# Adaptation Strategies to Address Climate Change Impacts on Coastal Māori Communities in Aotearoa New Zealand: A Case Study of Dairy Farming in the Horowhenua-Kāpiti Coastal Zone

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*Huhana Smith[1,3]
Penny Allan[2]
Martin Bryant[2]
Derrylea Hardy[3]
Martin Manning[2]
Murray Patterson[3]
Moira Poutama[1]
Abdullah Richards[2]
Jane Richardson[3]
Aroha Spinks[1]

[1]Te Rangitāwhia Whakatupuranga Mātauranga Ltd;
[2]Victoria University of Wellington; [3]School of People, Environment and Planning, Massey University
(* Dr Smith is the lead author; subsequent authors are in alphabetical order)

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**Reviewed by Dr April Bennett**
**School of People, Environment and Planning**
**Massey University**

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**He moteatea mō te wai**

Ko te mātauranga he wai nō ruawhetū
*Māori knowledge flows from the cosmos / the stars*

Kia mahara koe i te puna inā inu koe i te wai
*When you drink the water, remember the spring*

He pukenga mai te hohanga tangata, he nohanga tangata, he putanga korero
*The spring is likened to a repository of knowledge where the grinding stone made by humans is used; regarded as the place for human wellbeing, and the site from whence knowledge flows*

He wai ki te tāne, he toto ki te wahine.
*Like the water of men, like the blood of women*

Ko wai koe?
*Who are you?*

Ko wai ahau?
*Who am I?*

Ko wai ahau
*I am water.*[1]



Published by the Horowhenua Coastal Climate Change Project Research Team

1 Dr Rangi Matamua delivered this powerful message in his keynote address at the inaugural He Manawa Whenua conference, in Kirikiriroa/Hamilton on 1 July 2013. He provided one of the opening addresses at this conference, organised by Te Kōtahi Institute based at the University of Waikato.

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School of People, Environment and Planning

Massey University

Private Bag 11052

Palmerston North

New Zealand

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# EXECUTIVE SUMMARY

This report summarises the research undertaken in the research project, *Adaptation Strategies to Address Climate Change Impacts on Coastal Māori Communities,* (CO1X1445), which was undertaken for the 18 months ending June 2017, with Māori coastal communities in the Horowhenua–Kāpiti Rohe. This research was funded within the Vision Mātauranga programme of The Deep South Te Kōmata o Te Tonga National Science Challenge. In this project, our research team explored how a better understanding of aspects of the Mātauranga Māori worldview could be explored and developed alongside climate change science, geomorphology, ecological economics and design principles, to inform new paradigms for resilience and adaptation to climate change for coastal Māori communities.

Our teams and cultural informants well understand that Mātauranga Māori is a sophisticated and dynamic knowledge system, which over generations has been challenged and disturbed by misinterpretation, ignorance and disregard to its insights. Whilst we note impacts on inter-generational transference of knowledge or barriers to accessing this ancestral knowledge for benefit of today, more Hapū and Iwi participants are experiencing first-hand how positive intercultural dialogue can activate revitalisation of fragmented ecosystems, which is vital for our future generations' holistic wellbeing. This research approach was harnessed during former research conducted by members of this research team in projects with case studies in the Horowhenua region, including Terrestrial Ecosystem Services for Māori, Manaaki Taha Moana and the Rae ki te Rae Bicultural Design Studio[2], and was integral to this project.

Adaptation to sea level rise in rural and peri-urban areas needs to be done differently to that in cities because of the less intensive forms of coastal development. In considering water management, for example, it must account for more extensive flooding and potential salination of groundwater for the communities who depend on it. The research described in this report sought to address climate change impacts on coastal communities, providing information and capability to help Māori envisage economically sustainable adaptation strategies that will enhance and restore Māori cultural relationships to the coast. The research proposes new forms of holistic engagement with and within coastal societies, which it is hoped will lead to proactive approaches that anticipate change as well as benefit from it. Māori communities collectively hold land as sources of 'cultural identity and mana', a world view where private property values are not based on market monetary values. Preservation of such Māori values in the face of major coastal changes is a significant challenge.

The need for research such as this is increasingly evident, given that New Zealand has significant levels of development in coastal areas that are already affected by sea level rise. Erosion of beaches and the collapse of some coastal infrastructure during storms is already evident in several parts of the country. More subtle and widespread effects such as flooding due to rise in groundwater can also be

[2] See all reports from Manaaki Taha Moana research project funded by the Ministry for Business, Innovation and Employment (and formerly, the Foundation for Research Science and Technology) on the website www.mtm.ac.nz.

significant. In very recent months, communities around Aoteaora New Zealand have been reeling from effects of extreme weather conditions experienced over our summer, and the ill effects of recent flooding of whole townships due to cyclones and increased rainfall. Professor David Frame recently discussed how ‘floods, attribution and the power of citizen science [might] help us understand our climate and be more prepared.’

Our research shows that, for the southwest coastal region of Horowhenua to Kāpiti, localised and forecasted extremes of climate change relate to wide-ranging meteorological hazards. Since 2005, these extremes have been assessed as increasing threats to lifelines and services coming from more frequent heavy rainfall events and associated floods causing a range of problems from erosion and landslides in hill country, to further sedimentation of waterways in coastal plains. Furthermore, sea level rise will increase the impact of high tides and storm surges on coastal erosion. Flooding will make groundwater aquifers near the coastline vulnerable to saltwater intrusion. Changes in temperature and rainfall regimes will cause problems for plant and animal pest eradication programmes.

As the likely climate change scenarios predicted for our coastal region will be experienced more frequently, more extreme weather events and associated flooding of coastal areas will require ongoing solutions-focused research. Our team has synthesised former research results with new findings, as outlined in this report, into a major convergence of effort and experience, in order to tackle the major environmental issue of our time – climate change and its impacts.

Our multidisciplinary research team developed a range of potential adaptation strategies around three broad themes: Protect; Adapt/Anticipate; Retreat. This toolbox of adaptive strategies was formulated based on the research findings which indicated a number of key strategies that (if implemented over time) the research team envisages will maximise economic productivity and protect coastal farms from the variability of climate change impacts. The toolbox is intended to be a guide to the choices farm managers, trustees and shareholders might make over time, based on the most current scientific research about climate change and its potential impact on the coast.

These strategies were developed via a participatory process of hui/wānanga and hīkoi with the local community, and were also presented via four exhibitions. The exhibitions were part of an active research process that tested ideas and sought feedback which would inform the next stage of the research. A key concept presented at the third exhibition was the idea of thresholds—environmental indicators that could herald the shift of a farm’s landscape from a river mouth to an estuary, potentially affecting the viability of the farm. The knowledge and perception of thresholds will empower communities to adapt when they are ready.

Possible adaptations explored by the team include extensive re-vegetated buffers on coastlines, diversified farming practices and managed retreat from the coastline to help mitigate adverse effects of flooding, high tides, storm surges, saltwater intrusions into groundwater, temperature and rainfall fluctuations for key Māori economic agricultural bases.

The role that wetlands can play in protecting against some of the likely impacts associated with climate change is also critical, and coastal communities will need to consider the degree to which they wish to utilise increasingly wet land to their advantage, or continue with historically-applied strategies to attempt to keep coastal land dry.

A detailed ecological economics investigation was undertaken to assess three future scenarios for wetlands on coastal dairy farm(s) in the rohe, from an Integrated Economic Production and Ecosystem Services Valuation approach. Each of the scenarios was assessed using an ecosystem services approach where their economic valuation could be directly compared with an economic valuation of the dairy farming operations, with the intent of therefore integrating ‘economic’, ‘ecological’ and other values into the one analytical framework. This underscored the very high comparative economic value of wetlands compared with other types of land cover/land use. In the next phase of the research, we will develop a scenario modelling tool to project the scenarios forward to 2045/2046, and then assess for that year the overall economic value of each scenario across each of the 18 ecosystem services and various financial information about the dairy farming and forestry activities. Given the significant ecological value that wetlands provide to coastal areas, this enhanced understanding of the ecological and economic implications of different scenarios for the use of wetlands in coastal farms is critical.

Our research has shown that coastal ecosystems are vital and important for stabilising the coastline, improving groundwater management, and acting as a buffer for the more intensively managed areas further inland. More resilient approaches to coastal stabilisation should involve maintaining a sequence of plant species starting with saltmarsh plants and salt tolerant grasses by the high tide level and then going back in stages using species such as harakeke, cabbage trees, kahikatea, manuka and many more.

It is envisaged that the research described here will be continued over the next 18 months in Phase 2 of this project. Through Iwi and Hapū participation to prioritise adaptation strategies for valued coastal ecosystems, transition action plans will be co-developed that identify the critical issues facing coastal communities to adapt to the impacts of climate change on coastal areas.

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# 1 INTRODUCTION

## 1.1 The Purpose of this Report

This report gives an account of the research project entitled, *Adaptation Strategies to Address Climate Change Impacts on Coastal Māori Communities* (CO1X1445). The report is intended to provide the funders and stakeholders of the project with a background to the need for the research, an overview of the aims and objectives of the project, the rationale for the design and methods employed in the project, an outline of the research activities that were undertaken in the case study rohe, and the main adaptation strategies that were generated in the project. Key findings and recommendations are also outlined at the end of the report.

## 1.2 Climate Change in New Zealand

New Zealand has a very significant level of development in coastal areas now being affected by sea level rise (McGranahan et al., 2007). Erosion of beaches and collapse of some coastal infrastructure during storms is already evident in several parts of the country but more subtle and widespread effects can be significant, such as flooding due to rise in groundwater over land less than 10m above the current sea level (e.g., Bjerklie et al., 2012; Nicholls & Kebede, 2010). According to the last Intergovernmental Panel on Climate Change (IPCC) assessment report (Church et al., 2013), Wellington has places where coastal flooding can become 1000 times more frequent by 2100 for a mid-range future climate scenario. Similarly, in the Horowhenua–Kāpiti region, extreme wave height during storm events is increasing nearly ten times as much as sea level (Young et al., 2011). Such events are clearly becoming major issues for coastal management.

Adaptation strategies to deal with such coastal changes must also deal with significant uncertainties. The last IPCC assessment report (Church et al., 2013) gave a very wide 66% likely range for the increase in global average sea level of 0.28–0.98m by 2100, with the upper end of this range continuing to rise at a rate of 16mm $yr^{-1}$. However, recent reviews suggest these numbers can be conservative (Horton et al., 2014); and that they are not a sufficient basis for risk management (Hinkel et al., 2015). With Greenland ice sheets changing more extensively than considered (Khan et al., 2014), some major uncertainties in future ice sheet responses were not covered (Arthern et al., 2015; Gasson et al., 2015; Rignot et al., 2015). Limits to predictability reflect the current rates being more than ten times faster than any identified past changes (Masson-Delmotte et al., 2014). Ice sheet models can now finally reproduce why sea level was about 20m higher than at present. The last time the $CO_2$ greenhouse gas was as high as it is now, suggests that sea levels can rise by 2m per century (Pollard et al., 2015). Whether this would happen gradually, or in spurts, remains a major question. Such deep uncertainties around the rates of climate change and its impacts mean that coastal management must focus on ways of increasing resilience to such changes by evaluating a wide range of ongoing adaptive strategies.

As indicated in the 2005 Millennium Assessment Report, and as stated by the IPCC, there will be a range of climate change stressors for the world. Climate change and excessive nutrient loadings are the two main drivers that will become more severe.[3] In Aotearoa New Zealand, the most important direct drivers of ecosystem change will increase in the first half of the 21st century. Unfortunately, over 50% of Māori assets or bases are in industries that are all climate change dependent and therefore vulnerable, namely fishing, forestry and agriculture.[4]

In July 2014, the IPCC Working Group Report clearly established how human action has been the dominant factor in warming that has taken place since the middle of the last century: “The impacts of climate change will leave no part of the world untouched and unaffected."[5] The report stated further the essential need for:

> “…*urgent, concerted adaption and mitigation measures both to at least dramatically reduce, if not prevent, destruction of homes, global food insecurity, water shortages, economic instability, and potential increases in violent conflict, due to more extreme weather and climate change*.”[6]

In 2014, it was noted by the Green Party of Aoteaora New Zealand, how the “European Commission has agreed to cut emissions by 40% from 1990 levels by 2030.” When questioned by the Green Party in January 2015, the National government refused to reveal a 2030 target. When projected emissions are expected to rise by 50% in the next 10 years under the previous National government’s policies, “New Zealand has a moral responsibility to act, and a unique opportunity to transition to a smarter, cleaner, more prosperous economy.”[7]

According to key Māori scholars such as Dr Rhys Jones, Māori health is dependent on the stability of social, cultural and economic determinants, all of which depend on the sustainability of natural ecosystems.[8]

### 1.3 The Deep South Te Kōmata o Te Tonga National Science Challenge

The Deep South Te Kōmata o Te Tonga National Science Challenge (NSC) is one of 11 NSCs that were created by the government, under the Ministry of Business Innovation and Employment (MBIE)[9]. The NSCs provide funding to New Zealand researchers to tackle some of the biggest science-based issues and opportunities facing New Zealand. They aim to take a strategic approach to the government’s science investment by targeting a series of goals which, if achieved, will have a major and enduring benefit for New Zealand. They are meant to draw scientists

[3] Millennium Ecosystem Assessment core writing team, 2005, *Millennium Ecosystem Assessment Synthesis Report,* Pre-publication final draft. Approved by MA board on March 23, 2005, United Nations Environment Programme, Millennium Ecosystem Assessment Secretariat, World Resources Institute, Washington, DC, 17.
[4] Dr Rhys Jones, 2013, ‘Climate change and Māori health’, in Katene, S & Mulholland, M., (eds.) *Future challenges for Māori : He kōrero anamata*, Huia Publishers: Wellington. 77
[5] Sourced from http://www.ipcc.ch/
[6] Sourced from http://www.ipcc.ch/
[7] Sourced from https://www.facebook.com/nzgreenparty/photos
[8] Dr Rhys Jones, 2013, ‘Climate change and Māori health’, in Katene, S & Mulholland, M., (eds.) *Future challenges for Māori : He kōrero anamata*, Huia Publishers: Wellington.
[9] See http://www.mbie.govt.nz/info-services/science-innovation/national-science-challenges; http://www.deepsouthchallenge.co.nz/programmes

together from different institutions and across disciplines to collaboratively focus on large and complex issues facing New Zealand.

One of the 11 NSCs is "The Deep South – Te Kōmata o Te Tonga[10]. Launched in August 2014, with funding of up to $51.1 million over 10 years, this NSC is hosted by the National Institute of Water and Atmospheric Research (NIWA) and has a mission to enable New Zealanders to adapt, manage risk and thrive in a changing climate. The Deep South NSC is working to understand the role of the Antarctic and Southern Ocean in determining New Zealand's future climate and the impact this role has on key economic sectors, infrastructure and natural resources.

Within the Deep South NSC, there are five programmes[11]:

1) *Engagement* – helping New Zealanders to make decisions informed by climate science, and to inform Deep South Challenge research;
2) *Impacts and Implications* – understanding the potential impacts and implications of climate change for New Zealand to support planning and decision-making, and aid adaptation efforts;
3) *Earth System Modelling and Prediction* – developing and utilising the New Zealand Earth System Model to produce improved projections of climate change;
4) *Processes and Observations* – to improve our understanding of the global climate system by observing processes in Antarctica, the Southern Ocean, and the atmosphere; and
5) *Vision Mātauranga* – strengthening the capacity and capability of iwi/hapū/whānau and Māori business to deal with climate change impacts, risks and adaptation; Ko ngā mahi inaianei hei oranga mo rātou apopo.

The five strategic elements of the *Vision Mātauranga* (VM) programme of the Deep South NSC are: Kaupapa Māori research principles; governance Māori; engagement, collaboration and partnerships; research capability, capacity and leadership; and transformative context and future-focused research.

Vision Mātauranga science projects are built around four research themes:

i) Understanding climate change - linkages, pressure points and potential responses;
ii) Exploring adaptation options for Māori communities;
iii) Assistance to Māori businesses to aid decision-making and long-term sustainability;
iv) Products, services and systems derived from mātauranga Māori.

In mid-2015, the Deep South NSC released a Request for Proposals for VM research, for projects to be conducted over an 18-24 month period, with funding available for up to $250,000 + GST per project. The projects had to fit at least one of the above-mentioned VM research themes. The remainder of this report outlines the

[10] See http://www.mbie.govt.nz/info-services/science-innovation/national-science-challenges/deep-south and http://www.deepsouthchallenge.co.nz/

[11] See http://www.deepsouthchallenge.co.nz/programmes

project that the research team described in Section 2.3 gained funding to conduct, from the VM research fund of the Deep South NSC. This project was designed to fit the following Deep South NSC theme: *Exploring Adaptation Tracks for Māori Communities*, but also relates to aspects of all of the Deep South NSC Vision Mātauranga Themes.

### *1.3.1 Contribution of this Project to the Deep South NSC*

This project sought to advance the knowledge and contribution of the Deep South Challenge mission in the following ways. Strategies for proactive forms of adaptation to sea level rise are still at a very early stage of development and have thus far focussed primarily on urban areas or on major coastal infrastructure such as the Thames Barrier (Ranger et al., 2013). These now need to be extended in ways that cover quite different situations that can occur in rural and peri-urban areas, where preservation of social, cultural and environmental values is acknowledged as having a growing importance.

The social dimensions of climate change raise even bigger issues for consideration when developing response strategies. For example, detailed reports by NIWA for Greater Wellington Regional Council (GWRC) on coastal management issues (Bell & Hannah, 2012; Lane et al., 2013) have not led to any clear plan for response. Similarly, Kāpiti Coast District Council (KCDC) commissioned a series of reports on coastal management, but as soon as these highlighted the potential to affect property values, there was immediate and very strong opposition. A more recent and detailed report also showed that the earlier ones were basically correct (Carley et al., 2014), however there has still been no form of social engagement that could lead to effective response strategies. The role of councils when considering adaptation to sea level rise is now recognised as raising a new type of legal issue (Williams, 2015).

In this context, the Horowhenua–Kāpiti region was deemed to be appropriate for new research examining how to develop better approaches to social engagement when considering response to sea level rise. Explicit consideration of iwi and hapū perspectives is critical, as a recent review of New Zealand's adaptive capacity found that such perspectives can reflect a clear sense of inter-generational stewardship (Manning et al., 2014) as an active exercise of kaitiakitanga. Further, iwi and hapū in the case study rohe are actively involved in issues such as Proposed District Plans. This is part of the growing recognition that Māori bring a sense of values that treat the environment and people as closely inter-related. To this end, many iwi and hapū authorities have developed strong working relationships with respective councils (local and regional) in the potential research rohe, with a range of active Memoranda of Partnership or other forms of iwi and hapū-led decision-making committees.

The research described in this report sought to address climate change impacts on coastal communities, providing information and capability to help Māori envisage economically sustainable adaptation strategies that will enhance and restore Māori cultural relationships to the coast. The research proposes new forms of holistic engagement with and within coastal societies, which it is hoped will lead to proactive approaches that anticipate change as well as benefit from it. Māori communities collectively hold land as sources of 'cultural identity and mana', a world view where private property values are not based on market monetary values. Preservation of such Māori values in the face of major coastal changes is a significant challenge.

In addition, adaptation to sea level rise in rural and peri-urban areas needs to be done differently to that in cities because of the less intensive forms of coastal development. In considering water management, for example, it must account for more extensive flooding and potential salination of groundwater for the communities who depend on it.

### 1.4 Funding and Duration of the Project

The research team's proposal to conduct research, as outlined below, was successfully funded by NIWA, who administer the Deep South National Science Challenge. The total funding for the project was $250,000 + GST, for the 18-month period, 1 October 2015 to 31 March 2017. The project was not dependent on co-funding; however, a number of external agencies were involved in the project including galleries who supported exhibitions, which are described later in the report.

### 1.5 The Horowhenua Coastal Climate Change Research Team

The research team included very experienced climate change scientists, ecological economists, landscape architects and kaupapa Māori and action research researchers, with a proven track record to undertake complex cross-cultural, collaborative research projects; e.g., Manaaki Taha Moana (MTM) (MAUX0907) received a gold rating from MBIE in 2014.

Dr Huhana Smith was the Research Leader Māori for the project. Originally contracted by Te Rangitāwhia Whakatupu Mātauranga (Dr Smith's Research Consultancy), Dr Smith took up employment at Massey University during the course of this project, as the Head of School, Whiti o Rehua, Toi Rauwhārangi, Massey University. Dr Smith also led the Horowhenua case study for MTM, is an experienced kaupapa Māori environmental researcher, creative thinker and an artist/designer.

In this project, Dr Smith worked with other iwi and hapū researchers from the rohe including Aroha Spinks and Moira Poutama, to coordinate and lead hui with key iwi and hapū, to identify and contribute Mātauranga Māori knowledge alongside manawhenua representatives from the Te Ātiawa, Raukawa ki te Tonga and Toarangatira (ART) Confederation of iwi, and contribute to the written publications and exhibition. Aroha Spinks was the Kairangahau/Iwi Researcher, and Moira Poutama the Kaiwhakarite, both from Te Rangitāwhia Whakatupu Mātauranga.

One of the other Principal Investigators on the project was Professor Penny Allan, Programme Director of Landscape Architecture, Victoria University of Wellington.

Professor Allan led the design aspects of this project, with Martin Bryant, Abdallah Richards, and students from the Masters in Landscape Architecture course at Victoria University of Wellington. Prof Allan and Dr Smith's prior environmental revitalisation design work won the 2015 New Zealand Institute of Landscape

Architecture's Te Karanga o te Tui award and a cultural heritage significance award at International Biennale of Landscape Architecture in Barcelona in 2014, and was used as the basis for the research design involving the development and communication of adaptation strategies referred to throughout this report.

Another Principal Investigator was Professor Martin Manning, Emeritus Professor of the Victoria University of Wellington, who was an independent contractor to the project. Professor Manning was Director of the IPCC Working Group I Technical Support Unit, which produced the 4th Assessment Report on Climate Change for governments and won the Nobel Peace Prize. He is an Officer of the New Zealand Order of Merit for his services to climate change. As inaugural Director of the New Zealand Climate Change Research Institute at Victoria University, he led the most comprehensive interdisciplinary study carried out so far on New Zealand's capacity to adapt to climate change, which showed that Māori perspectives can be quite different when considering the future (e.g., see Manning et al., 2014). Professor Manning's significant knowledge and experience of related research enabled him to lead the climate change science contributions to the project.

Professor Manning liaised closely with Dr Jane Richardson from the School of People Environment and Planning (PEP) at Massey University. Dr Richardson led the geomorphology research. Her research expertise is focussed on fluvial geomorphology, in particular the influence of climate change on river systems and catchments in New Zealand.

Professor Murray Patterson, who is the Chair of Ecological Economics in the School of PEP at Massey University, led the ecological economics focussed research on the project. Professor Patterson was the Science Leader for MTM, and is an A-grade PBRF researcher with over 30 years' experience leading integrative cross-cultural research. Ms Hardy, also from Massey's School of PEP, assisted with the ecological economics research and the integration of findings from the research, and wrote the final report. She was the project manager for this research and the previous the MTM programme.

