Waikato Regional Council Technical Report 2024/28

Climate change hazards and risks in the Waikato region

ISSN 2230-4363 (Online)
waikatoregion.govt.nz

Prepared by	Whitney Mills, Lisa Armstrong, Derek Phyn, Celeste Davies-Calway
For	Waikato Regional Council Private Bag 3038 Waikato Mail Centre HAMILTON 3240
Publication date	23 May 2025
Document ID	30901441

	Name	Date
Peer Reviewer	James Hughes, Technical Director: Climate and Resilience, Tonkin+Taylor	24 April 2025
Approving Manager	Rick Liefting	23 May 2025

Disclaimer

This technical report has been prepared for the use of Waikato Regional Council as a reference document and as such does not constitute council policy.

Council requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved and is accurately reflected and referenced in any subsequent spoken or written communication.

While Waikato Regional Council has exercised all reasonable skill and care in controlling the contents of this report, the council accepts no liability in contract, tort or otherwise, for any loss, damage, injury or expense (whether direct, indirect or consequential) arising out of the provision of this information or its use by you or any other party.

Acknowledgement

The completion of this report has been made possible by the contributions from a wide range of technical experts and staff members from all local authorities across the Waikato region.

Firstly, thank you to the wider Regional Resilience team at Waikato Regional Council for their technical knowledge and support with the development of this report and wider risk assessment work across natural hazards. Special thanks to:

- Celeste Davies-Calway for her work and support surrounding coastal hazards and understanding sea-level rise across the region. Additionally, thank you to Rick Liefting and Stephen Hunt for supporting Celeste.
- Thank you to Lisa Armstrong for her project management of this report and support with scoping and writing this report.
- Thank you to Lauren Empson and Nina Harris for their geographic information system support, navigating the Waikato Regional Climate Change Risk Identification Workbook (excel spreadsheet) and Ministry for the Environment downscaled projection data.
- Rick Liefting for his guidance and mentoring support and always reminding me of the end goal.
- Ben Worth as our communication advisor on reviewing this report.
- James Hughes from Tonkin and Taylor for undertaking the high-level risk identification phase and being the technical reviewer of this report.
- Derek Phyn from the Spatial Analysis and Modelling team for his work on the climate change data inventory.

I would like to extend a large thank you to the region's climate change and sustainability leaders from across all the territorial authorities for always allowing me to check in with them to ensure this report was going to support them and their councils on their climate change risk assessment journey. Additionally, thank you to Joy Moir for co-ordinating this group.

Thank you to the Waikato Lifeline Utility Group members for their review of infrastructure and utility risk information across the region.

Thank you to other regional councils from across the country for their support and sharing their knowledge and experience undertaking regional risk assessments. Thank you to Northland Regional Council, Bay of Plenty Regional Council, Greater Wellington Regional Council and Environment Canterbury.

Table of Contents

Figures

Tables

Abstract

The climate in the Waikato region is changing, and it is important to understand what risks the region may face as a result. This report provides an overview of climate change hazards and risks identified through a high-level risk identification and screening process, incorporating insights from council subject matter experts, iwi and external stakeholders. The process aimed to compile a comprehensive list of potential climate change risks through desktop reviews, workshops, surveys and stakeholder engagement.

Key hazards of interest included higher temperatures, drought, extreme weather, flooding, and coastal hazards. A total of 231 direct risks across 44 elements and 55 indirect risks across 37 elements were identified, spanning the natural, built, economic, and human domains.

This report, which covers the geographic area of the eleven councils in the Waikato region, provides insights into the hazards and potential risks associated with climate change that are likely to affect the Waikato region, across five domains (human, natural environment, economy, built environment, governance).

Executive summary

The Waikato region is already experiencing the impacts of climate change, which pose significant risks to the economy, our communities, infrastructure and environment. This report aims to provide a summary of the climate change risks identified through a high-level risk identification and screening project led and funded by the Waikato Regional Council. This project aligns with step 1 of the Ministry for the Environment's climate change risk assessment and adaptation process.

