Executive Summary

This report assists in providing long term guidance for the future management of coastal hazards in the Wairarapa. It provides information on the underlying issues on sea level rise, storm surge, tsunami, coastal erosion and maritime and recreational hazards. It complements the views published by the Ministry for the Environment on climate change and coastal erosion in New Zealand.

The Wairarapa coast is at risk from all of the above hazards. Recent reports and published literature suggest a large destructive tsunami (5-10 m or possibly greater) is likely to impact somewhere on the Wairarapa coast in the next 150 years. Damaging storm surges causing accelerated erosion of dune material and inundation of low lying land can be expected approximately once every 50 years at Castlepoint or Riversdale. The majority of the Wairarapa coast is in a state of natural erosion and rates of cliff recession have been measured at over 1 m per year along several eastern Palliser Bay sites. Sea level in New Zealand is rising and is projected to keep rising for several centuries. The most likely scenario for sea level rise due to human induced global warming along the New Zealand coast is for a rise of between 0.3 and 0.5 m in the next 50 to 100 years. This will worsen the storm surge, tsunami and coastal erosion hazards, although the El Niño-Southern Oscillation and Interdecadal Pacific Oscillation (IPO) cycles, which produce sea level fluctuations in the order of 0.15 m, will be the dominant control over these hazards in the next 40-50 years. Sea level rise will keep changing the physical drivers such as wind, waves and sediment transport patterns and the hazards that these drivers create.

Pressures to develop the Wairarapa coast are growing. A robust planning and policy framework is in place to cope with these coastal hazards, although it is not always used as effectively as it could. The New Zealand Coastal Policy Statement (NZCPS) is an important document for regional and district councils when it comes to planning for coastal hazards and the way in which these hazards are continually being changed by sea level rise. In largely undeveloped areas, such as the Wairarapa, pre-planned retreat using coastal hazard zones is the only cost effective long term option to deal with tsunami, storm surge, coastal erosion and sea level rise hazards.

Education must form an important part of future hazard planning in the Wairarapa. There is a need for education on all coastal hazards. A better informed public will gain acceptance of the consequences of these hazards and will be more likely to buy into response options at the local level.

There is a need for more information on current coastal processes. Very little is known about the large scale sediment transport patterns along the Wairarapa coast. More research is required to allow coastal setback zones to be put in place in undeveloped areas and to be updated where they already exist. Mapping coastal topography is a key requirement for advancing our knowledge of tsunami, storm surge, coastal erosion and sea level rise hazards. Progressing with both of these requirements may require regional or even national co-ordination.

Due to the Wairarapa coast being mostly undeveloped and the gradual nature of the worsening of the sea level rise hazard, there is the time in the Wairarapa to plan prudently for many of the coastal hazards. This planning must begin now, particularly with respect to coastal hazard zones, coastal process research and public education and involvement programs. There is a strong policy framework in place, and with education, public discussion, further research, gradual adjustment to long term response options and more comprehensive regulation, this framework will provide the necessary guidance to help protect land, infrastructure and people from coastal hazards.

Acknowledgements

I wish to thank Rylee Pettersson, Karen Williams and Steve Blakemore for their comments on the draft of this report, Grant Kneebone for the lending of valuable coastal process literature, and Des Peterson for his assistance with preparing the ArcView figures and plotting the 10 m contours at Riversdale and Whatarangi. I would also like to thank Helen Marr for her assistance with regional and district planning issues.

This report was prepared by Sam Barrow, Wellington Regional Council.

Contents

Chapter 1.

Introduction

1.1 Introduction

The purpose of the Wairarapa Coastal Strategy is to enable the community to establish a long-term integrated strategy to protect, manage and develop the coastal environment. The strategy has a long term planning horizon (looking towards our grandchildren's future), and the recommendations and outcomes of the strategy are intended to go beyond the scope of the Resource Management Act to encompass wider Council and community goals.

It is intended that this technical report on coastal hazards will feed into subsequent documents such as the Issues and Options Paper, and the draft and final versions of the Coastal Strategy, as well as assist with various community consultation forums. This report is one of a series aimed at addressing key technical issues for the Strategy. Other technical reports include:

- Planning Context and Methods
- Landscape
- Natural Environment and Ecology
- Heritage
- Built Environment and Infrastructure
- Access and Recreation
- Land Use & Development

The Coastal Strategy process is being undertaken by the Wairarapa Coastal Strategy Group, comprising the Masterton, Carterton, and South Wairarapa District Councils, the Wellington Regional Council, and local Iwi. This group formed after concerns that development was proceeding along the Wairarapa coast in an ad hoc and fragmented way. The development of the Wairarapa Coastal Strategy will span three calendar years, with most of the work occurring in 2002 and 2003 (Figure 1.1).

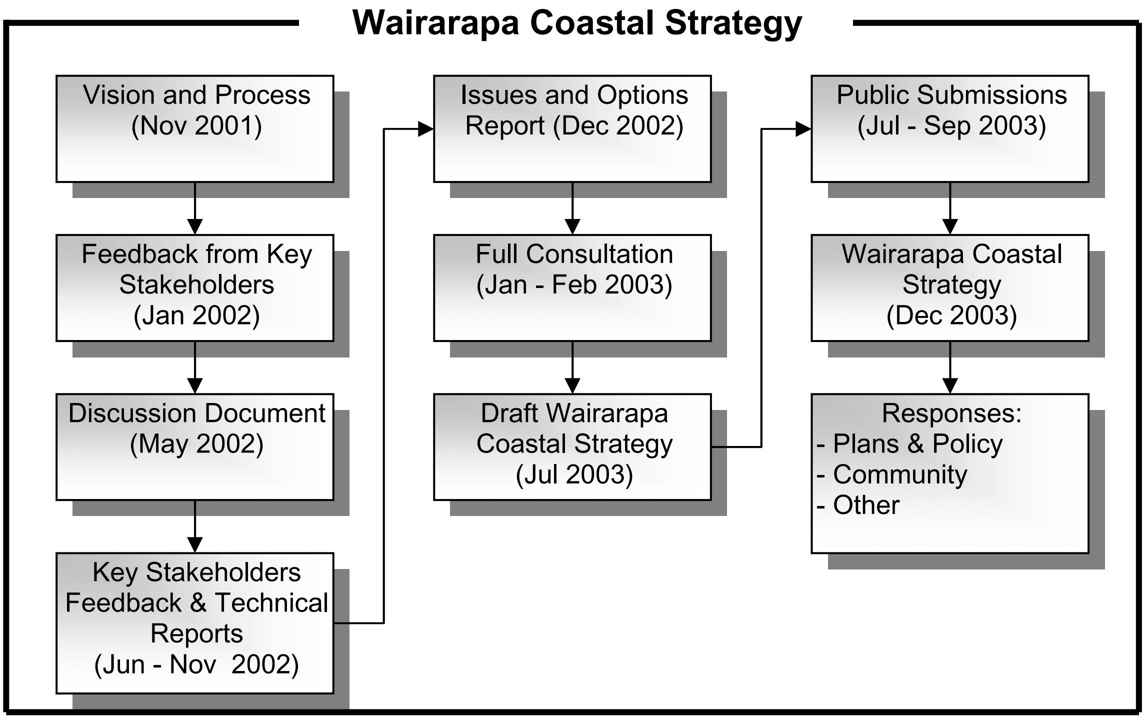

Figure 1.1. Wairarapa Coastal Strategy process

A key issue for sustainable and integrated management is to minimise potential conflict between land uses and values on the coast such as natural character, landscape, natural ecosystems, cultural heritage and recreation. Likewise, coastal land uses and values can be impacted upon by factors such as natural hazards (particularly erosion) and infrastructural constraints.

1.2 Purpose of This Report

The purpose of this report is to highlight the coastal hazards that need to be considered for prudent planning of the Wairarapa coastal environment. It has been written for the benefit of the Wairarapa Coastal Strategy. It discuss how these hazards may affect, or are affecting the management of land, people and structures on the coast, and sensible directions for planning to mitigate against their harmful affects.

This has been a desktop study. It provides an up to date gathering, and brief comment on, existing information and research on coastal hazards relevant to the Wairarapa. Some of this information, such as that relating to global warming, is relatively new or poorly understood in general. Clear explanation of what this information could mean for coastal hazard planning is required and is discussed in this report.

1.3 Aims and Objectives

To comprehensively deal with the topic of coastal hazards is an enormous task for any stretch of coast, regardless of the coastal setting. The processes involved in creating potentially hazardous coastal environments include a complete range of geological and atmospheric processes, the forecasting and mitigating of which has now become complicated by the advent of the new and ever changing impacts of human induced global warming. This report aims to assist planners understand the underlying issues with coastal hazards in the Wairarapa and provide initial guidance for developing future plans to mitigate against their harmful effects.

Specifically, the aims of this report are to:

1. Provide an overview of the planning framework allowing for the management coastal hazards.
2. Provide brief physical descriptions of the coastal hazards likely to affect the Wairarapa to increase awareness of their associated effects.
3. Describe how these hazards specifically affect the Wairarapa coast and what the vulnerabilities are.
4. Taking into consideration the Wairarapa's physical coastal environment and the level of knowledge on Wairarapa coastal processes, and the guiding policies of the main statutory framework, provide some direction for sensible future management of coastal hazards in the Wairarapa.
5. Provide a list of helpful further reading to supplement the topics discussed. A glossary of terms used in the text is also provided.

1.4 Report Structure

The introduction states the main aims of the Wairarapa Coastal Strategy and this report. Chapter 2 provides an outline of the statutory framework in place to plan and mitigate against coastal hazards nationally and locally. Chapter 3 begins by clarifying the terms used in the report to describe the coastal zone, as used by coastal planners and researchers, and describes the coastal setting of the Wairarapa. It then briefly describes the coastal hazards and their associated harmful affects which can potentially impact the Wairarapa coast. Chapter 4 discusses those hazards with respect to Wairarapa vulnerabilities. Chapter 5 provides some future direction for coastal hazard management in the Wairarapa. Chapter 6 provides conclusions and recommendations.

Chapter 2.

Statutory Framework for Managing Coastal Hazards

This section briefly outlines the statutory framework in place to guide the management of coastal hazards. The management of coastal hazards in New Zealand is conducted mainly through the framework provided by the Resource Management Act 1991 (RMA). The purpose of the Act is to promote the sustainable management of natural and physical resources. All policies, methods and rules developed under this legislation with regard to all natural hazards must therefore take into account this purpose.

The Resource Management Act 1991

Natural hazards are addressed in the following sections of the RMA:

> **3.** ***Meaning of ``effect''---In this Act, unless the context otherwise requires, the term ``effect'' in relation to the use, development, or protection of natural and physical resources, or in relation to the environment, includes--***
>
> *(e) Any potential effect of high probability; and*
>
> *(f) Any potential effect of low probability which has a high potential impact.*

Coastal hazards fall within these meanings and are required to be taken into account in the preparation of planning documents and the consideration of activities requiring resource consent.

Section 2 of the Fourth Schedule of the RMA sets out the matters that should be considered when preparing an assessment of effects on the environment in relation to natural hazards as follows:

> **2.** ***Matters that should be considered when preparing an assessment of effects on the environment---Subject to the provisions of any policy statement or plan, any person preparing an assessment of the effects on the environment should consider the following matters:***

(f) Any risk to the neighbourhood, the wider community, or the environment through natural hazards or the use of hazardous substances or hazardous installations.

30. Functions of regional councils under this Act---

(1) Every regional council shall have the following functions for the purpose of giving effect to this Act in its region:

c. The control of the use of land for the purpose of---

(iv) The avoidance or mitigation of natural hazards

d. In respect of any coastal marine area in the region, the control (in conjunction with the Minister of Conservation) of---

(v) Any actual or potential effects of the use, development, or protection of land, including the avoidance or mitigation of natural hazards and the prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances

31. *Functions of territorial authorities under this Act---Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:*

b. The control of any actual or potential effects of the use, development, or protection of land, including the implementation of rules for the avoidance or mitigation of natural hazards and the prevention and mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances:

35. ***Duty to gather information, monitor, and keep records---(1) Every local authority shall gather such information, and undertake or commission such research, as is necessary to carry out effectively its functions under this Act.***

5) The information to be kept by a local authority under subsection (3) shall include--

(j) Records of natural hazards to the extent that the local authority considers appropriate for the effective discharge of its functions;

65. *Preparation and change of other regional plans---(1) A regional council may have, in addition to its regional coastal plan, one or more regional plans prepared in the manner set out in the First Schedule.*

(c) Any threat from natural hazards or any actual or potential adverse effects of the storage, use, disposal, or transportation of hazardous substances which may be avoided or mitigated

New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement (NZCPS) was issued in 1994 by the Minister of Conservation, and sets out coastal policies in order to achieve the coastal management regime in the Resource Management Act 1991. The Act requires a coastal policy statement to guide the management of the coastal environment. The NZCPS is particularly relevant for regional and local authorities. Section 3.3 recognises that there is a relative lack of understanding about coastal processes and the effect of activities in the coastal zone and that a precautionary approach should be used on proposed activities. Section 3.4 of the NZCPS discusses the management of coastal hazards and recognises sea level rise, coastal erosion and seawater inundation as potential management problems. The policies recognise the general dynamic and unpredictable nature of coastal processes over time. Emphasis is placed on avoiding development in hazardous areas, and where existing use of land is threatened, mitigation using coastal protection works only when there are no other practicable options for the future. Section 3.4 – "Recognition of natural hazards and provision for avoiding or mitigating their effects" is given below.

> ***Policy 3.4.1***
>
> *Local authority policy statements and plans should identify areas in the coastal environment where natural hazards exist.*
>
> ***Policy 3.4.2***
>
> *Policy statements and plans should recognise the possibility of a rise in sea level, and should identify areas which would as a consequence be subject to erosion or inundation. Natural systems which are a natural defence to erosion and/or inundation should be identified and their integrity protected.*
>
> ***Policy 3.4.3***
>
> *The ability of natural features such as beaches, sand dunes, mangroves, wetlands and barrier islands, to protect subdivision, use, or development should be recognised and maintained, and where appropriate, steps should be required to enhance that ability.*
>
> ***Policy 3.4.4***
>
> *In relation to future subdivision, use and development, policy statements and plans should recognise that some natural features may migrate inland as the result of dynamic coastal processes (including sea level rise).*
>
> ***Policy 3.4.5***

New subdivision, use and development should be so located and designed that the need for hazard protection works is avoided.

Policy 3.4.6

Where existing subdivision, use or development is threatened by a coastal hazard, coastal protection works should be permitted only where they are the best practicable option for the future. The abandonment or relocation of existing structures should be considered among the options. Where coastal protection works are the best practicable option, they should be located and designed so as to avoid adverse environmental effects to the extent practicable.

Regional Policy Statement

The Regional Policy Statement (RPS), prepared by the Wellington Regional Council in 1995 provides an overview of the natural hazard issues facing the region and a framework for managing these hazards. The hazards considered are those defined in Section 2 of the RMA, i.e., earthquake, tsunami, erosion, volcanic and geothermal activity, landslip, subsidence, sedimentation, wind, drought, fire or flooding. There are several policies in the RPS directly relevant to planning development at the district level and these are detailed under district plans below.

Regional Coastal Plan

The Regional Coastal Plan (RCP) controls activities in the coastal marine area (CMA) of the Wellington Region. The outer boundary of the CMA reaches as far as the territorial limit at sea and the inner boundary is the line of mean high water springs. This inner boundary is, by nature, dynamic. Its position changes with altering shoreline profiles and sea levels.

The RCP recognises the presence of coastal hazards in coastal resource management planning, although there are no specific rules controlling the use of the coast to reduce the impacts of coastal hazards.

Within the general objectives and policies of the RCP several references are made to coastal hazards. A general environmental objective of the plan is that:

"Any adverse effects of natural hazards are reduced to an acceptable level".

Development activities are considered more specifically in the general objective (4.1.11) stating:

"That the location of structures and/or activities in the coastal marine area does not increase the risk from natural hazards beyond an acceptable level".

There is also a general policy dealing with development activities in the coastal marine area (4.2.21), stating that the activities must take appropriate account of natural hazards. Natural hazards in the coastal marine area in the RCP include erosion, sedimentation, inundation, tsunami and earthquake.

Palmer 1993 outlines regional council functions, duties and powers and liability in respect of natural hazard mitigation. An interpretation is provided of regional council statutory functions, powers and duties under the Resource Management Act and related statutes.

