Vulnerability and adaptation to sea-level rise in Auckland, New Zealand

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List of acronyms

ACC	Auckland City Council
AEP	Annual exceedance probability
ARC	Auckland Regional Council
ARI	Average return interval
CMA	Coastal management area
EQS	Engineering quality standards
GCM	Global climate models
GIS	Geographic information system
GNS	Geological and Nuclear Sciences
ICZM	Integrated coastal zone management
IPCC	Intergovernmental Panel on Climate Change
MCC	Manukau City Council
MfE	Ministry for the Environment
NES	National environmental standard
NIWA	National Institute of Water and Atmospheric Research
NPS	National policy statement
NZCPS	New Zealand Coastal Policy Statement
RMA	Resource Management Act 1991
RPS	Regional policy statement

Executive summary

Research purpose

This report sets out the findings of an Auckland-based case study investigating vulnerability and adaptation to sea-level rise at existing residential settlements. This case study focused on two coastal settlements, Mission Bay / Kohimarama, and Kawakawa Bay, both part of New Zealand's largest city—Auckland. A case study methodology was applied to conduct an in-depth investigation of the issues related to planning for long-term sea-level rise and coastal-hazards management at the study sites, and more generally for *existing development* in the Auckland region.

The study aimed to investigate:

- how Auckland may be affected by changing coastal conditions as sea level rises
- adaptation options for responding to sea-level rise and barriers to their implementation
- the potential that different management options have for reducing vulnerability and increasing resilience of existing coastal settlements.

Research questions

The study was structured around answering the following four research questions:

1. What effect will sea-level rise have on extreme sea levels at the study sites, and how will the impacts related to a 1 percent annual exceedence probability (AEP)[1] event vary for a range of sea-level rise scenarios change (in the absence of adaptation)?
2. How are coastal hazards and projected sea-level rise managed in Auckland and at the study sites?
3. What adaptation opportunities and barriers exist at the two study sites?
4. Could managed retreat be implemented at either of the study sites? What are the particular issues for, and barriers to, implementing managed retreat?

Research findings

Participating councils are in the early stages of planning for future sea level rise

This study found that current coastal management at the participating councils was in the early stages of considering sea-level rise effects, and that in most instances the use of adjusted flood-mitigation measures (e.g. minimum site levels) was considered adequate for protecting private property against hazard risk. However, guidance information generated by participating councils has not taken into account the potential for high rates of sea-level rise by 2100. Recent internationally published projections (e.g. Pfeffer, et al., 2008; Rahmstorf, 2007) indicate that the *rate* of sea-level rise could increase dramatically in the second half of the twenty-first century. This means that if

[1] AEP is the probability that a given water level will be exceeded within a 1-year time period, and is usually expressed as either a fraction or a percentage. An alternative way of describing flood risk is in terms of average return intervals (ARI).

proactive responses are delayed, responses could be required much more rapidly in the future, which could have significant structural and economic implications for future generations.

Coastal-hazards risk will increase at Mission Bay / Kohimarama and Kawakawa Bay and adaptation will be required

Mission Bay / Kohimarama and Kawakawa Bay, Auckland will experience increasing coastal-hazard risk as the numbers of people and property potentially affected by storm events increases as sea level rises. Findings from the present study suggest that existing settlements in the Auckland region may already be 'locked in' to a coastal adaptation approach focused on maintaining the current coastline through coastal stabilisation. This approach will decrease community resilience and increase vulnerability in the long term, even if it is found to be a successful short-term response. Retreat offers an alternative approach that is strongly aligned with reducing community vulnerability and increasing resilience. However, strong opposition from communities to any retreat approach is expected. Developing trusted climate science information, education around coastal hazard risk, and participatory community-led decision making were identified as central enablers for a retreat approach to be included as a viable coastal-adaptation option for communities in the Auckland region.

1 Introduction

1.1 Research purpose

This report sets out the findings of an Auckland-based case study investigating vulnerability and adaptation to sea-level rise at existing residential settlements. This project has been conducted simultaneously as master's thesis research and as one of three case studies that form Objective 2 of the collaborative, interdisciplinary research project on Community Vulnerability, Resilience and Adaptation to the impacts of climate change. The project is led by Victoria University and funded by the Foundation for Research, Science and Technology (FRST)[2]. The aim of the project was to develop a *'New Zealand specific framework for the comprehensive identification of community vulnerability, and options for increasing resilience'* (CCRI, 2008, p. 3).

This case study focused on two coastal settlements, Mission Bay / Kohimarama, and Kawakawa Bay, both part of New Zealand's largest city—Auckland. A case study methodology was applied to conduct an in-depth investigation of the issues related to planning for long-term sea-level rise and coastal-hazards management at the study sites, and more generally for *existing development* in the Auckland region.

The study aimed to investigate:

- how Auckland may be affected by changing coastal conditions as sea level rises
- adaptation options for responding to sea-level rise and barriers to their implementation
- the potential that different management options have for reducing vulnerability and increasing resilience of existing coastal settlements.

1.2 Research questions

The study was structured around answering the following four research questions:

1. What effect will sea-level rise have on extreme sea levels at the study sites, and how will the impacts related to a 1 percent annual exceedence probability (AEP) event vary for a range of sea-level rise scenarios change (in the absence of adaptation)?
2. How are coastal hazards and projected sea-level rise managed in Auckland and at the study sites?
3. What adaptation opportunities and barriers exist at the two study sites?
4. Could managed retreat be implemented at either of the study sites? What are the particular issues for, and barriers to, implementing managed retreat?

1.3 Research methodology

To address the research questions, potential inundation during a 1 percent AEP event was mapped at the study sites and potential socio-economic impacts were assessed using geographic information system (GIS) analysis. A series of in-depth interviews were conducted using this information about changing risk. Impacts and adaptation response information were used in the interviews to discuss

[2] FRST was merged in February 2011 with the Ministry of Research, Science and Technology (MoRST) to form the Ministry of Science and Innovation (MSI), which is responsible for the policy and investment functions of both those agencies.

experiences of sea-level rise response to date and views regarding options for the future. Qualitative thematic analysis of the interview transcripts was undertaken to describe the current approach, issues, and barriers to coastal-hazards management and sea-level rise response; and the views of interview participants to various sea-level rise response options at the two study sites.

1.4 Research framework

1.4.1 Vulnerability

In this study, vulnerability is understood as a function of exposure, sensitivity, and adaptive capacity—a framework that reflects the vulnerability-assessment literature (Cutter, 1996; Metzger, Leemans, & Schröter, 2005; Metzger & Schröter, 2006; Preston, et al., 2008; Preston & Stafford-Smith, 2009; Schröter & ATEAM consortium, 2004; Smit & Wandel, 2006; Turner II, et al., 2003) and as used in the IPCC Fourth Assessment Report 2007, which defines vulnerability as 'the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change' (Intergovernmental Panel on Climate Change, 2007, p. 883). Vulnerability and its components are shown in Figure 1.

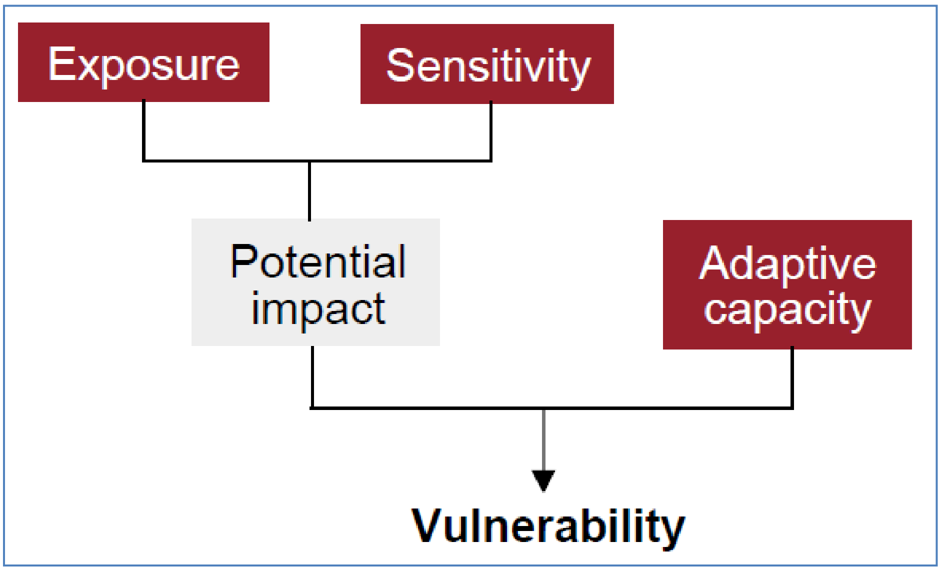

Figure 1. Vulnerability and its components (Allen Consulting, 2005)

1.4.2 Exposure

Exposure generally refers to the state and change in external stresses that a system is exposed to. In the context of climate change, these are normally specific climate and other biophysical variables (including their variability and frequency of extremes). The location of people and assets can also be regarded as exposure (Intergovernmental Panel on Climate Change, 2007; Preston & Stafford-Smith, 2009).

1.4.3 Sensitivity

Sensitivity is the degree to which a system is affected, adversely or beneficially, by a given exposure (Intergovernmental Panel on Climate Change, 2007). A system can be sensitive to direct (physical) impacts (e.g. a given change in rainfall affects the water supply of a city) as well as indirect (socio-economic) impacts (e.g. age structure of a population influences the degree to which mortality increases during a heatwave).

1.4.4 Adaptation

Adaptation is *change* made by a given system in response to expected and / or experienced exposure and sensitivity to climatic stimuli, and is defined as the '*adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*' (IPCC, 2007a, p. 27). Adaptation can be autonomous or planned. It can be implemented in anticipation of future events, concurrently as events occur, or reactively after events have occurred. Table 1 provides a typology of adaptation responses, including adaptation at different scales, in different forms, and the degree of change. Given an expected degree of exposure and sensitivity to an external climatic stressor or stimulus, the adaptation that actually occurs in anticipation or response to stimuli is then essentially influenced by a system's adaptive capacity.

Table 1. Typology of adaptation actions, modified from Smit & Wandel (2006)

Intent	Timing	Spatial scale	Form	Degree of change
Planned	Anticipatory	Local	Behavioural	Incremental
Autonomous	Concurrent	Regional	Financial	Transformational
	Reactive	National	Technological	
			Institutional	

1.4.5 Adaptive capacity

Adaptive capacity describes the ability of a system to adapt to climate change—to moderate potential damages, take opportunities, or cope with adverse impacts (Intergovernmental Panel on Climate Change, 2007; Smit & Pilifosova, 2003).

Adaptive capacity includes:

- coping capacity (the ability to accept the impacts and recover back to the system state before the impact, but does not change the system's exposure or sensitivity to reduce future impacts)
- the ability to adapt (the change in a system's exposure or sensitivity to reduce future impacts).

Both coping capacity and ability to adapt can change over time for a number of reasons, for example socio-economic change in a given area (Adger, 2006; Yohe & Tol, 2002; Turner II, et al., 2003; Eriksen & Kelly, 2007).

The general framework described above represents a static snapshot of vulnerability in time. It does not show interactions between components, nor the steps that can increase or reduce vulnerability over time. Vulnerability is dynamic spatially and temporally, especially as risks and their consequences are unlikely to increase linearly with increasing frequency and intensity of extreme events. Further, adaptive capacity at the household, community, and regional scales are interlinked and influence each other. Dynamic interactions between the components of vulnerability through time and space mean that, further to the static framework given above, temporal and spatial components are also central to understanding and reducing vulnerability (Smit & Wandel, 2006; Smit & Pilifosova, 2003).

Adger (2003) demonstrates that adaptive capacity is place and culture-specific and can only be identified through place and culture specific research. Moser and Ekstrom (2010) highlight the interconnected structural elements that provide the wider context within which adaptation decision making takes place. The identification of these structural elements—the actors, the governance regime in which they operate, and the characteristics of the system exposed to climate change—can help to diagnose adaptation barriers.

An important insight from the resilience literature (Nelson, et al., 2007) is that adaptation can go beyond being related to specific (static) risks. Through a resilience lens, adaptation is seen as the ability to maintain a response capacity in the face of risks that keep changing and evolving. Human capital, governance structures, and institutional flexibility are salient characteristics of human-ecological systems that strongly influence successful adaptation to such changing risks. That is, adaptation in which responses exhibit opportunity taking, and through system feedbacks, adaptation of the system as a whole over time (Nelson, et al., 2007, p. 199).

1.4.6 Coastal vulnerability

A large body of work has developed specifically focused on vulnerability assessments of coastal regions (IPCC CZMS, 1992b; Vellinga & Leatherman, 1989; Klein & Nicholls, 1999; Klein & Nicholls, 1999; McFadden, et al., 2007). A number of approaches for conducting coastal vulnerability assessments have been developed, beginning with top-down approaches that focused on using a priori vulnerability indicators (IPCC, 1990; IPCC CZMS, 1990; Nicholls, 1994), to more recent top-down approaches that have built tools to quantitatively model vulnerability and build vulnerability indices (Hinkel & Klein, 2009).

The Common Methodology for Assessing the Vulnerability of Coastal Areas (IPCC CZMS, 1992a), an early coastal vulnerability assessment method, has seven analytical steps. The steps outline a process to identify areas, people, and natural resources that are at risk, and to identify and assess the costs and feasibility of responses in those instances of high risk, using seven indicators. The common methodology, and subsequent early studies, developed some useful indicators for assessing the exposure and sensitivity of coastal systems to sea-level rise and related impacts, some of which are used in this study.

However, early methodologies have been criticised for not taking into account local social and cultural contexts in relation to adaptation, among other things. More recently applied 'bottom-up' approaches have aimed to increase understanding of the local situational context (physical, social, institutional factors) to allow the practical application of adaptation activities at the local scale (Smit & Wandel, 2006). The Intergovernmental Panel on Climate Change (IPCC) (2007a) identified the importance of development pathways for a community's vulnerability to climate change, rather than solely the magnitude of biophysical changes. This approach is consistent with a system / resilience framework.

Within the context of coastal-hazards management, the legacy of past decisions (e.g. the location of existing settlements and protection measures) affects today's management choices, and decisions made today will in turn affect the pathways taken in the future. Studies using the common methodology have not typically considered local coastal interactions, nor local constraints and barriers to specific adaptation options. It is this sort of interaction, particularly, between local government and the communities in the Auckland region, and the local barriers that policies face, that this case study explores. For example, this study investigated the extent to which the system for governing coastal hazards is starting to move beyond the legacies of past rather static approaches to coastal-hazards management, to take a more dynamic view of risks over time and look to processes to increase community engagement as part of building resilience to changing risks.

2 Case study background

2.1 Sea-level rise and adaptation options

2.1.1 Projected sea-level rise

Global mean sea level has risen, and will continue to rise, due to anthropogenic climate change

Global mean sea level is rising as a result of anthropogenic climate change and will continue to rise for hundreds of years (IPCC, 2007b; The Royal Society of New Zealand, 2010). New Zealand's mean sea level rose at an average rate of 1.6mm per year throughout the twentieth century, corresponding approximately with observations of the global mean (Hannah, 2004). It is expected that New Zealand's mean sea level will continue to rise approximately in line with global mean levels over the coming century (MfE, 2008). An acceleration in the global mean rate of rise that has been observed in the second half of the twentieth century has not been observed in New Zealand's tidal record (Hannah, 2004; Bindoff, et al., 2007). However, New Zealand's mean sea level is estimated using just four tide gauge records (Auckland, Wellington, Christchurch and Dunedin), which must be corrected for land movement (Hannah, 2004), and satellite (altimetry) measurements introduced in 1993, which have recorded higher sea level values around New Zealand (AVISO, 2010), are not yet included in analysis of mean sea-level change for New Zealand (2004).

For timeframes beyond 2100, sea-level rise of 10cm per decade should be considered

The IPCC's most recent scientific assessment of climate change presented multiple model-based projections of sea-level rise that ranged from 18–59cm of sea-level rise to the 2090s, relative to 1990 levels (Meehl, et al., 2007). The range represents outputs from a range of global climate models (GCM) for six different future emissions scenarios. Observed sea-level rise from 1990 has been tracking at the upper end of IPCC projections (Bindoff, et al., 2007). To achieve sea-level rise around the lower end of the projected range, global greenhouse gas emissions would have to be stabilised in the very near term (Ministry for the Environment, 2008).

Because GCM assumptions include static ice-sheet melt at 1990 rates, the IPCC cautioned that an additional 10–20cm of sea-level rise could be expected—if the rate of ice-sheet melt increased linearly with global temperature (Meehl, et al., 2007). Dynamic ice-sheet processes are not currently included in global climate models. For this reason, the IPCC 2007 report emphasised that the model-based projections given did not represent an *upper limit* for sea-level rise over the twenty-first century, nor could a *best estimate* for sea-level rise by 2100 be given.

New Zealand's current guidance on incorporating sea-level rise into long-term council planning and coastal-hazards management (Ministry for the Environment, 2008) is based on the 2007 IPCC projections. MfE recommends that for the timeframe to 2100 a base value sea-level rise of 0.5m relative to 1990 be assessed, as well as:

> *'assessment of the potential consequences from a range of possible higher sea-level rises of at least 0.8m (relative to 1990)'* (Ministry for the Environment, 2008, p. 20).

The 0.8m value takes into account a linear increase in the rate of ice-sheet melt with global temperature. The MfE guidance also emphasises that sea level will continue rising beyond 2100, even if greenhouse gas emissions are stabilised in the near term. Thus, it is recommended that for timeframes beyond 2100, sea-level rise of 10cm per decade should be considered.