The output of the project is this report, which covers the geographic area of the eleven councils in the Waikato region. It provides insights into the hazards and potential risks associated with climate change that are likely to affect the Waikato region, across five domains (human, natural environment, economy, built environment, governance). The project aims to help inform future work programmes, assist current adaptation projects, and support communication of key risks to communities and stakeholders.

The high-level risk identification and screening process involved desktop reviews, workshops, surveys, and stakeholder engagement to compile a comprehensive list of potential climate change risks. Key hazards identified include higher temperatures, drought, extreme weather, flooding, land instability including increased erosion, and coastal hazards. The process identified 231 direct risks across 44 elements and 55 indirect risks across 37 elements and five domains. Climate change risks are provided at a high level, and geographic examples are noted where risks are currently known or expected to be present.

New climate change projections indicate that the region will face higher temperatures, leading to more hot days and fewer frost days, with the most significant increases expected in summer. Droughts will become more frequent, increasing the risk of water shortages and wildfires. Rainfall variability will result in more intense extreme rainfall events and increased flooding, particularly in communities with inadequate stormwater infrastructure. Windy days are expected to decrease, but the intensity of extreme storm events (ex-tropical cyclones bringing high winds and heavy rainfall) is projected to increase. Sea-level rise will exacerbate coastal inundation and erosion, with extreme sea levels occurring more frequently. Groundwater levels and salinity will be influenced by sea-level rise and rainfall patterns, affecting aquifers and increasing saltwater intrusion. The Hauraki Plains and other low-lying areas are particularly vulnerable to these changes. Coastal communities, including those on the Coromandel Peninsula and the west coast, will face heightened risks from sea-level rise and coastal erosion. These changes underscore the need for ongoing climate risk assessments and adaptation planning to mitigate the impacts on the region.

To assist territorial authorities with identifying the hazards and risks that may be most relevant to them, an overview of climate change hazards and risks for each district is provided. For example, the Hauraki District is highly exposed to increased temperatures, which will lead to a range of risks to primary sector such as water availability, and the communities that rely on them. This, in turn, can negatively affect animal welfare and farm productivity, leading to increased stress on the community.

From a Waikato community and local government perspective, several community adaptation projects are in progress across the Waikato region, where climate change risks are identified and managed at the local community level through adaptation planning. Each project is at different stages of the Dynamic Adaptive Pathways Planning (DAPP) 10-step decision cycle.

Community adaptation projects highlight the region's proactive approach to climate adaptation, emphasising community involvement, flexible planning, and long-term sustainability. Work on regional spatial planning supports the consideration of climate risk in strategic growth management and planning for development and critical infrastructure. These ongoing efforts aim to ensure that the Waikato region remains resilient and prepared for the impacts of climate change. By understanding and addressing these risks, the region can better protect its economy, people, infrastructure and environment from the adverse effects of a changing climate.

Every individual, organisation and sector will need to adapt and plan for climate change. This report has compiled extensive information to aid the development of climate adaptation plans at a range of scales and by a range of stakeholders, including businesses, primary producers, communities, iwi/Māori, researchers, local government, and public sector agencies. This report can help identify areas needing focused risk management, initiate detailed risk assessments, raise community awareness about climate change and prioritise adaptation responses and investment. However, due to the evolving nature of climate science and potential unforeseen events, users are advised not to base decisions solely on this report but to consider a broad range of sources, quantitative information and expert opinions.

1 Introduction

1.1 Purpose

The Waikato region is already experiencing the impacts of climate change, which pose significant risks to the economy, our communities, infrastructure and environment. To support the Waikato region to respond to climate change, Waikato Regional Council has led and funded a project to provide a regional understanding of climate hazards and current and future climate risks. This project aligns with step 1 of the Ministry for the Environment's climate change risk assessment and adaptation process.

The output of the project is this report, which covers the geographic area of the eleven councils in the Waikato region. It provides insights into the hazards and potential risks associated with climate change which are likely to affect the Waikato region, across five domains (human, natural environment, economy, built environment, governance).

