PLANNING ON A RETREATING COASTLINE: OAMARU, NORTH OTAGO, NEW ZEALAND

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GNS Science Report 2009/25
August 2009

BIBLIOGRAPHIC REFERENCE

Forsyth, P.J. 2009. Planning on a retreating coastline: Oamaru, North Otago, New Zealand, *GNS Science Report* 2009/25. 57 p.

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ISSN 1177-2425
ISBN 978-0-478-19684-9

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ABSTRACT

The natural phenomenon of coastal erosion becomes a hazard when it poses a threat to property and/or life. Erosion of the coastline in and near the township of Oamaru (North Otago) threatens property, assets and infrastructure close to the coast. Both short-term erosion events (particularly in 2007), and long-term retreat (over thousands of years) are observed.

Coastlines are naturally dynamic, but human actions have also had measurable effects, even during the relatively short period of European settlement in New Zealand (~ 170 years). Future climatic warming, with associated sea level rise, is likely to exacerbate coastal erosion on cliffed coastlines such as those at Oamaru. International approaches to dealing with coastal erosion, including the concept of "managed retreat", have an application in New Zealand although our coastal planning framework (principally under the Resource Management Act 1991 and the New Zealand Coastal Policy Statement) is unique to this country. Under the Resource Management Act, regional councils and territorial authorities (city and district councils) are required to have regard to the effects of climate change.

The geographic and geological setting of Oamaru explains some of the observed features of coastal retreat. Most of the town is built on a coastal terrace, which consists predominantly of unconsolidated deposits and terminates in a sea cliff. Wave climate, longshore drift and the nature of beach sediment contribute to a sediment deficit that allows storm waves to break against the foot of the cliff at times, causing erosion. Parts of the coast have been modified, for example by reclamation, rock armouring and breakwaters. However, in the long term, some of the coastal terrace on which the town is built will continue to be eroded away.

This study describes recent erosion effects at several sites within Oamaru township and further south along the coast. Council responses to the erosion hazard include zoning and setbacks, control of subdivisions and new developments, and hard coastal defences. These are part of the spectrum of possible statutory responses used by councils around New Zealand and elsewhere. Related (non-council) research includes analysis of coastal sediment budgets and rates of shoreline retreat, and community awareness of coastal erosion in this area.

Some suggestions for further study are given, such as monitoring district and regional plan outcomes and effectiveness in this area, researching the role of insurance in modifying actions of property owners, and evaluating risk acceptance in the Oamaru/Waitaki community.

KEYWORDS

Oamaru, Otago, erosion, coast, cliff, sea level, climate change, hazard, geology, sediment budget, beach profile, RMA, planning, zoning, setback, coastal defences, sea walls

1.0 INTRODUCTION

The aim of this study was to investigate coastal erosion near the North Otago town of Oamaru – its geological and historical context, magnitude and effects, and the actual and potential land-use planning responses to it.

Erosion of the coastline north and south of the town of Oamaru has been noted since European settlement (about 170 years ago). Property, assets and infrastructure placed close to the coast are now at risk (or have been destroyed). In addition to the observed short-term erosion trend, geological analysis suggests that the coast is in a state of retreat in the long term (thousands of years). Significant erosion events in the winter of 2007 were the impetus for the study. The report was not commissioned by the local district or regional council, but council staff assisted with gathering information for the study.

The study is based on:

- press clippings (for immediate eye-witness reports)
- scientific studies (for long-term analysis)
- interviews and discussions with relevant people in Oamaru and Dunedin
- websites of councils and other relevant organisations.

The report comprises twelve sections. Sections 1, 2 and 3 are introductory, and describe the scope of the report and the national and global context of the study. Sections 4 and 5 describe the town of Oamaru and the adjacent coast, including the geographical and geological setting, and the nature and extent of coastal erosion. Section 6 describes some of the possible planning responses to the coastal erosion situation, and section 7 discusses the actual responses by the local district and regional councils. Section 8 summarises an earlier survey of coastal communities, including Oamaru, that explored perceptions of natural hazards and the risks of living on the coast. Suggestions for further work, and conclusions, are listed in sections 9 and 10. The many people who contributed to the report are listed in the Acknowledgements (section 11), while section 12 lists the documents and websites cited in the report.

2.0 PHYSICAL ENVIRONMENTAL ISSUES

Coastal erosion is a natural phenomenon that has occurred throughout all of geological time, but it becomes a hazard when it poses a threat to property and/or life. Coastal erosion can be exacerbated by human activities, on both local scales (for example, by built structures such as sea walls, or by human-caused sedimentation changes) and larger scales (for example, by sea level rise caused by anthropogenic climate change). Coastlines have always been dynamic features, evolving in response to changing conditions. Historically, the management of coastal erosion has been dominated by the "hold-the-line" paradigm (e.g. Blackett & Hume 2006). However, it is now recognised that working with natural processes, rather than against them, is more likely to have long-term positive environmental outcomes.

2.1 Dynamic coastlines

Coasts can be very generally classed as eroding (temporarily or permanently cutting back) or accreting (building outwards over time). Erosion and accretion can occur in a cyclic pattern, and can also occur in a series of episodic steps, for example, related to storm events (Ministry for the Environment (MfE) 2008). Even over short distances of coast, patterns of erosion and accretion can vary, depending on a complex interaction of different natural factors and processes. These include hydrodynamic driving processes (such as waves and storm surges), geology (such as the nature of rock or sediment along the coast), geomorphology (such as beach and barrier type), and sediment supply. Tectonic uplift and subsidence also influence coastal environments, and in tectonically active areas such as New Zealand it can be difficult to separate the different factors operating on any given coastline. There is a wide range of timescales over which coastal erosion or accretion occur, ranging from individual storms, through annual and El Niño cycles, up to long-term outbuilding or retreat at decadal, century or millennial scales (MfE 2008).

In New Zealand, human records of coastline change typically go back only a few hundred years (the duration of Polynesian and European settlement), with written, drawn or photographic records covering only the last 170 years or so. Detailed monitoring of coastline changes is available for a few areas and generally covers only a few decades. Geological techniques, such as radiocarbon dating and studies of fossils, can extend this record back thousands or millions of years, depending on the preservation of suitable materials. Geomorphology – the study of landscapes – can also provide valuable insights into coastline changes over geological time.

Human actions have had measurable effects on coastlines, even during the relatively short period of European settlement in New Zealand. Some effects are local and probably reversible (for example, the effects of sand and gravel mining on mobile beaches may disappear quite quickly once mining stops, provided that these activities are sited wisely in relation to the direction of longshore sediment movement (e.g. Gibb & Adams 1982). The invasion of non-native species, such as marram grass, causes the building of sand dunes that are higher and steeper than those built around native sand-binding vegetation, but this also is reversible. On the other hand, reclamations, sea walls and other engineering works designed to “protect” the coast may actually worsen effects at the site or at neighbouring sites – merely shifting the problem or creating a new one. For example, Jacobson (2004) states:

> “On a retreating coastline without a seawall, the natural features of foreshore, beach, dune, inter-dune wetlands, estuaries, etc will migrate landward to take up a new position as sediment is interchanged between these features by waves and wind. On a retreating coastline with a seawall, the natural features of foreshore, beach, dune, interdune wetlands, estuaries, etc cannot migrate landward. As each feature reaches the wall, it will progressively disappear.”

Breakwaters at Oamaru and Timaru have affected adjacent sections of shore, contributing to both accretion and erosion (Gibb & Adams 1982; de Lange 2007). At Oamaru, Dickson et al. (2007) note that cliff erosion is concentrated adjacent to the end of any hard structure.

2.2 Climate change

The Intergovernmental Panel for Climate Change (IPCC) is continually assessing the current state of scientific knowledge on climate change. The IPCC released its Fourth Assessment Report in April 2007:

> “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level” (IPCC 2007).

Climatic warming will affect existing coastal hazards by changing some of the drivers of these hazards. It is likely to exacerbate coastal erosion, mainly through a rise in sea level and possibly also through changes in storminess and wave conditions (MfE 2008). The Fourth Assessment Report of IPCC estimated a range of projected sea-level rise of 0.18–0.59 metres by the decade 2090–2099 (mid-2090s) relative to the average sea level over 1980–1999 (IPCC 2007). Sea level rise may well be greater than this, depending on the rate of growth of greenhouse gas emissions and other factors. Sea level will not stop rising at 2100, but will continue to rise for many centuries into the future. The Ministry for the Environment 2007 guidelines “Making Good Decisions – Climate Change Effects” suggest planning for at least a 50 centimetre rise in sea level, and assessing the sensitivity of the activity to a possible 80 centimetre rise, by 2090 (MfE 2007). A comprehensive review document (MfE 2008) contains much more detail on projections of climatic changes for New Zealand.

Section 3.3 of the MfE 2008 report explores the likely effects of climate change on cliffed coastlines, concluding that “simple” cliffs are likely to be highly sensitive to sea level and wave height changes, and moderately sensitive to changes in storm surges and precipitation. However not all sea cliffs are the same (in fact few are “simple” on close inspection), and the effects of climate change will be highly dependent on how resistant their geological materials are to erosion. Where cliffs are fronted by a gravel beach, changes in the rate of retreat of the cliff will be linked to changes at the gravel beach, which in turn may respond differently to the physical effects of climate change. From the foregoing, it is clear that robust predictions cannot be made at present regarding erosion rates on specific sections of coast; but it is fairly certain that low cliffs of weak sedimentary materials, with little or no gravel at the foot, will experience similar or greater rates of erosion in the near and distant future.

3.0 NEW ZEALAND PLANNING ENVIRONMENT

3.1 Planning in New Zealand

The pre-eminent legislation governing planning in New Zealand is the Resource Management Act 1991 (RMA) and its subsequent amendments. This is the main legislation under which district and regional plans are implemented. The purpose of the RMA is to ensure that natural and physical resources are sustainably managed for present and future generations; the sustainable management principle underpins all decisions made under the RMA.

Most relevant to the topic of this study, the Resource Management (Energy and Climate Change) Amendment Act 2004 introduced the requirement to have particular regard to the effects of climate change (Part II of the RMA, section 7(i)). In the context of the RMA, 'particular regard' may be given to the effects of climate change:

- As an integral part of making decisions on resource consent applications and notices of requirement under the RMA for which the effects of climate change may be significant
- In proactively assessing policy statements and plans, as they come up for review or other changes are proposed, to identify whether more explicit and/or up-to-date policies are needed to address the effects of climate change than are currently provided. Thus, considering the effects of climate change can be integrated into local authorities' strategic and long-term planning

(Quality Planning Climate change guidance note).

Other legislation relevant to coastal environmental planning includes:

- the Local Government Act 2002 (LGA), the foundation legislation for the local government sector. Among other functions, it encourages local authorities to focus on promoting the social, economic, environmental and cultural well-being of their communities, consistent with the principles of sustainable development. Consultation between local authorities and their communities leads to the development of community outcomes and long-term council community plans (LTCCP). The sustainable development approach is described in section 14 of the LGA and is one of eleven principles governing the way local authorities must provide for the present and future needs of their communities.

- the Building Act 2004, Building Regulations 1992, and Building Code, which provide New Zealand's main framework for governing building work. These mainly apply to the physical aspects and regulation of building work, rather than the locations of buildings, but are relevant to planning in hazardous environments. For example, floor levels above flood limits may be imposed under the Building Act.

These are the most significant pieces of legislation, but there are a number of other authorities with responsibilities for the coastal environment under legislation other than the RMA, including:

- Department of Conservation
- Land Information New Zealand
- Maritime New Zealand
- Ministry of Economic Development
- Ministry of Fisheries
- Ministry of Justice
- New Zealand Historic Places Trust

(Quality Planning Coastal land development guidance note).

Regional councils and territorial authorities (city and district councils) have different roles and responsibilities in the management of the coastal environment (Fig. 1). The functions are set out in s30 and s31 of the RMA. Regional councils are responsible for preparing and implementing regional policy statements, which define the roles and responsibilities for natural hazard management in that region (these vary across the country). Regional councils also prepare a mandatory regional coastal plan that covers the coastal marine area. In general, regional councils are responsible for the area below mean low water springs. Territorial authorities are responsible for district plans that manage the effects from the use, development or protection of land above mean high water springs. District plans may include hazard zones or setbacks from the coast.

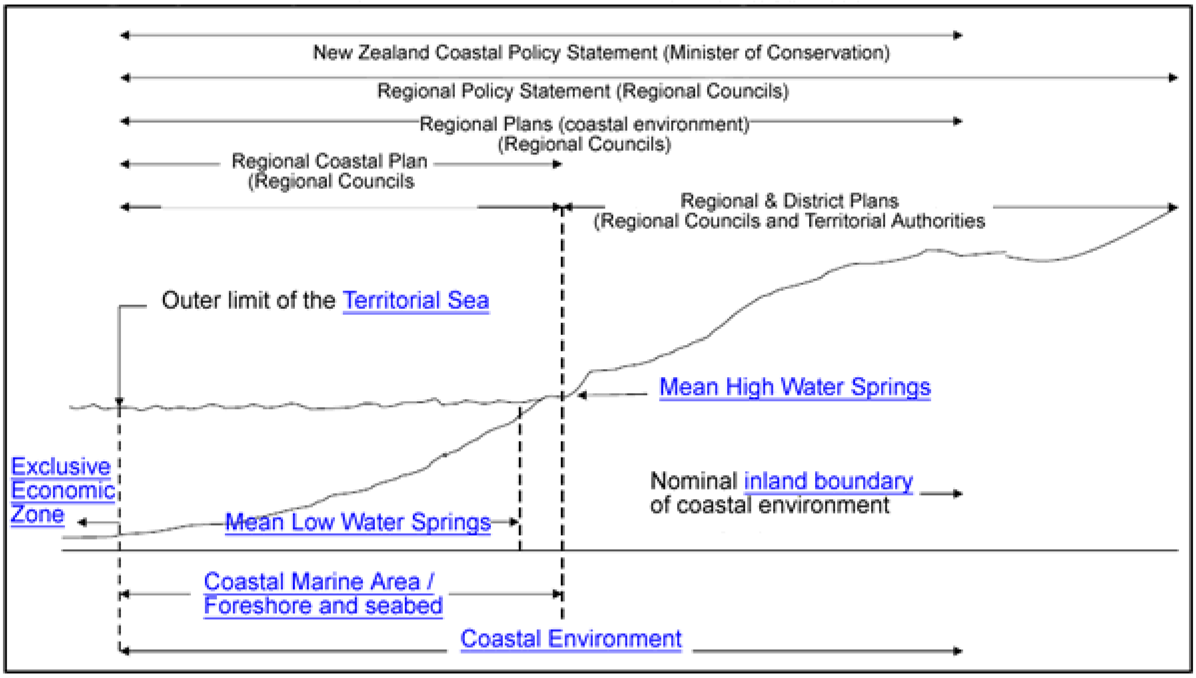


Figure 1: Roles and responsibilities for management of the coastal environment under the RMA. From Quality Planning website (Coastal land development guidance note).