It is the rate of rise, rather than the total amount, that correlates with global mean temperatures

In the four years since the 2007 IPCC report, projections of sea-level rise have changed dramatically (The Royal Society of New Zealand, 2010). Significant advances have been made in understanding the processes contributing to sea-level rise, showing that *all* sea-level rise observed since 1950 could be explained by climate change (where previously it could not) (Domingues, et al., 2008); that the contribution to observed sea-level rise of glacier and ice-sheet melt is much higher than was previously thought (Velicogna, 2009; Domingues, et al., 2008); and that, in the past, sea level may have risen more than 2m per century (Rohling, et al., 2008). Recent projections of sea-level rise to 2100 include higher levels of rise than have previously been published, based on semi-empirical methods used to extrapolate from past temperature and sea-level records (Rahmstorf, 2007; Horton, et al., 2008). The increase in recent projections of sea-level rise to 2100 is due to the inclusion of much higher contributions of ice-sheet melt in projections. The IPCC (2007) projections assumed glacier and ice-sheet melt contributed just 25 percent to sea-level rise to 2100. However, Domingues et al. (2008) showed that the contribution of glacier and ice-sheet melt to sea-level rise is now around 60 percent, indicating that the contribution of these factors will continue to increase over the twenty-first century. Support for the semi-empirical method for projecting sea-level rise developed by Rahmstorf and others has been supported by recent work (Kemp, et al., 2011) that has found that it is the *rate* of sea level rise rather than the total amount of rise that correlates with global mean temperature over the last 2000 years.

Change will occur much more rapidly in the second half of the twenty-first century

Table 2 shows recent scientific projections of sea-level rise by 2100. Dynamic ice-sheet melt could result in sea-level rise considerably larger than IPCC model-based projections (2007), with some studies finding that increases of 1.6 to 2.0m by 2100 cannot be ruled out (Rahmstorf, 2007; Horton, et al., 2008; Pfeffer, et al., 2008). The serious risks associated with these higher estimates of sea-level rise by 2100 affirm the need for the full range of plausible sea-level rise projections to be carefully considered when making decisions in the areas of long-lasting infrastructure and settlement development (Nicholls, et al., in press). Recent studies have also found that the rate of sea-level rise is likely to be much higher in the second half of the century than in the first, indicating that change will occur much more rapidly in the second half of the twenty-first century. This may result in the need for rapid response measures (with significant economic and structural implications), especially if inertia in governance structures constrains early proactive adaptation.

Table 2. Recent scientific projections of sea-level rise by 2100, adapted from The Royal Society (2010)

Source	Projected sea-level rise by 2100 (m)
Pfeffer (2008)	0.8–2.0
Rahmstorf (2007)	0.5–1.4
Horton (2008)	0.5–1.0
Grinstead (2009)	0.3–2.2
Vermeer (2009)	0.75–1.9
Jevrejeva (2010)	0.6–1.6

2.1.2 Adaptation options

Increasing development and rising property values along the coast, coupled with rising sea levels and other climate-related impacts are expected to significantly increase coastal-hazard risk over the twenty-first century. Uncertainty around the future rate of sea-level rise, questions about the response of coastal processes to large amounts of sea-level rise, and institutional and social barriers make responding to and coping with future sea-level rise and its impacts a major challenge for coastal management (Cutter, 2008; Ministry for the Environment, 2008; Blackett, et al., 2010; Cayan, et al., 2009; Titus, et al., 2009).

The IPCC (IPCC CZMS, 1990; IPCC, 2007a) outlines three broad strategic options for responding to sea-level rise:

1. **Protect** landward property using structural and non-structural coastal engineering structures.
2. **Accommodate** human settlements to the changing conditions through structural changes to buildings.
3. **Retreat** from coastal-hazard-prone areas of the coast.

Beneath these high-level response approaches sits a range of specific response options and mechanisms for their implementation.

Coastal protection attempts to 'manage' natural processes rather than managing people and land use to avoid coastal hazards

Coastal protection works include structural coastal engineering works such as sea walls, revetments, groynes, and breakwaters; and non-structural coastal engineering such as beach nourishment and dune creation and restoration (see Appendix 1 for a comprehensive list of sea-level rise response options). Coastal protection refers to 'hold-the-line' response strategies that attempt to 'manage' natural processes, as opposed to a focus on managing people and land use to avoid coastal hazards.

Accommodation measures adjust human structures and behaviour to minimise risk

Accommodation measures include emergency planning and individual flood-protection measures such as raising site levels, buildings, and infrastructure; and changing building codes. Accommodation measures by themselves do not attempt to control natural processes, but rather adjust human structures and behaviour to minimise risk. Accommodation measures may be an effective response to periodic inundation, but are unlikely to be an effective response to a trend rise in the scale or frequency of inundation and erosion.

The availability and affordability of insurance is likely to change

Insurance operates in New Zealand to underwrite risk, but recent disasters have highlighted that its availability and affordability is likely to change. Increasing limits to the commercial insurability of coastal property is going to have to be addressed by local government, through a careful long-term planning process to avoid and minimise risk in which managed retreat will play a part in some existing settlements.

Retreat adjusts human settlements and structures in response to coastal hazards

Retreat can be reactive (abandonment of property) or planned. Planned retreat refers to the landward relocation of buildings and infrastructure when they are threatened by coastal hazards, and can include policies and rules to limit new development and redevelopment in coastal hazard areas and eventually removing or relocating buildings and assets landward in identified areas. Retreat adjusts human settlements and structures in response to chronic coastal hazards. Planned retreat is not considered widely applicable for highly developed urban areas with high levels of sunk costs. Examples of planned retreat are predominantly cases where the land reclaimed by the sea has been rural farmland or a natural system (e.g. a wetland or estuary)(Rupp & Nicholls, 2002). Numerous methods and tools have been developed to assist in making decisions about the most appropriate type, scale, and timing of adaptation at various scales from the global to the local (Dickinson, 2008).

2.2 Legislative context

In New Zealand, responsibility for the (sustainable) management of natural and physical resources, including avoiding or mitigating the effects of coastal hazards, is devolved to local authorities. National instruments, technical support, and emergency funding come from central government. New Zealand has a two-tiered local authority structure of regional councils and territorial authorities (district and city councils) within regional boundaries. Local authorities derive their powers and responsibilities from a number of statutes that define, support, and guide the management of coastal hazards and sea-level rise in New Zealand.

The key statutory instruments setting out the roles and responsibilities for the management of coastal hazards and sea-level rise are the: Local Government Act 2002; Resource Management Act 1991 (RMA); New Zealand Coastal Policy Statement 1994 and 2010 (NZCPS); Building Act 2004; and the Civil Defence Emergency Management Act 2002. Since 2004, the RMA has empowered exercising functions under the Act to have particular regard to the effects of climate change and thus provides for anticipatory planning approaches for sea-level rise risk. The emergency management legislation addresses reduction, readiness, response, and recovery from hazards—in practice the emphasis is on the last three components. However, none of the key instruments mentioned here explicitly encourage communities to consider long-term dynamic adaptation to evolving coastal hazards, or mention concepts such as transformational change, which may be required as changing risks signal that 'coping' will not remain tenable in the future. Two exceptions are the 1994 NZCPS's recognition of the need to consider coastal-management options such as 'abandonment or relocation of existing structures'[3], and the 2010 NZCPS's mention of managed retreat in the context of climate change[4].

2.3 The study sites

Two study sites were selected to assess and compare adaptation response opportunities and barriers for existing development. Both areas have been identified as having existing settlements that may be affected by sea-level rise, primarily due to their low-lying elevation and proximity to the coast (Ramsay, at al., 2008a; Ramsay, et al., 2008b). The adjacent bays, Mission Bay and Kohimarama, are considered as one study site, and Kawakawa Bay another site, seen in Figure 2—a map of the Auckland region and the position of each of the study sites in relation to each other.

Mission Bay / Kohimarama is a centrally located settlement with high-density, high-value development, existing coastal-defence structures, and very low social deprivation scores (Crampton & Atkinson, 2007). In contrast, Kawakawa Bay is a small settlement on the fringes of the Auckland region, with low-levels of development, lower-value property, and mid-to-high-level social deprivation scores (Crampton & Atkinson, 2007). Until 1 November 2010 they were under the jurisdiction of different territorial authorities. Mission Bay / Kohimarama was within the Auckland City Council (ACC) boundary, and Kawakawa Bay was within the Manukau City Council (MCC) boundary. On 1 November 2010, all the Auckland authorities were amalgamated into one—the Auckland Council (a unitary authority with both regional and territorial responsibilities and powers), which is currently developing a spatial plan and a unitary plan for the region.

Auckland is New Zealand's largest city, home to one third of the country's population, and is growing quickly. Auckland's current population of 1.4 million (Statistics New Zealand, 2010), is projected to reach two million by 2035, in just 24 years (Auckland Regional Council, 2010). Auckland is a coastal region with significant areas of existing development at risk from coastal hazards, such as erosion and episodic inundation, which are expected to be exacerbated by projected sea-level rise (Auckland Regional Council, 2009).

[3] Policy 3.4.6 of the NZCPS 1994.

[4] Objective 5 and Policy 25 of the NZCPS 2010.

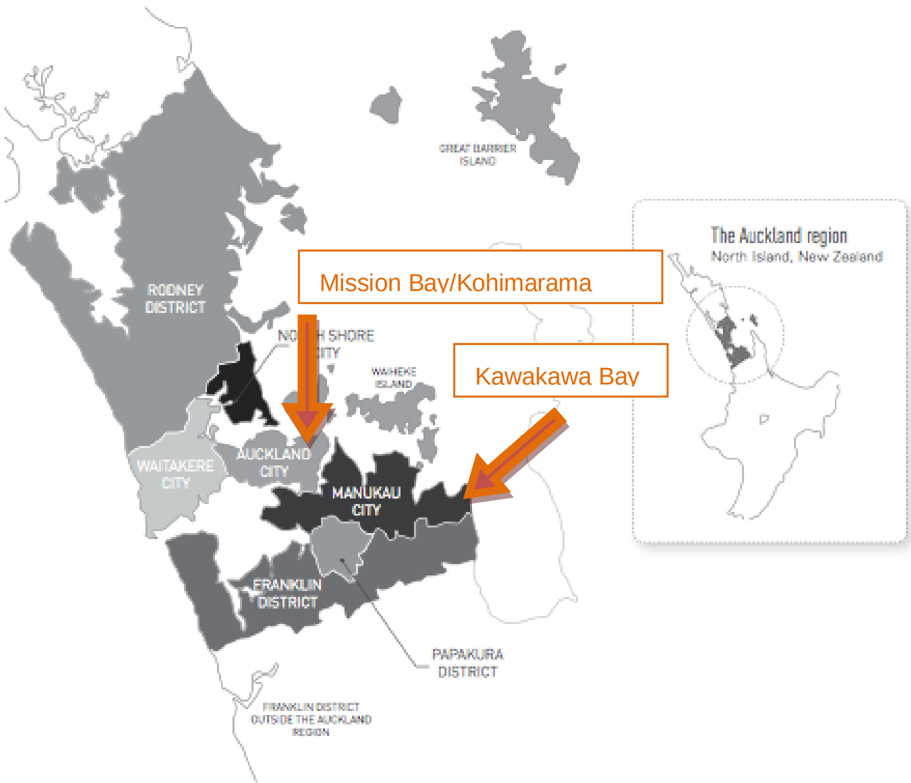

Figure 2. **Map showing the case study locations within the Auckland Region. The map also shows the former district and regional council boundaries. The inset map shows Auckland region within the North Island of New Zealand (© Auckland Council, reprinted with permission).**

2.3.1 Mission Bay / Kohimarama

Mission Bay and Kohimarama are situated approximately 7km east of central Auckland on the southern shore of Waitemata Harbour. The combined population of Mission Bay and Kohimarama is around 12,180. This area is affluent—it has one of the highest average income levels in New Zealand, some of New Zealand's most expensive properties, and low socio-economic deprivation scores (Statistics New Zealand, 2010; Crampton & Atkinson, 2007). Figure 2 shows the eastern bays area with Mission Bay / Kohimarama circled. Mission Bay is the bay to the left and Kohimarama to the right of the inside of the circle.

This area has a long history of Māori settlement. Ngāti Whātua (iwi of the Auckland isthmus region) regard the coastline and waters of this area as having high cultural significance for their tribe (B. Papa, December 08, 2010). European settlement began in the 1840s. Rapid development of the eastern bays suburbs began after the completion of Tamaki Drive in 1932 (Auckland City Council, 1999). Since then, land use in this area has been predominantly low-to-mid-intensity residential development, with limited multilevel development. A mix of other uses exists, including low-intensity commercial development in small pockets, and high levels of recreational use.

The area's views, beaches, coastal reserves, restaurants, and retail centres and the Tamaki Drive 'Scenic Way' make this stretch of coastline one of the most popular recreational areas in the region (Auckland City Council, 1999). The area is considered both a highly modified residential (and in some parts semi-urban) environment and a sensitive coastal system, with a coastal sensitivity rating of five (significant sensitivity), on a scale of seven—one being low sensitivity and seven being extreme sensitivity[5]. Significant natural character, amenity value, and indigenous flora are important issues highlighted by local authorities in the region (Auckland City Council, 1999).

Coastal environment and processes

The coastline in this area is a sheltered harbour environment with relatively low-energy wave action (Auckland City Council, 1999). Construction of Tamaki Drive involved considerable modification of the coastline including the construction of a sea wall that runs from Mechanics Bay to St. Heliers Bay (this includes the study area). The sea wall altered the natural shape of the coast and coastal processes. As well as this, the increase in impermeable surface area and development of the stormwater system draining into the small embayments has resulted in altered sediment and current patterns.

Coastal hazards and management decisions to date

Mission Bay / Kohimarama has experienced long-term coastal erosion following the construction of the Tamaki Drive sea wall (Abott.J.E., 1987, cited in Hamill, 1988). Historic long-term erosion led to the loss of the high tide beaches in both embayments, and the partial failure of the Tamaki Drive sea wall. Council response has been to publicly fund beach renourishment at Mission Bay in the mid-1990s, and at Kohimarama in the mid-2000s. It is unknown how long renourishment undertaken at the sites will last. Further coastal protection works are expected to be required in the future if protection of the sea wall, road, and adjacent coastal reserve is to continue (Beca Carter Hollings & Ferner Ltd, 2003).

Figure 3. Satellite image of the Eastern Bays area, Mission Bay (left) and Kohimarama (right) are circled (Source: Google Earth, 2010).

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[5] See Buckland Brown Ltd. (1994) for methodology and criteria of this rating.

A small number of houses are believed to be at risk of inundation today for a 1 percent AEP water-level event (Ramsay et al., 2008a). However, the main disruptions caused by large coastal storms today would be:

- over topping of sea walls and inundation of reserve land and Tamaki Drive
- traffic disruption due to the road being inundated
- potential damage to the Tamaki Drive sea wall and erosion of beach sediments.

Areas susceptible to current inundation risk up to the 1 percent AEP storm tidewater level are considered by council to be adequately accounted for by council maps of areas prone to flooding (Craig, 2010). New development in identified flood-risk areas is subject to minimum freeboard[6] standards under section 5D of the Auckland City Council District Plan Isthmus section (Auckland City Council, 1999). Because current flood risk is managed through minimum freeboard levels for buildings, no further action has been taken in response to new information showing changing risk of coastal inundation. Council officers have identified that the new Auckland Council will have to take considerable steps to plan for changing conditions due to projected sea-level rise (Craig, 2010).

Figure 4. Looking east along Kohimarama beach at mid-tide, 2010. (© 2010 Georgina Hart)

[6] Freeboard is a factor of safety usually expressed in feet above a flood level for purposes of floodplain management.

Figure 5. Looking east along Kohimarama Beach during the storm of January 23 2011 (© 2011 Benjamin Eitelberg. Reprinted with permission)

Figure 4 shows Kohimarama beach at mid-tide, looking east. Figure 5 shows Kohimarama beach at high tide during a large coastal storm event on the weekend of 22–23 January 2011, looking east. This storm resulted in coastal inundation, as well as stormwater flooding. Private properties were flooded as a result of this storm. However, this flooding was primarily caused by stormwater system overflow caused by rainfall. The Tamaki Drive sea wall (seen in Figures 4 and 5 above) is considered a significant regional asset with iconic heritage values. This heritage status, coupled with the large scale of sunk costs in the Tamaki Drive scenic way (road, cycle ways, coastal reserve, and sea wall protection), may represent existing 'lock in' to a particular pathway for response to sea-level rise—the continued armouring of the coast to protect these assets and values.

2.3.2 Kawakawa Bay

Kawakawa Bay is situated approximately 40km south-east of central Auckland on the southern shoreline of the Tamaki Straight, to the south east of Waitemata harbour. Just over 1000 people live at Kawakawa Bay. The population is a mix of retired and working people. Above the permanent resident population there is a non-resident population of absentee holiday home property owners. The Bay has low-to-mid-level socio-economic deprivation scores (Crampton & Atkinson, 2007).

The Bay is defined by Pawhetu Point to the west and Kawakawa Bay boat club to the east, and is about 4km long with a central headland, Te Iwirahirahi Point, seen in Figure 6 (below) dividing the embayment into two (Tonkin & Taylor Ltd, 2007). Kawakawa Bay's western embayment has a sandy shoreline, while the eastern embayment has a mix of sandy and cobble shoreline with several rock outcrops (Tonkin & Taylor Ltd, 2007). The Kawakawa Bay shoreline is designated a Regionally Significant Landscape (Rating 5), but has no coastal protection areas identified in statutory plans (Auckland Regional Council, 1999b). Kawakawa Bay is classed as an 'inshore wave environment', exposed to fetch and depth limited wind-generated waves from the north-west to north-east (Tonkin & Taylor Ltd, 2007; Auckland Regional Council, 2000).

Land use in Kawakawa Bay has been predominantly grazing for farming. Since approximately 1950, the coastal margin has been developed for residential dwellings, mostly for retirement and holiday homes. Dwellings at Kawakawa Bay have been unserviced and have relied on tank water for supply and septic-tank systems for wastewater disposal. Development has occurred primarily in two areas of low-lying land adjacent to the road and coastline, as can be seen in Figure 6, in areas zoned 'residential settlement unserviced'. Beyond this land is farmland zoned 'rural'. The Clevedon-Kawakawa Bay Road and Kawakawa Bay Coast Road run along the backshore of Kawakawa Bay, separated from the coastline by a narrow strip of grass (Manukau City Council, 2002).