Regional and District Plans Outside Wellington

Tonkin and Taylor (2002) reviewed eight regional and 14 New Zealand district plans to establish how coastal hazards, specifically tsunami, are addressed around the country. Of the plans, 16 had objectives relating to natural hazards, most of these concerning coastal hazards. Only five of the plans adopted rules which related to coastal hazards or some other natural hazard. They found no plans had any objectives or rules specifically addressing tsunami hazard in New Zealand. However, the rules relating to coastal hazards, such as coastal building line restrictions and relocatable building zones for coastal erosion, go some way to dealing with the tsunami hazard in these areas.

DTec consultants (Christchurch) and NIWA have undertaken a survey of territorial authorities and regional councils to assess the degree to which their plans and policies have specifically taken sea level rise into account (Bell et al 2001a). While all councils are aware of sea level rise as a potential threat the level of restriction applied varies across different plans. Southland, Otago and Bay of Plenty regional coastal plans have included a magnitude of sea level rise to be used for developments and consents. Canterbury, West Coast, Waikato, Auckland and Northland have restrictions on structure and reclamation design due to sea level rise but are not so definite as to what restriction they will apply. Gisborne and Bay of Plenty coastal plans are the only plans to state that the effects of sea level rise will be incorporated into hazard zones. The survey also found that plans which have more emphasis on sea level rise as opposed to other coastal hazards are those within more densely populated areas and with more infrastructure i.e. it is mainly the city plans which consider sea level rise to be a threat.

Wairarapa District Plans

District Plans are responsible for controlling activities in the coastal management area landward of mean high water springs. The width of this area is not fixed and has been determined differently by each council. In the Masterton, Carterton and South Wairarapa regions this area is primarily rural in character.

District plans are currently prepared by the Masterton, Carterton and South Wairarapa district councils and they must not be inconsistent with all other policies and plans above it in the framework including the NZCPS. The three Wairarapa territorial authorities have primary control over the use of coastal land.

All three district plans have policies and rules guiding development within coastal hazard zones. The Masterton District Council identifies "natural hazard areas" as:

> *An identified area in which the risks from a specified natural hazard have been determined to be unacceptable because of the frequency and magnitude of the hazard in relation to the adverse effects that the use and development of the effected land may have on community safety, changes in the level of risks in other areas or offsite impacts on the environment in general.*

Natural hazard areas are identified in the plan and for coastal areas include:

- *Riversdale Urban Management Area; the hazard area varies in width as shown on the maps in Appendix F2 (page 234). Reference should always be made to Appendix F2 in conjunction with the rules.*
- *Castlepoint Urban Management Area; 30 metres*
- *60 metres along the rest of the coast.*

The hazard area for Riversdale Beach is a zone of varying width lying landward of the toe of the dune and in some places traverses over the front row of sections. The Plan states that the area seaward of this hazard line may be subject to possible coastal erosion up to 2050 AD Any application for an activity in these coastal hazard zones is assessed according to the following criteria:

- *The probability and possible magnitude of an event.*
- *The type, scale and distribution of any potential effects from the hazard(s).*
- *The nature of the activity and the degree to which it may increase the potential risk to human life, other property and/or the environment.*
- *The measures proposed to mitigate any effects, alternative means of mitigation considered (such as the ability to relocate a dwelling or establish an appropriate foundation height) and their various potential impacts.*
- *Any recommendations from a qualified professional such as a specialist engineering geologists or geotechnical engineer.*
- *The outcome of any consultation undertaken with the regional council and any recommendations resulting from that consultation.*

The Carterton District Council recognises the coast is subject to coastal inundation and erosion. The Plan specifically recognises the possibility of a locally generated tsunami and that there will be little warning for such an event. However, the plan does not deal with tsunami, except to the extent provided by the coastal management area. This coastal management area is a zone within 60 m of mean high water spring.

Specific criteria are used to assess the adverse effects of development within the coastal management area.

The South Wairarapa District Council Plan also includes a coastal hazard zone and under *6.2.2 Building Standards*, it is stated that:

> *(1) Subject to (2) below, no building shall be erected within 30 metres of:*
>
> > *(a) The mark of mean high water springs of the sea; or*
> >
> > *(b) The margin of every lake in excess of 8 hectares in area; or*
> >
> > *(c) The banks of all rivers and streams which have an average width of not less than 3 metres; or*
> >
> > *(d) 5 metres of any other water course.*
>
> (2) *The requirements in (1) above shall not apply to farm culverts and bridges or to buildings and structures for protection of the natural values of the wetland, river or lake and its margins from human activities or interpretation of the natural values of the area within which the wetland, river or lake is located, or for public safety, may be permitted closer. Such buildings would include boardwalks, tracks, bridges, interpretation signs, hides, animal or plant enclosures or enclosures.*

The South Wairarapa District Council Plan also states, in *Section 7 – Assessment Criteria*, that:

> *(14) Activities in the coastal environment will be assessed in terms of the relevant provisions of the regional policy statement, in particular, Part 7.4, Policies 1 and 2.*
>
> *(15) Activities near water bodies will be assessed in terms of the adverse effects on riparian and coastal vegetation and in particular, the value of such vegetation to enhance water quality, reduce the potential for erosion and lesson the impact of flooding and enhance aquatic and terrestrial habitat.*

Relevant sections of Policies 1 and 2 of Part 7.4 of the Regional Policy Statement include:

Policy 1 *To give effect to the following matters when planning for and making decisions on subdivisions, use and development in the coastal environment.*

(4) Protection of the integrity, functioning and resilience of the coastal environment in terms of the:

(a) Dynamic processes and features arising from the natural movement of sediments, water and air;

Policy 2 *To consider, where relevant and to the appropriate extent, the following matters when planning for and making decisions about subdivision, use or development in the coastal environment:*

(3) The potential impact of projected sea level rise;

Policy 6 is also relevant for land use planning at the district level and puts an emphasis on planning for low probability, high impact events, as recognised in Section 3 of the RMA. Policy 6 of the Regional Policy Statement states:

Policy 6 *To adopt a precautionary approach to the evaluation of risk in making decisions that affect the coastal environment, recognising that there will be situations where there is a low probability of an event occurring, but that such an event has the potential to create major adverse effects. Such events include:*

(1) Earthquakes and tsunami;

(2) Maritime shipping disasters; and

(3) Accidents involving release of contaminants into the coastal marine area.

The Building Act

Section 36 of the Building Act deals with building consents on hazard prone sites. Restrictions are applied to building activities subject to erosion, avulsion, alluvion, falling debris, and subsidence, therefore they have some relevance to land use planning in coastal areas. The three Wairarapa territorial authorities administer the Act and can place controls on buildings in tsunami and storm surge flooding areas.

The Civil Defence Act 1983 and Subsequent Plans

The Civil Defence Act, National Civil Defence Plan, Wellington Regional Civil Defence Sub Plans and the District Council Civil Defence Plans describe the responsibilities, organisation and concept of operations necessary for national emergencies and smaller civil defence emergencies. Part 4 of the Wellington Regional Council Civil Defence Sub Plan deals specifically with responding to a major tsunami event. The role of the Pacific Tsunami Warning Centre in warning of distantly generated tsunami for New Zealand is described.

The Civil Defence and Emergency Management Bill currently before parliament states that Civil Defence Emergency Management Groups must be formed by regional and territorial authorities to deal with the four R's of comprehensive emergency management: reduction, readiness, response and recovery. Lifeline utilities must also be sure they can function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency. This is particularly relevant for lifeline utilities when considering tsunami and storm surge events.

Non-statutory Methods

Non-statutory methods are available for regional and district councils in mitigating coastal hazards. These include education and awareness programs, coastal signage, coastal care groups, reserve management and research and hazard identification.

Chapter 3.

What are the hazards?

3.1 Introduction

The Wairarapa coast is exposed to several types of processes that could harm life or property in the coastal area. For hazard planning purposes it is helpful to deal not with all of these processes individually, but to categorise each coastal hazard based on its end effect. For example, storm surge is a coastal hazard influenced by many different meteorological and hydrological processes and morphological elements, but the result is inundation of normally dry land by seawater, increased coastal erosion and damage to infrastructure. It is these effects that must be planned for, therefore it is the storm surge and all the processes and elements which this term embodies which must be considered when designing hazard zone widths, for example.

This chapter very briefly introduces each of the hazards by describing their general nature and the processes and elements which make up each one. It is not the purpose of this chapter to provide detailed information on these hazards or how these hazards specifically affect Wairarapa coastal localities. Several sources of information are referred to should a more in-depth description be required.

The coastal hazards affecting the Wairarapa are broken into six main categories. They are tsunami, storm surge, coastal erosion, long term sea level change, recreational and maritime hazards, and land based hazards. Coastal erosion is described in the sea level rise section. While coastal erosion is occurring independently of sea level rise, an understanding of coastal erosion is a major part of dealing with the coastal effects of sea level rise. Coastal erosion is dealt with separately when the hazard specific to the Wairarapa is discussed.

3.2 Definitions

The coast and the coastal zone

The coastline is where the land meets the sea. However, it is not easy to define exactly where the sea finishes and the land begins. Scientists and coastal planners use different definitions of the "coast" and "coastal zones" and elements within these areas and so it is important to distinguish between the two types of definitions to avoid confusion. Scientists sometimes refer to the "coastal zone" as the area between the landward limit of marine influence and the seaward limit of terrestrial influence (Carter 1988). As well as this, coastal process scientists use terms to describe processes of waves and currents in the nearshore and the morphology of the littoral zone. These definitions are well established and important when describing coastal processes and the hazards they create.

Coastal planners in New Zealand have defined the "coastal zone" in many different ways and for various management purposes in legislative documents, plans and reports. However, the general definition of the coastal environment (i.e. the coastal marine area and the area landward of this, as separated by the line of mean high water springs) provides a definition suitable for delegating responsibility to the various authorities. **Figure 3.1** shows the terminology used by coastal scientists in coastal process studies. A full explanation of these terms can be found in the glossary. These terms will be referred to as required throughout this report.

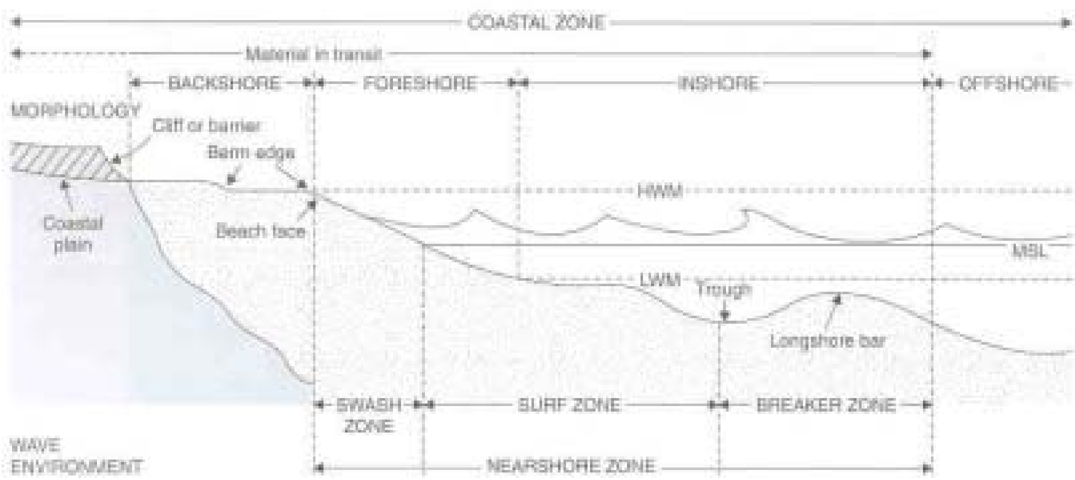

Figure 3.1. Morphological and wave process terms used to describe the coastal zone. Terms used throughout the report are described in the glossary (From Haslett 2000).

3.3 Coastal Setting

Before defining and describing the coastal hazards affecting the Wairarapa, and discussing the possibilities for managing and mitigating against the harmful effects of these hazards, it is important to “set the scene” by first describing the coastal setting of the Wairarapa, particularly its coastal geomorphological setting.

An emphasis is placed on the current processes and morphology rather than the paleoenvironments. While both can provide important clues to the hazardscape of an area, the current processes and landforms are more relevant for planning in the next 50-100 years. Also, there is very limited information available on paleoenvironments in the Wairarapa.

The study of coastal geomorphology, in a very broad sense, deals with the morphological makeup of coasts and the past, present and future processes that contribute, or may contribute, towards that makeup. Understanding the coastal geomorphological and geological setting of an area means understanding the type and severity of hazards that have, or may, affect that area.

The Wairarapa coast is largely unpopulated and rural in character with low lying coastal settlements or infrastructure at Ocean Beach, Lake Ferry, Ngawi, Whatarangi, Flat Point, Riversdale Beach, Castlepoint and Mataikona **(Figure 3.2)**. Riversdale Beach has the greatest number of permanent residents so from a susceptibility viewpoint, represents the highest coastal hazard area in the Wairarapa.

Coastal and submarine geology

A zone of strain and crustal deformation occurs through the east of the North Island because of the subduction of the Pacific Plate under the Indo-Australian Plate. In the Wairarapa, the Pacific Plate is in a relative movement beneath and towards the Indo-Australian Plate at approximately 40 mm/year. The Pacific Plate starts sliding beneath the Indo-Australian Plate at the Hikurangi Trough, about 150 km east of Castlepoint. The Wairarapa area, both onshore and offshore, is characterised by numerous strike-slip and dip-slip faults. Coasts of this type are often referred to as collision coasts or leading edge coasts and are usually characterised by rocky cliffs and platforms and dominated by erosion.

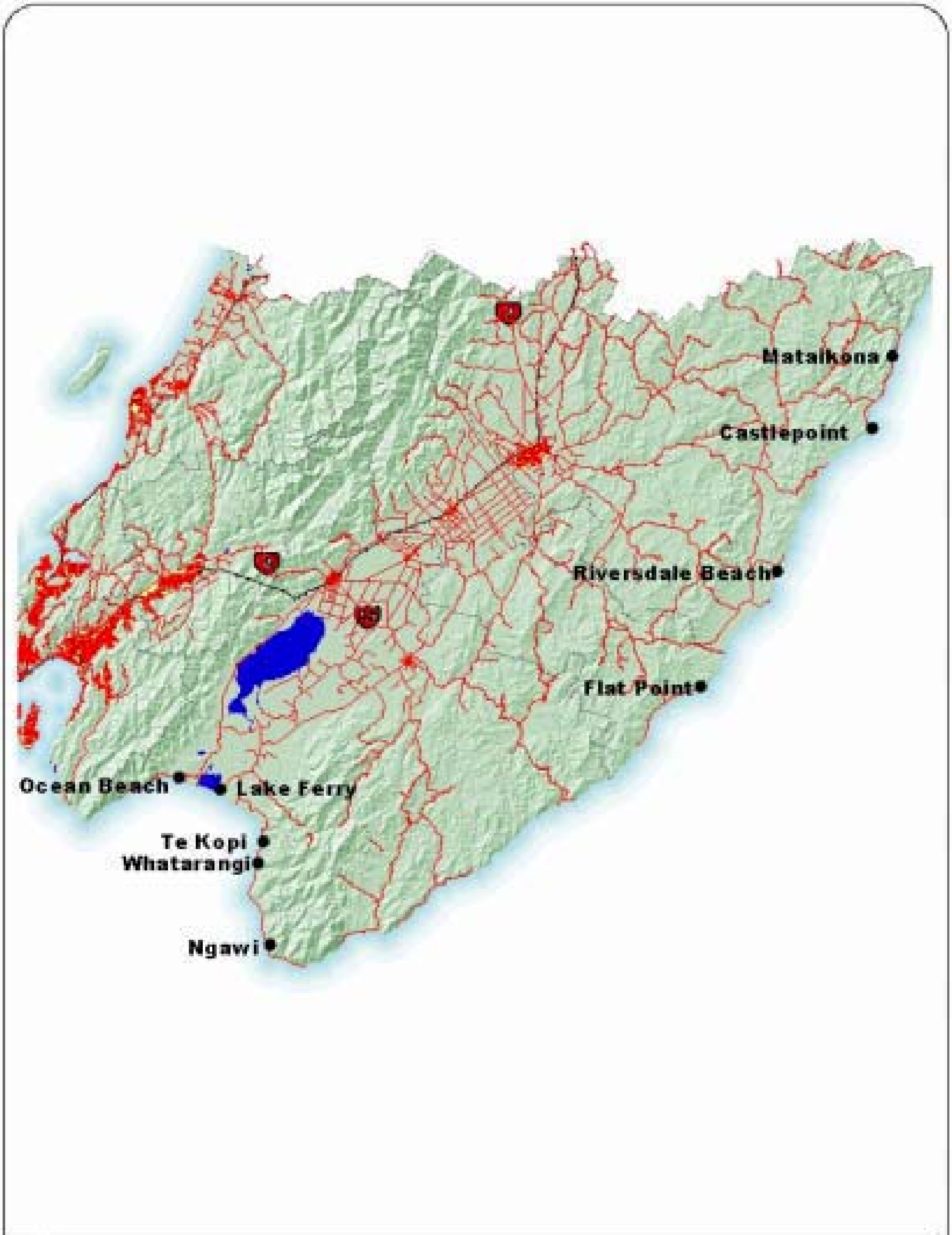

Figure 3.2. Main Wairarapa coastal settlements

Wellington Regional Council

Offshore, the Wairarapa consists of a narrow continental shelf to the south which widens to the north. Numerous offshore faults have been mapped, particularly to the south east of the Wairarapa (see Barnes and Audru 1999a, 1999b, Barnes et al 1998, Carter 1989). The nature of the bathymetry offshore from the Wairarapa has implications with respect to the coastal hazards they create. The bathymetry is diverse and rugged with potential for landslide generation and dip-slip fault rupture **(Figure 3.3).**

The Wairarapa landscape is predominantly Quaternary in age due to continuing active tectonics, erosion of uplifting mountains and deposition into lowlands. The Wairarapa coastline is made up of many different rock types with a wide range of ages and physical properties. The Cape Palliser area consists of well indurated greywacke and is extremely rugged in nature. Softer limestones and mudstones occur in many areas including Palliser Bay, White Rock and Castlepoint.