3.2 New Zealand Coastal Policy Statement

The national importance of the coastal environment is recognised in the New Zealand Coastal Policy Statement (NZCPS) 1994, which provides the national policy framework for integrated coastal management under the Resource Management Act (RMA). The 1994 NZCPS has been reviewed (Rosier 2004, Jacobson 2004), and the Department of Conservation has since prepared and publicly notified the Proposed New Zealand Coastal Policy Statement 2008 (Proposed NZCPS). The review by Jacobson (2004) focused on the role of the NZCPS in promoting sustainable management of coastal hazards, and suggested numerous changes and additions to improve its effectiveness. Many of these suggested amendments were incorporated into the Proposed NZCPS, submissions on which are currently being considered (2009) by a Board of Inquiry appointed by the Minster of Conservation.

The practicalities of implementing the Coastal Policy Statement – in particular the ‘precautionary approach’ to environmental sustainability – were studied by Chandran (2007), who considered that the influence of the NZCPS may have been constrained by those charged with implementing it at the local level.

In addition, a National Environmental Standard (NES) on sea level rise is currently being drafted, and it is anticipated that this will be made public during 2009.

3.3 Assets, investment and insurance in the coastal environment

A high proportion of New Zealand's urban development has occurred in coastal areas, and about 70% of New Zealanders live in coastal towns and cities (de Lange 2007; MfE 2008). Some of this development has been located in areas that are vulnerable to coastal hazards such as coastal erosion – estimated by Gibb (1984) to be almost half of the country's coastline. In recent years, demand for coastal property for residential development, and the value of coastal property, have trended steeply upwards (Jacobson 2004), and as development and property values increase, the potential impacts and consequences of coastal hazards also increase. Already, coastal erosion is a frequent cause of disputes between landowners and local authorities (de Lange 2007), and is drawing the attention of insurers (see further below in this section). Managing this escalating risk over the coming decades now presents a significant challenge for planning authorities in New Zealand (MfE 2008).

New Zealand is not alone in facing these challenges: ongoing coastal erosion in the United Kingdom has required local authorities to develop shoreline management plans, and the Environment Agency's coastal erosion maps have predicted the shape of the coastline 20, 50 and 100 years into the future (New Civil Engineer, 7 June 2007). The difficult issues of maintenance (or abandonment or removal) of historic coastal defences, and compensation for property owners, are being faced by many developed nations, giving rise to the concept of managed retreat (also called "planned retreat") – see further below (section 6.7). One form of managed retreat is "Managed Realignment" (also called "De-Embankment" in mainland Europe), where artificial barriers are being breached intentionally to enhance habitats such as salt marshes and tidal estuaries (Online Managed Realignment Guide (OMReG) website, http://www.abpmer.net/omreg/). However, this is a rather different concept from abandoning homes and infrastructure to marine encroachment, or relocating settlements entirely.

The New Zealand insurance industry has become concerned at recent claims for weather-related damage, and predicts that these will only increase as the effects of climate change become more apparent (Insurance Council of New Zealand Chief Executive Chris Ryan, addressing the Local Government New Zealand 2007 conference; Otago Daily Times, July 18 2007). In rare situations, houses on eroding coastal strips have actually become uninsurable (insurance underwriter John O'Hara, quoted in Dominion Post, April 15 2006), and mainstream publications such as New Zealand Consumer (July 2005) have published articles on coastal erosion. Hazards managers and risk analysts are raising the concept that societies, as well as councils, must plan for climate change, and the insurance industry wishes to become involved with finding solutions. Former Prime Minister Helen Clark suggested that small towns may have to be moved from high-risk areas (Otago Daily Times, July 18 2007). Professionals in meteorology, earth and atmospheric sciences, insurance and planning are periodically reported in newspapers and magazines, advising on coastal erosion hazards and issues. Public awareness is raised by these types of coverage, which must form a valuable background to the necessary actions of territorial authorities and the government.

4.0 THE OAMARU AREA

4.1 Oamaru township

Oamaru is the main town of North Otago in the South Island of New Zealand (Fig. 2). The earliest human occupation of the district is thought to have occurred about 850AD, when the Waitaha people settled at the Waitaki River mouth. European exploration of Otago took place during the 1840s, and the town of Oamaru was laid out in 1858 under the direction of the surveyor John Turnbull Thomson.

Oamaru Harbour was the hub of 19th century development, with principal exports of gold and agricultural produce (wool, grain and meat). The natural harbour was enhanced by the addition of a breakwater (Macandrew Wharf), which was completed in 1884. The commercial centre of the town in Victorian times boasted many fine buildings constructed from the local limestone, which is still generally known as “Oamaru stone”. Although commercial usage of the harbour has dwindled over time, this Victorian architectural landscape is now promoted as a major heritage attraction. The township has spread out from the harbour area, and now covers 4055 ha (including the subsidiary township of Weston, further inland), with a population of 11 424 at the 2006 census (Waitaki District Council website). The Port of Oamaru has declined in importance since the advent of containerised shipping, and today the major transport links are State Highway 1 (passing through the modern town centre) and the South Island Main Trunk railway line (passing along the coastal side of the township). The main industries in Oamaru are meat and other food processing, support for the agriculture and horticulture of the wider district, education and tourism.

4.2 Geological setting

The main geological maps covering the area are those of Gage (1957) and Forsyth (2001). According to these, the principal geological and geomorphic features of Oamaru township (Fig. 3) are:

- the headland of Cape Wanbrow, south of the town, which is composed mainly of volcanic rocks of Eocene age (approximately 33 million to 40 million years old). These rocks underlie not only the headlands but also the southern parts of the town (South Hill, Awamoa) (Fig. 4A). The rocks are well exposed at the Harbour Board quarry at the end of Macandrew Wharf, and at Boatmans Harbour on Cape Wanbrow. In places they are covered by loess (wind-blown silt), which can be seen in the “badlands” along Breakwater Road and on the Graves Walkway (on the Cape Wanbrow headland).

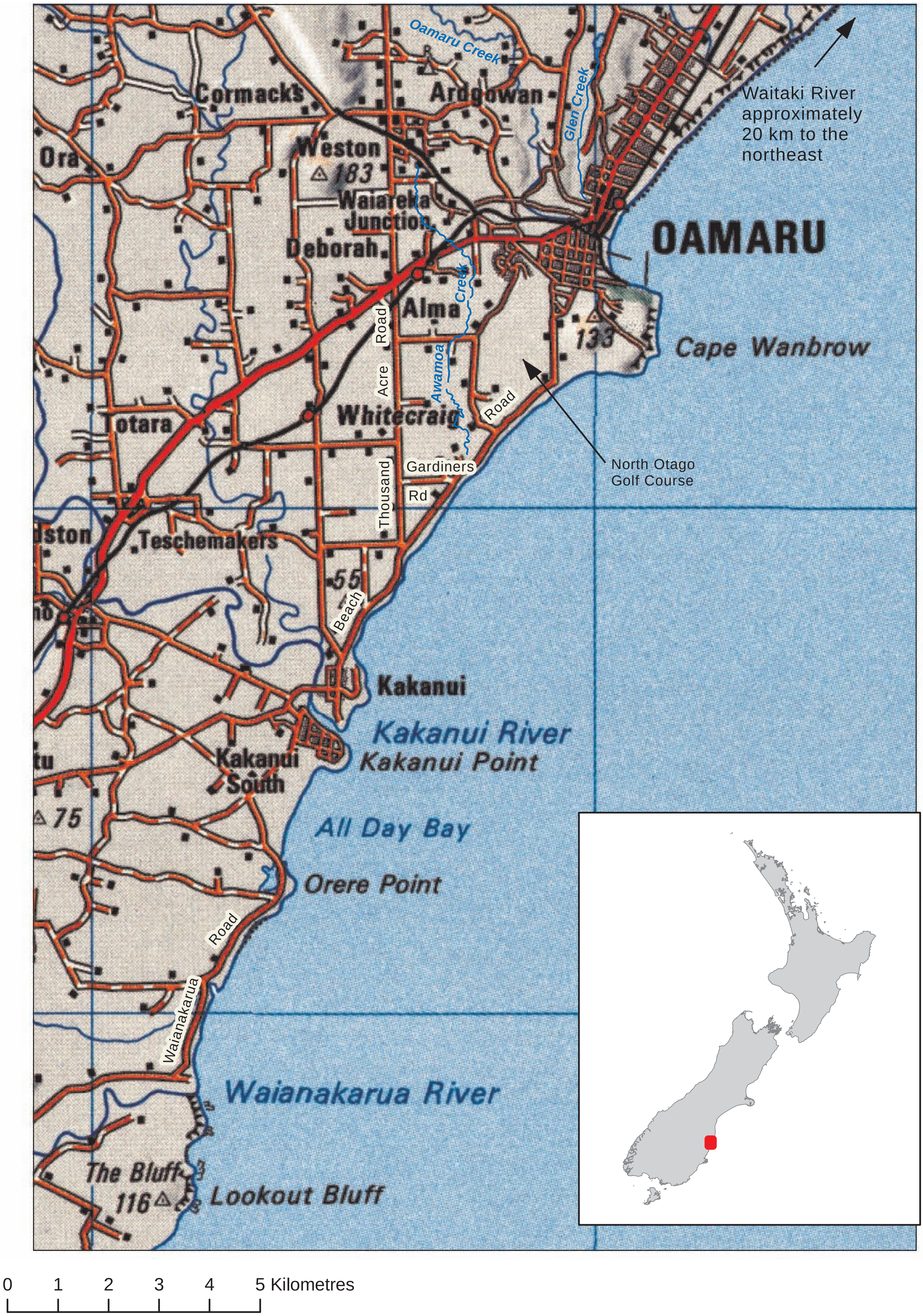


Figure 2: The study area in North Otago, from Oamaru to the Waianakarua River. Base map from NZMS 262 sheet 15 Waitaki.

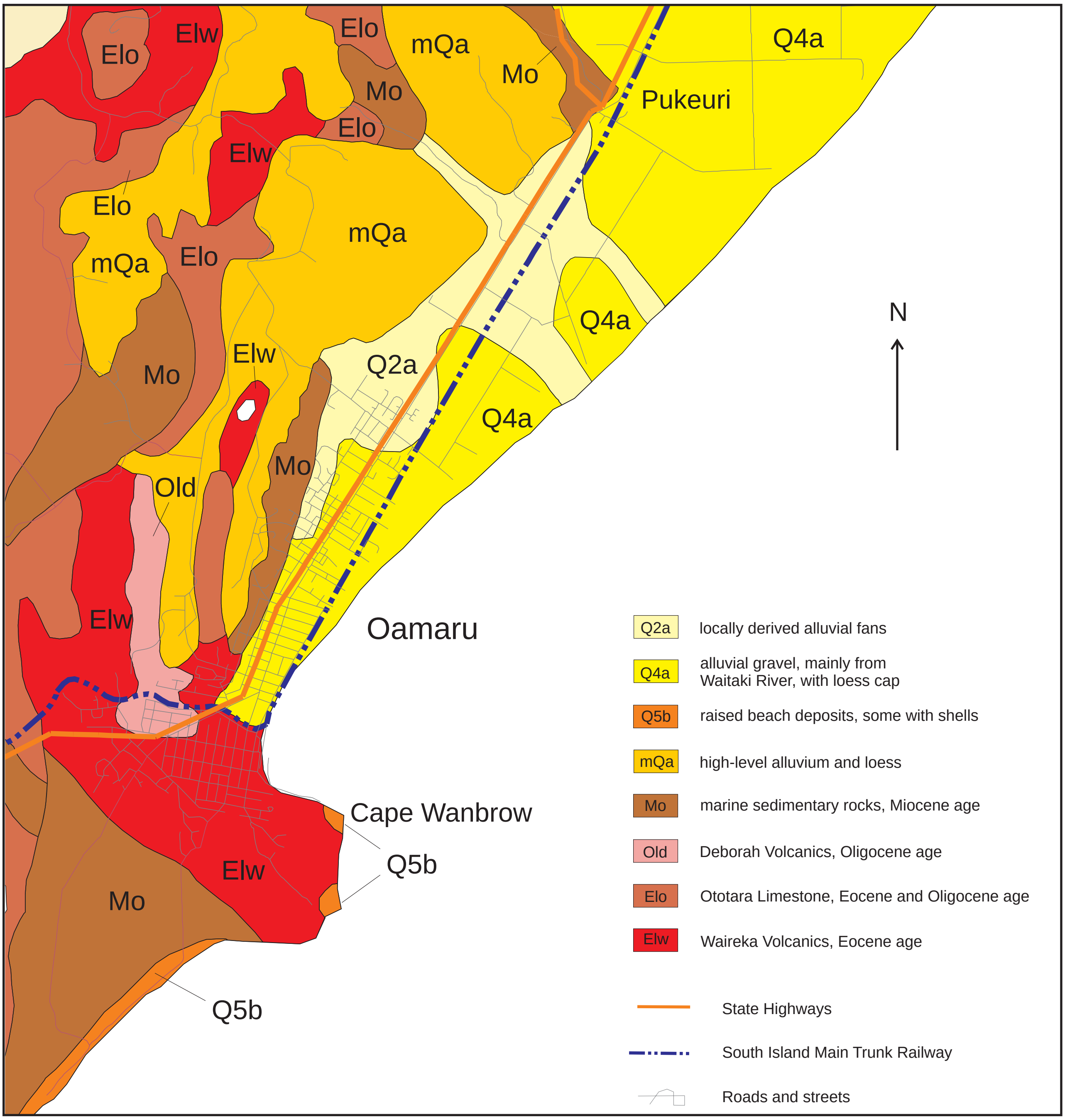


Figure 3: Geological map of the Oamaru area. Simplified from the regional geological map of the Waitaki area (Forsyth 2001).