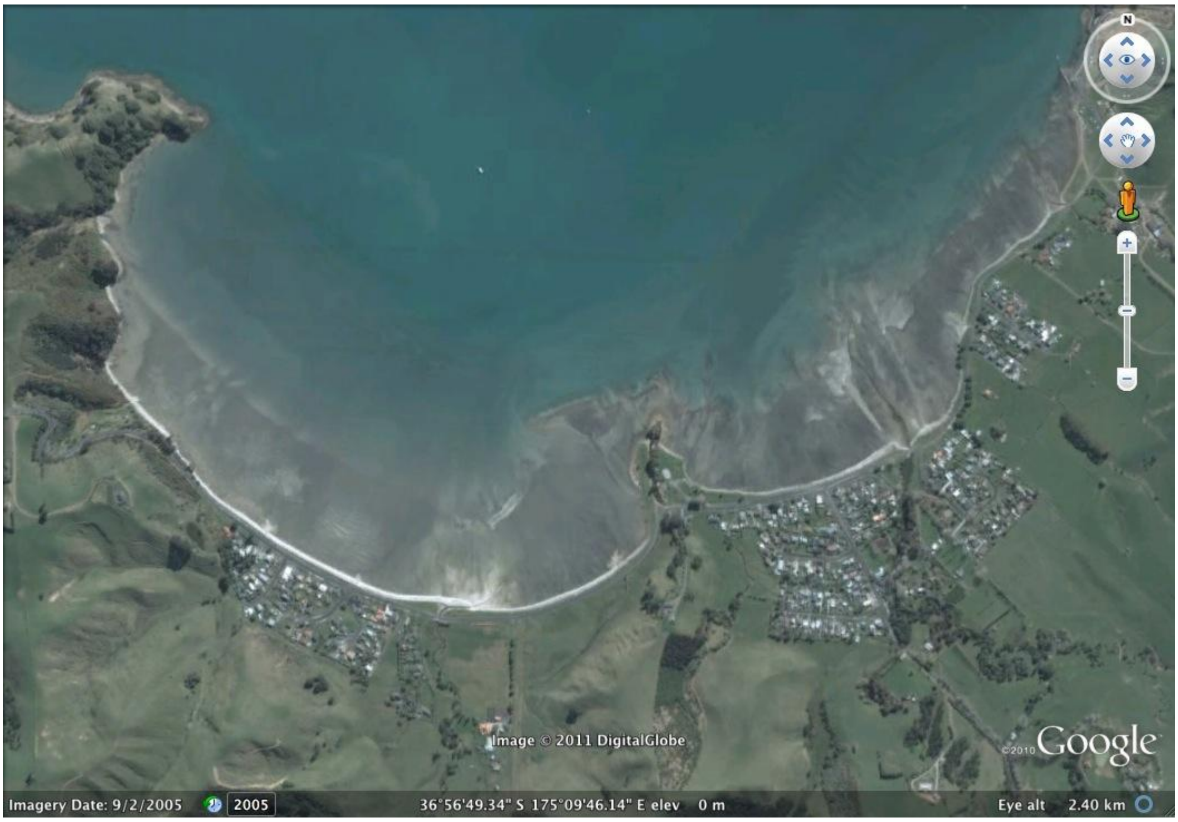

Figure 6. Satellite image of Kawakawa Bay (Source: Google Earth, 2010)

Coastal hazards and management decisions to date

Based on ARC indicative topographic, bathymetric, and water-level data contained in the ARC beach monitoring database, Tonkin & Taylor (2007; 2003) found that Kawakawa Bay is exposed to erosion and inundation risk. Much of the Kawakawa Bay coastline is stable, although erosion has been observed where the coastline has been modified or land has been reclaimed. These localised areas of erosion are at Te Iwirahirahi Point and Rautawa Stream (east and west). The erosion rate is considered low but, because of the proximity of infrastructure, the risk is considered significant (Tonkin & Taylor Ltd, 2007). Ad hoc consented and unconsented coastal protection structures have historically been built along the Kawakawa Bay shoreline. MCC commissioned a coastal engineering assessment for the area in 2003, and subsequently an upgrade of coastal protection measures in 2007. Tonkin & Taylor designed a coastal protection response plan to manage erosion at Kawakawa

Bay that involved a mix of structural and non-structural engineering measures, including renourishment of some areas and a stone revetment in one area. The management response does not include a long-term plan and the environmental-effects report for the works acknowledges that the effects of climate change and sea-level rise will need to be considered for the area. In summary, current coastal protection at the site can only be considered a short-term response to coastal erosion and further measures will be required.

Tonkin & Taylor qualitatively assessed that inundation would be likely during a 2 percent AEP event (50-year average return interval—ARI). From this assessment, Tonkin & Taylor (2007) inferred that infrastructure and buildings on low-lying land in this area are susceptible to inundation. Riley Consultants found no major reported flood issues for Kawakawa Bay. However, Riley Consultants also made the assumption that low-lying coastal areas, where residential properties are situated, are prone to flooding based on their elevation and proximity to the coast, streams, and the large catchment area that drains into the coastal area (Riley Consultants Ltd., 2001). MCC managed flood risk through engineering quality standards (EQS) in its district plan. The EQS prescribes that all development will have a minimum site level (mAVD-46), and minimum freeboard levels for all development sites adjacent to open channels and overland flow paths (Manukau City Council, 2002). The district plan does not directly refer to coastal inundation or coastal areas, but it is assumed that minimum sites levels adequately protect buildings from coastal inundation up to the 1 percent AEP level. Adjusted minimum site levels have been recommended to take into account sea-level rise of up to 0.66m to the 1 percent AEP standard (Ramsay, et al., 2008b).

3 Potential impacts of sea-level rise

Sea-level rise is expected to worsen the occurrence of erosion and inundation around New Zealand's coast. The geophysical characteristics of a given area of coast will determine to what degree erosion or inundation increases or is initiated. Currently, coastal inundation risk exists at both sites. However, the risk is low and presents only a small disruption to people so it is not considered a priority at either settlement, and current flood-risk management is considered satisfactory. This section presents this study's investigation of how coastal flood risk could change with sea-level rise at the study sites.

3.1 Methods

GIS analysis was used to assess the potential impacts of a 1 percent AEP event for three sea-level rise scenarios at the two coastal settlements. To do this the National Institute of Water and Atmospheric Research (NIWA) was commissioned to derive extreme sea level static inundation contours for Waitemata Harbour. Full details of the methods used to generate the inundation contours can be found in the original studies on the influence of climate change on extreme sea levels around the ACC and MCC district coastlines (summarised in Appendix 3 of this report) (Ramsay et al., 2008b; Ramsay et al., 2008a). Future sea-level rise can be added to extreme sea-level values to estimate how inundation risk may change with long-term sea-level rise.

Potential static inundation extent during a 1 percent AEP event was mapped using GIS. The number of people, property, and the total economic value of property potentially affected during a 1 percent AEP event for three sea-level rise scenarios were estimated using GIS analysis.

The information generated in this component of the case study is not designed to be the basis of specific planning decisions. Rather, the information is designed to give an indication of the scale of the issue at the case study sites and, in doing so, provide contextual background for the in-depth investigation of the opportunities for, and barriers to, adaptation to sea-level rise investigated through in-depth interviews conducted for this study.

3.1.1 Selecting sea-level rise scenarios

Scenarios of future sea-level rise were selected for this study based on an adaptive risk-management approach consistent with IPCC guidance on developing sea-level rise scenarios (Nicholls, et al., in press). Sea-level rise scenarios of 0.5m, 1.0m, and 1.5m were selected for this study, reflecting the latest scientific findings projecting sea-level rise to the end of the century. The sea-level rise scenarios represent local relative sea-level rise, and are measured relative to present day (2007) local mean sea level. A further scenario of 2.0m sea-level rise was also assessed. However, it was found that the difference in impact and expert views regarding the required adaptive response, from 1.5m to 2.0m sea-level rise, was minimal at the study sites due to the sites' topography. Consequently, the results of the 2.0m scenario are not presented here.

Timeframes are not assigned to the three sea-level rise scenarios. This is consistent with an adaptive-management approach, whereby risks and responses are assessed independent of the timeframe at which impacts and responses may occur. Specific timing of responses may be applied subsequently, and can be reviewed as new information becomes available. The higher sea-level rise scenarios investigate the implications of high-impact low-likelihood scenarios of sea-level rise and the potential responses required to cope with the assoiated change. Options can be investigated and left open for the future. However, if the rate of sea-level rise does not increase rapidly in the twenty-first century then adaptive responses planned to cope with this can be put off or modified. In the same way, if sea-level rise rates increase more rapidly than expected, responses planned for the long term can be brought forward to respond to changing conditions. Such an approach gives decision makers some flexibility in response.

3.1.2 Limitations

Coastal erosion, permanent inundation, groundwater-level rise, and the interaction of freshwater flooding and sea-level rise are further processes that may be affected by sea-level rise that lie outside the scope of this study, but may have significant implications for existing development around the Auckland region, and warrant further investigation. Climate change may result in local changes to extreme sea levels, not only through sea-level rise, but also due to changes to the frequency, intensity, and tracking of low-pressure systems, and the occurrence of stronger winds. Changes to these phenomena are not assessed in this study, but may have significant implications for coastal hazard risk along the Auckland region coast, and also warrant further investigation. Additionally, current rates of erosion; the potential for increased erosion at the study sites; and potential responses were discussed qualitatively with key informants in the interviews conducted for this study.

More comprehensive approaches to estimating the impacts of coastal inundation can be undertaken by various methods. For example, undertaking integrated hydrodynamic modelling of storm events, deriving damage estimates, and incorporating future socio-economic scenarios into vulnerability assessments. The Riskscape Tool[7] developed by NIWA and Geological and Nuclear Science (GNS) is an already existing multi-hazard assessment tool that could be used to develop more detailed vulnerability assessments at the case study sites and for the Auckland region. However, substantial further hydrodynamic modelling and asset database development would be required to do this (R.Bell, June 13, 2011). This was beyond the resources available for this case study.

3.2 Changing 1 percent AEP levels and inundation mapping

This section presents the results of the extreme sea level analysis and inundation mapping. To account for the variance in water levels for each AEP and the confidence limits associated with each estimate, a 'lower' and an 'upper' water level and associated contour was derived for the present day and each sea level scenario (0.5m, 1.0m, and 1.5m). Table 3 shows the upper and lower water levels for each AEP for the present day and each sea-level scenario for Waitemata Harbour. To assess potential inundation extent at the study sites, the *lower* AEP level has been used to create inundation maps and GIS analysis of people and properties potentially affected. The water levels in Table 3 were converted to land contours in GIS using Light Detection and Ranging (LIDAR) digital elevation models of city districts provided by ACC and MCC.

[7] http://www.riskscape.org.nz/about

Table 3. Predicted water levels above Auckland Vertical Datum (AVD-46)[8] for AEP of 50%, 10%, 2%, and 1%, for Waitemata Harbour, for the present day and with local relative sea-level rise of 0.5m, 1.0m, and 1.5m relative to present day mean sea level (2007 MSL).

Sea-level scenario		1 % AEP	2 % AEP	10 %AEP	50 %AEP
Present day	Lower	2.18	2.15	2.01	1.87
	Upper	2.40	2.35	2.21	2.07
0.5m SLR	Lower	2.68	2.65	2.51	2.37
	Upper	2.90	2.85	2.71	2.57
1.0m SLR	Lower	3.18	3.15	3.01	2.87
	Upper	3.40	3.35	3.21	3.07
1.5m SLR	Lower	3.68	3.65	3.51	3.37
	Upper	3.90	3.85	3.71	3.57

Potential inundation extent was initially assessed for the 50 percent, 10 percent, 2 percent and 1 percent AEP levels. Comparing AEP levels, as seen in Table 3, indicates that the Waitemata Harbour extreme sea-level distribution curve is shallow, meaning that the difference between the highest water level during a relatively frequent storm (50 percent AEP) and a relatively infrequent storm (1 percent AEP) is not large. It can be seen that the current (highest) water level associated with a 1 percent AEP event (2.2–2.4m AVD-46) will be experienced almost yearly with just 0.5m sea-level rise. The current 1 percent AEP water level does not present a significant risk to people or property at the study sites. However, what this study shows is that a 1 percent AEP event in the future *will* present a significant risk to people and property at both communities, indicating that current coastal-hazard management measures will not be satisfactory. Further to this, the relatively small scale disruption experienced at the study sites during large but infrequent storms *today* will be experienced as often as yearly with a 0.5m sea-level rise, and more frequently with sea-level rise above 0.5m (see Appendix 3 also).

Figures 7 and 8 show mapped potential static inundation for Mission Bay / Kohimarama and Kawakawa Bay for the 1 percent AEP water level (lower estimate) for the present day and with local relative sea-level rise of 0.5m, 1.0m, and 1.5m relative to present day (2007 MSL). The 1 percent AEP water level was mapped and is presented here as this represents the statutory flood-risk planning standard used by councils (Auckland Regional Council, 1999a), and is the AEP scenario shown and discussed in the interview process conducted for this study. The mapped land contours represent static inundation only, identifying land area that lies below the derived storm tide levels listed above. The land contours do not take into account other factors present during a coastal storm, such as wave action or the effect that existing or future coastal structures may have on inundation extent. Hannah et al. (2011) show that above any rise in local relative mean sea level due to climate change,

[8] 0m AVD-46 measured as 1.743m above Chart Datum and defined as mean sea level for Auckland region.

an additional 20cm should be taken into account for regional sea-level change due to the effects of seasonal, interannual, and interdecadal climate-ocean cycles on regional sea levels. Therefore, these inundation maps may underestimate inundation extent during a 1 percent AEP event.

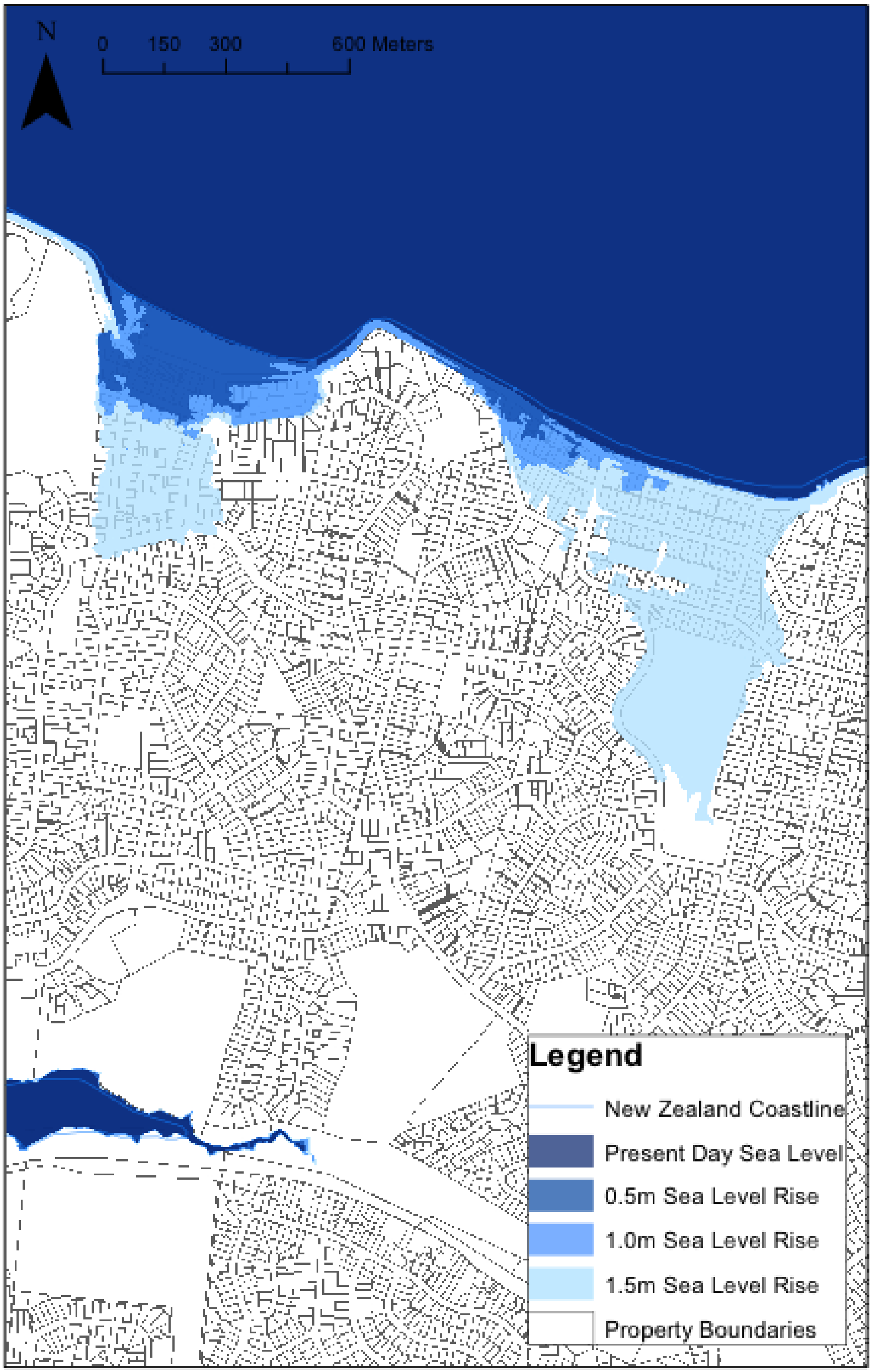

Figure 7. Change to extreme tide levels and potential static inundation for a 1% AEP event with sea-level rise of 0.5m, 1.0m, and 1.5m (lower bound), at Mission Bay / Kohimarama.