Furthermore, the research team aimed to link in with and build upon Massey University's Innovative River Solutions group and their research looking at potential impacts of climate change on rivers in the Greater Wellington Region; Dr Anthony Cole's earlier work mapping climate change for Horowhenua; and the work of Dr Charlotte Severne and others on climate change, ocean research and Māori development (e.g., see King et al., 2010).

Thus, the research team had extensive experience of multi-disciplinary cross-cultural research, and a proven track record of completing externally-funded research such as this to a high standard. A close relationship also existed between the Māori researchers and the Māori community involved in the research.

## 1.6 Engagement and Capacity Building

Engagement and capacity building was an important factor in the design of this research. Therefore, as well as the research team itself, it was intended that opportunities be made available to others to engage in this project, including

Students in the Master of Landscape Architecture and Master of Architecture from Victoria University of Wellington; and from Massey University's School of Art | Whiti o Rehua based at the College of Creative Arts | Toirauwhārangi, Wellington.

Additionally, we aimed to work with members of the Te Ātiawa, Raukawa ki te Tonga and Toarangatira (ART) Confederation of iwi, of which members of the research team have a long-standing relationship through whakapapa, policy and planning projects with respective councils, inter-Rūnanga activities and Treaty Claim research processes. Approval to approach participants was gained on 5 August 2015 at the Whakakauae Research symposium held at Rata Marae, Rangitikei.

The project also aimed to build research capability for iwi and hapū by supporting an emerging researcher, Aroha Spinks, to complete her PhD and gain ongoing research experience. Likewise, Mahinaarangi Baker was mentored through the beginning of her related PhD studies at Massey University, supervised by Professor Patterson, which is funded by an alternate source – her PhD is developing models/processes to ensure mana whenua perspectives can be incorporated into cross-cultural decision making policies, which Professor Patterson is supervising with Drs Smith and Professor Russell Death, at Massey University.

It was also envisaged that there would be enhanced learning for all at Māori farm governance and operational levels, and increased understanding amongst marae and associated iwi and hapū within the case study rohe.

## 1.7 Other Outputs

This project worked with local iwi and hapū to address the implications of climate change on Māori farms. The project considered the interdependence between cultural, economic and ecological issues to explore practical, culturally-appropriate adaptive and diversified land use practices that are better suited to the changed conditions, which are likely to result due to climate change impacts. A series of adaptation scenarios were developed for the stakeholder groups that engaged in the research, but which are applicable across the rohe. These diversified practices will help Māori farming communities be more self-reliant, less vulnerable and therefore more resilient. The remainer of this report explores the development of these adaptation scenarios in more detail.

In addition to wānanga/hui, this report is one of the main outputs required by the funder of the project, as described above. A number of additional outputs were produced, including a journal article that has been submitted to a peer-reviewed journal to communicate the research methods and findings nationally and internationally, including the effectiveness of the method of social engagement described in this report to improve the readiness of Māori communities to identify and action adaptation strategies for future climate change impacts. Various exhibitions are described throughout the remainder of this report, which were a major means of communicating the research findings with end users and stakeholders. Additional reports and journal articles are also underway to further explore the various findings of the study. The reports will be shared through all libraries in the research rohe and University libraries throughout New Zealand to foster widespread dissemination of research findings. Copies can also be made available to interested end user groups and participants of the research.

## 1.8 Continuation of this Project

From the outset, it was intended that this project would be the start of ongoing research to more fully explore, with tangata whenua, the implications of what is required to adapt livelihoods to the reality of climate change impacts on the coastal zone. We aim to extend the research further in the next phase of the research, to build upon the findings described in this report, to investigate in more detail the feasibility of alternate future scenarios that the local community wish to pursue to be better prepared for the likely climate change impacts that will be experienced in the rohe. This next step is outlined in more detail at the end of the report, but will involve holistic engagement with local stakeholders and decision makers to collaboratively develop transformative adaptive Transition Action Plans to address climate change impacts for coastal communities.

## 1.9 Outline of the Report

This chapter has provided an overview of the background to the research, including why it was conducted, the research funding, the research team and the potential for continuation of this research. Chapter 2 sets out the aims and objectives of the research, the case study location, the research aims, research design and methods, and an overview of the research activities conducted throughout the project. The report then presents and discusses the results of the various focussed research themes, in terms of Mātauranga Māori research and stakeholder engagement through hui wānanga and hīkoi (Chapter 3); climate change science and geomorphology (Chapter 4); ecological economics (Chapter 5); and the design-led adaptation strategy planning and communication, including the final exhibition (Chapter 6). Chapter 7 summarises the conclusions and recommendations from the research, including proposed ongoing research. The Bibliography and Appendices are found at the end of the report.

# 2 RESEARCH AIMS, DESIGN AND METHODS

## 2.1 Aims of the Research

The aim of this research was to contribute to a framework for resilience in coastal Māori farming communities by identifying culturally-informed climate change adaptation strategies, taking the economic, environmental and cultural implications into consideration.

The project also sought to build Māori capacity to proactively and productively adapt to climate change, leading to new processes of effective social engagement for dealing with this issue.

Because of their quite specific ownership patterns and relationship to the whenua, Māori have the potential to act as role models for other coastal farms in New Zealand. Thus, it is intended that the learning from this research may be applicable to other Māori faming coastal communities throughout New Zealand who are also tackling the impacts of climate change both now and into the future.

## 2.2 Geographic Location of the Research

The focus of the research was on the flood plain between Paekakariki and Levin as shown in Figure 2.1. The research team aimed to work with key iwi representatives from the wider ART (Ātiawa, Raukawa and Toarangatira) Confederation of iwi in the research rohe, and other stakeholders, to explore adaptation options for Māori farming communities.

The area is significant because this extensive flood plain supported some of the most significant wetlands in Aotearoa, as former sources of livelihood for Māori communities in the region. In the early 1900s, 98% of these wetlands were drained for agricultural purposes, with increased dairying within the last 40 years. Māori farms in this region currently adopt industrialised, intensified farming practices because they are deemed profitable, despite the current slump in the dairy market. Overall, such monocultural uses of Māori land holdings come at great environmental cost which, when coupled with the unpredictability of future climate change impacts, make these floodplain communities and their landholdings particularly vulnerable.

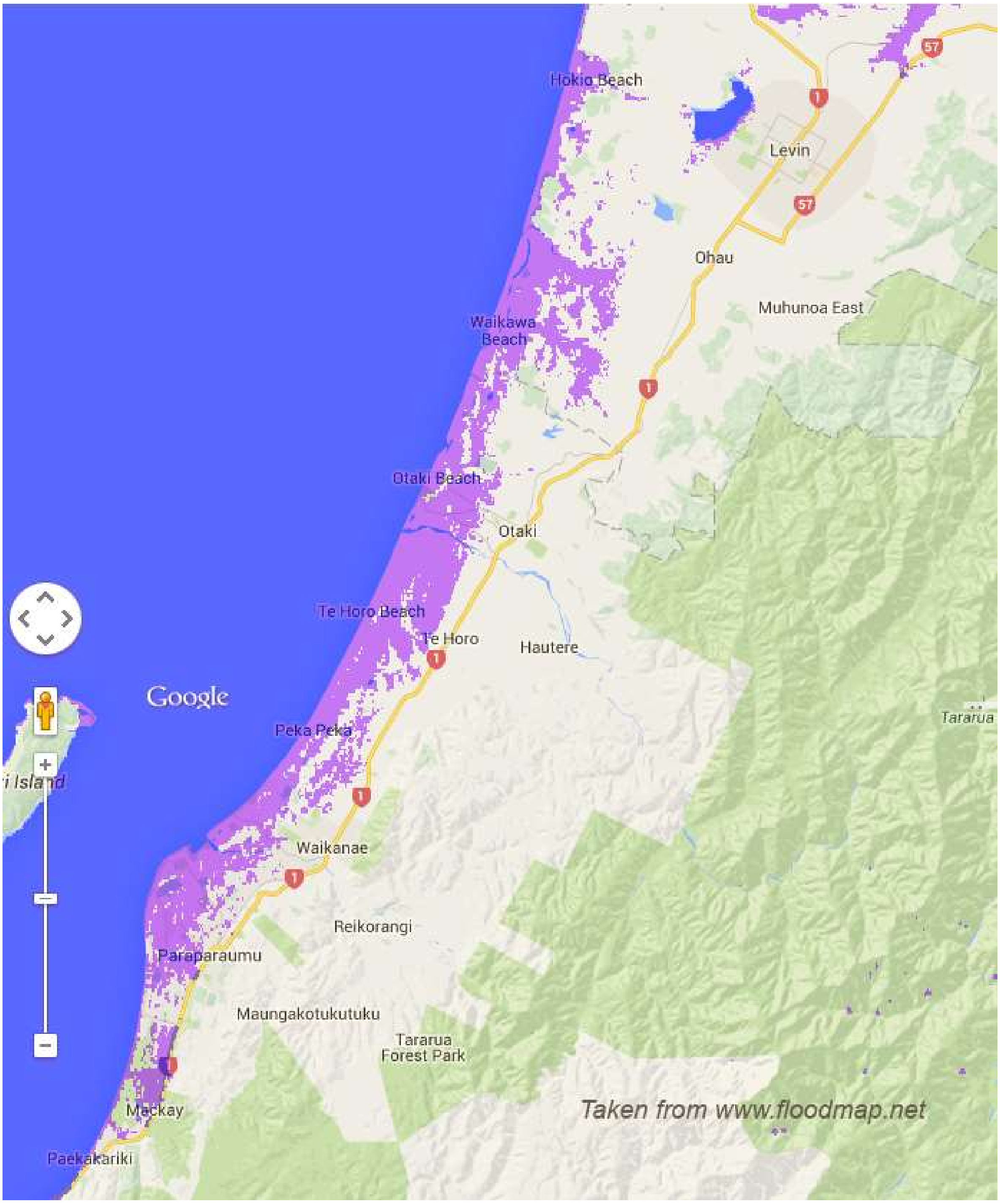


Figure 2.1 Horowhenua/Kāpiti coastline

N.B. Mauve shading shows coastal areas in the Horowhenua–Kāpiti district less than 10 m above current sea level and so where groundwater levels can be expected to be directly influenced by the rise in sea level. Until more detailed studies of groundwater in this region are done, this should only be taken as indicative of the areas for future risks. Elevation data from "Water Level Elevation Map (Beta)" http://www.floodmap.net/

## 2.3 Proposed Research Approach

This cross-cultural, inter-disciplinary, collaborative, participatory action research project was designed around wānanga to bring together iwi and hapū, stakeholders and the research team, as a way of co-producing new knowledge and capability to identify, respond and adapt to potential climate change impacts. The research team attempted to be as responsive as possible to end user priorities, and there was therefore some iteration between the planned research phases as research findings were explored and assessed with the local community. The research team aimed to develop three adaptation scenarios for participating case study farms, though we ended up identifying numerous additional options, as is detailed in the next chapter. The scenarios were informed by our research into climate science, geomorphology, Mātauranga Māori, design and ecological economics.

The research design and methodology of this project was based on two very successful projects recently undertaken by key members of the proposed team. The two projects, the MBIE-funded Manaaki Taha Moana (MTM) (www.mtm.ac.nz) and Rae ki te Rae Bicultural Design Studio, both address resilience strategies for local iwi and hapū in the Horowhenua. This project used established kaupapa Māori research principles, and protocols developed and effectively applied during the gold rated MTM and Rae ki te Rae (Allan & Smith, 2013, 2014). The research protocol guides the Rae ki te Rae process and encourages a flourishing of innovative research at the interface between cultures. The action research methods applied in MTM and in this project, preserve and restore natural biodiversity and integrity in wetlands and estuaries, and their relationships to a wide range of aquatic species.

Our research approach built upon these innovative research methods to support the Deep South NSC mission. Earlier work (e.g., King et al., 2005, 2012, 2013; Warmenhoven et al., 2014) covered ways in which a Māori sense of intergenerational responsibility could establish a basis for developing ways of adapting to future changes. In this project, this was extended in ways that focus on a clearer identification of thresholds for the sustainability of current practices, the timescales for implementing different response options, and approaches that can lead to collective agreement.

Thus, the research aims and objectives necessitate including participatory research methods whereby tangata whenua, in particular but also other stakeholder groups, are actively involved in guiding the development of research questions and the means by which those questions are researched.

The research approach intentionally integrated Mātauranga Māori together with the latest knowledge developments in climate science, through design, to provide critical links between science, planning and design, and decision making. All research described below was undertaken in an interdisciplinary manner with the sub-teams liaising regularly to share knowledge, make decisions and progress the research.

To achieve the project aims and objectives, the research plan included the following phases:

1. Introductory wānanga;

2. Detailed research in the following areas, to inform identification of adaptation options, given local conditions:
   i) Mātauranga Māori
   ii) Climate change / geomorphology
   iii) Design
   iv) Ecological economics;

3. Series of hui and scenario planning to identify and design preferred adaptation strategies;

4. Final research hui and reporting to communicate research findings (report(s)/journal articles + exhibitions).

It should be noted, however, that a great deal of flexibility was built into this research design to allow for community needs, interests and priorities, which evolved as the research progressed. This flexibility within the research process allowed for it to be conducted in a less linear fashion. Thus, there was purposeful allowance for longer periods of investigation on specific areas where this was prioritised by stakeholders, and additional formal and informal hui and planning sessions within the team and with interested members of the local communities.

The rationale for inclusion of Mātauranga Māori, climate change/geomorphology, design, and ecological economics are detailed in the remainder of this chapter, along with a description of the research activities that were undertaken, accordingly.

The research findings are explored in the following chapters. It should be noted, however, that although specific research activities may be listed under a particular field of enquiry, in an effort to help the reader digest the various aspects of the research in smaller components – i.e., Mātauranga Māori, climate change science/geomorphology, design, or ecological economics or design, in practice the fields of enquiry overlapped substantially, and contributed to each other. In many cases issues were discovered and responses developed in a completely collaborative fashion. Thus, knowledge and learnings discovered primarily within one field of enquiry were incorporated into the analysis being conducted by others within the research team. Thus, the research activities and findings are inter-related and very much a “group effort”, and the research should accordingly be interpreted as inter-connected, cross-cultural, and inter-disciplinary.

## 2.4 Mātauranga Māori Research: Stakeholder Engagement, Hīkoi, Hui and Wānanga

Stakeholder engagement was an integral part of the research design, facilitated primarily through the use of hui, wānanga and hīkoi, to ensure Mātauranga Māori perspectives and tangata whenua values and interests informed the specific research issues that were investigated by the research team, and the generation of potential adaptation options of relevance to the case study rohe.

It is strategic for Iwi and Hapū to exercise tino rangatiratanga to determine their own futures; collaborate well with other experts and specialists to achieve better outcomes for ecosystems; and use these combined voices based on evidence-based research for hands-on action to revitalise and buffer freshwater coastal ecosystems into the marine. This Mātauranga Māori informed the development of preliminary adaptation options for coastal farming communities in the rohe.

Aroha Spinks, Moira Poutama and Huhana Smith therefore organised and ran a series of wānanga, hui and hīkoi with iwi, hapū and Māori farms in the rohe, and identified Mātauranga Māori knowledge regarding climate change resilience and adaptation. This approach built on previous research conducted in the MTM programme referred to previously, which highlighted critical tools that reclaim the right of iwi and hapū to reassert their identity to place; to be authoritative in research and findings; to identify and resist disturbances besetting place, and to build resilience for the challenges of climate change.

### *2.4.1 Introductory Series of Hui/Wānanga with Case Study Participants*

This aspect of the research began with introductory hui/wānanga with case study participants. This participatory action research project was originally intended to focus on two case study farms to capture the specific risks and opportunities of local areas, based on projected future climate change-related impacts in the region (see Figure 2.2). At the early stages of planning, it was envisaged that Tahamata Incorporation and Incorporation of Ransfield's would form one case study, and Katihiku Ahu Whenua Trust the other[12]. At the proposal writing stage for this project, provisional support was gained from six kaumatua, the Chairperson and/or Boards of Tahamata Incorporation, Incorporation of Ransfield's, Te Hatete Whanau Trust and other key members of Katihiku Ahu Whenua Trust. The Māori research team talked closely with Te Iwi o Ngāti Tukorehe Trust members and kept them alert of matters arising from this research.

When the research team was notified that the funding proposal was successful, and contracting was completed with NIWA, formal engagement with stakeholders for the project began. By the end of 2015, the team had engaged with relevant iwi and hapū, farm boards and chairs, including a presentation at Tahamata AGM on 4 December 2015, and secured Tahamata Incorporation, Incorporation of Ransfield's and Te Hatete Whanau Trust as one case study between Ōhau River and Waikawa. Dr Smith finalised agreement with whanau from Katihiku south of Ōtaki River for second case study, through communication with Mark Wilson and others. An initial outline of research hui was held at Taaringaroa meeting house in Ōtaki led by the Māori researchers with the wider team meeting with key informants who expressed interest in being involved. A later vision hui was held with people from Katihiku in April 2016.

After contracting with NIWA for the establishment of this project was completed in mid-November 2015, a series of hui were held to discuss which coastal zones and ecosystems in the rohe were to be focussed on for detailed research. At this stage, the team also explored potential adaptive strategies that had been utilised nationally and internationally to address climate change impacts for scenarios such as: extreme climate and sea level rise; dune mobility; erosion and landslides; sedimentation in lower flood plains; and ground water inundation.

[12] These entities are hereafter often referred to as 'Tahamata' or 'Tahamata Farm'; 'Ransfields'; and 'Katihiku', respectively.


Figure 2.2 Research Rohe, with location of Case Study farms (Tahamata/Ransfield's/Hatete Whanau Trust to the north, Katihiku Ahu Whenua Trust to the south). Drawn by Winston Dewhirst and Abdallah Richards

### *2.4.2 Ongoing Series of Hui, Wānanga and Hīkoi*

A series of ongoing hui, wānanga and hīkoi were held between the research team and the local community, in an effort to garner interest in the community for the climate change adaptation research, and participation in the identification of adaptation priorities for detailed investigation.

The purpose of the hui was to enable the research team, iwi and hapū participants and farm representatives to talk about their hopes for the future, and foundational values that inform decision making and climate change adaptation strategies. The outcome of these hui would guide the research team in pinpointing the detailed ongoing Mātauranga Māori, design, ecological and economic research to be undertaken in the Project.

There was then opportunity to discuss potential impacts on the case study region and identify potential climate change risks requiring further research, and agree on specific research questions to be addressed in the remainder of the project.

The research team engaged with hapū and stakeholders to seek a better understanding of how the biophysical aspects and cultural practices influence farm operations, what works, and what could work better. This engagement was to provide input for the basis for considering the possibilities of slow and fast adaptive techniques; and preferred areas for ongoing detailed investigation in 2016.

Appendix A lists the information sought by the research team, which was pre-determined prior to the hui with input from all members of the research team. Korero at the hui, therefore, intentionally focussed on the following key themes –
-*Strategic Direction*:
vision, challenges, long term plans, criteria for decision making about farm planning;
-*Economic Factors*:
vulnerabilities, investment strategy for development, productivity measures, degree to which value of natural and socio-cultural factors impact on decision making;
-*Farm Practices*:
layout of farm, use and location of buildings, vegetation, degree to which Māori values impact decision making about farm operations, day to day management of farm, response to seasonal issues, pasture monitoring, regularity of flooding events and managing them;
-*Environmental Factors*:
effluent management systems, riparian strips/fencing, groundwater monitoring, other;
-*Social/Cultural Factors*:
potential for public access, pathway for younger generations to be involved in the farms, vision.

### *2.4.3 Final wānanga / hīkoi*

In conjunction with the final exhibition described in section 6.4, a weekend wānanga was held on 3 November 2017 at Tukorehe Marae. This was a pre-opportunity for whanau, shareholders, iwi and board members to engage in the research findings thus far and a mini exhibition of key deigns from Master's students; a range of large scale maps and dune contour maps; a chance to contribute to the overall vision, and a means for the teams to tell more about what would happen at the final exhibition of designs to be held in a disused dairy shed on Tahamata farm, Kuku, Horowhenua in early 2017.

Informed by the korero with the local community and case study stakeholders, as described above, several detailed investigations were undertaken, in the areas of Climate change and geomorphology; ecological economics; and design-informed planning for adaptation strategies. These were all conducted alongside the Mātauranga Māori and stakeholder engagement initiatives referred to above.

The outcomes of these hui/wānanga and hīkoi phases of the research are detailed in Chapter 3.

## 2.5 Climate Change Science / Geormorphology Research

Led by Prof Manning and Dr Richardson, this research was designed to build upon earlier preliminary FRST-funded work conducted by some of this proposed research team, which looked at terrestrial ecosystem services for iwi and hapū in the rohe, the way in which the landscape has changed over the last 100 years and projections into the future, including estimated projections of sea level rise by 2100 by Dr Anthony Cole and Dr Huhana Smith (MAUX 0502) (see Figure 2.3). These investigations are described in the following sub-sections; the results are outlined in Chapter 4.

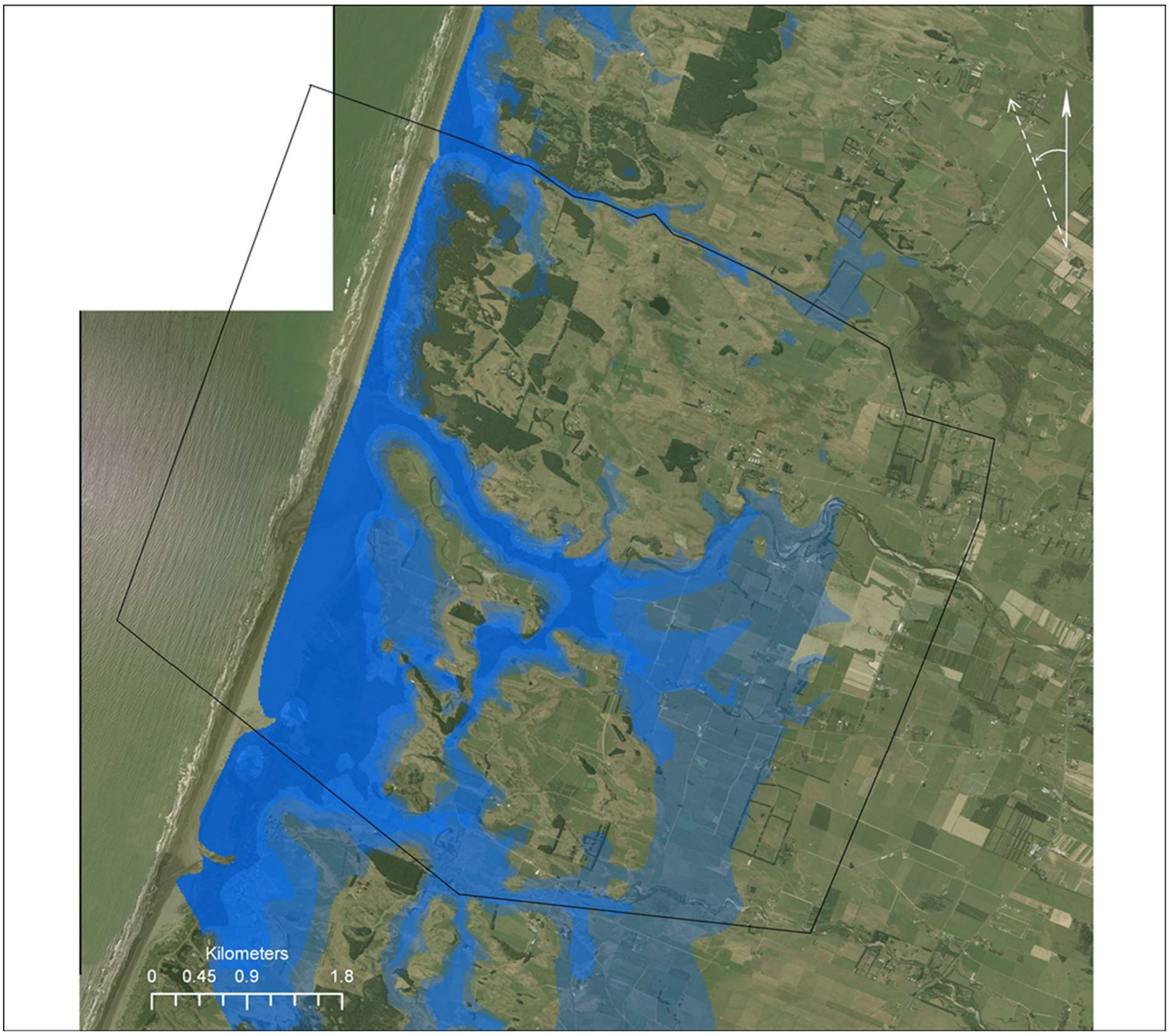


Figure 2.3 Projected sea level rise in part of the case study rohe to the year 2100 (Source: Smith 2009).