Numerous wave cut terraces along the Wairarapa coast indicate the area is undergoing long term relative uplift. Seven uplifted beach ridges can be seen at Turakirae Head, the oldest being 6500 years (Kamp and Vucetich in Soons and Selby 1982). Older and higher marine benches, which formed during the last interglacial period when sea level was about 120 m higher than today, have also been mapped in many coastal localities in the Wairarapa. For example, marine benches 200 m above sea level occur at Flat Point.

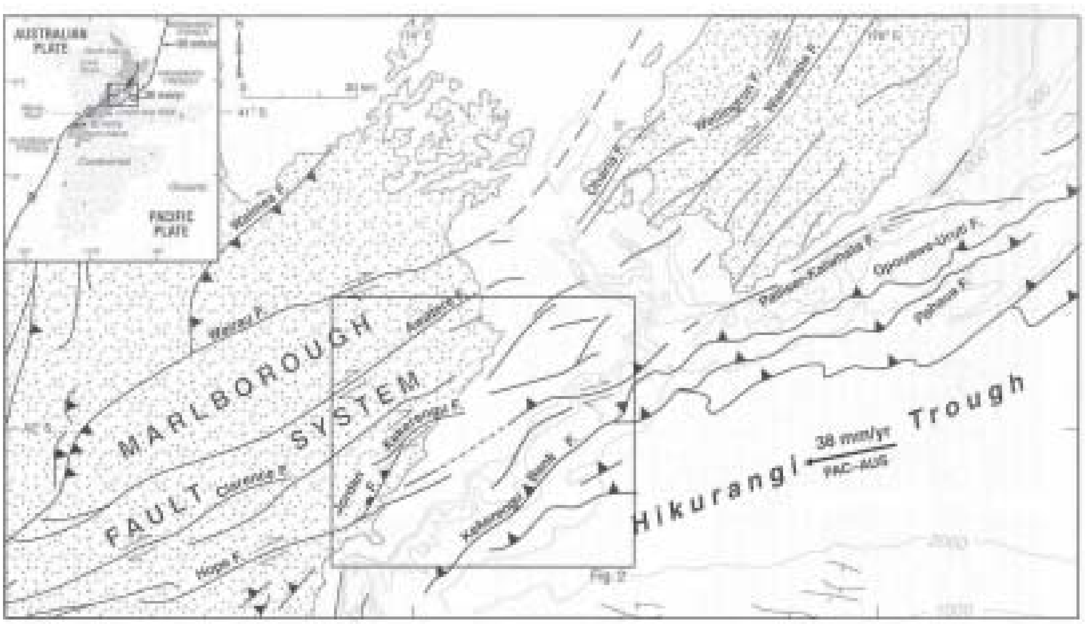

Figure 3.3. Major structural elements of the Pacific - Indo-Australian plate boundary zone in central New Zealand including the major offshore faults and bathymetry (m) (From Barnes and Audru 1999b).

Coastal type and coastal classification

The coastal geological setting of the Wairarapa has a strong influence on the hazards which exist there. The Wairarapa coast is a leading edge coast (or collision coast) and processes of erosion are dominant with very little sediment being deposited. Within this classification coasts can also broadly be described as exhibiting either erosional or accretional features. Much of the Wairarapa coast is in a state of erosion, although areas such as Riversdale and Castlepoint and other small pockets of beach material around the coast are accretional features.

Marine erosion generally produces retreat of the coast in the form of sea cliffs. Erosive cliffs normally undergo very slow rates of decay, although in cases where sea cliffs consist of soft material such as unconsolidated sandstone or mudstone, rates of erosion can be spectacular. Typical cliff recession rates for soft mudstone and sandstone cliffs are between 0.1 and 1.0 m/year (French 2001). This is the case at several locations in the Wairarapa, particularly in eastern Palliser Bay. The more resistant rocks retreat more slowly and remain as headlands while weaker formations are cut back to form embayments. Coastal limestones often form headlands such as at Castlepoint. Typical limestone recession rates are in the order of 1 mm to 1 cm/year (French 2001). Recession rates for Greywacke cliffs, such as those around Cape Palliser, are considerably less than this.

Although the Wairarapa coast is made up mainly of rugged, rocky outcrops, erosive cliffs and raised wave-cut platforms, there are also two types of beach deposits representing less energetic long term depositional environments. These two types are the sandy beaches found at Castlepoint and Riversdale Beach and the gravel and mixed sand/gravel beaches found in small pockets in many places along the eastern Wairarapa coast and the more extensive area on the seaward side of Lake Onoke and western Palliser Bay. While these sections of the coast do represent depositional environments, all beaches along the Wairarapa coast are highly dynamic and exposed to high wave energies (described below). They can therefore be subject to periods of erosion on time scales ranging from single storm events to decadal cycles of variability in climate, and longer.

Beaches are simply accumulations of unconsolidated sand, gravel, cobbles or boulders, or some mixture of these. The overall morphology of these beaches reflects the wave climate of the area and provides clues to the potential coastal hazards. In general, beaches of fine sand, such as Castlepoint and Riversdale, have low slopes and wide surf zones. In contrast the gravel and mixed sand/gravel beaches found in the Wairarapa have steep slopes and a narrow surf zone, if any at all. This contrast of beach type has prompted the development of the classification scheme by Write and Short (1983), which recognises a continuum of beach types based on beach slope, beach material and breaker type. At one end of the scale are dissipative beaches such as Castlepoint Beach and Riversdale Beach. Waves break well offshore on these beaches and continuously loose energy as they move towards the shoreline. During storm events when wave heights increase the waves simply break and dissipate their energy further offshore. The coarser grained beaches of the Wairarapa represent the intermediate and reflective parts of the classification scheme where the wave energy dissipation is concentrated in a much narrower band, close to the shoreline. Both are able to absorb considerable energy from waves and remain intact due to their transportable nature. This makes them very effective natural defences and prevents the steady erosion found on cliff sites. However, the way they respond to changing wave energies and man-made structures can still be a hazard for unmanaged beachfront property. Because populations invariably exist in these environments, an understanding of beach processes is often just as important, or more important than understanding sea cliff erosion.

Wave climate

All coasts are affected by wave energy. On wave dominated coasts, such as the Wairarapa, waves provide the energy that drive most of the coastal processes that create many of the coastal hazards we experience. An understanding of wind and wave climate is central to understanding the coastal geomorphological setting of an area and the potential hazards.

New Zealand's landmass shelters the east coast of the country from the prevailing westerlies and the wind generated waves from these winds. The prevailing wave type along the eastern New Zealand coastline, when observed from the shore, is a southerly sea, 0.5-1.5 m in height with a 7-11 second period (Pickrill and Mitchell, 1979). Although the western and southern wave climates of New Zealand are much more energetic, eastern New Zealand, including the Wairarapa coast, is still a high energy wave environment. The east coast can also receive significant energy from the rarer deep depressions or ex-tropical cyclones in the Pacific which can produce very high wave heights and long periods (i.e. Wahine Storm, Waitangi Day storm).

There are very few actual wave records along the Wairarapa coast, and where they do exist they are generally only observations from ships. However, there are two sites off the Wairarapa coast where a 20 year hindcast (from 1979 to1998) has been carried out (Gorman and Laing, 2001). These two sites were Te Kaukau Pt. and Riversdale Beach. The dominant wave direction for the Wairarapa is from due south but waves can arrive from a wide ranging window from due east to south-south-west. Waves coming from the south occur approximately 30 % of the time and from the south-south-west approximately 25 % of the time. For the remaining 45 % of the time waves come from the east and southeast. This predominant wave direction from the south produces a net movement of sediment northwards along the coast. In comparison, much narrower wave direction windows occur on the south Wellington coast and the Kapiti Coast. **Figure 3.4** shows the distribution of significant wave height for the sites off Riversdale Beach and Te Kaukau.

3.4 Tsunami

A tsunami is a very long period wave, or series of waves, generated by some sort of large disturbance on or close to the sea floor, or in rare instances on the sea surface or in the atmosphere. Sources so far recognised as causing disturbances capable of creating tsunami waves include submarine fault rupture, submarine volcanic eruptions, submarine landslides, terrestrial landslides along coasts, meteorite impact, and large atmospheric disturbances caused by volcanic eruptions or upwarping of large areas of land (Lowe and de Lange 2000). This last group can be termed meteorological tsunami and are generated by disturbances in the atmosphere which travel at the same speed as a tsunami wave in the ocean, allowing energy to be transferred from the atmosphere to the ocean (de Lange and Healy 1999).

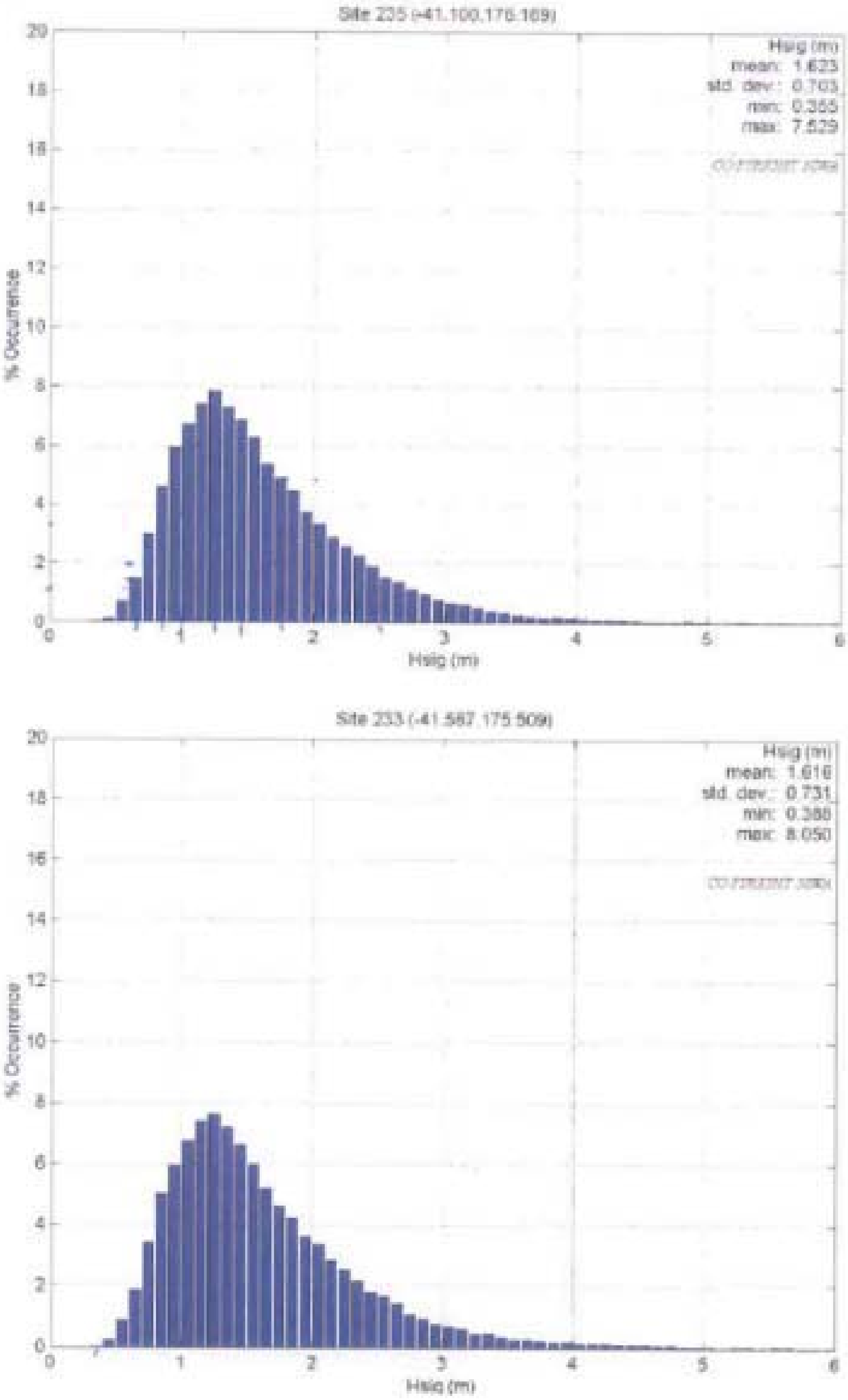

Figure 3.4. The distribution of significant wave height (average of the highest third of all waves) off Riversdale Beach (top) and Te Kaukau (bottom) (50 m water depth). The results are based on a wave hindcast for the period 1979-1998 inclusive, by Gorman and Laing 2001.

Submarine fault rupture and submarine landslides are the most common mechanisms for causing tsunami. Understanding the different processes involved and the different characteristics of the wave they produce is important when planning for tsunami hazard and understanding the risk for areas such as the Wairarapa, where there is a clear threat from both types. They both propagate and run up on land in different ways. Landslide generated tsunami do not have the capability to travel very great distances from their point of generation. Even a very large landslide generated wave will not be destructive once it travels more than about 1000 km from its source. Sources of relevance for the Wairarapa include areas on the continental shelf and slope off the east coast of New Zealand, particularly Cook Strait and the Hikurangi Trough. Unfortunately the propagation characteristics of landslide generated tsunami are still poorly understood due to the complex nature of the physical characteristics of a moving landslide. How energy is transferred to the water is still unclear. What is known is that landslides generate a limited number of waves that are not periodic, that is, they propagate independently of each other and do not arrive at the coast with a definable period, as fault generated tsunami do.

Tsunami created from fault movements do, however, travel vast distances through open ocean without dissipating much energy. Relevant sources for the Wairarapa therefore come from local sources as well as further afield, such as the west coast of South America and Alaska. For a tsunami to be created from submarine fault displacements there must be an abrupt displacement of water involving large volumes of water. The force from the sea floor must be applied rapidly and over a large area. This requires an earthquake of at least magnitude 6.3 and the hypocentre must be close to the sea floor. Subduction earthquakes i.e. those associated with the sliding of oceanic crust beneath continental crust, as is the case off the Wairarapa coast, can be very effective in generating tsunami, due to the large areas of sea floor involved.

Fault rupture mechanisms produce a long sequence of periodic waves which travel at approximately 800 km/hr and can be destructive over very large distances. The period of the waves is usually in the order of 15 to 60 minutes. Wave heights are indistinguishable in the open ocean.

As these waves travel towards a continent such as New Zealand they will undergo transformations which can increase or decrease the hazardous effects felt on the coast. Refraction will occur when the waves begin to bend towards shallow water, focussing the wave energy. Waves travelling over deeper water will tend to be dispersed. Waves can also be reflected off steep rises on the sea floor, such as the continental slope. However, waves can also be reflected off the shoreline and meet with the later incoming waves to magnify wave heights. As the sequence of periodic waves approach the shoreline they will undergo further transformations which again significantly alter the waves characteristics. These transformations are similar to those experienced by normal swell moving into shallow water, including the increase of wave heights.