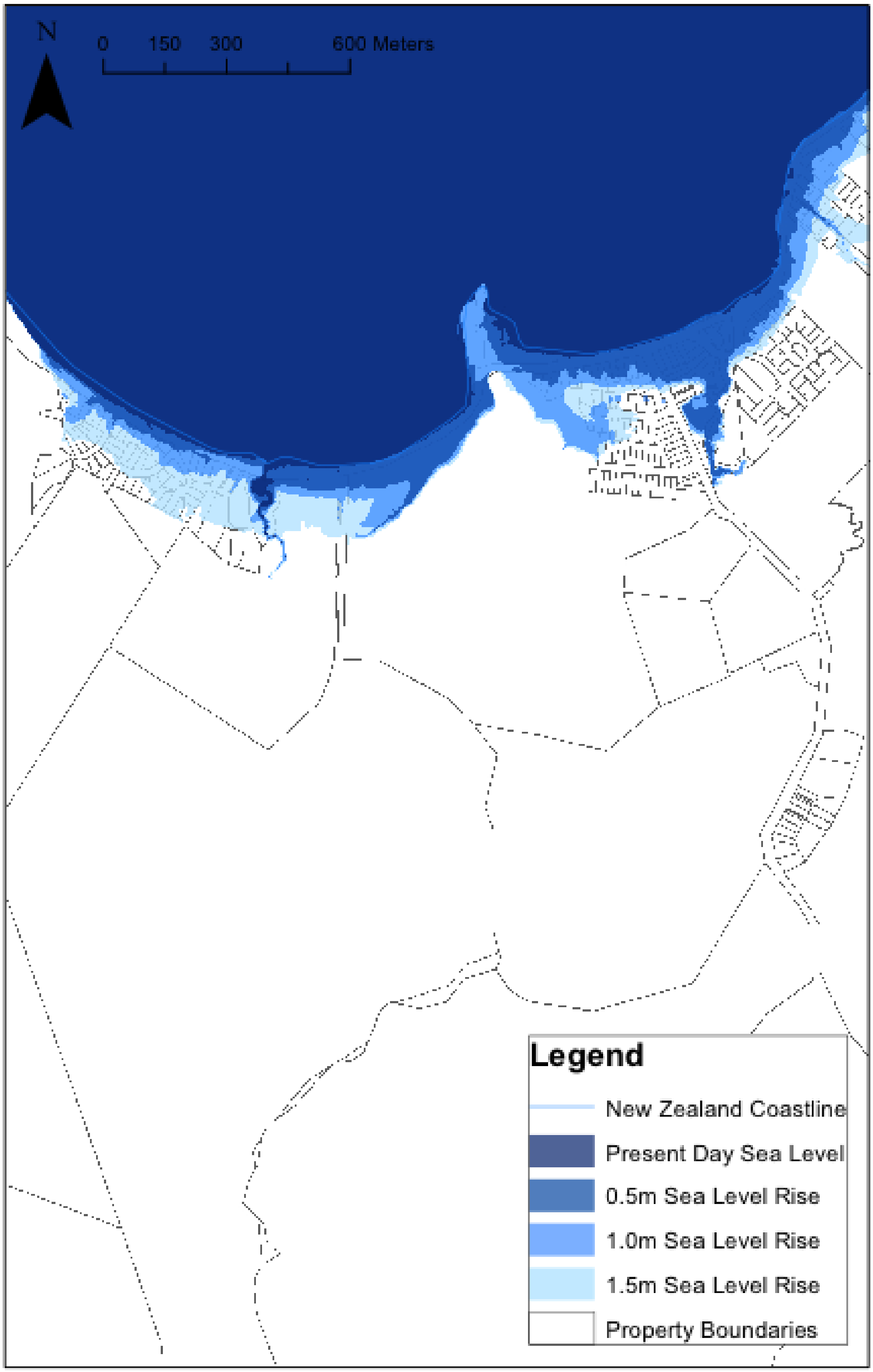

Figure 8. Change to extreme tide levels and potential static inundation for a 1% AEP event with sea-level rise of 0.5m, 1.0m, and 1.5m (lower bound), at Kawakawa Bay.

Figures 7 and 8 show the degree to which coastal inundation may affect Mission Bay / Kohimarama and Kawakawa Bay during a 1 percent AEP event as local relative mean sea level rises. For the present day, a 1 percent AEP event will result in little inundation, and is not expected to represent any major disruption to either site. With 0.5m sea-level rise, a significant portion of residential property at Mission Bay and Kawakawa Bay could be inundated, whereas at Kohimarama the impact is relatively small. A rise up to 1.0m represents a relatively small increase (from 0.5m) in inundated area and affected property at all sites. For a rise of 1.5m, a significantly larger area is affected in all areas, except the eastern Kawakawa Bay embayment where the additional flooding for increased sea level of 1.5m is relatively small. The maps show that a local mean sea-level rise of 0.5m will represent a major disruption to the eastern embayment at Kawakawa Bay, and at Mission Bay. A mean sea-level rise of 1.5m would result in a major disruption at the western embayment at Kawakawa Bay and Kohimarama. One result of generating vulnerability information such as mapping inundation risk, is the ability to identify how timing of response will be needed. If response can be spread over time (e.g. sea wall construction or retreat at Mission Bay could be planned for in the next 40 years, and at Kohimarama after this) then risks are managed or avoided where they need to be, at the time they need to be, and adaptation costs can be incurred with appropriate timing specific to spatially explicit risks rather than more generalised representations of changing risks.

3.3 Results: Potential socioeconomic impacts

Potential socio-economic impacts associated with rising sea level at the study sites were investigated by estimating the numbers of people and properties, and the total economic value of properties potentially affected by inundation during a 1 percent AEP event, based on current population and property value data. These estimates provided an indication of the scale of potential consequences of inundation at the study sites.

Population data refers to counts of 'usually resident population'[9] and was retrieved from Statistics New Zealand 2006 national census meshblock[10] data. Property information was made available by ARC, and property value data was based on the most recent available ratings valuation (2007 / 2008). ArcGIS software ArcMap was used to conduct GIS analysis to extract property numbers and values, and the numbers of people residing seaward of mapped inundation contours.

Table 4 shows the number of people usually resident within the meshblock area units that were at least 50 percent covered by the related inundation contour. This may under represent the number of people potentially affected at Mission Bay / Kohimarama for the 1.0m sea-level rise scenario, as the same number of meshblocks were affected, as for the 0.5m scenario. All were >50 percent, but to different degrees, meaning that the same count is given even though the number of people potentially affected differed between these two scenarios. Data at a finer scale than the meshblock would be required to correct this. The results for the number of properties potentially affected highlights the difference between the 0.5m and 1.0m scenarios more clearly, as data is at the scale of individual properties.

[9] The census group 'usually resident population' is a count of all people who usually live in a given area and are present in New Zealand on census night. This count excludes visitors to the area and usual residents who are temporarily overseas on census night (Statistics New Zealand Census 2006, accessed August 11, 2010).

[10] A meshblock is the smallest geographic unit for which statistical data can be accessed. 2006 census data is the most recent census data.

Table 4 shows the number of local residents potentially affected by inundation during a 1 percent AEP event at the study sites will increase with sea-level rise. At Mission Bay / Kohimarama, 0 percent would be affected by a 1 percent AEP event today. Of the area's residents, 4.2 percent would be affected by a 1 percent AEP event with sea-level rise of both 0.5m and 1.0m, and 13.6 percent with 1.5m sea-level rise. At Kawakawa, the proportional impact on the community would be much higher with numbers potentially affected by inundation reaching more than 50 percent of the area's population during a 1 percent AEP event with 1.5m sea-level rise.

Table 4. The number of people and percentage of census area population potentially affected during a 1% AEP event for the present day and three sea-level rise scenarios.

Study area		Sea-level scenario (mAVD-46)			
		Present day (mAVD-46)	0.5m SLR (mAVD-46)	1.0m SLR (mAVD-46)	1.5m SLR (mAVD-46)
Mission Bay / Kohimarama	Number of people	0	~518	~518	~1653
	% of population	0 %	4.2 %	4.2 %	13.6 %
Kawakawa Bay	Number of people	0	~324	~399	~525
	% of population	0 %	32.4 %	39.9 %	52.5 %

Figure 9 shows the change in the number of properties potentially affected by coastal inundation during a 1 percent AEP event as sea level rises up to 1.5m above 2007 levels (lower-bound estimates) at Mission Bay / Kohimarama (combined) and Kawakawa Bay. Figure 10 shows the change in total economic value of properties potentially affected by coastal inundation during a 1 percent AEP as sea level rises up to 1.5m above 2007 levels (lower-bound estimates) at Mission Bay / Kohimarama and Kawakawa Bay.

Based on the socio-economic impacts analysis conducted, it is clear that in the absence of adaptation response the number of people and properties and the value of damage to property potentially affected by coastal inundation will increase substantially with just 0.5m sea-level rise, and dramatically with sea-level rise higher than 0.5m. With a 1.5m sea-level rise, as many as 360 properties and 1600 people could be affected by coastal flooding during a 1 percent AEP event in Mission Bay / Kohimarama, and 140 properties and 500 people in Kawakawa Bay. The results of this analysis highlight the importance of considering and preparing for higher sea-level rise scenarios. The potential impacts related to these scenarios will be so much higher than for mid-range (sometimes called 'best-estimate') projections, and the potential that these upper range estimates will occur cannot be ruled out.

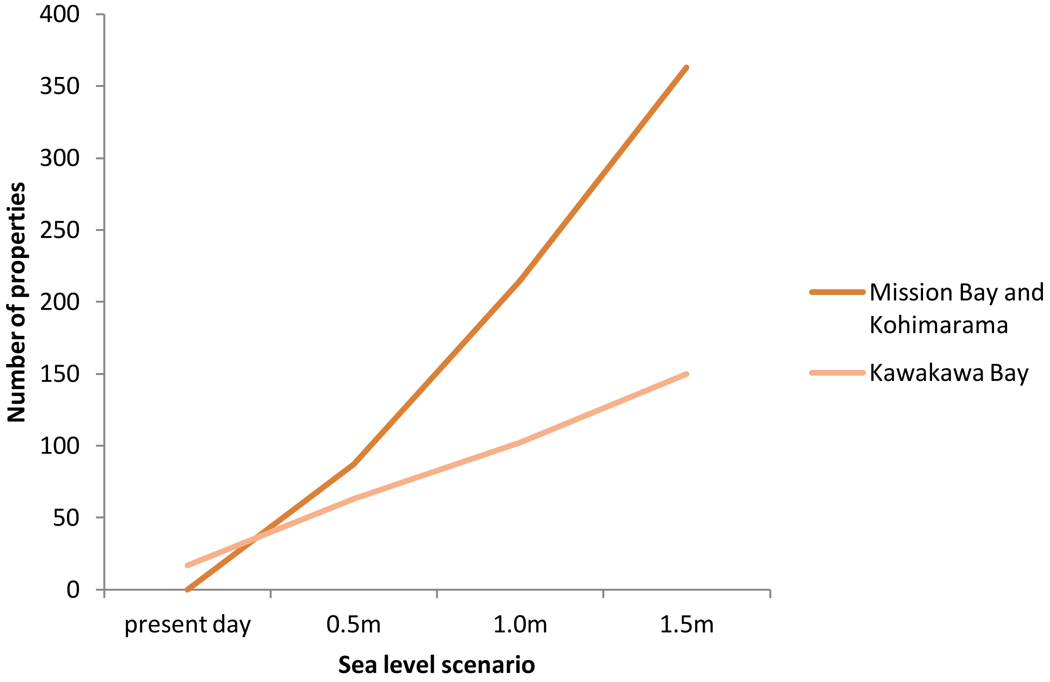

Figure 9. **Number of properties potentially affected by coastal inundation during a 1% AEP water level event, for present day local mean sea level and for local relative sea-level rise of 0.5m, 1.0m, 1.5m, and 2.0m sea-level rise (lower bound) at Mission Bay / Kohimarama and Kawakawa Bay.**

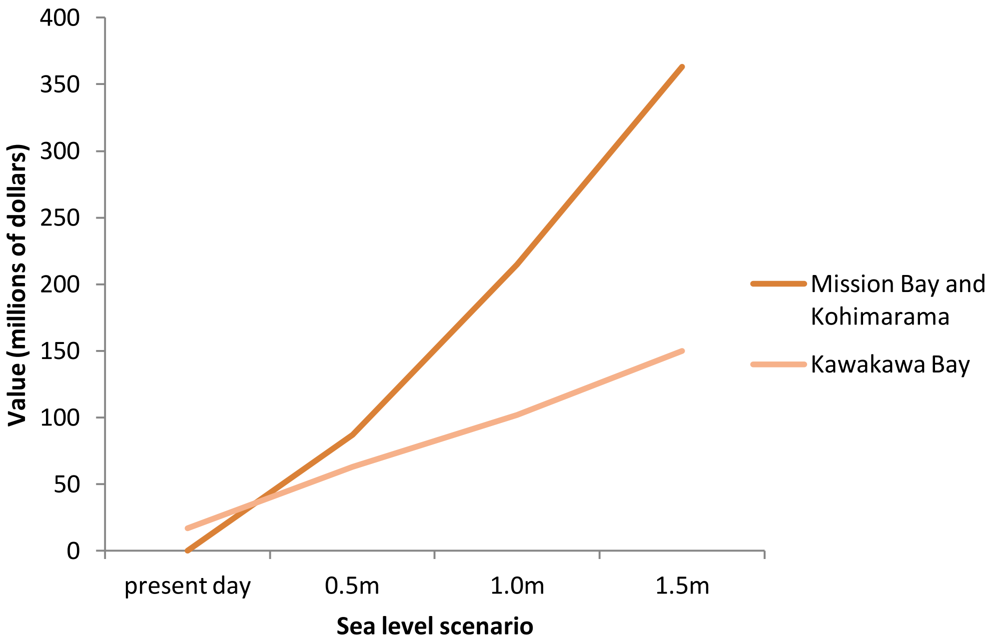

Figure 10. **Total economic value of properties potentially affected by coastal inundation during a 1% AEP water level event, for the present day local mean sea level and for local relative sea-level rise of 0.5m, 1.0m, and 1.5m (lower bound) at Mission Bay / Kohimarama and Kawakawa Bay.**

4 Adaptation opportunities and barriers

Semi-structured in-depth interviews were conducted to investigate adaptation opportunities and barriers at the study sites. The interview transcripts were analysed thematically, based on the methodology set out by Braun & Clark (2006). Twenty-five participants were selected from local government, and relevant fields (e.g. coastal science, coastal engineering, resource management law). Interviews ranged in length from 60 to 120 minutes. See Appendices 4 and 5 for an indicative interview schedule and a full list of participants. The interviews were structured around two main themes, with subsections for discussion.

1. The current approach to coastal hazards management
    a. Preparing for sea-level rise
    b. Planning timeframes and horizons
    c. Response options at the study sites (study site inundation maps and impacts information were introduced and discussed at this point)
2. Including retreat as part of the management toolbox
    a. Managed retreat as a potential response option
    b. Barriers to managed retreat

4.1 Coastal-hazards management: The current approach

Issues surrounding recent coastal development and coastal-hazards management have been well documented in New Zealand (Hume & Blackett, 2007; Wilson, 2010; Turbott, 2006; Gregory & Young, 2002; New Zealand Climate Change Office, 2003; Blackett, et al., 2010; Duthie, 2005; Cheyne, 2007; Hayward, 2008). This case study investigated the current approach to coastal-hazards management in Auckland to set the context for further discussion of adaptation options for the two study sites.

4.1.1 The former Auckland Regional Council

The role of the former ARC was to conduct regional scale natural hazards research, and to provide coordination and support for on-the-ground coastal-hazards management by territorial authorities. ARC fulfilled its roles predominantly through regional planning documents: The Auckland Regional Policy Statement (RPS) and The Auckland Regional Plan: Coastal (Auckland Regional Council, 1999a; Auckland Regional Council, 1999b). The regional plans have provided general policies to guide district council in coastal-hazards management.

The Auckland RPS establishes the region’s approach to coastal hazards and sets the region’s flood protection standard at the 1 percent AEP water level. The RPS states that new development should avoid exposure to coastal hazards and that, where development already exists, measures to mitigate the adverse effects of coastal hazards should not adversely affect the coastal environment or worsen coastal-hazards risk. The phenomenon of sea-level rise is acknowledged but no specific guidance is included, nor is the ongoing and evolving nature of coastal risks highlighted (Auckland Regional

Council, 1999a). However, an update of the RPS in respect of climate change effects and adaptation is overdue, and a review of the RPS is underway[11].

From the regional council perspective, interview participants emphasised the variable nature of coastal-hazards risk along the coast. Therefore, participants felt that to impinge on a property owner's development rights by applying development restrictions through generalised hazard zoning may not be justified, given the site-specific nature of coastal hazards. There was also a view held that such action by council could be indefensible in the Environment Court, if contested. It is important to note that in regions where development restrictions have been put in place in coastal-hazard zones in regional or district plans they have been upheld in the Environment Court in numerous examples (Ministry for the Environment, 2008).

The regional council participants' perspectives that coastal-hazards management is best handled through the case-by-case resource consent process is consistent with the 'specific-risk' approach of conventional risk management, which in turn is well adapted to the largely static structure of the RMA. The RMA puts considerable emphasis on allowing private property owners to pursue their own current interests, or 'wellbeing', as per the language of Section 5 of the Act. There is little emphasis on councils pursuing collective action in the public interest, although in principle councils are empowered to take action that is forward looking and speaks to the collective interests of future citizens.

4.1.2 Territorial authorities

The approaches taken by the seven territorial authorities that operated in the region until 31 October 2010 varied. For new development, planning tools have been used to manage coastal hazards. These have included requiring coastal setbacks; setting minimum site levels; setting minimum freeboard levels within identified floodplains; and requiring resource consent within identified coastal-flooding areas (controlled activity), which may include attaching conditions to resource consents requiring hazards be avoided or mitigated.