This report may be used to support:

- identifying domains and sectors where more focused effort is required to understand and manage climate change risks, including data acquisition and research
- undertaking detailed risk assessments at a range of scales to understand the severity of climate risks over different time periods and emission scenarios—these assessments may help to prioritise investment and action and can be specific to species, environment, sectors or at varying scales
- utilising spatial exposure modelling to support quantitative spatial risk assessment to understand spatially where and when risks may occur
- identifying and assessing cascading and interconnectedness of risks using a system thinking approach to understand the broader impacts.

It is important to recognise that climate change is a complex and multifaceted phenomenon influenced by numerous interrelated factors, many of which are subject to change over time. A rigorous process has been employed to gather accurate and up-to-date data; however, uncertainties inherent in climate modelling, data availability, and future scenario projections cannot be eliminated. Appendix 1 documents the limitations and assumptions of this report. Due to the evolving nature of climate science and the potential for unforeseen events, the actual outcomes of climate change risks may differ from those described in this report. Therefore, users of this report are cautioned against making decisions solely based on the information provided herein. Decisions related to planning and investment, adaptation, and policymaking should consider a wide range of sources, expert opinions, quantitative data and ongoing research.

1.2 Report structure

The report is structured as follows:

- Regional context - section 2
- Methodology – section 3
- Summaries of district climate change hazards and risks – section 4
- Climate risks to Māori – section 5
- Climate projections and hazards for the Waikato region – section 6
- Climate risks in the Waikato – section 7

    - This section provides summaries of the climate risks identified in the high-level risk identification and screening process. The risks are set out by domain and risk focus areas.
    - Any spatial understanding is also noted, where geographic examples were provided in the risk identification and screening process.
- Adaptation planning case studies - section 8

The appendices contain the detailed information and references that informed this report. The Waikato Regional Climate Change Risk Identification Workbook in Appendix 2 is a key source of information as it documents all risks gathered and identified to the region throughout the course of this project. Further analysis of the risk workbook has also been carried out to identify which risks are relevant to each territorial authority.

2 Waikato regional context

In the heart of the upper North Island, our region includes the Bombay Hills, Coromandel Peninsula, Mōkau, the slopes of Mount Ruapehu and everything in between. The region includes 11 districts and six principal iwi groups:

Districts

- Thames-Coromandel District
- Hauraki District
- Waikato District
- Matamata-Piako District
- Hamilton City
- Waipā District
- South Waikato District
- Ōtorohanga District
- Waitomo District
- Taupō District
- Rotorua Lakes District

Principal iwi groups

- Hauraki iwi
- Waikato – Tainui
- Raukawa
- Maniapoto
- Te Arawa (river iwi)
- Tūwharetoa

The Waikato region is rich in natural resources, including New Zealand's longest river and largest lake, around one-quarter of its best soils, 70 per cent of its geothermal resources, its largest karst area, as well as internationally significant wetlands. The region is made up of 1200 kilometres of coastline and many distinct landforms, from mountainous areas, plains and urban and rural development. These features that make the Waikato a diverse and resource rich region also present hazards such as flooding, sea-level rise and erosion.

The region is home to an estimated 506,000 people – around 10 per cent of the total population of New Zealand. More than one-third of the people of the region live in Hamilton City, with nearly another 30 per cent living in the Waikato and Waipā Districts. Population density is high in Hamilton, at around 1,600 people per square kilometre. Southern parts of the region – especially Ōtorohanga, Taupō and Waitomo Districts – are much more sparsely populated, with the lowest population density in the Waitomo District, which has an average of just 3 people per square kilometre.

Overall, the age distribution of the Waikato population is not dissimilar to that of New Zealand as a whole. However, this varies greatly across the region. Hamilton City has a particularly young population – its median age of 32.7 is one of the youngest in New Zealand (which has a median age of

37.9). In contrast, Thames-Coromandel has the highest median age (54.8 years) of any district in New Zealand. Hauraki and Taupō Districts also have populations skewed towards the older end of the distribution (47.5 and 41.9 per cent respectively).