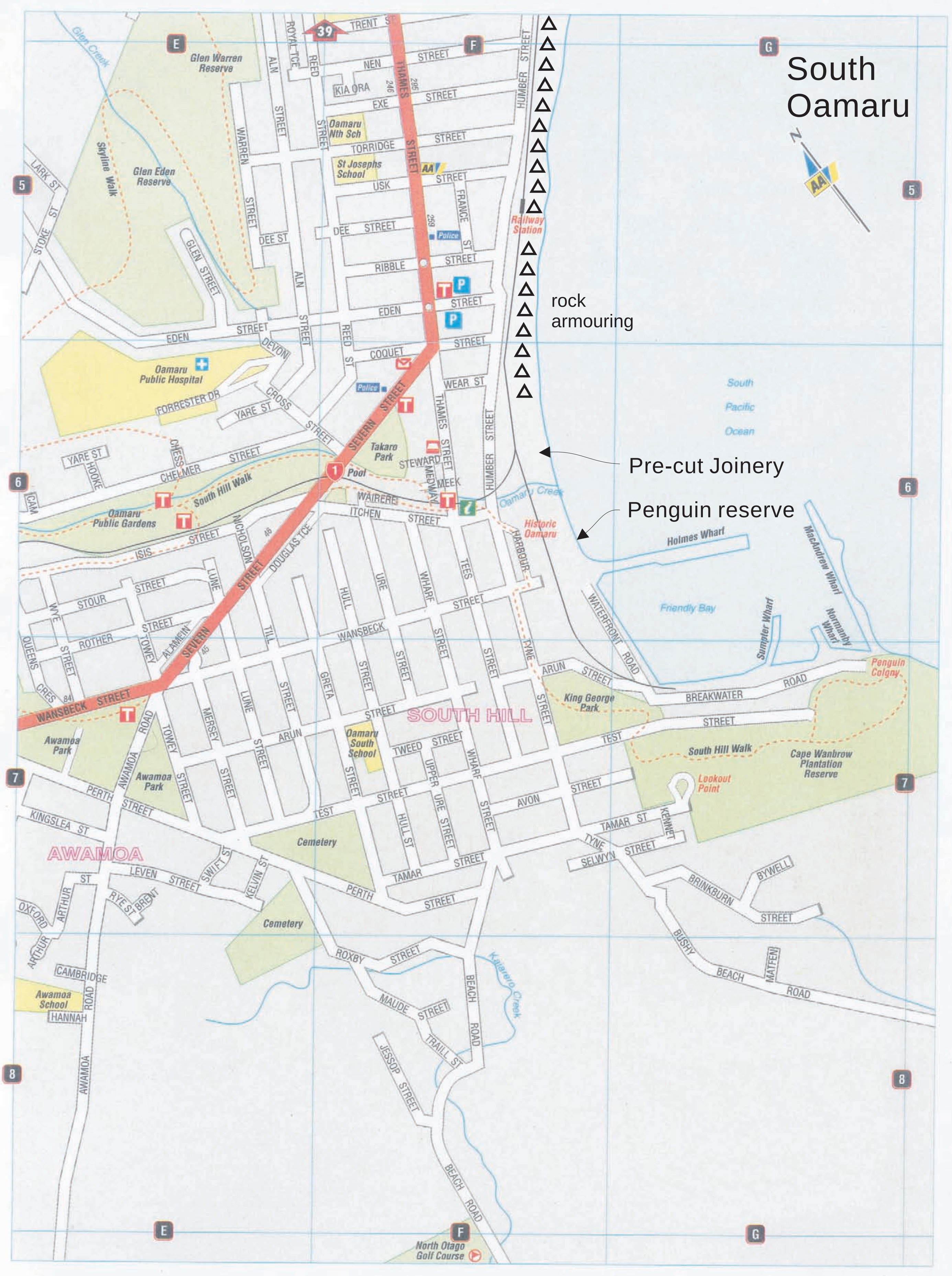


Figure 4A: The southern part of Oamaru township.

Figure 4B: The northern part of Oamaru township.

- a low coastal terrace, north of Cape Wanbrow, on which much of the town, the state highway and the railway are built (Fig. 4A, B). The coastal terrace is composed of alluvium (river and stream deposits) and capped by up to 5 metres of loess (wind-blown silt), both deposited during late Quaternary time – approximately the last 130 thousand years. The seaward edge of the terrace is an actively eroding sea cliff, which exposes the loess underlying the coastal terrace but generally not the alluvial deposits beneath (at least in the town area).
- a dissected tableland, with a seaward-sloping surface that is clearly seen from Lookout Point on South Hill (Fig. 5). It is underlain mainly by sedimentary marine rocks of Miocene, Oligocene and Eocene age (ranging approximately from 26 million to 36 million years old) and capped by high-level alluvial gravels and loess (perhaps up to half a million years old). Ardgowan (Fig. 2) is built on part of this tableland, and Glen Creek is cut into it. The rocks are best exposed in Glen Creek and in Landon Creek (between Oamaru and Pukeuri).
- the escarpment separating the coastal terrace from the dissected tableland, which is a former sea cliff. It has been modified by stream erosion and the build-up of local alluvial fans (loess and alluvium washed down from the tableland) at the cliff foot.

Figure 5: View north from Lookout Point on South Hill. Holmes Wharf (centre) encloses Friendly Bay (beyond trees). The whole of the coastline from Holmes Wharf into the distance is subject to erosion. Much of the township is built on a coastal terrace, which is underlain by alluvium and loess. The tableland beyond, underlain by older rocks, slopes gently seaward and forms the skyline. In the far right distance is part of the Waitaki River alluvial fan.

The coastal terrace surface continues northeast from the town, past Pukeuri to the mouth of the Waitaki River. The thickness of the loess cap decreases in this direction. The coastal cliffs likewise change towards the northeast, where they become higher, and fronted by gravel beaches. This is directly related to the change in geological materials that make up the coastal terrace. Erosion of the Waitaki River fan alluvium produces sand and gravel that nourish beaches and protect the base of the cliffs from heavy seas, while erosion of loess at Oamaru supplies clay that is lost offshore and creates little beach sediment (Dickson & Hicks 2007).

The coast in this area is dominated by wave action from the southeastern sector (Otago Regional Council 1991) or southerly quadrant (Gibb & Adams 1982). These waves are generated not only by southerly and easterly winds, but also from westerly winds whose waves are refracted around the southern South Island and travel up the eastern coast. The high winds generated in the Southern Ocean make the east coast of Otago susceptible to significant and moderately frequent wave attack. Storm events reinforce the tide-driven current that flows northwards, controlling longshore drift.

Although the Waitaki River, about 20 km northeast of Oamaru (Fig. 2) is a major transporter of sediment to the coast, this northerly flow means that little if any of the Waitaki sediment arrives at Oamaru. South of Oamaru, the Clutha, Taieri and other smaller rivers also bring sediment to the coast, but very little of this is carried north around Cape Wanbrow to supplement the inshore environment around Oamaru (Gibb & Adams 1982; Otago Regional Council 1991). Therefore there is commonly a sediment deficit in the vicinity of the township. Further details of the wave climate and sediment budget for the Oamaru/Waitaki coast are given by Gibb & Adams (1982) and Hicks et al. (2006).

The steep slope behind the coastal terrace is a former sea cliff (Gage 1957), implying that the unconsolidated sediments of the coastal terrace have built out since the sea retreated from that position (through sea level fall, land elevation, or both). Therefore it becomes important to know how long ago the sea was lapping against the foot of the tableland. The geological information currently available suggests that this was during the last major interglacial period, known as the Kaihinu Interglacial or Oxygen Isotope Stage 5, between 71 000 and 128 000 years ago. Former shorelines have been identified on Cape Wanbrow, where marine shells deposited 5 metres above present sea level have been dated at 130 000 years old (Forsyth 2001). The loess underlying the coastal terrace is thought to date from the last glacial period (Otira Glacial, Oxygen Isotope Stages 2-4). The relevance of this to the present study is that:

- marine erosion of the coastal terrace at Oamaru is occurring under present-day conditions;
- sea level is predicted to rise in future, which is likely to cause increased erosion;
- given a long enough period of erosion, there is no apparent reason why the coastal terrace could not be removed entirely in the very long term, allowing the sea to reoccupy its former shoreline at the foot of the escarpment.

4.3 Human modification of the Oamaru coastline

Although Cape Wanbrow shelters Oamaru Harbour from southerly swells and longshore current, additional shelter for the harbour was deemed necessary during the development of the port. This was created by Macandrew Wharf (also known as the Oamaru Harbour breakwater) and Holmes Wharf (also known as the North Mole), which together shelter the area known as Friendly Bay (Fig. 4A). The wharves are also understood to have a function in protecting the town of Oamaru from marine erosion (J. Chandra, WDC, pers. comm. 2007). There are current proposals to extend the breakwater structures (see 7.1.2 below, Waitaki Community Plan).

Part of the shoreline has been reclaimed or otherwise altered during the development of Oamaru, probably in an informal or ad-hoc way. The deposited materials (such as building spoil, wood, metals, asphalt, concrete and rock) are now being revealed by the erosion of the sea cliff (Fig. 6). The position of the shoreline before European settlement has not been investigated for this report, but it could perhaps be determined by detailed studies of historical maps and records, as has been done for long-term erosion studies (e.g. Gibb 1978). Gibb & Adams (1982) schematically show an area of reclamation between Holmes Wharf and Macandrew Wharf.

Figure 6: Reclaimed land immediately north of Holmes Wharf exposed by wave attack (the northern abutment of the wharf is at far left). The reclamation consists of unconsolidated rock rubble, masonry, asphalt and soil. Photo 12 March 2009.

Seaward of the central part of Oamaru, rock armouring has been placed for approximately 1.5 km along the shoreline where the railway line runs closest to the sea (from just north of the mouth of Oamaru Creek, to about Orwell St.) (Figs 4A, 4B, 7 and 8). This material was placed by New Zealand Railways in the 1930s to safeguard their facilities (Otago Regional Council 1991), and included the dumping of several old locomotives (ODT 18/2/09). The rock wall was maintained only occasionally, until a period of coastal attack (1968-74) when additional rocks were added (Otago Regional Council 1991). Following a further period of low or no maintenance (D. Sulzberger, pers. comm. 2007), the rock wall is currently being repaired on behalf of Ontrack (New Zealand Railways Corporation). This wall is not the responsibility of Waitaki District Council.

Figure 7: Rock armouring along the coastline at Oamaru Railway Station, looking northeast. The rock wall was undergoing maintenance work at the time of the photo (see yellow digger, just visible upper centre-left). In the distance the cliffed surface of the Waitaki River fan can be seen. Photo 12 March 2009.

Figure 8: The beach at Orwell St, Oamaru. At left is the northern end of the rock armouring placed to protect the railway line. Loess cliffs centre and right were directly attacked by waves in June 2007 and more recently-fallen material is seen at centre. Above the loess is a significant thickness of material from the last ~ 150 years, containing rubble, wood, concrete, glass and metal. The relationship of the visible storm beach (berm) to the present beach is seen in Figs 9 and 10. Photo 12 March 2009.

5.0 EROSION OF THE OAMARU COASTLINE

The coastline at Oamaru, and to the north and south of the township, is generally in a long-term state of retreat apart from a few small areas of temporary coastal accretion (Gibb 1978; Gibb & Adams 1982; Otago Regional Council 1991; Hicks & Todd 2006; Hicks et al. 2006; Dickson et al. 2009 in press). Most of the coastline is cliffed, with varying widths of gravel beach in front. Episodic erosion of the cliffs is caused by a combination of storm waves and gravity (falling of cliff materials). The rate of erosion is influenced by the amount of beach sediment fronting the cliffs (Hicks et al. (2006). Extensive background information on erosion processes along the Waitaki coast is given by Gibb & Adams (1982) and Hicks et al. (2006).

Local information in this section has been sourced primarily from the Otago Daily Times newspaper, including online searches (http://www.odt.co.nz/). Other sources include studies by NIWA (National Institute of Water and Atmospheric Research) and the Otago Regional Council, Google Earth imagery, and a ground inspection during March 2009.

5.1 Northern township

The northern part of Oamaru township (Fig. 4B) hosts mainly residential and light industrial land uses. Waitaki Boys' High School is also situated in this part of the town. Ongoing erosion here has been reported frequently through the 20th century and in recent years, particularly by the Otago Daily Times.

Firman Joinery building:
In the autumn of 2007, it was noted that wave action was removing gravel from the beach in the northern part of Oamaru, exposing "clay" (predominantly loess) at the base of the cliffs. This resulted from a period of southerly swells approaching the coastline at an angle of 45°, the angle that maximises longshore transport and moves beach sediment northward most rapidly (Dickson et al. 2007). During the weekend of June 23-24, a deep depression off the eastern coast of the South Island caused heavy swells from the southeast. The waves began cutting into the base of the cliffs, previously stripped of the protective gravel beach, and the cliff edge moved inland to threaten the Firman Joinery Ltd building in lower Weaver Street (ODT 26/6/07; Fig. 9). The following day an estimated 6 m of cliff retreat occurred and the seaward wall of the factory was undermined. By June 28, cliff retreat was estimated at 10 m and part of the factory floor and wall had collapsed into the sea (ODT 28/6/07).

The period of active cliff retreat ended after 6 days of heavy seas. The factory operations were forced to move to new premises, and the seaward part of the building was demolished in July (ODT 20/7/07). The total amount of cliff retreat in front of the factory was later estimated at 15 m (ODT 28/12/07) or 10–20 m in a study by NIWA (Dickson & Hicks 2007). Photos show that erosion in this area has proceeded by a series of "bites" or scallops into the cliff edge (Figs 9, 10; also see Fig. 20).

According to the NIWA study, a section of cliff top only 800 m further north than the Firman Joinery factory (probably at Caledonian Road) retreated less than 0.5 m during the 2007 erosion events (Dickson & Hicks 2007). While erosion in 2007 may have been localised near lower Weaver Street, long-term erosional trends have been noted at many sites along the south side of the Waitaki alluvial fan – including at Waitaki Boys' High School, approximately 1.5 km northeast of the Firman Joinery building.

Figure 9: The Firman joinery factory site in Lower Weaver St. Upper photo: The site during a period of active erosion (view towards the north). Note the height of the cliff exposed to wave attack during storm conditions. Photo courtesy of Otago Daily Times, published 27 June 2007.

Lower photo: The remaining part of the factory in 2009 (at right; view towards the south). Note the gravel storm beach built up against the sea cliff. Concrete rubble apparently placed for coastal protection is seen further left, then the loess cliffs at Orwell St (shown in Fig. 8) and finally the rock armouring alongside the railway in the left distance. Photo 12 March 2009.