### *2.5.1 Literature Review of Climate Change Science and Geomorphology*

Literature reviews of the most up-to-date science around climate change were conducted, analysing the national and international climate change literature to determine the most up-to-date climate change projects, and applying that knowledge to the specific conditions of the case study rohe.

Professor Manning investigated how the most recent findings on sea level rise (SLR) and the groundwater response across low lying land, with its implications for increased flood risk, could be made directly relevant for the Horowhenua–Kāpiti region. This investigation included a review of the most recent science giving ranges for future SLR, their rates of change, and potential effects on low lying land. This review focused on developing constructive forms of communication about such changes, the timescales over which different changes can occur, and ways of dealing with some inevitable uncertainties.

Summaries of this information were made available at our meetings with iwi.

A subsequent more detailed review of literature was then conducted on the effects of sea level on groundwater and coastal flooding to estimate the areas that will be affected by rises of 0.5 to 1.5 m. Initial analysis indicates that land lower than 10 m will see a rise in groundwater but the amount seems to decrease exponentially rather than linearly with height.

More specific approaches to identify thresholds were developed, and their early warning signs, at which current practices start to rapidly become more risky (e.g. by applying the Kane et al. (2015) approach used in Hawaii).

A literature review of river management of the Ōhau river was completed with a discussion document looking at river behaviour and management of the Ōhau river under predicted climate change and sea level rise. A number of key thresholds were identified from a geomorphological perspective which were incorporated into the key messages at the exhibition and contributed to the development of geomorphologically-grounded adaptation strategies.

### *2.5.2 Sourcing Data to Better Understand Local Conditions*

An early task was to determine the science/environmental indicators and to set parameters for research; e.g. how far into the future to model, what sea level rise data to work to, e.g. .5m/1m, 1.5m etc. and what the associated impacts were likely to be. This would then enable the research team to determine the extent to which areas at risk of storm surge and flooding could be defined to the extent done previously for different scenarios in the Hutt Valley and elsewhere.

Getting appropriate LIDAR data for the case study rohe proved to be a challenge. The coarse grain data first accessed by the team was inadequate – a finer grain is necessary to get a detailed understanding of the potential of these sites. Liaison with groups such as NIWA, GWRC and Horizons Regional Council was required to co-ordinate and, if possible, update information for the study.

There was a lack of groundwater and tidal or storm surge data, but comparisons were made with the Waimea/Waikanae river areas where more data and groundwater modelling was available.

Coastal classifications had to start with a simple ‘influenced by river mouth/no influence’ approach, which was progressively refined by bringing in archaeological studies of past changes, the effects of Māori and European settlement and ways in which wetlands could be maintained as a buffer zone.

The team viewed all mapped data to date from KCDC, identified gaps in information, and liaised with Horizons Regional Council over access to their data. All data of relevance was collated and inserted into a Droxbox folder set up for this project to allow the team to share material, maps, GIS, photos, papers, etc.

Prof Manning used satellite data to track significant differences between regional sea level rise around New Zealand and the global average.

Prof Manning and Dr Richardson met with Peter Blackwood (River Engineer) at Horizons Regional Council on 9 Nov 2016 to discuss flood mitigation and channel management of the Ōhau River, and gain required data to complete the analysis.

#### *2.5.3 Study Site Geology, Cycles of Disturbance, Tidal Cycles*

A literature review of study site geology was undertaken and key events in the coastal evolution of the Kāpiti-Horowhenua Region identified, as well as cycles of disturbance influencing the coastal zone and the pertinent natural cycles of sea level change over a range of time and spatial scales - which will be the background for anthropogenic climate change. Prof Allan and Abdallah Richards worked with Prof Manning and Dr Richardson to synthesise this information and communicate it visually as part of the Wai o Papa Waterlands Exhibitions (31 May and 21 June 2016) and provided supporting explanatory text (see Chapter 6).

#### *2.5.4 River Management in a Changing Climate*

Dr Richardson focussed on the potential geomorphic response of rivers, in the case study region, to climate and sea level change. She used a Geographic Information System (GIS) and geomorphic approach to determine potential future landscape response to climate change and identify areas most at risk to increased flood frequency and/or magnitude, sea level rise, and alterations in the water table. This provided a geomorphic context for developing a framework for identifying the risks of climate change impacts, identify potential thresholds for change and informing plans to respond and adapt to change in a sustainable way.

GIS analysis was completed using data from soil surveys (including drainage class), flood mapping and modelling and LiDAR, to identify areas of the Tahamata farm that are most vulnerable to sea level rise and climate change. Land use data from this analysis was used to determine the area under 2 scenarios (do nothing or actively establish wetlands) for the ecological economics analysis.

### 2.6 Ecological Economics

#### *2.6.1 Literature Review of Socio-Economic Issues in the Rohe and New Zealand*

An initial literature review was undertaken, summarising the socio-economic climate change research in NZ, with a focus on the Horowhenua region. This was to inform the research team as to the “big picture” issues that might impact on adaptation options for this rohe, given local socio-economic conditions. This included an examination of local government websites, media reports about climate change impacts in the region, and published reports. A broad review of material on central government websites in relation to climate change impacts for New Zealand was also conducted.

This information was reviewed, and informed the assessment of the feasibility of adaptation strategies, particularly in terms of options that would require funding from groups such as Councils or Central Government.

### *2.6.2 Ecological Economics Analysis of Wetlands Scenarios*

As is described in the subsequent results chapters, as the research progressed, the design and science teams developed a number of potential adaptation options that could potentially be applied by Māori coastal farming communities in the case study rohe. However, the most pressing issue that repeatedly arose, and which was asked by Tahamata Board members and stakeholders from various farming groups in the rohe, was: “what do we do about the increasingly ‘wet’ land on our coastal farms”?

Thus, based on research priorities that surfaced throughout the project as perceived by the research team, and end user priorities identified at wānanga and hui (e.g., research team wānanga on 15 Sept 2016, followed up with a hui with Tahamata Board members and the research team at Tukorehe marae on 3 November 2017, and a later meeting on 19 January 2017 at Massey University with Prof Patterson, Dr Smith, and Ms Hardy from the research team, and James Mackie from Tahamata), it was agreed that an ecological economics analysis of three wetland scenarios for Tahamata, would be undertaken[13], as a critical first step in any adaptation planning for climate change impacts on the coast and related impacts for land use in the rohe. The three wetland scenarios, applicable for next 30-45 years were:

A. Drain the wetlands and/or contiguous land[14];

B. Extend the wetlands. Possibly including some element of ‘eel and whitebait’ production for commercial purposes;

C. Do Nothing to the wetlands, and assume reference level climate change. Under this scenario, the wetlands can change due to climate change, but not due to human interventions[15].

The *overall aim* of this analysis was to identify and place monetary values on ecosystem services affected by hydrological changes brought about by climate change in the case study area. In quantifying the total economic value of these wetland changes, the analysis took into account the ‘conventional’ economic values (e.g., farm income, profits) as well as the ecological values that normally are not a

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[13] It was understood that while the specifics of this research were applicable for Tahamata, the findings would still be of relevance to other coastal farms in the rohe, and throughout New Zealand.
[14] Later conversations with various Tahamata Trustees and stakeholders revealed that significant drainage of wetlands on that property was not an option they were considering, and thus the option of “Significant Drainage to Minimise Wetland area” was not progressed.
[15] Upon investigation, it was confirmed that even under a “Do Nothing” scenario, taking the projected climate change and geomorphological changes into consideration, wet areas on Tahamata farm would increase naturally; therefore, “natural increase in wet land” and “actively increasing wetland areas” were analysed as separate scenarios.

valued in monetary terms. The purpose of this monetary assessment of ecological values was not only value commercial costs and benefits, which is usually the case in economic analysis; but to also monetise costs and benefits that are usually not priced in ecological analysis – for example, the value of wetlands in processing nutrients and wastes that are not usually priced in economic analysis and therefore often ignored.

In this context, an ecological economic evaluation of the Tahamata farm[16] in the case study area was undertaken for three scenarios (drain some of the wetlands; extend the wetlands, particularly those areas that will become more waterlogged under climate change; do nothing). To enable stakeholders to explore other possible options (e.g., how land areas under dairy farming versus wetlands can be changed), a simple prototype spreadsheet model has been constructed.

The *methodological process* involved the following steps:

- Development of a conceptual framework for valuing the natural capital and the ecosystem services value of wetlands in the case study area. This included 'conventional' economic values such as farm income, as well as recognising those ecosystem services values that are not normally 'priced' – for example, the flood protection value of wetlands.
- The identification (and where possible the monetary valuation) of the ecosystem services provided by the wetlands in the case study area, for the 3 wetland scenarios.
- The monetary valuation of commercial revenues and costs (from a farm operation point of view), for each of the 3 wetland scenarios.
- Integrating the data from the above steps, to provide an overall picture of the costs and benefits (in monetary terms) of the three wetland scenarios.

To undertake this analysis, available data could be either taken from other studies found in the published literature, or figures specific to Tahamata could be used, if these were able to be provided to the research team.

Dr Richardson liaised primarily with Professor Manning to provide the following data to use in the analysis, and also sought the data from Horizons Regional Council. Originally, it was hoped that the analysis could be conducted for the years 2015, 2030, 2045 and 2060. However, upon further consideration, it was agreed that this analysis could not reliably be conducted for a timeline that extended beyond 30 years. This is due to the uncertainty around the magnitude and pace at which sea level will rise in the future, which will be determined by future greenhouse gas emissions, complex ocean, ice and climate responses and regional sea level effects. The further out the projections the greater the uncertainty.

Thus, the analysis was conducted for the year 2016, and 2046 (30 years into the future).

[16] It is hoped that this research can be completed with Incorporation of Ransfield's, Hatete Whānau Trust and other farms along the coast, in Phase 2 of this project, if funding is successfully secured and these groups wish to participate.

Data requirements were as follows:

a. Maps of wetland coverage for each of the three scenarios, for the years: 2016, 2046.
b. Amount of hectares of wetland coverage for each of the three scenarios, for the years: 2015, 2030.
c. Maps of any land use change brought about 3 scenarios, along with a quantification of the hectares of land use change. For example, under Scenario 'A' (Drain), how many hectares is drained, and what is this drained land used for (eg, dairy farming)? For the years: 2016, 2046.
d. Financial data of the dairy farm operations.
e. Total number of livestock by type, and per hectare, for those areas affected by each of the wetland scenarios. Total production measured in physical terms – e.g., livestock sold per year, kg of milk fat per year.
f. Eel and whitebait production per year (if applicable).
g. A general description of the climate change forecast for the case study from 2016 to 2046. (For example, change in temperature, rainfall, and intensity & frequency of flooding events). This description can be in the form of a narrative, sprinkled with a few facts and figures.
h. The general description of the hydrological changes for the case study area from 2016 to 2046. (For example, projected changes in the water table, changes in water flows along watercourses, likely hydrological inundation of drained wetland areas etc.).

To facilitate the ecological economics analysis of different adaptations scenarios related to wetlands, Jane Richardson assembled the GIS data, which included identifying and requesting data mentioned by Horizons Regional Council in various reports, including:

a) most recent LiDAR data for our sites south of the Ōhau River;
b) the shapefiles for flooding in 2008;
c) stopbank location shapefile;
d) the shapefiles for the maps in the Tahamata Soil Health Plan report No 21,
e) Tahamata paddocks;
f) soil type;
g) drainage class;
h) pugging; and
i) land use capability class.

Murray Patterson, with Derrylea Hardy and Jane Richardson, accordingly, conducted a broadbrush ecological economics analysis of climate change scenarios and adaptation options. A prototype framework was developed, and applied for the three Tahamata case study scenarios, the results of which are depicted in Chapter 5.

## 2.7 Design-led Research to Identify and Communicate Adaptation Strategies

'Design' research synthesises complex environmental, cultural and economic information to design possible futures for a region or a locality and communicates it in ways that the local community can more easily grasp. This project purposefully employed design-led methodologies throughout the research to:

- use a combination of hui and design to liaise with the local community;
- integrate complex information from a wide range of different disciplinary sources including climate change science, geomorphology and spatial and geographical analysis to identify key issues such as vulnerable settlement patterns, inappropriate farming practices, iwi resource management and the degradation of critical ecosystems in the region;
- develop a series of adaptation options that addressed those issues;
- identify critical environmental thresholds and;
- communicate them to stakeholders and the wider community.

This research was led by Penny Allan, Huhana Smith and Martin Bryant, with research assistant, Abdallah Richards. Input was also provided by Landscape Architecture Students from Victoria University. The following sub-sections provide an overview of the specific research activities that were undertaken. The results of this research are outlined in Chapter 6.

### *2.7.1 Literature/Design Review of Coastal Adaptation Strategies*

Thorough analysis of case study sites was undertaken. Based on discussions with climate change scientists and stakeholders, key issues requiring further research were identified. This identification informed subsequent desktop research into international coastal adaptation strategies and also relevant past cultural responses to major climatic changes.

An initial literature/design review was then undertaken, including a graphic analysis of national and international design precedents of climate change adaptations, categorised to provide a clear understanding of what is possible and how adaptations can create transformative outcomes. An Annotated Bibliography of design strategies for coastal communities affected by climate change was developed; i.e., a knowledge bank of climate change adaptations from different environments globally, cross referenced to scientific knowledge, with conclusions developed on the applicability of these precedents to the Horowhenua coastal areas.

### *2.7.2 Identification of Initial Adaptation Options*

The design research was based on a network of methods including design studio and exhibitions.

All design work was based on initial analysis by the design and science teams. The analysis included gathering data to map the associated impacts and risks of storm surge and flooding, and developing site analysis drawings, which included topography, land use, land ownership, vegetation cover, site history, spatial impacts of sea level rise, agriculture and farming. Professor Bruce McFadgen whose work on archaeo-seismology and correlations between tsunami, quake activity and climatic conditions, was particularly relevant.

All data and design was augmented through discussions with local communities, including a series of hui with scientists and designers (in Wellington, Waikanae and Kuku) to contribute relevant collective data and knowledge for the project in the first quarter of 2016.

The design and climate change science team members collaborated to determine patterns of disturbance and the rates of natural response over decadal to geological time frames, including discussions about evidence for rapid coastal responses to past earthquakes and the extent to which this is related to an ongoing build-up of sediments south of the Manawatu river. This raised new questions on the extent to which development of agriculture, land and water management may have altered the range of natural responses.

*Design Studio*

To launch the design phase, an interdisciplinary design studio was conducted with 55 Victoria University Masters students (landscape architects, architects and interior architects) looking at adaptation strategies for the Ōhau Farm blocks communities. All students attended a Pōwhiri and hīkoi at Tukorehe Marae, Kuku. The Mātauranga and korero gathered during this process was used as the basis for designed adaptation options for the project.

The design and science teams were closely involved in all aspects of the studio, designing the brief, working with students through one-on-one and group critiques of their work, delivering seminars and providing information as necessary. The studio brief asked students to envision the development of the farm over the next 100 years.

Landscape students were asked to look at the entire farm and its environmental context and imagine the long-term impacts of climate change and the potential for adaptive cultural and resource management practices. Interior architects were asked to propose adaptive reuse solutions for disused buildings on the farm that might generate alternative income, and architecture students were asked to design papa-kāinga settlements to accommodate the many whānau wishing to return to the whenua.

The three-month long studio culminated in an exhibition which showed a wide range of design responses. The team 'sifted' this work and found that certain design strategies kept recurring. These strategies were ultimately developed into the toolbox of strategies described in detail later in this report.

All completed maps were uploaded to drop box for the team's use.

### 2.8 Identification and Communication of Preferred Adaption Strategies

Based on prior research by the team, a series of adaptation strategies was thus formulated by Prof Allan, Prof Bryant and Abdallah Richards. This toolbox of adaptation strategies relates to the potential localised climate change impacts.

The toolbox is flexible enough that Stakeholders might decide themselves which strategies are most suitable for their farms, or combine them in a variety of ways.

These adaptation strategies were visually expressed and presented back to the community for discussion and refinement.

A series of landscape architecture designs were developed to convey the complex information. These designs were shown in a series of exhibitions, which are depicted in Chapter 6.

# 3 RESULTS – MĀTAURANGA MĀORI: STAKEHOLDER ENGAGEMENT, HUI AND WĀNANGA

## 3.1 Introductory Series of Hui, Wānanga and Hīkoi

The full team met to agree upon a detailed research plan and allocate tasks for the first phase of the project. This hui was held at Huhana Smith's house at Kuku on 19 November 2015.

Importantly, there was a hīkoi on 1 December 2015 for the Tahamata/Ransfield's case study, with members of the research team and case study representatives.

The first major hui at which all stakeholders in the rohe were invited to collaborate with the research team regarding the project, and were given the opportunity to share their values and vision for the Māori-owned coastal lands in the rohe was held on 17 December 2015. This was our first attempt to engage widely with stakeholders from all potential case study farms and the wider communities in the rohe.

This hui was attended by the research team with iwi and hapū from case studies and the ART confederation. The purpose of this hui was to: introduce the research team, share the research aims and objectives, establish research protocols, share knowledge with the local community about the latest climate change science projections and give an overview given of regional climate change research conducted by the team in the first quarter of the project. This was presented visually in a powerpoint display which included many photos, with time for participant questions and observations.

The korero at this hui revealed that climate change adaptation strategies would need to consider agriculture and food production, i.e. diversifying productivity; and that indicators, from both a scientific (tipping point) and Mātauranga Māori perspective, might prove fruitful for design because they are accessible to the community and therefore empower the community to act autonomously and incrementally to changing environmental conditions. Thus, these issues were agreed as the basis for detailed ongoing research by the team.

At this early stage of the project, it was also becoming apparent that there was resistance to the project from some within the farming community, and a reticence by some people to engage in "climate change" planning. This wariness by some within the community about the need to address climate change, or indeed whether or not it was even "real", continued throughout the project.

## 3.2 Ongoing Series of Hui, Wānanga and Hīkoi – Identifying Stakeholder Values and Priorities for Climate Change Adaptation Research

*Hui with iwi and hapū participants and the climate change team were held, that focused on Mātauranga Māori and those with long term knowledge about Mātauranga Māori indicators and 'reading' changing environmental conditions. In particular, we met with Te Ātiawa ki Whakarongotai on 15 February 2016.

*The Katihiku wānanga was postponed from 7th February to Sunday 27 March 2016, due to tangihanga. This date was postponed again with a new date sought into April 2016. This wānanga forms part of the iwi/hapū and multidisciplinary discussion on the use of design. It led into the visioning hui for key representatives from all case study areas, (e.g., Trust members, farm board members, farm operations and management team, shareholders).

*Printed copies of maps were presented to iwi and hapū at these wānanga and visioning hui.

*Dr Smith liaised with the design teams and artists on an initial exhibition to be held at Victoria University in late April 2016. This included a focus on the maramataka or Māori lunar calendar from kaumatua accounts; use of early hand written lunar calendars; names of Māori water; water imagery and maramataka signs used by Raukawa-based tohunga.

*Relevant project information was relayed to iwi and hapū at Tahamata on 21 March 2016 at the monthly farm board meeting, where Dr Smith presented the Board with an updated monthly report.

Regular updates were provided to Tahamata Board (for example, See Appendix B & C) and Ransfield's Farm Managers, including development of a series of questions to elicit information from them such as their visions and strategic planning for the farm, and economic and environmental issues that are relevant to climate change adaptation strategies.

* On 21 April 2016 at Taringaroa meeting room next to Raukawa Marae, Ōtaki, a visioning hui was held with case study stakeholders (10) including Farm Board Trustees/Managers of the 2 case study farms – Incorporation of Ransfields and Katihiku Ahu Whenua Trust – as well as with members of Te Hatete Ahu Whenua Trust[17].

As stated previously, Appendix A lists the information sought by the research team, which was pre-determined prior to the hui with input from all members of the research team. Kōrero at the hui, therefore, intentionally focussed on the following key themes:

> -Strategic Direction: vision, challenges, long term plans, criteria for decision making about farm planning;
>
> -Economic Factors: vulnerabilities, investment strategy for development, productivity measures, degree to which value of natural and socio-cultural factors impact on decision making;
>
> -Farm Practices: layout of farm, use and location of buildings, vegetation, degree to which Māori values impact decision making about farm operations, day to day management of farm, response to seasonal issues, pasture monitoring, regularity of flooding events and managing them;
>
> -Environmental Factors: effluent management systems, riparian strips/fencing, groundwater monitoring, other;

[17] Tahamata Incorporation members could not make the hui.

-Social/Cultural Factors: potential for public access, pathway for younger generations to be involved in the farms, vision.

A transcript was written of the korero that transpired at the hui, with representatives from Katihiku Ahu Whenua Trust, Hatete Whanau Trust and Ransfield Incorporation on 12 April 2016[18]. The visioning workshop revealed that the vision for both farms and trusts included the following key messages:

- Bringing whanau back to the whenua
- Ensuring farms are economically viable
- Include traditional resource management where possible (kai moana, eels etc)
- Protecting the farm for future generations
- Acknowledge and protect cultural/ancestral sites and burial areas

The outcome of discussions at the hui were a list of values and priorities for each of the three case study farms (and an additional whanau grouping) who were at the hui.