Tsunami Hazards

The hazards from tsunami are created from runup processes. These can be broken into water impact effects, debris impact effects and still water effects. Waves will either behave as a rapidly rising and falling tide or as a breaking wave referred to as a bore. Most tsunami reaching New Zealand have acted as a rapidly moving tide with some bore formation up rivers and in estuaries. The runup height during these types of events is usually similar to the wave height. If the wave breaks into a bore at or before the shore, the maximum runup will usually be less than the wave height.

The level of tsunami hazard is generally evaluated by the maximum tsunami runup level i.e. the vertical runup level. Shallow onshore slopes generally reduce runup heights due to the frictional forces involved, but the area of land affected can still be large due the low slope angles. A steep onshore slope can encourage a runup height greater than the wave height. Surface roughness is also a major factor in determining runup heights. Vegetation, uneven topography and buildings help to dissipate energy and reduce runup heights.

If a tsunami comes onshore as a breaking wave then severe damage or complete destruction close to the coast can result **(Figure 3.5)**. The damage is mainly caused from the very high water current speeds produced from the turbulence. This turbulence can shift very large objects such as trucks and large fishing boats and cause complete destruction to buildings. These entrained objects, which can be anything from boats to grains of sand, will also increase the damage and create an even more life threatening situation. A breaking wave also has the capacity to bring onshore a huge amount of offshore sediment which will be deposited onshore as the energy from the turbulence subsides. Hazardous substances such as oil or chemicals can also be spread during tsunami runup.

Figure 3.5. Some of the destruction caused by the 1993 tsunami which hit Okushiri Island and southwest Hokkaido, Japan on July 12, 1993, killing 120 people. The tsunami was generated by a magnitude 7.8 earthquake close to the island. Photograph taken by George Butcher.

While breaking waves can be very damaging, the currents produced in the runup and backwash of a non-breaking wave can still be damaging and life threatening. The interactions between runup and backwash are complex, but often the backwash velocities of a non-breaking wave are greater than the runup velocites. The backwash will travel down the path of least resistance such as rivers and small streams or any man made topographic low leading to the sea. Most deaths associated with tsunami are either associated with people being swept out to sea by the backwash or colliding with entrained debris. Estimating the turbulence and current speeds likely for specific localities is very difficult due to the uncertainty of the type and size of wave likely to affect certain areas as well as the fact that a tsunami wave can recontour the land as it comes onshore, thereby affecting the return flow characteristics.

Still water effects of tsunami include the unwanted pooling of water on land after the tsunami waves have passed, and the contamination of productive land and buildings by salt water. There is very little known about the short and long term effects of salt water contamination from tsunami. The effects to rural areas such as the Wairarapa could be catastrophic.

3.5 Storm Surge

Storm surge is the world's most destructive natural hazard in terms of lives lost. More people die from storm surges each year around the world than from all other natural hazards combined. In New Zealand storm surge is probably the second most common natural hazard after flooding (de Lange 1996).

A storm surge is an abnormal, temporary rise in the level of the ocean causing flooding of low lying coastal areas. This rise in sea level is caused by a combination of the low atmospheric pressure associated with the passing of low pressure weather systems, and the action of wind blowing across the surface of the sea. For every 1 hPa drop in atmospheric pressure there will be approximately 10 mm of sea level rise below the mean pressure of 1014 hPa. This is called the inverted barometer effect. The action of wind blowing across the sea surface also adds to the overall bulge in the ocean if the wind is either blowing onshore or along the shore with the coast on its left.

In New Zealand these two mechanisms will contribute about the same amount to the total storm surge height. This total storm surge height will max out at around 1 m in New Zealand waters, although the total inundation level for some storms could exceed this substantially due to several factors. These include higher river levels around river mouths, wave set up at the coast, runup of large storm waves on the shore and longer term fluctuations in sea level caused by the El Niño-Southern Oscillation (2-5 years) and the Interdecadal Pacific Oscillation (IPO) (20-30 years). Both of these cycles are able to alter sea level, worsening or lessening the effects of storm surge elevations.

Obviously the tide plays an important role in understanding storm surge risk. The term 'storm tide' can be used more easily by emergency managers and planners as it refers to the maximum elevation gained by sea water due to a combination of the high tide and the storm surge components.

Storm surge hazards

The main hazards associated with storm surges are the flooding of low lying coastal land, the unusual penetration of storm waves and the increase in coastal erosion. Flooding from storm surges are generally more damaging than from river flooding due to the salinity of sea water and the damaging effects of storm waves. Coastal erosion during storm surges is generally worse than during non-storm surge events, even if the waves are the same height. This is due to the waves being able to break further inshore than normal due to the deeper water created by the storm surge. Not only are the waves able to erode material further inland and over a wider area than normal, but there is a greater capacity to transport sediment offshore. The sediment is often transported beyond the limits where normal 'fair weather' cycles can bring this sediment back towards the shore. More detail on storm surge and tidal extreme risk analyses can be found in Tait et al (2002) and de Lange (1996).

3.6 Tide

The tide is a regular and predictable raising and lowering of the water level along the coast and forecasting this type of coastal wave is important for coastal hazard prediction. There are many different tide generating constituents which generate waves of different periods, but the most obvious one is the main lunar semidiurnal constituent of 12.42 hours, which has the greatest influence over the normal tidal cycle. The size of this vertical variation is often of a similar order of magnitude to other changes in sea level which are considered hazards, such as tsunami, storm surge, wave attack and long term sea level rise. While tides are not a hazard on their own, they provide a 'dynamic base level' over which the hazardous processes operate. In the Wairarapa the normal tidal range is small at about 1 m. Even so, for communities such as Riversdale located close to sea level, 1 m is more than enough to make the difference between a potentially catastrophic tsunami or a non-damaging tsunami. While the timing of storm surge and tsunami events is difficult to predict, the timing of the tides can be accurately calculated and periods where extreme high tides are predicted can be ‘flagged’ as potentially high risk times for storm surge, wave attack and tsunami events. An extreme example of this will occur in Wellington on 10 April 2012 where the high tide is predicted to reach 0.89 m above the Wellington Vertical Datum (Tait et al 2002). A similar occurrence will occur on 7 April 2091. Smaller, less extreme high tides will occur more often than this. Normal spring high tides occur every two weeks.

3.7 Sea Level Change and Coastal Erosion

The level of the sea is always rising and falling and there are several mechanisms for this. The short term fluctuations in sea level have already been described. These include waves, storm surge, tsunami and tides. Their effects on the shoreline are highly variable over time and space, even within regions such as the Wairarapa.

Long term sea level changes are the result of changes in the amount of water stored, or density of surface water in the oceans and changes to the level of land masses. Eustasy is the change of the water level and isostasy is the vertical movement of land associated with the loading and unloading of continental ice. These two processes operating together produce the long term changes in sea level we are now observing along coastlines around the world.

Sea levels have naturally fluctuated over the Quaternary period (last 1.81 million years) by more than 100 vertical metres due to changes in the amount of water stored as ice. Sea level reached highstands during the interglacial periods and lowstands during glacial periods. About 6000 years ago sea level reached its present state and has remained fairly constant since. However, there is now strong evidence the global climate changes and associated sea level rise which have been observed over the last 50 years are human induced (IPCC, 2001a). This rise has been caused by a variety of factors but can be mainly attributed to the thermal expansion of the oceans caused by higher global air temperatures. The sea has been heating up and expanding in a vertical direction. There has so far been no significant contribution to rising sea levels from the melting of the polar ice sheets.

Long term changes in sea level affect the entire globe, but not necessarily by the same amount in all areas. Sea level rise relative to the landmass is what coastal planners and communities have to plan for, rather than the global sea level rise. Global sea level rise is the average vertical rise of the worlds oceans. Relative sea level rise is the net rise relative to the landmass of a region. The tide gauges around New Zealand which are used for sea level rise predictions in New Zealand measure relative sea level.

Global climate and sea level rise predictions

The Intergovernmental Panel on Climate Change (IPCC) has been established by the United Nations Environment Programme and the World Meteorological Organisation. Every five years since 1990 it has produced an assessment of global changes in greenhouse gas levels and sea level rise. **Figure 3.6** shows envelopes for global temperature and sea level rise produced by the IPCC. Several different ocean-climate model simulations were used with many different emission scenarios. The lighter outer zones cover the range of uncertainties in individual model projections.

New Zealand predictions of climate change and sea level rise are discussed in Chapter 4.

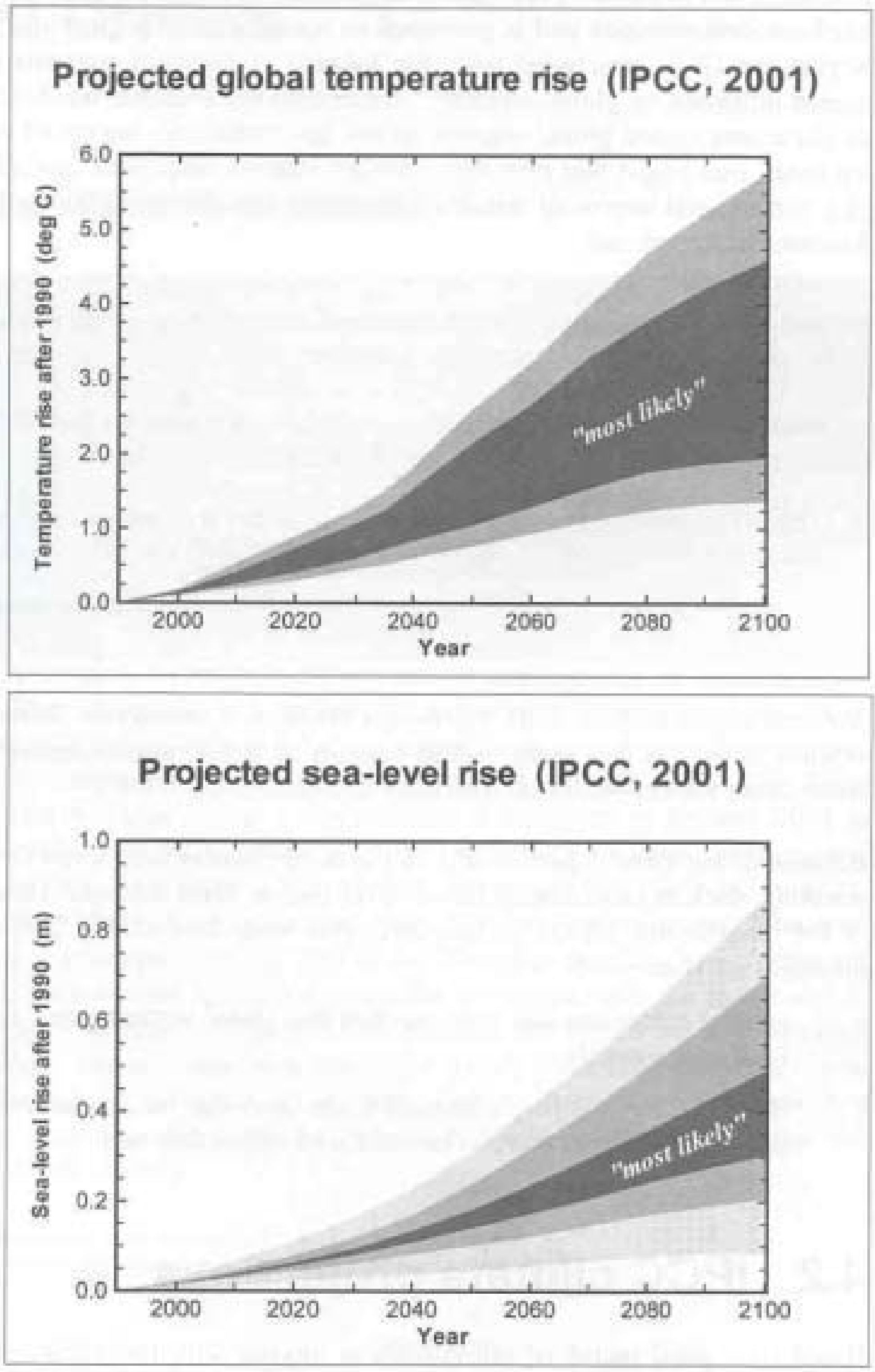

Figure 3.6. The IPCC (2001a) climate model predictions up to 2100. The upper graph shows global mean air temperature rise. The lower graph shows global mean sea level rise (From Bell et al 2001a).

The effect of climate change and rising sea level on other coastal hazards

Awareness about the effects of climate change on coasts generally focuses on rising sea level. However, it is very important to distinguish the different physical drivers of physical change along coasts, as changes in wave climate, wind, rainfall, temperature, ocean currents, the IPO and other cyclic climate patterns will pose addition issues for the coast. Climate change will eventually affect all these drivers.

How will shorelines respond to sea level rise?

All coastal types respond differently to rising sea level. All coasts can achieve some sort of equilibrium and a rise in sea level will affect this state. In very basic terms, if a coastline is going to achieve equilibrium after sea level rise, it will have to relocate inland. The profile will erode, the coastline will move inland, and the profile will reform in the same position relative to the tidal range. Brunn (1962) first defined this process. The shoreline retreat rate, R, due to an increase in sea level, S, can be expressed as:

$$R = \frac{1}{\tan\theta} S$$

where θ is the typical bottom slope. There are many criticisms of this model based on its simplicity and it has been refined several times since, but it is still the most common model used in analysing potential shoreline movements due to sea level changes.

The Brunn Rule demonstrates that a small increase in mean sea level can be expected to result in a substantial shoreline retreat. For example, a coast with a typical bottom profile slope of 0.01 – 0.02, and a predicted sea level rise of 0.4 m to 2100 (this is close to the New Zealand predictions), a shoreline retreat of approximately 20 m can be expected. Note this is approximately half of the value Purves and Hastie (1992) estimated for Riversdale Beach. This is because the present predictions for sea level rise are substantially less than the 1990 values used in the calculation by Purves and Hastie.

3.8 Maritime and Recreational Hazards

Maritime and recreational hazards include the hazards associated with navigation, commercial fishing, marine oil spills, search and rescue, recreational use of the surf zone and offshore and coastal engineering structures. While these types of coastal hazards are often not considered within normal coastal hazard management plans, they have caused far more deaths and injuries than coastal erosion or any of the other coastal hazards in New Zealand. These hazards are discussed further in Chapter 5.

Chapter 4.

The Wairarapa Context

4.1 Introduction

The Wairarapa is susceptible to all of the coastal hazards described in the previous chapter. This chapter is an introduction as to how these hazards are affecting, or may affect the Wairarapa coast. The limited knowledge on coastal processes and past events is drawn upon to help define the level of risk from coastal hazards.

4.2 Coastal Erosion

As discussed earlier, much of the Wairarapa coast is eroding mainly due to energy inputs from the sea. The most serious coastal erosion problem occurs in Palliser Bay. The depositional beach environments have also been subject to periods of significant erosion, although their ability to adjust to changing wave energies and the abundance of stored material in these areas generally ensures they are in a steady state of equilibrium. However, for planning purposes in the next 50-100 years, the problems experienced at Riversdale Beach and Castlepoint in historical times are still significant erosion hazards.

Eastern Palliser Bay

Coastal erosion in this part of the Wairarapa has been well documented in the media and in consultant's reports. A significant problem exists on the eastern side of Palliser Bay where property, buildings, and the access road are under threat **(Figure 4.1)**. In general, the area consists of a narrow gravel beach backed by soft tertiary mudstone cliffs. This beach provides little protection from southwest to south-south-east wave attack.

Figure 4.1. The typical nature of coastal land in eastern Palliser Bay. The top photograph shows the coastal road cut into the soft mudstone cliffs. An artificial boulder beach is currently being constructed to protect the road from disappearing completely. The bottom photograph, taken in February 2000, shows houses under threat at Whatarangi. Several buildings have been lost to the sea in this area. The amount of land lost in this area since 1996 is shown in Figure 8.