Figure 10: The present land surface, sea cliff and beach at Lower Weaver St, Oamaru, just north of the Firman joinery site (looking towards north). This area is visible in the background of Fig. 9 (upper). Squared blocks of limestone set into the top of the loess mark foundations of a former building, and modern deposits of spoil are also visible. Note storm beach (berm) well above present wave height, and more recent falls of material from the cliff onto this beach. Photo 12 March 2009.

Waitaki Boys' High School:
The sea cliff is known to have retreated significantly within historical time at Waitaki Boys' High School (Fig. 4B). The earliest records held are from 1861, since when cliff erosion has claimed land on the seaward (eastern and southeastern) side of the school. Gibb (1978) calculated a net rate of erosion, in the period 1861 to 1976, of 0.58 m per year. Otago Regional Council (1991) calculated an average annual rate of erosion "of the order of 0.6 m"; in the 30 years up to 1991, the erosion rate was about 0.7 m per year. This tallies well with an estimate of about 30 m over 40 years (0.75 m per year) by former pupils at the school. In this time, a line of large trees and rough open land adjacent to the playing fields have been lost, and new lines of trees have been planted further inland. Some 80 m of land have been lost here since 1861 (Otago Regional Council 1991).

Southern Waitaki River alluvial fan:
Further northeast along the coastline towards the Waitaki River, farming is the predominant land use and coastal erosion does not affect as many roads, houses and structures. There have been fewer contemporary reports of damage, but several studies of long-term erosion cover this area.

Gibb (1978) calculated net erosion rates on the “south Waitaki fan” from 0.59 m to 1.97 m per year. The highest erosion rates were at the end of Corbett Road (on the coast about 11 km northeast of Waitaki Boys’ High School) and southeast of Oamaru Airport (about 3 km further northeast again). Gibb & Adams (1982) give an average rate of 1.1 m per year, and a maximum of 2.0 m per year, along the coastline of the south Waitaki fan.

An Otago Regional Council (1991) report gives an annual erosion rate of about 0.8 m per year in the area between north Oamaru and the Waitaki River, based on aerial photography. A NIWA study (Hicks & Todd 2006) calculated typical long-term erosion rates of 0.6 to 0.7 m per year on the south Waitaki fan, covering the period 1864/5 to 2000. Some periods have greater erosion rates than others – for example, a period of accelerated erosion was identified between 1943 and 1977.

Even longer-term erosion rates, calculated over the past 7000 years (from the time of post-glacial sea level rise), are close to 0.8 m per year (Dickson et al. 2009 in press).

5.2 Southern township

The southern part of Oamaru includes the harbour, with its enclosing breakwaters, and Oamaru Creek (Fig. 4A). As well as the main retail area and some light industry, there are major tourist attractions including the historic precinct of Oamaru stone buildings, and colonies of little blue penguins. The well-publicised penguin viewing area is located at the end of Waterfront Road (Breakwater Road on some maps), but there is also a penguin refuge reserve near the mouth of Oamaru Creek, not open to the public. This second penguin population is monitored as a “control”, in order to show whether the tourist venture is having any impacts on the penguins at the more “public” site.

Oamaru Creek Penguin Refuge:
The penguin refuge reserve just south of the mouth of Oamaru Creek was set up in 1992 and has recently been affected by the same erosion events that claimed the Firman Joinery factory (above) and the Pre-cut Joinery building (below). The refuge is sited between Oamaru Creek and Holmes Wharf, on the seaward side of the Harbour Street historic precinct (less than 70 m away at its closest point).

Volunteer refuge guardian Lorraine Adams has been shifting penguin nest boxes inland, in response to marine erosion, for several years. In August 2007, she reported that the refuge had lost land to the sea (ODT 2/8/07), and during the following summer heavy seas again eroded the coastline, displacing penguins and nesting boxes. In the worst affected area, shore retreat was estimated at up to 3 m (ODT 11/2/08, 12/2/08). By July 2008, the inland boundary fence came under threat from the sea, with part of the reserve shrinking to only 1 m wide (ODT 29/7/08). Approaches to the district council and the Department of Conservation were unsuccessful in getting the reserve extended. At the end of August the whole width of the reserve at the southern end had been lost and part of the fence had been removed (ODT 30/8/08), and further erosion was reported in October (ODT 4/10/08). A visit to the site in March 2009 showed that the fence at both ends of the reserve had been truncated by marine erosion, but a pile of stone blocks in the middle part of the reserve had

Figure 11: The Oamaru Creek Penguin Refuge. The upper photo shows the northern end of the refuge and the lower photo shows the southern end. The ends of the fence around the refuge have been truncated by the sea. The squared blocks of limestone are dumped masonry rubble which have had some effect in protecting the central part of the refuge from erosion. All of the currently exposed sea cliff at the refuge consists of rubble and reclamation materials. Photos 12 March 2009.

apparently protected the shoreline in that area (Fig. 11). Some penguin nesting boxes were still in place. The eroded sea cliff (1-2 m high) revealed reclamation fill of rubble, metal and concrete (Figs 6, 11).

This part of the coastline receives some protection from Holmes Wharf and appears to experience relatively short-term changes in erosion and accretion. Gibb & Adams (1982) state that following construction of Holmes Wharf, the shoreline north of the wharf advanced by 63 m (a rate of 0.7 m per year). They show a “local counter drift” from north to south as creating this accumulation. By 1991, the gravel beach was 50 m wide; this was described as “natural reclamation” in a photograph from about that time (Otago Regional Council 1991). All that gravel, and part of the low coastal terrace behind it, has since disappeared, a retreat of the order of 90 m (calculated from measurements on Google Earth imagery dated September 2006). At the time of writing (2009), the back fence of the penguin reserve was only 66 m from the eastern side of the historic precinct, with the land on the seaward side of the fence varying from nil to about 10 m wide. The reserve area appears to be most vulnerable to heavy seas from the northeast (Otago Regional Council 1991).

Pre-cut Joinery building:
The former Pre-cut Joinery factory is a privately owned building just north of the mouth of Oamaru Creek. It stands on land on the seaward side of Humber Street that is leased from the Waitaki District Council. In June 2007 it was reported that the sea was close to the edge of the vacant building (ODT 28/6/07). A further period of strong easterly winds and heavy rain caused flooding and erosion in Oamaru at the end of July. The building was being increasingly undercut by the sea and the area was cordoned off as dangerous in early August (Fig. 12), and soon after part of its eastern wall collapsed into the sea (ODT 2/8/07). Although it was reported that a demolition order would be issued, (ODT 25/8/07), part of the building was still standing in March 2009 (Fig. 12).

In June 2007, erosion also occurred along the central part of the Oamaru foreshore where rock armouring had weakened. It was reported that rail containers stored opposite the Oamaru railway station were undermined by the sea (ODT 28/6/07). In March 2009, repair work was being carried out on the rock wall opposite the railway station (Fig. 7), and included the removal of old locomotives dumped for erosion protection in the mid-1930s (ODT 18/2/09). Where a gravel beach formerly existed at the foot of the sea wall, the waves now wash directly against the rock armouring.

In June 2007 and February 2008, significant wave erosion damaged the Macandrew Wharf/Oamaru Harbour breakwater, continuing a history of wave attacks on the structure since the last upgrade in 1936 (ODT 16/2/2009; Otago Regional Council 1991). Waitaki District Council had suspended regular maintenance of the breakwater, but has now implemented a renewal programme involving placement of rip-rap material and concrete tetrapods (Fig. 13) to protect the structure.

Figure 12: The Pre-cut Joinery factory site near the mouth of Oamaru Creek.
Upper photo: Pre-cut Joinery building after undercutting by the sea in 2007 (view towards the south). Rocks in the foreground are part of the rock armouring visible in the lower photo. Photo courtesy of Otago Daily Times, published 2 August 2007.
Lower photo: View north from the mouth of Oamaru Creek, towards the Pre-cut Joinery building, in 2009. Fallen concrete slabs from the factory lie across the sea cliff. Beyond is a short section of loess cliffs, and the southern end of the rock armouring placed to protect the railway line. Photo 12 March 2009.

Figure 13: Concrete tetrapods are manufactured in bulk in the old Harbour Board quarry, near the penguin viewing area at the end of Waterfront Road, Oamaru. Photo: I.M Turnbull, 26 July 2007.

5.3 Beach Road and Waianakarua Road

The coastal roads between Oamaru and the Waianakarua River (Fig. 2) run along the top of the sea cliff in many places and have suffered from coastal erosion problems for decades. Local councils have repaired several sites repeatedly over the years, and one section has been closed. Waitaki District Council has commissioned various consultants' reports exploring options and solutions for these problems, including a report by Opus International Consultants that was still awaited at the time of writing.

Beach Road:
The coastal road south from Oamaru to Kakanui – Beach Road – is a subsidiary road for local and tourist use and but is also designated as a bypass for State Highway 1 if needed. The stretch of Beach Road between the North Otago golf course and Thousand Acre Road (shown on some topographic maps as White Rocks Road) runs along the top of low coastal cliffs (1 to 10 metres high) that have been eroding for many years. Between 1957 and 2002, the average rate of erosion along Beach Road was about 50 cm per year, and a 2002 consultancy report estimated that this part of the coast had been eroded by up to 29 metres over 28 years in some places (ODT 7/7/07).

North of Awamoa Creek, part of the road was shifted further inland in 2004, and gabions and large blocks of rock (rip-rap) were placed against the sea cliffs. Further erosion of this area in June 2007 (Fig. 14) revealed items such as railway lines, asphalt and an old boiler or engine littering the beach at the foot of the cliffs; these were probably used in earlier attempts at cliff protection. In March 2009, the sea was again washing against the foot of the cliffs at this site.

Just south of Awamoa Creek, erosion in July 2007 reduced the road to one lane, and emergency works were needed to restore it to two lanes (ODT 6/7/07). The seaward edge was buttressed with rock armouring (Fig. 14).

About 1.5 km southwest of Awamoa Creek, the section of Beach Road between Gardiners Road and Thousand Acre Road was closed in February 2008, because of erosion from heavy seas (ODT 13/2/08). In March, Waitaki District Council received a report suggesting that closing a 1.2 km stretch of Beach Road would be cheaper than continuously repairing it, and heard a prediction from the roading assets manager that eventual abandonment of a much longer section of the road from the North Otago golf course to Thousand Acre Road was possible (ODT 22/3/08). By April, the single-lane unsealed detour along Gardiners Road was being blamed for car accidents (ODT 4/4/08), and in May, council was calling on the government to share the costs of dealing with the ongoing coastal erosion in the district (ODT 8/5/08). A further erosion event occurred in June, cutting chunks out of the temporarily closed section of Beach Road (ODT 10/6/08). New rock armouring was tested by another erosion event in July (ODT 31/7/08). The section of Beach Road between Gardiners Road and Thousand Acre Road remains closed. A site inspection in March 2009 showed that the waves are breaking against the foot of the rock armouring (Fig. 15), and the inland side of the road has been cut back into loess. Gardiners Road (part of the detour) remained unsealed with a 50 kmh speed limit at the time of writing, but Waitaki District Council has decided to seal it in the future (ODT 27/5/09 and 31/8/09).

Waianakarua Road:
Further south along the coast, Waianakarua Road (which links Kakanui with Waianakarua) has been similarly affected by coastal cliff erosion. There are two main areas of active erosion: immediately south of Orore Point (Fig. 16), and just north of the Waianakarua River mouth (Fig. 17).

In the winter of 1978, a section of sea cliff was cut back to within “a foot” (about 0.3 m) of Waianakarua Road, requiring the (then) Waitaki County Council to rebuild and protect the road (Otago Regional Council 1991). The location of this road repair is not known.

In May 2008, further protection work was needed just south of Orore Point, where the road was reduced to one lane by coastal erosion (ODT 8/5/08), and in late July it was reported that the section north of the Waianakarua River mouth had also been reduced to one lane (ODT 31/7/08). In August 2008, councillors again recommended emergency works south of All Day Bay (Orore Point) so that the seaward lane could be re-opened. Rock protection and gabions were placed on a 45 m stretch of the road (attracting a 76% subsidy from the New Zealand Transport Agency). A council survey showed that over 70% of affected landowners

Figure 14: Beach Road near Awamoa Creek. Upper photo: North of Awamoa Creek, part of Beach Road has been shifted inland. In the foreground are materials used in ineffective attempts at cliff protection. Road works just visible in the middle distance are shown in the next photo.

Lower photo: Restoring an eroded section of Beach Road south of Awamoa Creek in July 2007. Photos: I.M Turnbull, 26 July 2007.

Figure 15: The closed section of Beach Road, near the intersection with Thousand Acre Road, looking north towards Cape Wanbrow. An actively eroding section of cliff can be seen beyond the rock armouring. Photo 11 March 2009.

Figure 16: Waianakarua Road – view towards the north from immediately south of Orore Point. The most distant rocks on the beach are natural, but the paler rocks right of the car have been placed to protect the road. In the foreground, the seaward road edge is actively slumping outwards. Photo 11 March 2009.

on Waianakarua Road wanted the erosion repaired, although the mayor acknowledged that this road could provide council with difficulties in the future (ODT 20/8/08).

A visit in March 2009 showed that the sea cliffs at the two main erosion sites are up to 6 metres high, but commonly lower, and are cut mainly in loess and fine-grained alluvium with some rounded river gravels near the mouth of the Waianakarua River. In some places, particularly beneath headlands, the cliffs show *in situ* volcanic rocks at the base. Cracking of the road verge on the seaward side of the road is within 60 cm of the road edge (as marked by a painted white edge line) near the Waianakarua River mouth, and within 1 metre of the road edge south of Orore Point, showing that slumping continues at these sites.

Figure 17: Gabions and rock armouring on Waianakarua Road, just north of the Waianakarua River mouth, looking northwards. Beyond the rock wall, the cliff consists of loess overlying Cenozoic volcanic rocks. Despite this protection work, cracking of the seaward road verge extends to within 60 cm of the road-edge white line. Photo 11 March 2009.

6.0 POSSIBLE PLANNING RESPONSES

This section of the report describes some possible planning responses to coastal erosion (and climate change in general). Details of the actual planning responses to coastal erosion around Oamaru are covered in the following section.

Local government is required to plan for known hazards, including climate change (Part II of the RMA, section 7(i)). Even if climate change effects are gradual, and planning documents have only a limited life, land-use planning decisions have long-term implications. The issues are well covered in the guidance manual on Coastal Hazards and Climate Change (MfE 2008), with examples from New Zealand and elsewhere. Of relevance to the present study are:

- Sea level rise and climate change
- The precautionary principle
- Time scales
- Hard and soft coastal defences
- Zoning
- Setbacks
- Managed retreat

The best option for managing coastal hazards, of course, is avoiding development in areas susceptible to hazards. Ideally, new subdivisions and developments should be located and designed so that the need for hazard protection works is avoided (New Zealand Coastal Policy Statement 1994, Policy 3.4.5). This approach may be achievable in undeveloped parts of the coast, but can be difficult to implement elsewhere. Managing risks where coastal development has already occurred provides a challenge for practitioners and councils, as avoiding risks is not always a feasible option and there is often pressure to provide coastal protection works to protect private property (Quality Planning Coastal land development guidance note).