*After the Visioning Hui held with case study farm representatives, the team were able to prioritise specific research to help coastal farming communities work through the implications of climate change on their coastal farms, and the potential loss of land that is currently deemed as “productive” due to climate change. Issues raised by stakeholders at the Visioning Hui included the importance of the farms providing an ongoing economic base for hapū and also preserving important cultural values and practices, and exploring alternative land uses such as tourism or activities that help people “re-see” cultural values, protection of taonga species such as whitebait, ability to live on the land into the future albeit acknowledging there may be a need to move marae perhaps, schemes to build capability of the young people to work on the land, sustainable papakainga, habitat enhancements for alternate income; e.g., harakeke or organics and utilise benefits of returning more wetlands.

*On 26 May 2016, Aroha Spinks and Moira Poutama, from this research team, informed Nga Hapū o Ōtaki members of the Wai-o-Papa exhibition opening on the 31 May 2016 (see Chapter 6).

*Aroha Spinks also had a hui with Tanira Cooper, a teacher at Whakatupuranga Rua Mano on 27 May 2017, where she discussed the possibility of taking students to the Deep South project exhibitions; Tanira shared that there were a few high school students at their kura interested in Landscape Architecture as well as kaitiakitanga careers, with three young women that Aroha met being keen to pursue related environmental studies.

*Aroha Spinks and Moira Poutama met with Te Waari Carkeek and Ariana Te Aomarere (Ngāti Raukawa kaumātua) on 1 June 2017 and encouraged them to view the Wai-o-Papa Exhibition as they live in downtown Wellington where the exhibition was being held – this suggestion was positively received.

*Aroha Spinks invited her contacts at the two Kura Kuapapa in Ōtaki, namely Tanira Cooper at Whakatupuranga Rua Mano and Roimata Baker at Te Rito Kura Kaupapa,

[18] This transcript is not included in this report, due to the confidentiality of some of the information shared at the hui; but a synopsis can be made available to stakeholders if requested.

to the Exhibition on 21 June.  She also informed them of the offer by Martin Bryant (UoV member of this research team) to take the students on a tour of the University, with positive responses from Roimata and Tanira on the same day (08/06/16) – Roimata: “I am very interested in taking a van through.  Perhaps several from each kura? Ka korero tātou akuanei ne?”  Tanira: “E mea ana koe Whaea Roimata”. (We will talk soon, shall we? You bet Whaea Roimata).

*The team continued to work on plans to bring Kura Kaupapa students from Ōtaki to the Wai-o-Papa exhibitions in the future, as they relate to local environs, and to increase hapū and iwi numbers attending. To this end, it was purposely planned to hold one exhibition on-site in one of the redundant dairy milking sheds. It was also hoped to liaise closely with hapū and case study stakeholders, including the Te Rangi team of this research project, to develop a template that could be used to guide stakeholders in understanding which factors are most important for focussed ongoing ecological economics analysis of adaptation strategies for climate change impacts.

*The team held more onsite hui, to continue working on: the impacts and indicators framework and get a sense of the communities understanding of sea level rise, its impacts and/or how they would recognise it; and to work on identifying decision thresholds (i.e. at what point are they no longer able to use some paddocks for grazing).

### 3.3 Wai o Papa: Waterlands Exhibition; Stakeholder Wānanga at Ngāti Tukurohe Marae

Earlier exhibitions in this series were held at Victoria University of Wellington, and are detailed in Chapter 6. This chapter focuses on the localised community engagement with iwi and hapū from the case study rohe, on the whenua.

*An end user engagement wānanga was held at Tukorehe marae, Kuku on 3 November 2016, whereby the research team provided an uptake to end users and stakeholders on the research findings to date, and sought feedback. Various landscape architecture designs were also exhibited.

This wānanga was attended by all members of the research team, who presented about the Mātauranga Māori contributions; climate change and geomorphological research; ecological economics, design and other stakeholder engagement aspects, collated from this research to date. There were tables set up to facilitate stakeholder engagement and input from iwi, hapū and community member reps regarding their values and aspirations for these coastal regions. The team encouraged discussion and thinking about climate change adaptations for valued ancestral coastal lands. We also had two students from Whakatupuranga Rua Mano (WRM) Kura Kaupapa attend the exhibition and presentations. A WRM teacher, Tanira Cooper, also supported them. Other End User attendees included representatives from Te Hatete Trust, Tahamata incorporated, Incorporation of Ransfields, and others.

This hui in November 2016 included findings from the latest of the Wai o Papa: Waterlands Exhibition. It was also an opportunity to engage with Tangata whenua from the rohe. At the hui, the research team presented their research findings to date, in terms of the: Mātauranga Māori input and stakeholder engagement that had occurred; the climate change and geomorphology research including visual mapping of the predicted climate change sea level rise for the rohe over a 100 year period; the proposed ecological economics analysis in relation to wetlands, the potential adaptation strategies that had been generated; and the models and images of Victoria University Landscape Architecture student designs of potential adaptation strategies (these are reported on in Chapter 6).

A range of images follow (Figures 3.3.1a-e; Figure 3.3.2) with whanau members as well as tamariki (children) of various whānau who attended.


Figure 3.3.1a Presentation by the Research Team at the Stakeholder Wānanga

As can be seen from the photos below, there was a lot of interaction between people who attended the hui, with stakeholders and the research team discussing the research, pinpointing issues on maps, and interacting with the architectural designs.

Figures 3.3.1b-c Tamariki interacting with the visual displays and models

Figure 3.3.1d-e Tamaraki interacting with models and photos presented at the stakeholder wānanga

Figure 3.3.2a Kaumatua Yvonne Wehipeihana Wilson, Marshall Petley, Ani Adds and Te Huaki Kamariera adding to the dune contour maps as part of collating a vision from whanau and Ransfield's farm members.

Figure 3.3.2b Stakeholders Reviewing Adaptation Designs


Figure 3.3.3 The Research Team with Key Participants at the Stakeholder Wānanga on 3 November 2016

Stakeholders were asked to provide feedback on the research findings to date and to share their aspirations and any questions they had for the research team (for example, see Figures 3.3.2a-b and Figure 3.3.3). A summary of stakeholder feedback is below:

Te Hatete Trust

- What economical return can we look to for replacing pine trees in this and neighbouring land holdings?
- What is the potential of aqua/eco-tourism?
- Hatete Trust total support for Aqua culture i.e. tuna and whitebait farming
- Good visual props that reflect the level of restorative restoration happening in this landscape.
- Need to educate our whanau regarding conservation.

Tahamata Incorporated

- Our old people always said there is a relationship between the sea and the land.
- Enjoyed the local fresh produce restaurant idea.
- Need to promote the importance of wetlands.
- Consider promotion of aquaponics and subsistence living using biodiversity principles.
- Respect Papatūānuku and care for her and she will care for you.
- Need future planning and encourage our mokopuna to enrol and be educated in environmental courses.
- Work collectively with the other Māori farms.

Incorporation of Ransfield's

- I would like to see more freshwater crayfish in our rohe.
- Look into possibility of goats for cheese, other animals for other products.
- Looking at diversifying our farm for other economic bases e.g. gardens, trees (special).

Others

- I would like to see the survival of our sand dunes.
- Can observe changes based on what I see on the land.

*Huhana Smith had further discussions with Tahamata Board at the monthly hui on 21 November 2016 where possible drainage options in paddocks around wetland region were discussed with aerial maps taken to the meeting to mark up. This information was supplied to the ecological economics team members for inclusion in that part of the project (see Chapter 5).

*A hui was held with James Mackie (Chairperson of Tahamata Trust) in January 2017, regarding the ecological economics work being conducted about future scenarios for wetlands and drainage activities on Tahamata farm.

*It was originally planned to have a 'week long camp' at Kuku on 27-31 Jan 2017, but this was not able to be carried out. Therefore, the research team worked on weekends and Thursdays in February/early March to ensure every surface of the dis-used diary shed at Tahamata Dairy Shed was cleaned and ready to receive exhibition banners, artworks, panels and the Master's student or professional teams' works.

*Points to note regarding stakeholder engagement:*

Ongoing engagement between the research team and the wider community occurred throughout the duration of the project, through both formal and informal means. As the research progressed, however, it became apparent that there were some difficulties in securing times to meaningfully engage with Katihiku Ahu Whenua Trust and, to a lesser degree, Ransfield Incorporation, who had attended hui and been engaged at visioning hui and later wānanga. Members of the Hatete Whanau Trust became actively engaged as a case study participant group. Various shareholders of farm groupings across the rohe engaged with the research through hui, hīkoi and wānanga.

### 3.4 Whakatairangitia rere ki uta, Rere ki tai – Final Wānanga and Hīkoi, Stakeholder Engagement

On the weekend of 10-12 March 2017, the final wānanga and hīkoi for the project was held, including a final exhibition. This was a significant undertaking, implemented to foster engagement with end users and the wider community. Massey University co-funding was secured through an internal grant to enable Huhana Smith to contribute supportive funds to the dairy shed exhibition "Whakatairangitia Rere ki Uta Rere ki Tai" (Proclaim it to the land, proclaim it to the sea). In securing a Massey University Research Fund (MURF) grant, we were able to provide a strong visitor experience and cover expenses for the lead up to the exhibition with hireage costs of machinery and equipment to help clean up the site. Also, the project sourced further Deep South Engagement funding support from NIWA/MBIE to ensure food, marae hireage and the Vision Mātauranga principle investigators were well cared for.

Some 70-100 people attended the powhiri at Tukorehe Marae, and the event itself. Additional people came on Sunday 12 March to see the exhibition and participate in the hīkoi, despite the wet weather (see Figure 3.4.1).

A wide range of interested people attended – not only local residents (notified by leaflet drop into their mailboxes) but also others notified of the event by people Dr Smith had met previously at environmental workshops in Sydney. Some members of the case study farms came to the event, but not to the extent we had hoped. Building upon the major successes of the dairy shed exhibition event and how the team managed to ensure tangata whenua engagement, for the next phase of the research, the team will make a concerted effort to further engage with case study participants.

Other Vision Mātauranga Research Leaders projects in the Deep South NSC were supported by the Deep South NSC Engagement Fund to attend the weekend wānanga, to speak about their projects and provide visitors with expanded understandings on what is being undertaken around Aotearoa.

There were many others from local environmental or sustainable industry groups, Massey University artists and leaders, Māori resource managers (e.g., Garth Harmsworth from Manaaki Whenua Landcare Research), members of the Kāhui Māori for the Deep South National Science Challenge, and also many from the Deep

South project itself. Their experiences were profoundly positive with some feedback as follows.

The day following the event, Apanui Skipper, Māori Development Manager from NIWA, emailed an extensive list of people who had been invited to the event by Dr Smith, to say:

> *Tēnā koe e te tuahine*
>
> *Me mihi ka tika ki a koe me tō tāua nei iwi a Ngāti Tūkorehe, nā rātou i patu nei i a tātou ki te kai reka rawa atu nē Moira! Ka nui te mihi ki a koutou katoa he nui te aroha, he nui hoki te manaakitanga i ūwhia ki runga ki a mātou katoa. Thoroughly enjoyed your hospitality, reconnecting with our whanaunga & enjoying the sharing of your mahi.*
>
> *Ngā manaakitanga o te wāhi ngaro*
> *Apanui*

Darren King, Science Leader – Vision Mātauranga of the Deep South National Science Challenge, similarly congratulated the team, saying:

> *Kia ora e Huhana, koutou maa -*
>
> *I tautoko Apanui's whakaaro below.*
>
> *On behalf of the Kahui and the wider Deep South Challenge we are grateful for the opportunity to have shared time with you all.*
>
> *I am hopeful that many more people will get to see the tremendous mahi produced through your project in the months ahead.*
>
> *Mauriora, mauritau*
>
> *Noho ora mai, Darren-Ngaru*

Rhian Salmon from Victoria University of Wellington also sent Dr Smith a congratulatory email, thanking the team for "*a wonderful exhibition and event ..... and thank you for extending the invite to the broader Deep South challenge team (and babies), it was such a special day*".

While only one hīkoi took place on Sunday, the group talked at length about the ecological economics scenarios for wetlands on Tahamata, relaying the recommendation that Tahamata put a hold on drainage activities until a hui can be held with Tahamata board and the research team.

Figure 3.4.1 Some of the audience in attendance on for the event,11 March 2017

*Whakatairangitia rere ki uta, Rere ki tai* exhibition was very successful in terms of disseminating challenging information about climate change from a Mātauranga Māori, science, design and art perspective. Whakatairangitia rere ki uta, Rere ki tai grounded each shed in a Māori theme, whether Whakapapa, Hīkoi or Korero tuku iho. The exhibition reflected Māori cycles of change through the maramataka and associated customary knowledge, whilst also successfully incorporating the vision of iwi and hapū participants into the science and design presentation too. Further details about the exhibition are provided in Chapter 6.

In addition to the weekend wānanga/hīkoi and exhibition in March 2017, Dr Smith also met with Tahamata Board in March to update them on research progress and recommendations stemming from our wetlands research for their farm. We hope to continue this research with them in Phase 2 of this project, for which funding has been successfully gained from the Deep South National Science Challenge.

## 3.5 Communicating Research Findings to Other Professional Bodies and Conferences

In addition to the above mentioned methods to communicate the research as widely as possible, and to foster end user engagement, the research was also presented to the international research community at various conferences including:

* Derrylea Hardy presented a paper, Engaging with Local Communities to Address Complex Coastal Management Issues: Cross-cultural collaborative research for coastal wellbeing in New Zealand. Published Abstract and Proceedings of the ISEE 2016 Conference: Transforming the Economy – Sustaining Food, Water, Energy and Social Justice, University of DC, Washington DC, USA, 26-29 July 2016.

*Huhana Smith presented a paper at the *Mapping Spectral Traces 8: The Place of the Wound* International Symposium, 17-19 October 2016, at Maynooth University, South Campus, Maynooth, Ireland. She was an invited visiting scholar at this symposium, funded by the Irish Research Council New Foundations scheme.

She was also a member of the International Keynote Panel and Discussion: The Place of the Wound, 17 Oct 2016, Maynooth University, Ireland. She gave a presentation to Geography Students, Maynooth University, 20 Oct 2016.

*Huhana Smith presented on “The practice of cross-cultural restoration and concentrated dialogue” at the *Global Ecologies-Local Impacts* conference, Sixth Biennial Conference of the Association for the Study of Literature, Environment & Culture, Australia & New Zealand (ASLEC-ANZ) and Sydney Environment Institute (SEI), University of Sydney, 24 Nov 2016.

She also liaised with key scholars and museum workers over a possible international exhibition of art, design, architecture and contemporary Māori/indigenous art on climate change (http://www.asle.org/calls-for-papers/global-ecologies-local-impacts-aslec-anz-2016-conference/)

*Huhana Smith participated in the *Re-(E)mergence of Nature in Culture workshop*, University of Sydney on Thursday 23 February 2017. From Aotearoa, Australia and the USA, scholars from and of indigenous cultures, politics, philosophy, law and literature gathered for a multi-disciplinary one-day workshop devoted to examining the merger of culture and nature in indigenous thinking and practice, and recent interpretations/integration in law, politics, literature, architecture and philosophy. They are critically challenging the millennia-old (Western) endeavour to banish ‘brutish nature’ from the cultural - an endeavour so successful that humankind in controlling life form and function, now faces extinction unless the re-emergence of the natural and cultural succeeds.

*Jane Richardson presented a paper at the 3rd European Climate Change Adaptation Conference in Glasgow on 5-9 June 2017, “Adaptation strategies to address climate change impacts on coastal Māori communities in Aotearoa-New Zealand:  integrating a geomorphological perspective”.

*The research team are continuing to present findings from the research to local, national and international audiences.

### 3.6 Published Outputs

Written outputs were generated to communicate the research results, including this written report, and a journal article. It is envisaged that additional reports and/or journal articles may also be generated from this research. For example, Huhana Smith is drafting an article for the Journal of Modern Environmental Science and Engineering, ‘The practice of cross-cultural restoration and concentrated dialogue and engagement between Western sciences and customary ecological and cultural knowledge embodied in mātauranga Māori.’ Additionally, there is a report being reviewed for publication by the end of 2017 by Patterson et al. detailing the ecological economics-focussed research.

# 4 RESULTS – CLIMATE CHANGE / GEOMORPHOLOGY

## 4.1 Summary of International Climate Change Science: Sea Level Rise

Professor Manning conducted a comparison of recent analyses for future sea level rise with the 2013 Intergovernmental Panel on Climate Change (IPCC) report. The 2013 IPCC Assessment report used four scenarios (RCPs) for future greenhouse gas emissions together with some early models of ice sheet behaviour to estimate future sea level rise (SLR) by 2100. However, it was recognised that these models might not be covering all aspects of ice loss in the Antarctic and a qualifying statement noted that such Antarctic ice loss might add "several tenths of a meter during the 21st century" (Church et al., 2013).

The issue of "how much sea level rise (SLR) should coastal communities plan for?", is not straightforward, as this is itself still a rapidly developing field of science. Thus, all estimates of future SLR should be used as part of a broader risk management perspective.

The 2007 IPCC Working Group I (WGI) Assessment found that there was a growing discrepancy between observations and climate models and so concluded that an upper bound for SLR by 2100 could not be specified. The 2013 WGI report then had a chapter focussed on SLR *(*Church et al., 2013) with estimates based on a new set of climate models, but it also used subjective judgement to estimate wider uncertainty ranges for these. Furthermore, this analysis used observed values for ice sheet loss, rather than estimates from models, in order to reproduce the total SLR observed over the 20th century. This failure of models to reproduce the last 100 years of sea level rise led to an inference that natural causes of warming around the 1930s had led to some significant loss of ice in the Arctic and so these were not due to increasing greenhouse gases[19].

Changes in the rate of SLR, and major shifts between the processes causing these, are now starting to be seen more clearly. For example, while thermal expansion due to warming of the oceans contributed 40% of sea level rise over 1971 – 2010, this was only 34% over 1993 – 2010 (ibid.) and a more recent analysis now puts it at 28% over 2005 – 2013 (Cazenave, 2015). Other factors causing sea level rise include loss of glaciers and ice sheets in Greenland and Antarctica, but also involve significant changes in groundwater storage (Wada et al., 2012) and changes in the ocean's surface mixed layer and in heat exchange between that and the deep ocean water which have very different thermal expansion coefficients.

Since 2013 several much more detailed analyses of the Antarctic ice sheets have been done and all have found that they can play a significantly larger role.

Figure 4.4.1 shows ranges for the lowest and highest scenarios used in the IPCC 2013 assessment as well as for one of the two mid-range scenarios that was used in a wider range of climate models. These scenarios are being compared with the upper end of the range for future sea level rise given in two of the more recent analyses and which now cover the processes for Antarctic ice sheets in much more detail.

[19] See Figure 13.7 and comments in section 13.3.6 of Church *et al*, 2013.

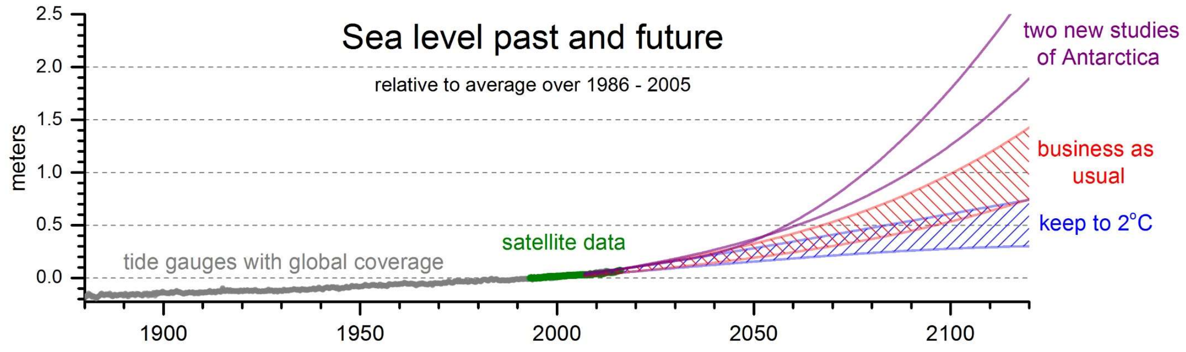


Figure 4.1.1 Sea level projections
N.B. The grey line shows changes in global average sea level measured by tide gauges at coastal locations around the world. The green line shows the global average derived from satellite data that started in 1993. The curves from 2010 on are projections into the future derived in climate models with the blue and red ranges being from the last IPCC assessment report and the two lines above that from more recent studies (Golledge *et al* 2015; DeConto and Pollard 2016) that use more detailed analyses of Antarctic ice sheets.

The present rate of SLR is similar to the top end of the range given by the IPCC models for 2010 - 2020. On this basis, the bottom end of a range to be used for planning would now be 0.5 m over the next 100 years with this rate also continuing throughout the 22nd century. The Golledge et al. (2015) results are giving about 0.6 m over the next 50 years and 1.7 m over the next 100 years. The DeConto & Pollard (2016) results might be considered as a possible worst case scenario reaching 0.7 m and then 2.5 m over these periods. In all cases rapid changes do not start until after 2050 and over the next 100 years these reach rates of about 20 mm/yr for RCP8.5, 32 mm/yr for Golledge et al. and 55 mm/yr for DeConto & Pollard.

A recent re-analysis of the satellite data for global average sea level since 1993 has revised earlier values and identified an increase in the rate that now appears to be more consistent with the observations of accelerating loss of ice sheets in the Antarctic and Greenland (Watson et al., 2015). Figure 4.1.1 shows this new data[20] and the average rate of 5.3 mm/yr after 2011 is at the upper end of the range predicted by climate models in the last IPCC assessment for the 2010 – 2020 period.

The satellite data have been revised slightly but the recent higher rate continues after what still seems to be a transition in mid-2011. The CSIRO group make the point that we do not know whether this rate should be expected to continue, however, from a risk management perspective the higher rate of change should not be ignored either. Furthermore, the first analysis that showed this increase in the rate of SLR noted that it occurred at the same time as an increase in the rate of ice loss which is adding to the effects of heat uptake by the oceans (Yi et al., 2015).

The full range for changes in sea level produced by the climate models used in the last IPCC assessment report is shown in Figure 4.1.2 as changes relative to mid-

[20] N.B. Although the Chief Executive of CSIRO, Australia, has decided to fire the world's most distinguished scientist in the field of sea level rise, i.e. John Church, his group is still managing to update some of their data, as evidenced in Figure 4.2.3.

2007. Thus, the data appears to be showing a transition from following the lowest rate given by climate models to a rate of increase that is currently a bit more than their highest rate predicted for this decade.

