.162
12/07/1998 @ 00:00:00	2.158
31/03/2002 @ 00:35:00	2.157
12/08/1998 @ 01:00:00	2.156
14/08/1972 @ 01:06:00	2.154
14/10/1962 @ 22:55:46	2.149
02/06/1965 @ 23:29:57	2.149
08/10/2005 @ 13:20:00	2.147
12/10/2000 @ 22:10:00	2.137
03/04/1980 @ 00:10:07	2.136
26/06/1958 @ 22:41:28	2.132
28/05/2002 @ 11:55:00	2.131
23/05/1982 @ 23:03:21	2.130
08/02/1989 @ 12:15:00	2.130
06/09/1990 @ 23:30:00	2.130
14/06/1972 @ 00:10:00	2.129
09/08/1994 @ 23:45:00	2.129
21/07/1970 @ 00:14:00	2.128
09/08/2002 @ 23:20:00	2.127
23/06/1974 @ 00:15:00	2.126
16/07/1976 @ 19:35:17	2.126
06/06/2004 @ 00:50:00	2.126
07/10/1994 @ 11:37:30	2.125
17/05/1972 @ 03:00:00	2.124
14/11/2001 @ 22:00:00	2.124
26/05/2001 @ 00:40:00	2.123
15/07/1998 @ 02:00:00	2.117
05/10/2005 @ 23:50:00	2.114
18/08/1970 @ 23:14:00	2.113
06/03/1979 @ 12:00:00	2.110
10/08/1991 @ 23:15:00	2.110
11/07/1972 @ 23:15:00	2.106
12/12/1977 @ 11:39:26	2.105

Event Date/Time	Elevation (m)
02/07/1996 @ 23:45:00	2.103
26/05/1998 @ 23:30:00	2.102
26/09/1976 @ 12:15:00	2.101
24/06/1978 @ 00:57:47	2.100
02/08/1988 @ 01:15:00	2.099
28/08/1992 @ 10:45:00	2.099
08/08/1975 @ 23:03:38	2.098
07/11/2002 @ 12:10:00	2.098
26/08/1976 @ 22:48:50	2.096
07/09/1995 @ 21:15:00	2.095
16/10/2001 @ 22:30:00	2.095
30/09/1996 @ 00:00:00	2.092
25/06/2001 @ 01:25:00	2.090
18/04/2003 @ 11:50:00	2.089
23/11/1980 @ 11:28:32	2.088
20/12/1972 @ 10:19:03	2.087
26/07/1986 @ 01:45:00	2.086
29/09/1981 @ 11:14:29	2.085
07/09/1979 @ 23:21:48	2.083
19/08/1993 @ 23:45:00	2.082
13/11/1996 @ 12:00:00	2.082
08/02/1962 @ 00:13:21	2.081
23/06/1990 @ 23:15:00	2.081
17/09/1974 @ 23:30:00	2.080
04/07/1960 @ 02:32:22	2.080
05/06/1981 @ 00:33:08	2.080
07/04/1997 @ 10:45:00	2.080
03/03/2006 @ 13:35:00	2.079
06/04/1962 @ 23:48:11	2.078
11/07/1968 @ 23:10:53	2.078
16/10/1970 @ 23:28:00	2.076
13/07/2002 @ 00:10:00	2.076
04/10/1975 @ 21:45:00	2.073
09/09/1998 @ 00:00:00	2.072
23/05/2001 @ 23:00:00	2.072
10/12/1977 @ 09:53:17	2.071
03/07/1981 @ 23:59:49	2.071
28/08/1965 @ 23:27:32	2.070
30/07/1969 @ 23:45:00	2.070
24/12/1995 @ 12:15:00	2.070
27/06/1998 @ 00:45:00	2.069
03/02/1995 @ 13:00:00	2.066
15/11/2004 @ 12:35:00	2.066

Event Date/Time	Elevation (m)
26/03/1967 @ 10:36:12	2.065
19/02/1980 @ 12:51:26	2.062
13/04/1979 @ 11:16:29	2.059
11/06/1980 @ 21:38:29	2.057
19/03/1996 @ 22:45:00	2.057
14/10/1996 @ 11:15:00	2.057
22/11/1968 @ 11:28:23	2.056
25/06/1993 @ 02:15:00	2.056
24/09/1980 @ 22:00:00	2.055
27/03/1982 @ 12:14:07	2.055
02/02/1991 @ 13:00:00	2.054
04/04/1996 @ 23:30:00	2.054
05/04/1982 @ 08:44:46	2.049
27/08/1984 @ 23:30:00	2.048
30/07/1992 @ 23:30:00	2.047
19/03/1992 @ 11:00:00	2.045
01/05/1976 @ 07:58:41	2.043
09/08/1990 @ 00:00:00	2.042
30/05/1995 @ 23:30:00	2.042
04/11/1998 @ 10:15:00	2.042
07/08/1974 @ 00:00:00	2.041
15/08/1996 @ 23:30:00	2.041
25/12/2003 @ 11:55:00	2.041
17/10/1997 @ 23:30:00	2.040
20/02/1996 @ 11:45:00	2.037
15/08/1992 @ 23:30:00	2.034
25/09/2000 @ 20:50:00	2.034

Table B3 Future Information Recommendations

Information Recommendations	Soft shore		Inundation/flooding		Cliff instability		Wind blown sands	
	Regional Scale	Site specific	Regional Scale	Site specific	Regional Scale	Site specific	Regional Scale	Site specific
LiDAR								
open coast	X	X	X	X	X	X	X	X
estuary	X	X	X	X	X	X		
Water level analysis								
open coast			X	X				
estuary			X	X				
Video Analysis								
open coast	X	X						
estuary								
Geology Failure mechanisms								
open coast					X	possibly		
estuary					X	possibly		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