Beca Carter Hollings and Ferner (1994) undertook a three stage study on the coastal erosion problem between Te Kopi and the Whatarangi Cliffs subdivision, including the Whatarangi Cliffs. Attempts were made to estimate past erosion rates and predict future erosion rates for the area. Tables of experienced erosion and assessed erosion potential have been taken from this report and are shown in **Table 4.1** below to give an indication of the severity of the problem. The erosion has been cyclic and severe periods occurred in the 1930's, 1976-1977 and 1992-1994**.**

Figure 4.2 clearly demonstrates the scale of the erosion problem in Palliser Bay. A 2001 aerial photograph is shown with the 1996 cliff position drawn in using a 1996 aerial photograph. During this period there has been over 10 m of cliff line retreat in front of some of the houses.

Castlepoint

As with any beach, Castlepoint experiences fluctuations in the quantities of sand stored in the nearshore and backbeach areas. When sand levels are low on the beach, the base mudstone becomes exposed which unfortunately seriously affects recreational activities taking place on the beachface such as the Castlepoint horse races. Cross-shore transport of sand in this area will generally occur during times of increased onshore storminess. The sand will return during quieter periods. This process of erosion and accretion of the cross shore beach profile due to changing wave energies is a relatively well understood process. However, there is currently insufficient beach profile data from Castlepoint to be able to model the process and better explain how the timing of exposure and burial of the mudstone is related to wave energy and climatic fluctuations.

Significant exposure of the mudstone base occurred in 1994 and prompted the Masterton District Council to instigate a coastal erosion study (OCEL 1995). The report noted that only one other significant period of mudstone exposure occurred which was around 1915. Many other less significant episodes of erosion causing exposure of the mudstone have occurred since. It seems reasonable to assume that almost complete removal of the sand from the beach is at least a 50 year event. However, activities on the beach are affected when the mudstone base is only partially exposed.

Experienced Erosion		
Area	**Period**	**Average erosion (mm/year)**
Te Kopi North	1944-1973 1973-1979 1979-1993	153 641 371
Te Kopi Central	1944-1973 1973-1979 1979-1993	30 30 30
Te Kopi South	1944-1973 1973-1979 1979-1993	50 492 212
Whatarangi Cliffs	1968-1993	80
Whatarangi (Blue Disc) Subdivision	1944-1973 1973-1979 1979-1993	91 1440 166
	1898-1973	400
	1960-1993	420
	1992-93	1300
50 year erosion potential		
Area	**Minimum (m)**	**Assessed Maximum (m)**
Te Kopi North	7.8	32
Te Kopi Central	1.5	24.5
Te Kopi South	2.5	24.5
Whatarangi Cliffs	4.0	15
Whatarangi Subdivision	4.5	72

Table 4.1. Experienced erosion and assessed erosion potential at selected eastern Palliser Bay sites (From Beca Carter Hollings and Ferner 1994).

Figure 4.2. Coastal erosion at Whatarangi 1996-2001

Wellington Regional Council

10 0 10 20 30 Meters

It is very likely that Castlepoint, as well as other sandy Wairarapa beaches, respond to the interdecadal fluctuation of the 20-30 year IPO cycle, as well as the 2-5 year Southern Oscillation cycle. It is hard to use return periods to estimate erosion episodes while also taking into consideration the effects of these cycles.

Erosion of the roadside area in front of the houses behind the sea wall along the beach front is currently seen as a problem by residents and new protective measures are planned to counter the recent trend of erosion in this area.

Riversdale and surrounding coastline

Sediment transport patterns at Riversdale Beach are a little better understood than at Castlepoint. There is more opportunity for longshore transport of sediment at Riversdale Beach than there is at Castlepoint. In plan form the beach is very exposed to the open sea, essentially being a straight piece of coast facing the south-east. However, offshore reefs and shore platforms provide some protection for the shore.

Gibb (1986) has made a preliminary assessment of the erosion hazard at Riversdale Beach and the surrounding coastline. Long term trends of erosion and accretion since 1902 were studied. According to Gibb, along the 4 km of Riversdale Beach the southern third has eroded at 0.1-0.42 m/year, the middle third has accreted at 0.06-0.63 m/year and the northern third has eroded at 0.02-0.16 m/year. In addition, severe storms causing short bursts of erosion occurred in July 1985 and July 1978. Up to 30 m of erosion has occurred in the middle section of the beach as a result of short term erosion events since 1902.

Gibb also studied historic coastal erosion from 1976 to 1986 from Flat Point to Whareama. Coastal erosion dominates along this 30 km section of coast. The low sea cliffs at flat point are eroding at rates of 0.4 to 1.8 m/year, 0.7-3.0 m/year at Homewood and Matariki, 0.4-1.8 m/year at Waioronga and 0.4-1.0 m/year at Orui. While this loss of land has implications for land use in the area, it provides a good source of material for Riversdale Beach. More detailed information on beach profile response to storm events and dune erosion can be found in Gibb (1986).

4.3 Tsunami

All of the Wairarapa coast is susceptible to some degree to the effects of tsunami, and the vulnerability of the Wairarapa coast is now well documented (e.g. Geoenvironmental Consultants 2001, Tonkin and Taylor 2002). The Geoenvironmental Consultants report provides a comprehensive scope and bibliography of tsunami hazards and the risk for the Wellington region and should be referred to if more detailed information is required on tsunami risk in Wellington and the Wairarapa.

Possible tsunamigenic sources for the Wairarapa coast

The Wairarapa is susceptible to tsunami for two main reasons. Firstly, it is exposed to the Pacific Rim, and secondly, it lies locally within an active convergent plate tectonic region, as discussed in Chapter 3. The Wairarapa is therefore susceptible to both distantly generated and locally generated tsunami.

The most likely source for a distantly generated tsunami for the Wairarapa is from the west coast of South America. Waves from this region affecting the east coast of New Zealand are prominent in the historical record (see de Lange and Healy 1986). Another possible distantly generated source is from North America, between Alaska and Oregon. The 1964 Alaskan earthquake produced a tsunami from this region which affected New Zealand (Geoenvironmental Consultants 2001). Other less likely sources include Japan and the Kuril Islands in the South Pacific.

Local sources of tsunami for the Wairarapa are less well understood, although this information gap is being narrowed. The importance of local source tsunami for the Wairarapa region was confirmed by the occurrence of the 9 -10 m tsunami which ran up into Palliser Bay as a result of the 1855 earthquake on the Wairarapa Fault (Grapes 2000; Goff et al 1998).

Barnes et al 1998, Barnes and Audru 1999a and Barnes and Audru 1999b give the most up to date and comprehensive descriptions of the bathymetry, stratigraphy and fault systems of the Cook Strait, Eastern Wairarapa and Eastern Marlborough areas.

Knowledge of these areas is set to improve through the continuation of the major seabed research program currently funded by FRST (Foundation for Research Science and Technology) and carried out by NIWA (National Institute of Water and Atmospheric Research). While it can be said with certainty at this stage that there are potential landslide and fault rupture tsunamigenic sources in the region, there is still considerable data processing and interpretation and modelling of results to be carried out before the wider implications for regional hazard planning can be considered. This processing and interpretation involves much seismic, bathymetric, core and hydrological data.

Local tsunamigenic sources for the Wairarapa in the Kaikoura region and the rest of the east coast of the North Island also needs to be considered, although as the term implies, it is the very close sources (i.e. those that actually lie within or very close to the region concerned) which are most important when considering tsunami hazards from 'locally' generated sources.

Table 4.2 below gives further details on the physical characteristics of different types of tsunami likely to affect the Wairarapa and the associated hazards.

Likely return periods and wave height for a tsunami somewhere on the Wairarapa coast

The expected size and associated recurrence intervals of tsunami are the two most important parameters to understand when planning for tsunami hazard. It is possible to attempt estimates of both of these for the Wairarapa using a combination of historical records, paleotsunami evidence, and examples from similar settings around the world. This has been done by Geoenvironmental Consultants (2001). For a 5-10 m wave height the return period is estimated to be approximately 100-150 years for the eastern Wairarapa coast and 100-250 years for the south Wairarapa coast. These return periods are significant for coastal planning in the next 50-100 years. Historical occurrences in the Wairarapa and elsewhere suggest a distantly generated tsunami will probably be less than 5 m (de Lange and Healy 1986) and that a locally generated tsunami could be in the order of 10-15 m (Eiby 1982).

Generating mechanism	Propagation characteristics	Runup characteristics	High/med/low hazard in Wairarapa	Possible sources	Past examples affecting the Wairarapa	Further Information
Subduction earthquake	Can travel large very distances, multiple waves will propagate, height not discernible over ocean.	Tidal like movement likely from distant sources. Bore formation and destructive currents at coast possible. Runup height can exceed wave height. Runup heights will vary along coast. 5 m possible from distant sources, 15 m possible from local sources.	High	South America, Hikurangi Trough	1868 from northern Chile, 1877 from northern Chile, 1922 from central Chile, 1960 from southern Chile.	de Lange and Healy (1986)
Submarine fault rupture	Can travel large distances, multiple waves, height not discernible over ocean.	Same as subduction earthquake.	High	South America, Hikurangi Trough, Cook Strait Faults, Eastern Marlborough Faults.	Indistinguishable from above examples.	
Co-seismic landslide (landslides generated during fault rupture)	Cannot travel large distances, one or more waves will propagate, may produce chaotic sea in ocean.	Bore formation at the shore likely with destructive currents and suspended sediment. Runup height may not be as great as fault rupture types due to concentrated dissipation of wave closer to the shore. 15 m or greater possible from local sources.	Med-high	Cook Strait Canyon, Hikurangi Trough, Kaikoura Canyon.	1855 Wairarapa Earthquake. A landslide may have had some influence in generating the 9-10 m high wave in Palliser Bay.	Grapes (2000) de Lange and Healy (1986). Geoenvironmental consultants (2001).
Landslide (landslides triggered without the occurrence of an earthquake or the earthquake plays no important part in wave generation).	Cannot travel large distances, one or more waves will propagate, may produce chaotic sea in ocean while propagating.	Same as co-seismic landslide.	Med	Cook Strait Canyon, Hikurangi Trough, Kaikoura Canyon.		
Continental slope collapse	May travel great distances.	Runup heights in the order of 300-500 m along coastal hills.	Low	Continental slope – Kaikoura to East Cape.	Debris avalanche off Ruatoria, East Cape, approximately 100,000 years ago.	Lewis et al (1999)

Table 4.2. Tsunami generating mechanisms and associated characteristics of waves able to affect the Wairarapa.

Understanding potential wave height for locally generated tsunami will be the most beneficial approach to understanding tsunami hazard in the Wairarapa. Although tsunami return periods are also important, refinement of these values will not be of as much benefit to coastal planners as knowing more about possible wave heights of locally generated tsunami. A better understanding of these potential wave heights will come with the advancement of the seabed research program by NIWA.

The most vulnerable areas – the runup hazard

When compared to many areas the Wairarapa's present hazard is reduced somewhat by the steep nature of the coastline and its sparse population and the limited infrastructure at risk. However, as stated in Chapter 1, the focus of the Coastal Strategy is to plan for the long term, when considerably more infrastructure is likely to be located on the coast.

The most vulnerable land is obviously that which is low lying with respect to sea level. If 'low lying' is taken as everything below the 10 m vertical contour line, and considering the general runup behaviour of tsunami waves, then there is opportunity for damage to life and property at Ocean Beach, Lake Wairarapa, Lake Ferry, Eastern Palliser Bay (including Whatarangi and Ngawi), White Rock, Manurewa Pt., Glendhu Rocks, Flat Point, Riversdale Beach, Castlepoint, Whakataki and along the Mataikona Road.

The lower Wairarapa Valley is the largest area of low lying land in the Wairarapa exposed to the ocean. The 10 m contour line reaches almost as far as Martinborough and Featherston. Because of the large distance this represents, it is very difficult to estimate the runup height of a theoretical 10 m wave in this area. However, it is most unlikely that a large locally generated wave would approach this line due to friction and energy dissipation of the wave. The greatest amount of damage will be south of Lake Wairarapa, although water levels within the lake could affect the Western Lake Road due to the Ruamahanga River providing a channel for bore propagation into the area.

The settlements of Lake Ferry, Ngawi and Whatarangi are the most vulnerable in the South Wairarapa due to their proximity to sea level and the coastline.

Considerable infrastructure is situated below 10 m, and close to the coastline, at Riversdale Beach and Castlepoint. These two areas represent the greatest runup risk in the Wairarapa.

A 10 m contour line has been plotted by WRC for this report for Whatarangi and Riversdale and serves to display the typical amount of susceptible infrastructure for coastal communities built close to the shore **(Figure 4.3 and 4.4)**. This line does not indicate the runup extent of a 10 m tsunami. Tsunami inundation maps showing the likely runup behaviour of a tsunami have not been plotted. However, it is likely that water would reach further inland than indicated by the 10 m line in the small stream valleys that flow down to the beach. It is also likely that all houses located inside the 10 m line will experience inundation and damage to some degree in the event of a tsunami with a wave height of 10 m. The greatest hazard at Riversdale Beach will exist at the northern end of the settlement adjacent to the Motuwaireka Stream, along the front row of houses which would absorb much of the energy from a breaking wave, and in the topographic lows leading to the beach.

4.4 Storm Surge

As with tsunami, all parts of the Wairarapa coast are susceptible to the effects of storm surge.

Due to the deep, open nature of the Wairarapa coast, and its location below latitudes which regularly receive the full force of tropical cyclones or other intense low pressure systems, storm surge elevations are unlikely to be great by world standards, such as those often reported in Bangladesh, some Pacific Ocean islands, or the eastern United States. However, as shown by previous storm surge events along the New Zealand coast, storm surges are still a very significant coastal hazard that need to be planned for and are the second most frequently occurring natural hazard (de Lange 1995).

In July 1985, a severe storm occurred off the Wairarapa coast causing a storm surge of unknown size. It is these conditions of a low pressure system somewhere to the east of the North Island which is most likely to create a storm surge able to affect the Wairarapa coast. At Riversdale Beach there was overtopping and breaching of the

Figure 4.3. 10 m contour line at Riversdale Beach

Wellington Regional Council

Figure 4.4. Approximate 10 m contour line at Whatarangi
Wellington Regional Council

foredunes causing extensive flooding and some structural damage to houses (Gibb 1986). Gibb reports flooding 100 m from the beach and 50 to 80 mm of water around the motels at the northern end of the beach. Still water levels were likely in the order of one metre above the normal height. This particular storm has a return period of 50-100 years, therefore it is reasonable to suggest that a storm surge creating similar effects can be expected to occur at least as often as this in the Castlepoint/Riversdale areas.

Other storm events which have involved storm surge elevations occurred in February 1936, 9-10 July 1954, 10 April 1968 (Wahine Storm) and 6 February 2002 (Waitangi Day Storm). Storm surge elevations were likely in the order of 0.5-1.0 m for these events and wave set up at the coast could have added another metre to the storm tide elevation. The February 1936 storm tide reached 1.7 m above the Wellington Vertical Datum and is probably a good indication of the 100 year storm tide for the Wellington region (Tait et al 2002). The beach environments of Castlepoint and Riversdale Beach are most at risk from the effects of storm surge due to the ability of storm surges to modify, erode and inundate transportable sediment type coasts.

A more accurate prediction of storm surge frequencies and magnitudes in New Zealand is made difficult with the Southern Oscillation phenomenon. During the La Nina phase there are generally more northeasterly flows and less southwesterly flows, increasing the amount of onshore winds occurring along the eastern North Island and increasing the likelihood of storm surges. Episodes of erosion will also increase along the eastern North Island during these periods.

4.5 Sea Level Rise

As already discussed, the IPCC predictions are for global average climate changes, but it is acknowledged that the range in regional variation of climate and sea level response could be substantial. So what sort of sea level rise can be expected in a region such as the Wairarapa? Analysis of relative sea level trends at New Zealand’s major ports since 1900 produce a rate of sea level rise of 1.7 +/- 0.4 mm/year (Hannah 1990). This equates to a relative rise of about 20 cm since 1900. This value is similar to the global average published by the IPCC indicating that the New Zealand coastal land masses are relatively stable and have not moved much vertically. New Zealand's most accurate long term sea level record is from the Port of Auckland. **Figure 4.5** shows the annual trend of sea level rise in the port with a projection out to the year 2100 and associated envelopes of error. The most likely scenario is a 0.3 to 0.5 m rise in sea level along the New Zealand coast by the year 2100. Further explanation of how these figures were obtained can be found in Hannah (1990) and Bell et al (2001b).

