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The impact of climate change on the archaeology of New Zealand's coastline

A case study from the Whangarei District

Simon Bickler, Rod Clough and Sarah Macready

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Te Papa Atawhai

Cover: Ngunguru midden, 2004. *Photo: S. Bickler.*

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Abstract

With rising sea levels, changes in precipitation patterns and an increased incidence of severe weather events being predicted as a result of global climate change, the Department of Conservation commissioned a study to determine the potential impacts of these effects on New Zealand's archaeological sites, which are mostly located near the coast. A Geographic Information System (GIS)-based case study examined the distribution of archaeological sites in the Whangarei District and assessed the risk to the archaeological resource primarily from sea level rise associated with future climate change. The results of the analysis are fairly conclusive. Currently, the major threats to archaeological sites in coastal areas are erosion, flooding and ground instability, and some sites are at risk from more than one of these threats. Approximately one-third of the recorded site locations in the Whangarei District are potentially threatened by these hazards, regardless of any future climate change effects. Climate change will exacerbate existing coastal hazards, and increase the likelihood and severity of impacts on archaeological sites. An additional 2.5–10% of archaeological sites might be affected by increased threats due to predicted changes in climate, including rising sea levels. The types of sites that are most likely to be affected in the Whangarei District are coastal midden and small habitation sites relating to Māori occupation. Although these could be affected by all three of the major hazards identified, they are particularly susceptible to coastal erosion. Land stability issues and flooding are likely to affect a greater range of sites, including larger sites such as pā and sites relating to early European settlement. It is not possible to quantify the risk to sites from increased land instability as a result of global climate change, but it is noted that any increase in extreme weather events would not be confined to coastal areas. These sites potentially hold significant information relating to the history of both the district and New Zealand. The implications of the study are that coastal sites are already under considerable threat, and that important archaeological information is being lost at a rate that may increase significantly in the future. Action is needed now to protect or retrieve the information from significant sites under threat in coastal areas before these sites disappear completely.

Keywords: climate change, archaeological sites, site destruction.

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1. Introduction

1.1 This study

Island nations face an uncertain future, with the possibility of significant changes to their coastlines as a result of global climate change, the evidence for which has grown substantially over the last few years (IPCC 2007; NIWA 2007). The effects of global warming can include sea level rise, changes in temperature (which in turn result in changes in vegetation), increased storm surge activity and flooding. New Zealand is similar in size to Great Britain, with an extensive and complex coastline, but it differs from Britain in that the archaeological record here is massively weighted towards that coastline. The coast has been the focus of settlement both for the ancestors of the Māori people arriving from Polynesia around 800 years ago and for European settlers arriving in the 19th century. Consequently, major changes to New Zealand's coastline as a result of climate change will impact significantly on the archaeological record.

Walton (2007) identified some of the many and varied threats relating to climate change that are likely to affect archaeology in New Zealand. He highlighted the need for an effective response from historic heritage agencies based on a combination of good monitoring systems, physical protection and, where the latter cannot be achieved, the recording and investigation of sites before they are destroyed. Other calls to action have also been made (e.g. McGovern-Wilson 2008) but have only rarely resulted in any particular actions.

The Department of Conservation (DOC) has initiated a number of steps to promote an effective response to climate change threats, including this Geographic Information Systems (GIS)-based case study examining the distribution of archaeological sites within the Whangarei District and assessing the extent of the exposure of recorded sites to the adverse effects of climate change. The aim was to attempt to quantify the level of risk at the broad district level, within the limitations of the available data. This study explores the likely impacts of climate change on the survival of sites within one particular region of New Zealand (Whangarei District) and considers the implications for other parts of the country.

It is recognised that climate change is not the only threat to archaeological sites, or necessarily the greatest threat in the short term. Tsunamis are high in people's consciousness (e.g. McFadgen 2007), and weather patterns such as the cycle of El Niño and La Niña have also probably impacted on archaeological sites, although to what extent is not well documented (McFadgen 2001). Earthquakes have also played a significant role in the history of New Zealand and, as events in Christchurch in 2010 and 2011 have demonstrated, can have a devastating effect on the survivability of both built heritage and subsurface archaeological sites. Less dramatic threats also exist and continue to affect the survival of archaeological sites—everyday farming, industrial and other modern human activities (including rampant coastal development). It is clear, however, that climate change will accelerate the effects of existing natural hazards to the point where it will be the greatest threat to the survival of sites in coastal areas in the longer term.

It is now widely accepted that there has been and continues to be a general warming of the average air and ocean temperatures globally, and that much of this increase is likely to be attributable to the observed increase in human-induced greenhouse gas emissions. The Ministry for the Environment (MfE) recently published a report on the phenomenon of climate change and coastal hazards (MfE 2008; updating an earlier 2004 report). The report outlines the nature of the increasing coastal hazards and risks facing New Zealand as a result of climate change, and concludes that (MfE 2008: vii):

1. 'A high proportion of New Zealand's urban development has occurred in coastal areas and this has intensified in recent years ... As development and property values in the coastal margins increase, the potential impacts and consequences of coastal hazards also increase.'

2. Coastal hazard risk 'will be exacerbated in many places by the effects of climate change. Climate change will not introduce any new types of coastal hazards but it will affect existing coastal hazards by changing some of the hazard drivers. It will exacerbate coastal erosion and inundation on many parts of the New Zealand coast … '.
3. The consequences of climate change are now a necessary consideration for coastal planning as many land-use planning decisions have long-term implications even if the climate change effects are gradual.

The MfE report is intended as a guidance manual for local government, and its main focus is on impacts on property and people. It does not address impacts on heritage values as a result of climate change, although it recognises the need for local government to provide for 'the natural character, ecological, landscape, amenity, public access, cultural and spiritual values of the coast' (MfE 2008: 5).

In addition to outlining the key effects of climate change on coastal hazards, the MfE report sets out a risk assessment framework so that the effects of coastal hazards and climate change can be factored into decision making, planning and policy development at local government level. While the framework does not specifically address risks to archaeological sites, with some adaptation the framework can provide a useful basis for assessing risks to sites in coastal areas.

This report includes a summary of the archaeological resource in the Whangarei District and the likely changes to the climate that are expected over the next century. We then present the results of the GIS analysis, which combines location information on archaeological sites in the Whangarei District with hazard data relating to coastal erosion, flooding and land stability. These results ('Model 1') are then extended to examine future impacts on archaeological sites as a result of climate change ('Model 2'). A case study relating to archaeological sites in the Whangarei District is presented. This case study complements the GIS models to show how coastal hazards impact on specific archaeological sites. We then summarise the results and explore the implications of the research for areas outside the Whangarei District. Finally, we set out a basis for evaluating future risks to archaeological sites, and argue for the prioritisation of effort in the long-term management of threatened sites, including the urgent recovery of significant information from the diminishing archaeological resource.

1.2 Archaeology in the Whangarei District

1.2.1 The Whangarei District

The Whangarei District extends along the east coast of the North Island of New Zealand, from the eastern end of Langs Beach (north of Mangawhai Heads) in the south, to Helena Bay in the north, and inland as far as Opouteke (Fig. 1). The district is dominated by Whangarei, the largest city north of Auckland, which is situated at the western end of a large harbour with extensive mangrove and estuarine catchments, rich shellfish beds, and other marine resources. The harbour entrance at the eastern end of the harbour is a relatively narrow channel that is bordered by the Whangarei Heads area to the east and the Marsden Point – One Tree Point area to the west. The last decade or two have seen increasing subdivision of the farmland and orchards surrounding the city of Whangarei, extending westwards towards Maunu, eastwards beyond Onerahi and south onto the Whangarei Heads. On the southern side of the harbour, the Ruakaka – One Tree Point area has also seen increasing subdivision. The wider district remains largely rural, with extensive farmland, and large areas of both native and exotic forestry. There are a number of smaller settlements along the coast, including Waipu, Pataua, Ngunguru, Tutukaka, Matapouri and Whananaki. The district also includes several offshore islands, notably the Poor Knights and Hen and Chickens Islands.

For Polynesians arriving from the tropics hundreds of years ago, the Whangarei District was a highly favourable area for settlement. The sheltered Whangarei Harbour and other major rivers and inlets (Ngunguru, Horahora, Ruakaka, Pataua, Taiharuru and Whananaki), with their rich

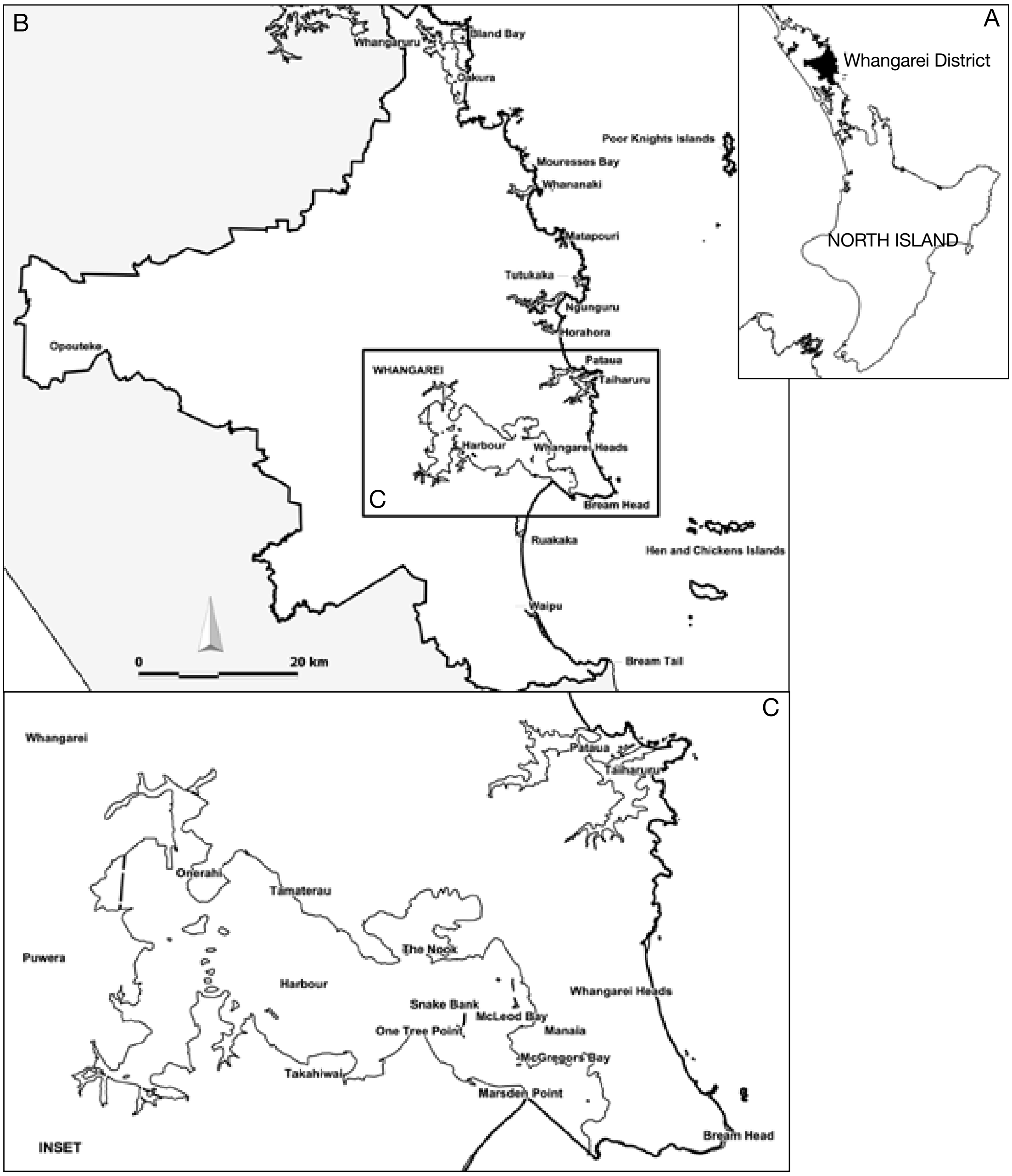


Figure 1. Map showing A. The location of the Whangarei District, Northland, in relation to the North Island of New Zealand; B. Places in Whangarei District referred to in the text; C. Whangarei Harbour area in more detail.

marine resources and easy accessibility by canoe, attracted occupation from the earliest times. Thorne (1876) described moa bones and obsidian tools in locations around the Whangarei Heads and particularly at Pataua, indicative of this early 'Archaic' settlement. Similarly, European settlers and traders rapidly adapted to their new country during the 19th century, setting up homes and gardens alongside farming and extractive and other industries along this coastline.

1.2.2 Archaeological research in the Whangarei District

Archaeological research in the Whangarei District has followed the pattern of archaeological research throughout New Zealand. Initial excavations in the 1960s heralded the start of professional archaeology in the country and focused on small investigations of a few archaeological sites. During the 1970s and 1980s, large-scale archaeological surveys of land blocks were undertaken, many relating to forestry activities, and a limited number of excavations were carried out. In the 1990s, archaeological investigation and survey expanded considerably in response to the pressures of development, and this expansion has escalated in the last few years. As a result, there is a growing corpus of information derived from investigations of pre-contact (in most cases) Māori sites and historic period sites relating to European settlement of the district that has enhanced our understanding of the past. However, the information has been gathered piecemeal as the result of development pressures, leaving many important research questions unaddressed.

Archaeological surveys

Archaeological surveys and site recording have provided a much broader understanding of the pattern of Māori and early European settlement in the Whangarei District. Probably the largest survey in the district was carried out by Nevin and Nevin (Nevin 1984), the main focus of which was on the southern side of Whangarei Harbour, where a large number of sites (mostly middens) were identified near the coast. Further inland, a wider range and a large number of sites were identified in the Takahiwai hills, including pā, pit and terrace sites, and evidence of gardening as well as the ubiquitous middens were also found. In the inland areas around Takahiwai and near Ruakaka, the Māori settlement pattern appears to have been focused around the higher ridges, where pā sites offered some defence from raiding parties travelling through the area and where gardening was carried out. Access to the rich marine resources would have been straightforward and, during the seasonal cycle, family groups probably moved down to the dune lands to collect food for storage and, perhaps, exchange.

Additional surveys have continued throughout the district, including surveys carried out under employment programmes (Deverall & Te Wake 1981), Rickard's survey of scenic reserves (Rickard 1984), Maingay's survey of the Kamo district (Maingay 1989) and Slocombe's survey of the Tutukaka area opposite Ngunguru Sandspit (Slocombe 1991), all of which have expanded the number and range of archaeological sites identified in the district. Slocombe's conclusions could be applied to most of the coastal zone:

> *The majority of recorded sites within the Tutukaka study block are located along the coastline and in close proximity to sandy bays. The site distribution reflects a strong dependence on the marine resources of the area. A variety of seafoods from both open sea and the sheltered estuary would have been readily available.* (Slocombe 1991: 8)

With the exception of the 2006 New Zealand Archaeological Association (NZAA) upgrade project, which involved a resurvey and reassessment of sites that had already been recorded, subsequent archaeological surveys have been driven by development proposals and have focused on smaller areas (individual properties). In the area south of Whangarei Harbour, this has included several surveys in the Ruakaka – One Tree Point area (e.g. Best 1996; Fredericksen & Bader 1997; Phillips & Harlow 2001; Phillips 2004; Prince 2004a; Campbell 2005; Plowman & Clough 2005; Clough & Farley 2006; Bickler et al. 2007; Clough & Macready 2008a).

In the Whangarei Heads area, recent surveys have included assessments of land blocks covering several acres at McLeods Bay (Prince 2004b), Taurikura Bay (Baquié & Clough 2006), Taiharuru (Prince & Clough 2004), Tamaterau (Judge & Clough 2006a), Parua Bay (Judge & Clough 2006c) and elsewhere. Infrastructure projects undertaken by Whangarei District Council (WDC) have also involved recent survey (Plowman & Clough 2007; Clough & Macready 2008b).

Closer to the city of Whangarei, a number of surveys that have resulted in limited excavation have been carried out as the urban limits have expanded and new suburbs have been created. One such example is along Limeburners Creek (Bickler et al. 2010), although many have been much smaller in scale than this. Evidence for early use of the area is hinted at by the presence of chert working floors in the suburb of Onerahi, as described by Fredericksen (1990); large quantities of chert flakes, hammerstones and other debitage were mapped, and preliminary descriptions of the tools were carried out.

Recent surveys for proposed coastal subdivision have also been carried out in the wider Whangarei District, including at the Ngunguru Sandspit (Best 1994; Nevin 2001; Bickler et al. 2004); Whananaki (Maingay 1990a, b.; Harlow 1999; Plowman et al. 2008b); Waipu (e.g. Phillips et al. 2005; Judge et al. 2007) and elsewhere.

However, increasing subdivision pressure in the Whangarei District means that the aforementioned are only a sample of the survey work that has been carried out recently. Archaeological sites recorded during these and other surveys have progressively been added to the NZAA database, which provides the basis for this study. They have provided a broad understanding of site type and distribution, but more detailed information relating to the timing, changes in settlement pattern and material culture can only be recovered from archaeological excavations.

Archaeological excavations

A number of archaeological excavations have been carried out in the Whangarei District. The early excavations included a site at Smugglers Bay, Bream Head, at the southern tip of the Whangarei Heads (site Q07/103). This was a large midden site investigated in the 1960s, which produced evidence of significant shellfish cooking, as well as seal, dog, bird, tuatara and fish bone, chert flakes and hāngī stones, and fishing equipment. This is suggestive of an 'Archaic' period site, although the available information is limited (Green & Davidson 1964, cited in Phillips & Harlow 2001: 14; and NZAA Site Record Form for Q07/103).

Another early excavation was at Ruarangi Pā (Q07/30), south of Whangarei city towards Otaika. Houses and middens within the defences were investigated, with cockles being overwhelmingly the most common shellfish identified. The site appeared to have been occupied a number of times from the 1700s onwards (Hougaard 1971, cited in Phillips & Harlow 2001: 12–13).

In 1976, a large midden, Q07/58, was excavated by Nichol and Walton at Port Whangarei, which indicated extensive shellfish processing in this area (Nichol 1977; Walton 1977). Other smaller excavations in the district during this era (e.g. Maingay 1986) provided some data on the archaeological sites, but these generally did not include radiocarbon dates, making them difficult to locate in time.

Most of the more recent archaeological investigations have taken place in response to coastal subdivision and development. These investigations have included the excavation of a small pit and terrace complex (Q07/897) in Ruakaka (Best 2000), where a sequence of pollen data was retrieved that illustrated changes to the local environment caused by Māori and then Europeans, with increasing evidence of small species such as bracken (*Pteridium esculentum*) entering areas that were previously dominated by large trees. The site included a cache of digging implements of unknown, but relatively 'modern', age (i.e. the 1800s onwards, where radiocarbon techniques become problematic) and a midden on the ridge above the cache, which returned a radiocarbon date of 1640–1870 (at 2σ). Firescoops at Ruakaka excavated by Prince (2008) did not produce dates, but are probably typical of sites in this part of the district.

Numerous midden sites in the One Tree Point area have been investigated within the last decade (Phillips & Harlow 2001; Campbell 2006; Bickler et al. 2007; Plowman et al. 2008a). These will be discussed in greater detail in the case study (section 4).

At Puwera, to the southwest of Whangarei, an investigation of three archaeological sites in 2008 by Clough & Associates and the University of Auckland (Turner et al. 2010) has provided evidence of inland settlement areas. The Puwera sites included remains of houses, extensive storage pits, cooking areas and stone working dating from the 16th–18th centuries. The storage facilities suggest that major gardens were located nearby, while the range of stone and obsidian tools demonstrate that the inhabitants had access to a range of materials sourced throughout the country. The results from Puwera contrast with those from other locations in the Whangarei catchment, such as One Tree Point, but given the difference in environment (inland hills as opposed to coastal dunes), this is not surprising.