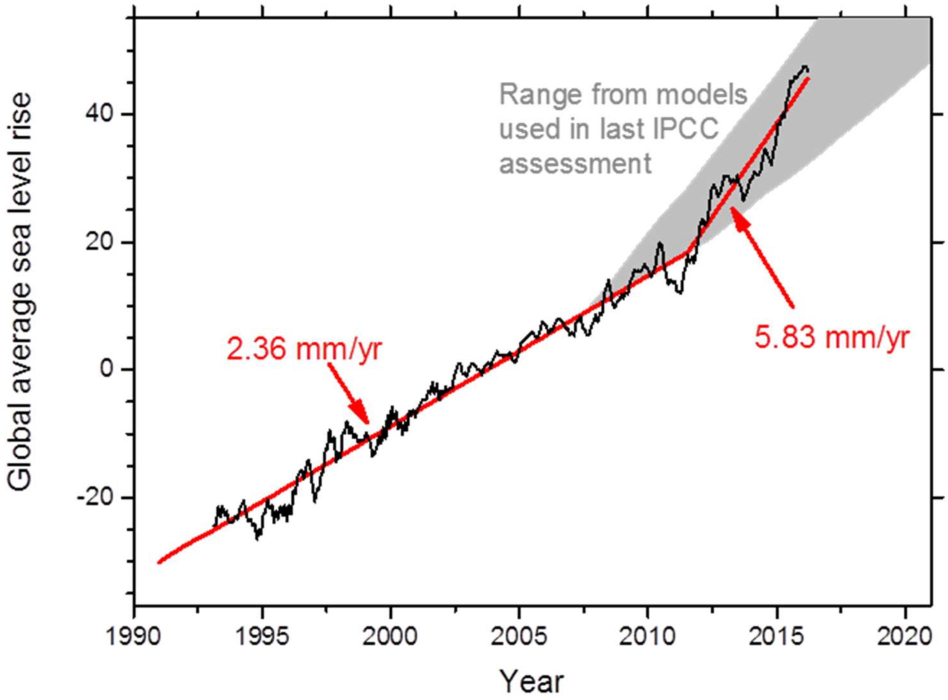


Figure 4.1.2 Global average sea level from satellite data (black) starting in late 1992 based on Watson *et al.* (2015).
N.B. Red lines show a piecewise linear fit to the data with one transition point. The grey band shows the range of climate model projections from the IPCC Working Group I 2013 report.

Changes in sea level have significant regional variations and most of the Western Pacific has had larger than global average rates for the last twenty years. Figure 4.1.3 shows trends since 1993 based on the data to 12 July 2016. To some extent these changes show correlations over time with decadal scale variations in climate such as the El Niño Southern Oscillation but it is still not clear to what extent this spatial pattern, that has higher than average rates of change around New Zealand, will continue over the long term.

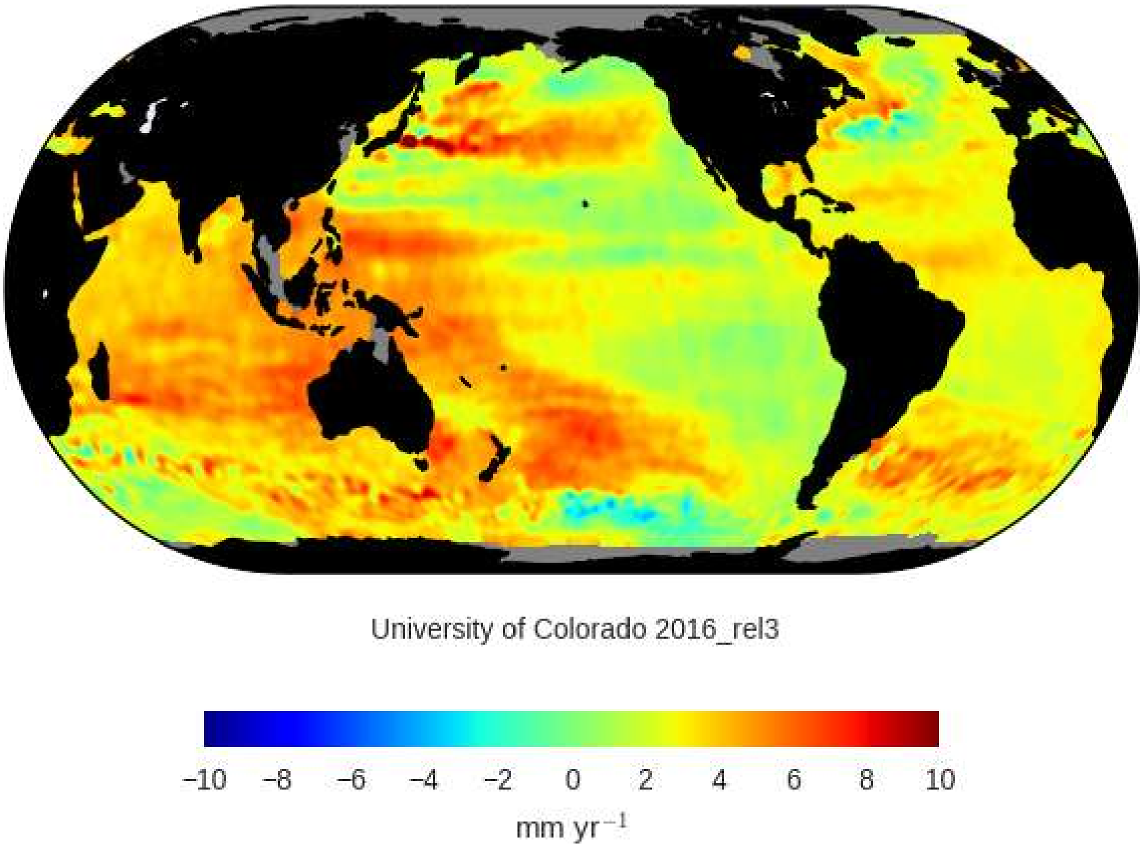


Figure 4.1.3 Map of sea level trends from the Colorado University Sea Level Research Group http://sealevel.colorado.edu/content/map-sea-level-trends as of 12 July 2016

## 4.2 A Review of the Climate Change Literature in New Zealand

What follows is a summary of Professor Manning's compilation of the climate science literature, focussing in on that which is relevant in planning for coastal changes in the Horowhenua-Kāpiti region, followed by a review of how adaptation strategies should be developed.

Figures 4.2.1 and 4.2.2a-b below show water levels at Ōhau river delta, Kuku Beach Road, at various times. In the latter figures, high and low tides are about 2.3 m different at the bottom of Kuku Beach Rd, in December 2015.

Figure 4.2.1 A low tide showing higher than normal water levels across the Ōhau river delta at the end of Kuku Beach Rd a week after the storm surge that affected this region on July 24, 2016

Figure 4.2.2a High tide, bottom of Kuku Beach Road, December 2015

Figure 4.2.2b Low tide, bottom of Kuku Beach Rd, December 2015

*Sea Level Rise*

Variations in sea level around New Zealand have shown significant rises and falls correlated with the El Niño Southern Oscillation (ENSO) but for the last 20 – 30 years the falls have become much smaller. To show this variation, Figure 4.2.3 compares New Zealand tide gauge data for five coastal sites[21] with satellite data for seven locations around the south of the North Island that have had their seasonal cycles removed.

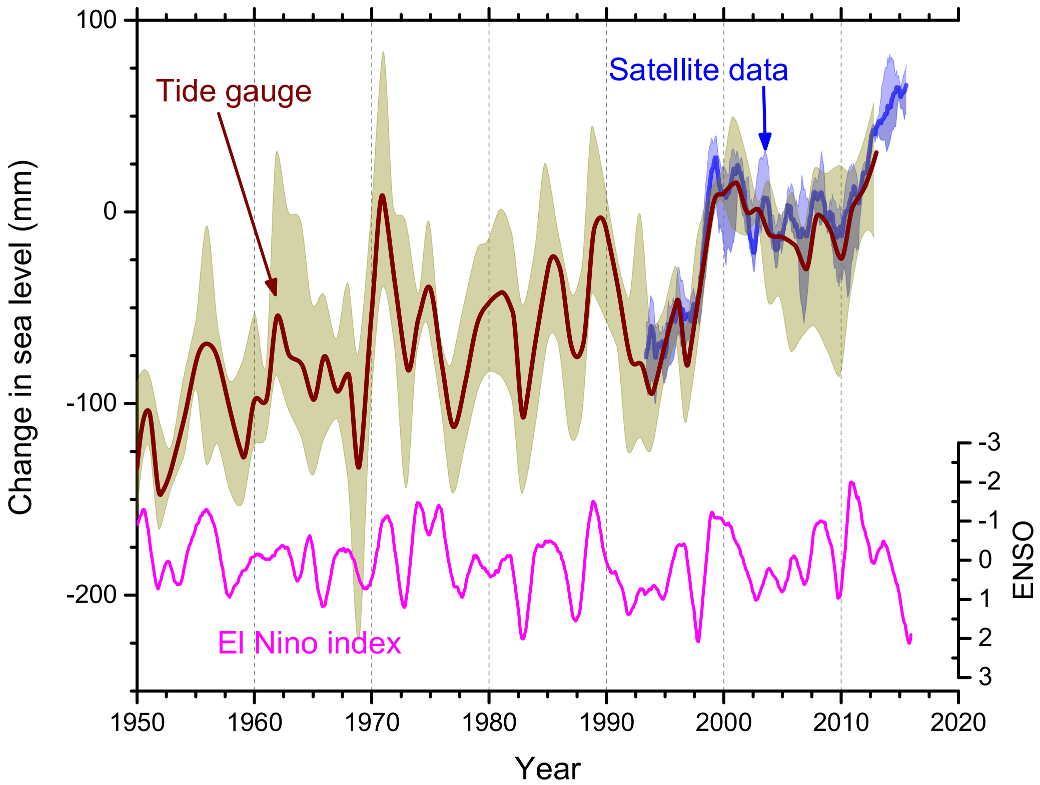


Figure 4.2.3 Changes in sea level around New Zealand over 1950 - 2016
N.B. Annual tide gauge data are shown as the average (dark brown) and range (light brown) across five locations. Similarly, satellite data are shown (blue) for seven locations around the south of the North Island after removing their monthly and seasonal cycles. For this comparison each data set has been adjusted to an average of zero over 2000 - 2005. The lower graph shows the El Niño Southern Oscillation index with the vertical scale reversed to show the correlation that existed prior to 2011.

Despite coming from two very different types of measurement, the data agree quite well and show fluctuating rates of change. For 1993 – 2000 and 2010 – 2015 these changes have been in the range 14 – 19 mm/yr, i.e. 5 to 6 times the global average. There was a decrease from 2000 to 2010 but this was much less than had occurred after previous rapid rises such as that in 1970. The ENSO index in the lower panel also shows that its negative correlation with sea level rise has not continued since 2011.

[21] See https://data.mfe.govt.nz/table/2523-annual-mean-sea-level-relative-to-land-19002013/

A recent reanalysis of earthquakes for the bottom of the North Island and top of the South Island has shown that ones due to major subduction occurring at plate boundaries are occurring across this region about every 350 years (Clark et al., 2015). This has been related to the 1855 Wairarapa earthquake that caused a significant amount of subsidence in some areas and significant changes to the shoreline.

It has also been found that the bottom of the North Island is having a slow ongoing subsidence (Beavan & Litchfield, 2012) in the range 0.7 to 4.5 mm/yr for coastal sites from Levin to Wellington, and with an average of 2.1 mm/yr. Tide gauge data can be influenced by coastal subsidence whereas the satellite data shown above is not.

However, both types of data have too much short term variability so far to determine whether a geological subsidence of about 2 mm/yr is being confirmed by differences in the two types of sea level data.

Regional changes in sea level differ from the global averages covered here so far. Satellite data has shown sea level increasing in the Western Pacific, including the area around NZ, much more than in the Eastern Pacific. But the extent to which that is the result of decadal scale variations in ocean circulation or part of a longer term trend is still not clear (Palanisamy et al., 2015).

While New Zealand has tide gauge records that monitor sea level going back to the 1890s, these are only continuous since the late 1940s; are on the eastern side of the country; and can be influenced by ongoing slow movements of tectonic plates Hannah, 2015). More frequent data is available from 1998 on but while some studies suggest that Auckland is the most reliable site (ibid.), others suggest that Wellington is (Watson et al., 2015). The most recent revision to the satellite data, mentioned above, is likely to improve its agreement with the New Zealand tide gauge records (Bell and Hannah, 2012) but this revision has yet to be carried out.

The Parliamentary Commissioner for the Environment (PCE) 2015 report (Parliamentary Commissioner for the Environment, 2015) has identified risk areas for New Zealand's coastal regions where LiDAR data was available. However, other LiDAR data does exist for the Ōhau river area from the Horizons council and should now be calibrated against the data used in PCE report. The PCE (2015) report also used heights relative to the Mean Highwater springs (MHWS-10) sea level rather than the average low tide level that is used more generally in tidal reports and local government databases[22].

Two issues in the PCE report relevant for the Horowhenua – Kāpiti region are that low lying land areas can be set well back from the coastline, as seen in Ōtaki, and these areas often follow the small river estuaries.

A closely related issue for coastal management is that the 99th percentile for storm wave height has been increasing in the New Zealand region at about ten times the rate for sea level (Young et al., 2011). This means our west coast, including the Horowhenua – Kāpiti region, are seeing a trend in wave height in strong westerlies of ~30 mm /yr. However, the extent to which this trend will continue is not known and it

[22] For example, such as http://apps.geocirrus.co.nz/HTML5/Index.html?viewer=kcdc

could be one of the changes in southern hemisphere climate that are attributable to loss of stratospheric ozone and creation of the ozone hole over Antarctica rather than increasing CO2 etc. *(*Thompson et al., 2011; Eyring et al., 2013*)*.

Given the limits to current projections of future sea level rise when considering the Horowhenua – Kāpiti region, it is suggested that the following high and low cases be used for increases in sea level when considering options for adaptation measures (see the Table below).

Table 4.2.1 High and Low Cases, Sea Level Rise, Horowhenua – Kāpiti Region

| | Low case | | High case | |
|---|---|---|---|---|
| | SLR | Max rate | SLR | Max rate |
| 2045 | 185 mm | 5.6 mm /yr | 305 mm | 11 mm /yr |
| 2075 | 385 mm | 7.4 mm /yr | 758 mm | 20 mm /yr |
| 2115 | 735 mm | 9.6 mm /yr | 1558 mm | 20 mm /yr |

In summary, the trend for sea level rise around New Zealand has been about 5 mm/yr over the last thirty years and so significantly larger than the global average of about 3 mm/yr. But changes in regional sea level of up to 100 mm are occurring in less than a decade and over the last twenty years these increases have not been compensated for by a subsequent drop in sea level to the extent seen previously. Large variations in the rate of sea level rise around New Zealand make it harder to predict when a threshold for the sustainability of some current practice will be crossed, but at this stage a rate of 200 mm/decade would be a more reasonable approach, rather than using 200 mm over 30 years!

*Implications of the above findings for the Ōhau-Kuku-Waikawa Coastline*:

The implications of the above findings for the Ōhau-Kuku-Waikawa Coastline are as follows. Coastal geomorphology for this region still needs to be considered in more detail to understand how it will respond to SLR (see next section).

Figures 4.2.4a-c below taken from Google Earth show the Ōhau river mouth location for various time periods between 2005-2015.

Natural evolution processes for the sand dunes have been identified in some detail (McFadgen, 1997) and sediments coming from the Manawatu river are clearly accumulating along the coastline in this region. There is also evidence that the dunes can move rapidly enough to destroy forests (McFadgen, 2010).

Land development since the 19th century has made significant differences in some parts of the wider region, such as the development and then abandoning of harbour facilities in Foxton, and establishment of stop banks and risk based approaches to land use around the Manawatu river. Channelling of water for drainage and farm water supplies, together with roading, will also have significantly modified the region's hydrology more widely.

A report for the Horizons Regional Council (Tonkin & Taylor Ltd, 2013) has considered coastal hazards for this area and showed that shoreline accretion is occurring at rates of 1.3 to 3.4 m /yr. This also shows that a large area of land set back from the sand dunes and from the Ōhau to Waikawa rivers was susceptible to 1% Annual exceedance probability (AEP) events and the extent to which this went inland was beyond what was covered in that report. However, it used a coastal hazard assessment by Roger Shand for the Ōhau river and it is not clear to what extent that assessment covered the shoreline accretion and accumulation of sand dunes that have also been identified in this area.

Coverage of future SLR in the Tonkin & Taylor report was also based on the MfE 2008 report and that MfE report is no longer consistent with the last IPCC assessment, or with the science literature summarised in the previous section.

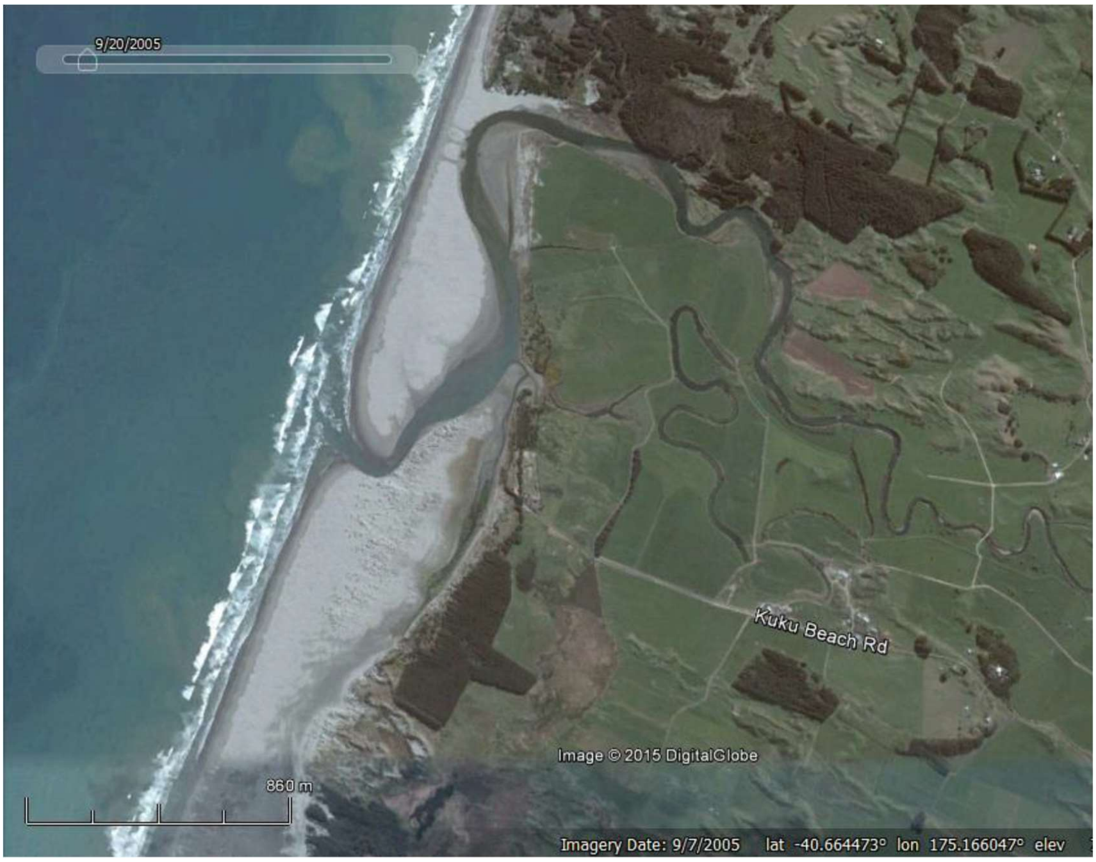


Figure 4.2.4a Google Earth image showing the Ōhau river mouth location for 9/7/2005

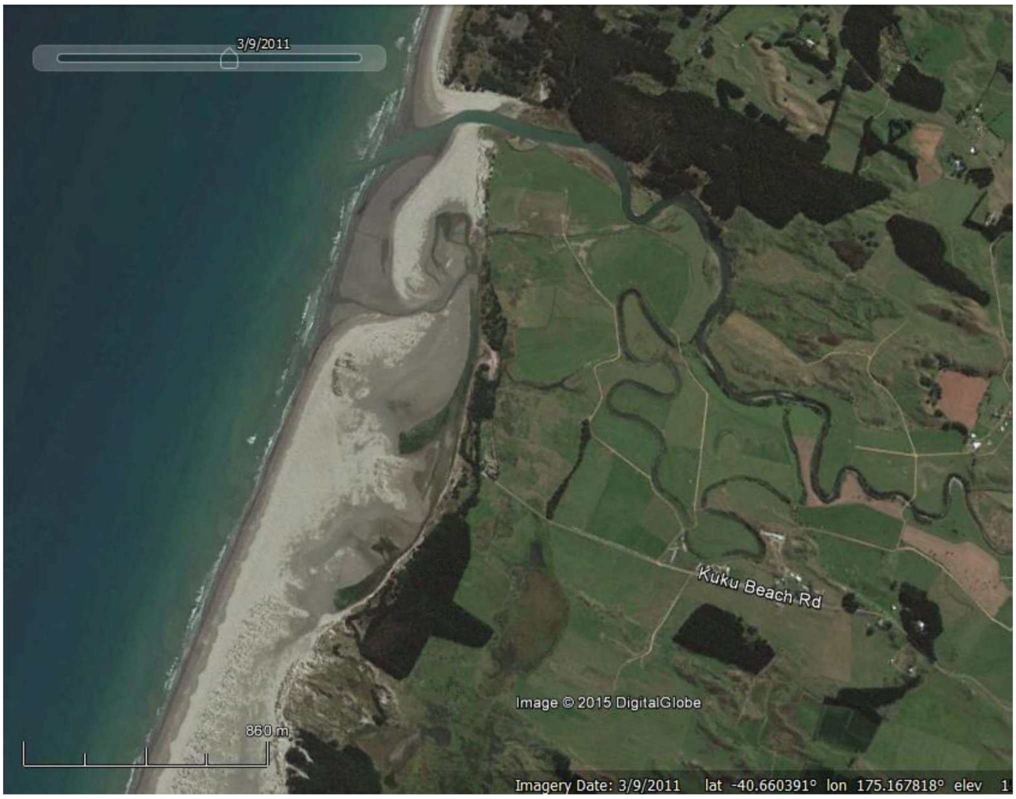


Figure 4.2.4b Google Earth image showing the Ōhau river mouth location for 3/9/2011

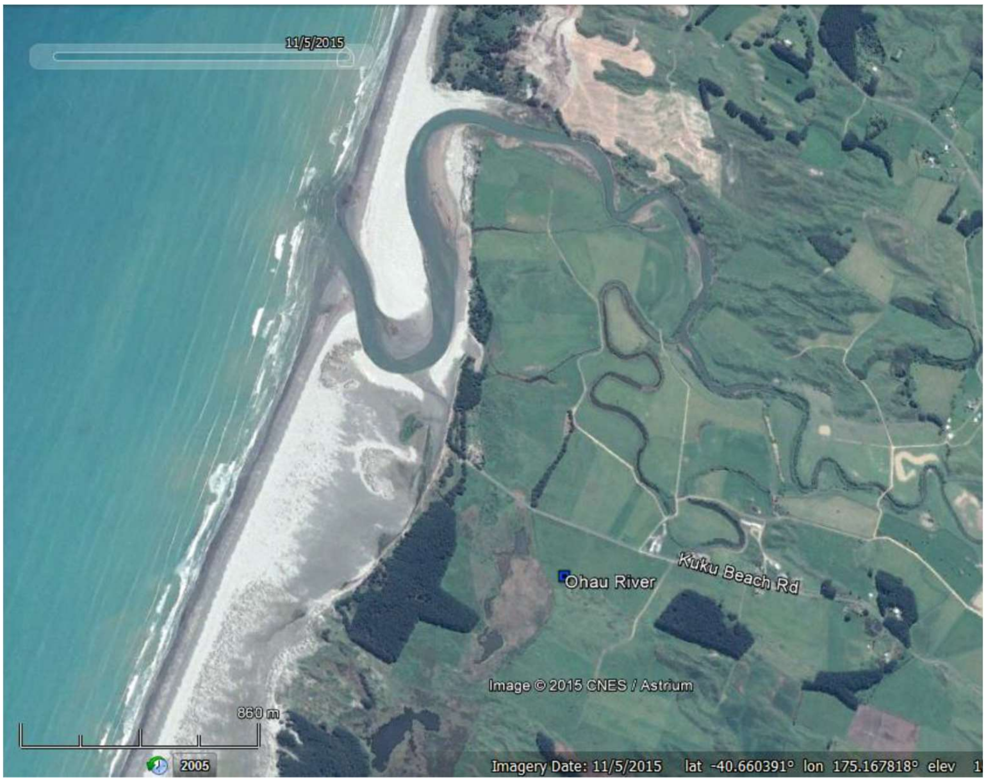


Figure 4.2.4c Google Earth image showing the Ōhau river mouth location for 11/5/2015

Variations in the Ōhau river mouth location can be seen in Google Earth as shown in Figure 4.2.4a-c. These changes imply that the position of the river mouth is very susceptible to major flood events but that it tends to return to a state where it flows south behind sand dunes before breaking out into the sea. This finding is also consistent with the sand dunes continually building up due to sediments coming down from the Manawatu river.