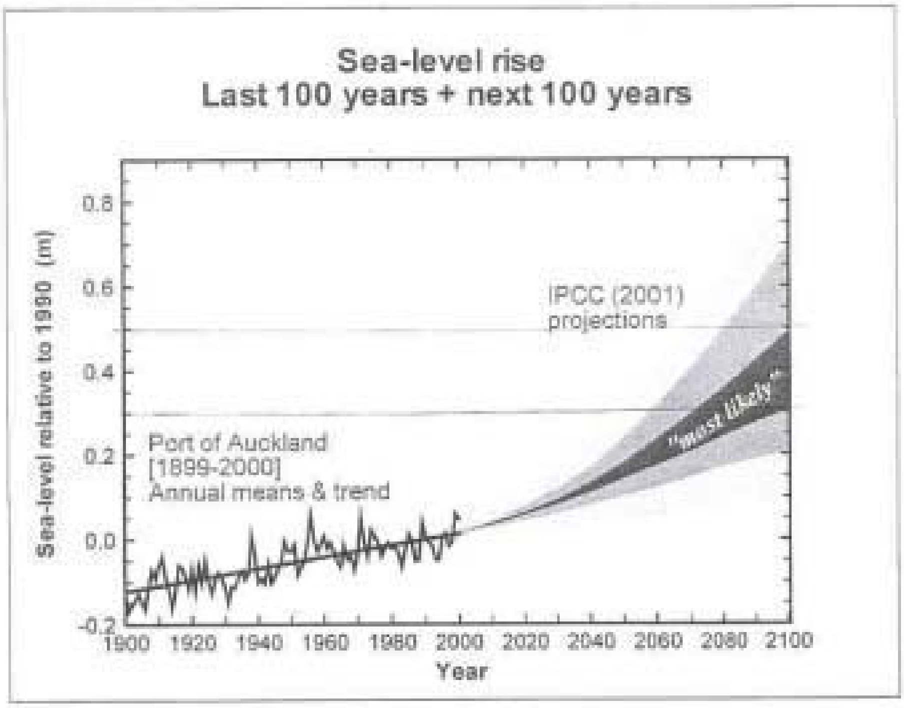

Figure 4.5. The relative sea level trend for Auckland since 1899. The "most likely" zone spans the range of average estimates of several climate-ocean models. This zone indicates the most likely relative sea level rise for New Zealand will be 0.3 – 0.5 m by the year 2100 (From Bell et al 2001a).

Translating long term global average projections from the IPCC to what is likely to occur in New Zealand and in specific New Zealand regions is complicated by regional tectonics and the way in which climate change effects the coastal drivers of each region. The Wairarapa coast is undergoing long term uplift and any future rise of coastal land will lesson the effects of sea level rise. This vertical movement of land can happen very gradually and slowly over time. This type of gradual movement is likely to be happening in the Wairarapa due to subduction of the Pacific Plate pushing up the Indo-Australian of which the Wairarapa coast is part. Slow vertical movement may also be occurring in the Wairarapa due to the after affect of the melting of ice sitting on continents during the last ice age. However, rates of gradual uplift and subsidence along coasts are generally a lot less than the average predicted rise in sea level for New Zealand.

The vertical movement of land can also happen in large, sudden movements. Such movements in the Wairarapa could be up or down, and could possibly be in the order of metres.

In the Wairarapa in the next 50 to 100 years, climate change will likely cause:

1. Coastal inundation of very low lying land due to rising sea levels. This is the permanent intertidal submergence of low lying land and does not refer to sediment erosion. There are very few areas of the Wairarapa where this effect will need to be a consideration due to the rugged and steep nature of the coast.
2. More frequent coastal flooding from storm surges and an effective worsening of the overall tsunami hazard. The overall rise in sea level will substantially increase the probability that a given contour height will be exceeded by a tsunami or storm surge. For example a land height that only gets exceeded 0.01 % of the time at present will be exceeded 5-9% of the time after a 0.3-0.4 m sea level rise (Bell et al 2001). This consideration will be most important at Castlepoint and Riversdale.
3. Landward shoreline migration of the coastal profile due to sediment transport. This equates to a loss of land through increased coastal erosion. The speed with which this happens will depend on how the coastal drivers for each locality react to climate change. **Figure 4.6** generalises the impacts that sea level rise will have on the different types of coasts in the Wairarapa. In general, coasts that are already subject to erosion will be worst off.

It is unlikely that sediment eroded from the Wairarapa coast would be able to keep up with the increased erosion that sea level rise will cause, so an overall increase in the rate of erosion is likely. Riversdale and Castlepoint are generally in a state of equilibrium or may be accreting slowly, but can suffer significant erosional episodes. The generalised impact of sea level rise for these types of beaches will be somewhere between the situations represented in the top two sketches of Figure 4.6.

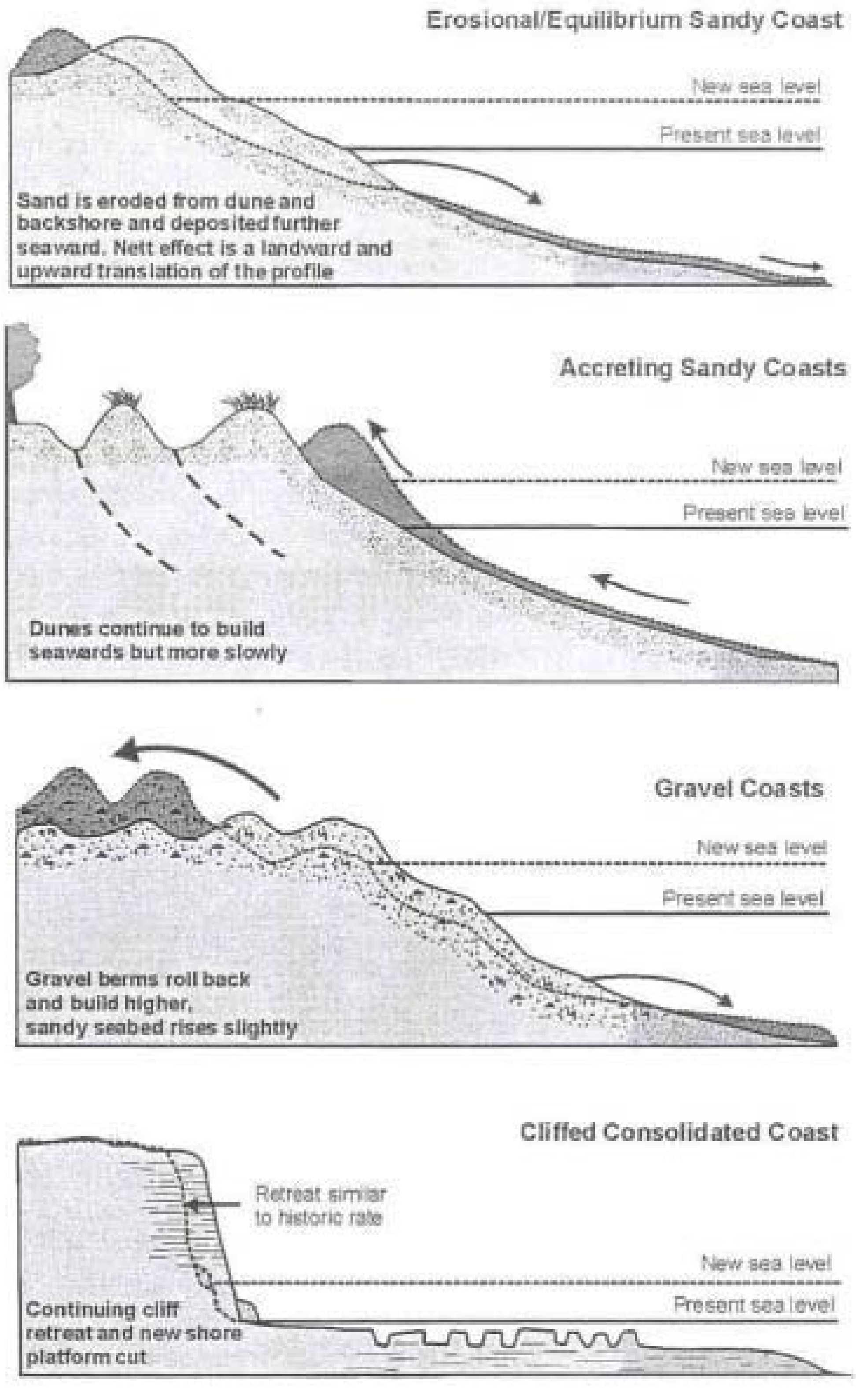

Figure 4.6. Generalised impacts of sea level rise on sandy, gravel and cliffed coasts (From Bell et al 2001a).

Gravel beaches, which comprise the vast majority of Wairarapa beaches, will respond differently to sea level rise. There will be less material deposited offshore and the beaches will tend to build up higher, and in a landward direction. This backward retreat of gravel beaches will be slower than the backward retreat of the sandy beaches. The erosion of the low and high sedimentary cliffs will probably continue to erode at the same rate they have. The direct effect of sea level rise on coastal erosion is not expected to be significant for another 40 to 50 years when sea level is projected to be around 0.14 – 0.18 m higher than toady. In the meantime Southern Oscillation and IPO cycles will be the dominant control over coastal erosion hazards in the Wairarapa region.

4.6 Land Based Hazards

Much of the Wairarapa coast consists of a narrow strip of land confined by steep hill slopes or cliffs. This section looks briefly at the hazards which occur in these areas. The hazards considered in this section are not influenced by wave action on the shore, but occur due to localised coastal meteorological conditions and mass movement processes.

Wind

It is well known, due to the dominance of northwest winds in the Wairarapa that the ranges bounding the Wairarapa to the west and northwest are subject to frequent high winds. On the east side of the ranges, high winds are common along the downslopes of the ranges. This "mountain wave" flow is created when air is forced over mountain ranges transmitting a wavelike disturbance upward through the atmosphere so the mountain distorts the flow. In the lee of the range, the mountain wave forces the airflow in the lowest few kilometres downwards so that a wind maximum appears just downwind of the mountain crest (Porteous et al 1999).

This lee zone effect is also likely to operate over the eastern hills, causing frequent strong winds along the coast. Damage to coastal structures from strong northwest, as well as southerly quarter winds has occurred in the past. Because of the often localised effect of strong winds along the Wairarapa coast, particularly at Castlepoint, and the ability of these winds to cause damage to structures not designed for high wind zones, wind hazard can be considered a coastal hazard.

Simulation of the 1 in 475 year return period wind gust at Castlepoint leads to a wind speed of 180 km/hr. Comparisons of modelled 142 and 475 year return period wind gust speeds for the Wairarapa coast and Masterton are shown in **Table 4.3**. The maximum observed gust of 213 km/hr observed at Cape Palliser was recorded during the Wahine Storm. All values in the table amount to hurricane force winds (i.e. over 119 km/hr). The 142 year modelled gust at Castlepoint and Cape Palliser of 198 km/hr equates to a category 3 hurricane (177-209 km/hr), as defined by the 1-5 Saffir-Simpson Hurricane Scale (5 being the most intense). The 475 year modelled gusts equate to a category 4 hurricane. Structural damage to houses can be expected with wind speeds over category 3. These wind speeds are a significant hazard not only for human safety but also for engineering structures. Large trees can be blown down and caravans and poorly constructed signage will be destroyed.

	Max. observed gust	**142 year modelled gust (km/hr)**	**475 year modelled gust (km/hr)**
Masterton	148	162	180
Castlepoint	183	198	216
Cape Palliser	213	198	216

Table 4.3. Comparison of Castlepoint, Cape Palliser and Masterton maximum observed gusts with modelled 142 and 475 year return period gusts (From Porteous et al 1999). The 142 and 475 year modelled gusts at Castlepoint and Cape Palliser equate to category 3 and category 4 hurricanes respectively.

Rainfall and slope instability

In the Wairarapa, relatively confined areas of the coast can experience high rainfall events. Alternatively, prolonged wet periods can lead to saturated ground conditions. Under these conditions slope instability may occur in the form of slips, earthflows and slumps. Often this is exacerbated by the concentration of water on slopes from downpipes and tank overflows. Such movements have occurred in the past at Castlepoint.

Depositional fans are prominent in several places along the coastal strip. During high rainfall events, streams can leave their course and flow randomly over the fan causing severe damage through flooding, scouring and deposition. This has occurred in the past at Ngawi.

Very steep slopes are also vulnerable to slope failure under the influence of gravity. Such failures can be triggered by earthquake shaking with the resulting debris and rock falls a hazard to developments at the bottom of steep slopes.

Chapter 5.

Future Management of Wairarapa Coastal Hazards

5.1 Coastal Erosion

Coastal erosion is dealt with at the district level more often than any other coastal hazard due to its direct and continuous effect on the wellbeing of affected coastal residents (e.g. Beca Carter Hollings and Ferner 2000, Dahm 1999). Policies, rules, and the associated information gathering inevitably focus on coastal erosion before any other coastal hazard, primarily due to public pressure and the urgency of the problem for the life of affected structures. Other coastal hazards are rarely planned for, and the coastal erosion problem is usually only dealt with once structures and valuable property are being actively threatened. This is the case in Palliser Bay where physical protection measures are being implemented in the form of an artificial boulder beach in order to save the access road to Ngawi and Cape Palliser. Coastal hazard zones which theoretically take into account future erosion trends for which activities are restricted or discretionary are in place in the Masterton, Carterton and the South Wairarapa Districts.

Periodic cycles of erosion are recognised at both Castlepoint and Riversdale and coastal hazard zones to deal with the associated hazards are in place. The protection measures going ahead at Palliser Bay have begun to reduce erosion in this area for the time being. However, there are vast areas of unpopulated Wairarapa coast where there is potential for development in which virtually nothing is known about long term erosion and accretion trends. Unlike coasts which have already been developed, the Wairarapa has the opportunity to put in place a sound strategy to promote a sustainable approach to the management of coastal erosion, and other coastal hazards, which is consistent with the principles of the RMA and the NZCPS. While site specific management strategies are already in place for some areas, it should be the focus of future coastal erosion management plans to produce a strategy which enables coastal communities to live with coastal erosion while minimising the need to modify the natural processes in the future. Apart from the need for further scientific investigation into coastal processes, this can be achieved through encouraging coastal dwellers to accept and live with coastal erosion where this is possible, and to discourage development close to the coastline, as most coastal erosion problems exist because development has occurred too close to the sea.

Strategies produced to deal with coastal erosion in other New Zealand areas have relevance to the Wairarapa situation. The proposed risk management strategy for mitigating the coastal erosion risk in the Waikato region (Dahm 1999) proposes a region wide strategy which focuses on avoiding and reducing the risk, encouraging coastal communities to accept and live with coastal erosion, and placing an emphasis on public information and advice. This approach is compatible with the general objectives of sustainable coastal management of coastal erosion. It focuses on developing a pattern of land use and development that minimises the need to modify natural shoreline processes.

The coastal processes of the Wairarapa are largely unstudied. Very little is known about the large scale sediment transport patterns, hydrodynamics, and coastal erosion and accretion trends. If this lack of knowledge remains, it will hamper the development of meaningful long term management plans dealing with coastal erosion in the Wairarapa.

5.2 Tsunami and Storm Surge

While the likelihood and probable magnitude of future tsunami and storm surge events are now well understood, there is still much research required, including data collection, before the hazard from these events can be presented responsibly in a spatial format for individual communities (i.e. lines on maps for each settlement for various return period events). However, there are still management steps which territorial authorities and the WRC can take now towards mitigating these hazards. These have been outlined in the report "Options for managing risks from tsunami in the Wellington Region", by Tonkin and Taylor. This report has produced recommendations that the territorial authorities of the Wellington Region can follow and has worked within the current bounds of scientific knowledge on tsunami hazard in the Wellington Region. It has recognised the difficulties of planning for tsunami when the scientific knowledge is not yet at a stage where accurate inundation maps can be drawn. The report is based on the Seven Principles for Planning and Design for Tsunami Hazards developed as part of the National Tsunami Hazard Mitigation Program in the United States (National Tsunami Hazard Mitigation Program 2001) and has been examined for its applicability to New Zealand conditions.

The seven principles are:

1. Know your community's tsunami risk: hazard, vulnerability and exposure.
2. Avoid development in tsunami runup areas to minimise future tsunami losses.
3. Locate and configure development that occurs in tsunami runup areas to minimise future tsunami losses.
4. Design and construct new buildings to minimise tsunami damage.
5. Protect existing development from tsunami losses through redevelopment, retrofit and land reuse plans and projects.
6. Take special precautions in locating and designing infrastructure and critical facilities to minimise tsunami damage.
7. Plan for evacuation.