Around Kamo, north of Whangarei, volcanic soils provided conditions for gardening similar to those of the fertile soils of central Auckland for both Māori and early European settlers (Johnson 2002: 60). Archaeological investigations at site Q06/486 included evidence of Māori occupation dating to the 17th century, with nearby evidence of 19th-century activities relating to the transformation of the landscape for farming. Stone walls dating from the 19th century onward are common across the district (see e.g. Prince 2009) and provide a visible symbol of the transformation of the Whangarei District into a pastoral landscape.

A number of investigations, generally of midden sites, have also been carried out on the Whangarei Heads. These include sites at Reotahi Bay (Campbell & Keith 2007) through to McGregors Bay, where dates from the 15th–17th centuries were obtained (see e.g. Bickler et al. 2008). Middens associated with pits and terraces were investigated at Tamaterau to the northwest (Judge & Clough 2008), which probably represented the living, gardening and storage areas that made up part of a relatively large settlement associated with a pā (Q07/673) in the 17th or 18th centuries. Recent infrastructure works undertaken by WDC have also exposed McGregors Bay (Q07/796), and a complex multi-occupation site at Urquharts Bay (Q07/751), with radiocarbon dates suggesting occupation in the mid-15th to mid-16th centuries and the 16th to 17th centuries respectively (Judge et al. 2010). During earlier investigations of Q07/751 in Urquharts Bay, human remains, garden soils and food storage pits have been found with large middens which probably represent the range of occupation and activities around the northern harbour (Judge & Clough 2006b; Phillips 2006a; Phillips & Druskovich 2009).

Investigations are increasingly being carried out further afield as coastal subdivisions and related infrastructure are developed up and down the coastline; for example; at Whananaki (Bickler et al. 2009b) and Waipu (e.g. Bickler et al. 2006; Baquié et al. 2007; Felgate 2008). However, most investigations undertaken to date in the Whangarei District have been relatively limited in scope and have generally been carried out in response to development rather than as part of a focused research programme.

1.2.3 The archaeological record

Archaeological research carried out to date has identified more than 2400 archaeological sites in the Whangarei District, which are clustered around the main harbour and along the Pacific coast (Fig. 2). The majority relate to pre-contact Māori occupation, but sites relating to post-contact Māori occupation and early European settlement are also represented. The contribution of all periods to the archaeological record is acknowledged, but for the purpose of the current GIS study of the potential effects of climate change on the archaeological record, no attempt has been made to distinguish between different periods of Māori occupation or between Māori and early European archaeological sites.

In the absence of information from archaeological investigations or specific historical records, it is not generally possible to distinguish between pre- and post-contact Māori settlement sites. Information recorded by early missionaries in the 1820s indicates that plundering and fighting in the area caused most of the inhabitants around Whangarei Harbour to flee inland; later, when peace returned, the coastal areas were repopulated, with the focus of occupation on the coastal kāinga (several of which are named) rather than the fortified pā (Pickmere 1986: 4–14). This indicates that a number of the traditional coastal sites continued to be occupied well into the 19th century, but it is generally not possible to determine to which sites this applies on the basis of the site records.

Sites relating to European settlement, however, can often be distinguished from sites relating to Māori occupation by the types of sites recorded. Generally, sites such as middens, caves/rockshelters, pits, terraces and pā describe pre-European archaeological heritage, while structural remains such as building foundations, logging dams, mines and so on relate to the period after the arrival of the first Europeans. It is recognised, of course, that some 'European' site types may in fact relate to post-contact Māori land use.

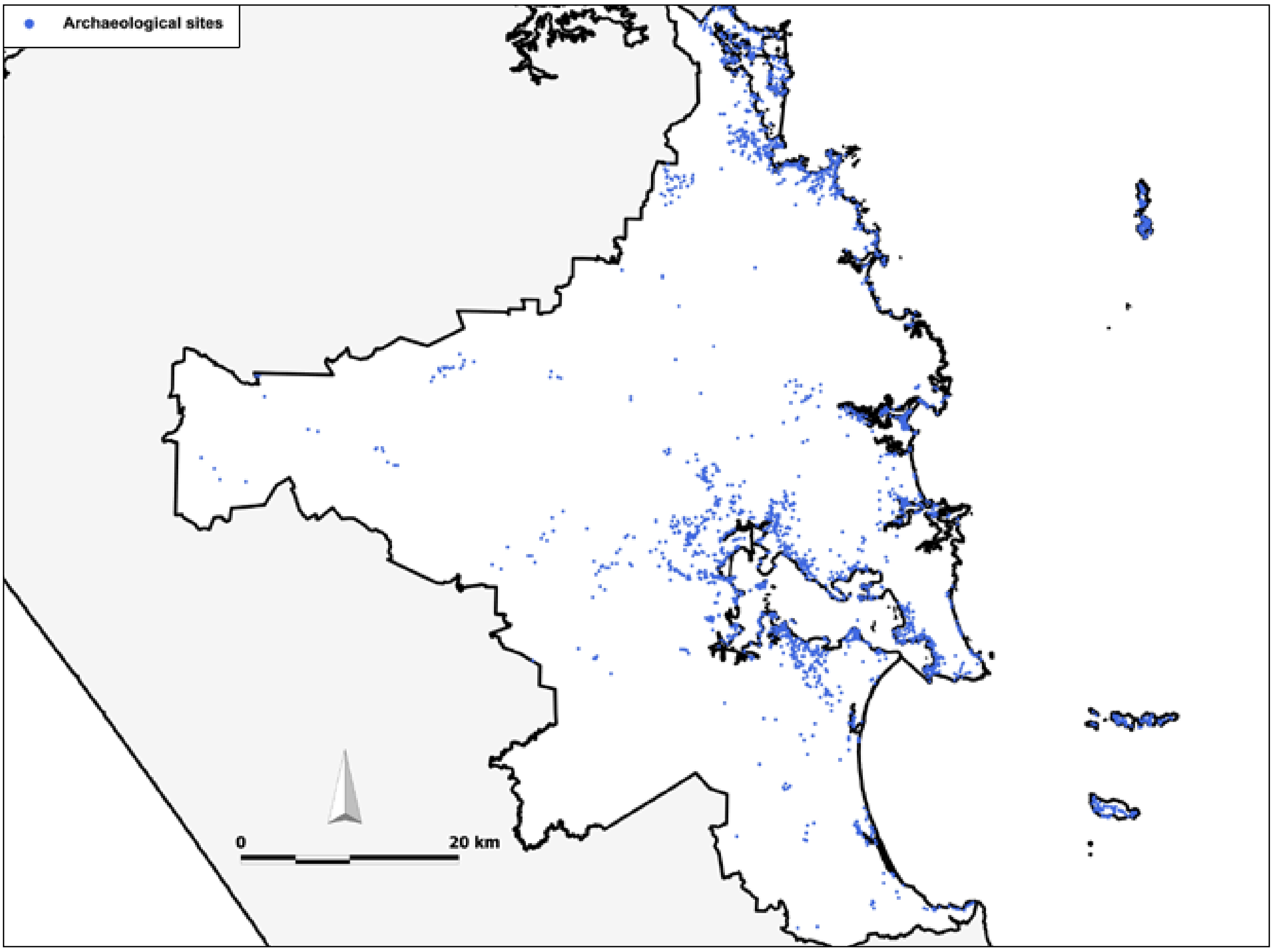


Figure 2. Distribution of recorded archaeological sites (shown as blue dots) in the Whangarei District.

The archaeological sites relating to Māori presence in the Whangarei District over the past millennium are similar to those in the rest of the country and include:

- Pā (fortified locations)
- Pits (for storage—mainly for root crops but also for other purposes)
- Terraces, house platforms (living areas)
- Gardens (boundary walls, mounds, drainage features)
- Middens (shell dumps and/or cooking locations)
- Quarries and other material resource zones
- Burials (urupā, kōiwi tangata)

The arrival of Europeans in the district changed the nature of archaeological remains from the mid-19th century, and the sites seen from this period onward include:

- Houses and their related structures
- Agricultural sites (e.g. farm buildings, stone walls)
- Industrial and/or commercial sites (e.g. mills, lime works, forestry and mining structures)
- Maritime sites (e.g. whaling stations)
- Military sites (e.g. redoubts)
- Social sites (e.g. churches, cemeteries)

In addition to sites containing, or likely to contain, archaeological remains are sites such as artefact findspots, with no known associated remains; botanical sites, with vegetation indicative of former settlement but with no known archaeological remains; and places with heritage links (such as 'chiefs' meeting places'), the archaeological status of which is unclear.

1.2.4 Overview of archaeology in the Whangarei District

Archaeological research has broadly established that a large number of archaeological sites dating from early Māori settlement through to early European settlement of the area are located in the Whangarei District; that many of these sites, including large middens, pā and sites relating to early European farming and industry, have left major visible and subsurface remains; and that a number of rare sites, particularly those used as sources of stone for tool manufacture, are located in the district. Evidence for settlement in the 'Archaic' period, albeit limited, indicates that the district was one of the earliest in New Zealand to be settled and the site distribution data also demonstrate that it was to become one of the most densely settled.

However, in many ways, archaeological research in the district remains in its infancy. For example, the identification and systematic archaeological excavation of the earliest ('Archaic') sites in the Whangarei District has occurred only sporadically in the past two decades. The information we have has tended to come from the study of artefact collections (see Turner 2000: 340). These 'Archaic' sites are generally located near the coast and near waterways in areas that are particularly vulnerable to erosion. In addition, few pā sites in the district have been dated and their development during the last few hundred years remains under-researched. Overall, only a few sites have been subject to major excavation, but those few have been productive in terms of information gained regarding the range of activities, artefacts and settlement in the district. Environmental history is also becoming of increasing interest. The results show that many of the remaining recorded sites are likely to contain significant information.

In the Whangarei District, as throughout much of New Zealand, many archaeological sites have been destroyed by recent development in the area, which has increased the value of the remaining intact archaeological sites. As elsewhere, archaeological sites are concentrated along the coastline in areas that are the most vulnerable to natural threats and human activities. However, there is no programme operating in the district that actively protects archaeological sites or even systematically monitors their condition.

The value of these sites is that they are both the physical expression of local and regional identity for those living in the district, and contain untapped information relating to the history of the district and New Zealand. Sites that can be preserved *in situ* are a valuable asset not only for the community, but for visitors from elsewhere. However, there remains a pressing need to extract what information we can from sites that are rapidly disappearing and are not likely to survive for reasons that are explored in this study. The information contained in these sites can considerably enhance our understanding of the past. For example, coastal middens may contain environmental, dating and settlement information that may be crucial to our understanding of the pre-European settlement sequence, the effects of settlement on the natural environment and the processes of cultural transformation involved in the development of Māori society from East Polynesian origins. Of particular relevance to this study, archaeological research can also shed light on past climatic changes or seismic events such as rising sea levels, flooding, tsunamis and earthquakes, and the effects of these on settlement patterns and food resources, improving our understanding of naturally occurring events and processes, and the extent to which future events may be natural or human-induced occurrences (see e.g. McFadgen 2007; Goff et al. 2010; Smith & James-Lee 2010; Smith 2011).

Reliable reconstruction of the past depends on the examination of a range of archaeological sites of different periods across different environments and landscapes within the district (and nationally), and must inevitably focus on the areas of earliest and densest settlement, which are predominantly within the coastal areas.

1.3 Climate change in the Whangarei District

1.3.1 Predicting the effects of climate change

Predicting the specific effects of the general warming of the average air and ocean temperatures (i.e. climate change) in any particular region is difficult because the complexity of the environmental interactions and human responses vary from area to area. However, MfE (2008) attempted to 'downscale' the global trends for the New Zealand situation and outlined the implications of climate change for the country's coastal margins. A summary of the major changes that can be expected and the level of confidence in these expectations is provided in Table 1, with the effects that will have the greatest impact on archaeological sites highlighted.

Projected changes in sea level remain controversial and it is very difficult to make estimates at this stage, but MfE (2008) provided general estimates for coastal planning purposes. The other key factors relevant to archaeological sites are precipitation and storm damage. Snow and glacier effects are not discussed here, as they are not major factors in the Whangarei District.

Table 1. Summary of expected climate change in New Zealand (adapted from MfE 2008: Box 2.1, and pp. 19–20). Shaded areas indicate the effects that will have most impact on archaeological sites in the Whangarei District.

FACTOR	EXPECTED CHANGE	CONFIDENCE LEVEL
Sea level	A base value sea level rise of 0.5 m relative to the 1980–1999 average should be used out to 2100.	Estimated for planning purposes
	An assessment of the potential consequences from a range of possible higher sea level rises should be made in undertaking assessments. At the very least, all assessments should consider the consequences of a mean sea level rise of at least 0.8 m relative to the 1980–1999 average out to 2100.	Estimated for planning purposes
Temperature	Increase in mean temperature, of more than that observed in the 20th century's warming.	Very confident
	Increase in mean temperature by 0.9ºC by 2040 and 2.1ºC by 2090.	Moderate confidence
	Least warming in the spring.	Low confidence
	Fewer cold temperatures and frosts, and more high-temperature episodes.	Very confident
Precipitation	Increase in annual mean rainfall in Tasman, West Coast, Otago, Southland and Chatham Islands.	Moderate confidence
	Decrease in annual mean rainfall in Northland, Auckland, Gisborne and Hawke's Bay.	Moderate confidence
	Heavier and/or more frequent extreme rainfalls where mean rainfall increases are predicted.	Confident
	Heavier and/or more frequent extreme rainfalls.	Moderate confidence
Snow	Shortened duration of seasonal snow lying.	Confident
	Rise in snowline.	Moderate confidence
	Decrease in snowfall events.	Low confidence
Glaciers	Continued long-term reduction in ice volume and glacier length.	Confident
Wind	Increase in annual mean westerly component of windflow across New Zealand.	Moderate confidence
	About a 10% increase in annual mean westerly component of flow by 2040 and beyond.	Low confidence
	By 2090, increased mean westerly component in winter (>50%) and spring (>20%), and decreased westerly component in summer and autumn (20%).	Low confidence
	Increase in severe wind risk possible.	Moderate confidence
	Up to a 10% increase in strong winds (e.g. >10 m/s or top 1st percentile) by 2090.	Low confidence
Storms	More storminess possible, but little information for New Zealand.	Low confidence

The predictions for New Zealand summarised in Table 1 (see MfE 2008: chapter 2) can be applied to the Whangarei District to suggest:

- An increase in mean temperature of approximately 1°C by 2040 and possibly doubling by 2090.
- A general reduction in precipitation, particularly during winter months.
- A rise in sea level of between 0.18 m and 0.59 m from 1980–1999 averages by 2100; however, global estimates vary by up to 1.25 m depending on the model used, and for risk assessment purposes MfE (2008) recommended that a potential rise of 0.8 m be allowed for.
- Increasing westerly wind component.
- Increasing 'storminess'.

There is considerable variation in the estimates of sea level change. Hannah (2004: 3) suggested that there has been an increase of around 2.1 mm/year since the start of the 20th century, with no clear signs of any acceleration in recent times; instead, periods of greater fluctuation particularly relate to the El Niño Southern Oscillation (ENSO) and the Inter-decal Pacific Oscillation (IPO) as a result of the frequency of storm surges. At the other end of the scale, Rohling et al. (2008) suggested that sea level changes of up to 1.6 m per century may occur in the future.

1.3.2 Coastal hazards exacerbated by climate change

As stated in section 1.1, archaeological sites are vulnerable to coastal hazards (among other things), and these in turn are impacted on by physical drivers. For most archaeological sites, the impact of a gradual change in sea level is of less concern than some of the other consequences of climate change, namely those changes in the physical drivers influencing coastal hazards. The drivers of most relevance (see MfE 2008: 2.4) are:

- Larger tidal ranges, especially in shallow harbours, river mouths and estuaries (as in many parts of the Whangarei coastline)
- Higher storm surges and changes in storm tide levels
- Wave dynamics on coastal sites

As stated in section 1.1 of this report, MfE (2008) argued that climate change will not create any new coastal hazards, but will exacerbate existing coastal erosion or inundation problems at many locations.

Impacts on New Zealand's coastal margins as a result of sea level rise and possible climate change impacts on other physical drivers that shape the coast will include:

- Increased coastal inundation
- Increased coastal erosion
- Salinisation of surface freshwater and groundwater
- Tsunami inundation
- Reduced effectiveness of coastal defence constructions

Another consequence of climate change is changing plant distributions (Cassar 2005). As temperatures increase, vegetation and indeed whole ecosystems are likely to change. Changes in vegetation will result in changes to the degree of root damage and other biological activities impacting on subsurface archaeological features. Human responses in terms of changing coastal settlement patterns and additional coastal defences will clearly also affect archaeological sites.

1.3.3 Landform

Landform is a major factor that will affect the extent to which areas containing archaeological sites are vulnerable to the types of hazards likely to be encountered as a result of climate change. Table 2 shows the relative sensitivity of different landforms in coastal New Zealand locations to climate change effects. Landforms such as coastal dunes, beaches and spits, as well as cliff locations are the areas most likely to contain archaeological sites in the Whangarei District. Many of these areas are exposed to the Pacific Ocean and the relatively intense geomorphological forces at play there. Not all of these effects are negative for archaeology, as dune progradation can improve the preservation of archaeological sites. Furthermore, vegetation can be essential to the stabilisation of dunes, and so where climate changes assists that process, it can afford some additional protection to sites in this sort of landform.

Rivers and streams are also major focal points of archaeological sites, and are subject to significant changes in response to rainfall patterns and land stability hazards. Changes here not only expose archaeological remains to erosion, which can very rapidly lead to their destruction, but on occasion can shift large amounts of material over archaeological sites, causing them to become buried.

Other types of landforms identified in Table 2, such as flats, contain few archaeological sites but were utilised by earlier populations in the area. Within Whangarei Harbour, for instance, other processes can be seen to affect coastal archaeological sites. These include not only urban development around Whangarei itself, but also, crucially, the secondary natural processes

Table 2. Relative sensitivity of coastal landforms to changes in different climate change drivers (adapted from MfE 2008: Table 3.1).

COASTAL LANDFORM	CLIMATE CHANGE DRIVER				
	SEA LEVEL RISE	STORM SURGE	PRECIPITATION	WAVE HEIGHT	WAVE DIRECTION
Simple landslide	High	Low	High	High	Low
Composite cliff	Moderate	Low	Moderate	High	Low
Complex cliff	Moderate	Low	High	High	Low
Relict cliff	High	Low	High	High	Low
Embryonic dunes	High	High	Low	High	Low
Foredunes	High	High	Moderate	High	Low
Climbing dunes	Moderate	Moderate	Moderate	Moderate	Low
Relict dunes	Low	Low	Moderate	Low	Low
Parabolic dunes	Moderate	High	Low	High	Low
Transgressive dunes	Moderate	Moderate	Low	Moderate	Low
River delta	High	High	Moderate	High	Moderate
Tide-dominated delta	High	High	Low	High	Moderate
Wave-dominated delta	High	High	Low	High	Low
Shore platform	High	Moderate	Low	High	Low
Sandflats	High	High	Low	High	Low
Mudflats	High	High	Low	High	Moderate
Pioneer saltmarsh	High	High	Moderate	High	Low
Saltmarsh	High	High	Moderate	High	Low
Sand beach	Moderate	Moderate	Low	Moderate	High
Gravel beach	Moderate	Moderate	Low	High	Moderate
Mixed beach	Moderate	Moderate	Low	High	Moderate
Composite beach	Moderate	Moderate	Low	High	Moderate
Boulder beach	Low	Low	Low	Moderate	Low
Barrier island	High	High	Low	High	High
Barrier beach	High	High	Low	High	High
Spit	High	High	Low	High	High
Cuspate foreland	Low	Low	Low	High	Low

that result from human activity. Some idea of the complexity of the relationships between the archaeological record and environment are exemplified by the chert working floors at Onerahi opposite Whangarei airport, which were referred to in section 1.2.2. These consisted of large scatters of stone tool debris on what had been sandy beach, according to aerial photographs dated to 1940. By 1990, this tidal zone had become mangrove swamp as a result of the building of a railway embankment nearby following WWII. Fredericksen (1990: 152) observed that it 'can be anticipated that with the further growth in the mangrove mudflats … most of the site will become entirely obscured within the next few years'. The long-term outcomes for archaeological features in these dynamic environments are rarely positive.