In comparison, Figure 4.2.5 below shows that the smaller Waikawa stream reaches sand dunes and then flows south before breaking out; and this has been more stable over the period covered by these images, probably because the sand dunes are higher and covered in denser vegetation.

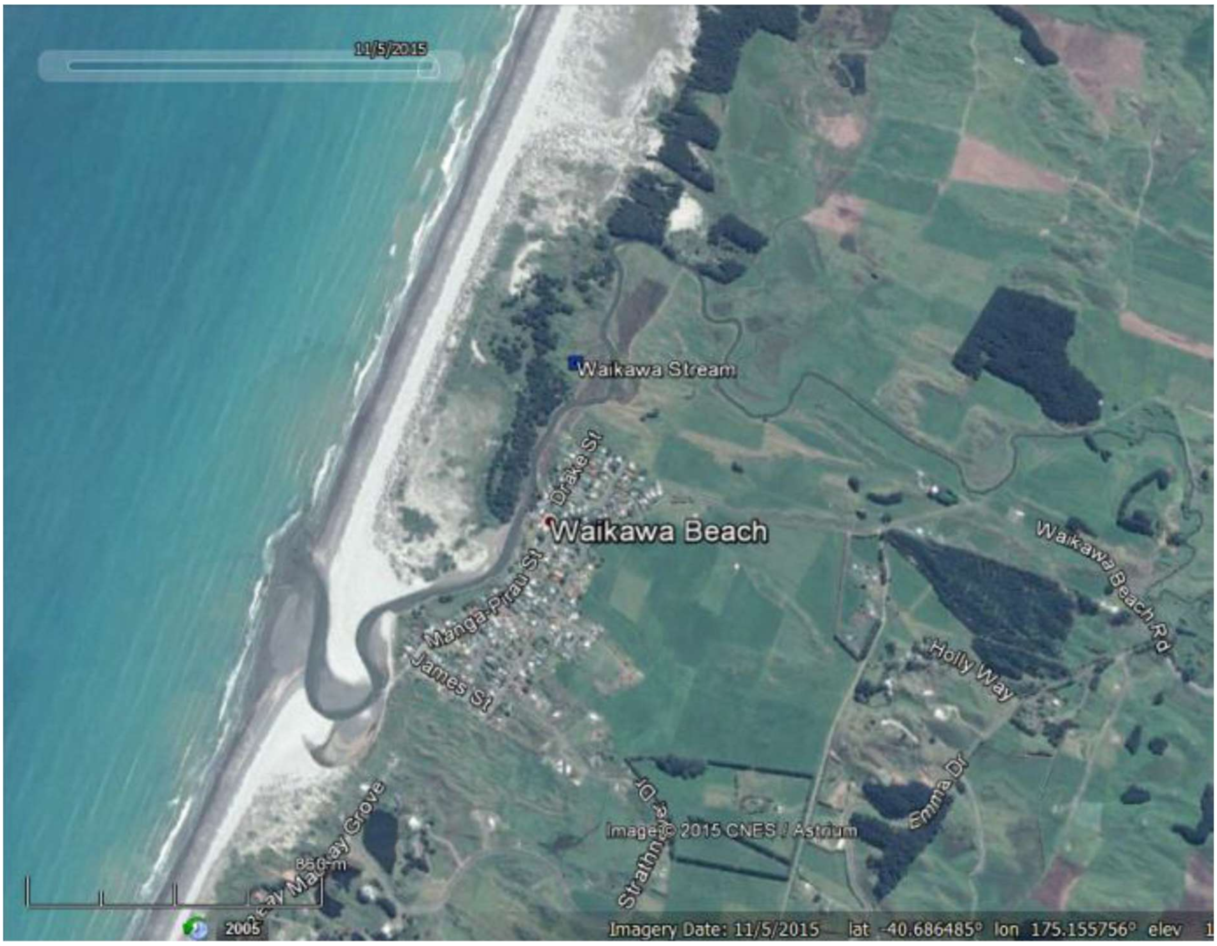


Figure 4.2.5 Google Earth image of the Waikawa river at the same scale as used for the Ōhau river mouth

The next two landscape photos (Figures 4.2.6a-b) show some of the differences between the mouth of the Ōhau and Waikawa river areas, with the upper one being for Ōhau and both looking north. For the Waikawa river the sand dunes are much higher, vegetation is thicker in many places and the pine forest area on the right is on the seaward side of the river.

Figure 4.2.6a Mouth of the Ōhau river area, looking north

Figures 4.2.6b Mouth of the Waikawa river area, looking north

This initial review of some issues for the coastal geomorphology suggests that sand dunes can become a natural buffer zone for storm surges and so significantly reduce the impacts of sea level rise. As these sand dunes can be increasing in height, protecting them from flood events can lead to the development of more vegetation and more resilience to future changes.

*4.2.1 Impact of SLR on Coastal wetlands and groundwater*

The potential for SLR to lead to salinisation of groundwater has been identified as a major issue for many parts of the world that are reliant on groundwater as a source of water. This topic is already a controversial issue in Kāpiti where groundwater is used as a resource for town water supply in summer. Greater Wellington Regional Council have noted there is already evidence for salinisation of groundwater occurring 600 m in from the coast, but the Kāpiti Coast District Council still reached an agreement to withdraw more water from wells when the Waikanae river is at low levels (*Mzila, 2013)*.

Sea level rise is expected to make salinisation more serious, but other groundwater studies have shown that this can also lead to a rise in the groundwater levels that offsets much of the salinisation, but increases flood risk. See Figure 4.2.7 below.

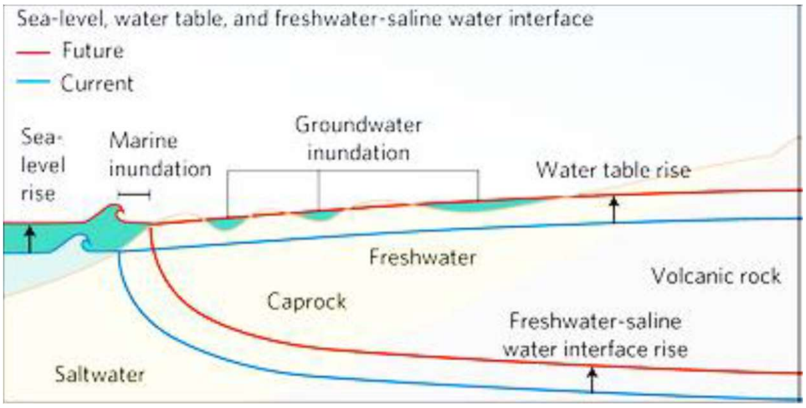


Figure 4.2.7 A rise in sea-level will generally affect groundwater levels and its flow in coastal regions leading to more extensive flooding (Source: Rotzoll & Fletcher, 2013).

Online tools, based simply on the land elevation, now show the areas of the USA that will be affected by SLR in order to raise more awareness of these issues[23]. A "Low Elevation Coastal Zone" has also been defined as land less than 10 m above sea level where groundwater changes are expected to occur (McGranahan et al., 2007), and that has been backed up by detailed groundwater modelling studies in the USA (Bjerklie et al., 2012).

To apply these types of international studies to the Horowhenua – Kāpiti area will require a better analysis of groundwater. While some local studies have shown significant interactions occurring between the Waikanae river and surrounding groundwater (Osborne, 2006) it is still not clear how this applies more broadly. Also while there is monitoring of groundwater levels in a number of wells in the Kāpiti area, very little is known about the rate of groundwater flow through this area. Studies done in the 1980s for some parts of New Zealand showed a very wide range of groundwater flow rates occurring rather than a single homogenous flow, but that was done using short-lived radioactive tracers that are no longer allowed (McCabe et al., 1983).

For the Ōhau – Kuku – Waikawa area it will be important to understand more about the groundwater capacity and how it varies seasonally and in response to heavy rainfall events. As the Ōhau river has a significant catchment area in the Tararuas but then a very small gradient over the lower 8 – 10 km, it can be directly linked to groundwater in ways that buffer the more extreme flood events but also lead to much more extensive flooding once a groundwater capacity is exceeded.

The proactive forms of development that are now being used to restore wetlands set back 0.6 – 1 km from the shoreline could also establish a buffer zone to protect against salinization of groundwater. However, the extent to which a prolonged drought might drop the water table and lead to salinisation in the wetlands needs to be considered.

Thus, research should identify a priority order for different approaches to monitoring and protection of groundwater in order to ensure that a sustainable approach can be developed to cover the region's wetlands and agriculture while also allowing for a sea level rise of up to 2 m. In particular, defining a practical set of early warning

[23] See: https://coast.noaa.gov/slr/

indicators should be done now, but with some anticipation that more advanced forms of monitoring will become more affordable because this is a growing issue globally.

An initial approach can use the existing LiDAR maps for the coastal area and an assumption that groundwater levels will increase in response to sea level rise by an amount that decreases linearly with ground elevation and becomes zero at 10 m above sea level. However, the LiDAR does not go far enough back along the Ōhau river for this to give a complete picture at this stage.

Sea level rise can cause a rise in groundwater over low lying land and an increase in the frequency and extent of flooding. The last IPCC report showed results for several places, including Wellington, where a rise of 0.5 m would make flood events 1,000 times more frequent (Church et al., 2013). Observations in the USA have already shown an increase in the frequency of coastal inundation and indicate that this is likely to start occurring more than 30 times per year over the next few decades (Sweet & Park, 2014).

Identifying areas that will be vulnerable to this rapid increase in flood frequency requires a better understanding of the links between groundwater and sea level. A preliminary analysis of groundwater data for the Kāpiti region has shown that it has significant tidal cycles which reduce with distance from the coastline but which go much further inland around rivers. For example, the tidal cycle along the coastline in the Kāpiti – Horowhenua region has a range of up to 2.3 m, and groundwater levels in Kāpiti are varying by up to 1 m.

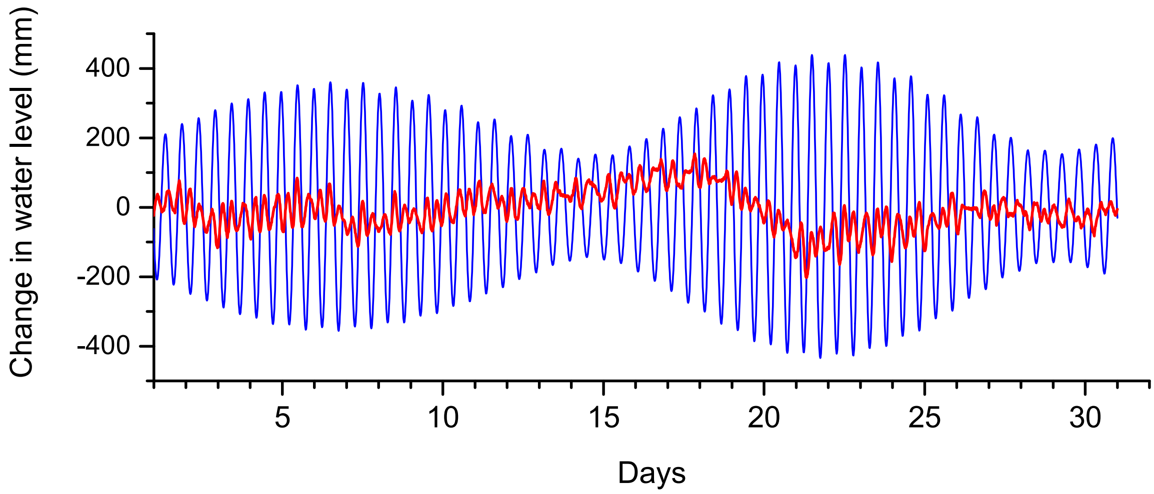


Figure 4.2.8 A tidal cycle (blue) fitted to groundwater levels in 2015 at well R26/6594 by the Waikanae river using five frequencies to follow different lunar and solar influences (see: http://www.vims.edu/research/units/labgroups/tc_tutorial/tide_analysis.php). N.B. The difference between the tidal cycle and observed data is shown in red and all these values are relative to a long term average.

Generally the amplitude of the tidal cycle in groundwater decreases exponentially with distance from the shoreline (Bjerklie et al., 2012) but some sites clearly have a more direct connection with the ocean than others. A relationship between the groundwater tidal cycle and distance from the high tide line is shown in Figure 4.2.9 below for twelve wells in the Waikanae – Te Horo region. This shows a range of decreases in the cycles and a 90% decrease occurring over distances ranging from 190 m to 800 m from the coastline. Furthermore, well R26/6594 is about 1400 m from the high tide level at the beach but only about 280 m from the Waikanae river and using its position relative to the river makes it much more consistent with what is seen in other groundwater wells. This shows that the groundwater response to sea level extends much further inland around the river estuary areas.

The site in Figure 8 that is furthest inland (R26/6284) is located where the Waimea river used to be in the late 19th century before some change occurred between 1890 and 1896 that led to water flow in this region becoming predominantly down the Waikanae river (Maclean, 1988). The groundwater tidal cycle seen for this site, that is more than 2.5 km from the shoreline, may relate to aspects of the ground structure that reflect its history as part of a river over 100 years ago. But in contrast, there are several groundwater monitoring sites in Kāpiti that are less than 1 km from the high tide level and where no tidal cycle can be identified. This shows that there can be a wide range of groundwater response to sea level rise.

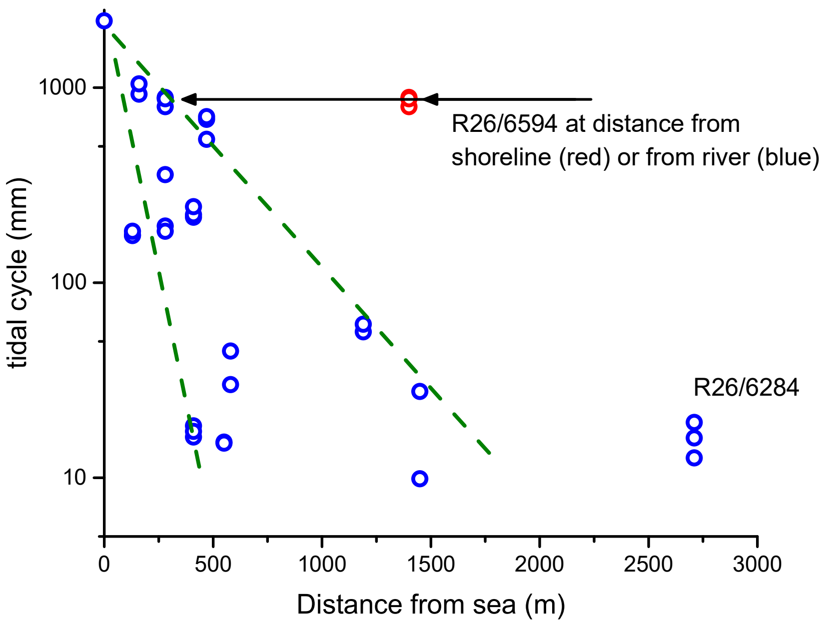


Figure 4.2.9 Amplitude of tidal cycles in groundwater at different distances from the coastline in the Kāpiti – Te Horo region

N.B. The value at zero distance is the corresponding amplitude of tidal cycles at the coastline. The green dashed lines show the ranges of changes with distance mentioned in the text.

A recent Otago Regional Council report has done a detailed study of the effects of sea level rise on South Dunedin and has shown that an increase in flooding will limit the future sustainability of some housing areas (Goldsmith & Hornblow, 2016). While the socio-economic context is very different to that for the Horowhenua – Kāpiti areas, the coastal processes are similar and what is happening now in South

Dunedin can be an indicator of what will occur in the future around the Ōhau – Kuku coastal area.

Much of the focus for South Dunedin is now on how groundwater levels effect the frequency and extent of floods and the 2016 report has extended an earlier study done by BECA in 2014 now recognising that the height of the groundwater table varies by as much as 0.6 m due to groundwater flow out of aquifers. This new analysis indicates that sea level rise will result in ponding of water at the surface but that this does not just occur first on the lowest land, but rather where the water table is currently closest to the surface. Consequently a better understanding of variations in water table height is needed to identify areas most at risk.

The other issue with groundwater response to climate change is how it can affect the extent and frequency of flooding. Groundwater levels are generally more than 1 m below the surface but the response to rainfall depends on the porosity of the soil and the extent to which water is also being held by pore spaces of the unsaturated (or vadose) zone above the water table. ‘Specific yield’ is a soil property more relevant than porosity and this is the volume of water that can drain from soil under gravity (van Gaalen, et al. 2013). Whereas porosity can be large in soils that have either large or small particles, smaller particles can create more retention of water on their surfaces and so tend to reduce the specific yield. A typical value for this in sandy soils around coastal areas is about 22% which means that rainfall of 10 mm would correspond to a 45 mm rise in the groundwater level.

Vegetation also increases the retention of water in soils and creates capillary forms of groundwater retention where all the pore spaces can be filled with water even though they are still well above the normal groundwater level. This reduces the volume available for storage of rainfall. Surface water movement and lateral groundwater flow also lead to effects that increase the sensitivity of groundwater levels to rainfall and several studies have shown that 10 mm of rainfall often leads to effective rises in groundwater of 300 mm (van Gaalen et al., 2013).

An example of groundwater response to rainfall in the Kāpiti – Ōtaki region is shown in Figure 4.2.10. The rise in water level occurs over hours and is much more rapid than the following drop that takes several weeks. Also this shows that there is a cumulative effect of repeated rain events. However, R26/7025 has higher land next to it and this appears to be increasing the rise in groundwater.

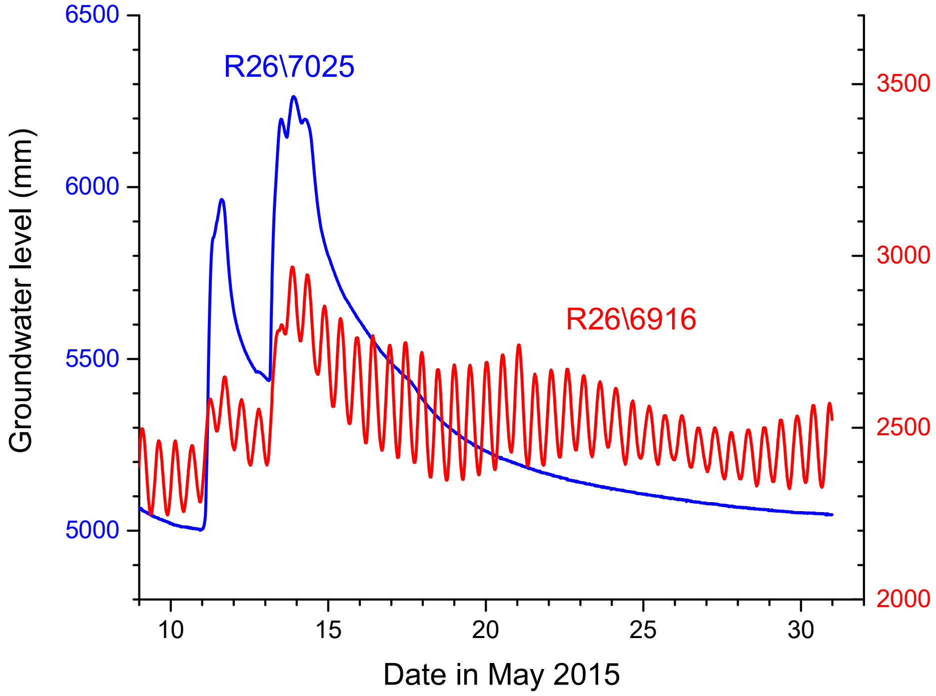


Figure 4.2.10 Groundwater response to rainfall occurring over four days at two sites in Waikanae. R26\7025 is further back from the coastline and R26\6916 is near the Waikanae river

### *4.2.2 Coastal storm events*

New Zealand is in one of the regions where significant increases in extreme wave height has been seen in satellite data (Young et al., 2011) and several subsequent studies have shown that this has become a more significant cause for coastal impacts on the west coast of the USA than the rise in average sea level. Much of the coastal erosion in that region is related to storm surges that add metres to the water level height and these are related to ENSO type conditions which are expected to become more frequent due to climate change (Ruggiero, 2013). While this was mentioned as an issue for the Kāpiti region in a recent review done for the district council (Carley et al., 2014), there has not yet been any detailed study of the extent to which storm surges are actually affecting the Horowhenua – Kāpiti region.

However, the persistent form of storm surge that hit much of the Wellington region's west coast on July 24th raised the local sea level by more than a metre at high tide and showed a range for different levels of vulnerability along the coastline, with developed residential land being much more prone to erosion than the natural sand dunes.

 

Figures 4.2.11a-b The left photo shows storm waves hitting the natural sand dune in Waikanae on July 24th, 2016 and the right one (Dominion Post) shows part of a 10 metre erosion of a residential section adjoining the beach on the south side of Paraparaumu that occurred in the same event

As shown in Figures 4.2.6a-b, water levels appeared to be higher than normal at low tide over the wide river delta area at the bottom of the Ōhau river. Higher water levels were more obvious at the bottom of the Waikawa river where water covered land that is normally above the low tide level and this suggests an ongoing outflow of water from the catchment areas inland occurs for more than one week.

### *4.2.3 Implications for Flood Risk*

An increasing frequency of “Nuisance flooding” caused by sea level rise is already being seen across many of the less exposed parts of the eastern US coastline that have coastal development on low lying land. This observation is an early warning sign that future changes can become very widespread. Australian studies have shown that the frequency of future coastal flooding will depend on local tides but can increase very significantly (Hunter, 2010). For example, the last IPCC Assessment showed that SLR of 0.5 m can increase the frequency of coastal flooding events by more than 1,000 in parts of the Wellington region so that what was a “one in a hundred year” event becomes almost a monthly occurrence (See Fig. 13.25 in Church et al., 2013).