In Auckland, the need for coastal-hazard management at existing properties exists today due to a legacy of coastal development that has not taken the dynamic nature of the coast into account. For existing development, the response by councils has been reactive and driven by affected property owners' resource consent applications for structures to protect their property from erosion, or calls from a community that a public asset is being damaged and requires protection. The result is a legacy of ad hoc structural coastal protection works (consented and unconsented), which have been constructed along the region's coastline to protect both public and private property. Works directly protecting private property have predominantly been privately funded and executed. Where public property has been affected (e.g. coastal reserves and roads), district councils have routinely opted for engineered protection works and, more recently, beach nourishment to protect public assets from erosion. However, response by the councils to develop and fund coastal-erosion management to protect public assets has occurred only once significant erosion and damage to property has occurred. Erosion management has not been planned in anticipation of predicted erosion.

[11] A review of the RPS was started in 2008. However, the draft RPS was not publicly notified due to planned changes to the Auckland region governance structure, which took effect on 1 November 2010. The draft RPS was passed on to the new Auckland Council for consideration.

Over recent decades, problems associated with structural coastal protection works have arisen, both nationally and internationally, which has caused a shift in approach to coastal-hazards management in several countries. In New Zealand, the need to consider alternative response options has been introduced into coastal-hazards management guidance through the NZCPS (1994 and 2010). The NZCPS discourages the use of structural coastal protection as a response to coastal hazards. The NZCPS stipulates that structural protection works should only be constructed if they are the *best practicable* option, and that other options including managed retreat should be considered (Department of Conservation, 2010). This approach has been reflected in Auckland planning documents including the Auckland RPS and the Auckland Regional Plan: Coastal.

However, at the implementation level, structural-coastal protection continues to be the status quo response to coastal-hazards management, and no examples of planned retreat of private property from coastal hazards yet exists in the Auckland region. A number of non-structural ('soft') protection examples exist, most notably Mission Bay / Kohimarama, where the beaches have been renourished in works funded by council to protect high-value public assets. A number of retreat examples in other situations exist. ARC and Rodney District Council were involved in a participatory coastal management process at Muriwai Beach (an open ocean west coast beach), where a public building was threatened by erosion. After more than a decade of negotiations amongst the community, and with the councils, the relocation of the surf-lifesaving building back from the coastline was agreed upon (Blackett, Hume, & Dahm, 2010). Waitakere City Council undertook a comparatively large-scale voluntary retreat plan involving private residential properties built within a 100-year river floodplain (Atlas Commnications & Media Ltd., 2010). There are examples of councils adaptively managing coastal hazards in other areas of New Zealand, for example the Hawke's Bay and Canterbury regions.

4.1.3 Coastal-hazards management barriers

Existing use rights and the political nature of coastal-hazards management decisions impede progress

Several district council participants said that councils '*can't really do anything*' about coastal hazards on existing properties. Under Section 10 of the RMA, district councils cannot affect land use on existing development. However, regional councils can override existing use rights in regional plan policies and rules, which must then be given effect by district councils. In Auckland, no such regional and district coordination for the management of coastal hazards was initiated. Regional guidance is broad and does not directly affect existing development.

Participants reported that individuals could exert influence on councils to gain consent to construct coastal protection, even though these works may be counter to planning guidance. This influence was related to an individual's influence within their community, their wealth (i.e. access to resources), and their personal level of determination to protect their property (i.e. how much time and resources they were willing to pour into gaining a consent to engineer the coast). Participants noted the political nature of decision making about coastal-hazards response options, where decisions about coastal-hazards management at the council level may override regional policy and / or advice from council officers based on pressure from property owners. Because of this, managing coastal hazards on existing development was seen predominantly as a political issue that was beyond the power of advisers.

There are conflicting views on approaches to coastal-hazard management

Conflicting views were expressed regarding what approach to coastal-hazards management for existing property is most appropriate. From the comments of participants, it appears that in Auckland views differed around: 1) the right of individuals to protect their property, versus the potential adverse social and environmental effects of coastal-protection works; and 2) who bears the cost for coastal-hazards management response. For example, costs may be spread across ratepayers or borne by the individual property owners affected. Conflicting views among key advisers in relation to these social, environmental, and economic factors increases the complexity of decision making for coastal-hazards management.

A low-priority status and consequent limited resource allocation have resulted in knowledge and implementation gaps at the regional and local levels

Participants from ARC reported significant regional knowledge gaps in the information held on coastal hazards. The only monitoring of coastal hazards done regionally is of beach erosion at 16 sites. Sea level is recorded at the Waitemata Harbour tide gauge, administered by the Ports of Auckland Limited, and incomplete information is kept on coastal storm events. Inundation is not monitored. This monitoring gap was identified by the former ARC, with the aim of eventually establishing an inundation component to coastal-hazards monitoring. However, this had not yet occurred at the time of writing. No regional assessment of future inundation risk exists. In terms of assessing future risks, a regional coastal-hazards assessment projecting potential erosion for the twenty-first century, and a regional assessment of potential sea-level rise for the twenty-first century have been completed.

Significant knowledge gaps include storm event and inundation monitoring; the collation of coastal hazard information into a (publicly accessible) natural-hazards database; and research into the potential social, economic, and environmental implications of coastal-hazard impacts and response options. These matters are currently under discussion in the new Auckland Council in the context of the spatial and unitary plans being prepared.

Interview participants reported that barriers to improving knowledge around coastal hazards and their management stemmed from coastal hazards having a low priority in competition with other issues on councils' agendas, which results in a lack of resources being allocated for this issue. Several reasons were given for its low-priority status, including few reports of actual damage to private property due to coastal hazards; the low frequency of large coastal storms and the length of time since the *last* large scale coastal event to impact Auckland's developed coastal areas. These possible reasons for a low-priority focus on coastal-hazards management were expanded upon to identify perceived risk of coastal hazards as low by the public, key management staff, and councillors. Some regional council interview participants expressed frustration at experiencing limited capacity to complete important coastal-hazards management functions under the RPS.

Working in silos has prevented integrated coastal-hazards management

Managing coastal hazards requires an integrated cross-disciplinary approach to address the multi-disciplinary and cross-boundary nature of coastal-hazards management. Participants expressed difficulties in terms of achieving comprehensive or consistent coastal-hazards management due to the prevalence of silos operating within council organisations. Lack of integration of coastal-hazards management across areas, vertically and horizontally within councils, was identified as a key limiting factor to achieving comprehensive coastal-hazards management for the region.

Some interview participants reported lack of clarity regarding the roles and responsibilities of Auckland regional and territorial authorities in relation to coastal-hazards management. Coastal-hazards management is the joint responsibility of regional and district councils under the RMA. The RMA does not make clear distinctions between the roles of regional and territorial authorities in their similar and sometimes overlapping responsibilities to avoid or mitigate coastal hazards and the effects of response options on the environment. However, the RMA provides for the RPS to give high-level planning direction to this effect, and the RPS must be implemented by both regional and district councils.

The Auckland RPS Proposed Plan Change 10, notified in 2005, aimed to define more clearly the distinct roles of the regional and territorial authorities in this area. However Plan Change 10 only became operative at the end of October 2010, several days before the establishment of the new Auckland Council. How this more clearly defined natural-hazards management approach is to be adopted, modified, and carried out under the new governance structure of the Auckland Council is yet to be seen.

Organisational restructuring and turnover can result in shifting approaches and loss of knowledge

ACC and ARC developed an integrated coastal management strategy for the eastern bays area (including Mission Bay / Kohimarama) in the mid-1990s (Auckland City Council, 1999). This non-statutory management strategy comprehensively detailed the various issues for the area in an integrated manner, as well as establishing strategies for achieving community goals and council responsibilities. An ACC adviser reported that, although some of the strategies within the document were taken up and funded by various operational arms of ACC, the approach outlined by the strategy now appears to be overlooked and operational arms of council have reverted to working in 'silos'. No known monitoring or review of the strategy has taken place since it was published in 1999.

This lack of follow-through or a consistent approach was characterised as being commonplace and typically caused by council leadership changes, staff turnover, and / or organisational restructuring. Leadership and higher-level support for the Eastern Bays Coastal Management Strategy was a key enabler for developing the strategy. However, since its completion council teams have been restructured, leadership has changed, and employees have moved on. Subsequently, other issues have been given priority and this comprehensive strategy and the process for its achievement has essentially been lost.

4.2 Preparing for sea-level rise

Coastal-hazards management presents significant challenges to local government and communities, as discussed above. Sea-level rise adds a further dimension to the challenges of coastal-hazards management that had yet to be fully addressed by councils in the Auckland region before council amalgamation. The legislative amendment introducing consideration of the effects of climate change as a local government responsibility in 2004, together with general increased attention to the issue of sea-level rise, has seen coastal hazards take on greater significance for council natural-hazards staff. However, the interviews carried our in this study suggest that sea-level rise response was seen as being in its very early stages in the Auckland region and involved significant barriers to progression. This study assessed how consideration of sea-level rise is being incorporated into the participating councils' activities by investigating:

- use of and views on MfE's national guidance (Ministry for the Environment, 2009) on incorporating sea-level rise into coastal-hazards management
- research and policy relating to sea-level rise
- perceived issues and barriers to incorporating sea-level rise into coastal-hazards management, and opportunities to improve adaptive response to projected sea-level rise.

4.2.1 Ministry for the Environment guidance on sea-level rise for local government

MfE first published guidance on sea-level rise for local government in 2004. This information was updated in 2008 (Ministry for the Environment, 2008; Ministry for the Environment, 2009). The MfE guidance focuses on coastal-hazards management, recommends and outlines the use of a risk-management approach for decision making in response to increased coastal hazard risk, and recommends projections of sea level for use in coastal-hazards assessment. The MfE guidance has been used widely to begin incorporating consideration of sea-level rise effects into council long-term planning, but several issues emerged from discussion of the guidance with participants.

Several participants expressed a *lack of trust* in information from MfE—those participants were resistant to using the MfE guidance to guide work in this area, or to trust the outcomes of applying the guidance for coastal-hazards management. Misinterpretation of the guidance was also an issue. One participant felt that the guidance recommended a national blanket approach to considering sea-level rise and to developing coastal policy, as opposed to conducting regional and local assessments, and developing local policy based on these. This misinterprets the guidance, which allows organisations to set the parameters of the risk assessment being undertaken, and places emphasis on the local nature of sea-level rise impacts. Finally, positive responses were narrowly focused upon participants' (or organisations') use of the report's sea-level rise projections, and not the overall approach suggested by the guidance. In some cases, only the lower-level projection had been adopted, without consideration of the higher-level projection included in the guidance document. This presents a significant potential for maladaptive planning, if higher levels and faster rates of sea-level rise continue not to be considered.

4.2.2 Research and planning responses at Auckland councils

Auckland's regional planning documents do not provide detailed guidance on sea-level rise. ARC was in the process of developing specific guidance for district councils on sea-level rise in its review of the RSP. Specific sea-level rise figures were to be included, based upon the MfE guidance. The review process was stopped before completion as a result of the council amalgamation and this work was passed onto the new Auckland Council. The RPS review and update of information and guidance on sea-level rise was positioned to provide support to district councils on sea-level rise and coastal-hazards management.

To meet legislative requirements regarding climate change, and because of concerns regarding sea-level rise, councils assessed in this study have been commissioning research to assess the effects of sea-level rise (and other climate change effects) on coastal hazards over century-scale timeframes (e.g. the next 50–140 years). The aim of this work has been that knowledge generated can be the basis for evidence-based decision making for long-term planning by council. This section reviews studies that were completed by ARC, ACC, and MCC. This review was limited to councils officially participating in this study, although Rodney District Council and North Shore City Council commissioned similar studies.

ARC completed a regional assessment of likely sea-level rise to 2100 but used projections that underestimated sea-level rise

In 2010, ARC commissioned a technical study (Hannah, et al., 2011) to assess the most likely regional rate of mean sea-level rise for the twenty-first century. Conflict over what sea-level rise to plan for is a key issue for sea-level rise adaptation, discussed below. The findings of Hannah et al. (2011) provide an evidence base for selecting a regional rate of sea-level rise that could underpin impacts assessment and planning decisions, in the absence of statutory guidance. However, Hannah et al. (2011) under-emphasise important components in sea-level rise projections such as the effect of dynamic ice-sheet melt (Nicholls & Cazenave, 2010; Church, et al., 2008; Vermeer & Rahmstorf, 2009).

Hannah et al. (2011) conclude that the MfE guidance provides an adequate mean sea-level rise rate (0.5–0.8m by 2100) for the Auckland region based on the Auckland long-term tide gauge record, the short term (10 year) digital sea level record, Holocene period sea-level data, and projections of future sea-level rise. Hannah et al. argue that, based on sea levels for the Auckland region derived from geological records, a low-probability upper limit of sea-level rise for next 90 years is no more than 0.8m. This demonstrates that New Zealand is not adopting the latest international science on sea-level rise, which shows that the potential for sea-level rise to 2100 is much higher than this (Meehl, et al., 2007). Recent studies from the international scientific community emphasise that global mean sea-level rise of 1.5–2.0m by 2100, based on recent observations of ice-sheet melt and the potential for dynamic ice-sheet melt over the twenty-first century, cannot be ruled out. Furthermore, the practice of setting an 'upper limit' for sea-level rise to 2100 also perpetuates the current static approach to coastal risk, which underestimates the higher end of the range of projections, and increasing rates of change. This approach also indicates that the uncertain nature of sea-level rise and the dynamic nature of coastal risk over the coming century are not being communicated fully to decision makers. Risk-based decision making and proactive adaptation will continue to be limited as long as decision makers are not made fully aware of the potential for dynamic and ongoing change in coastal risk due to sea-level rise and other climate change effects.

ARC did not comprehensively investigate the potential regional effects of climate change and sea-level rise on coastal hazards

Significant gaps exist in the current knowledge regarding the potential effect of sea-level rise on coastal hazards for the Auckland region. A regional study assessing potential coastal erosion over the twenty-first century was completed in 2006 (Reinan-Hamill, et al., 2009). The study includes the potential effect of a linear rate of sea-level rise of 0.5m by 2100 on beach erosion rates, based on the Bruun Rule[12] (Bruun, 1988). The study does not consider the potential for more rapid rates of sea-level rise, the continued effect of sea-level rise beyond 2100, or other climate change effects on erosion (i.e. increased frequency and intensity of storm events).

ACC and MCC commissioned NIWA to investigate sea-level rise along their jurisdictional coasts

The former ACC and MCC both commissioned the NIWA to investigate the effects of sea-level rise on mean and extreme sea levels along each council's jurisdictional coast (Ramsay, et al., 2008a; Ramsay, et al., 2008b). Sea-level rise scenarios were developed based on MfE guidance on sea-level rise (Ministry for the Environment, 2009). However, the two studies used different approaches to assess sea-level rise. ACC assessed ranges of sea-level rise for each of three future time periods: 0.18–0.27m (2050s), 0.47–0.81m (2100s), and 0.97–1.31m (2150s). MCC assessed sea-level rise of 0.33m to the 2050s, and 0.66m to the 2080s.

In response to Ramsay et al.'s (2008a) findings, the former ACC was advised that no immediate action was required due to current storm surge risk being adequately accounted for through ACC's information systems, which identified properties at risk of stormwater flooding, and required minimum freeboard within those areas. Therefore, it was noted that the new Auckland Council would be best positioned to plan for sea-level rise and other climate change effects at the coast, which would need to include a strategic consideration of if, when, and where retreat options would be adopted (Craig, 2010).

Recommendations have not been implemented yet due to the reorganisation of Auckland councils

Based on Ramsay et al.'s (2008b) findings, the former MCC was advised to manage increasing coastal inundation risk through EQS minimum site levels set in the district plan. To ensure that building site levels were above the 1 percent AEP water level with 0.66m sea-level rise, its was recommended that minimum site levels be adjusted up by several tens of centimetres. The adjustment was not adopted because of the Auckland Council amalgamation process. The new Auckland Council was considered the most appropriate body to make changes in response to the new information regarding sea-level rise and coastal hazards. Participants from both councils noted that the results of the reports (indication of areas potentially at risk of coastal inundation in the future) should be already being applied in the resource-consent process. However, how they would be applied is unclear, without guidance for interpreting the results of the studies being available to consenting officers and decision makers. Further to this, the consenting process does not generally apply to existing settlements, except where significant changes to existing uses are proposed.

[12] The 'Bruun Rule': an empirical model that provides a formula for estimating shoreline erosion for a given rise in sea level. The rule suggests that for a given rise in sea level there is a corresponding landward and upward movement of the coastline (Reinan-Hamill, R., et al., 2009).

The assessments were developed as the basis for long-term council planning, but recommendations derived from the study's findings did not acknowledge and create a 'buffer' for some important components not assessed in the studies. For example, wave action, and the combined effect of coastal erosion, groundwater level change, and storm water flooding. Likewise, neither council considered sea-level rise of more than 0.8m by 2100. MCC did not consider continued sea-level rise beyond the 2080s.

Participants from the former MCC asserted that current flood-risk management approaches (minimum site and freeboard levels) would be adequate for managing increased coastal inundation risk. However, the Council did not assess the socio-economic or health impacts of flooding; or any comparative study of the implications of responses. For example, using adjusted EQS minimum site levels alone relies heavily on property redevelopment cycles to affect flood protection of existing buildings. This may leave a significant number of properties unprepared for increased coastal-inundation risk in the future. This approach also makes no effort to limit development in coastal-hazard areas, which, in the Auckland context, is likely to lead to increasing numbers (and value) of properties at risk of erosion and inundation. In addition, there is increased risk to coastal and intertidal ecosystems as their landward migration is constrained by impermeable human structures (coastal squeeze).

Response to the inundation studies was sensitive within the councils

Response to the above inundation studies was sensitive within both councils. Reluctance to make the information publicly available was reported by interview participants. The reports are publicly available on request, but have not been widely acknowledged or accessed. ARC staff reported not being able to obtain a copy of the ACC report 3 years on from its completion.

Interview participants identified at least three implications of the experienced sensitivity around new information about changing inundation risk.

1. Some perceived inundation mapping to be emotive and controversial.
2. For this reason, information such as changing flood risk affecting private property needs to be carefully managed.
3. A serious plan to manage the release of new information such as this, and to use it to begin a conversation with potentially affected communities, had not been initiated at the time the interviews took place.