The ethnic makeup of the region is also like New Zealand but has a significantly higher share of people identifying as Māori (24 per cent compared to 17 per cent nationally) and lower shares identifying as Pacific people or Asian. The main exceptions to this are in South Waikato, with a large Pacific community, and Hamilton City with a large share of Asian people. While the Māori proportion of the population is high across most of the region, it is particularly high in the south of the region, including Waitomo (45 per cent), South Waikato (36 per cent), Ōtorohanga and Taupō (both 30 per cent) (Keenan et al., 2023).

There are many socio-economically deprived areas within the Waikato as shown below in the social deprivation index map of the Waikato region (see Figure 1), with many that are also exposed to climate-related hazards. Generally, these locations have limited ability to respond to natural disasters (i.e., lower income levels, poor access to transport, lack of reserve food supplies, inequitable distribution of infrastructure etc.), which therefore increases their vulnerability. Lack of resources associated with socio-economically deprived areas can reduce the ability of these communities to prepare and/or respond.

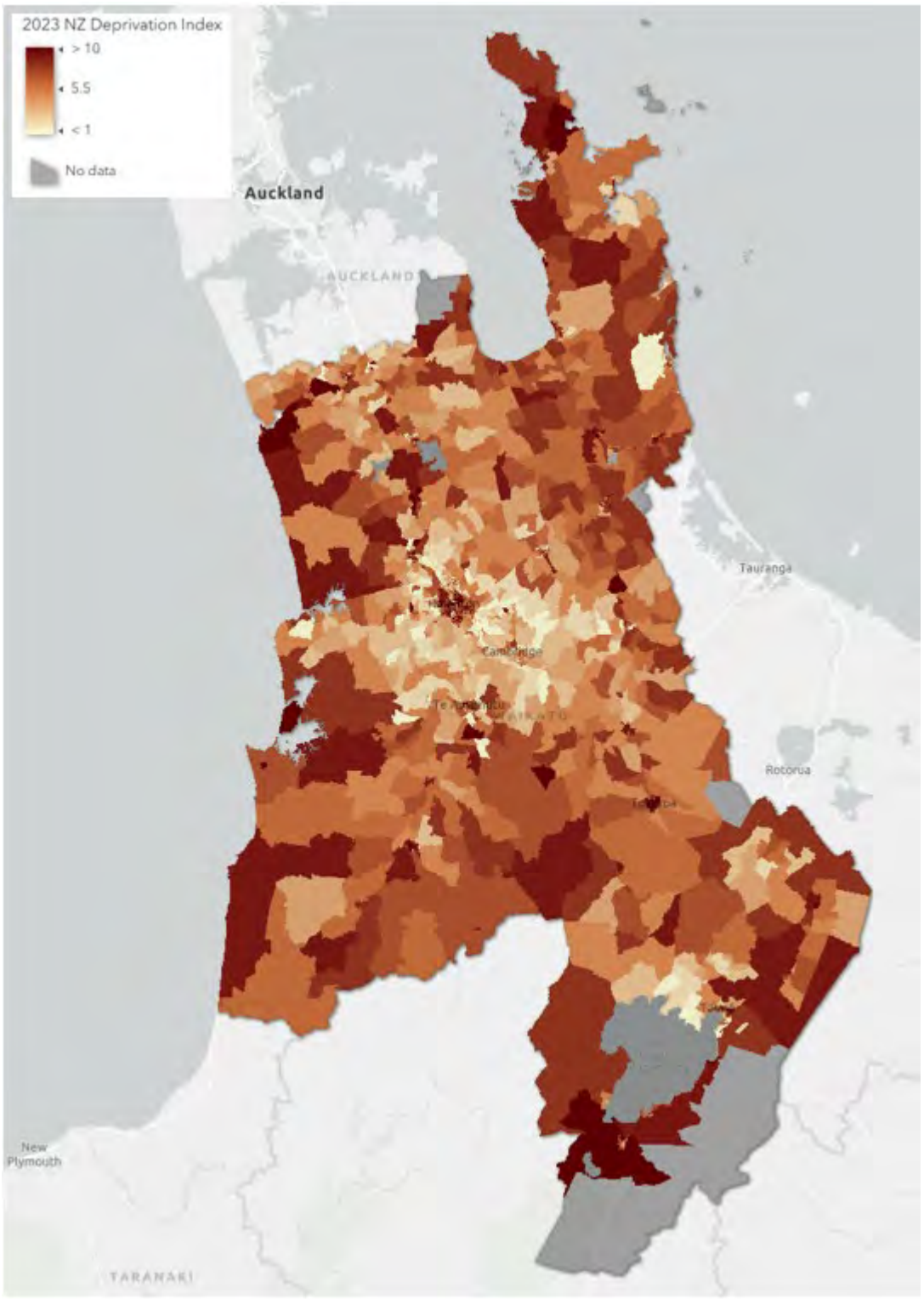


Figure 1 **Overview of social deprivation index for the Waikato region from the 2023 New Zealand census (Stats NZ, 2023).**