All these management actions are able to be implemented through the regional plans, district plans, the Building Act and building consents, LIMs and PIMs, civil defence plans, community, strategic and annual plans, and public signage and education programs.

The report identifies the next step for territorial authorities to take with implementing these principles. This involves preparing a coastal contour map, overlaying elements at risk, deciding on the best management principles to apply to each type of coast based on elements at risk, and together with the WRC, implementing a strategy for the preferred management options. This implementation strategy could include:

- Reviewing the effectiveness of current coastal hazard plans in dealing with tsunami (e.g. coastal erosion setback distances often go some way to dealing with the problem).
- Consideration of regional and district plan changes.

- Consultation with the community and council members to raise the awareness of the risk from tsunami.
- Incorporation of an implementation strategy into annual and strategic plans.

Contour intervals and maps

The 20 m contour is currently the lowest contour drawn in the Wairarapa**.** A more detailed contour map is an essential requirement before any of the principles 1-6 can be implemented.

It is the recommendation of Tonkin and Taylor (2001) and Geoenvironmental Consultants (2001) that it is prudent to plan for a tsunami in the next 100-250 years in the Wairarapa region with a runup height of between 5 and 10 m. Therefore, at the very least, a 10 m contour line must be plotted for the entire Wairarapa coast. This will allow identification of shoreline facilities and structures that could be damaged in a likely tsunami and help with development planning. The 10 m contour line should represent the area inside which the seven principles are applied as far as possible. In addition, the plotting of a 5 m contour line to define two areas of different risk would be helpful. This gives the option of using the principles in different ways for the two zones. Contour intervals of 0.5 m or less will be required before any further scientific studies on tsunami runup behaviour can proceed and tsunami and storm surge inundation maps produced. Collecting this information at the same time as the 5 and 10 m contours would be very helpful towards progressing with management option 1 – know you communities tsunami risk.

Tsunami and storm surge education and Principle 7 – plan for evacuation

Education plays a very important role in the management of natural hazards, particularly coastal hazards which are less easily understood and therefore less easily accepted as a fact of life. Education and awareness is particularly important for tsunami and storm surge hazards which are the least well understood of all natural hazards. This poor understanding, together with the lack of detailed scientific knowledge makes it a difficult task for rules or even policies to be developed by planners at a district level, even though the national framework encourages this to take place. Education forms an important part of Principle 7 – plan for evacuation. Implementing this principle is the most effective way of reducing the number of lives lost in areas at risk from destructive locally generated tsunami, such as the Wairarapa.

Public education is a social process, not simply a decision that's made or an action that's carried out, and will take many years for the desired outcome to be achieved. Many different methods are available for disseminating information to the public on tsunami hazards. These include signage, media coverage, community and public talks and brochures. Work which has already been initiated in the Wairarapa includes beachfront signage warning of the hazard from locally generated tsunami, and information posters and this needs to continue with the co-operation of all three district councils. The beach front signage currently in place needs to be added to using signs such as the one shown in **Figure 5.1** which is designed to provide people with a clearly defined safe route to take in the case of a strong earthquake. The information contained on any new signage needs to be supported using other education tools such as those mentioned above. Information on tsunami and other natural hazards can also be supplied by the regional and district councils to schools for inclusion into science curriculum, if the schools desire this.

5.3 Sea Level Rise

Within the current framework for managing coastal hazards, regional councils and territorial authorities are able to make plans now for how to deal with rising sea levels and the associated worsening of coastal hazards. However, this process will be a challenging one and will constantly need to consider new climate change and coastal process research findings and how to assimilate these new facts into coastal hazard management plans. Within even a 50 year time frame there will need to be regular re-assessments of the hazard and risk from all coastal hazards. Successful management plans will require an acceptance from the public that climate change and sea level rise are happening and education on how these changes are going to affect the coast.

Assessments of the degree to which coasts will be affected i.e. their vulnerability, will need to be ongoing. The adaptive capacity of communities needs to be assessed in

Figure 5.1. Tsunami evacuation route sign used in other high risk areas around the world prone to tsunami from local sources. In such areas there may be no time for authorities to issue the usual tsunami warnings.

order to know how to absorb the consequences. The full range of costs associated with responding to sea level rise needs to be considered and this must include cost benefit studies and social impact studies.

Responding to coastal erosion hazards, sea level rise and other inundation hazards on any coast must involve choosing one, or using some combination of the following options:

- Doing nothing; taking no action against the impending or active hazard
- Adaptation to better absorb the effects of the new hazard environment
- Managed landward retreat and relocation
- Soft coastal defence options
- Hard coastal defence options

Figure 5.2 summarises the methods for implementing these actions. Adaptation means continuing to use the threatened land and facilities by accommodating for the changing coastal hazards, and letting the coastal processes follow their natural path. This involves such responses as raising and retrofitting threatened buildings to cope with the retreating shoreline, raising or redesigning coastal infrastructure such as roads and storm water systems, and changing land uses to suit the new conditions.

Retreating and relocating requires a planned and progressive move of infrastructure away from the coast. As with the adaptation method, the natural coastal processes are left to take their own course. If the coast is undeveloped, as is the vast majority of the Wairarapa, then under this option future developments close to the coast need to be prevented. Generous coastal buffer zones would need to become the focus of district plans when considering hazard mitigation and a routine part of coastal developments. Managed retreat is the most common response to coastal erosion hazards in New Zealand and in many parts of the world. Often this type of response is the only one available as the alternatives are too expensive. Using planned retreat as an option is also consistent with the overall goals of the RMA and policy statements in the NZCPS.

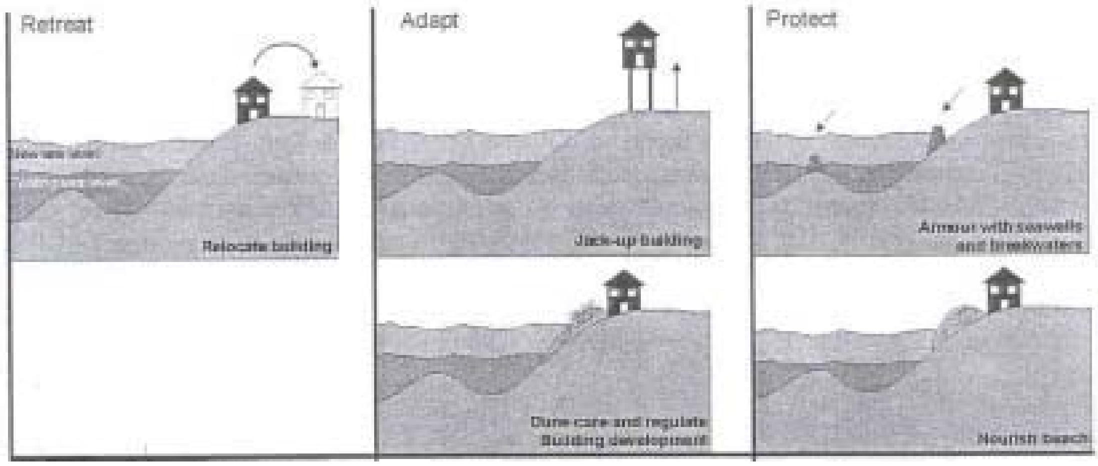

Figure 5.2. Response options to sea level rise for open coasts such as the Wairarapa can be divided into retreating, adapting or protecting (From Bell et al 2001a).

Seeking to alter the natural coastal processes operating in order to protect against coastal erosion and inundation is the third group of management options available. The methods used can be broken into 'hard' and 'soft' options. Hard options include sea walls, groynes, toe protection for cliffs and offshore structures such as breakwaters and submerged reefs. Soft options include beach nourishment, dune building and preserving natural features. The existence of dunes and other natural features help with defending the coast.

Hard protection measures provide an impenetrable barrier between the sea and the land. They absorb and often reflect wave energy and prevent this energy from interacting with the land. Sea walls are the most common form of hard protection structure and work to protect the land behind the wall often to the detriment of the beach in front of it.

Although employing hard protection methods are often inconsistent with the aims of the RMA and NZCPS policies, they are invariably the first method applied to coastal land under threat, and there are many reasons for this. The public usually regard sea walls as the safest method of coastal management. This is because they form a solid barrier and they are perceived to form a greater level of protection from the sea than soft options, such as beach nourishment. Sea walls provide a considerable feeling of security amongst coastal residents and are therefore readily accepted as the best option. While sea walls do a great job of protecting what is behind over short and medium time scales, they unfortunately do not deal with the actual cause of the erosion and there can be many undesirable effects to the beach in front of the wall and to adjacent stretches of coast. Areas downdrift of sea walls will often suffer increased erosion due to a decrease in sediment supply and this can result in scour around the ends of the structure, necessitating maintenance of the wall. However, properly designed sea walls provide excellent protection for valuable property and land that can not be protected in other ways.

Unsuccessful sea walls have often been installed around New Zealand in an ad-hoc nature due to a poor understanding of the coastal systems which they operate in and limited budgets, and the Wairarapa has not been immune to such activities. Because much of the Wairarapa is undeveloped, hard protection structures should not need to be a significant part of future coastal response to sea level rise or other coastal hazards. It may prove appropriate however, for sea walls to be part of the medium term solution (approx. next 50 years) in areas where they already exists i.e. Castlepoint, Riversdale Beach and eastern Palliser Bay.

Beach renourishment, or beach feeding, is a common soft option method of coastal protection. Beach renourishment is the artificial adding of sand to a beach which is undergoing undesirable erosion and has been used in many New Zealand locations (e.g. Foster et al 1996; de Lange and Healy 1990; Healy et al 1990; Kirk and Weaver 1985). Adding sand to a beach increases the area available for recreation and dissipates wave energy further offshore, away from threatened infrastructure. Beach feeding as a form of coastal defence in the Wairarapa will not be a major consideration in any future hazard mitigation plans. This is mainly due to the physical nature of the coast i.e. there very few sandy beach types which would accept foreign sediment, and very few areas where such sediment could be easily sourced. It is vital that sediment of a similar type to that which is being added to is used as the nourishing material.

Other soft options such as dune stabilisation and building should form a significant part of any soft option management plan where these environments exists e.g. Castlepoint and Riversdale Beach. Dunes play a vital role of the stability of the beaches in front of them and the protection of land behind them. They therefore represent a vital part of coastal defence systems and coastal hazard mitigation plans on most sandy shorelines. In general, dunes need to be free to interact with other natural processes and be mobile. There needs to be as much sediment available as is required by the dunes to go through phases of erosion and accretion. The introduction of hard solutions such as sea walls often seriously restricts the availability of sediment and adversely affects the ability of dunes to protect the land behind. Development on top of sand dunes also seriously effects the mobility of dunes. Dune vegetation needs to be of the correct species and kept to a minimum to avoid trapping the sand in one place. Whereas hard structures such as houses, sea walls and groynes are a major consideration in dune health, other activities such as walking, driving vehicles, undesirable dune species and grazing are only minor concerns to the health of dune systems. However, even these activities can cause dune blowouts during future storm surge and wave attack events, increasing flood inundation levels and damage.

A comprehensive summary of hard and soft solutions and the issues which can arise from their use is given by French (2001).

5.4 Maritime and recreational hazards

Maritime and recreational hazards include the hazards associated with navigation, commercial fishing, marine oil spills, search and rescue, recreational use of the surf zone and offshore and coastal engineering structures. While these types of coastal hazards are often not considered within normal coastal hazard management plans, they have caused far more deaths and injuries and harm to the environment than coastal erosion or any of the other coastal hazards in New Zealand.

Surf zone hazards

The surf zone consists of the zone of breaking waves along a coast, the character of which can present a serious hazard for recreational users of the coast. The greatest hazards arise from the set up of longshore and shore perpendicular (rip) currents due to waves breaking and causing a net movement of water towards the shore which must somehow return back to the sea. Riversdale Beach and Castlepoint both attract regular use of the surf zone during summer months. Understanding these hazards involves gaining a detailed understanding of the interaction of surface water currents including rip currents, long shore currents and tidal currents as well as wave breaking processes in order to design models to predict their behaviour. Such research is ongoing and with time models specific to New Zealand will be developed which can be applied in a general manner to swimming beaches to help classify hazardous beach conditions (Bryan 2002).

To further understand public risk on beaches, Surf Lifesaving Australia adopted a program with Sydney University to develop a comprehensive, standardised and scientific information base on all Australian beaches with regard to their location, physical characteristics, access, facilities, usage, rescues, physical and biological hazards, and level of public risk under various wave, tide and weather conditions (Short 1993). Such a program highlights the importance of beach hazard education in reducing deaths and injuries and provides an excellent model for countries such as New Zealand to follow. Further resources and ideas for managing beach safety can be found through Surf Life Saving New Zealand, Surf Life Saving Australia, the Water Safety New Zealand web site, or through the web site of the City and County of Honolulu Emergency Services Department, who regularly deal with extreme beach and wave hazards and public safety.

Waves along coasts can represent a significant tourist and recreational resource if managed effectively. Much effort is now being placed on improving the safety and increasing the quality of waves and coastal dynamics in many areas around the world, including New Zealand (Black 2000). Such plans usually involve the building of artificial submerged reefs that can have beneficial implications for coastal erosion management and water recreation.

Castlepoint rocks

The reef at Castlepoint is a nationally recognised fishing location as well as a popular attraction for visitors to the beach. The lower parts of the reef are easily overtopped in moderate sea conditions and even in slight sea conditions waves can wash over into the lagoon on the sheltered side **(Figure 5.3)**. As with many other open coast locations around New Zealand, there have been deaths in the past from people being knocked off the rocks and drowned due to a lack of awareness and general understanding of wave hazards. Warning signs are already in place on the beach and the hazard must continue to be treated through signage and general education programs such as those used by surf life saving associations. Preventing access to this part of the coast would not be consistent with the RMA policies of preserving public access to the coast where possible.

Figure 5.3. Aerial view of the Castlepoint coastal recreational area (Photo from IGNS photo library).

Marine oil spills

New Zealand's coastal and marine environment contains many species, habitats and other resources that could be severely affected by oil pollution. The most sensitive areas are coastal, where oil can strand on the foreshore. Even very small spills are likely to cause environmental damage, have impacts on amenity values and interfere with the use of the coastal environment. Most spills within New Zealand waters are likely to occur close to the coast or in harbours. Due to the high energy wave climate and local weather patterns in the Wairarapa, oil will probably impact the coast and coastal resources within hours of a spill.

It is normally not reasonable for responders to be able to prevent all oil from stranding on shorelines. Because of this, New Zealand's approach is to focus primarily on shoreline protection and clean-up.

Under the Maritime Transport Act 1994 the Director of Maritime Safety is required to prepare and maintain the New Zealand Marine Oil Spill Response Strategy. Under the Maritime Transport Act 1994 (section 284) the purposes of the strategy are to:

- *Describe the actions to be taken, and by whom, in response to an oil spill in New Zealand marine waters*
- *Promote a standard response to marine oil spills in New Zealand*
- *Promote the co-ordination of marine oil spill contingency plans and the action taken in response to marine oil spills under such plans.*

In line with established international practice, New Zealand has adopted a three-tiered approach to all aspects of marine oil spill preparation and response. Tier 1 is site-specific and includes most shore-side industry with oil transfer sites, offshore installations, pipelines and all vessels from which a spill of oil is possible. All Tier 1 sites and vessels are expected to be able to provide a clearly identifiable first response to pollution incidents for which they are responsible.

Regional councils and those unitary authorities acting as regional councils under the Maritime Transport Act 1994 make up Tier 2. These agencies must maintain the regional marine oil spill contingency plan for their region. Within their regions, these councils will respond to marine oil spills that exceed the clean-up capability of Tier 1. They will also respond to those spills for which no responsible party can be identified. The Maritime Safety Authority will provide regional councils with adequate resources to ensure that sufficient equipment, trained personnel and opportunities to exercise their expertise are available for them to competently undertake this role. The Wellington Regional Council appoints a Harbourmaster who is responsible for the Tier 2 response. The harbourmaster and harbours department is also responsible for enforcing the Wellington Regional Navigation and Safety Bylaws and navigational aids.

Tier 3 is the responsibility of the Maritime Safety Authority. When, due to size, complexity or environmental impact, containing and cleaning up a marine oil spill exceeds the capacity of the resources available at both Tier 1 and Tier 2 level, the

Maritime Safety Authority will assume responsibility for managing the response under the National Plan.

Chapter 6.