6.1 Sea level rise and climate change

Some New Zealand councils are already updating regional and district plans to include consideration of climate change effects. For example, Tasman District Council, in the Tasman Resource Management Plan (Chapter 13 – Natural Hazards, 1 November 2008) has the section 13.1.30 Principal Reasons and Explanation (although this section is not yet operative):

> "The District has a substantial length of coastline that is subject to coastal erosion. There is a relatively high risk of erosion affecting soft shorelines around the District, particularly at … [list of places].
>
> Significant new built developments in areas that have been identified as subject to coastal or river erosion and inundation are likely to require capital-intensive protective works so are best avoided in such locations. Rules seek to avoid the future demand for protection works and to avoid the effects of known hazards.

> Council considers that as a contingency measure, the advice of the Ministry for the Environment given in June 2004 should be adopted in coastal planning. That advice was that a mid-range prediction for sea-level rise of about 30 - 50 centimetres (New Zealand average) between 1990 and 2100 can be expected with a high level of confidence. This rise is one expected consequence of global warming: others are changing climatic conditions, which include an increase in rainfall intensities and frequency and severity of storm events. All three factors place low-lying coastal margins at risk of both flooding from the landward side and inundation from the sea, or transformation by the processes of erosion and deposition."

Christchurch City Council has also addressed the matter of sea level rise and the time scale for planning purposes. Sea level rise was already mentioned in the City Plan (partially operative November 2005). However, proposed Variation 48 – Management of the Flood Hazard in Christchurch – should strengthen the application of knowledge about climate change (Forsyth 2006). This is before the Environment Court at the time of writing. The variation establishes Flood Management Areas (FMAs), where the levels of flood protection can be mitigated mainly by increasing minimum floor levels. Existing levels of flood protection are stipulated by the Building Act (floor levels at 50-year flood level), but Building Act provisions do not take account of sea level rise. In FMAs subject to tidal influence, the minimum floor level will include sea level rise through to the year 2100. Christchurch City Council hope to make Variation 48 operative during 2009 (G. Dixon, CCC, pers. comm. 2009).

Whakatane District has identified areas of land where coastal erosion and inundation are currently occurring and where erosion and inundation are predicted to occur by 2060 and 2100, taking into account the effect of sea level rise. The council has now completed Variation 6 to the Proposed Whakatane District Plan, to enable management of these coastal hazards. The decision was released on 30 January 2009.

6.2 Precautionary principle

The concept of the "precautionary principle" is implied in the RMA and is directly stated in the Civil Defence Emergency Management Act 2002 (MfE 2008).

The precautionary approach is also incorporated into the proposed New Zealand Coastal Policy Statement:

> "Policy 5 Precautionary approach
> A precautionary approach shall be adopted towards proposed activities whose effects on the coastal environment are uncertain, unknown or little understood, but whose effects are potentially significantly adverse to that environment."
> (Department of Conservation 2008).

New Zealand case law supports this principle:

> "Given the uncertainties in this area of planning, a precautionary approach should be taken"; Bay of Plenty Regional Council v Western Bay of Plenty District Council A 27/02 Skinner v Tauranga District Council A 163/02 (cited in appendix, MfE 2008).

The precautionary principle has been applied in New Zealand coastal planning for some years. For example, the Bay of Plenty Regional Coastal Environment Plan (2003), Section 11.1 notes that prudent action is possible even without universal agreement:

> "The prospect of global climate change has added an extra dimension to the coastal hazards issue in recent years…
> The International Panel on Climate Change (IPCC) publishes projections of future sea level rise. Not all scientists agree with these projections. However, a prudent council exercising the appropriate duty of care would be unwise not to adopt those projections. Accordingly this plan advocates the application of the most recent IPCC best estimate for sea level rise….".

However, there are (or have been) some barriers to applying the precautionary principle, as noted by Chandran (2007). Specifically, planners may construct their own meanings of what the precautionary approach is, or may look for scientific proof for adopting the precautionary approach, which tends to subvert the very purpose of the precautionary principle. Scientific uncertainty exists in the coastal environment, as in all other areas of environmental management. Specialists can only provide their best estimate of how events could proceed, but it is important to use a precautionary approach and act on these predictions (Blackett & Hume 2006).

6.3 Time scales

Natural processes happen on time scales ranging from seconds to millennia, but human activities tend to be viewed within timeframes of years to decades. Councils are elected every three years and their plans range from annual to ten-yearly. However, sustainability (mandated under the RMA, "for future generations", and a cornerstone of good planning practice) must be seen in terms of decades and centuries.

Longer-term views are most useful for considering coastal erosion and other hazards. Hazard zones are generally based on the probability of an area being affected within a certain timeframe, commonly 50 or 100 years in coastal settings. The UK Environment Agency has prepared coastal prediction maps for 20, 50 and 100 years into the future (New Civil Engineer, 7 June 2007).

New Zealand case law supports the use of a 100-year period in planning:

> "A 100-year timeframe is appropriate for considering coastal issues"; Bay of Plenty Regional Council v Western Bay of Plenty District Council A 27/02; Skinner v Tauranga District Council A 163/02; and Fore World Developments Ltd v Napier City Council W 029/06 (cited in appendix, MfE 2008).

Examples of using such time scales are Christchurch City's Variation 48, which considers 200-year flood levels and sea level rise as far ahead as 2100, and Whakatane's Variation 6 (predicting areas of erosion and inundation by 2060 and 2100). In another Canterbury example, the Timaru District Plan (2005) adopts the 100-year coastal erosion line (areas identified as subject to coastal erosion within 100 years) from the Regional Coastal Environment Plan. This line is shown on the District Plan maps.

It seems generally accepted that a 100-year planning horizon should be used in this field, but this does not preclude consideration of longer timeframes.

6.4 Hard and soft coastal defences

Where assets are at risk, it is inevitable that protection will be called for. Coasts with a history of erosion generally have various types of “hard” protection, such as sea walls, dumped rock and rubble, railway scrap, fences and groynes (most of which can be seen around Oamaru). Although these human interventions may satisfy the community and adjacent landowners for a while, history shows that they are rarely successful in the long term. Wherever “protection” works have been established, there is pressure to maintain or extend them. In fact, “hard” structures have been shown to cause increased erosion elsewhere along the coastline, and particularly adjacent to the ends of the structures, resulting in increased demand for further protection. Examples of this have been documented internationally and in New Zealand (e.g. Blackett & Hume 2006). Moreover, development may intensify inside the “protection” of a sea wall. Yet it has been estimated that most constructed coastal defences on New Zealand’s coastline that protect residential property will have a limited lifetime – at best, probably around 10–20 years – and on retreating coastlines, the effectiveness of such defences is continually being reduced (MfE 2008).

Worldwide, these sorts of concerns are leading to increasing resistance to the use of seawalls. They have already been banned in some US states. While still widely used in New Zealand at least one coastal expert believes that their role will significantly diminish over time (Dahm 2003).

Best practice is now considered to consist of working with natural processes along the coastline, rather than against them. On sandy coastlines, beach restoration projects aim to return to the natural beach profile, widening it and rebuilding sand dunes by trapping the sand that moves onshore during fair weather. Native plants have been used successfully to bind sand, and they build dunes of more appropriate scale and type than introduced plants such as marram grass. Sand dunes are protected in most district and regional coastal plans.

The best practice for eroding cliffs, such as those of Oamaru, is less clear-cut. As rebuilding the cliffs is not possible, the safest long-term approach must be one of managed retreat. Although rock armouring may slow the rate of cliff erosion, it is not a true long-term solution. Where gravel beaches front the bases of cliffs, they form important natural buffers to coastal erosion by dissipating the force of waves. The supply of gravel to these beaches may be amenable to some management (for example, by regulating gravel extraction or harbour dredging). However, most aspects of the longshore transport of gravel (influenced by weather and climate factors) are not controllable.

6.5 Zoning

“For existing communities in coastal hazard areas, there is a spectrum of management options, ranging from a focus purely on short-term property owner expectations at one end to a focus purely on long-term community expectations at the other end” (Jacobson 2004).

The most restrictive management options would allow no development, or redevelopment, that would increase the value of assets at risk within coastal hazard zones (for example, areas calculated to be subject to coastal hazard risk within the next 100 years). Management options in the middle of the spectrum include prohibiting subdivision or multiple dwellings in coastal hazard zones, and allowing re-development of single dwellings only if relocatable or if vulnerability is reduced in some other way. Some councils are exploring these options. The most permissive management options would allow development at the risk of the developer, with only warnings for prospective purchasers (for example, using s72-76 of the Building Act to tag titles with hazard information). The most permissive options would certainly increase assets at risk from coastal hazards (Jacobson 2004).

The Ministry for the Environment gives a very succinct series of management options:

- plan to avoid new development in coastal hazard areas
- plan to reduce risks in areas already developed/subdivided
- plan for evacuation

(MfE 2008).

One of the most obvious planning tools in this situation is zoning to control coastal development. A hazard zone is defined as the width of shoreline that is likely to be affected by coastal erosion or flooding by the sea during a specified period. Although in some areas flooding is the greater hazard, most zoning is based on erosion. Accreting coasts are not generally considered to be hazardous. Methods of determining hazard zonation vary widely and may include traditional and local knowledge, reliable historic data, monitoring, aerial photography, surveys, and map analysis, to yield a figure of average annual change or long-term trend (e.g. Gibb 1978). Coastal hazard zones have been used in New Zealand since the 1980s, and have been refined and applied in planning ever since (e.g. Gibb 1983; Jongens et al. 2007).

An equation for calculating the width of a coastal hazard zone for a 100-year planning horizon is given by Tonkin & Taylor Ltd (2008):

$$Hz = ST+SE+DS+SL+(LT \times 100)$$

Where Hz is the width of the hazard zone;
ST is the allowance made for short-term shoreline fluctuations;
SE is the shoreline response to storms;
DS is the dune stability factor, namely an allowance for the dune slope that will result following an erosion event;
SL is the magnitude of shoreline retreat from predicted sea level rise; and
LT is the long-term rate of shoreline movement in metres per year.

Another equation for calculating the width of a coastal hazard zone was developed for unstable sea cliffs in North Shore City (Auckland region) by Jongens et al. (2007):

$$CLHZ = S+(RT)+F$$

Where CLHZ is the width of the coastal landslide hazard zone;
R is the rate of long-term retreat of sea cliffs;

S is the horizontal distance representing the potential average sudden retreat of the cliff top;
T is the hazard assessment period of 100 years; and
F is a safety factor calculated from the maximum uncertainties in the other factors, plus a measurement uncertainty in accurately locating the cliff-top.

While developing such equations is a very useful step, in practice many of the terms and factors are very difficult to quantify. Even though Jongens et al. (2007) give substantial guidance and actual data for quantifying their terms, certainty may never be achievable, and it is therefore appropriate to invoke the precautionary principle in most cases.

In the Canterbury context, the Regional Coastal Environment Plan (2005) of Environment Canterbury defines two hazard zones: land at risk from coastal erosion within 50 years, and land at risk in the period 50 to 100 years. These hazard zones are shown on the maps that cover each district, and an appendix describes how they were determined (a combination of ground surveys, aerial photo interpretation, historical data and extrapolation). The zones vary in width from nil (e.g., not mapped on cliffs of Banks Peninsula) to about 400 m (on Kaitorete Spit). Width has been calculated from the maps available online (http://www.ecan.govt.nz/Plans+and+Reports/Coast/ regional-coastal-env-plan-2003.htm) in terms of distance inland from the coastal marine boundary (line of Mean High Water Springs). Some district councils have adopted these hazard lines on planning maps as part of their own land-use zoning. For example, Hurunui and Timaru show the 100-year (landward) line, while Selwyn uses the seaward line. Immediately north of the Waitaki River (in Waimate District) the zones total less than 100 m wide.

Once a coastal zone has been defined, restrictions may be placed on development. However, getting the hazard zonation passed into law via District Plans is not easy, as parties wishing to develop the land or those fearing that their assets will lose value generally oppose restrictive zoning. For example, Christchurch City's proposed Variation 48 (improving management of flood and sea level rise hazards) was publicly notified in December 2003 and had not yet been implemented in March 2009. However controversial, coastal experts recommend drawing hazard lines across properties as part of facing up to reality, and as fundamental to improved management of these areas (Dahm 2003).

The Coastal Hazards and Climate Change guidance manual (MfE 2008) has a substantial section on risk management and adaptation through land-use planning (section 6.5), which includes discussion on the respective roles of district and regional councils, and the effectiveness of rules. It notes that there are significant barriers to achieving effective risk reduction through the land-use planning framework. Putting a line on a map for a hazard zone is relatively easy compared with implementing it, especially when assets are already in the hazard zone.

6.6 Setbacks

A good setback in a coastal setting includes:

- the "average annual change" or long-term trend
- the credible change in any one event e.g. "a 100 year storm" (actually the storm with 1% probability of occurrence in any one year)
- a factor of safety to allow for uncertainties

(M. Hilton, Department of Geography, University of Otago, pers. comm. 2007).

Well-designed setbacks allow communities and local authorities to set boundaries for future discussion and action, and provide a buffer space for the naturally occurring movements of the shoreline (Blackett & Hume 2006). Setbacks and similar management methods can be applied by district councils, generally within designated hazard (or other management) zones. Regional council plans may show hazard zonations but not give rules for activities within the zones. Regional councils may only control land uses within the coastal marine area (below mean low water springs).

Robust setback methodologies and practices are seen in some North Island areas, such as Ohope Beach (Whakatane District), where years of both monitoring and development pressure are taken into account. Some areas have monitoring data going back to 1977, when a series of storms caused increased awareness of coastal erosion. In the Ohope area, the hearings on Variation 6 (Coastal Hazards) contain a wealth of scientific detail relevant to coastal planning in the New Zealand context (www.whakatane.govt.nz/PoliciesPlans/DistrictPlanning/default/Variation6CoastalHazards.htm). In other places, a setback may be some arbitrary figure estimated to give an adequate buffer, such as 20 m or 100 m.