The Whangarei District is a relatively tectonically stable area (McFadgen 2007: 158), which makes it less vulnerable than other areas to the types of major land shifts seen in the Hawke's Bay and Christchurch areas. This does not, however, prevent the district from being affected by some of the side-effects of events occurring elsewhere. Archaeological sites around the country show possible evidence of tsunami and volcanic eruptions, including some in Northland (McFadgen 2007: 221ff).

1.3.4 Conclusions

The Whangarei District contains a range of archaeological sites that are concentrated near the coast, along the edge of harbours and near rivers. Although the detailed effects of climate change in the district cannot be predicted with any certainty, the projections to date, particularly relating to increasing storminess and rising sea levels, suggest that climate change will have significant impacts on archaeological sites in both the shorter and longer term.

It is clear that a wide range of factors may come into play in any specific situation, and so any assessment of the vulnerability of specific areas or sites will depend on a holistic analysis of the ecology, physical form and type of archaeological site involved.

In broad terms, the main climatic factors that currently result in the erosion of and damage to archaeological sites in the Whangarei District, and which are likely to increase as a result of climate change, are:

- Sea level rises
- Heavier and more frequent extreme rainfalls
- An increase in storminess

2. Methodology

2.1 Methods

Archaeological spatial and site type information derived from the CINZAS database[1] was incorporated into the data supplied by WDC's GIS department. This information included spatial coverages relating to coastal erosion, flooding and land stability hazard zones developed by WDC. Boundary and broad contour data were also provided. The database created was then analysed using Mapinfo and Manifold software.

The data were used to examine two models relating to the vulnerability of archaeological sites to the various hazards. Model 1 examined the extent of current threats to archaeological sites in coastal areas, based on site location and the hazard zones defined by WDC. Model 2 expanded the first model to incorporate the potential extent of future site destruction as a result of climate change increasing the current hazards.

The effects of coastal hazards on the survival of archaeological sites were examined in greater detail using information around the entrance to Whangarei Harbour as a case study. The implications of the results of the GIS analysis and the case study were then considered, and an outline framework for evaluating risks to archaeological sites in the Whangarei District and elsewhere was developed.

2.2 Sea level and hazards

Given the variation in estimates of sea level change for New Zealand (see e.g. Hannah 2004; Kennedy 2008; Rohling et al. 2008), a 'hazard-based' approach was used to identify the most likely areas where archaeological sites would be damaged or destroyed. The hazard data incorporate areas that are already vulnerable to coastal erosion where effects would be exacerbated as mean sea levels rise. This obviates the need for fine-scale contour data that can mask vulnerability. Sites on cliffs, for instance, may be well above sea level but can be undermined by erosion.

Although this approach leaves out areas where no previous hazard that might lead to archaeological sites being destroyed has been identified, this scenario was incorporated into the models presented by examining the straight-line distance of all archaeological sites from the coast in the Whangarei District to assess vulnerability, as discussed below.

2.3 Caveats

A number of caveats must be applied to use of the archaeological database in this study. Although the database included the results of the recent NZAA Archaeological Site Upgrade Project in the Whangarei District (see e.g. Walter 2006), the accuracy of information on the current status of archaeological sites was not always reliable. For example, sites that could not be relocated in the field or that were presumed destroyed may still exist, especially midden sites for which records are based on surface exposure of remains that may be present more extensively below the surface. A number of other sites have been destroyed by development since

[1] Central Index of New Zealand Archaeological Sites, Department of Conservation, Wellington. This has subsequently been replaced by NZAA's ArchSite database.

completion of the Upgrade Project. Consequently, since it was beyond the scope of that project to examine individual site records, the data used included all of the sites recorded in the district. Therefore, it should be noted that:

- The accuracy of archaeological site locations in the database is variable.
- The identification of sites as 'archaeological' is not always accurate.
- The current state of the sites is often unknown and a number of the sites included in the database are likely to have been destroyed.
- There has been inconsistency in the grouping of archaeological features (sometimes they were grouped together for site recording purposes, sometimes they were recorded as separate sites).
- There has been inconsistency in site recording standards.
- The distribution of sites often reflects the areas that have been surveyed and not all areas have been subject to systematic survey.
- Even where areas have been surveyed, archaeological sites are generally identified on the basis of their surface expression. Many additional sites may be completely buried and, therefore, remain unrecorded.

Despite these caveats, several factors indicate that use of the database is still of value. Firstly, although the sites currently recorded are only a proportion of the total number of sites present in the landscape, archaeological sites continue to be added to the NZAA database at a significant rate (e.g. Darmody 2008), reflecting the amount of surveying being carried out prior to land-use changes and development.

Secondly, our experience in surveying many areas within the Whangarei District in connection with land-use applications suggests that, generally speaking, those areas with the densest distribution of recorded archaeological sites are also the areas most likely to contain additional unrecorded sites, while those areas with relatively few recorded sites mostly reveal few additional sites even when surveyed systematically. In particular, coastal zones are dense with sites not only because they have generally been surveyed more, but also because Māori settlement was focused along the coast and waterways; and early European settlement has the same coastal bias. However, a number of significant sites are located in the more sparsely occupied inland areas.

Thirdly, we note that the site record is probably skewed in that it includes most of the more 'significant' (and in particular the largest) archaeological sites, as these are more likely to have been formally recorded from documented sources or survey results. This bias is partially compensated for by the recording of sites such as pits and middens, which have relatively high ground visibility and, therefore, are well represented in the database owing to the survey work. Those sites with limited or no surface expression no doubt remain under-represented, but this can be balanced against the fact that many sites in the current database have already been destroyed.

Therefore, overall, we can argue that despite the many caveats and difficulties associated with the use of the archaeological database, the large number and wide range of archaeological sites recorded to date remains representative of the archaeological sites in the Whangarei District, and can be used to generate a reasonable assessment of the impacts of climate change at a district-wide level.

3. Results

3.1 GIS information

Geographic Information Systems (GIS) provide a useful way of presenting complex hazard and risk information in relation to information about heritage landscapes (see also Cassar 2005: 44). The use of GIS in this context needs to be understood as a way of modelling the relationships, and it must be recognised that the models created are subject to ongoing refinement.

The following database layers were made available from the GIS of the WDC data:

- WDC boundary
- Distribution of recorded archaeological sites
- 20-m contour data
- Coastal hazard data (showing areas of coastal erosion)
- Flood hazard data
- Ground stability data

These layers were used to investigate two models:

- Model 1—Current threats to archaeology in the Whangarei District, based on:
  —Archaeological site distribution and density
  —Archaeological sites and distance from the coast
  —Archaeological sites and current hazards (coastal and land instability)
- Model 2—Future site destruction in the Whangarei District as a result of climate change, based on:
  —Increasing the areas of coastal hazards
  —Estimated rates of site destruction

3.2 Model 1—Current threats

3.2.1 Site density and distribution

Over 2400 sites have been recorded in the Whangarei District, of which just over 200 are located on offshore islands (Table 3). These include sites relating to pre- and post-contact Māori occupation, and to 19th-century European settlement of the area.

Sites with Māori cultural associations dominate, and include more than 300 pā sites, more than 900 midden sites, and nearly 900 pit and terrace sites, as well as approximately 40 sites associated with Māori horticulture and a number of burial locations. Nineteenth-century sites relating to early European settlement are far fewer in number, and include house sites and a range of early industrial sites (flax milling, mining, etc.). Above-ground structural remains are more likely to be present at these sites.

An analysis of the archaeological site distribution clearly reveals the problem confronting the archaeological record—survival in the face of rising sea levels. Figure 3 shows the spatial density of sites recorded in the district. As many as 60% of the sites are located within 1 km of the coast,

Table 3. Numbers of archaeological sites recorded in the Whangarei District. Source: WDC GIS Department (2007).

SITE TYPE	MAINLAND	OFFSHORE	TOTAL
Agricultural/pastoral	5		5
Artefact find	28	5	33
Botanical evidence	10		10
Burial/cemetery	37	10	47
Cave/rockshelter	1	9	10
Cement/lime works	1		1
Chiefs' meeting place	2		2
Church	1		1
Coal mining	1		1
Commercial	2		2
Defensive—Military	1		1
Defensive—Pā	305	14	319
Flax milling	2		2
Flour milling	1		1
Forestry	37		37
Gold mining	2		2
Historic—Domestic	10	2	12
Historic—Settlement/township	1		1
Industrial (unspecified)	14	2	16
Māori horticulture	41	28	69
Midden/oven	897	23	920
Pit/terrace	785	109	894
Source site	2		2
Transport/communication	8		8
Unclassified	4	3	7
Whaling station	1		1
Working area	7	1	8
Total	2206	206	2412

and about a third of those are within 100 m of it—and some are already in the water. A high proportion of sites, therefore, have the potential to be affected by coastal hazards such as flooding and erosion.

Midden sites of various sizes and configurations predominate in the coastal zone (which is not surprising), and it is these sites that are under greatest threat. Middens are the most commonly recorded site type in New Zealand archaeology, which to some extent lowers their individual value (unless they are large, complex or of an early date). They are also the site type most likely to be destroyed or modified as a result of development pressures because of the higher value placed on Māori earthwork sites, especially pā, and on built heritage structures relating to European settlement. This bias is concerning, as some of these middens date from the 'Archaic', or earliest, period of occupation in New Zealand, and there is a real possibility that a significant proportion of our resources relating to this period will erode away unrecorded. The loss of middens relating to later periods is also of concern, as many have the potential to provide significant environmental and socio-economic information, and some may have associated subsurface structural remains. It is also worth noting that in the Whangarei District, middens make up a far lower percentage of sites (c. 38%) than is the case nationwide (closer to 70%).

3.2.2 Distance of sites from the coast

The distance of the archaeological sites from the MHWM (mean high water mark) of the coastline was calculated using the GIS data, the results of which are shown in Fig. 4. There are limitations to the accuracy of this information because the exact location of a site was not always known (except for sites included in the 2006 NZAA Upgrade Project); the extent of the sites had not been recorded; and the distance from the coastline was calculated as a straight line, irrespective of topography. The analysis, therefore, underestimates distance along the ground, but the approximations are acceptable as the focus is on sites near the coast. (Sites that are either mistakenly or accurately recorded as being located in the water are, for the purposes of this analysis, considered to be 0 m from the coastline.)

The results suggest that around 450–500 of the identified archaeological sites in the Whangarei District are within 75 m of the coast and the majority of those are within 50 m (Fig. 4). This means that around 20% of the sites can be considered to have a moderate to extreme risk of coastal hazards such as erosion and subsidiary effects based purely on distance from the coast. Elevated sites are also not immune to coastal effects, as erosion often results in landslips that destroy sites.

While outside the scope of the current study, it is noted that archaeological sites that are 20–200 m from the coast are also at risk from development pressures owing to their desirable proximity to the coast.

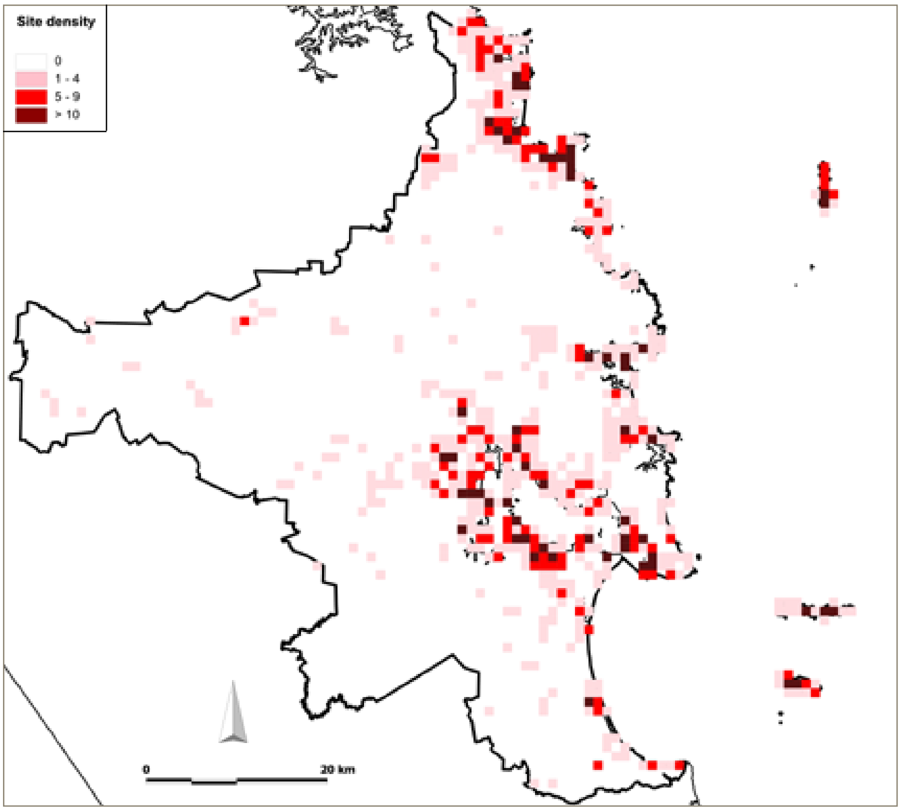


Figure 3. Spatial density of archaeological sites in the Whangarei District (grid size: 1 km^2).

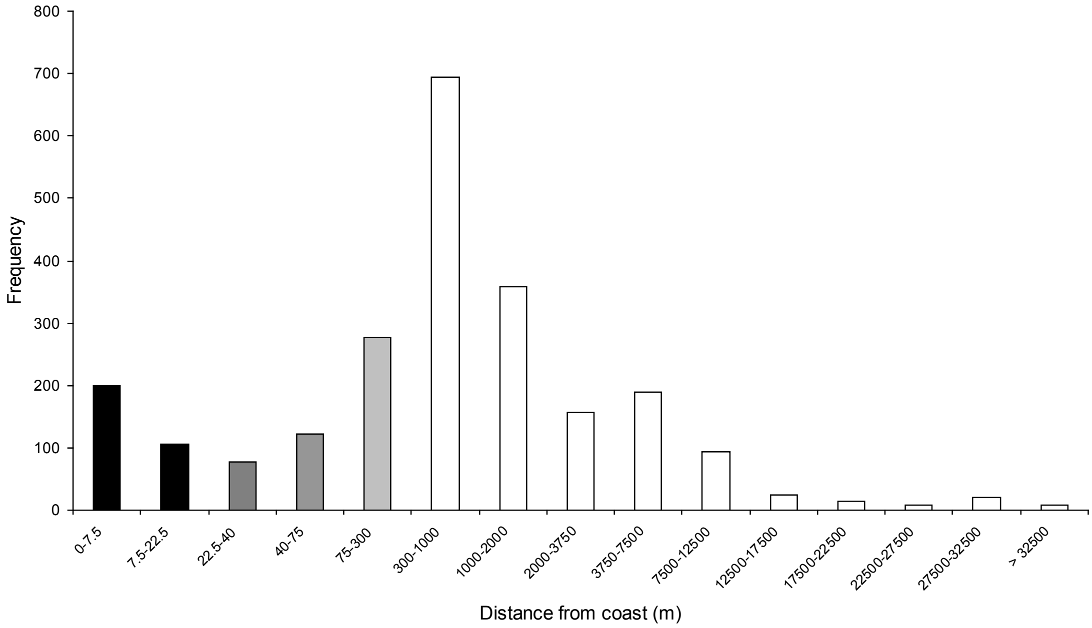


Figure 4. Distribution of archaeological sites in the Whangarei District in relation to the straight-line distance from the nearest coast. Shading highlights the likely threat to archaeological sites based on coastal hazards (darker shading represents greater threats).

3.2.3 Current mainland hazards

As set out in section 3.1, based on the GIS layers developed by WDC, three types of hazards were used to assess the vulnerability of mainland sites to climate change:

- Coastal erosion (referred to in the WDC GIS as 'coastal hazard')
- Flooding
- Ground instability

Each of these layers was added to the GIS database and all sites identified within these areas were flagged as being in the hazard area.

Coastal erosion

The 'coastal hazard' overlay of WDC relates to exposed coastline prone to coastal erosion. Short-term coastal erosion occurs because of storm events such as high winds, waves and increased water levels along the coastal foreshore (WDC 2007: chapter 56, p. 4).

A buffer zone of 10 m was added around the coastal erosion lines identified from the GIS data (Fig. 5). Although this is a relatively conservative buffer, it allows vulnerable sites to be specifically related to identified hazards rather than to the more general criterion of proximity to the coast. Just under 70 sites were identified as being within this coastal erosion hazard area: 3 pā sites (representing 1% of pā sites), 59 midden and oven sites (representing 7% of those sites), and only 4 archaeological sites made up of pit and terrace sites (representing only 1% of those sites).

As the data reveal, only a few pā sites and small pit and terrace complexes are vulnerable to the coastal erosion hazard. The vast majority of sites considered vulnerable to coastal erosion are the middens that dot the coastline. These sites can probably be considered to be extremely vulnerable to future destruction and indeed many have probably already been destroyed. Coastal erosion is particularly active in these areas and it is likely that sites that have not been identified previously will continue to be exposed, and will then become vulnerable to ongoing erosion.

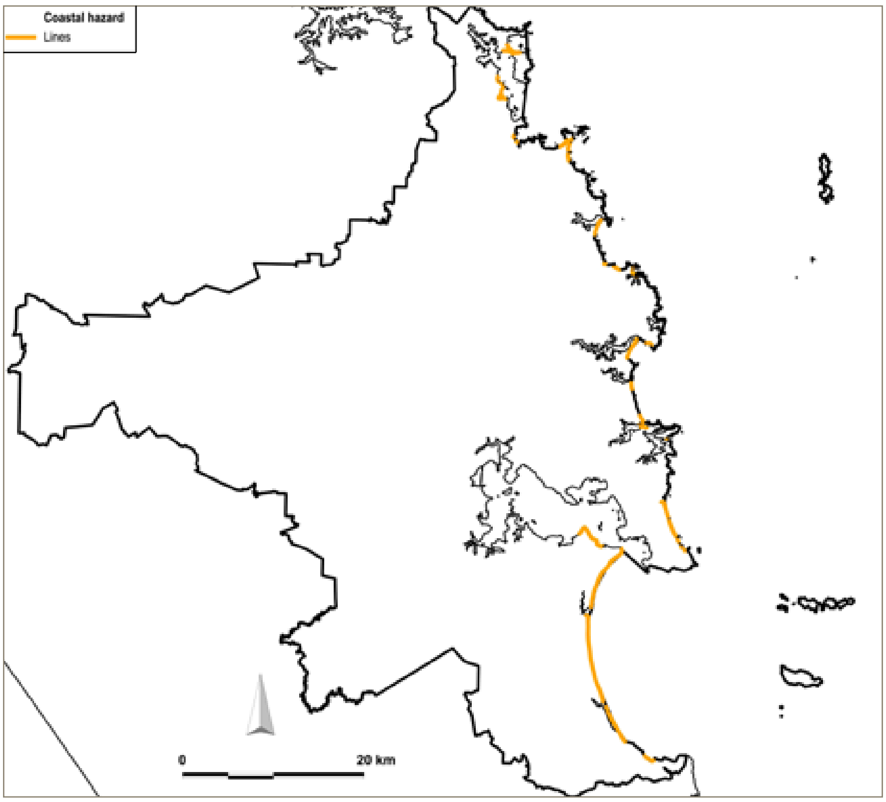


Figure 5. Coastal erosion hazard zones in the Whangarei District. Data source: WDC GIS Department.