Continuing work on this issue internationally is being used to define a threshold in the frequency of flooding at which point response measures should become adopted (Sweet & Park, 2014), but it is also becoming clear that there can be very rapid transitions from the “nuisance” level to unsustainability. Kane et al. (2015) have shown that a critical point can be identified at which the coastal land area that is being affected starts to increase very rapidly, and for a sea level rise scenario applied in Hawaii they found this critical point in time could vary from 2028 ± 25 years for more vulnerable areas to 2066 ± 16 years for less vulnerable ones.

Approaches to identifying a sequence of decisions that need to be made and their timescales have been developed by the New Zealand Climate Change Research Institute in conjunction with Greater Wellington Regional Council and other councils. An example of this approach is shown in Figure 4.2.12.

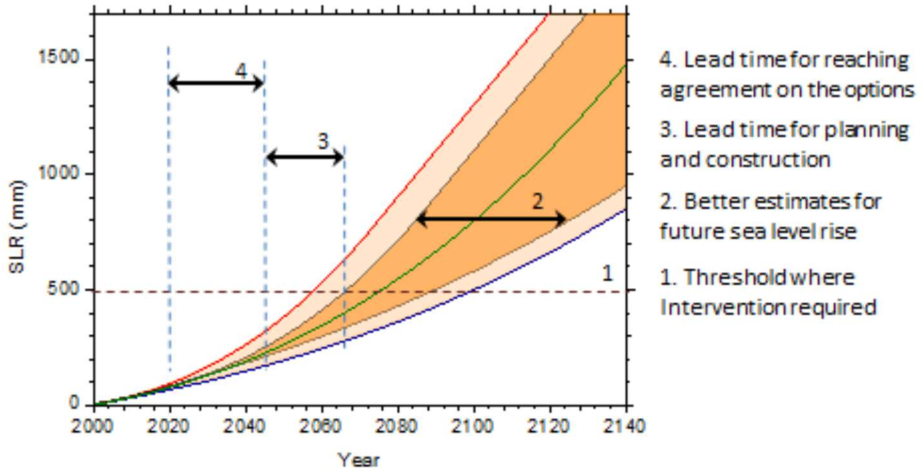


Figure 4.2.12 Timescales for planning responses to SLR depend on a composite of the evolving scientific analyses, that hopefully will reduce uncertainties in the future, as well as the governance and decision making processes, but also social acceptance of change

Within the time and resources available in this project, it was not possible to come up a framework for the Horowhenua – Kāpiti region that identify thresholds at which coastal flooding becomes much more frequent. This issue is also closely linked to the groundwater response covered in the previous section. But because there are stopbanks along the Ōhau river the main area for flood risk is probably the low lying land between the Ōhau and Waikawa rivers and parts of the Tonkin & Taylor (2013) report are relevant for this area.

### *4.2.4 Dynamic Coastlines*

There is now an increasing amount of literature covering a wide range of natural responses to sea level rise and its links to changes in frequency and extent of flooding. Much of this research is showing that natural processes have a capacity for dynamic responses that can substantially mitigate impacts or even mask them out entirely. However, several of these studies have shown that natural adaptation tends to become hindered or totally prevented by coastal developments in the forms of buildings or infrastructure.

While a recent review paper (Lentz et al., 2016) was focused on the North East US coastline it shows that a range of natural processes such as vertical accretion and lateral migration can either keep ahead of sea level rise or lead to slow transitions to marsh land. Land elevation is usually the first determinant for a natural response that can also be quite dynamic and substantially mitigate impacts. More than 70% of the natural coastal landscape was found to have a capacity to respond dynamically to sea level rise in ways that are not covered in normal inundation models. But developed land was generally found to be the most vulnerable and natural beaches the least vulnerable.

Another major and detailed review of coastal responses to change (Fitzgerald et al., 2008) has covered migration of sand dunes and the adaptation of wetlands in ways that are directly relevant for the Ōhau – Kuku river mouth area. A widely used Bruun rule has been shown to be misleading by more detailed studies, but generalised versions of that rule which allow for dynamic responses in sand dunes do appear to be more reliable. See Figure 4.2.13 below.

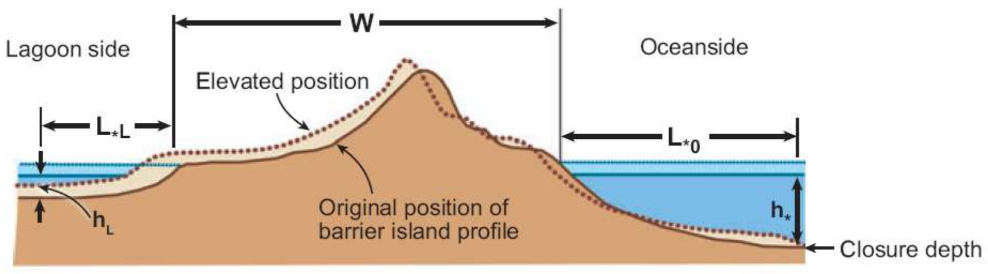


**Figure 6**

The Generalized Bruun rule of Dean & Maurmeyer (1983) showing the entire barrier island system maintaining its form while migrating landward under the influence of sea-level rise.

Figure 4.2.13 Generalized Bruun rule, Dean & Maurmeyer (1983)
(Source: Figure 6, Fitzgerald et al., 2008).

Similarly this paper goes into the range of processes that lead to “delicate balances between accretion and subsidence, bioproductivity and decomposition, erosion and vegetative stabilization” (see Figure 4.2.12), which take place in wetlands set back from the beach and which are all are very relevant for the lagoon areas at the bottom of the Kuku Beach road.

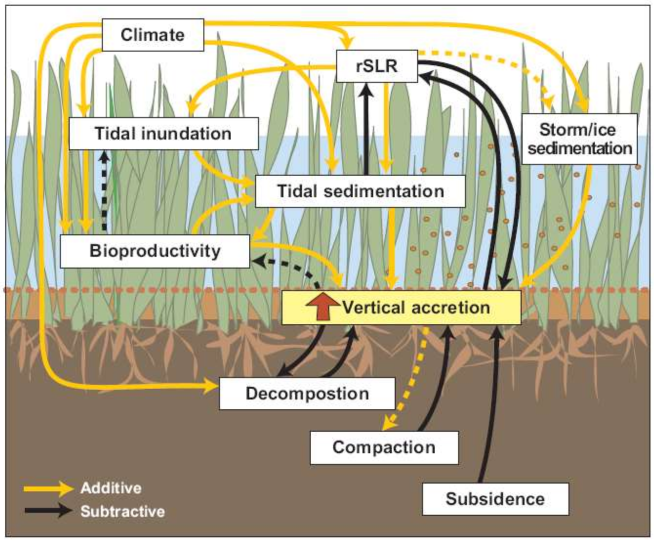


Figure 4.2.14 Major factors affecting marsh elevation
(Source: Argow, 2006).

Studies like those depicted above have suggested that wetlands and sand dunes can adapt to rates of sea level rise up to about 5 mm/year. However, this adaptation is strongly influenced by natural accretion rates and so for the Ōhau – Kuku river mouth the rate of accumulation coming from the Manawatu river and other sources is a key factor as this rate could be significantly larger than occurs in places like the USA because New Zealand is geologically much younger.

### 4.2.5 Coastal management in the face of change: A Summary

Sea level has been going up for more than 100 years due to the expansion of seawater as it gets warmer, and the increasing rates of melting glaciers and ice sheets. The global average sea level has gone up by about 40 mm in the last ten years, compared to about 30 mm in the previous ten years. This finding matches the evidence for an accelerating loss of ice in both Greenland and the Antarctic with associated global effects.

Estimates for future sea level rise have slowly increasing rates until about 2050 followed by a rapidly increasing range from then on. Uncertainties that may occur come from the wide range of future greenhouse gas emissions and because of limits to our knowledge about the rate at which ice sheets respond. When global temperatures were a bit more than 1°C warmer than now, that is 120,000 years ago, paleo-climatic data shows that sea level was about 6 metres higher but the rate at which that occurred is not well known. Scientific analyses reproducing these past changes in any detail have only become possible in the last two years.

Rise in sea level has direct effects on rivers well back from the coastline and can lead to significant increases in the frequencies and areas covered by flood events on low lying land.

For example, it has been shown that a 0.5 m rise in sea level will make what has been a one in a hundred-year event, for the Hutt river occur several times per year. Similar increases in flood frequency can be expected for the Ōhau and Waikawa Rivers.

The Horowhenua coastline has moved significantly in both directions (east and west) over the last thousand years, but in the recent past sediment accumulation from the Manawatū River appears to have been the dominant factor. However, sand dunes caused by sediments coming down the coastline are also being affected by flood events as is seen by more vegetation having become established by the mouth of the Waikawa Stream than at the larger Ōhau River. Some of the Ōhau sand dunes are more than 2 m high and appear to be stable at present, but the coastline continues to accrete, or move out.

Establishment of pine forests has stabilised sand dunes in several parts of the Horowhenua coastline and protected inland areas from sand drifts. However, similar coastal pine forest areas in Florida and north-east Italy are showing signs of collapse due to salinization of the groundwater. For forests between the Ōhau and Waikawa Rivers an outflow of groundwater is currently expected to be dominant and holding back salt water intrusions, but the extent to which this will be maintained as sea level rises is not yet known, see Figure 4.2.15.

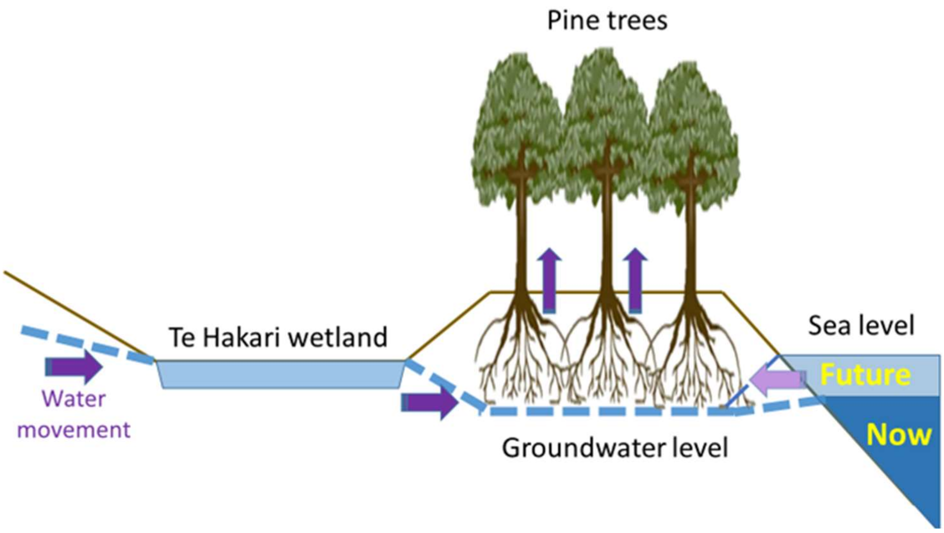


Figure 4.2.15 A schematic image of groundwater movement and the potential for this to change because of sea level rise

## 4.3 Geomorphology

### *4.3.1 Tidal Cycles*

Tidal cycles impact on sea levels. For the exhibition (see Section 6.1), Professor Manning and Dr Richardson determined the tidal cycles for the case study region[24], as depicted in Figure 4.3.1 below. This is the tidal cycle for groundwater levels in February 2008 for well R26/6566, which is by an estuary where the Waikanae river meets the beach. Blue dots are the observed hourly average groundwater levels, red a fit for the tidal cycle plus an annual cycle to cover longer term variations. Green dots are the residuals –with their vertical axis in mm on the right hand side – showing weekly variations of about 200 mm over this month.

Similarly, Figure 4.3.2 shows the tidal cycle for well R26/6284, which is in Waikanae park by Park Avenue and about 2.7 km from the beach. Tidal cycles are much smaller but appear to have a minimum amplitude near the middle of the month as is the case for the groundwater cycle seen near to the river and beach. In addition to the residuals (green) from the tidal cycle fit, those for the R26/6566 well (as shown above) are also plotted here and show correlation at some times, but probably other factors as well.

[24] Tidal cycle periods were used based on the Virginia Institute of Marine Science web page: http://web.vims.edu/physical/research/TCTutorial/tideanalysis.htm with five sinusoidal components of: 12.421, 12.000, 12.658, 23.935 and 25.819 hours.

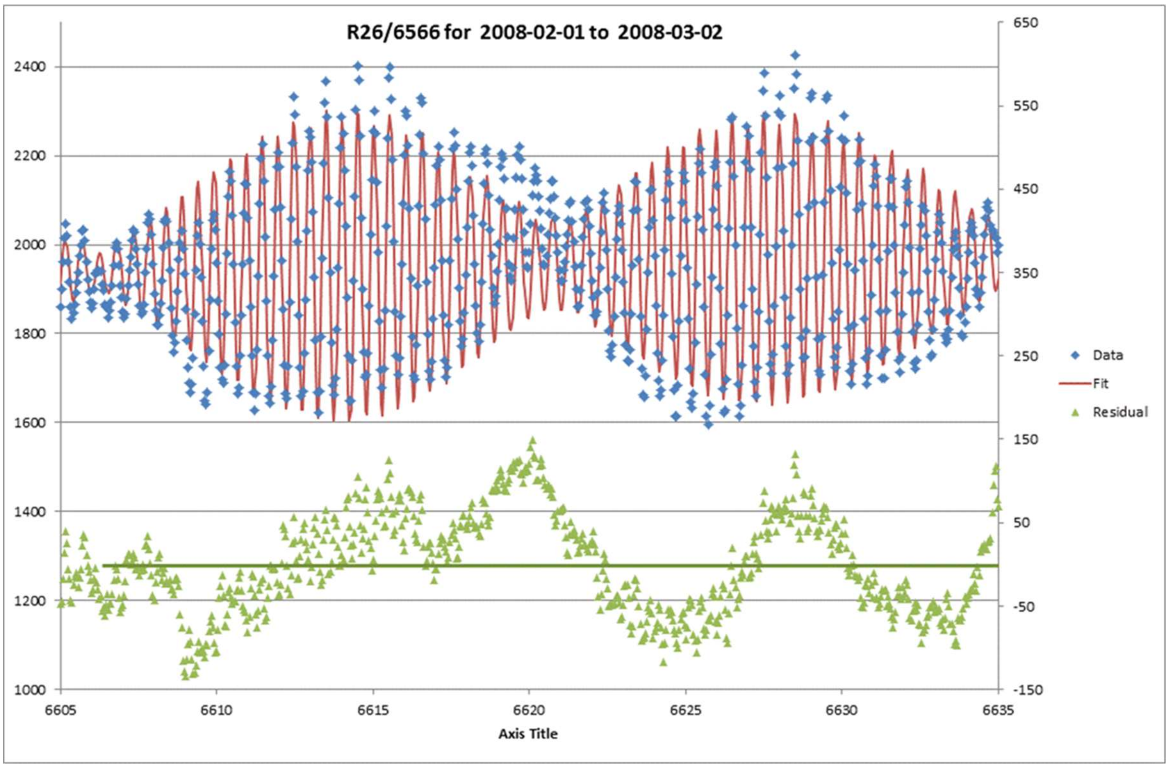


Figure 4.3.1 The tidal cycle in a Kāpiti groundwater well, February 2008, well R26/6566, Waikanae river estuary

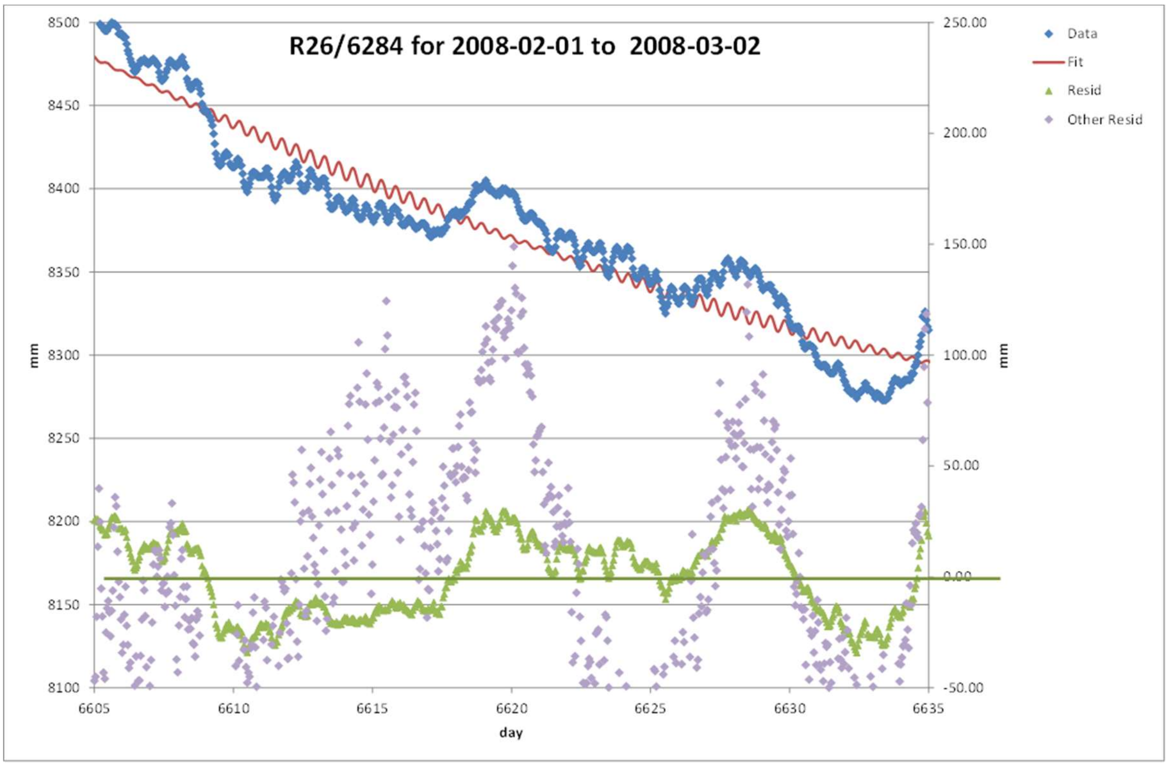


Figure 4.3.2 The tidal cycle in a Kāpiti groundwater well, February 2008, well R26/6284, Waikanae park by Park Avenue

### *4.3.2 River Behaviour and Management in a Changing Climate*

Many New Zealand rivers are extremely dynamic and can experience rapid adjustment in response to changes such as catchment deforestation or climate change. Managing such dynamic rivers in ways that maintains the natural character and diversity, while protecting productive land and the built environment, is complex and challenging.

The IPPC fifth assessment report has identified that many regions will experience an increase in the frequency of extreme climate events – which will have a likely impact on river behaviour. In the west of the lower North Island projected changes in climate variables include enhanced westerly wind flow, increase in annual precipitation and increases in the intensity of rare daily rainfall extremes[25]. More frequent or intense rainfall will affect the likelihood of rivers flooding and potentially influence sediment supply. At the coast, rising sea level and storm surges will exacerbate river flooding.

<u>Current management of the Ōhau River</u>

The Ōhau River, a wandering gravel bed river, can be considered an aggrading system, with high rates of sedimentation in the active channel and floodplain with material sourced from the Tararua ranges.

There is a change of river grade (slope) at State Highway 1 and Catley's and Burnell's bends where the river deposits its gravel bedload (labelled in Figure 4.3.3). Below the Catley's-Burnell's bends deposition in the channel and berms consists of mainly finer sands and silts.

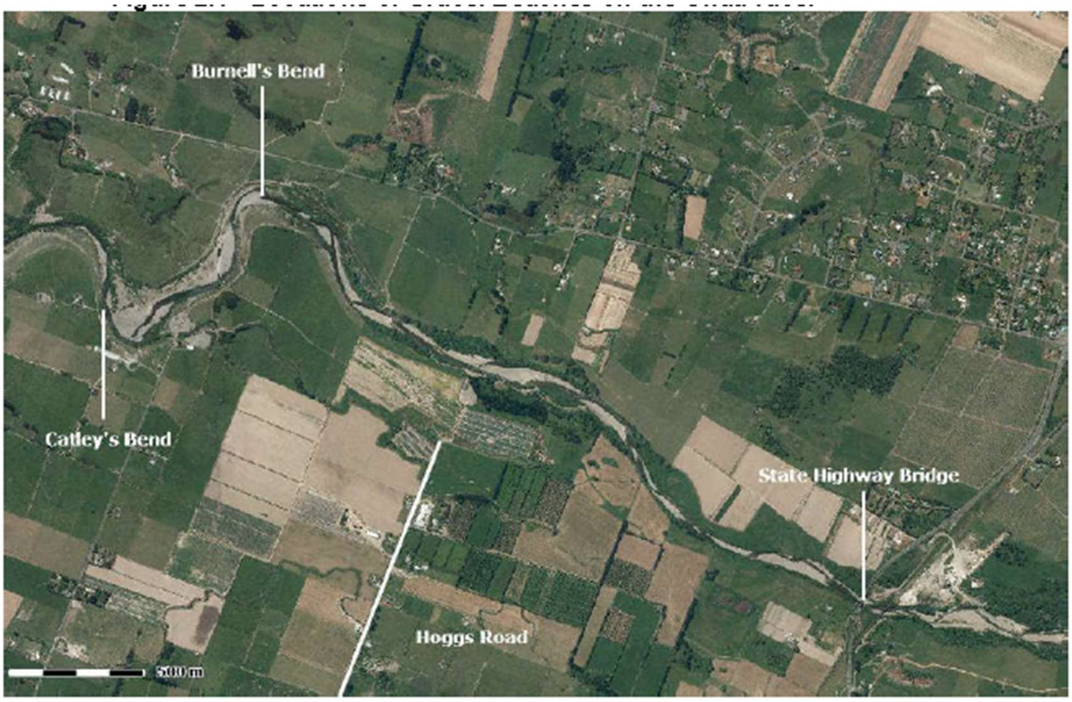


Figure 4.3.3 River grade, Catley's-Burnell's bends

[25] See: http://ipcc-wg2.gov/AR5

Key findings to note are:

- Continuous stopbanks were constructed in the 1970's close to the active channel below SH1 and along the outer bank at Catley's-Burnell's bends. They were designed for nominal protection from a 25 year return period flow.
- Stopbank crests heights were raised after large flood events in 1986, 1990 and 1993.
- A review in 1997 identified deposition problems and a reduction in channel capacity at Catley's-Burnell's bends, and recommended gravel extraction from this area.
- There have been frequent flood overflows at the Catley's-Burnell's bends which have caused widespread flooding.
- In January 2008 the stopbanks were breached. The extent of this flooding was digitised by Horizons and is shown in Figure 4.3.4.
- A Scheme Investigation in 2008 (Williams, 2008) found a loss in channel capacity between 1971 and 1994/95 surveys, and some decline in capacity below Catley's-Burnell's bends. The report recommended raising stopbanks and gravel extraction to improve flood protection.
- A report in 2012 (Bell, 2012) examined the gravel resource of the Ōhau River. The study found that the total volume of gravel has remained constant in the active channel since 2007. However in general the pattern was one of degradation above Catley's bend and aggradation downstream. The report recommended monitoring below Catley's bend as gravel extraction may be required in future to maintain channel capacity.
- No major work has been done on the stopbanks since the 2008 report (pers. comm. Peter Blackwood). The stopbank height at Catley's and Burnell's bend currently would not be up to a 20 year protection standard (pers. comm. Peter Blackwood).
- Horizons have recently produced 0.5% AEP (Annual Exceedance Probability) with 500 mm freeboard "indicative floodable area" maps for the Ōhau River. They were created by Hinewai Pouwhare-Anderson, based on a HECRAS model calibrated to the 20 year 2008 flood. This map (Fig. 3) shows that a large proportion of Tahamata would be flooded in a 1 in 200 year flood event (0.5% AEP).