One theoretical aspect of setbacks is whether they can be "rolled back" if necessary. This would involve ultra-long-term planning and has not been attempted so far in New Zealand. Regular reviews of coastal setbacks should identify whether landward extension is required.

6.7 Managed Retreat

"Managed retreat" is a strategic decision to withdraw, relocate or abandon assets at risk. At present, relocation of properties tends to occur on a case-by-case, occasional basis, with no council having yet developed a district or region-wide strategic approach to reducing coastal hazard risk in this way (MfE 2008). Managed retreat options allow the community time to gradually pull back from high-risk areas (Blackett & Hume 2006).

Managed retreat includes modifying a building, for example by raising its level; relocating it within a property boundary; relocation to another site; or large-scale relocation of settlements and infrastructure. Plan rules, property title covenants and financial mechanisms such as subsidies or insurance incentives may all play a part in encouraging and enabling forms of managed retreat. All possible options need to be explored, as experts predict that "given the level of existing coastal development in coastal margins around New Zealand, the use of planned or managed retreat will need to become a fundamental and commonly applied risk-reduction measure within the next few decades" (MfE 2008).

Some district plans specify that new buildings within coastal erosion hazard zones should be relocatable – for example, Tauranga City Council requires that an alternative building site be identified that is clear of the city's defined coastal hazard zone. Whakatane District's Variation 6 (Coastal Hazards) proposed that an alternative building site (ABS) would need to be identified for any subdivision and construction of new dwellings within the Coastal Hazard Erosion zone. This would be a site to which buildings could be practicably moved when they are threatened with exposure to coastal erosion, and the site would have to remain vacant (and thus available for future use). Following submissions, it was decided that the ABS need not be necessarily contiguous to the development but could be "within the locality".

Not all councils are convinced that relocatable buildings are a practical solution: Southland District Policy NHZ.11 states that:

> "… coastal erosion can be rapid and thus the perceived option of relocatable buildings is inappropriate.
>
> Explanation
> Coastal erosion often happens during major storm events. Such events are impossible to predict and their speed of movement and severity makes the option of relocatable buildings in a coastal hazard zone inappropriate."

Some experts have pointed out that relocatable buildings, though appropriate in some circumstances, still permit development in areas subject to significant risks. Such measures are more appropriate as a transition mechanism until more comprehensive forms of planned retreat have been adopted (MfE 2008).

Another possible method to encourage development away from coastal hazard zones was suggested by the commissioners in the Whakatane District Variation 6 hearings. This option comprised graduated rules with less restriction (in terms of the activity being prohibited, non-complying, controlled or discretionary) in more landward areas.

7.0 PLANNING RESPONSES AT OAMARU

This section describes the actual planning responses to marine erosion in North Otago, from the Waitaki District Council and the Otago Regional Council.

7.1 Waitaki District Council

7.1.1 Waitaki District Plan

The Waitaki District Plan (dated 1996) was made partly operative in 2004. An example of the maps in the District Plan is given in Fig. 18. The plan outlines natural hazards in section 4, where coastal erosion and inundation from the sea are listed among the hazards posing the greatest potential risk. In section 4.2 (Issue – Threat to People and Property), coastal morphology is described and a coastal erosion rate is given: "The coastline from Oamaru north can have rates up to 1 metre erode in any year". Otago Regional Council information is quoted: "land up to 80 metres inland from the present day coast north of Oamaru is likely to become at risk from coastal erosion over the next 50 years. Towards Waitaki River assets up to 90 metres from the present day coast may become at risk.”. The source of this information is apparently the Regional Council coastal hazard study of 1991 (see below).

Policies (section 4.2.2) require consent for subdivision along the coast, to avoid or mitigate the likelihood of damage to future assets. This is implemented by rules on subdivision (4.2.3). Subdivision activities are controlled in respect of natural hazards, which include erosion (14.3.3.5).

New coastal protection works are discouraged (Policy 4.2.2.6), but some existing protection works may be maintained (in consultation with the Otago Regional Council) to protect existing assets. The protection of cliff edges from inappropriate land management practices is encouraged, and is to be achieved by providing information or advice (4.2.3.3). Collecting information on a hazards register is another implementation method to achieve the natural hazards policies (4.2.3.6). However, the hazards register covers only contaminated sites, flood-prone areas (derived from ORC information) and landslips (J. Chandra, pers. comm. 2009), and it would therefore not be effective in the case of coastal erosion. Storm surge and tsunami modelling for the Otago coastline (undertaken by NIWA on behalf of ORC) have been provided to Waitaki District Council (G. Palmer, ORC, pers. comm. 2009).

The building setback along the coast in the Rural General zone is 100m (4.2.4), and this is explicitly to protect assets from coastal erosion, and to protect wildlife, habitat, and coastal natural character generally. Within this strip no building, forestry or excavation is permitted (4.4.7). The clearance of indigenous vegetation within 100 m of mean high water springs (MHWS) is controlled (site development standard 4.4.7 [3]).

In 2005, Variation 2/ Plan Change 2 (Landscape and Visual Amenity) was proposed, making the coastal scenic area now a minimum of 100 m, and wider as required (Fig 19). This area is primarily designated for landscape protection, but it is convenient that it can also have a function in protecting against erosion. The variation/plan change includes rules on new buildings, earthworks, utilities and exotic tree planting in significant landscapes along the coast (these activities would require a resource consent as a restricted discretionary activity). At the time of writing the council hearings are still in progress, but the new provisions have effect pursuant to clause 16B(2), Schedule 1 of the RMA and are annotated in the District Plan. However, the Township, Business, Residential and Rural Residential zones do not have the coastal scenic area notation or the associated rules.

Following pages:

Figure 18: Waitaki District Plan map of part of northern Oamaru township.

Figure 19: Waitaki District Council proposed coastal scenic area for Variation 2 (Landscape and Visual Amenity). The coastal scenic area (blue outline) varies in width in the rural area and is not designated in much of the township area.

Waitaki DISTRICT COUNCIL

DATE: JULY 2004

District Boundary
Railway Line
Property Boundary
Airfield Surface Boundary
Rivers and Lakes

Business 1
Business 2
Business 3
Business 4
Business 5
Business 6
Business 7

Business H
Omarama Airfield A
Omarama Airfield B
Township
Macraes Mining
Cement Policy Area
Flight Protection Area

Residential
Rural General
Rural Residential
Rural Scenic
Designation Areas
Designation Site
129 Designation Number

ZONES

BUS 1 - 7	Business 1 to 7
BUS H	Business Heritage
RES	Residential
RG	Rural General
RR	Rural Residential
RS	Rural Scenic
TSP	Township

Location Diagram

54 55 57 58 60

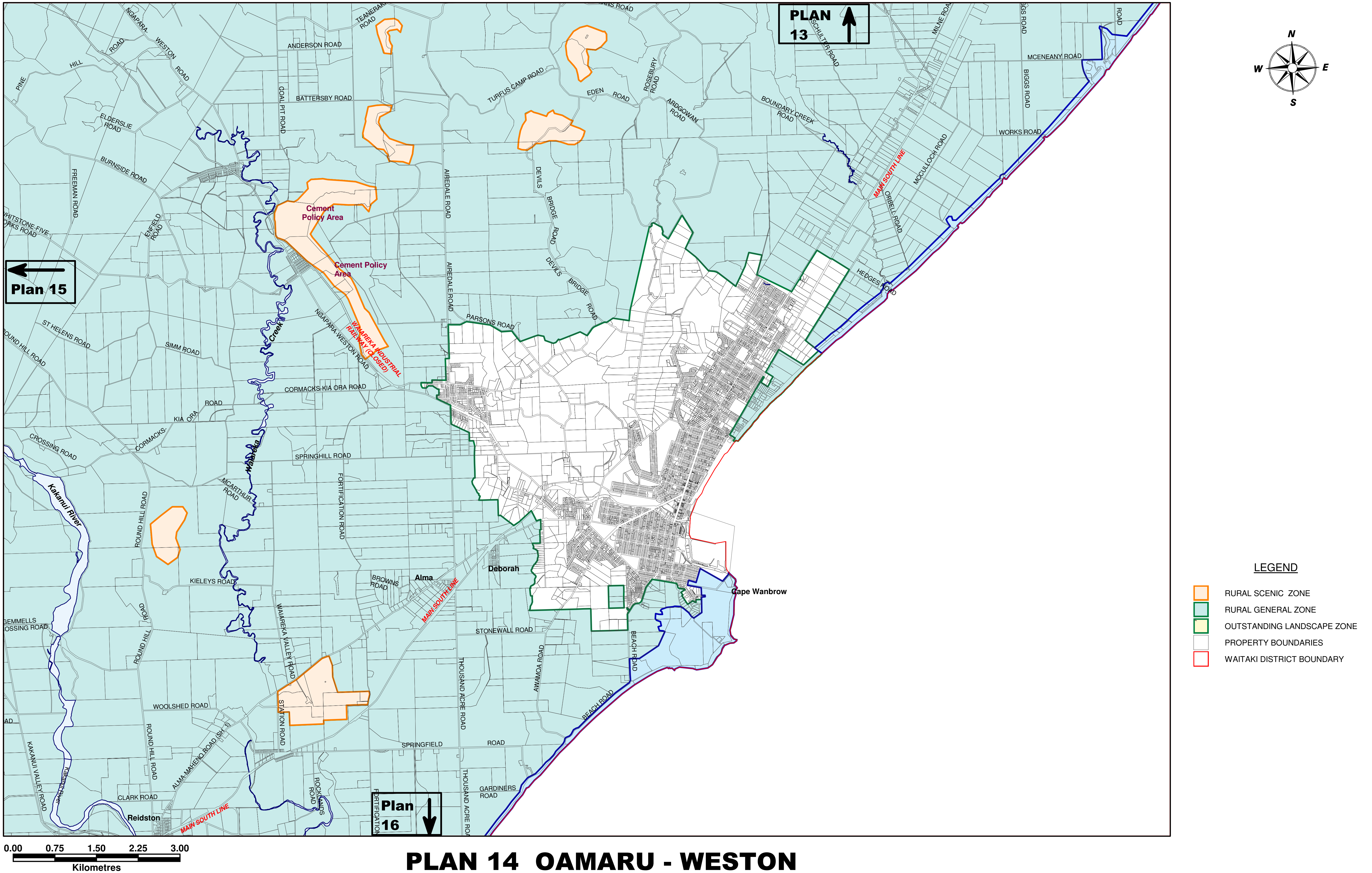
N W E S

Scale: 1:5000 @ A3

OAMARU

Map No: 58

WAITAKI DISTRICT PLAN LANDSCAPE VARIATION PROPOSED ZONE BOUNDARIES



PLAN 14 OAMARU - WESTON

FIRST SERIES,
2ND DRAFT 06/08/05

Figure 20: Cadastral data overlaid on a vertical airphoto dramatically illustrates the retreat of the coastline in northern Oamaru. The Firman joinery in Lower Weaver St is labelled as 1A. Stormwater pipes appear in green and a sewage pumping station in yellow. Note grey property boundary out to sea (lower centre). The coast has been eroded further since the photo was taken in 2005. This image was made available by Waitaki District Council, aerial photography sourced from Terralink International Ltd.

Waitaki District Council staff well understand that the effects of sea level change and climate change will become more important, and are committed to planning for the long term, according to Jack Chandra, WDC planning manager, in an interview in 2007. He considers that planning in the district should not allow assets to be placed at risk in hazardous locations, despite the high demand for coastal land. The 100 m wide coastal strip was established both to preserve the coastal landscape, and to provide a buffer for coastal erosion. In future, he believes council should be consciously avoiding placing assets in the way of hazards, and further plan changes may be needed to achieve this. For example, the notated coastal scenic area may need to be widened or rolled back in future. However, WDC does not monitor the coastal erosion situation in any systematic way, seeing this as the role of ORC. Various departments of council may keep their own records of erosion issues that they see as relevant.

The Waitaki District Council's Assets Group Manager is currently Neil Jorgensen (previously Dean Sulzberger). In interviews, both recognised the significance of the retreating sections of the coastline. Mr Sulzberger saw the 100 m coastal setback in the District Plan as being largely related to erosion, with its landscape protection function being a more recent addition. He considered that the existence of the strip indicates that erosion is an issue, and that this would motivate all concerned to avoid putting assets at risk (i.e. it has a public and council staff education/awareness function).

Waitaki District Council does not envisage extending the existing coastal protection works further along the northern part of the township (but note the more recent proposal to extend rock armouring in front of the historic town centre, see below). North of the township, the northernmost council asset at risk is the sewage treatment plant (located on the north side of Landon Creek, about 3 km south of Pukeuri) but council has no budget or intention for coastal protection in this direction. Estimated erosion rates should leave the sewage ponds safe within their design lifetime (N. Jorgensen, pers. comm. 2009).

Although some property boundaries are now out to sea (Fig. 20), the council does not compensate owners for property lost to marine erosion, and has never claimed to protect the coastline. It does not have insurance against such damage, and the emergency fund for repairs does not extend to payouts to property owners. Note that the Earthquake Commission (EQC) may cover residential property affected by cliff retreat during a storm event as 'storm damage', but erosion regarded as natural and gradual would not be covered (L. Dixon, EQC, pers. comm. 2009). (The Oamaru properties that have collapsed because of cliff retreat, described in section 5 above, were not residential.)

Mr Jorgensen saw ongoing roading problems (Beach Road, Waianakarua Road) as the main coastal erosion issue. For this local roading system, providing access for residents is seen as the main priority, although some roads also function as bypasses for State Highway 1. Council's emergency fund for repairs has been used for roading repairs in this area.

Waitaki District Council has recognised that future development needs to be constrained by natural hazards such as coastal erosion. Council is very aware of this risk, and any building development, if allowed within erosion prone areas of the coast, would probably have the hazard noted on the property title via s73 of the Building Act (J. Chandra, pers. comm. 2009).

In 2006, the council commissioned a Coastal North Otago Structure Plan, in order to determine areas in the district suitable for expansion. The plan would have included 'constraint analysis' to identify areas that should be eliminated from future development (because of natural hazards, among other factors). Unfortunately, this study was abandoned after some preliminary work.

7.1.2 Waitaki Community Plan 2009–19.

The Community Plan was adopted on June 30, 2009. The council's planned activities relevant to coastal erosion are mainly found in the sections on Roading and Oamaru Port.

The Roading section refers to the Draft Coastal Erosion Management Strategy that is currently under development. This is a plan for the long-term management of the coastal route between Oamaru and Waianakarua. The strategy will make recommendations on the long-term future of these routes and whether, for example, the closed portion of Beach Road should be re-opened. This could affect communities such as Kakanui. The community plan allows for $500 000 per year from 2010/11 onwards for implementing the strategy. In addition the council has approved the sealing of Gardiners Road, part of the bypass for the closed section of Beach Road, at a cost of $150 000.