Flooding

The flood hazard overlay (Fig. 6) identifies 'land which, on the information currently available, is susceptible to flooding; either due to rivers or streams overflowing their banks, inundation from the sea during high tides or storm surges, or to water ponding during extended periods of wet weather' (WDC 2007: chapter 56, p. 1). Not all of the flood hazard zones, therefore, relate to coastal hazard.

No buffer zone was added to the line delineating land vulnerable to flooding, but the sites that were identified as being vulnerable to this hazard were identified and plotted (Fig. 7). Approximately 140 sites were identified as being located within flood hazard zones (twice the number identified within coastal erosion zones).

As expected, midden sites again dominate in terms of overall numbers, but a greater diversity of sites was identified as being vulnerable to the flooding hazard than was the case for the coastal erosion hazard. A greater percentage of pit and terrace sites, and a similar proportion (though higher numbers) of pā are affected. A number of early European industrial and other sites are also vulnerable.

Flooding will not necessarily destroy archaeological remains; its effect will depend on the nature of the site as well as how the flooding occurs. Midden sites will often survive inundation if they are well sealed, but flooding tends to result in damage because it is often accompanied by movements of the soil. This suggests that large 'flood zones' are less of a threat than areas associated with rivers and streams, where water flow is more of an issue before, during and after a flood. Some early European sites with fragile structural remains, and sites that include metal components, will also be vulnerable to flood damage.

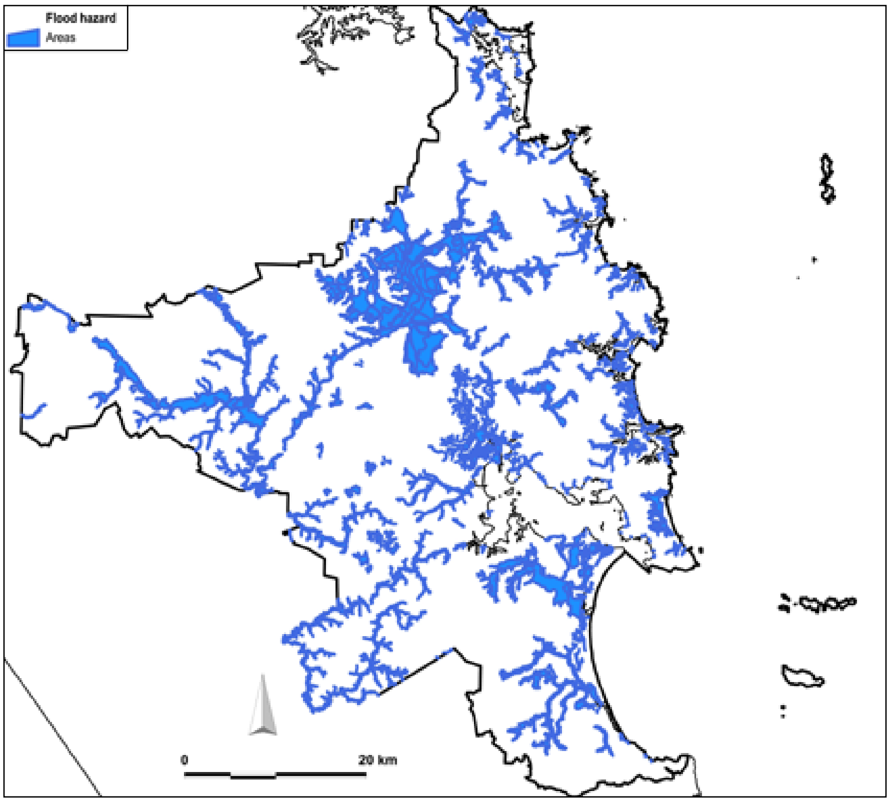
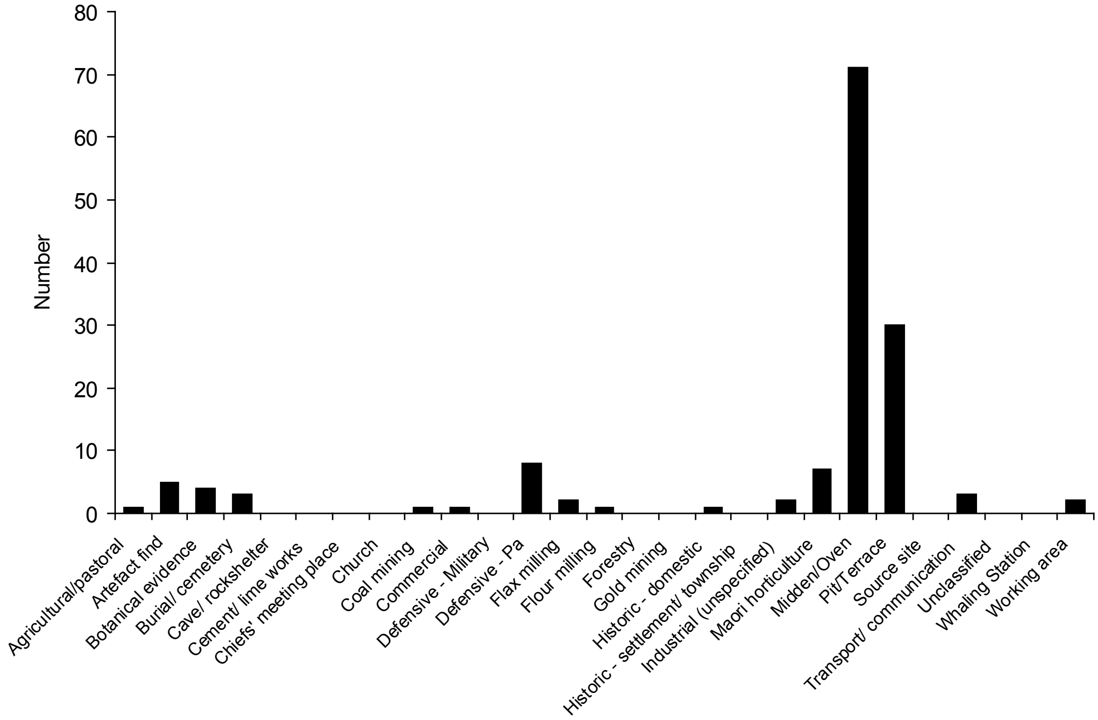


Figure 6. Flood hazard (shaded areas) in the Whangarei District. Data source: WDC GIS Department.



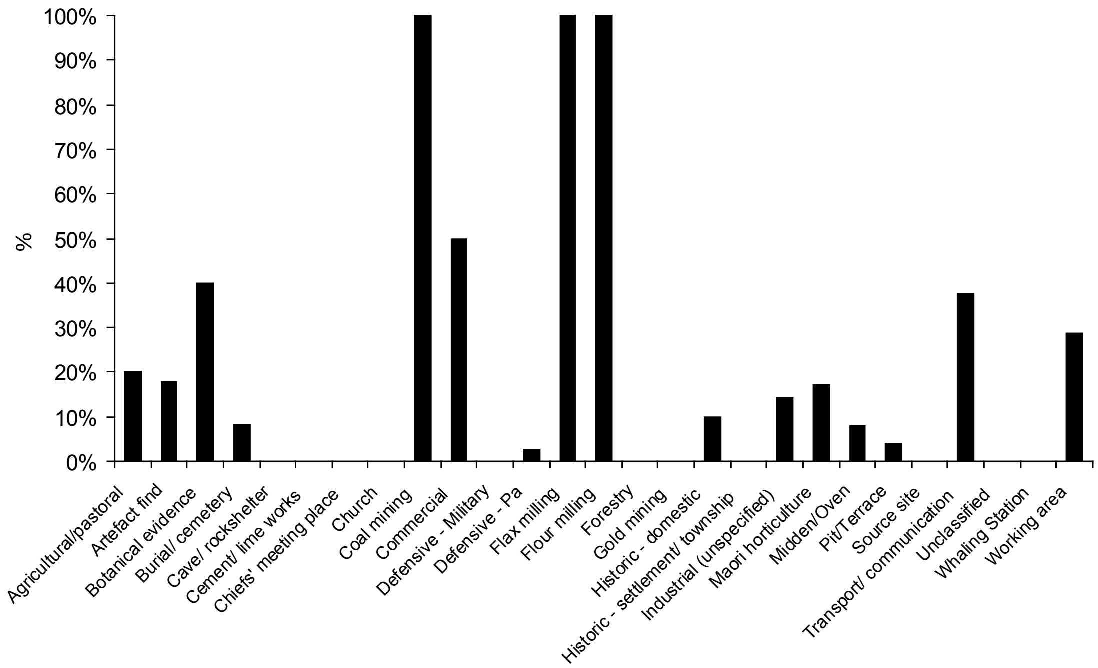


Figure 7. Number and percentage of archaeological sites, by type, found in areas that are likely to flood in the Whangarei District.

Ground instability

A map has been prepared for WDC (based on data by Tonkin & Taylor collected between 2001 and 2006) that identifies those areas with a high probability of slope instability. This exercise was undertaken in response to development pressures. Most of the areas assessed are in the coastal zone, but some areas on the outskirts of Whangarei were also included.

Ground instability hazard zones (Fig. 8) generally cover different landforms from the coastal margins and flood zones, particularly in being higher in elevation, although there are overlaps with the other hazard types. The instability also varies in severity. Sites within these hazard zones were flagged as being vulnerable to damage owing to ground instability and the results were plotted by site type (Fig. 9). Over 620 sites were found to be within ground instability hazard zones.

The results showed that midden sites and pit and terrace complexes are most vulnerable to ground instability, with almost equal numbers of these sites under threat. A considerably higher number and proportion of pā sites are vulnerable to this hazard than to either coastal erosion or flooding. Like flooding, however, ground instability can affect a diverse range of site types. These include a number of the less common site types, particularly relating to the historic period, for many of which only a few examples have been recorded and so any effects could be significant.

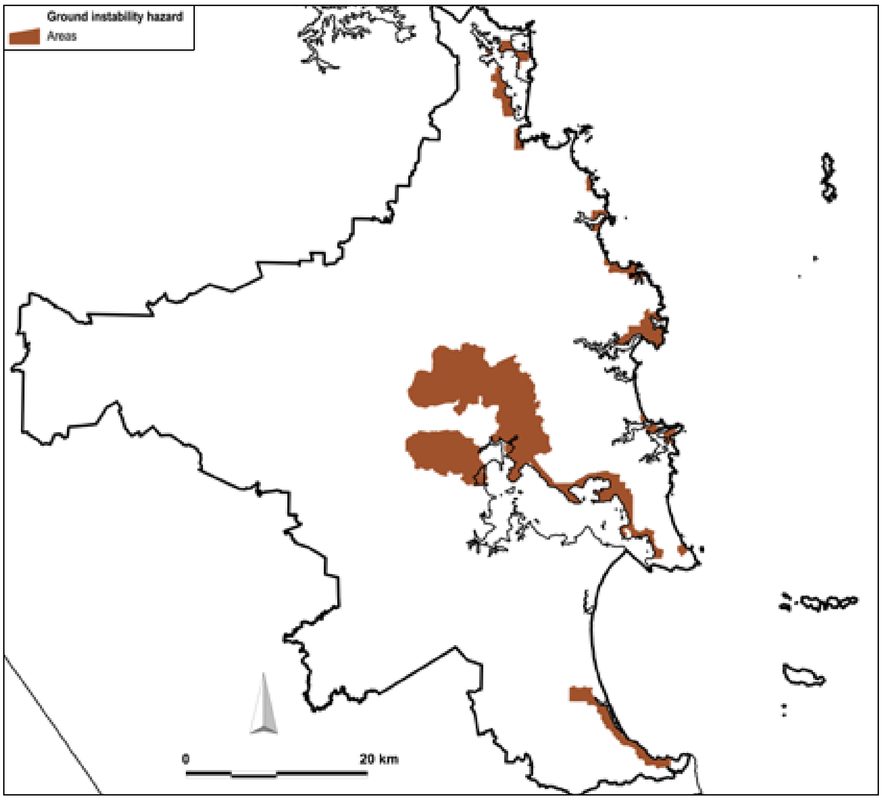


Figure 8. Ground instability hazard zones (shaded areas) in the Whangarei District. Data source: WDC GIS Department.

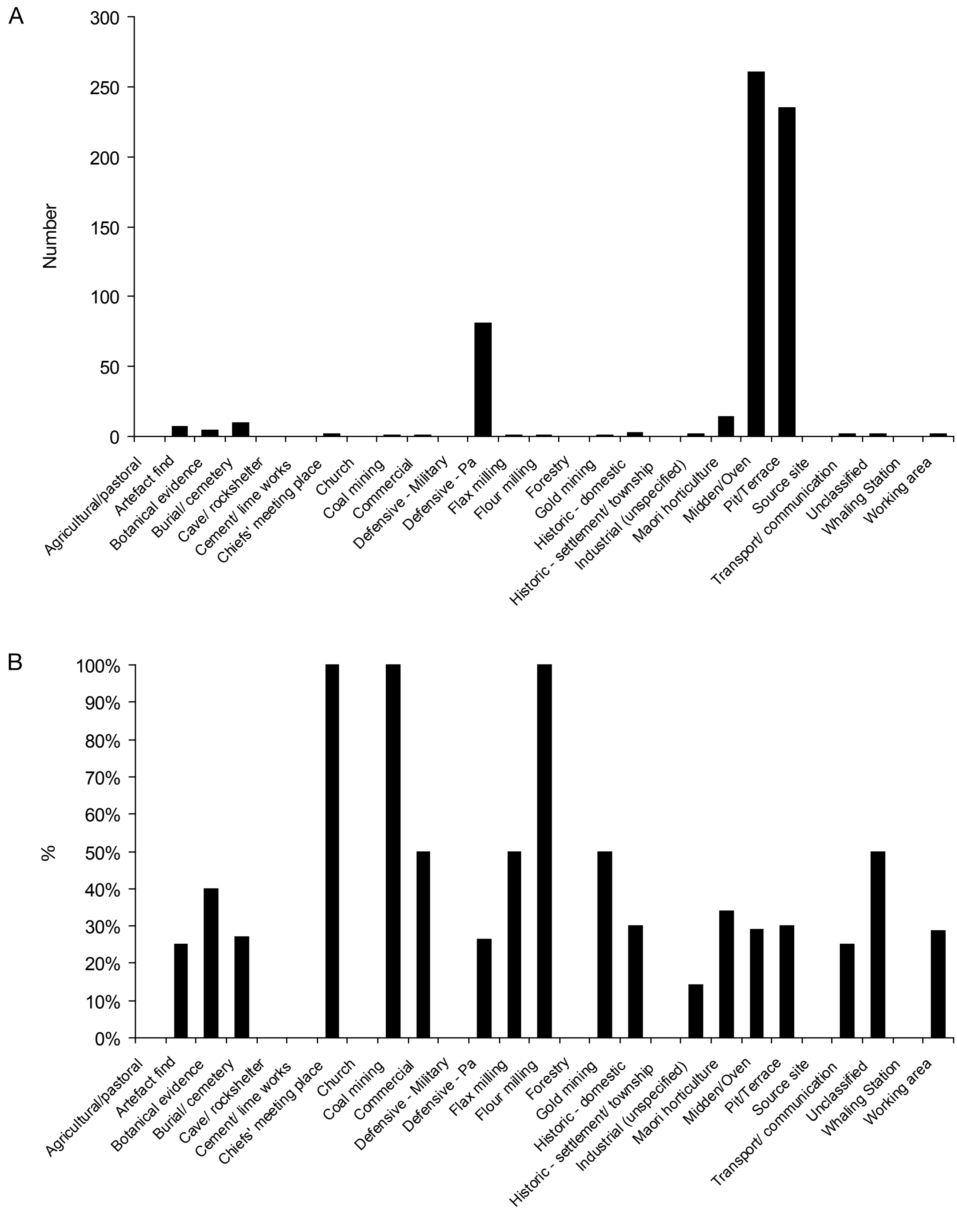


Figure 9. A. Number of archaeological sites and B. Percentage of each site type in ground instability hazard zones in the Whangarei District. percentages indicate what proportion of each site type is within the zones (e.g. there are only two chiefs' meeting places and both (100%) are within the zones).

Distribution of vulnerable sites

The results of the three analyses have been combined in Fig. 10 to show the distribution of sites that are currently vulnerable to any of the three hazards identified. Each point represents a 1-km area and shows the proportion of sites within that area affected by the different hazard types. As expected, archaeological sites and hazards coincide in the coastal areas (including the harbour and river mouths). Land instability is the overwhelming threat in this analysis, although there is variation in the severity of the threat and the likelihood of damage actually occurring. The coastal hazard zones are probably the most dynamic.

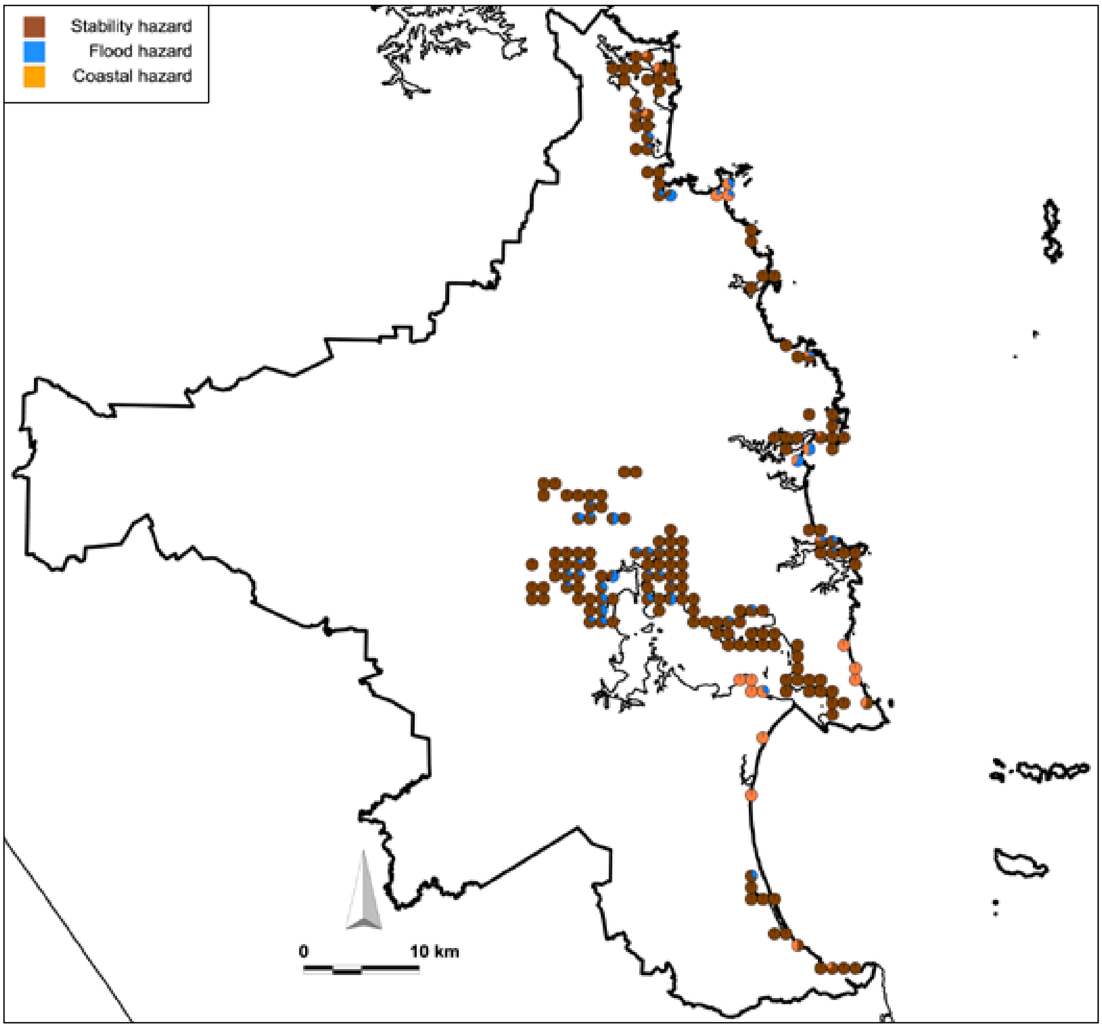


Figure 10. Distribution of vulnerable sites in the Whangarei District (excluding offshore islands) and hazard types to which they are vulnerable. Each point represents a 1 km area.