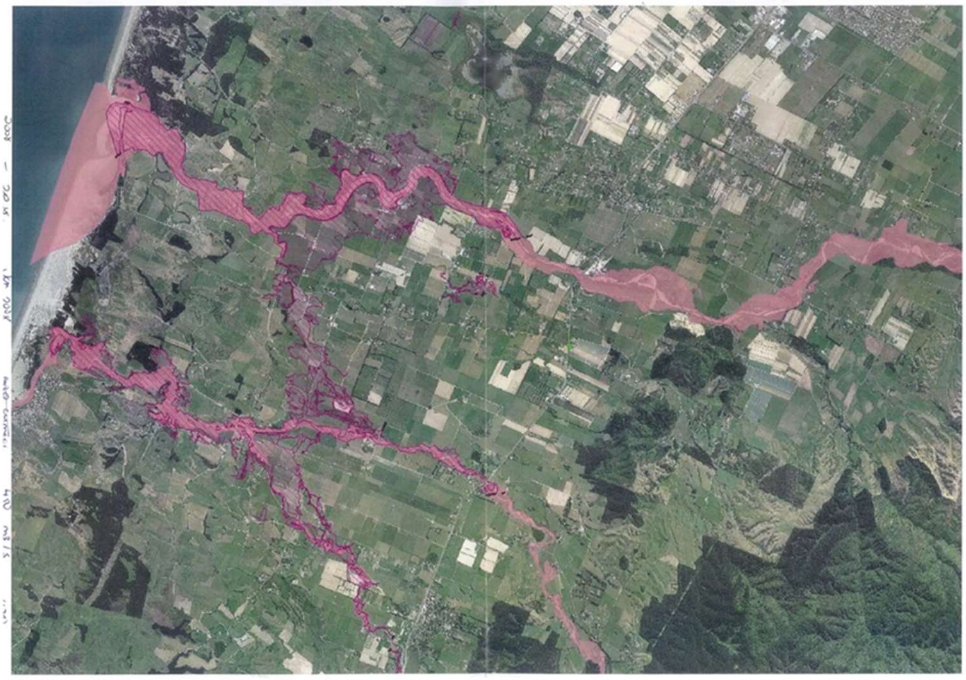

Figure 4.3.4 January 2008 flood extent map. 1 in 20 year flood (flow 450 m3/sec), Ōhau River
(Source: Horizons Regional Council).

The hatched area in Figure 4.3.4 shows the observed minimum wet extent for the flood of 8 January 2008. The 1 in 20 year flood extent and modelled flood extent would be greater than shown.


Figure 4.3.5 0.5% AEP (Annual Exceedance Probability) with 500mm freeboard "indicative floodable area" map. Ōhau River. Flow at ~700 m3/sec
(Source: Horizons Regional Council).

Climate change and effects on flood frequency

The graph below (Figure 4.3.6) was supplied by Peter Blackwood (River Engineer - Horizons Regional Council) and shows the flood frequency curve calculated for the Ōhau River.

Key points to consider are below:

1. The onset of climate change is expected to increase flood risk. Future floods are likely to be bigger. Modelling work on the Hutt River indicated the potential for a significant increase in flood frequencies over the 21st century under climate change scenarios (Ballinger et al. 2011). However the magnitude of the change varied considerably depending on the emissions scenario and climate model used. The authors found that for the Hutt River under a high emissions scenario, flood return periods could reduce to a fifth of current-day values on average.
2. It is also worthwhile to note that flood frequency curves are constructed from a relatively short observed and historical flood record. In the absence of palaeoflood data (which provides a much longer flood record), the flood risk can be underestimated.
3. It seems highly likely that with the projected change in climate variables the Ōhau River will experience larger and more frequent flooding. Based on results from the Hutt River a 1 in 20 year flood currently capable of breaching the stopbanks would increase in probability to a 1 in 4 year event under a high emission scenario.

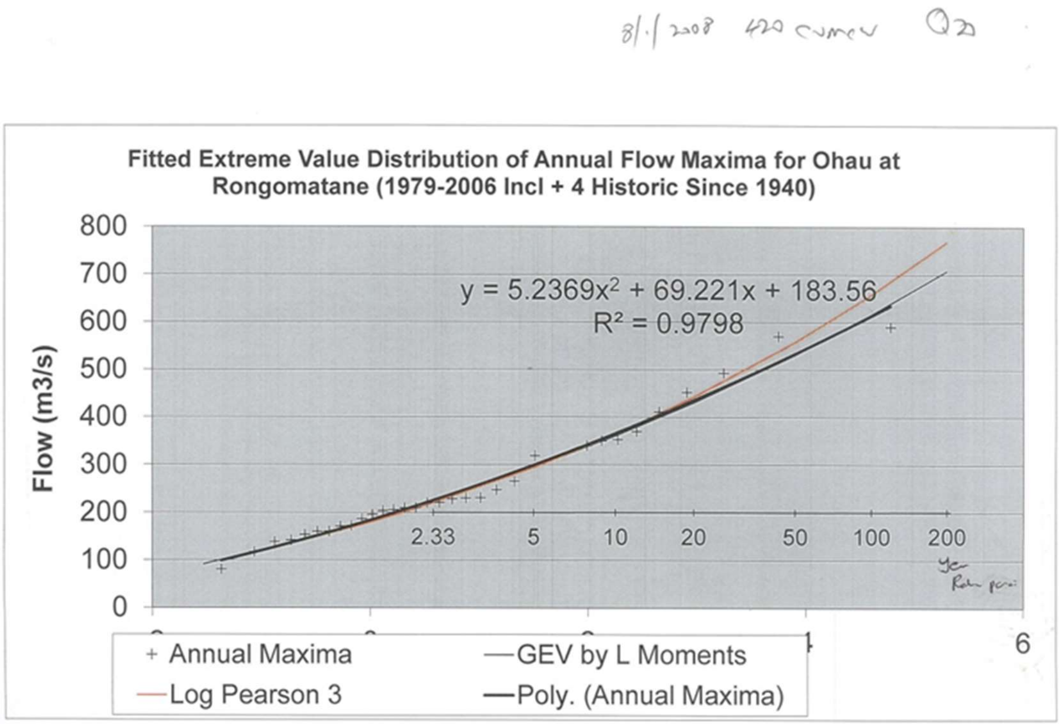


Figure 4.3.6 Flood frequency magnitude for Ōhau at Rongomatane (Source: Horizons Regional Council).

The key implications and issues for Tahamata that arise from these findings are:

1. A large proportion of the land area of Tahamata is at risk from river flooding. Climate change is expected to increase that risk – even without taking sea level rise into account.
2. The river is aggrading below Catley's bend with finer and less commercially valuable sediment. Both the 2008 and 2012 reports signalled issues around loss of channel capacity and the associated increased flood risk.
3. There has been no major work done on the stopbanks since a 2008 report that recommended raising the crest height. It would seem reasonable to suggest that expensive flood protection work for this part of the Ōhau would not be a priority for a regional council with a declining population (and rating base). There is also reduced acceptance from rate payers to subsidise costly river management schemes.
4. A rise in sea level will cause further aggradation (or sediment build up) in already aggrading lower reaches of the river, thereby reducing channel capacity and exacerbating coastal flooding.
5. Tahamata have raised the issue of increasing wetness of paddocks that border the wetland area (25 Hectares) and drainage has been suggested (Figure 4.3.7).


Figure 4.3.7 Areas of Proposed Drainage

### *4.3.3 Overview of River Response to Environmental Change*

Like many natural systems, river systems exhibit a high degree of complexity and dynamism, with sediments transported and deposited within the catchment, continually creating and eroding landforms over a range of spatial and temporal scales. River morphology (or form) is conditioned by the interaction between the sediment and flow regime within the constraints imposed by the boundary conditions (i.e., geology). A river system is considered to be in equilibrium when there is a balance between the sediment load and the hydraulic capacity of the river to transport the sediment. Changes in parameters such as discharge and sediment supply will affect this balance, and river channels will respond and adjust their form through the processes of sediment deposition (aggradation) and erosion (degradation). The sediment transport regime of a river can be influenced by both external and internal controls.

A number of external environmental changes have the potential to influence the hydrological and sediment regime of a river system, including; land-use change, climate change and sea level change. In terms of climate change, rivers respond to climate through changes in flood frequency and magnitude. The nature and magnitude of river response varies considerably, but in many cases increased flood frequency increases river activity and floodplain alluviation (sedimentation). Changes in sea level alter the balance of erosion and deposition processes operating within river channels. At its simplest, river response to sea level change involves either aggradation (deposition) or incision as the river adjusts to a new equilibrium profile. There are many factors that contribute to the complexity of river response to changes in sea level, including: the direction duration and magnitude of sea level change, geologic controls, valley morphology and potential for adjustment and alluvium characteristics. Studies have found that river response to sea level rise can be fluvial aggradation, channel avulsion, and changes in channel pattern and shape.

An additional aspect to consider when assessing potential river response to environmental perturbation is that in the fluvial system there is often not a straightforward cause and effect relationship. River systems can exhibit nonlinear behaviour in response to external forcing. Nonlinear dynamics, whereby system outputs are disproportionate to system inputs, have been identified in a number of different fluvial processes, including; bed load transport, avulsion frequency and meander behaviour. The causes of nonlinearity in fluvial systems include factors such as thresholds, storage effects, and saturation and depletion effects. Geomorphic thresholds can be external or internal, and have been defined as the condition at which there is an abrupt geomorphic change in response to progressive change in external controls, such as climate, sea level or land use change.

Increasingly, the role of flooding is attracting more attention under prediction of anthropogenically-forced climate change and increases in extreme precipitation effects. The geomorphic response to floods is variable, ranging from minor morphological changes to catastrophic adjustment. The nature and magnitude of channel response to flooding has been found to be influenced by a number factors including; land-use, flood power, shifts in the climate regime and flood history. The geomorphic effectiveness of floods (or how much the river will change) is also determined by valley floor and channel configuration. For example, in an assessment of the impact of a 1 in a 100-year flood in the Kiwitea Stream, Fuller (2008) found that diverse channel behaviour in response to a large flood event reflected differences in catchment and reach sensitivity. In particular, catastrophic channel transformation occurred where floodwaters were confined at channel bends, while in less confined reaches dissipation of flood flow significantly reduced erosion.

### 4.4 Potential river response to predicted climate change impacts in the Kāpiti-Horowhenua region

- The study sites are located adjacent to the Ōhau and Ōtaki rivers which are relatively unconfined, and have adjusted their form in response to environmental changes in the past. These rivers can be described as wandering gravel-bed rivers.
- Dune belt sedimentology (sand and alluvial gravels) of the study sites suggest that there is high potential for floodplain reworking (floodplain sediments are highly erodible).
- Predicted changes in sea level will force rivers to adjust their gradient. A rise in sea level will cause aggradation (or sediment build up) at the coast and exacerbate coastal flooding.
- Potential river response to sea level rise include; channel change, floodplain inundation, transition from fluvial to estuarine sedimentation at the coast, meander migration and increased sinuosity.
- Nonlinear behaviour in the fluvial system in response to external forcing will mean that channel adjustment to rising sea levels will not be gradual or incremental but will rather involve abrupt geomorphic change.
- The pace of sea level rise will also impact on the ability of rivers to achieve an equilibrium state, and they will consequently be less stable if sea level rise is rapid.
- The predicted increase in frequency of high intensity rainfall events will also impact on the discharge regime and river behaviour. Possible responses include; increase in flood magnitude and/or duration, increase in the geomorphic effectiveness of floods, bank erosion and meander migration (with loss of land), channel cut off, channel widening, increase in floodplain inundation and sediment deposition on the floodplains (accretion).
- More intense rainfall coinciding with storm surges (and higher groundwater levels) will exacerbate coastal flooding.
- More frequent extreme rainfall events could have an impact on slope stability (i.e., increase the occurrence of landslides) in the upper catchment and increase sediment supply to the river.

# 5 RESULTS – ECOLOGICAL ECONOMICS ASSESSMENT

## 5.1 Broadbrush Socio-Economic and Ecological Assessment

### *5.1.1 Socio-Economic Profile of Horowhenua Region*

A broad desktop literature review of the socio-economic profile, demographics and local government initiatives for the region was conducted. Appendix C provides a Socio-Economic profile of the Horowhenua region, with data from the Horowhenua District Council website.

### *5.1.2 Media Reporting of Climate Change Impacts*

Limited media accounts were found of the impacts of climate change in the case study region. In 2012, there had been various reports in the media highlighting the potential risk for Kāpiti beachfront properties from predicted shoreline erosion and flooding, which would devalue 1800 homes, according to a Coastal Erosion Hazard Risk report commissioned by Kāpiti Coast District Council[26]. The report, commissioned to comply with the Government's New Zealand Coastal Policy Statement 2010, which requires councils to make coastal hazard assessments, stated that within 100 years, 220 properties would be affected in Paekakariki, 435 in Raumati, 545 in Paraparaumu, 240 in Waikanae, 170 in Te Horo/Peka Peka and 175 in Ōtaki. Owners of million-dollar beachfront homes along coastal affected areas in Paraparaumu and Waikanae had received letters from the council telling them their property and insurance values were likely to be affected by the new data, which would be included in future land information memorandums (Lims) on those properties.

The competency of the council for relying upon the science underpinning the KCDC-commissioned report was questioned by various land owners, and their lawyers, in various media reports.

These media reports typically showed land owners being angered or upset due to Council draft policies that included potential risk of future flood or erosion due to climatic and environmental changes, largely due to the impact of this risk on property values and insurance premiums. Media reports[27] were found of Australian land owners being similarly affected[28].

### *5.1.3 Broadbrush Review of Local and Central Government Provisions for Future Flooding*

Ministry for the Environment (2010) summarises the Ministry's technical report detailing a tool for estimating the effects of climate change on flood flow. It provides an overview of the expected impacts of climate change on flooding such as changes in rainfall, temperature, sea-level, storminess and sediment transport processes. It also provides practice information and guidance to help local authorities incorporate

[26] For example, see: http://www.stuff.co.nz/national/7558732/1800-Kāpiti-beachfront-homes-at-risk;
[27] For example, see: http://www.lakesmail.com.au/story/303690/clock-ticks-for-home-thanks-to-climate-change-requirements/?cs=750
[28] One affected Australian resident stated that flood and sea-level rise mapping had already seriously affected his insurance, which had gone from $660 the previous year, to $4119 if $2281 for the flood cover was included.

climate change impacts into flood risk management planning through providing examples of approaches local government has taken[29].

The report notes the expected mid-range changes in annual mean temperature (see Figure 5.1 below); and the expected increases in the frequency and intensity of extreme rainfall, especially in places where mean annual rainfall is also expected to increase.

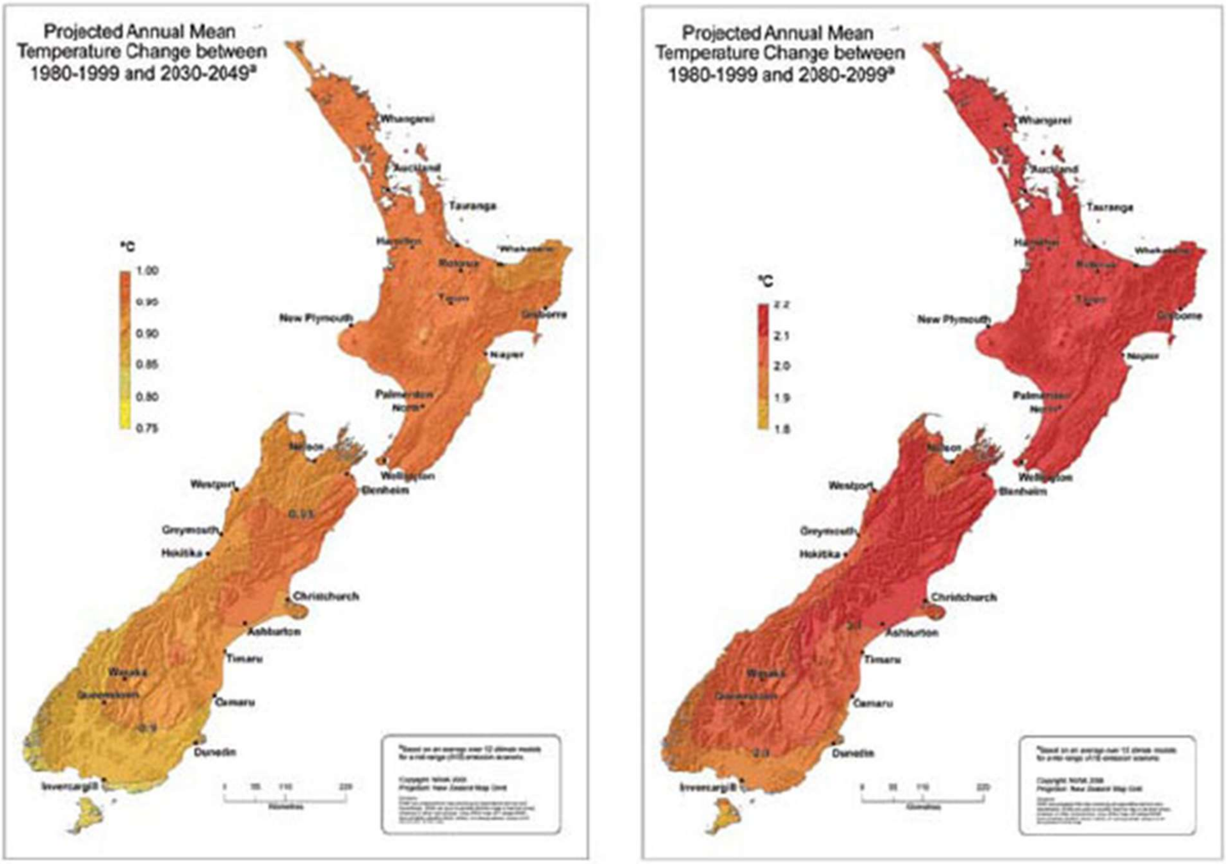


Figure 5.1.1 Projected mid-range changes in annual mean temperature (in °C) relative to 1990
(Source: Ministry for the Environment, 2010).

The report goes on to state that changes in seasonal and annual rainfall patterns, as well as changes in extreme rainfall, will be important factors for understanding future flooding. Generally, wetter conditions in some areas may also change the antecedent or initial conditions, so that floods could occur more often. Changes in climate can also affect the magnitude of a flood by indirect means. For example, any change to the balance of sediment transported within a river, storminess, sea levels or even the cycles of natural variability in the climate can all have an effect on river processes and flooding.

Figure 5.1.2 shows that the projected change in the average annual rainfall has a pattern of increases in the west (up to 5 per cent by 2040 and 10 per cent by 2090)

[29] http://www.mfe.govt.nz/publications/climate-change/preparing-future-flooding-guide-local-government-new-zealand/part-four, retrieved 15 Sept 2016.

and decreases in the east and north (exceeding 5 per cent in places by 2090). This annual pattern results from the changes in rainfall in the dominant seasons of winter and spring.

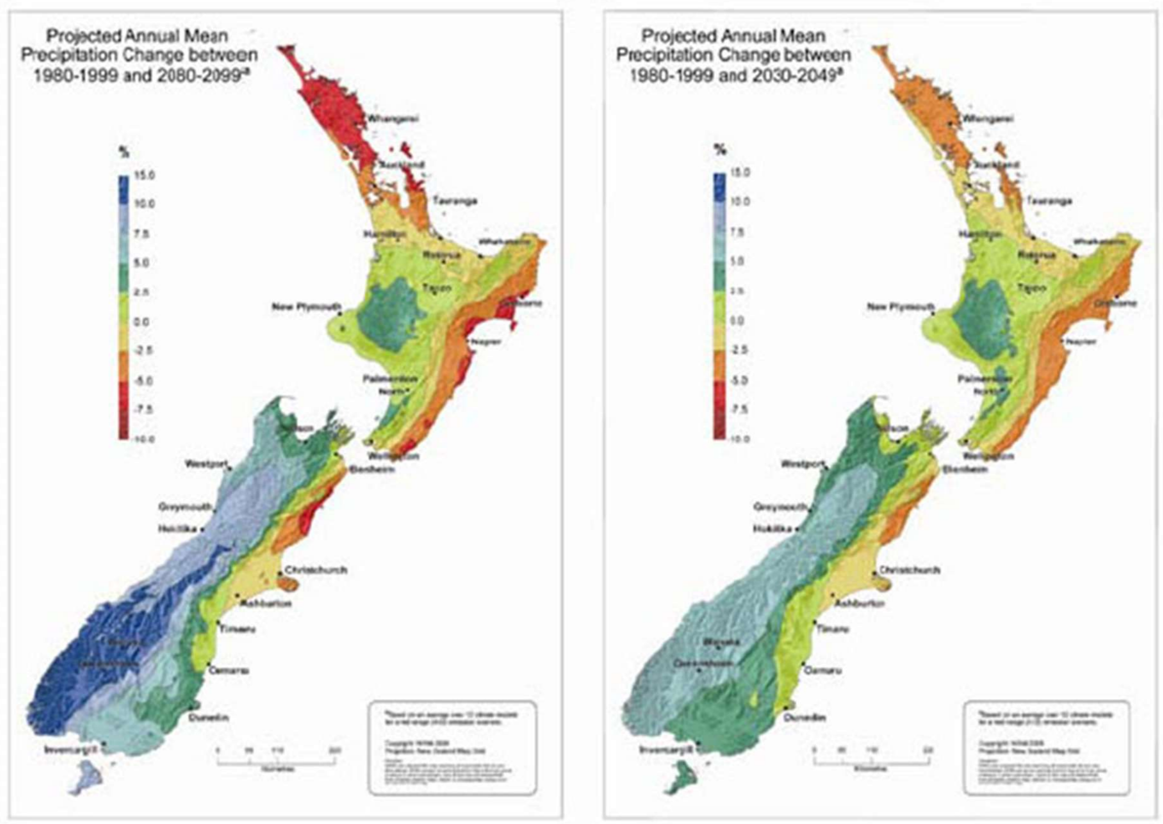


Figure 5.1.2 Projected mid-range changes in annual mean rainfall (in %) relative to 1990
(Source: Ministry for the Environment, 2010)

The report (ibid.) differentiates between seasonal mean rainfall projects, as depicted in Figure 5.1.3. Of relevance to the case study region, the report states that for summer, seasonal mean rainfall may decrease up to -5 percent in the Kāpiti region. For winter, marked increases in seasonal mean rainfall are projected, particularly in the west, with parts of Manawatu increasing by over 10 percent. For spring, smaller increases of up to 5 percent are expected for most of the Manawatu.