Conclusions and Recommendations

The Wairarapa exists within one of the world's great active tectonic regions. This tectonic setting produces some of the essential requirements for the establishment of major populations, such as a deep harbour and abundant clean water. It also creates many different natural hazards, some of which will impact the coast.

On wave dominated coasts, such as the Wairarapa, waves are the most important driver of coastal processes. Without a good understanding of a regions wave climate, little progress can be made with understanding many of the serious coastal hazards which affect the region. The Wairarapa coast is a high energy wave environment. Almost the entire Wairarapa coast is in a state of natural erosion. This is due to the active tectonic setting, the soft nature of many of the sea cliffs, the high wave energies and the lack of a plentiful supply of sediment into most parts of the region. Those parts of the coast existing within a depositional environment include the beaches of Riversdale and Castlepoint. These areas are either in a dynamic state of equilibrium, or undergoing a period of temporary erosion or accretion. Understanding the dynamic nature of these beach environments is just as important as understanding sea cliff erosion when planning for coastal hazards.

The Resource Management Act and all other policy which comes under this umbrella, provides the necessary framework for planning for natural hazards, including coastal hazards.

The NZCPS is the most important policy document for guiding coastal hazard management in the future, particularly for regions such as the Wairarapa, due to its largely undeveloped nature. The policies within the NZCPS recognise the dynamic and unpredictable nature of coasts in general. It places an emphasis on avoiding development in hazard prone areas. Non-statutory methods of mitigating coastal hazards, such as education and awareness programs, are also available. These methods are becoming increasingly important with the onset of global warming and the increased severity of the more poorly understood coastal hazards such as storm surge and sea level rise.

6.1 Coastal Erosion

Most of the Wairarapa coast is in a state of long term erosion due to natural processes. Erosive episodes can also affect property and infrastructure at Castlepoint Beach and Riversdale Beach. These parts of the coast are probably not undergoing long term erosion but still suffer from cyclic periods of erosion from wave attack. Individual episodes of erosion will continue and there is the potential for coastline retreat in the order of metres for individual storm events at Riversdale Beach. Erosion processes are less well understood at Castlepoint Beach. Removal and deposition of beach material exposing and covering the basement rock will continue, but more work is required before it is known how this affects the stability of the road in front of the houses.

Future coastal erosion management plans in the Wairarapa should focus on developing a pattern of land use that minimises the need to modify natural shoreline processes. Where possible, communities need to be encouraged to accept coastal erosion through public information and advice. Because the Wairarapa coast is largely undeveloped, management plans consistent with the NZCPS should be attainable. Generous coastal hazard zones that take into account historical erosion rates and allow for the effects of sea level rise must form an integral part of plans for developing coast.

Coastal protection works will likely be an effective option in the immediate future for those areas where such measures already exists.

The large scale coastal erosion and sediment transport patterns along the Wairarapa coast are, overall, poorly understood. This knowledge needs to improve. This can be achieved through research that is integrated with the wider sediment budget research programs either underway or planned by such organisations as NIWA. The last 'overview' of erosion and accretion trends on the New Zealand coast was completed in 1984. Smaller research programs involving wave and beach profile data collection will also help towards understanding sediment transport and the coastal erosion problem for specific localities.

Recommendations – Coastal erosion

Responding to the coastal erosion problem at Castlepoint and Riversdale Beach should include, in the following order of priority:

1) Avoiding further development of land close to the coast through enforcement using updated coastal hazard zones. This will first require attention to the recommendations listed in Section 6.6 – Information gaps.

2) Public education on the nature of the erosion problem.

3) The continuation and development of soft defence options such as dune care programs.

4) Hard defence options, most likely the upgrading of old, or possibly the addition of new sea walls.

Responding to the coastal erosion problem in undeveloped parts of the coast or where there could be development some time in the next, say 50 years, should involve:

1) Avoiding development of land close to the coast enforced through coastal hazard zones. This first requires attention to the recommendations listed in Section 6.6 – information gaps for coastal erosion).

2) Public education of the nature of coastal erosion in the Wairarapa focussing on potential developers.

In those areas where infrastructure is located on eroding cliffed coasts and structures are presently threatened or are been damaged by coastal erosion, the only options are to:

1) Employ hard defence options such as sea walls to physically protect property for the short to medium term.

2) Plan a program of retreat, or if this is not possible;

3) Don’t renew damaged structures i.e. do nothing.

6.2 Tsunami

All parts of the Wairarapa coast are vulnerable to tsunami and it is likely some part of the coast will receive a large (5-10 m) tsunami in the next 150 years. All coastal settlements are at risk from this event.

The last large tsunami to affect the Wairarapa coast was in 1855 when a 9-10 m wave ran up on the shore in eastern Palliser Bay. This was from a local source as a result of the 1855 Wairarapa earthquake. The hazards associated with such a tsunami will mean that a similar event today for any of the coastal communities in the Wairarapa will be devastating. Numerous distantly generated tsunami have also affected the Wairarapa in historical times but are poorly recorded mainly due to the lack of population and low tide levels at the time.

The Seven Principles for Planning and Design for Tsunami developed in the United States are relevant to New Zealand. All these actions can be implemented through the planning framework currently in place. The first principle – Know your community's tsunami risk: hazard, vulnerability and exposure, needs to be implemented as funds allow through further hazard studies. These studies should better define the tsunami risk using two main focuses:

1. The drawing of detailed contour lines (0.5 m intervals) for the whole coast and working towards the production of runup hazard maps showing infrastructure and land at risk.
2. Understanding more about the risk from locally generated tsunami. Such work is ongoing by NIWA. The WRC and district councils can play a role in assisting with the transfer of information to end users.

Principles 2 to 7 however, do not require any new hazard information to allow implementation. Of these principles, 7 - Plan for evacuation, is the most important in the immediate future. Designing an effective evacuation plan for a community must first involve gaining public acceptance of the tsunami hazard. This is a long term process.

Recommendations – tsunami

The Building Act, the RMA, the NZCPS, Civil Defence Plans and non-statutory methods provide the necessary framework for enforcing rules and educating the public regarding tsunami hazard mitigation. Recommended actions for dealing with the present tsunami hazard in the Wairarapa include the following, in order of priority:

1) Public education.

2) Know your community's tsunami risk. The risk from tsunami in the Wairarapa is now well documented, but more work is vital in the following areas:

   i) Obtaining detailed coastal topography data and producing runup maps which identify individual elements of coastal infrastructure and sections of land at risk.

   ii) Improving our understanding of the potential physical characteristics of locally generated tsunami.

   iii) Studying the effects of saltwater contamination on productive farmland, houses and other structures including engineering lifelines.

3) Plan for evacuation using the civil defence statutory framework and non-statutory means. This is a logical progression from (1) – public education.

4) Locate and configure development that occurs in tsunami runup areas to minimise tsunami damage.

5) Design and construct new buildings to minimise tsunami damage.

6) Take special precautions when locating and designing infrastructure and critical facilities to minimise tsunami damage.

7) Protect existing development from tsunami losses through redevelopment, retrofit and land reuse plans and projects.

8) Avoid development in tsunami runup areas to minimise future tsunami losses.

6.3 Storm Surge

As with tsunami, all coastal communities in the Wairarapa are at risk from the hazards associated with storm surge. New Zealand coasts do not receive the storm surge elevations of some overseas locations, but the combination of wind set up and low atmospheric pressure can raise water levels up to approximately 1 m above normal during storms. Wave set and other factors at the coast can increase this by 100%, and inundation levels, or 'storm tides', will reach over 2 m in the Wairarapa. The beach environments of Castlepoint and Riversdale are most at risk from the effects of storm surge due to the ability of storm surges to modify, erode and inundate transportable sediment type coasts.

Understanding the effects of the El Niño Southern Oscillation and IPO cycles on sea levels and weather patterns in the Wairarapa area is important for understanding the future risk from storm surges.

Recommendations – storm surge

Mitigating against storm surge hazards in the Wairarapa will involve, in order of priority:

1) Avoid development of land close to the coast enforced through coastal hazard zones. This first requires attention to the recommendations listed in Section 6.6 – information gaps for coastal erosion.

2) Know your community's storm surge risk. Understanding this risk can be achieved by:

   i) Obtaining detailed coastal topography and producing runup maps which identify individual elements of coastal infrastructure at risk.

   ii) Plotting the level of mean high water springs around the coast as a guide for building and foundation design.

iii) Apply a joint-probability method to determine the risk of storm tides from wind, atmospheric pressure, tide and wave set up effects.

iv) Undertake a study presenting a risk analysis of wave conditions along the Wairarapa coast.

3) Public education.

4) Soft defence options such as dune care programs.

5) Take special precautions in locating and designing infrastructure and critical facilities to minimise storm surge damage.

6) Protect existing development from storm surge losses through redevelopment, retrofit and land reuse plans and projects.

7) Hard defence options (for developed coast).

8) Avoid development in storm surge runup areas to minimise future losses.

6.4 Sea Level Rise

The most likely scenario for New Zealand waters is for a rise in sea level of between 0.3 and 0.5 m in the next 100 years. In the Wairarapa this will result in three main effects:

- Coastal inundation of very low lying land due to rising still water levels.
- More frequent flooding from storm surges and an effective decrease in tsunami return periods for equivalent associated wave heights.
- Loss of land due coastal erosion.

The direct effect of coastal erosion due to sea level rise is not expected to be noticeable for another 40 or 50 years. This is because these cycles can produce sea level rises of up to 0.15 m, which is comparable to the amount of sea level rise we can expect in the next 50 years (Bell et al 2001a). Until then the Southern Oscillation and IPO cycles will be the dominant influence over local sea levels and coastal erosion.

Recommendations – sea level rise

Responding to sea level rise and increased coastal erosion must involve carrying out (1) and (2) on an ongoing basis and, in the light of this ever changing new information, respond by choosing one or using some combination of the options (3) to (8):

1) Research how local drivers of coastal change (e.g. winds, waves, storms, river flow, sediment supply, temperature, currents) will be affected by global warming and sea level rise.

2) Understand what local shoreline response will be in the Wairarapa as a result of sea level rise.

3) Public education.

4) Soft coastal defence options.

5) Managed landward retreat and relocation.

6) Adaptation to better absorb the effects of the new hazard environment.

7) Hard coastal defence options.

8) Doing nothing; taking no action against the impending or active hazard.

Generous coastal buffer zones need to become a routine part of coastal development in the Wairarapa. Hard protection structures should not be a significant part of the future response to sea level rise and erosion hazards. It may be appropriate for some hard protection structures, most likely sea walls, to be part of the short and medium term solution at Castlepoint, Riversdale and Palliser Bay. It is unlikely beach renourishment will form an effective part of any future coastal protection schemes in the Wairarapa.

6.5 Maritime and Recreational Hazards

Maritime and coastal recreational hazards cause far more deaths and injuries, harm to the environment and cost insurance companies more money than any of the other coastal hazards in New Zealand. Consideration of surf zone hazards and hazards involving the general recreational use of the coast at Castlepoint, Riversdale and Palliser Bay in the form of public information will go some way to reducing accidents in these areas.

The threat of an oil spill is a reality for the Wairarapa coast. There is a comprehensive national plan to deal with New Zealand oil spills in New Zealand, including trained people within the Wellington Regional Council ready to respond with the help of the Maritime Safety Authority. However, further consideration of the environmental risks specific to the Wairarapa, including identification of high risk localities, will improve the effectiveness of future responses.

6.6 Information Gaps

In addition to the response options listed above for each specific hazard, there are several major information gaps which, when filled, will assist with implementing these recommendations. These have also been listed in order of priority and are in **Table 6.1** below.

Information gap	Effect	Recommendations
Lank of knowledge of regional sediment transport patterns and wave climate.	Future coastal hazard zones for undeveloped and developed coast cannot be designed with any confidence.	Become involved with promoting large, multi organisational, regional and national research programs on sediment transport and erosion and accretion trends. Promote and facilitate the flow of research information between NIWA, universities and local and regional authorities. Commission smaller local sediment and wave climate studies. Commission detailed, long term, local beach profile studies.
Lack of knowledge of the effects of local climate change on local coastal process drivers.	The overall severity of the effects of sea level rise for the region not known.	Become involved with promoting large, multi organisational, regional and national research programs on sediment transport and erosion and accretion trends. Promote and facilitate the flow of information between NIWA, universities and local and regional authorities. Smaller research programs also relevant.
Lack of detailed onshore topographic and bathymetric data	More detailed community tsunami and storm surge hazard assessments will be limited in scope.	Commission a program to map 0.5 m contours, beginning with the higher risk areas, or become involved with promoting a multi regional or national program to do the same.
Lack of understanding of risk from locally generated tsunami	Potential wave heights and recurrence intervals for locally generated tsunami cannot be estimated with confidence.	Promote and facilitate the flow of information between NIWA and local and regional authorities. Encourage and support university and Crown Research Institute work on the sea floor environment in the Cook Strait and eastern Wairarapa areas.
Lack of social and economic impact studies on the future effects of all coastal hazards	Adaptive capacity of communities is not known	Commission research into social and economic costs of restricting development and implementing the options for dealing with sea level rise, coastal erosion, tsunami and storm surge.

Table 6.1. The main coastal hazard information gaps in the Wairarapa, the effects of these gaps and the options for filling them.

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Useful tsunami information links page: http://www.pmel.noaa.gov/tsunamiReferences

Glossary

Adaptive capacity	The ability of a human system or ecosystem to adjust or respond to climate change (including both variability and extremes), to reduce potential damages, to take advantage of new opportunities arising from climate change, or to cope with and absorb the consequences.
Average global sea level rise	The overall rise in absolute sea level in the world's oceans.
Backshore	The zone of the beach profile extending landward from the sloping foreshore to the point of development of vegetation or change in physiography (sea cliff, dune field etc.).
Beach face	The sloping nearly planar section of the beach profile below the berm, which is normally exposed to the swash of waves.
Breaker zone	The portion of the nearshore region in which the waves arriving from the offshore become unstable and break.
Climate change	Any significant change or trend in climate over time, either in the mean state of climate and/or in its variability (e.g. extremes of temperature or rainfall, retreat or advance of glaciers, El Ni*ñ*o-Southern Oscillation). The IPCC include both 'natural' change and that attributable to human activities (e.g. use of fossil fuels).
Coastal marine area (CMA)	That area of the foreshore and seabed of which the seaward boundary is the outer limits of the territorial sea (12 nautical miles) and the landward boundary is the line of mean high water springs, except that

	where that line crosses a river, the landward boundary at that point shall be whichever is the lesser of 1 km upstream from the mouth of the river, or the point upstream that is calculated by multiplying the width of the river mouth by five (RMA 1991).
Coastal zone	The area between the landward limit of marine influence and the seaward limit of terrestrial influence.
El-Niño Southern Oscilation	The climate system that governs year to year climate variability in the Pacific and Indian Oceans.
Eustacy	Absolute level of the sea surface and its fluctuations.
Foreshore	The sloping portion of the beach profile lying between a berm crest (or in the absence of a berm crest, the upper limit of wave swash at high tide) and the low water mark of the run down of the wave swash at low tide.
Hypocentre	The point within the Earth along a rupturing geological fault where an earthquake originates.
Inshore	The zone of the beach profile extending seaward from the foreshore to just beyond the breaker zone.
IPO	Interdecadal Pacific Oscillation, a 20-30 year climate cycle in the Pacific that modifies the El Niño Southern Oscillation system.
Isostacy	The vertical movement of the land due to the loading and unloading of weights (e.g. ice).
Leading edge coast	A coast occurring on a continental margin close to a converging crustal plate boundary.
Littoral zone	Includes the entire beach environment from the backshore into depths where sediment is less actively transported by waves. This depth is imprecise, but is approximately 10-20 m.

Mean high water springs	(MHWS) The level of the average spring tides predicted around full or new moon periods.
Nearshore zone	A zone incorporating the swash zone, surf zone and breaker zone.
Offshore	The comparatively flat portion of the beach profile extending seaward from beyond the breaker zone (the inshore) to the edge of the continental shelf. This term is also used to refer to the water and waves seaward of the nearshore zone.
Relative sea level rise	This is the net sea level rise relative to the local landmass (which may be subsiding or being uplifted).
Sea level rise	The trend of annual mean sea level over time scales of at least two to three decades.
Surf zone	That part of the nearshore zone where incident waves break and breaking-induced processes dominate the fluid motion, and hence sediment transport processes.
Swash zone	The portion of the nearshore region where the beach face is alternatively covered by the runup of wave swash and exposed by the backwash.