Multiple hazards to sites

The results were also combined to determine the number and types of sites that are vulnerable to one or more hazards (Figs 11 & 12). As already established, midden sites, followed by pit and terrace complexes and pā sites are the most commonly affected (reflecting the relative frequency of these site types in the database). The majority of sites are vulnerable to a single identified hazard, but a number are vulnerable to two or, in the case of a small number of midden sites, all three of the identified hazards. Several of the rarer site types, including some of the early European industrial sites, are also vulnerable to a combination of hazards.

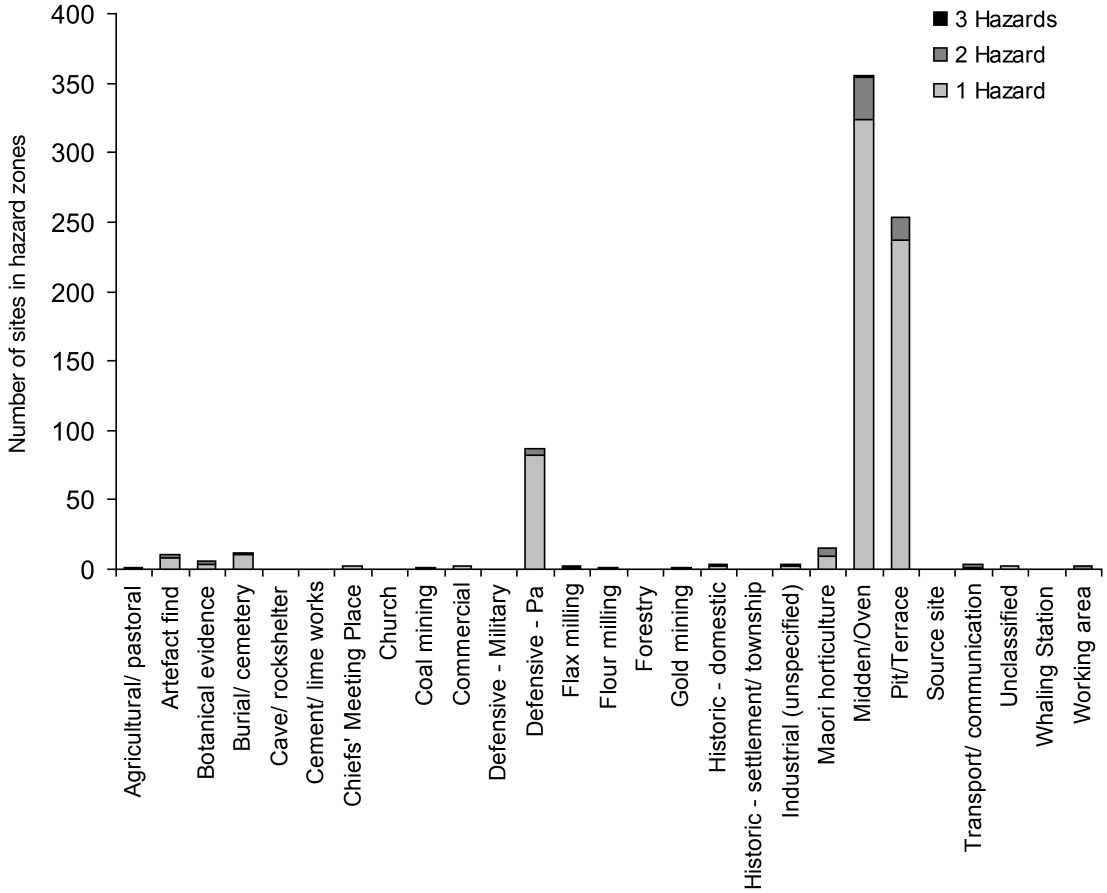


Figure 11. Numbers of archaeological sites, by type, in the Whangarei District affected by one, two or three hazards.

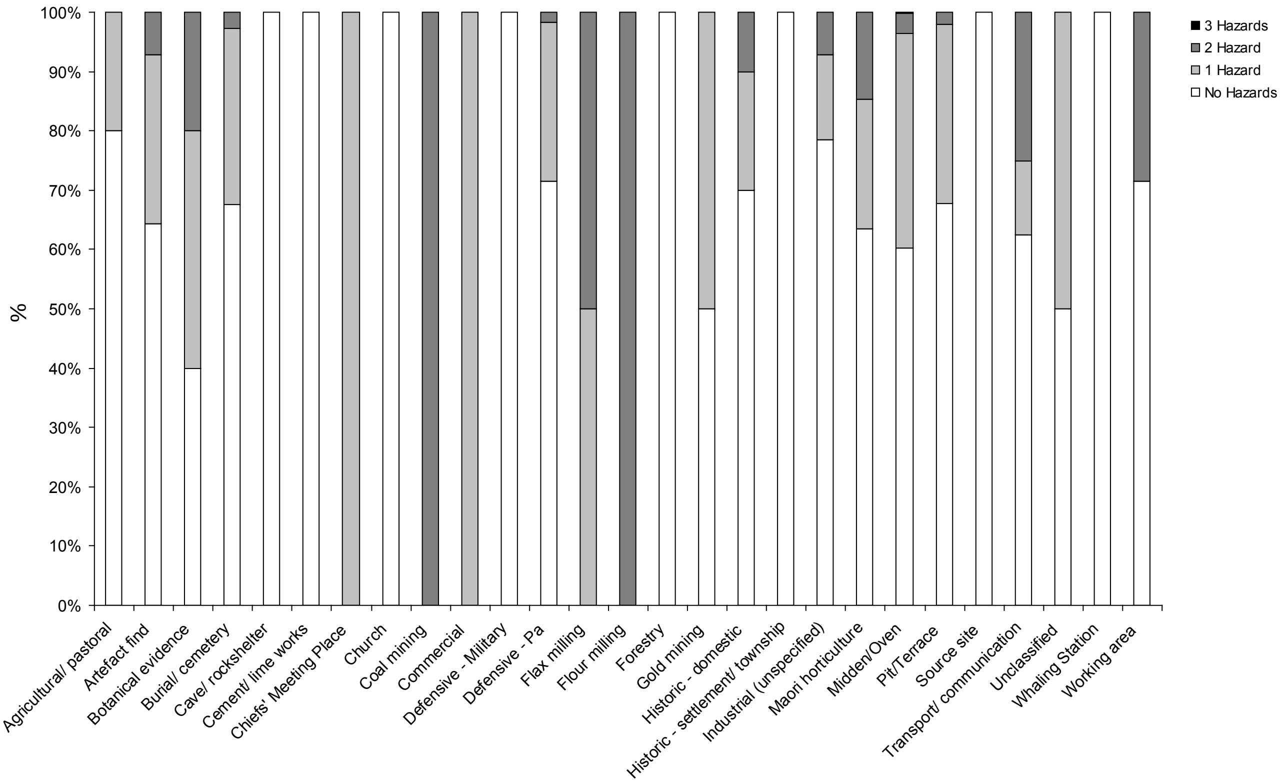


Figure 12. Percentage of archaeological sites, by type, in the Whangarei District vulnerable to no hazard ($n = 1444$), or one ($n = 689$), two ($n = 71$) or three ($n = 2$) hazards.

3.2.4 Current hazards on offshore islands

Hazards have not been determined for the main offshore islands within the Whangarei District, but analysis of the available data provides a useful basis for assessing the likely impacts in these locations.

Over 200 sites have been identified on these islands (Table 3; Fig. 13). Over half of these are pit and terrace sites, suggesting gardening and at least seasonal settlement in these locations. Midden sites make up a smaller proportion of the archaeological landscape than on the mainland, but are still a major component and are probably the sites most vulnerable to coastal erosion (the pit and terrace sites generally occupy higher ground, although a proportion would be vulnerable to coastal erosion and probably land instability hazards). The data available do not make it possible to assess what proportion of sites is under threat.

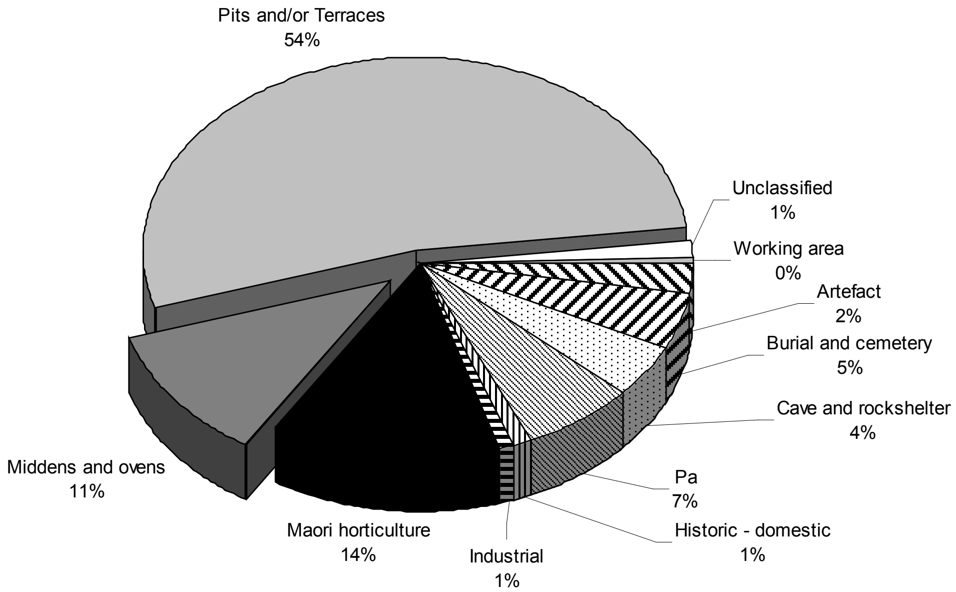


Figure 13. Proportion of archaeological site types on offshore islands in the Whangarei District.

3.2.5 Conclusions

As stressed throughout, the primarily coastal distribution of archaeological sites in the Whangarei District makes them particularly vulnerable to coastal erosion and flooding. In addition, land instability is a problem for many sites in coastal areas (as well as for sites further inland). Approximately 35% of all archaeological sites on the mainland are vulnerable to some form of hazard as currently identified. On offshore islands, that percentage may be higher, although no data are available to define the hazards. The most vulnerable sites are the midden and small coastal settlement sites associated with Māori occupation, and a few early European industrial sites further inland.

As stated previously, these hazards are only part of the problem facing archaeological sites in coastal areas, as sites are also under considerable threat from subdivision and development. The implications for the survival of the archaeological resource are serious, but further and more fine-grained analysis based on field assessment will be required to determine threats to specific sites, and to develop priorities for protection and management. The management of sites that are most under threat should include investigation and preservation by record, where the survival of a site is unlikely. This will be addressed further in the Discussion (section 5).

On the basis of this analysis, high priority should be given to the further assessment of sites from the 'Archaic' period, to more complex midden sites, and to the pā and small pit and terrace complexes within areas that are vulnerable to coastal erosion. One limitation of the current study is that we do not have data relating to how many of the midden sites identified relate to the 'Archaic' period, but as these are often located near river mouths (see e.g. Turner 2000: 316), they are probably particularly vulnerable to both flooding and coastal erosion.

A wider range of sites, including some of the early European industrial sites, are vulnerable to flooding and land instability hazards, with the latter potentially affecting a significant number of pā. The larger and more significant of these sites should be prioritised in any future risk evaluation exercise.

Detailed analysis of the threats to sites on offshore islands, where significant archaeological landscapes are recorded, should also be a priority. The presence of pā sites and a small number of burial grounds and historic sites would indicate that more fine-scaled analysis that considers the individual features of these sites is warranted. These sites are key elements in heritage landscapes that might be managed effectively as a group.

3.3 Model 2—Climate change effects

3.3.1 Climate change effects

Given that a number of archaeological sites are already at risk from coastal erosion, flooding and ground instability, the challenge is to determine the likely impacts of exacerbated coastal erosion or inundation problems on the survival of these sites.

Flooded areas are likely to expand as a result of climate change, and new areas are likely to become flooded. The most dramatic impacts, however, are likely to be from the increase in coastal erosion.

Three scenarios to examine the possible increase in the number of sites that may be vulnerable to future flooding, erosion and sea level rise as a result of climate change were tested:

- An increase in the width of the buffer zone around current coastal erosion hazard zones from 10 m to 50 m
- Creation of buffer zones of 10 m, 25 m and 50 m to the current flooding hazard areas
- Changes in the coastline and sea levels that put all sites within 50 m of the current coastline at risk

Increase in coastal erosion

To model an increase in the size of current coastal erosion hazards (and, therefore, not including new coastal erosion zones), the current coastal erosion zone was expanded from having the original 10-m-wide buffer (Model 1) to having a 50-m buffer. The increase in the number of sites affected was then examined.

The results show that expansion of the buffer zone increases the number of sites that are in the buffered coastal erosion hazard zone from 66 to 86 (Fig. 14). Regardless of buffer width, the majority of sites affected would be middens, although smaller habitation sites are also vulnerable. A few pā sites are also located near these hazard zones, although they are usually on high ground, which may reduce impacts.

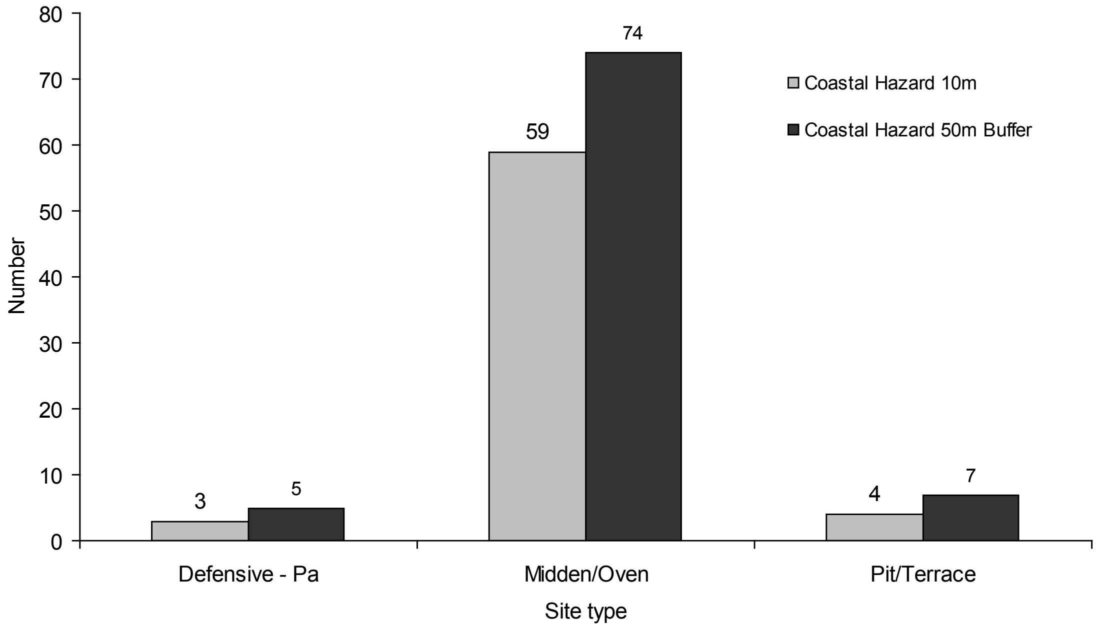


Figure 14. Number of archaeological sites in the Whangarei District vulnerable to coastal erosion according to Model 1 (10 m buffer; grey) and Model 2 (50 m buffer; black).

Increase in flooding

The flood hazard zone used in Model 1 (no buffer zone) was expanded using buffer widths of 10 m, 25 m and 50 m, and the number of sites found within these expanded areas was then compared. The results are shown in Fig. 15. A 10 m expansion of the flood zone resulted in quite a dramatic increase in the number of affected sites, rising from 142 (Model 1) to over 200. Middens, together with pit and terrace sites, would be the site types most greatly affected. A further expansion to a 25 m buffer was less dramatic, with only 15 additional sites possibly affected. Doubling that buffer to 50 m wide further increased the possible number of sites impacted to 305; however, this would be a very extreme scenario.

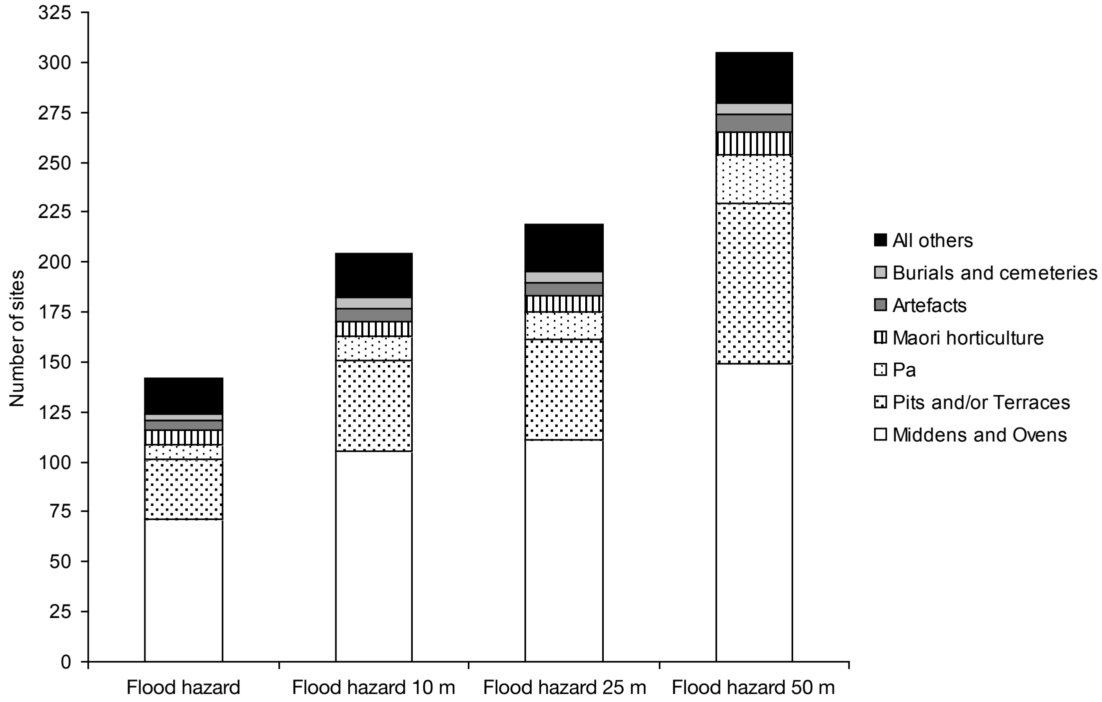


Figure 15. Number of archaeological sites, by type, in the Whangarei District that would be flooded as the flood buffer is increased from 0 to 50 m.

Coastline changes

A rise in sea level would change Whangarei's coastline dramatically but it is difficult to determine exactly what impact this would have on specific archaeological sites. As discussed earlier, changes in sea level can impact on sites in low-lying areas, as well as on elevated sites on unstable cliff faces, as these can be undermined by coastal erosion, leading to landslips.