Coastal-hazards assessments at the study sites did not consider sea-level rise

Studies assessing coastal hazards and protection response options at Mission Bay / Kohimarama and Kawakawa Bay did not directly assess the potential impacts of sea-level rise on coastal hazards. However, sea-level rise was noted as an important factor that will require consideration in the future, and is likely to mean that the current works will only provide a short-term response to coastal hazards (Tonkin & Taylor Ltd, 2007).

4.2.3 Timeframes and planning horizons

Regional and district plans are essentially long-term resource management tools that are reviewed and updated once every 10 years. Assessments of coastal-erosion hazards typically employ a 100-year time horizon, within which the progression of coastal change is predicted. Regional and district policies and rules in an operative plan may then take into account coastal change over a 100-year time horizon, and make restrictions or allowances for land use (or other) accordingly. Financial planning is implemented through 1-year operational plans, although these must be based on longer-term financial planning. Councils complete long-term planning for a 10-year timeframe through the long-term plan process. Councils also use long-term asset management plans over long time periods (e.g. 60 years). There are thus opportunities for coastal change to be managed effectively using the range of tools and processes already employed by the Auckland Council, as long as the Council continues to incorporate evidence from new studies and new scientific information as it changes over time, and as long as it looks forward to rates of projected sea-level rise, and the interaction of sea-level rise with other phenomena such as increased storm severity.

4.2.4 Incorporating sea-level rise into coastal-hazards management: Barriers and opportunities

Participants identified a number of issues and barriers that limited response to sea-level rise and increased coastal-hazards risk. In the first instance, the issues that already exist for coastal-hazards management have impacted on the capacity of councils to incorporate sea-level rise.

These include:

- coastal hazards being a low-priority issue
- lack of leadership
- limited resource allocation
- information gaps
- development pressures
- existing use rights under the RMA makes district council officers feel powerless to plan for changes to land use that reflects the risk to these properties.(implementation gaps between policy and the resource consenting level
- the political nature of responses when property is affected by a coastal hazard
- tensions between regional and district responsibilities, roles, and relationships—with lack of coordination and integration being identified as key issues.

Further to this, participants discussed barriers and opportunities specific to incorporating sea-level rise into coastal-hazards management practices, outlined below.

The focus is on climate change mitigation not adaptation

Climate change response has to date focused on efforts to reduce greenhouse gases (mitigation), and not on adaptation. Although a co-benefit of any mitigation efforts will be the reduced need for adaptation, especially if greenhouse gas emissions reductions are achieved globally, this lack of focus on adaptation has left a gap in the area of developing and understanding adaptation responses.

The long timeframes involved make it difficult to maintain issue saliency

The impacts of worsening coastal erosion and inundation are expected to occur decades from now. This long timeframe acts as a disincentive for advancing potentially unpopular policy or expenditure to prepare for sea-level rise. Long timeframes can also act to validate prioritising attention and expenditure on more pressing near-term issues.

There are differing levels of acceptance and prioritisation of sea-level rise as an issue

All participants personally believed that sea-level rise is happening, and agreed that adaptation to sea-level rise is an important issue for local government attention. However, participants reported that climate change science, including sea-level rise, is not always accepted with high levels of confidence at upper levels within councils and this presents an ongoing barrier to progress on adaptation. It was highlighted that it may only be one or two councillors (or managers within an organisation) who hold these views, but this opposition to accepting the reality of climate change can reduce the priority given to adaptation. For example, one participant explained how in a recent district plan review the explicit mention of sea-level rise was removed by decision makers from draft new rules to limit development at the coast in anticipation of sea-level rise effects.

This was reported as not uncommon when it comes to climate change issues. Another participant explained that discussing climate change adaptation is avoided in their team. They noted a preference for framing issues and responses in ways that do not engage directly in climate change and climate adaptation language, as this can be more acceptable to decision makers (who may be opposed to engaging on climate change issues). This can work because many climate change issues already arise in other areas, such as coastal-hazards management, meaning that explicit reference to 'climate change' may not need to be engaged in to achieve results with the aim of reducing climate change impacts in the future.

Even though all participants accepted the occurrence of sea-level rise, they gauged the relative importance of the risks differently. Some felt that sea-level rise was one of the most important climate change impacts for the Auckland region. Others viewed the risks as relatively small, far into the future, and / or manageable with adjustment to current flood-risk measures. Some noted that sea-level rise research is in competition with other issues and that managing it is not important enough to warrant serious effort at this point in time.

Experts reported that public perceptions of coastal-hazards risk are low

Participants reported that public perceptions of coastal-hazards risk in the Auckland region are low because coastal inundation is infrequent, rarely affects private property or damages buildings, and is localised when it occurs. Recent coastal inundation around Auckland may have heightened awareness of coastal-hazards risk, although the occurrence of damaging coastal events remains infrequent and few people would ever have experienced damage to their property due to a coastal storm event. Participants saw low perceptions of coastal-hazards risk (by the public and councillors) as a barrier to introducing new coastal-hazards management practices. Some participants took the view that because the perceived risk is low, members of the public or council will be unwilling to accept changes to status quo coastal management. Interview participants emphasised the importance of actual erosion or flooding events as drivers of action and change, noting that until several significant damaging events occurred in the region it would be hard to progress policy that might limit development.

There is debate over what level of sea-level rise to prepare for

There are large uncertainties regarding the rate at which sea level will rise this century and beyond. This has led to considerable debate within local government over what level of sea-level rise to plan for, and the call for a 'best-estimate' figure for sea-level rise has been made. The MfE guidance has been prepared to guide councils through a process of risk management, identifying specific sea-level rise values for every decade out to 2100, as well as advice for considering sea-level rise beyond 2100 for land uses and assets that will be long lived. However, because the guidance is not statutory, interview participants expressed concerns that planning based on the MfE guidance may not stand up to being contested in the Environment Court. The 2010 NZCPS (Department of Conservation, 2010) may change this perception. This statutory NPS gives quite specific guidance to councils on how to consider sea-level rise, which, in addition to the MfE guidance, is an opportunity to consider sea-level rise more specifically in plans. However, even if Auckland Council adopts a more comprehensive approach to addressing sea-level rise based on the MfE guidance and the 2010 NZCPS, the issue of potentially faster rates of sea-level rise this century would still not have been addressed, nor would the static risk-management approach have been expanded to include changing risk over time or the potential for surprises.

Local government leaders have called on central government to produce a national environmental standard (NES) specifically on sea-level rise. Although a draft was apparently produced to this effect in 2009, further progress on a sea-level rise NES has stalled. Interview participants noted that adaptation work at their councils has been hindered by uncertainties regarding sea-level rise projections. Confronting decision makers with information that is uncertain as to timing and levels of sea-level rise is perceived as providing no clear answers regarding change and consequently can result in the issue being disregarded. In some cases decision makers have seen uncertainty as a reason for inaction. There is also a lack of understanding that there is no 'best estimate' of sea-level rise, and that one is unlikely to be predicted.

National-level leadership could strengthen local adaptation planning

Climate change mitigation, rather than adaptation, has been the main focus at central government level. Resourcing of adaptation work is currently minimal at central government level. This appears to have impacted upon the progress of local government in managing this relatively new and complex set of issues. An opportunity exists to enable climate change adaptation at the regional and local levels through national-level leadership. This could be achieved a number of ways, including a climate adaptation strategy and research agenda, a NES framing sea-level rise and coastal management, and more specific guidance on the dynamic and ongoing nature of coastal risks and the need for long-term adaptive management approaches.

There are leadership, strategic planning, and integration opportunities for the new Auckland Council

The council amalgamation process emerged in this study as a limiting factor, as multiple work streams on sea-level rise management discussed in this study were put off by the Auckland councils in anticipation of amalgamation. How work in this area is to be continued under the new Council and governance structure was unknown, but the view of participants was generally that the new Auckland Council could not afford to ignore this issue and would need to make decisions regarding response to the latest sea-level rise projections and increasing coastal-hazards risk.

Leadership and support for adaptation to sea-level rise is required at a political level to progress proactive responses: to fill knowledge gaps, develop policy and response options, and to engage in participatory decision-making processes in affected areas. However, leadership to drive sea-level rise adaptation was identified as lacking within the Auckland councils that participated. Some participants noted that a strategic approach from a management level is required to overcome some of the identified barriers to progressing coastal adaptation.

Auckland Council is a unitary authority with joint regional and district council roles and responsibilities, and is developing a 30-year spatial plan and unitary plan for the region. These long-term planning documents offer a significant opportunity to develop specific objectives, policies, and rules regarding sea-level rise and coastal change for the Auckland region that have not previously been developed for much of the region. It has been shown in a number of case studies that to do this successfully through the planning process requires high-quality coastal-hazards mapping and a participatory community decision-making process. It seems unlikely that Auckland Council will achieve either of these, given the short timeframes allowed for the development of the present round of spatial and unitary plans (1 and 2 years respectively). However, the Auckland Council's spatial and unitary plans could include providing for the separate development of a strategic Auckland region climate change adaptation strategy, which could provide the regional leadership called for by participants in this study. A risk with a separate adaptation strategy is that it may not be sufficiently integrated with other aspects of planning, such as land use and transport infrastructure planning. However, a key purpose of such an approach would be to resource adaptation planning, which could then be integrated into the spatial and unitary plans through reviews processes, but of course this would require ongoing political support and follow-through.

Shift the focus from reactive coastal-hazards management to integrated coastal-zone management

Currently the focus is on reactively managing coastal hazards affecting existing property. A balance will need to be struck between protecting private property and maintaining natural and social (amenity etc.) values at the coast. It is clear that the balance can end up favouring private property needs at the expense of the natural coastal system or long-term community interests. A shift of focus from coastal hazards being a private property protection issue to being a coastal systems and sustainable-management issue could better enable proactive adaptation to coastal change. This approach is already implicit within the legislation (e.g. the RMA and Local Government Act), but does not appear to have gained acceptance from individual private property owners in many instances, as reported by interview participants.

The new Auckland Council coastal land and water team could provide the framework for integrating coastal-hazards management into a comprehensive coastal management approach. Coastal issues and management differ in some respects from other areas of natural-hazard management in that erosion and inundation are typically geographically limited and, compared to other natural hazards such as earthquakes, can—to some degree—be estimated. However, as with other natural hazards, managing coastal hazards involves a complex nexus of social, environmental, and economic trade-offs relating to private property. Introducing sea-level rise further differentiates coastal hazards from some other major natural hazards (e.g. earthquakes and volcanoes) as coastal-hazards risk is progressively increasing over time. Incorporating this dynamic view of coastal hazards management into integrated coastal zone management (ICZM) for the Auckland region could provide an important means to identifying these developing issues and engaging in a public conversation on sea-level rise response options.

4.3 Adaptation response options at the study sites

Participants were asked a series of questions regarding the implications of, and potential for, response options at the study sites. One percent AEP static inundation maps (Appendix 4) were shown to the participants, and coastal-hazard issues and management-response options at the study sites were discussed to set the context for this section of the interview.

Participants in this study viewed council involvement in adaptation for existing settlements as particularly complex, including interactions and conflicts between high-value properties, public expectations, risk perception, property rights beliefs, and environmental risks. Most of the interview participants felt that coastal protection and accommodation measures would offer the most practicable, acceptable options to respond to increasing coastal hazards in the future. Managed retreat was seen as a prohibitively expensive and unpopular response, making it untenable at highly developed high-value settlements. Most participants also felt that retreat could potentially be achievable at smaller, low-value settlements.

Participants emphasised the importance of the new Auckland Council in:

- developing and disseminating information on changing coastal risk
- ensuring that further development in areas susceptible to coastal hazards is minimised
- educating private property owners regarding the joint responsibility of property owners and the Council for adaptive response at existing sites
- using a participatory process for decision making in response to coastal hazards for existing settlements.

4.3.1 Limits to current measures for managing coastal hazards

For both study sites, most participants felt that for changing coastal inundation risk up to 0.5m sea-level rise, the current approach and / or relatively small scale, incremental adjustments to current structural protection and accommodation measures would adequately manage risks, in combination with emergency planning and private insurance. Some interview participants raised the issue of changing insurability for coastal property and a number of views were expressed regarding this issue. One view was that insurance companies would continue to insure properties, but with higher premiums, and that properties may become uninsurable. The issue of insuring coastal properties needs to be considered in decision making for adaptation assessment and development. However, little information is currently available in New Zealand on how insurability may change with climate change.

The change in inundation risk from a 1.0m sea-level rise or more was expected to require a significant shift in response. Many participants identified the existence of a threshold somewhere between 0.5–1.0m of sea-level rise, where the response approach would need to shift dramatically. These responses were based on the participants' judgements of inundation maps shown in the interviews.

Richard Reinan-Hamill (Senior Coastal Engineer, Tonkin & Taylor) anticipated that structural coastal protection works would be able to protect coastal settlements, and in particular the two study sites, with substantial rises in sea level (e.g. the scenarios discussed in the interviews went up to 2m sea-level rise and corresponding change to static inundation extent during a 1 percent AEP storm). Reinan-Hamill referred to the Netherlands, where land as much as 3m below sea level is protected from inundation to a 1000-year event standard, as an example of the technological and physical ability to engineer the coast against erosion and inundation. Reinan-Hamill estimated that any technological or physical limits to coastal protection would be very far off in the future (i.e. not this century). From this it can be inferred that economic and social limits are more likely to be met before any physical limits to coastal engineering and individual flood protection (and accommodation) works are reached. For example, several participants noted that high sea walls or houses on stilts might be unacceptable to some people, perhaps due to a perceived negative change to visual amenity.

4.3.2 Mission Bay / Kohimarama

Participants considered that Auckland Council would be likely to continue protecting Tamaki Drive from erosion by maintaining and adjusting (raising) the current sea wall and renourishing beaches. Reasons given for this included the high value of Council-owned assets along this coastline, the area's high amenity value for the Auckland region, the high value of development in the area, that Mission Bay / Kohimarama is home to some of Auckland's wealthiest and most powerful residents, Council aversion to loss of rating income under a retreat strategy, and a general aversion to attempting retreat in this area. It was widely assumed that the cost-benefit analysis for response options at Mission Bay / Kohimarama would weigh in favour of protection or accommodation works.

Erosion beyond the current sea wall is not expected to affect Mission Bay / Kohimarama because it is expected that the current coastline will be maintained. In the absence of maintaining the current coastline, erosion could occur at Mission Bay / Kohimarama once the Tamaki Drive sea wall is being regularly overtopped at high tide and during storms.

A number of issues and concerns were raised relating to coastal protection for this coastal area. These included: the equity issues around general rates paying for engineered protection for a small number of (wealthy) coastal residents, safety issues around major storm events overtopping sea walls and causing severe damage, the financial costs of coastal protection for council, and the environmental implications of further structural coastal protection.

A variety of response measures were seen as feasible

Various strategies to deal with the above issues were considered plausible. Targeted rating attached to flood-prone properties was suggested, to direct the costs of protection to those who are being protected. Targeted rates are just one example of a funding mechanism to enable an adaptive response and it was considered that further research into the specifics of financial tools for response options is needed. Flood-protection measures, such as pumping stations, were widely seen as being required if the Tamaki Drive sea wall was to be progressively raised.

In light of the negative associations now held about structural coastal engineering, suggestions were made regarding non-structural coastal protection works and accommodation measures being used at Kohimarama / Mission Bay. Beach renourishment, dune restoration, and individual flood-protection measures were all seen as viable options for the area. However, concerns were raised about the costs of recontouring the land and of how individuals might afford the additional costs of flood proofing their homes.

Some felt that adjusting the sea wall would not be acceptable to Auckland Council or the public, due to reasons like the degradation of environmental values that may result from this approach, or the high cost of ongoing protection works. In these cases, accommodation responses were seen as the most appropriate response option. Accommodation measures to protect individual property, such as raising minimum site and freeboard levels, floodable basements, creating additional water storage areas, and redirecting traffic during flood events were all viewed as appropriate and achievable responses that would adequately protect against increased inundation risk due to sea-level rise.

Retreat at Mission Bay / Kohimarama was not considered economically feasible

Retreat at Mission Bay / Kohimarama was not considered as economically feasible due to the very high value of coastal property in this area and due to perceived community resistance to this response approach. It was widely considered that residents would live with (accept) the risk of flooding, rather than leave their home, and would strongly resist any financial or psychological loss that may result from a retreat response. Compensation for land abandoned was not considered economically feasible for council, but even if compensation were available, it was felt that many residents would continue to resist leaving their homes.

Ngāti Whātua involvement in decision making is important

Several participants noted the importance of this area to Ngāti Whātua (local iwi), particularly the co-managed tribal land at Okahu Bay (adjacent to Mission Bay). No participants felt able to give comment on issues for Ngāti Whātua relating to sea-level rise and coastal management in the area, except Bernadette Papa (Ngāti Whātua) who was asked to participate to specifically discuss issues for Ngāti Whātua. Papa noted the importance of progress made towards positive environmental outcomes for water quality and ecosystem health in Waitemata Harbour through the co-management of Okahu Bay and involvement with ARC in coastal marine area (CMA) management.

Papa emphasised the importance of Ngāti Whātua participation in decision making for the coast in response to sea-level rise. Papa expressed concern at the idea of the area undergoing any *further* environmental degradation. The area has been modified to such a significant degree already, and recent (slow and minimal) ecological restoration progress achieved through the efforts of Ngāti Whātua would represent a significant loss to the iwi. However, conflict could emerge around this issue as a burial ground sits close to the Okahu Bay coastline, which may result in protection being a preferred option by some Ngāti Whātua leaders.

4.3.3 Kawakawa Bay

Coastal protection works were not considered economically feasible at Kawakawa Bay

In contrast to Mission Bay / Kohimarama, it was generally considered that coastal protection works would not be economically feasible at Kawakawa Bay because of the low value and low density of property at the settlement. This highlights the potential for bias in conclusions reached on the basis of cost-benefit analysis alone, where lower-value areas show lower benefit to cost ratios (Cooper & McKenna, 2008). Accommodation measures to protect dwellings from floodwaters were considered the most likely response option. The role of council in enabling individual-scale accommodation measures was considered (for both sites). The resource-management process was considered onerous or ‘punishing’ for these types of alterations and the costs on individuals can be high.