The total GDP of the Waikato in 2021 was $29.2 billion according to Statistics NZ, around nine per cent of the national economy. Apart from those regions that are home to our three largest cities (Auckland, Wellington, and Canterbury), the Waikato is the largest regional economy in New Zealand. The Waikato region's economy is broad-based, with significant specialisation and concentration of industries at a sub-regional level. A mix of activities contribute to regional GDP.

Figure 2 Structure of the Waikato economy (value added by industry) (Statistics New Zealand, 2023).

The Waikato is one of the most productive agricultural regions in New Zealand. Dairy and meat products make up around two-thirds of the Waikato's international exports. Most of the towns in the Waikato are highly dependent on agriculture for their economic sustainability.

Dairy farming is dominant. It was recently estimated that the Waikato has 3051 dairy herds – about 28.3 per cent of the total herds in New Zealand (Livestock Improvement Corporation Limited & DairyNZ Limited, 2022). Economically, dairying brings in $1.6 billion (around 5 per cent of regional gross domestic product) each year to the region, and it employs about 10,000 people. The agricultural sector also includes sheep, beef and goat farming, horse breeding and horticulture. Vegetable growing, which used to be centred around Pukekohe, has expanded and shifted south to the Matamata area.

2.1 Our region at a glance

Figure 3 below shows a high level overview of key statistics and features of the Waikato region.