The MfE (2008) report recommended that a potential 0.8-m increase in sea level by 2100 be used for planning purposes. As noted earlier, this figure encompasses a range of estimates of increase in sea level from around 0.2 m to 1.6 m. Detailed analysis that relates predicted sea level rise to coastline changes to determine which areas would be affected is possible using either LIDAR or high-resolution aerial photography contour data to generate a digital terrain model with contours in the 0.2–0.5-m range. However, neither of these was available and, as discussed earlier, the height of an archaeological site above sea level may not be a good indicator of its vulnerability.

Therefore, a broad approach has been taken that uses distance from the coast as a predictor for vulnerability to coastline changes rather than the specific sea level change. Sites already identified within coastal hazard zones would form a large component of the sites affected by future flooding associated with changes in sea level. Figure 4 shows the distribution of sites in relation to the straight-line distance from the coast. As sea level rises, sites located up to 300 m from the existing coastline would be increasingly vulnerable such that:

- In addition to sites already categorised as critically endangered (e.g. within 23 m of the coast), an additional c. 5% of archaeological sites may become vulnerable if sea level rises create impacts within 40 m of the coast.
- A further c. 8–10% of sites would become highly vulnerable if sea level rises impact on sites within 75 m of the coast.
- An additional 15% of sites would be affected if sea level rise effects extend to 300 m of the existing coastline.

The 300-m coastal limit may seem improbable, but normal erosion and accretion processes along the coast can be extensive if past history is any guide (see e.g. McFadgen 2007). Around rivers and streams that empty along the coast, the impacts of changes to sea level could extend inland significantly. The actual damage to sites would be highly variable, depending on the local topography. Impacts would also be affected by indirect factors, as infrastructure along the current coastline would have to be moved further inland as a result of climate change. The analysis presented here highlights the *vulnerability* of sites but does not necessarily indicate that they will be lost if they are near the coast.

3.3.2 Land instability

Although ground instability is a significant threat, future climate changes are more likely to increase the existing chance that the instability will be a problem, rather than necessarily increasing the vulnerable area (see Fig. 8 for the currently vulnerable area according to Model 1). An increase in the frequency and severity of storm events is predicted to be one effect of climate change, and this can have significant impacts on inland sites as well as those in coastal areas. The effects of Cyclone Bola in March 1988 demonstrated the impacts of a severe storm. In addition to causing coastal erosion, flooding and severe scouring of river mouths, Bola uprooted trees and caused major landslips. A number of archaeological sites, including several pā, were seriously damaged, and it is estimated that in some areas up to 60% of topsoil was lost from the hills (Pam Bain, East Coast Bay of Plenty Conservancy, DOC, pers. comm. to R. Clough, 2009). Similarly, extreme weather in Hawke's Bay in 2011 resulted in large-scale erosion of hills in many areas and significant damage to archaeological sites, but no systematic recording has been undertaken to determine the extent of this damage.

No attempt has been made here to quantify the increase in land instability hazard as a result of climate change, as this would require detailed analysis on a site-by-site basis and better predictions about the increase in storminess than are currently available.

3.3.3 Future impacts on offshore islands

As discussed earlier, the exclusion of archaeological sites on offshore islands from the previous analysis relates to a lack of information regarding hazards on the major offshore islands in the Whangarei District. However, these islands are relatively small and the archaeological sites on them are concentrated in the coastal zone, making these sites particularly vulnerable to future climate change effects.

3.3.4 Conclusions

The effect of climate change on archaeological sites cannot be predicted with any precision, but broad assessments can be made based on an increase in coastal hazards such as erosion, flooding and predicted sea level changes. In Model 2, buffer zones for the various hazards were either added where there were none or expanded to estimate the number of additional sites that might become vulnerable. It was found that increased coastal erosion and flooding could increase the number of sites currently identified as vulnerable (i.e. in Model 1) by 60; and the number could rise by an additional 2.5–10% from an estimated 760 vulnerable sites in Model 1 if, as expected, climate change exacerbates the existing coastal hazards.

Crucially, although Model 2 indicates that the number of additional sites impacted on may not be great, over a third of all sites are currently vulnerable according to Model 1. Thus, the increased pressures due to climate change will increase the likelihood that those sites will in fact be impacted.

It was not possible to assess the future effects of a general increase in storminess on archaeological sites as there are too many variables and insufficient data. However, the known effects of extreme weather events on archaeological sites in the past indicate that there is considerable potential for future climate change to result in additional impacts on sites on unstable land, both inland and near the coast, and on sites along rivers and at river mouths.

4. Case study—Whangarei Harbour entrance

This case study has been drawn from the authors' own work in the Whangarei District. It looks at the effects of coastal hazards on sites at the entrance to Whangarei Harbour—in particular at One Tree Point, but also on the eastern side of the harbour entrance, on the Whangarei Heads. This area has a diversity of both physical landscape and archaeological remains, allowing examination of how vulnerable the archaeology is to current coastal hazards (as outlined in sections 1.3 and 3.2).

4.1 Archaeology of the harbour entrance

As previously mentioned, the Whangarei District contains a wide range and large number of archaeological sites, many of which are concentrated around the harbour. A number of sites around the harbour have been excavated, providing the most detailed information we have for archaeology in the district.

The density of occupation in the Whangarei Harbour area was the result of a combination of factors that favoured settlement: access to marine and freshwater resources, fertile soils, water transport routes, and a sheltered and defendable harbour. There are many high-altitude areas that are suitable for the strategic siting of defensive sites with views out over the harbour and the approaches to it.

The coastline around the harbour varies topographically. On the western side of the harbour entrance is the Marsden Point – One Tree Point area (Ruakaka District), which is characterised by generally low-lying sand dunes. On the eastern side of the harbour entrance are the Whangarei Heads, which are characterised by relatively high cliffs rising rapidly from the water's edge. In both areas, there is significant evidence of Māori occupation (Fig. 16).

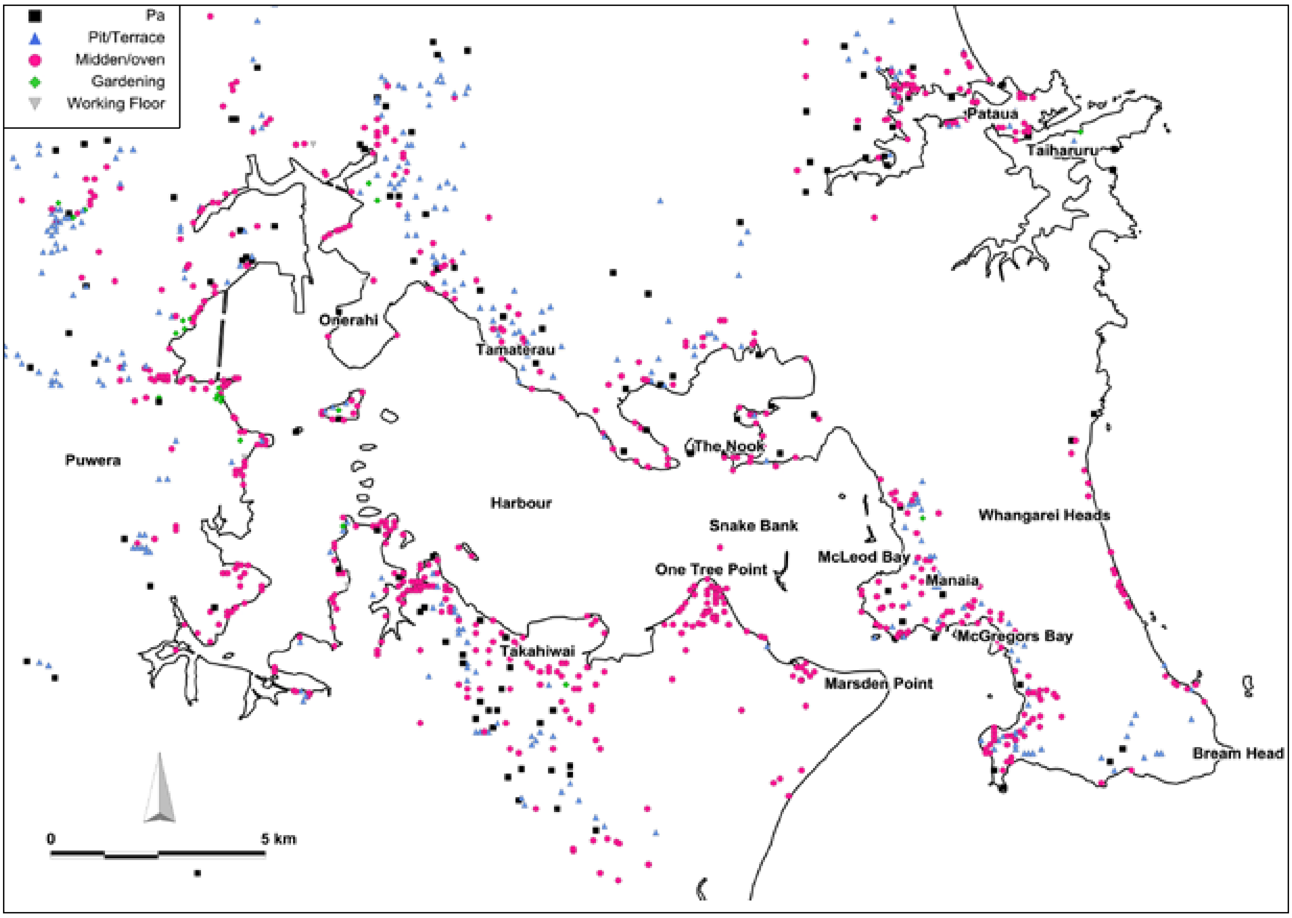


Figure 16. Location of recorded pā, pit, terrace, midden and tool working floors around Whangarei Harbour.

4.1.1 Marsden Point – One Tree Point

Development of the oil refinery at Marsden Point has obliterated the former archaeological landscape, but it is likely to have been similar to the midden-dominated landscape at One Tree Point further to the west (Fig. 16). This area of relatively low-lying sand dunes appears to have been used seasonally to exploit the rich resources of the coast. A large number of pā, pit and terrace sites are recorded to the west in the Takahiwai hills, and to the south near the Ruakaka River, indicating that these areas were the main focus of permanent settlement.

Middens excavated at One Tree Point by Phillips & Harlow (2001) were largely made up of cockle shells, and contained a large number of features including oven scoops, caches of hāngī stones, bin pits, and complexes of postholes and stakeholes. Site Q07/1124 (Fig. 17), for instance, probably had two phases of use and numerous cooking events. Postholes in the larger sites suggest the presence of a variety of shelters and, as Phillips & Harlow (2001: 35) argued, the main wooden components were deliberately removed for reuse. A line of stakeholes suggestive of a brush fence at site Q07/1123 (Fig. 17) also provides good evidence that some of these sites may have been occupied over a period of some months, probably for the duration of the summer (Phillips & Harlow 2001: 43ff). The other important features found at One Tree Point were odd-shaped 'bin pits', which were generally 40–120 cm long, 28–65 cm wide and up to 35 cm deep, and which were proposed as small storage pits for smoked shellfish by Phillips & Harlow (2001: 75). This is quite plausible, although one can also imagine that they may have acted as small pantries for storing root crops used during the stay on the dunes. Their presence also supports the notion that, in some cases, the occupation of One Tree Point could have lasted for a considerable number of weeks.

At the other end of the spectrum are the smaller sites, which consist of a number of cooking areas with little evidence of either housing or other activities (Phillips & Harlow 2001: 84; Campbell 2006; Bickler et al. 2007). These sites were probably just small cooking areas with only small shelters nearby. These are likely to have been widespread from One Tree Point through to Marsden Point.

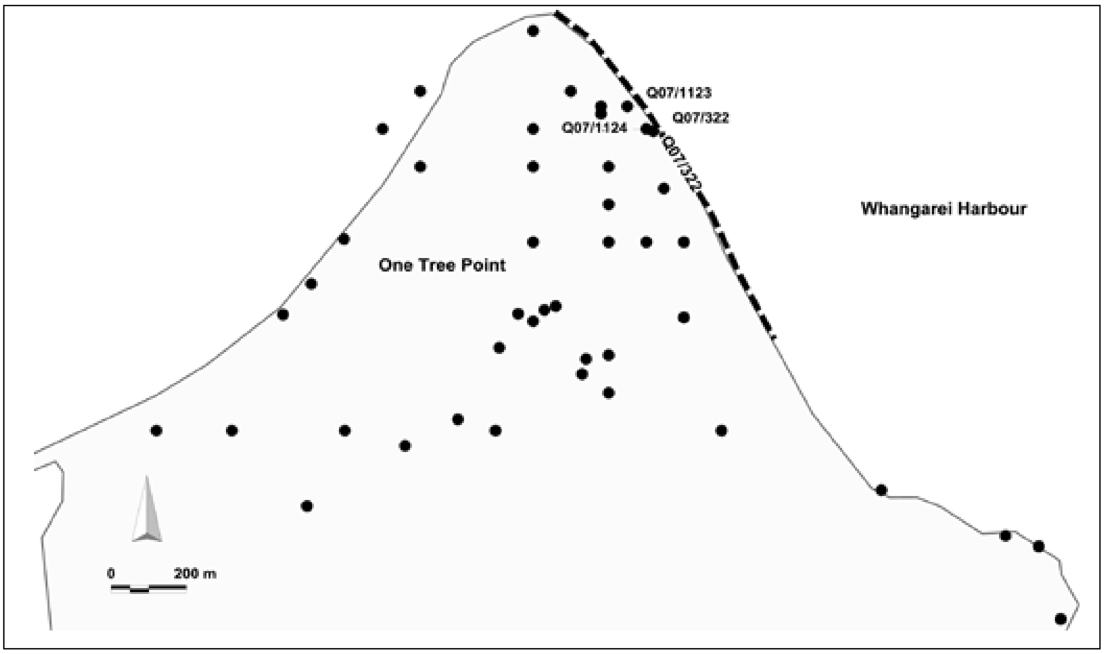


Figure 17. Distribution plan of previously recorded archaeological sites (black dots) at One Tree Point, showing the location of site Q07/1123 and site Q07/322, which is represented by the dashed line along the coast.

4.1.2 Whangarei Heads

In contrast to One Tree Point, the Whangarei Heads side of the harbour entrance consists of a series of small to medium-sized bays divided by headlands, in which settlement remains are often found. The bays generally have a narrow coastal shelf rising rapidly to the hills behind, and a more stable underlying geology. Most bays have one or two creeks; for example, Urquharts, McGregors and Taurikura bays.

The Heads have extensive evidence of pre-European Māori occupation, with a range of features including pits, terraces, shell middens, cultivation sites and pā (Fig. 16). As discussed in section 1.2.2, investigations in the 1960s at Bream Head found evidence of settlement dating back to the 'Archaic' period, and other investigations carried out over the last decade at McGregors Bay and elsewhere have been of sites of more recent date (e.g. Bickler et al. 2008; Judge & Clough 2008). The majority of sites investigated have been pipi midden sites, which contrast with the cockle middens identified on the opposite side of the harbour at One Tree Point (e.g. Bickler et al. 2008). Numerous surveys of properties within the bays at the harbour entrance have been carried out, especially over the last decade in response to development pressures, and consequently the archaeological landscape is reasonably well recorded and understood.

4.2 Environmental threats to sites at One Tree Point

While many of the archaeological sites at One Tree Point have already been excavated as a result of development there, other sites remain. As could be predicted, the risks to archaeological sites at One Tree Point as a result of climate change arise from two of the three aforementioned hazards:

- Flooding
- Coastal erosion

4.2.1 Flooding

The topography of One Tree Point (low lying, on top of an old dune surface) makes parts of it prone to flooding (Fig. 18), so that sites within these areas have the potential to be affected by future climate change. However, it is interesting to note that, for the most part, archaeological sites are not found in these wet areas, which were probably similarly flood prone in the past, as Māori would generally have avoided them, considering them too wet for settlement.

4.2.2 Coastal erosion

Due to the avoidance of wet areas by Māori, flooding is less of a damaging hazard for archaeological sites at One Tree Point than coastal erosion. Much of the coastline is within the coastal erosion hazard zone identified by WDC (Fig. 5). Development, of course, is taking an even more significant toll, both at Marsden Point at and around the oil refinery (where most of the recorded sites and probably a large number of unrecorded sites have been destroyed), and as a result of subdivision at One Tree Point.

A closer examination of site Q07/322 at One Tree Point illustrates the stresses that the archaeological sites are under and exposes some of the methodological problems associated with the current study. Site Q07/322 is recorded in most databases as a single point, as are all other sites in the Whangarei District, but an examination of the NZAA Site Record Form shows that, when originally recorded in 1981 and revisited in 1997, the site actually extended up to 800 m along the cliff (see Fig. 17). The deposits consist of middens, dominated by cockle shells, which are eroding at the top of the cliff (Figs 19 & 20). A total of 11 separate deposits along the cliff edge were identified in 1981 and that number increased to 15 in 1997. More recent examination by Dianne Harlow (pers. comm., 2009) noted 11.

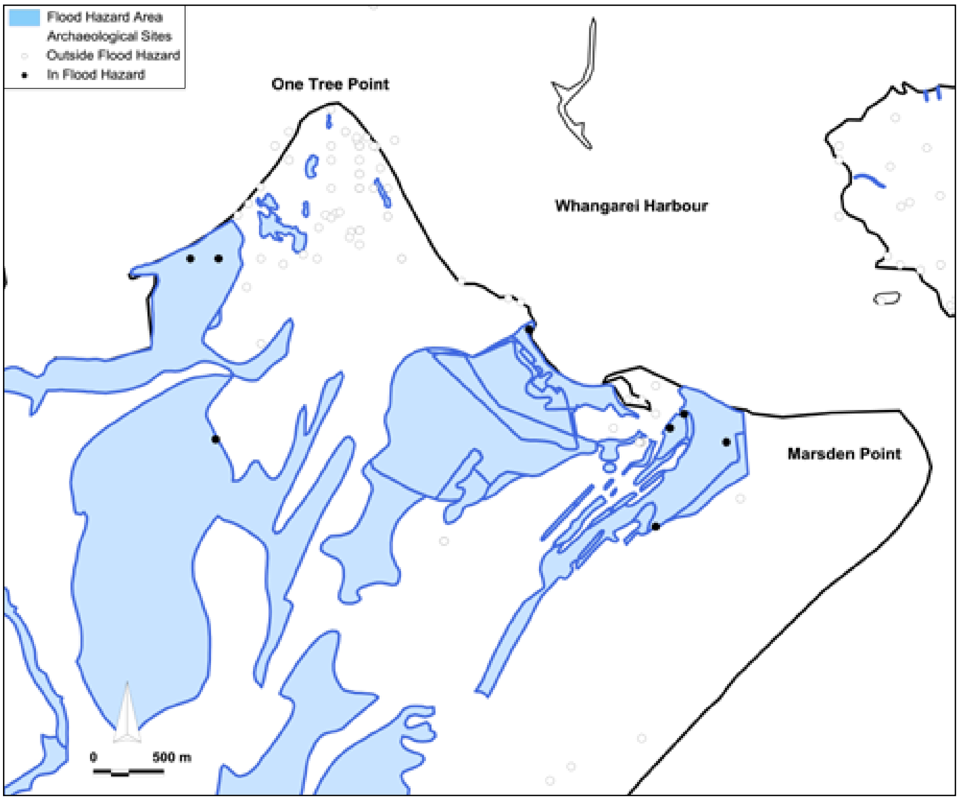


Figure 18. Archaeological sites in flood zones (black circles) and nearby sites (white circles) at One Tree Point. Shaded areas are the flood hazard zones. Data source: WDC.