Councils could look at removing potential barriers to individuals flood proofing their homes, such as providing funding assistance for affected property owners to make alterations.

Retreat was considered to be more economically feasible at Kawakawa Bay

The comparatively low number of properties affected, and numerous areas of undeveloped land at Kawakawa Bay, lend merit to considering a planned retreat approach. Even given these favourable conditions, participants felt that there would be a lack of community acceptance for any retreat scheme. However, the small size of the settlement and the potential for local land being made available for relocation of property or new development for displaced residents were confirmed as making retreat more readily envisaged in this area. The distance of Kawakawa Bay from central Auckland (and its location outside the metropolitan urban limits) means that property values are lower than in central suburbs. This implies a significantly lower potential economic loss to property owners in this area, and concurrently a lower cost to the council for any compensation offered. Issues concerning specific retreat implementation options were discussed with interview participants and the results of this discussion are summarised in Appendix 2.

Retreat would require a long-term approach and a suite of responses to address relocation, compensation, and equity issues

Interview participants noted that, to achieve retreat, councils would need to employ a combination of policies and measures. A suite of response options would be needed that address issues such as: relocation to another site, a long-term approach to retreat if a large number of dwellings are involved, and the potential for some financial assistance for those being relocated. Participants also emphasised that a retreat decision would have to be supported by the affected property owners to be implemented successfully. This is why both participatory decision making for voluntary retreat, and strong national and regional direction are seen as fundamental to achieving a shift from the coastal-hazards management status quo of structural coastal protection. The 2010 NZCPS (Department of Conservation, 2010) provides clearer direction than the previous NZCPS (1994) for councils regarding sea-level rise and coastal-hazards management, but does not include quantitative ranges for planning for sea-level rise. However, there is statutory provision in the RMA for NES, which could include such guidance.

Lower-income areas that do not have existing structural protection are vulnerable to inundation and will require assistance

The situation for Kawakawa Bay, described by participants, highlights the potential for inequitable coastal-management outcomes occurring as coastal risk increases over the twenty-first century. Coastal-hazards management responses are predominantly determined through cost-benefit analysis of response options on a short-term time scale (with net benefit seen as avoided loss of property today less costs of building protection today), with urgency proportional to the potential property values concerned. Other economic considerations, such as difficult-to-quantify non-economic values, and long-term costs and benefits, are rarely taken into account. Small, lower-socio-economic status communities are less likely to be afforded public intervention for coastal-hazards management. If Auckland Council decides not to protect its assets through structural or non-structural coastal engineering at Kawakawa Bay, coastal residents will be left exposed to worsening erosion and inundation of their properties over time. Some property owners in these areas may not be able to afford flood-protection works, and could then lose the ability to insure their property as sea levels rise and inundation becomes a certainty. This could leave lower socio-economic households more vulnerable to sea-level rise and coastal hazards as local and central government affords protection to high value assets and leave individuals in lower-value areas to fend for themselves. Alternative responses need to be investigated and developed for areas not protected by structural coastal engineering (structural and non-structural).

4.3.4 Existing use rights

Existing use rights are commonly identified as a barrier to attempting planned retreat from coastal hazards. However, this assumes that the approach taken would be one of 'compulsory' retreat without prior community buy-in. Participants in this study have identified the requirement of community buy-in for *any* coastal-hazards management response. Any coastal-hazards management approach will have to go through, at the very least, a public consultation process. For managed retreat, a more involved participatory process has been advised. This implies that retreat would be agreed to before the introduction of any specific rules by Council to require retreat. Experience with retreat in the Auckland region (Atlas Commnications & Media Ltd., 2010) shows that if a participatory planning approach is undertaken along with financial assistance, planned retreat can be successfully implemented. Further to this, the RMA allows regional councils to expunge existing use rights (compulsory) in response to natural-hazards risk.

4.3.5 Local infrastructure

In the case of any of the three key response approaches being followed, local infrastructure will need to follow suit to ensure the success of the approach. This highlights the need for a strategic approach to managing changing coastal risk. If resource consenting at the individual development scale is relied upon, serious adverse social and environment effects could be incurred, that could result in a maladaptive (Barnett & O'Neill, 2009) response incurring future costs through inflexibility.

4.3.6 Regional implications

There are a significant number of low-lying settlements in the Auckland region that will be affected similarly to the two settlements considered in this study. Mission Bay / Kohimarama and Kawakawa Bay represent contrasting situations for the Auckland region in terms of their proximity to the city centre, population, and intensity and value of existing property development. The Auckland Council is faced with a range of critical issues related to sea-level rise in different areas and for different types of land uses across the region (e.g. the CBD, the international airport, Tamaki Scenic Drive, culturally significant coastal sites, and regionally significant roads). These will pose competition for resources with potential damage avoidance in existing residential areas. There will be limits to rates increases to cover the many other pressing issues. This may mean that accommodation measures will be preferred as an incremental approach. However, this would ignore the potential for maladaptation, especially for assets and settlements that will be around beyond 2050 or 2100. Such an approach could be viewed as short term and purely interim, thus longer term strategic planning for response to sea-level rise will be required.

5 Conclusion

This study presents site-specific results of the potential impacts of coastal inundation as sea-level rises. It analyses adaptation opportunities and barriers for two coastal communities on the east coast of New Zealand's largest city, Auckland, and draws on the views of local government officers, coastal issues consultants, and community members as critical stakeholders. The views expressed in interviews with these stakeholders highlight that significant social and institutional barriers continue to constrain responses to this emerging challenge. Limited options for managing sea-level rise are seen within existing coastal-hazards management avenues. This suggests that wider perspectives and alternative avenues need to be considered and developed. For example, a strategic regional perspective; Māori, social justice, and equity-focused perspectives; and non-economic values assessments could assist in reframing the needs for, and implications of, a range of response options, and the values associated with specific areas.

Table 5 summarises the key findings of this study and relates them to the research questions investigated. This study found that current coastal management at the participating councils is in the early stages of taking sea-level rise effects into consideration, and that in most instances the use of adjusted flood-mitigation measures (e.g. minimum site levels) is considered adequate by many participants for protecting private property against hazard risk. However, guidance information generated by participating councils has not taken into account the potential for high rates of sea-level rise by 2100. When asked to consider the implications and responses required for higher sea-level rise scenarios, opinions expressed during interviews in this study shifted considerably and more substantial, costly, and controversial management responses were considered as being necessary. Recent internationally published projections (e.g. Pfeffer, et al., 2008; Rahmstorf, 2007) indicate that the *rate* of sea-level rise could increase dramatically in the second half of the twenty-first century. This means that responses could be required much more rapidly in the future, if proactive responses are delayed. This could have significant structural and economic implications for future generations.

5.1.1 Planning under uncertainty

Uncertainty surrounding sea-level rise projections, climate change scepticism, the low priority of coastal hazards, and the perceived unpopular nature of sea-level rise information and adaptation options have favoured responding to near-term development pressures rather than attempting long-term thinking to manage Auckland's coastal environment and development. Uncertainty surrounding sea-level rise appears to particularly provoke ongoing debate within local authorities. Some confusion appears to exist around the physical science basis, where uncertainties stem from, that uncertainties are unlikely to be 'resolved'; the interpretation and use of the MfE guidance on sea-level rise and approaches for decision making under conditions of uncertainty. Numerous scholarly works and practical examples of decision making and planning under conditions of uncertainty exist. However, it seems unlikely that many of these issues will be resolved without central government guidance, which was announced in the form of a forthcoming NES in early 2009, but is yet to eventuate. However, the recent release of the updated NZCPS (Department of Conservation, 2010) does provide some important direction, and could provide much of the national guidance required if proactively implemented.

Table 5. Summary of key findings of this study

Research questions				
How will sea-level rise affect extreme sea levels and coastal inundation risk?				
What are the implications of sea-level rise at Mission Bay / Kohimarama and Kawakawa Bay?				
What social and institutional barriers constrain coastal adaptation and what opportunities are present for improving adaptive capacity?				
What opportunities and barriers exist for specific response options at the study sites? In particular, for managed retreat?				
Key findings and themes	Green	Pink	Purple	Blue
Sea-level rise will progressively raise extreme sea levels and increase the risk of coastal inundation at the study sites.				■
The number of properties and total value of property potentially affected by coastal inundation (for a 1 percent AEP) increases at both sites to a significant degree for each of the three sea-level rise scenarios assessed.			■	
Existing coastal-hazards management issues largely influence response to sea-level rise to date. Barriers related specifically to incorporating sea-level rise into coastal-hazards management also exist.		■		
Examples of key issues and barriers include: inadequate leadership at all levels of government, lack of a strategic approach to either coastal-hazards management or climate change, the need for integration across areas of council activity, and knowledge gaps.		■		
The uncertainty of sea-level rise projections has resulted in some councils using single figure 'best-estimate' scenarios, which underestimate the real risk of the higher-end projections, and could result in maladaptation.		■		
National guidance from a national environmental standard has been widely called for. The new NZCPS provides clearer guidance to councils on sea-level rise, but it does not include quantitative sea-level rise estimates for planning purposes.		■		
Information, education, and engaging in a participatory decision-making process were seen as key components of an adaptive response to changing coastal-hazards risk.		■		
Windows of opportunity will need to be taken to enable adaptive responses. Future coastal hazards (flood and erosion) present opportunities to review current practices, learn from mistakes, and institute more adaptive and resilient practices.		■		
Coastal-hazards management responses can elicit strong responses from communities, which can vary significantly from community to community and individual to individual.		■		
Technological limits to structural coastal protection works are not seen as constraining within a relevant timeframe. Socio-economic / environmental limits to coastal protection measures are more likely to drive alternative responses.	■			
Significant barriers to attempting planned retreat in developed settlements exist, even for small settlements public opposition to retreat is seen as making it highly unlikely, unless strategically presented (see Appendix 2).	■			

5.1.2 Considering sea-level rise in regional planning

It was found that ARC, ACC, and MCC generally acknowledged the serious implications that sea-level rise may have for the region, and have begun to consider sea-level rise within council activities. However, a number of issues were identified regarding this.

- Existing coastal-hazards management issues are central to issues and barriers to preparing for coastal change due to climate change and sea-level rise.
- Current understanding and research is limited. There has been limited assessment of the effects of sea-level rise and climate change. The Auckland region lacks comprehensive or integrated assessment. There has been no assessment of potential socio-economic impacts and no analysis of response options.
- Issues specific to sea-level rise—such as its long-term progressive nature, uncertainty surrounding projections, and the inability to establish a 'best estimate'—have not been adequately considered.
- No comprehensive strategic approach, or process, has been established regionally or locally to prepare for projected coastal change or climate change more generally.
- A process (such as the risk-management framework in the MfE guidance) has not yet been adopted. However, several natural-hazards guidance notes exist that recommend the same or similar risk-based management.
- The issue of existing development had yet to be addressed.

5.1.3 Preparing for coastal change today

Participants in this study emphasised four key points relating to the response of local government in preparing for coastal change *today*.

- The importance of making coastal hazard information available to the public.
- The importance of understanding and framing the issues for communicating and educating the public about the risks and response options.
- The importance of local decision making for specific responses to coastal change for existing development (i.e. a participatory decision-making processes for existing development threatened by coastal hazards).
- The importance of avoiding further coastal development and intensification of existing coastal development (avoiding further increase in numbers of properties that will be affected).

5.1.4 Costs of flooding and flood-protection measures

The costs of coastal engineering and flood-protection measures to avoid loss of land and damage to property will continue to increase over time, and (if employed) would transform the Auckland coastline into a highly modified, engineered, and *high-risk* coastal hazard area, even though coastal-engineering protection aims to mitigate hazard risks. The risks of damage to property and loss of human life associated with engineering and other flood-mitigation measures have been demonstrated by catastrophic flooding in the Netherlands; and more recently in the United States, particularly in New Orleans and along the Mississippi River; and in Queensland, Australia. The impacts of flooding are well-recorded and not only damage property, but include lasting psychological impacts, erosion of social capital, and loss of confidence in government.

5.1.5 Response options

No matter what response approach is adopted, participants emphasised the importance of a strategic regional approach and community involvement in decision making. A regional approach to estimating the costs of adapting to sea-level rise may also significantly modify benefit-to-cost ratios, and in any case a static benefit-cost analysis approach is unlikely to be the most appropriate decision-making tool for dynamic coastal-hazards management.

The need to consider managed retreat from the coast has been signalled in New Zealand through the recently revised NZCPS (Department of Conservation, 2010). However, none of the councils that participated in this study had considered retreat options before engaging in this study. Council participants had limited knowledge of retreat concepts, options, and implementation, which limited the breadth of discussions in this study. The regional implications of widespread impacts of increasing coastal inundation indicate that public intervention to engineer the coast to protect both public and private assets is unlikely to be feasible at all sites affected, and that alternatives to 'protection' need to be actively investigated by Auckland Council. Accommodation measures are seen as a likely response. However, given the ongoing nature of sea-level rise it is likely that flood-protection measures will eventually become ineffective. Retreat is likely to be needed in at least some areas. This poses two significant issues: the first will be the equity issues involved in opting to protect some areas and not others, especially if protected areas have high socio-economic status and unprotected areas do not. The second will be the significant social barriers to planned retreat responses. It is likely that these two issues will pose lesser barriers if the longer-term dynamics of sea-level rise are better understood, and early consideration of options and their long-term merits, is undertaken.

A top-down response from any council is likely to elicit strong resistance from local communities. Adaptation strategies developed at the local scale with community buy-in are more likely to be successful. This means that decisions about a process for developing an adaptive response and investing in and starting that process are needed at the outset. Based on the input of participants, the following requirements for an effective adaptation strategy are summarised below.

- A regional strategic approach.
- A physical and social scientific evidence base.
- Identification of at-risk areas of all types (residential, commercial, rural, and natural ecological systems; including areas with exposed long-term public infrastructure such as bridges and coastal amenities) and their respective socio-economic vulnerability.
- An initial analysis of response options for each affected area, with priority accorded to the most vulnerable areas;.
- Council coordination and provision of information.
- Local-scale community plan development and decision making.
- Restriction of further development in 'coastal change' zones.
- Planning approaches that signal dynamic coastal hazard risk for at-risk properties, assets and infrastructure.
- Acknowledgement of the long-term nature of adaptation and strategies for ensuring that adaptation efforts are not short lived (i.e. follow-through).

Auckland Council has access to a range of New Zealand and Auckland-specific tools and guidance for assessing coastal hazards over long time periods, including sea-level rise and other climate effects (Auckland Regional Council, 2000; Auckland Local Authority Hazard Liaison Group, 2002; Ministry for the Environment, 2008). Requirements to comprehensively prepare for increasing coastal-hazards risk are well documented in the New Zealand and international literature (Dawe, 2008), and areas more critically affected by coastal hazards (today) than Auckland offer important examples of the process and potential pitfalls for coastal-hazards management in New Zealand (Blackett, et al., 2010). Auckland Council has recently been in a process of establishment, but is now positioned as the authority empowered to lead the Auckland region to prepare for adaptation to sea-level rise and other climate change effects.

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7 Appendices

Appendix 1: Sea-level rise response options

Sea-level rise response options, adapted from Bjilisma et al., 1995; Feenstra et al.; 1998; Klein et al., 2001.

Response Strategy	Type of adaptation		Timing of adaptation	
	Autonomous	Planned	Reactive	Proactive
Protection				
Hard structural options				
Dikes, levees, floodwalls		▯	▯	▯
Seawalls, revetments, and bulkheads		▯	▯	▯
Groynes		▯	▯	▯
Detached breakwaters		▯	▯	▯
Floodgates and tidal barriers		▯	▯	▯
Saltwater intrusion barriers		▯	▯	▯
Soft structural options				
Periodic beach nourishment		▯		▯
Dune restoration and creation		▯		▯
Wetland restoration and creation (*managed realignment*)		▯		▯
Afforestation	▯	▯		▯
Accommodation				
Emergency planning and management	▯	▯		▯
Modification of land use	▯	▯	▯	▯
Modification of infrastructure				
Modify buildings and building codes	▯	▯	▯	▯
Protect threatened ecosystems		▯		▯
Regulation of hazard zones		▯		▯
Hazard insurance to reinforce hazard regulation		▯	▯	▯
Provision of information about climate change risks for coastal properties				
Limiting ground water use to limit salt water intrusion				
Retreat (planned and unplanned)				
No new development in susceptible areas	▯	▯		▯
Conditional phase-out of existing development		▯	▯	▯
Withdrawal of government subsidies		▯	▯	▯
Abandonment of property	▯		▯	

Appendix 2: Managed retreat implementation options

Including qualitative assessment of the distributional effects, barriers, enabling factors, time frame and limitations of implementation options (Reisinger et al.; in print).