The Harbour Development Plan for Oamaru Port includes some changes from the previous community plan (2006 – 2016). Whereas the previous plan did not fund renewals of wharves and other structures, WDC now plans to actively manage the assets and maintain them in perpetuity. The main driver for this change in attitude is apparently the Heritage Port concept, but the ongoing coastal erosion and damage to historic areas must have also had an impact. The Harbour Development Plan includes road improvements, public spaces, walking and cycling routes; in addition, $1 800 000 is budgeted for Coastal Protection and $1 295 000 for Wharf Renewals (including Holmes Wharf). The coastal protection budget is divided into two parts, south and north of Oamaru Creek, at a cost of $800 000 and $1 000 000 respectively. The work is intended to improve the coastal protection of Oamaru town centre, from the Harbour to the end of Humber Street. Upon completion of the proposed works, hard coastal protection structures will be in place from Holmes Wharf, past the Penguin Refuge and Pre-cut Joinery building, to join the recently upgraded sea wall protecting railways land (which in turn extends to Orwell St). The work is scheduled for 2010–2012. A District Plan Variation, which will align the Waitaki District Plan with the Harbour Development Plan, is expected to be completed during 2009/10. Thus, for the existing assets of the historic part of Oamaru, the council proposes to both maintain and extend existing hard coastal protection works.

A further mention of coastal erosion is found in the District Planning section of the Community Plan. The Environmental Monitoring Strategy identified 'Natural Hazards (Coastal Processes)' as one of the issues to be addressed in State of the Environment reports over the life of the Plan. Council also intends to make progress on Variation 2/ Plan Change 2 (Landscape and Visual Amenity), and on an Oamaru Harbourside Variation. Good practice in sustainable management will be reinforced by putting more effort into managing compliance with resource consent conditions and reporting the findings publicly.

7.2 Otago Regional Council

The Regional Council's jurisdiction over the coastal area is seaward of the high-tide line (the line of mean high water springs), but an integrated approach with district councils is clearly desirable, and some coastal land is considered in the Regional Plan: Coast.

7.2.1 Regional Plans

The ***Regional Plan: Coast*** was publicly notified in 1994 and became operative in 2001. A full review is currently on hold (2009), pending the outcome of the review of the New Zealand Coastal Policy Statement.

Section 14 – Natural Hazards covers coastal erosion, and recognises some areas above the line of mean high water springs as cross boundary issues (they cross the boundary between ORC and district council responsibilities). Schedule 3.3 shows several Coastal Hazard Areas including 'CHA 1 Waitaki River – Oamaru' (from the southern bank of the Waitaki River mouth to about Oamaru Creek) (Fig. 21). It is described as 'Mixed sand and gravel beach erosion (property at risk)', with no further supporting text. Policy 6.4.4 recognises the coastal hazard area 'CHA 1 Waitaki River – Oamaru'. The policy for hazard areas is that 'the existence of these areas and the nature of the coastal hazard will need to be recognised and taken into account when considering activities in or around those areas.' Policies 14.4.1 to 14.4.4 in the Natural Hazards section cover:

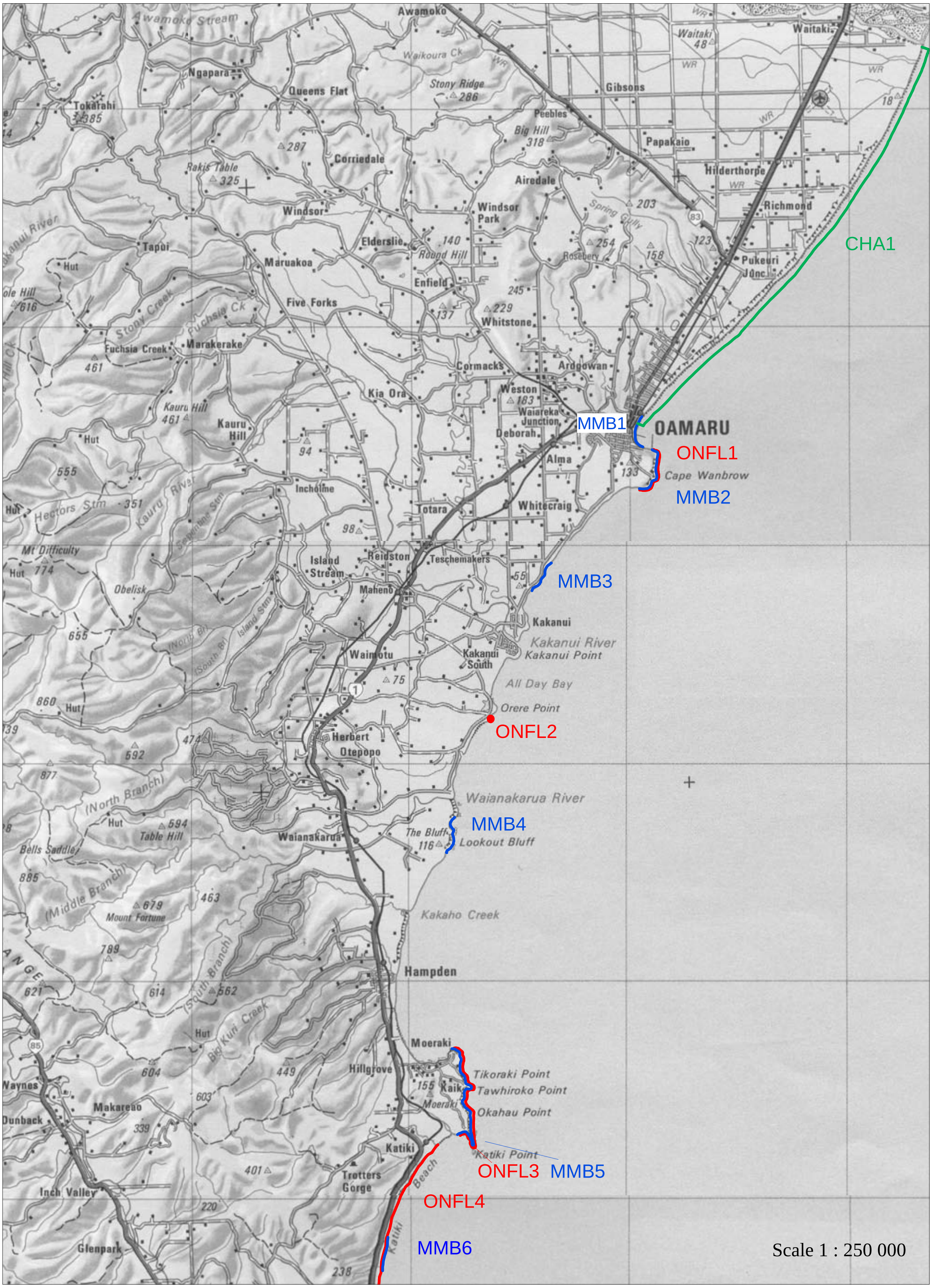
- avoidance/mitigation of the adverse effects of natural hazards
- recognition that activities in one area can result in adverse effects on other areas
- recognition in resource consents that sea level rise and other natural hazards may damage structures
- avoiding activities that may increase adverse effects associated with a hazard.

Section 17 – Review and Monitoring states that the council will consider monitoring natural hazards but gives no details about actual or potential projects and techniques for monitoring coastal erosion (i.e., this section of the plan is very general).

A ***Regional Plan: Climate*** is currently under development. This plan is outlined in the LTCCP 2009–2019 and is scheduled for completion by December 2011. Its emphasis will be on responding to the impacts of climate change. Current work by the council's strategy team involves establishing the foundation principles – for example, ensuring the safety of people and property, planning ahead, adopting a cautious approach, recognising that impacts will be ongoing, and easing the process of transition (M. Goldsmith, ORC, pers. comm. 2009).

Following page:

Figure 21: Otago Regional Council Coast Plan map (Schedule 3) showing the coastal hazard area CHA1 south of the Waitaki River. Schedule 3 text describes this area as 'Mixed sand and gravel beach erosion (property at risk)'. The other sites identified on the map are Marine Mammal and Bird Sites (MMB) and Outstanding Natural Features and Landscapes (ONFL).



Cross Boundary Areas

7.2.2 Coastal studies

In 1991, the Otago Regional Council carried out an investigation of coastal hazards that resulted in a coastal hazard zonation for the area north of Oamaru. They considered that a shortage of data made it potentially misleading to map such zones south of Oamaru. After factoring in the calculated historic erosion rates, expected sea level rise of one metre and an additional 20 m buffer zone, their suggested Coastal Hazard Zone was 80 m wide immediately north of Oamaru, widening to 90 m towards the Waitaki River (Otago Regional Council 1991). “Protected” areas of Oamaru township were excluded from the hazard zone, based on existing coastal protection works being maintained. Recommendations of the report were:

- Waitaki District Council considers options for preventing or restricting development in the designated coastal hazards zone
- Waitaki District Council considers options to maintain and upgrade as necessary foreshore protection (the rock wall alongside the railway and the harbour breakwaters) including extending shoreline protection northwards.
- Waitaki District Council and Otago Regional Council consider options for formal monitoring
- Road and rail authorities anticipate increased erosive attack at vulnerable locations
- Review coastal hazard zones and issues at least every ten years.

No ten-yearly review was completed, but a commissioned study (“Marine sedimentation and coastal processes on Otago Coast”) was begun. Completion of this report was suspended in 2007 due to a change in scope of the project by the ORC (J. Bell, ORC, pers. comm. 2009).

Monitoring of beach profiles is carried out approximately 5-yearly at 11 monitoring sites between the Waitaki River mouth and Cape Wanbrow. These were last surveyed in 2007/2008. Surveys date back to 1994, and for some sites, this was the third repeat survey. This monitoring programme is budgeted in the Annual Plan in the year it occurs.

In 2004, ORC obtained LIDAR data along the whole Otago coast, and has used it for hazard studies in several areas. The LIDAR data was used by NIWA to model storm surge and tsunami risk along the Otago coastline, for various sea level rise scenarios. LIDAR or other modern imagery can also be combined with old survey data (such as the original cadastre for Oamaru township, dated 1864 (Hicks et al. 2006)), to powerfully illustrate the effects of coastal erosion on property and infrastructure (Fig. 20).

Another aspect of coastal management relevant to the Oamaru erosion situation is that of sediment budgets and gravel extraction management. Environment Canterbury has investigated the status of gravel resources, and management implications, on the retreating coastline of South Canterbury (Single 2006). This report gives only a few details for the coastline south of the Waitaki River. The beach profile monitoring conducted by ORC would contribute to any such assessment for the North Otago area.

7.3 Other council responses in Oamaru

Further non-regulatory responses to coastal erosion noted during the study include:

Emergency repairs (usually of roads) by WDC under emergency powers. Emergency works provisions suspend any necessary resource consent requirements under the RMA during times of emergency – when the necessity for immediate action precludes following normal consent processes (section 330, RMA). Emergency provisions have been invoked for Beach Road, south of Oamaru. However, it is to be hoped that the forthcoming Coastal Erosion Management Strategy will allow longer-term strategies to be implemented.

Building community awareness. According to Mr Chandra (WDC), a talk in Oamaru some years ago by Dr Mike Hilton (Otago University), on the Oamaru coastline and naturally occurring coastal erosion, was successful in raising public awareness. Such exercises need to be repeated periodically to refresh community understanding and build awareness by repeated exposure.

Providing information to landowners is a non-regulatory approach that is often suggested, and one which may also be useful in building hazard awareness. It is one of the implementation methods listed in the Waitaki District Plan (4.2.3). However, in Oamaru it is thought that providing information via landscape guidelines (Appendix D of the District Plan) has not been very effective in managing effects on the landscape (according to the Section 32 Assessment for Variation 2/Plan Change 2). Although providing information about coastal erosion hazards may be helpful in a general sense, it needs to be backed up with regulatory measures.

Monitoring of shoreline changes. WDC does not carry out coastal monitoring. ORC has a 5-yearly programme of measuring beach profiles (see above), thereby building a dataset to enable the monitoring of trends. NIWA has recently carried out beach monitoring in the area, including trials of ground penetrating radar to calculate beach sediment volume (not only beach level, as in the ORC work). NIWA information has been used in both client reports and scientific papers (Hicks et al. 2006, Dickson et al. 2009 in press).

8.0 COMMUNITY PERCEPTIONS

In 2003, a national survey of coastal communities was carried out, with the aim of building a picture of local knowledge of coastal hazards (Johnson et al. 2003). Communities the length of New Zealand were asked nearly 50 questions about their coastal hazards awareness, what information they had about the hazards, what sources of information they used, and related matters. The results of the survey are available in tabulated form (Johnson et al. 2003), but detailed analysis has only been completed for some North Island areas.

Of the 300 surveys delivered to Oamaru addresses, 80 were returned (a 26.7% return rate). Return rates for the survey ranged from 18.5% to 58%, with a mean of 39.8%. The rest of this section summarises the results from Oamaru, comparing them in some cases with those from other communities. Percentages are generally rounded for ease of reading.

When asked to select the two natural hazards most likely to affect Oamaru, 84% listed coastal erosion (compared with tsunami 31%, storm 25%, and flooding 24%), showing that awareness of this hazard is high. 29% thought that coastal erosion was likely to affect their area within the next year, 42% expected it within the next 10 years, and 21% expected it to happen within their lifetime. These are not extremely high assessments of likelihood – in some North island communities, over 60% of respondents expected coastal erosion to affect their area within the next year. In Oamaru, 30% of those replying had personally experienced coastal erosion (compared with earthquake 38%, flooding 35%, and storm 31%). Respondents disagreed with the statement "coastal erosion is unlikely to be a problem in the area in their lifetime" and strongly disagreed with "the local beach will never be damaged by coastal erosion".

When asked the main cause of coastal erosion, 11% thought of changes in sand supply to the beach, 50% thought it was storms, and 42% thought of sea level rise (the remainder thought it was another cause or did not know). Responses to this question varied around the country, depending on the nature of the coastline in different areas, but storms were always rated highest. Communities were also asked what sort of coastal defence for severely eroding properties they most approved of. In Oamaru, "placing large rocks" (40%) and "building a sea wall" (35%) were the most favoured options, probably reflecting the existence of both in the town area already. Less-favoured methods were "move houses back from the beach front" (8%), "do nothing" (6%) and "beach nourishment" (5%). Nationally, hard coastal defences were generally approved (60% or more of responses in some localities), but some communities were quite evenly spread between "hard" and "soft" methods of managing coastal erosion. Acceptance of environmentally "soft" methods has also been noted in some North Island coastal communities (Blackett & Hume 2006; Becker at al. 2007).