The changing number of midden deposits reflects the complex situation relating to what has happened to the site since it was first recorded in 1981. Erosion at the base of the cliff occurs due to wave action, which undermines the top of the cliff where the midden components are located (Fig. 21). Parts of the cliff top collapse, taking down large chunks of the archaeological features with them. Pōhutukawa (*Metrosideros excelsa*) trees growing along the edge partly assist in stabilising the area, although roots invade the archaeological deposits, destroying those in their path. Once the coastal erosion proceeds beyond a tree's ability to stabilise the cliff edge, the tree itself collapses, dragging an even larger area of the cliff face down and with it more large chunks of archaeological deposits. This process is clearly visible in the area today (Fig. 22). All of this is exacerbated by water discharge from the cliff top and continuing use of the area.

It is likely, therefore, that the site was originally much larger (continuous along the cliff front for up to 800 m and perhaps a few metres wider), with a large part having eroded away over the centuries. Thus, since we do not have a description of the site prior to 1981, hundreds of square metres of archaeological deposit may have been lost without any dating or structural information being obtained. As the site erodes, fragmentation of the more continuous sections increases the number of visible midden deposits, until some of these visible deposits are destroyed and the number drops once more.

As noted earlier, rising sea levels and the increased storminess that are predicted as a result of climate change (MfE 2008: 30, 34) will cause even more coastal erosion of the cliff face, even though remedial efforts are planned (Dianne Harlow, pers. comm., 2009).

It is worth noting that the recording of large sites as single points creates difficulties for any GIS-based approach to predicting long-term impacts resulting from climate change and the prioritisation of sites for protection.

Figure 19. View of One Tree Point cliff face.
Photo courtesy of Dianne Harlow (2009).

Figure 20. Typical Q07/322 midden deposit on top of cliff face.
Photo courtesy of Dianne Harlow (2009).

Figure 21 (above). Typical collapse along cliff face.
Photo courtesy of Dianne Harlow (2009).

Figure 22 (right). View of damaged midden (Q07/322) due to erosion.
Photo courtesy of Dianne Harlow (2009).

4.3 Environmental threats to sites at the Whangarei Heads

In contrast to One Tree Point, the Whangarei Heads area on the other side of the harbour entrance rises relatively steeply in most areas. Many sites are at a higher elevation than at One Tree Point, and there is a much greater range of recorded sites, with many pā, pit and terrace sites located on higher land close to the coast. Midden sites are found along the beach, on natural and cultural terraces above the beach, and associated with settlement sites further uphill.

This area has not been identified as having a high risk of coastal erosion (Fig. 5), but erosion is evident along the inner harbour (e.g. Fig. 23). Flooding is not a major hazard in this relatively elevated area (Fig. 6), but ground instability is more of a threat (see Fig. 8), and middens are visibly eroding out on many of the hill slopes. Changes in the water table and flow, slumping, and storm damage can be seen to be affecting archaeological features, and many sites are visibly decaying (e.g. Fig. 24). Again, this area faces increasing threats from coastal subdivision and associated infrastructure projects.

The exacerbation of current threats as a result of future climate change will accelerate the processes currently being seen. While coastal erosion will be less severe than on the exposed One Tree Point coastline, it will still impact on a number of middens and small terrace sites on the coastal shelf. However, the effects on larger and more significant archaeological sites as a result of increasing numbers and severities of storm events may be more insidious. Landslips and slumping can occur rapidly on the spurs and slopes overlooking the coast, where pā and many of the settlement sites are located.

Figure 23. Coastal erosion at Q07/797 (around McGregors Bay, Whangarei Heads, November 2005).

Figure 24. Changes to water table and flow can undermine land and create slumping and erosion, as shown at Q07/797, McGregors Bay, Whangarei Heads (November 2005).

5. Summary and discussion

5.1 Summary of results

The results of the analysis are fairly conclusive regarding the implications of climate change for archaeological sites in the Whangarei District. Archaeological sites in the district are largely concentrated along the coastline. The sites include pre- and post-contact Māori and early European settlement sites. These sites are currently significantly threatened by coastal hazards such as flooding and erosion, as well as by ground instability (although it is more difficult to quantify this threat); in some cases, sites are at risk from a combination of hazards. About one-third of the recorded archaeological sites are already under threat, regardless of any additional climate change effects.

The effects of possible changes to the climate in the Whangarei District has been modelled at only a superficial level, owing to the limitations of the available data on site location, the lack of detailed contour information and the lack of reliable predictive climate change data. However, the modelling does suggest that:

- While around 760 sites are already under threat from coastal, flooding and land instability hazards, an additional 2.5–10% of archaeological sites will be threatened by the effects of climate change based on the predicted expansion of current hazard zones.
- Climate change will make it more likely that those sites within the identified hazard zones will be affected by those hazards.
- The severity of the impacts that the hazards will have on archaeological sites will be increased.

The types of sites that are most likely to be affected are midden sites and small Māori habitation sites, where these are near the coast. These sites are potentially affected by all of the major hazards identified. Larger sites, including pā and a few sites relating to early European settlement and industry, are more susceptible to land stability issues. Both flooding and land instability are likely to affect a wider range (though not a higher number) of sites than coastal erosion.

In general, increased temperatures, higher sea levels, and an increase in storm frequency and severity as a result of climate change will accelerate the ongoing damage to the archaeological record in the Whangarei District.

5.2 Implications for other areas

In other parts of New Zealand the archaeological record also has a primarily coastal focus, although significant archaeology is present in inland areas that are conducive to settlement. Frequent references to ongoing coastal erosion affecting archaeological sites can be found in the archaeological literature (e.g. Phillips & Allen 2006; Walton 2006: 37), which collectively paints a bleak picture across the country. This does not mean that all areas will be affected equally or that all changes will be negative. For example, Wells & Goff (2006) pointed to the progradation of dune systems on the west coast of the South Island during the last Alpine Fault ruptures in the past 650 years. Uplifted coastal areas due to earthquakes can also significantly alter the context of sites and, in certain cases, provide some degree of protection from erosion (e.g. McFadgen & Goff 2003). However, in terms of long-term survivability of archaeological sites in the coastal zones, relying on such ameliorating factors cannot be considered an effective management approach.

How climate change will impact on archaeological sites in the interior parts of the country has not been examined in this study, but an increase in extreme weather events would impact on the archaeological record everywhere. This will be particularly true in flood-prone parts of the country and may have additional implications for the survivability of built heritage (see, for example, McFadgen 2001).

Offshore islands are more likely to be affected by coastal changes, and the archaeological remains in these locations include some of the best preserved archaeological sites and landscapes, as many islands are in public ownership. Extensive survey work and management evaluation has been carried out in the inner Hauraki Gulf Islands on land administered by DOC; for example, relating to the significant archaeological landscapes on Browns Island (Motukorea) (Dodd 2006), Motutapu Island (Dodd 2007) and Motuihe Island (Dodd & Turner 2008). However, the potential physical impacts of natural hazards on archaeological sites are not generally explicitly evaluated as part of the management plans that have been developed. Indeed, some of the threats to the archaeological resource in the future may come from revegetation projects carried out as part of DOC's response to the need for carbon sequestration to meet New Zealand's Kyoto Protocol targets (see Dodd 2007: 262–263), adding to the pressure already created by existing community-driven revegetation programmes.

One notable exception, however, has been the attempt to protect the Sunde site on Motutapu Island, the earliest deposits of which pre-date the eruption of neighbouring Rangitoto Island. A programme of beach replenishment has recently been undertaken by the Auckland Regional Council (now Auckland Council) and DOC to protect the surviving remains of the site, which will be monitored to assess the effectiveness of this measure (Anne McKenzie, Auckland Conservancy, DOC, pers. comm., 2009).

There is a relatively high density of archaeological sites on New Zealand's islands that are close to shore, reflecting their use by Māori in pre-colonial times; however, archaeological sites have also been found on almost all of the more distant offshore islands, including the Chatham Islands, the Auckland Islands and the Kermadec Islands. These islands have received far less attention than those closer to the mainland, although the sites in these relatively isolated locations have high significance as they represent the more remote reaches of Polynesian (and European) exploration and colonisation. Climate change impacts are likely to be significant on these islands.

5.3 Gaps in current information and future research

This study is only a first step in the process of understanding the potential impacts of climate change on archaeological sites in New Zealand. It has been constrained by a number of limitations in the data available, in particular:

- Most sites are recorded as single point locations, rather than as the areas they actually (or at least are thought to) cover.
- Some sites are not accurately located.
- The current state of most sites is not monitored systematically.
- There are no accurate data regarding the loss of archaeological sites in the Whangarei District resulting from the different natural and human pressures on them.

More detailed analyses that address these problems are therefore required to build an accurate picture of climate change effects on archaeological sites in different regions of New Zealand. However, despite the limitations of the data, none of these considerations suggest that the vulnerability of sites identified in this report will be lessened, and it is important that appropriate mitigation is undertaken now, before it is too late for those sites that are currently under most threat.

Further research is also required to improve our understanding of the archaeological record and the impact that climate change will have on the archaeological resource. Models of climate change for New Zealand need to be 'down-scaled' to the local level before particular impacts on specific sites can be predicted with a high level of accuracy. However, it is important that this research is carried out as part of a programme that focuses on active management of the information loss associated with future archaeological site destruction as a result of climate change.

5.4 Risk assessment framework

Despite the current gaps in our knowledge, the results of this GIS study allow us to recognise and quantify (in broad terms) the potential future destruction of archaeological sites based on existing hazards and the likely effects of climate change. It should be possible, therefore, to develop a process for assessing the risk to archaeological sites based on current information and broad climate change predictions, and then use it (in combination with significance assessment) to prioritise the protection or investigation of archaeological sites in coastal areas. Risk assessments can be refined further as the gaps in our knowledge are filled and climate change effects become more apparent, and when decisions are being made to allocate resources to specific sites.

Standard risk management approaches and terminology can be adapted to form the basis of a risk assessment methodology for archaeological sites (Table 4, adapted from MfE 2008: 46). The risk assessment process would involve:

- The identification of hazards to specific archaeological sites (coastal erosion, flooding, land instability, rising sea levels).
- An assessment of the likelihood of the hazard impacting on an archaeological site.
- An assessment of the consequences to the site if the hazard impacted on the site, based on major damage to or destruction of the site.

Table 4. Key terminology used in risk assessment (adapted from MfE 2008: 46, Box 51).

TERM	DEFINITION
Risk	The chance of an 'event' being induced or significantly exacerbated by climate change, which will have an impact on an archaeological site or heritage landscape. It is measured in terms of consequence and likelihood.
Hazard	A source of potential harm to an archaeological site. Examples are coastal erosion or inundation.
Event	A coastal hazard incident that occurs in a particular place during a particular interval of time. It is distinct from a mere 'storm event', although it could be an event that occurs during a storm (e.g. erosion that results in loss of part or all an archaeological site).
Consequence	The outcome of an event, expressed qualitatively in terms of the level of impact. Consequences (or impact) can be measured in terms of direct or indirect physical damage to an archaeological site.
Likelihood	A qualitative (and possibly quantitative) measure of the probability or chance of something happening to an archaeological site.

The level of risk can, therefore, be evaluated in terms of the likelihood of hazards compared with the consequences of those hazards to arrive at a qualitative risk assessment (Fig. 25). The models developed in the GIS analysis can be used as the basis for assessing both of these components. A consequence can be simplified to be major damage to archaeological features probably leading to destruction of the site. While it is likely that the manifestation of a consequence would be gradual in any situation, for the most part, once sites are exposed to these hazards, it is more a matter of when the site will be completely destroyed rather than if it will be destroyed. The possible exception to this is flooding, which can inundate certain types of sites but not necessarily destroy their integrity. Table 5 proposes levels of risk associated with different hazards as identified in the GIS study.

This qualitative process can be converted to form part of a quantitative evaluation system used to assess the risks to particular archaeological sites.

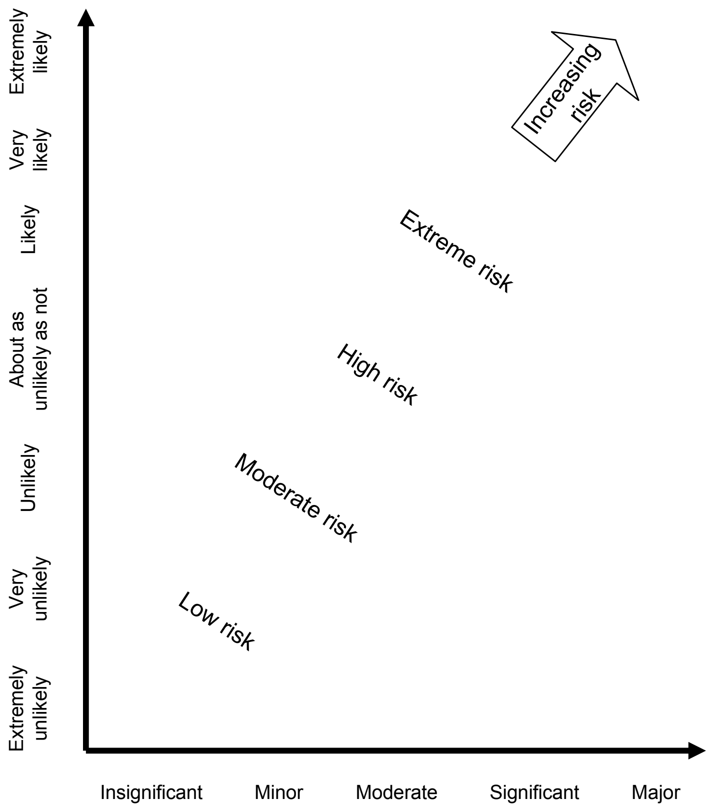


Figure 25. Risk and consequence of hazards (adapted from MfE 2008: Figure 5.6).

Having established the broad levels of risk based on proximity to hazard zones, a finer-scaled analysis of the types of archaeological sites and their vulnerability to different hazards would then be required, based on:

- The physical expression of the archaeological remains
- The location of the sites within the landscape

Table 6 illustrates a classification of sites identified in the Whangarei District according to the type of archaeological features they contain. Cultural association has not been specifically factored into this classification, and sites are classified simply as having built components (above ground usually), earthworks (both major and minor), a deposit of material (artefacts or rubbish), or being in or near the sea (maritime).

In general, the matrix shows what sorts of hazards are most likely to impact on different sites based on the type of features they contain and the topography of the area in which they are located. However, it simplifies the process and ideally requires further refinement. In many cases, archaeological sites contain a combination of feature types: for example, a pā site may include both minor and major earthwork components, as well as deposits such as middens and artefacts. Flooding may be a relatively minor hazard to these sites (usually they are located on high ground and so are unlikely to be affected), but a landslip can destroy a pā very quickly.

In summary, much greater precision could be achieved by using detailed site location and condition information based on recent field survey, and more detailed contour and topographic information.

Table 5. Risk by hazard to archaeological sites.

HAZARD	PARAMETERS	RISK
Coastal erosion	In or within 10 m of coastal erosion hazard zone	Extreme
	Within 10–25 m of coastal erosion hazard zone	Moderate
Flooding	Inside flood hazard zone	High
	Within 10 m of flood hazard zone	Moderate
Land instability	Inside land instability hazard zone	Moderate
Distance from coast	Within 15 m of coast	Extreme
	Within 30 m of coast	High
	Within 45 m of coast	Moderate
	Within 300 m of coast	Possible

Table 6. A. Matrix of threats to archaeological sites by location and feature category; and B. definitions of feature categories. E = erosion (coastal hazard), F = flood, L = land instability, S = secondary effects, T = temperature change.

A

FEATURE CATEGORY	COASTAL RIDGES	COASTAL HILLS	INTERIOR AREAS	LOW-LYING	NEAR WATERWAYS
Building/structural	E/S/T	S/T	S/T	F/S/T	F/S/T
Burial/sacred	E/F	E/L	E/L	F/E	F/E
Deposit	E	E/L	E	E/F	E/F
Maritime	S	-	-	-	S
Earthworks—Major	E/L	E/	E/L	E/L	E/L
Earthworks—Minor	E/L	E/L	E/L	E/F/L	E/F/L

B

SITE TYPE	FEATURE CATEGORY	SITE TYPE	FEATURE CATEGORY
Artefact	Deposit	Miscellaneous	Deposit
Botanical	Botanical	Pā	Earthworks—Major
Building	Building/structural	Pit	Earthworks—Minor
Cemetery	Burial/sacred	Platform	Earthworks—Minor
Church	Building/structural	Rua	Earthworks—Minor
Dendroglyph	Deposit	Shipyard	Maritime
Ditch	Earthworks—Minor	Shipwreck	Maritime
Farming	Earthworks—Minor	Stone feature	Building/Structural
Garden boundary	Earthworks—Minor	Stone wall	Deposit
Hāngī	Deposit	Stone working floor	Deposit
House floor	Earthworks—Minor	Terrace	Earthworks—Minor
Industrial	Building/structural	Timber	Earthworks—Minor
Maritime	Maritime	Urupā	Burial/sacred
Midden	Deposit	Weir	Maritime
Mining	Building/structural	Wharf/jetty/landing	Maritime

5.5 Prioritisation based on archaeological significance

Although the risk assessment process can be carried out irrespective of any measure of site significance, any response to the risks identified must realistically be based on a system of prioritisation that relates to the significance of the sites that are under threat.

Significance assessments have had a relatively controversial history in New Zealand archaeological research from the 1960s onwards (e.g. Green 1963) and the arguments will not be reiterated here. We do, however, consider that significance assessments, as advocated by Walton (1999), Walton & O'Keeffe (2004) and others, are an important part of resource management. As Prickett (2005: 59) argued:

> *The other side of a successful archaeological conservation programme is making hard choices regarding significant sites. I believe that in many parts of the country … unless there are arrangements for the on-going protection of particular significant sites, we will lose them along with the rest. If archaeologists will not take a lead in the selection of significant sites then there are two alternatives: someone else will do it for us, or, much worse, it will not be done at all.*

Although the problems associated with evaluating the significance of archaeological sites prior to subsurface investigation are recognised, significance assessment is a crucial component in prioritising limited resources for an increasing problem—the ongoing and accelerating destruction of archaeological sites. It is essential that available resources are directed towards the investigation of threatened sites that have the most archaeological value in terms of the information they can provide. For example, midden sites could be prioritised by age, their potential for associated structural remains and size (see Campbell & McGovern-Wilson 2009: 167 for further discussion on midden sampling). It is also important that a representative sample of sites both by type and region is given high priority for investigation.

Discussion of the basis and detailed criteria for archaeological significance assessment is beyond the scope of the current study, but we note that various territorial authorities have started to use such evaluations to prioritise the protection of archaeological sites in district plans. One example is the former Auckland City Council's Hauraki Gulf Islands and Isthmus District Plan initiative (Bickler et al. 2009a).

5.6 Responses to climate change threats

Effective responses to the problem of the long-term effects of climate change on archaeological sites in New Zealand, or to the ongoing destruction caused by current processes, have not yet been developed. This is due to a limited understanding of the scale of the problem, a lack of resourcing at national and regional levels, the current statutory framework for archaeological site protection, and the fact that most archaeological investigation in New Zealand is driven by development needs rather than research requirements. The following factors (adapted from Cassar 2005: 31–32) inhibit an effective response:

- A lack of understanding of the long-term changes, which means that existing resources for management are expected to go further.
- Most proactive conservation measures are more easily directed towards areas that are under least threat. For example, there is a tendency to engage in conservation schemes on dry-land earthwork sites rather than the management of possibly more valuable, buried, wet (or semi-wet) sites, which may also be under much greater threat.
- Insufficient incentives for landowners to manage the historic environment.
- Specific development proposals attract disproportionate resources for field survey and mitigation investigations to some archaeological sites, even when the quality of the site is not high.
- Coastal sites are under the very highest level of threat, but it is unrealistic to expect that development funding will be available for investigation and recording of the sites most under threat. Developers usually cannot, nor are they particularly willing to, purchase or develop land that is about to be eroded away by the sea.
- If landowners are not actively seeking to develop their land through the current processes (i.e. the Resource Management Act (RMA) 1991), and therefore willing to take responsibility for the demise of an archaeological site, there is no one else to call upon presently to fund recording prior to destruction, and there is generally no incentive to engage in any mitigation strategy for the loss of archaeological sites on their property.