Primary measure	Implementation detail	Distributional effect: who bears costs?	Key barriers and enabling factors	Time frame and certainty of retreat	Limitations
Prohibit/limit protection	Council decision in-principle not to upgrade or maintain, or to remove, existing protection Prohibition of privately funded or maintained protection works	Dependent on implementation details and combination with other measures	**Barrier:** Community resistance, and re-litigation as consequences start to 'bite' **Enabler:** national-level guidance that on-going protection is the exception, with decision-making criteria	Years to many decades Depends on timing and nature of sea level rise and combination of other retreat policies	Does not achieve retreat in itself but allows the physical process to occur and thus triggers need to move or abandon properties
Information on inundation and erosion risk	Preparation and publication of risk maps for range of future sea levels by councils Notification of future risk on Land/ Project Information Memoranda (LIMs and PIMs) for range of future sea levels	**Councils (community)** for preparation of risk maps **Owners of at-risk properties** if properties lose value; but no clear evidence that risk disclosure reduces property values in near term even for present-day risks	**Barriers:** Legal challenges to technical details; modelling erosion difficult; high costs for councils with long coastline **Enabler:** legislation to require preparation and disclosure of maps, including sea levels; central agency to fund or do risk assessments	First-pass modelling could be completed within a decade Many decades for complete abandonment of properties	Does not result in retreat per se but a precursor for retreat. Resulting retreat not likely to be consistent across properties unless additional planning controls put in place
User-pays for protection and insurance, based on actual risk	Removal of government-guaranteed insurance (through Earthquake Commission) for catastrophic coastal erosion and inundation Funding of protection works only through targeted rates levied on at-risk properties	**Owners of at-risk properties** whose costs of protection increase, or who can no longer afford protection	**Barrier:** Long history of government guaranteed insurance for flood and other natural hazards **Enabler:** unwillingness of community to pay for protection of a few properties; central government decision to change government-guaranteed insurance	Dependent on physical characteristics of coast as well as attitudes of property owners	User-pays approach removes community values from coastal management No recognition of ability to pay and its social implications Could still result in loss of beach amenity if property owners decide to meet protection costs
Change betterment limits to Earthquake Commission Act	Enable Earthquake Commission to make proactive payouts for flood proofing, relocation, and possible land purchase, rather than replacement of like with like	**Property owners** no longer able to reinstate their properties **Central government** liability could increase in short term	**Barrier:** Priority not given to long term cost reduction **Enabler:** legislation change to Earthquake Commission Act	Legislative change could be given effect quickly Would reduce exposure to risk over decades as damages occur	Reactive approach as only effective after buildings have been damaged; planning controls needed to shift from damage driven to proactive approach

Regulations limiting further development or reinstatement	Define hazard zones where further development or reinstatement after storm damages is prohibited Progressively extinguish existing use rights for properties at risk (subject to additional criteria and trigger points such as erosion events)	**Property owners** whose development potential is limited **Property owners** who lose existing use rights either following damage or because trigger point has been reached	**Barrier:** Legal challenges to hazard zones; interpretation of hazard zones as static and thus defining a "safe" space for landward development **Enabler:** central government guidance on hazard zone definition; funding for risk assessments; collaboration between Regional and District Councils	Hazard zones limit further development immediately Time-bound hazard zones (e.g. "area at risk by 2100") need to be re-drawn when sea level rise projections are revised or planning horizons change	Hazard lines can encourage development behind hazard line Disproportionate negative effects on property owners with lower socio-economic status
Relocation, removal, dismantling	Require relocation of buildings within property boundaries Require removal of buildings from coastal properties and transport to other blocks of land Dismantle buildings	**Property owners** face costs for removal and loss of equity in existing property, unless supported by other funds	**Barrier:** removal from beach-front blocks of land implies loss of status **Enabler:** clear trigger points for relocation/removal/dismantling-timeframes and council plans; community buy-in	Near-term up to many decades depending on rate of inundation and erosion	Lack of alternative blocks of land to receive removed buildings in highly developed suburbs Depending on the proximity of the at-risk property to the coast, on-site relocation may only be effective in the short-term
Re-zoning	Change land-use through re-zoning to public spaces and facilities, together with extinction of existing use rights following suitable triggers (such as end of lifetime of current owner)	**Property owners** whose ability to sell or extend their property is curtailed and limited to their own occupation or rental	**Barrier:** could result in depressed prices for residential properties and change character of suburbs **Enabler:** locations with mixed uses now may have greater potential for changing the mix; increase in public amenity values	Zoning changes could be signalled and implemented over time frames ranging from immediate to many decades	Additional measures would be needed to achieve complete retreat or transition to soft-buffer land uses, including mechanism for removal of buildings
Council purchase	Councils purchase at-risk properties (on voluntary or compulsory basis) and either dismantle or rent/lease back properties for fixed terms	**Community** bears primary cost if funded from rates or general taxes **Property owners** who saw properties as intergenerational investment bear secondary cost **Community and property owners** if shared approach	**Barrier:** difficulty of defining market value for at-risk properties; high costs for some locations; forced purchase difficult to enforce **Enabler:** wealthy community with strong community values; central government fund; legislation that facilitates forced purchases under certain conditions; tax incentives for property sales; community fund	Flexible; could state the timing of acquisition well into the future, or make it dependent on trigger points like sea level rise or dune movement/erosion Can be proactive rather than reactive (i.e. don't need to wait for erosion to occur)	May have highly disparate effects depending on social or cultural significance of properties to owners Risks encouraging further beach-front development since it implies certainty of future value Ostensible wealth transfer from community to select individuals if funded by community

Appendix 3: Summary of NIWA extreme sea levels methods and results

Annual exceedance probability (AEP) levels were derived from a generalised extreme value (GEV) model, and the 1 percent, 2 percent, 10 percent and 50 percent AEP sea levels were converted to land contours, using GIS software and LiDAR based digital elevation models[13] (made available by Auckland and Manukau City Councils) for present day sea level and for sea-level rise of 0.5, 1.0, 1.5, and 2.0 metres.

To predict extreme sea levels an accurate record of historic sea levels is required at each site of interest. Within Auckland's Waitemata harbour only one tide gauge record exists, positioned at Captain Cook Wharf, Waitemata Harbour. To predict extreme sea levels for the extent of the Waitemata harbour a number of steps were therefore completed (Ramsay et al., 2008a; Ramsay et al., 2008b):

- the long-term (>30 years) digital tide gauge data set was obtained from the Ports of Auckland Ltd., measured at the Captain Cook Wharf, Waitemata Harbour;
- historic storm levels since 1925 were added to this data set to ensure that the largest recorded events were included in the data set;
- extreme sea levels were *predicted* at the gauge site using the measured data;
- the Regional Harbour Model (Waitemata and Hauraki Gulf coasts) was used to create a synthetic sea level record for the sea level gauge site, and extreme sea level values were predicted (GEV model) using the simulated data: these were compared to the values derived from the recorded data set to validate the ability to simulate extreme sea levels for the other sites, which have synthetic data sets only;
- synthetic water level time series were created for the sites around the Waitemata Harbour using the Regional Harbour Model. These were used to predict extreme sea levels for each site using a GEV model fit to annual maxima data.

The GEV model for the Ports of Auckland Ltd. Captain Cook Wharf gauge data set suggested that the highest recorded sea level, which occurred during a storm in 1936 and measured 2.25m above AVD-46[14] (3.99m above Chart Datum), has a return interval of approximately 200 years (0.5 percent AEP). From the GEV model fit derived for each site a scaling factor was determined to translate the measured 0.5 percent AEP sea level of 1936 to each location.

NIWA Results: Change to extreme sea levels, Ports of Auckland Ltd. tide gauge

Table 4.1 shows estimated AEP storm tide levels for the Auckland tide gauge site at Captain Cook wharf, and change to AEP storm tide levels with sea-level rise of 0.5, 1.0 and 1.5m relative to present day mean sea level (2007 MSL). Table 4.1 shows how the water level associated with a given annual exceedance probability will increase with sea-level rise. For example, the 1 percent AEP storm water level will progressively increase from 2.24 (mAVD-46) to 2.74, 3.24 and 3.74 (mAVD-46) as mean sea-level rises to 1.5m above today's. Alternatively you can say that Table 4.1 shows that a storm

[13] LIDAR (Light detection and ranging) based digital elevation models provide accurate and detailed information about the height and shape of the land.

[14] Auckland Vertical Datum 1946.

reaching the water level of 2.24 (mAVD-46) or above (today's estimated 1 percent AEP) will occur nearly *once a year* with 0.5m sea-level rise, and more frequently (>50 percent AEP) with 1.0 and 1.5m sea-level rise.

AEP (percent) Return Interval	50 percent 2 yr	20 percent 5 yr	10 percent 10 yr	5 percent 20 yr	2 percent 50 yr	1 percent 100 yr	0.5 percent 200 yr
Present day (2007) (m AVD-46)	1.89	1.97	2.03	2.09	2.17	2.24	2.34
0.5m (m AVD-46)	2.39	2.47	2.53	2.59	2.67	2.74	2.84
1.0m (m AVD-46)	2.89	2.97	3.03	3.09	3.17	3.24	3.34
1.5m (m AVD-46)	3.39	3.47	3.53	3.59	3.67	3.74	3.84

Table 6. Predicted storm tidewater levels in metres above Auckland mean sea level datum (AVD-46) at the Auckland Ports Ltd. gauge site and their approximate AEP (% and approximate ARI) for the present day and for local relative mean sea-level rise of 0.5, 1.0, and 1.5m relative to present day (2007 MSL).

Appendix 4: Interview schedule

This interview schedule was designed for interviewing participants from councils and was adapted for non-council participants.

Adaptation of existing settlements to the impacts of sea level rise: A case study of two Auckland communities

Introduction (10min)

- Greetings & introduction, overview of information sheet and consent form
- Overview of the research goal and structure of the interview

Interview questions (60 – 75 min)

A. The current approach – limits and trade-offs:

1) Introductory questions.
   a. Name, position, role & responsibilities.
   b. In a few words - how would you describe your council's current approach to coastal hazards management;
   c. and your council's approach to sea level rise?

2) What specific regulatory and other tools does your council use to identify areas along the coast that may be affected by future sea level rise?

3) Has the recently revised Ministry for the Environment guidance been used? Does the MfE guidance made a difference to the coastal management your council undertakes already?

4) a) What planning timeframes does your council use for: 1) coastal residential development, 2) coastal commercial development, 3) coastal infrastructure, 4) coastal hazards, 5) climate change and 6) sea level rise?

   b) What consideration is given to events beyond each of these timeframes?

5) Your council has recently carried out detailed inundation studies into the impacts of sea level rise in terms of extreme coastal events (1% AEP), sea level rise, and coastal inundation for your district.
   a. What action has council taken in response to the information generated by that report?
   b. Have any external responses regarding the reports been received?
   c. Manukau City and Auckland City have both had similar reports completed but considered different levels of sea level rise and different time frames: Why did your council select the time frames and sea level rise scenarios that were used in its NIWA report?

6) Kawakawa Bay and the Eastern Bays - Kohimarama & Mission Bay:

[An introduction will be given here to the sea level rise contours this research project has had modelled for the case study sites; the extent of sea level rise considered; what the contours represent; and the numbers of people and value of assets at risk under each sea level rise scenario, looking at the imagery for each of the study sites and inundation contours for four sea level rise scenarios – 0.5, 1.0, 1.5 and 2.0 metres.]

Under the described scenarios of sea level rise:

   a. What management approach would be required under each scenario of sea level rise described? (e.g. When approximately would the current protection fail to protect the community, and a new approach have to be adopted?)
   b. What type and scale of protection would likely be needed, under each of these scenarios of sea level rise?

c. What would be a rough estimate of the costs of this type and scale of protection be? (For each of the scenarios)
d. How have costs of coastal protection been covered in the past?
e. Would another method of spreading the costs be likely to be needed in future? If so, what approach might be most acceptable?
f. What changes to the current management approach would need to occur to allow for that level of protection (we have discussed being needed) to be enabled?
g. Could the social amenity value of the beach (particularly beach access) be retained if the beach is to be protected to the level required, as discussed above?
h. To what extent might upscaling protection affect the social and environmental values at the coast for the two sites?

B. Including 'managed retreat' as part of the management toolbox:

Managed retreat is sometimes cited as an important potential response option for exposed coastal suburbs as sea level continues to rise.

1) Considering managed retreat as part of the local government toolbox:

a. Could a managed retreat approach feasibly overcome the sorts of limits we have discussed (in Part 1 of interview) as sea level continues to rise?
b. What difficulties might arise for implementation of retreat for *existing properties* as sea level rises?
c. At each of the three study sites, who would be most affected by retreat, and who would benefit?
d. How would the adoption of managed retreat at the three study sites (need to) differ?
e. Over what time frames could implementation options be effective?

2) Barriers to managed retreat:

Some barriers to managed retreat being included as a potential response option to sea level rise impacts (i.e. increased coastal hazards) have been suggested.

Private property rights

Councils can modify private property rights. Private property rights are not enshrined in New Zealand law; however, some citizens espsouse a private property rights perspective and this can exert considerable influence on council activities.

a. How does your council approach the issue of private property rights in relation to coastal hazards?
b. How could perceived private property rights be addressed to enable discussion and planning of managed retreat as a response option?

Costs

a. What cost considerations might constitute significant barriers?
b. Can you please indicate the approximate costs of a managed retreat approach at the three sites?
c. Who would bear these costs?
    i. How could costs be spread across the community?
    ii. How could the distribution of costs affect the feasibility of managed retreat?

Responsibilities of council and property owners

The mandate for and responsibility of local government to mitigate the adverse impacts of coastal hazards for its constituents, is clearly set out in the Resource Management Act and NZ Coastal Policy Statement. This is also reflected in Auckland's Regional Policy Statement and District Plans.

a. Where do you think responsibility should lie for reducing and mitigating coastal hazards?
b. In what ways could councils be adversely affected by not addressing coastal hazard impacts under rising sea level scenarios?
c. How could councils protect against liability while still meeting their responsibilities as sea level rises?
d. How does the current regulatory framework support or hinder the consideration of managed retreat as a response option?

Community views / acceptance

a. How are coastal property owners at each of the study sites likely to respond to the policy options we have discussed today?
b. How is the broader community in the study sites likely to respond to the options we have discussed today?
c. If property owners and the broader community (or parts of the broader community) are likely to object to managed retreat as a policy option, what triggers might change those views?
d. How might the inclusion of managed retreat as a policy option make communities better able to adapt to the impacts of sea level rise?

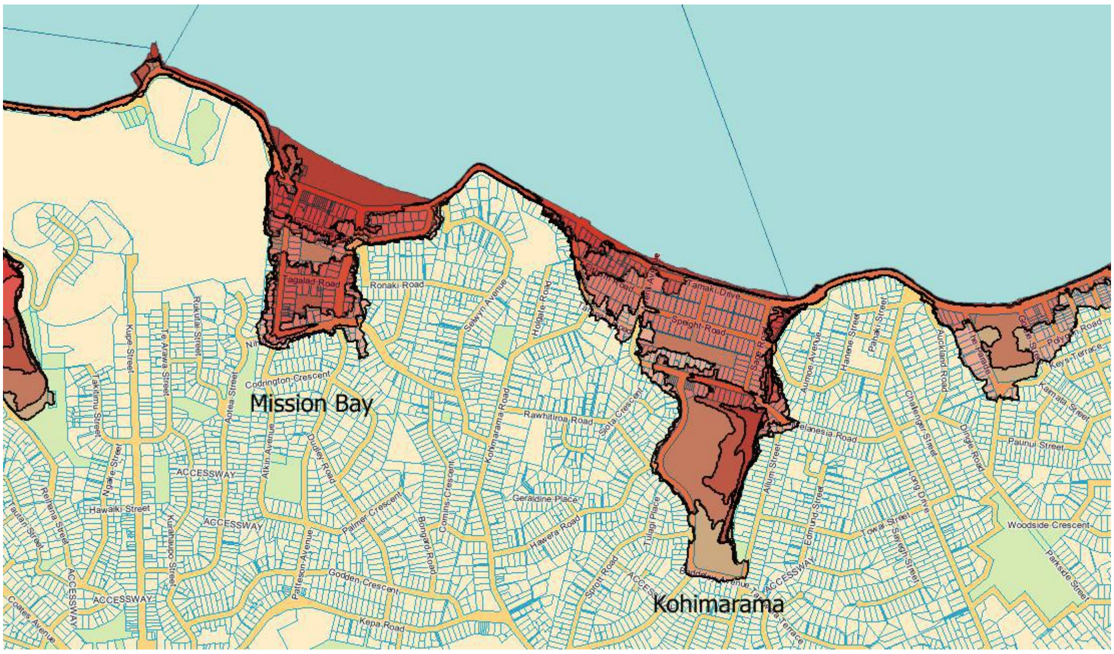

Figure 11. 1% AEP event static inundation contour for 0.5, 1.0, 1.5, and 2.0m sea-level rise at Mission Bay / Kohimarama.

Figure 12. 1% AEP event static inundation contours for 0.5, 1.0, 1.5, and 2.0m sea-level rise at Kawakawa Bay.

Appendix 5: Interview participants

No.	Name	Role	Organisation
1	Paul Walbran	Councillor	Auckland Regional Council
2	Jane Olsen	Manager, natural hazards team	Auckland Regional Council
3	Ryan Paulik	Advisor, natural hazards team	Auckland Regional Council
4	Quentin Smith	Coastal specialist, natural hazards team	Auckland Regional Council
5	Greg Hill	Consultant, planning	Independent
6	Jan Sinclair	Councillor, Kawakawa Bay area	Manukau City Council
7	Colin Davis	Chairman, Eastern Bays community board *former* Councillor, Eastern Bays area	Auckland City Council, Eastern Bays community
8	Confidential contribution	Senior policy analyst	Auckland City Council
9	Rob Harris		Franklin District Council
10	Mohammed Hassan Aida Rodic Bot Holm Zheng Qian	Three-waters team manager (Civil engineer) Storm water management Catchment planning Policy development: land use and water	Manukau City Council
11	Chris Stumbles	Stormwater engineer	North Shore City Coucil
12	Peter Wishart	Planner	Coromandel Thames District Council
13	Bernadette Papa	Analyst, Ngāti Whātua	Ngāti Whātua , Eastern Bays community
14	Bryan Mockridge	Community board member	Kawakawa Bay community
15	Warren Gray Julie King	Senior analyst/advisor (science) Senior analyst/advisor (science)	Ministry for the Environment
16	Raewyn Peart	Policy analyst, Researcher	Environmental Defense Society
17	Mark Bellingham	Environmental scientist	Forest & Bird Auckland
18	Paul Kench	Coastal scientist (physical processes)	University of Auckland
19	Richard Reinan-Hamill	Coastal engineer	Tonkin & Taylor (engineering & planning consultancy)
20	Jim Dahm	Coastal scientist, Consultant	Eco Nomos Ltd.
21	Marilyn Bramley	Resource management law lecturer	Massey University