On a scale of 1-5, where 1 is "not at all" and 5 is "a great deal", Oamaru people reported that they thought about coastal erosion a moderate amount (3). They reported talking about it "2.5" (halfway along the scale) and similarly for thinking it poses a threat (2.3). However, in terms of getting information on coastal erosion, they reported only doing this a little (1.5). Many Oamaru respondents (43%) said they had not heard or received any information about coastal erosion, while 28% reported getting information from friends and the local (district) council, and 20% reported that the regional council was their source of information. Most had never asked for information (74%), but 5% had asked the local council and 5% had asked the regional council. Information received about coastal erosion was rated as "consistent" or "fairly consistent" by 35% and "inconsistent" or "fairly inconsistent" by 16% of respondents.

Finally, people were asked whether they would be willing to pay via their rates for coastal hazard mitigation in their area. 15% of Oamaru respondents said "yes", 30% said "no" and 44% were not sure (the remainder were not ratepayers). This is the lowest rate of people in the survey answering "yes" to the question, by a large margin, with most communities having a "yes" vote of 50% or over (although not all had the option of a "not sure" vote, as different questionnaires were sent to some areas).

In summary, and generalising from the survey respondents to the larger population, awareness of coastal erosion is high in Oamaru, and fewer than 10% think that coastal erosion will not happen in their lifetime. Almost a third had experienced coastal erosion personally, but while they reported thinking and talking about it to some extent, few sought information about it. Friends were as important, or more important, sources of information than the district or regional councils (and research organisations barely figured). People regarded storms and sea level rise as the main causes of coastal erosion. The most favoured methods of dealing with erosion were the types of hard defences (rock armouring and sea walls) that already exist in the town, with “softer” methods (including managed retreat) approved by fewer people. Most people were either not prepared to pay for mitigation through their rates, or were not sure, which may merely indicate that Oamaru people prefer specific proposals to general questions.

9.0 FURTHER WORK

Further developments from this study could include:

- Monitoring District and Regional Plan outcomes and effectiveness in the area of coastal erosion. For example, is the designated coastal scenic area/coastal hazard area an effective planning tool to manage coastal hazards? How is it applied in actual resource consent applications? Are assets at risk in the coastal hazard area increasing or decreasing? Waitaki District Council may address some of these issues in future State of the Environment reports.

- Monitoring the effectiveness of any mitigation measures that are adopted, such as hard or soft coastal defences (including effects beyond the protection zones), or the provision of information to landowners/developers.

- Researching whether insurance has been paid out or declined for damage to assets due to coastal erosion/cliff retreat.

- Researching the use of emergency works provisions. If long-term solutions can be adopted, emergency works should not need to be carried out so often.

- Integrating all the existing sources of information – such as LIDAR data, beach profile/sediment volume monitoring, earlier studies, old aerial photography and cadastral data – to enhance understanding of erosion rates and refine predictions. Otago Regional Council reports that staff are currently working on this.

- Evaluating risk acceptance in the Oamaru/Waitaki community, building on the existing survey of community knowledge (Johnston et al. 2003). How do local people understand the coastal erosion risk and does this influence their actions? Do they think council activities are appropriate in this context? Such evaluation could be carried out as part of council’s annual survey of community views (the 'Communitrak’ survey), or by a specific survey (such as those conducted for other coastal communities, e.g. Becker et al. 2007).

- Further study on international best practice for slowing or mitigating coastal cliff erosion, for calculating the width of coastal hazard zones, and for implementing managed retreat.

10.0 CONCLUSIONS AND RECOMMENDATIONS

North Otago communities are faced with a situation of long-term coastal retreat that is placing important assets at risk, and may increase in the foreseeable future. Waitaki District Council and Otago Regional Council join a number of institutions around New Zealand, and elsewhere, that are coming to terms with these issues. The geological and geographic setting at Oamaru – a cliffed coastline and a sediment deficit (at least at some times) in the lee of Cape Wanbrow – makes management and restoration options different from those used on sandier coasts. In particular, managing gravel movement is more problematic than managing sand, as plantings cannot be used to help the beach return to a natural profile. However, the issues of damage to property and assets, erosion concentrated at the ends of existing “hard” coastal protection, siting of new developments, and compensation for landowners, are similar to those encountered elsewhere.

In terms of the spectrum of possible responses used by councils, WDC and ORC have so far tended to adopt the less controversial options. Zoning by both councils recognises the erosion hazard as a constraint on development and activities, but the hazard zones and setbacks are not applied in the most densely settled areas. The width of hazard zones and setbacks (including the proposed landscape zone of Variation 2 at 100 m or more) is appropriate for the present, although there is no official recognition that they may have to be rolled back in the long term, nor provision for doing this. The WDC hazards register does not yet include data on coastal erosion, and ORC’s regional natural hazards database is still under development, as is their Regional Plan: Climate.

The planning horizon appears to be about 50 years (ORC information cited in the WDC District Plan) although some council staff recognise that longer terms would be appropriate. Formal reference to longer time frames (such as 100 years) in planning documents would be welcome, and would contribute to raising community awareness. Acknowledgement that climate change and sea level rise are likely to exacerbate coastal cliff erosion would be useful, and could possibly be included in the ORC’s Regional Plan: Climate when it is developed. At present, however, the precautionary principle is not stated clearly in the ORC or WDC plans consulted. Monitoring of coastal change and beach profiles by ORC should allow trends to be monitored. Improved understanding derived from this work needs to be fed back into the local and regional planning environment, and to the public.

Given that some parts of the township are protected by hard structures (breakwaters, rock armouring), and that erosion is actively occurring where those structures are absent, the extension of hard structures to protect the historic part of the town (2009-19 Community Plan) is probably inevitable and could be seen as the lesser of two evils. Erosion at the northern end of the existing rock armour (near the former Firman Joinery site) will apparently be left unchecked at this time, and de facto “managed retreat” will ensue. Managed retreat is also being considered for parts of the road network south of the town, although emergency powers have been invoked to restore damaged roads until planning for the long-term management of the coastal route is agreed upon.

In summary, the main conclusions of this study are:

- Coastal erosion is significant (from 0.6 m to over 1 m per year) at Oamaru and also north and south of the town
- Sea level rise would probably accelerate this rate of erosion
- "Hard" coastal protection could slow erosion locally and in the short term, and is probably appropriate to protect the historic part of Oamaru, but could make erosion worse in adjacent unprotected areas
- Managed retreat is the only truly long-term solution for areas that cannot be protected
- Councils and communities need to build "adaptive capacity", i.e. the ability to adjust to erosion and cope with the consequences
- The councils and community at Oamaru have begun to engage with the issues, but community awareness (of hazards, risks and possible mitigation options) could be better
- Integrating all the existing sources of information about coastal erosion, and publicising the results, would be useful in raising awareness
- Formal mention in planning documents of managed retreat, coastal zone roll-back, longer timeframes and the precautionary principle would also be useful.

11.0 ACKNOWLEDGEMENTS

Interviews and discussions with Mr Jack Chandra, Mr Dean Sulzberger and Mr Neil Jorgensen of Waitaki District Council; Ms Jessica Bell, Dr Gavin Palmer and Mr Michael Goldsmith at Otago Regional Council; Dr Mike Hilton at the Department of Geography, University of Otago; and Ms Glenda Dixon at Christchurch City Council, are acknowledged with thanks. Dr Murray Hicks of NIWA kindly provided copies of several of his scientific papers and reports, and discussed their findings by email. Ms Meagan Newsham and Mr Lance Dixon at EQC explained insurance coverage for erosion and storm events. Ms Glenda Jenks (Otago Daily Times, Dunedin) and Ms Joanne Firman (Waitaki District Council) helped with acquiring photographs. Parts of the report were read by Mr Jack Chandra, Mr Neil Jorgensen, Ms Jessica Bell, Dr Gavin Palmer and Mr David Bruce (Otago Daily Times, Oamaru), and their comments and corrections are appreciated. The opinions in the report, however, are the author's own.

At GNS Science, Belinda Smith Lyttle, Ian Turnbull and Elly Lang helped with maps and report production. Phil Glassey and Wendy Saunders supported the study and reviewed the report. Additional reviews by Ian Turnbull and Julia Becker, and discussions with David Barrell, are also acknowledged with thanks. Funding for the study came from the Foundation for Research, Science and Technology "Hazards and Society" programme.

12.0 REFERENCES

Becker, J.S.; Stewart, C.; Coomer, M.; Hume, T.; Blackett, P.; Davies, A. 2007: Managing our coast: the tabulated results of two community surveys undertaken at Tairua and Waihi Beach. *GNS Science Report 2007/28*. 246 p.

Blackett, P.E.; Hume. T.M. 2006: Community involvement in coastal hazard mitigation: An initial scoping of process and pitfalls. *NIWA Client Report HAM2006-083*, prepared for GNS Science.

Chandran, K.V. 2007: Protecting New Zealand Coastal Areas: caught between Policies and Probabilities. Master of Environmental Planning dissertation, University of Waikato.

Dahm, J. 2003: Drawing the line at coastal erosion. *Asset Management 4(1)*. January 2003.

de Lange, W. 2007: Coastal erosion. Te Ara – the Encyclopedia of New Zealand, www.TeAra.govt.nz/EarthSeaAndSky/OceanStudyAndConservation/CoastalErosion/en

Department of Conservation 2008: Proposed New Zealand Coastal Policy Statement 2008. Published by DOC Policy Group Feb 2008.
Web address: www.doc.govt.nz/upload/documents/getting-involved/consultations/current-consultations/proposed-nzcps-2008-low-resolution.pdf]

Dickson, M.; Hicks, M. 2007: Rapid erosion at Oamaru. *NIWA Science 15(3)*. September 2007.

Dickson, M.E; Hicks, D.M.; Bind, J. 2007: Coastal Cliff Erosion near Oamaru. *Coastal News 36*. October 2007.

Dickson, M.E.; Bristow, C.S.; Hicks, D.M.; Jol, H.; Stapleton, J.; Todd, D. 2009 (in press): Beach volume on an eroding sand-gravel coast determined using ground penetrating radar. *Journal of Coastal Research*.

Forsyth, P.J. (compiler) 2001: Geology of the Waitaki area. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 19*. 1 sheet + 64 p. Lower Hutt, New Zealand. Institute of Geological & Nuclear Sciences Ltd.

Forsyth, P.J. 2006: Natural hazards in Canterbury – Planning for reduction. *GNS Science Report 2006/31*. 48p.

Gage, M. 1957: The Geology of the Waitaki Subdivision. *New Zealand Geological Survey Bulletin 55*. Wellington, Government Printer. 135p and maps.

Gibb, J.G. 1978: Rates of coastal erosion and accretion in New Zealand. *New Zealand Journal of Marine and Freshwater Research 12*: 429-456

Gibb, J.G. 1983: Combating coastal erosion by the technique of coastal hazard mapping. *New Zealand Engineering 38*: 15-19.

Gibb, J.G. 1984: Coastal erosion as a natural hazard in New Zealand. In: Speden, I.; Crozier, M.J.(comp) Scientific, economic and social reviews of natural hazards in New Zealand. Wellington, UNESCO. Pp 135-158.

Gibb, J.G.; Adams, J. 1982: A sediment budget for the east coast between Oamaru and Banks Peninsula, South Island, New Zealand. *New Zealand Journal of Geology and Geophysics 25*: 335-352.

Hicks, D.M.; Single, M.; Hall, R.J. 2006: Geomorphic character, controls, processes and history of the Waitaki Coast – a primer. *NIWA Client Report CHC2006-130*, prepared for Meridian Energy Ltd, September 2006.

Hicks, D.M; Todd, D. 2006: Historical changes in shoreline position and beach characteristics on the Waitaki coast. *NIWA Client Report CHC2006-091*, prepared for Meridian Energy Ltd.

IPCC 2007: IPCC Fourth Assessment Report: Climate Change 2007. Web address www.ipcc.ch/ipccreports/assessments-reports.htm

Jacobson, M. 2004: Review of the New Zealand Coastal Policy Statement 1994 – coastal hazards.

Johnston, D.M.; Leonard, G.S.; Bell, R.; Stewart, C.; Hickman, M.; Thomson, J.; Kerr, J.E.; Glassey, P.J. 2003: Tabulated results of the 2003 national coastal community survey. *Institute of Geological & Nuclear Sciences Science Report 2003/35.* 121 p.

Jongens, R.; Gibb, J.; Alloway, B.V. 2007: A new hazard zonation methodology applied to residentially developed sea-cliffs with very low erosion rates, East Coast Bays, Auckland, New Zealand. *Natural Hazards 40*: 223-244. DOI 10.1007/s11069-006-0019-5

Ministry for the Environment (MfE) 2007: Making Good Decisions – Climate Change Effects (pdf & online version). December 2007.

Ministry for the Environment (MfE) 2008. Coastal Hazards and Climate Change. A Guidance Manual for Local Government in New Zealand. 2nd edition. Revised by Ramsay, D, and Bell, R. (NIWA). Prepared for Ministry for the Environment. viii+127 p.
Web address: http://www.mfe.govt.nz/publications/climate/coastal-hazards-climate-change-guidance-manual/coastal-hazards-climate-change-guidance-manual.pdf

New Civil Engineer (magazine): 7 June 2007 issue

Online Managed Realignment Guide (OMReG) website: http://www.abpmer.net/omreg/).

Otago Regional Council 1991: North Otago coastal hazard mapping investigation discussion document. *ORC Discussion Paper Series No 3*. May 1991. 34 p.

Otago Regional Council website: www.orc.govt.nz

Quality Planning undated: Climate change guidance note. Web address: www.qualityplanning.org.nz/plan-topics/climate-change.php

Quality Planning undated: Coastal land development guidance note. Web address: www.qualityplanning.org.nz/plan-topics/coastal-land-development.php

Rosier, J. 2004: Independent review of the New Zealand Coastal Policy Statement. Commissioned by the Minister of Conservation.

Single, M. 2006: Oamaru to Timaru Coastal Report. Status of Gravel Resources and Management Implications. *Environment Canterbury Report No R06/14*. MWH New Zealand Ltd, January 2006. 11p.

Tonkin & Taylor 2008: Whakatane District Council Coastal Hazard Analysis. Volume 1, 2nd edition, September 2008.

Waitaki District Council website: www.waitaki.govt.nz