Sites on the coast best reflect the early history of tangata whenua as well as of the first European settlers in New Zealand. While the protection of individual coastal sites from climate change effects may be feasible in some circumstances (attempts to protect the Sunde site on Motutapu Island have already been referred to), in most cases, nature will take its course and sites will be destroyed at an increasing rate. If they are not investigated, sites will be lost forever both physically and in terms of the information they contain.

An effective response to this problem, however, will require a significant shift in current policy and approaches towards archaeological site management in coastal areas by the various heritage protection agencies.

5.6.1 Current situation

Territorial authorities operating under the RMA are required to recognise and provide for 'the protection of historic heritage from inappropriate subdivision, use and development' (s.6f) as a matter of national importance. The RMA promotes a sustainable management approach to natural and physical resources, and requires territorial authorities to avoid, remedy or mitigate any adverse effects on the environment. However, effects on archaeological sites cannot be 'remedied', and the extent to which archaeological investigation is recognised under RMA processes as mitigation for the loss of sites is unclear. Avoidance is the primary aim, but this is a passive measure—while steps can be taken to ensure that a site is not directly impacted on by development, there is no requirement to manage it subsequently, and the site does not gain any additional protection from natural processes. Ultimately, a general policy of avoidance will lead to the loss of archaeological information, as 'avoided' sites gradually succumb to these processes. This is particularly the case for sites immediately adjacent to the coast, as it is usually possible to exclude sites in esplanade reserves from development.

The benefits of archaeological investigation if sites are to be damaged or destroyed are recognised and provided for under the archaeological provisions of the Historic Places Act (HPA) 1993. The New Zealand Historic Places Trust (NZHPT) will generally impose conditions requiring recording and/or investigation, and much valuable information has been retrieved from mitigation investigations. However, most investigations are undertaken in response to development, as noted above, and so the focus is not on the sites most at risk from climate change effects. The NZHPT currently has no active programme to provide physical protection to sites (with the exception of built heritage), and until now has not been resourced to take the lead in promoting or implementing an archaeological research programme focused on coastal sites under threat. However, the development of strategies and responses to the effects on archaeological sites from climate change, economic and coastal development has now been identified as a 'Key Initiative' in the NZHPT *Statement of Intent 2009–2012* (NZHPT 2009).

DOC manages most of the publicly-owned coastal land and offshore islands in New Zealand, and hence a significant proportion of the sites under threat. Under the Conservation Act 1987, DOC is charged with managing this land and the natural and historic resources it contains for conservation purposes. In some areas, DOC has undertaken a significant amount of inventory of archaeological sites, as well as some ongoing condition monitoring. Key historic sites, including archaeological sites, have been selected by DOC for more active management, but these are generally larger and more visible sites that have the greatest potential for educational and visitor experiences. Few of the most threatened coastal sites would fall into this category, and there has been little attempt to preserve the information that is progressively being lost from these sites. A notable exception has been a project undertaken by Southland Conservancy and the University of Otago in collaboration with Southland District Council, Environment Southland, NZHPT and tangata whenua to identify coastal sites, assess their condition and deterioration rate, and identify management requirements; in 19 cases, salvage investigation was recommended (Jacomb & Walter 2005; Brooks et al. 2008). A programme of site investigation is currently under way to record the sites before they are destroyed by natural processes (Rachael Egerton, Southland Conservancy, DOC, pers. comm., 2009). This project provides a model that could, and should, be adopted elsewhere.

Land managed by territorial local and regional authorities (parks, esplanades and other reserves) also contains sites under threat, and it could be argued that the RMA imposes obligations to protect them. However, a similar situation applies: management of coastal archaeology has seldom involved more than inventory and the selection of some of the more significant (and less threatened) sites for scheduling. There are notable exceptions, such as the former Auckland Regional Council, which undertook regular condition monitoring of coastal sites (e.g. Mackintosh 2001), although the action taken to actively protect sites was not identified (and the future of this programme is unclear under the new Auckland Council).

Overall, there is no systematic or proactive response currently in place in New Zealand to prevent or mitigate damage to archaeological sites (and in particular those with no built component) as a result of natural processes, including those induced or exacerbated by global climate change.

5.6.2 The need for action

The MfE (2004: 11) report recommended that long-term monitoring of the effects of coastal hazards should be undertaken to improve our understanding of them, and to ensure that response options are effective and sustainable. Monitoring techniques need not be expensive (e.g. a regular photographic record), but in high-risk situations, robust monitoring programmes that will provide useful information for future assessments of coastal hazards and response options should be considered.

A number of tools are available to assist in improving monitoring, particularly in areas that are most vulnerable to rapid change—these include beaches, dunes and river courses, which are all major focus points for archaeological evidence. Differential GPS mapping of areas provides relatively inexpensive, high-quality data about changing landscapes, and a variety of remote sensing methods has already been applied throughout New Zealand to identify environmental hazards such as flooding and erosion (e.g. Joyce et al. 2009).

However, while we agree with the sentiment behind the monitoring approach, a more proactive response is required in the case of archaeological sites facing the threat of destruction from coastal hazards exacerbated by climate change. A photographic record of the destruction of New Zealand's heritage without gaining archaeological information would be a poor outcome for the country. Monitoring the condition of and threats to sites is important, but its purpose should be to identify when action to preserve or investigate sites is required, rather than to simply record the gradual disappearance of sites, and it should be followed up by action prioritised on the basis of risk level and site significance.

As a first step, a list of archaeological sites could be generated based on the broad level of risk they face, identified through GIS-based studies in other parts of New Zealand. Site-by-site assessment based on current condition and more detailed risk evaluation would then be required. The risk assessment framework outlined above combines:

- Evaluation of the likelihood of impacts on sites from identified hazards
- Evaluation of consequences (damage or destruction) to the archaeological record

These determine the level of risk to any particular site. On the basis of this information, combined with significance assessment, priorities can be set for protection, investigation or ongoing condition monitoring, as appropriate.

It is important that lists are generated and risk assessments and significance evaluations undertaken around the country using consistent criteria, which will require the development of national guidelines.

Ideally, a national register of archaeological sites at risk would be established and made available to heritage professionals, which would allow information relating to ongoing impacts on archaeological sites to be gathered, evaluated and used to prioritise the investigation of at-risk sites. The NZAA's new GIS-based national archaeological sites database (ArchSite) would seem to be the best vehicle for this, and site record forms already have provision for recording threats to sites. However, further refinement would be required to ensure consistency in risk evaluation.

It is also important that prompt action is taken now to investigate and record the information from priority sites under threat that have already been identified. Nationally, this is already happening in a limited way. For example, in Cooks Cove, north of Gisborne, a small village site that may date back to the 14th century has recently been investigated by the NZHPT and Otago University in response to threats from coastal erosion (Walter et al. 2010). Similarly, a number of coastal sites in Southland have been, or are scheduled to be, investigated in response to threats from natural processes identified through a coastal inventory and assessment programme (Brooks et al. 2008). However, so far, there has been no coordinated, prioritised, national approach to the problem, and these initiatives are the exception rather than the rule.

5.6.3 Key stakeholders

Effective action will require cooperation and coordinated effort by all heritage protection agencies and heritage stakeholders, particularly the following:

- The NZHPT has a key role in promoting research into the effects of climate change on archaeological sites, developing national guidelines, statutory advocacy under the RMA and facilitating archaeological investigation through the provisions of the HPA.
- DOC will mainly focus on the protection and investigation of at-risk archaeological sites on public conservation land. DOC also has an important statutory advocacy role in relation to archaeological sites elsewhere.
- Territorial authorities have a similar responsibility towards at-risk sites on council-administered land, an important role in protecting historic heritage (including archaeological sites) through district plans and RMA processes, and hold GIS data for planning, risk-assessment and heritage-protection purposes.
- Tangata whenua have both kaitiaki and statutory responsibilities in relation to archaeological sites with Māori cultural associations, and their involvement and support are essential to any programme of archaeological investigation in response to climate change.
- The NZAA manages the national archaeological database (ArchSite), which could be developed further to generate a national register of archaeological sites at risk from climate change (and other) effects.
- Universities have an important research role, which could be increasingly focused on investigation in response to climate change threats.
- Consultant archaeologists carrying out assessments in relation to land-use proposals also have a significant contribution to make, as they frequently have the opportunity to identify and assess at-risk sites on private (and other) land throughout the country.
- Museums are responsible for storing archival and artefactual material, including material retrieved from archaeological investigations, for current and future research purposes.
- Private landowners are often interested in protecting archaeological sites on their land, and their interest and cooperation are essential for the identification, assessment and any investigation of threatened archaeological sites.

5.6.4 Issues to be addressed

This study has identified the broad scale of the problem facing our archaeological heritage in one area of New Zealand, and the need for a proactive and coordinated response at national and regional levels. However, it is recognised that there are a number of constraints on achieving this that need to be addressed.

The first is a general failure by key stakeholders to recognise the scale of the problem facing coastal sites both currently and in the future as a result of climate change. Achieving this recognition will require public awareness programmes undertaken by the key heritage protection agencies as well as extensive consultation.

Another obvious constraint is a lack of resources to respond to threats to the archaeological resource. It is hoped that this study, by identifying and attempting to quantify the problem in the Whangarei District, will assist in gaining additional funding from government agencies for action in response to climate change. In addition, there is potential for a national coastal archaeological research programme, involving the Universities of Auckland and Otago, to attract major research funding. Developer funding will continue to make a contribution, but could perhaps be better directed towards the investigation of sites at greater risk and of higher archaeological significance than has often been the case in the past.

The current statutory framework for archaeological site protection and investigation under the RMA and HPA also imposes constraints. It is important that in resource consent situations under the RMA, there is recognition by territorial authorities that 'avoidance' of sites may not be the best outcome where this will result in the loss of archaeological sites through natural processes exacerbated by climate change. This recognition could lead to an increase in the number of high-priority sites threatened by climate change effects that are investigated as part of 'mitigation' for land development proposals.

Some streamlining of the statutory process under the HPA for the investigation of sites at immediate risk would also be of benefit. In some cases, limited investigation by archaeologists undertaking land-use assessments may be the only opportunity to record information from a site before it disappears. Unfortunately, the sometimes cumbersome authority process involved and the issue of costs means that such opportunities are generally not taken. While landowners cannot be expected to fund investigations unless they intend to damage or destroy the site for land-use purposes, the cleaning down and recording of profiles would be practical as part of an assessment, and midden samples could be collected and stored for future analysis by the NZHPT or designated agency, or studied immediately if funds were available.

The storage of archaeological material from excavations for future research purposes is also an issue. Traditionally, museums have been expected to act as a repository for all archaeological excavation materials and records, but there has been a significant increase in the number of investigations carried out over the last decade—most of them for land-use mitigation rather than research purposes, and many involving sites of limited significance. As a result, museum collection policies have become more restrictive, and museums have become more selective in the material they will accept. This will become more of a problem if, as envisaged, recognition of climate change effects leads to a targeted programme of investigation of coastal sites under threat.

6. Conclusions

The notion that we can save everything for all time is, I think, one that we have to seriously think about because it's unrealistic—we cannot. (Cassar 2007, University College, London[2])

6.1 Summary

This study shows that a significant proportion of archaeological sites in the Whangarei District are already under threat from a variety of pressures, both natural and human-induced. These pressures will be exacerbated as a result of projected climate changes in the future. At particular risk are sites that are near the coast or on relatively unstable land around Whangarei Harbour.

The study has clear implications for archaeological sites outside the Whangarei area. New Zealand is an island nation that has had a strong coastal focus throughout its history. As a result, the surviving evidence of this history is particularly vulnerable to the effects of future changes in climate. These sites not only contain a record of this history, but we are becoming increasingly aware of how the data about the past can be used to develop models about the future relating to changes in local ecosystems over time, how humans interact with the environment and how to respond to climate change (see e.g. preliminary work by Smith & James-Lee 2010).

This study is one of the first steps in the process of identifying the potential impacts of climate change on our archaeological heritage, and in promoting further research and action to address the problem.

6.2 Implications for DOC managers

The results of the GIS study presented here provide clear evidence of the urgent need to prioritise action on land administered by DOC. DOC administers over 200 reserves in the Whangarei District and approximately 470 archaeological sites have been recorded on these reserves, which represents almost 20% of the sites recorded in the Whangarei District. The density of archaeological sites is highest in those reserves that are near the coast and that are most vulnerable to erosion (Fig. 26). Table 7 lists the top ten reserves with the highest numbers of archaeological sites and provides an initial target for management action. However, all reserves near the coast should be included in this action.

Table 7. Top ten DOC reserves containing archaeological sites.

DOC RESERVE	NUMBER OF SITES
Hen & Chicken Islands Nature Reserve	117
Mimiwhangata Scenic Reserve	88
Poor Knights Islands Nature Reserve	79
Whangaruru North Head Scenic Reserve	41
Bream Head Scenic Reserve	38
Ocean Beach Recreation Reserve	15
Ruakaka-Bream Bay Scenic Reserve	12
Otaika Valley Scenic Reserve	12
Manaia Ridge Scenic Reserve	8
Mata Farm Settlement Scenic Reserve	7

DOC is in a strong position to carry out this work as a land manager with the responsibility for a significant proportion of recorded archaeological sites in the region, and as a heritage organisation whose focus is on conservation. DOC also has a statutory role as an advocate for heritage, and has strong relationships with other key stakeholders, including tangata whenua and the archaeological community in New Zealand.

[2] www.cbsnews.com/stories/2007/06/19/eveningnews/main2952286.shtml (viewed 22 March 2010).

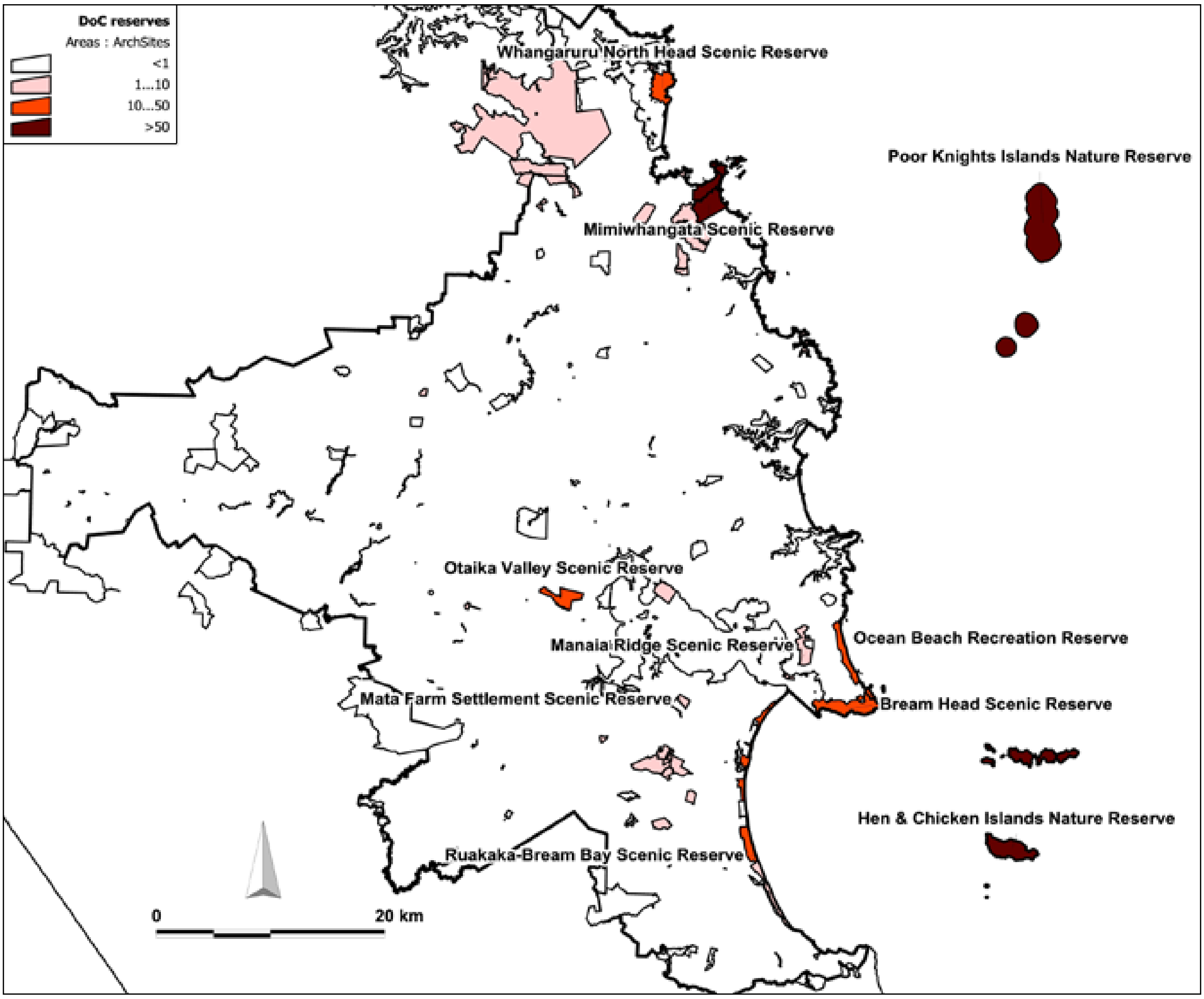


Figure 26. Number of archaeological sites within DOC reserves in the Whangarei District.

The following actions are recommended to DOC managers in the Whangarei District and around the country:

- Urgent identification of sites most at risk. This will require site visits and baseline condition inspection (if not already carried out), and prioritisation based on an assessment of risk, the potential significance of the sites and the need to protect information from a representative sample of sites.
- Consultation with tangata whenua, NZHPT and other key stakeholders to identify the risk to sites and seek support for the retrieval of valuable information that may otherwise be lost without record.
- Development of a programme of recording, sampling and investigation (as appropriate) of priority sites in association with tangata whenua, NZHPT and other key stakeholders. The involvement of university archaeologists and museum staff would be of particular benefit.
- Implementation of the programme, following the requirements of the HPA (1993) and good archaeological practice. If adequate resources are not initially available to process archaeological samples recovered from sites at risk, samples could be stored in a regional museum for future analysis and research.
- Provision of information about the programme and its results to stakeholders and the general public, to promote awareness of climate change issues and the need for proactive management of the archaeological resource.

6.3 Conclusions

It is clear that responses to the effects of climate change on archaeological sites must involve a shift from a passive monitoring process to a proactive effort to obtain as much information from this disappearing resource as possible. Although some sites may be able to be conserved *in situ*, this is unlikely to be feasible for the majority of threatened coastal sites. More detailed site-by-site risk assessment and evaluation are required so that action can be prioritised on the basis of threat level and site significance. A national register of archaeological sites at risk, generated from the NZAA database (ArchSite), would be of considerable assistance for ongoing research into the impacts of natural hazards on archaeological sites throughout New Zealand. This information would be a major resource for DOC and other heritage managers.

Achieving an effective response to the impacts of climate change will require wider recognition of the scale of the problem, supported by much more detailed analysis and risk assessment than has been possible in this broad, GIS-based study. It will require planning and coordination between all statutory heritage protection authorities and other heritage stakeholders (notably tangata whenua, universities, museums and professional archaeologists); it will require broad agreement from all stakeholders that action has to be taken, either to protect coastal heritage under threat or (which is likely to be the only feasible option in most cases) to investigate and record a large representative sample of sites under threat; it will require the development of detailed research strategies and programmes, and the identification of priority sites for investigation; and it will, of course, require adequate funding, which could potentially be drawn from various sources, including national and regional heritage protection agencies, research grants, and developers.

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