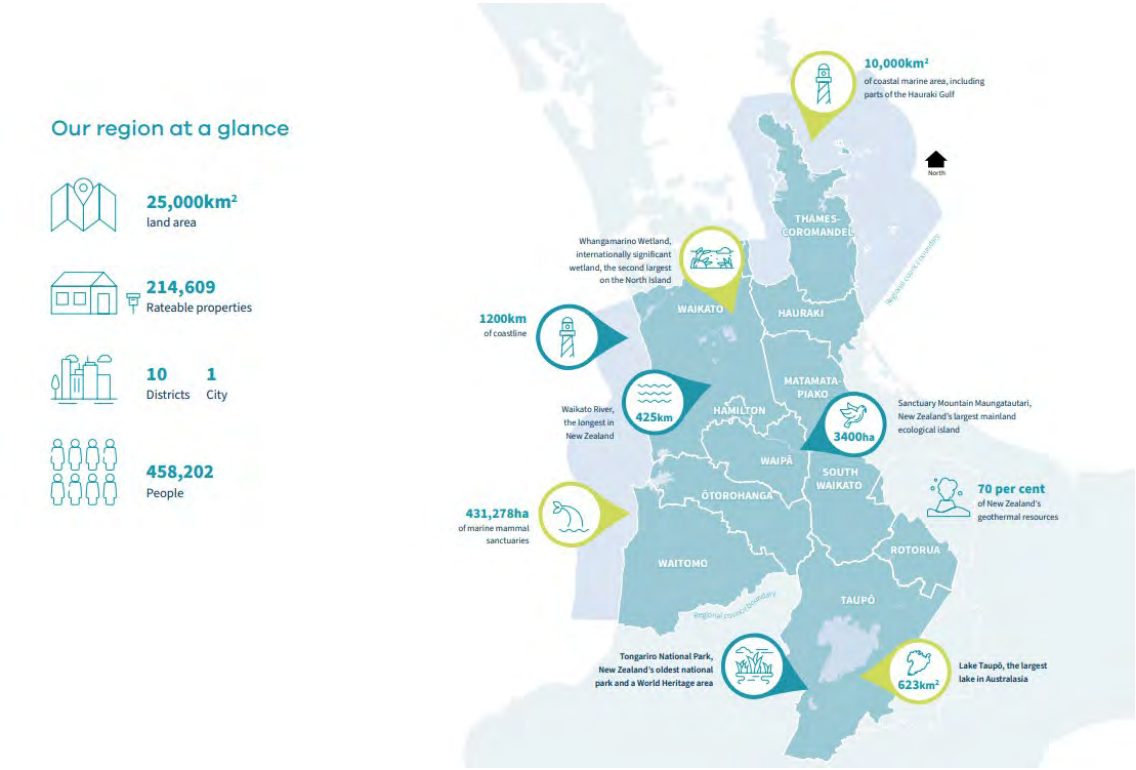


Figure 3 The Waikato region at a glance (Waikato Regional Council, 2023, p. 9).

2.2 Principal iwi groups

A guide to principal iwi groups in the Waikato region are shown in Figure 4.

Figure 4 Principal iwi grounds in the Waikato region (Waikato Regional Council, 2023c, p. 10).

3 Overview of methodology

Climate change risk assessments identify and rate risks to elements due to climate changes. This involves evaluating climate hazards, exposure of valued elements (e.g., people, assets, ecosystems), and their vulnerability. This report focuses on understanding the likely hazards and risks in the Waikato region as the climate changes.

This report is informed by a regional climate change risk identification project led by Waikato Regional Council, following the Ministry for the Environment, (2019) Guide to Local Climate Change Risk Assessments. This report and the high-level risk identification covers step 1 of the climate change risk assessment and adaptation process as set out in Figure 5.

The regional climate change risk identification project aimed to list potential climate change risks through desktop reviews, workshops and stakeholder engagement. Risks were categorised by hazard and risk elements and domains, consistent with the National Climate Change Risk Assessment. Appendix 1 provides a detailed explanation of the methodology undertaken in the high-level risk screening identification project which informs this report.

Steps 3 to 5 of the climate change risk assessment process are centred around community adaptation planning and are subsequent steps of the climate change risk assessment and adaptation planning process. To find out more about adaptation planning in the Waikato see Section 8.

Figure 5 **Overview of the climate change risk assessment and adaptation planning process (Ministry for the Environment, 2019, p. 9)**

4 District climate change hazard and risk summaries

The presence and impact of climate hazards, both now and into the future, vary across the Waikato region. It is important to understand that each Territorial Authority (TA), and consequently each community will be affected by climate change and its associated risks differently. Therefore, each will need to plan for climate change in a unique way.

Due to the presence and intensity of hazards across the region, some TAs have greater exposure to certain climate hazards than others. Consequently, the impact will vary across the region. However, a lower presence of hazards and risks in some TAs does not imply the absence of risks. There may still be smaller or localised areas within those TAs that are of higher priority.

Table 1 sets out an assessment of climate hazard exposure by district in the Waikato region.

Section 4.1 contains 11 maps, one for each district in the Waikato region. Each map provides a high-level overview of key climate hazards and risks for the district.

Table 1 **Assessment of climate hazard exposure by district in the Waikato region (Ministry for the Environment, 2024) (NZ Sea Rise, 2024) (Waikato Regional Council, 2025).**

Council	Flooding (Fluvial and Pluvial)*	Coastal hazards	Extreme weather	Higher temperature	Dryness and drought	Increased fire weather	Groundwater rise and salinity stress	Landslides and soil erosion	Marine heatwaves and ocean chemistry changes	Decreased frost
Thames Coromandel	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓✓	✓
Hauraki	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓	✓✓✓	✓
Waikato	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓	✓✓	✓✓	✓
Hamilton City	✓✓	N/A	✓✓	✓✓✓	✓✓	✓	N/A	✓	N/A	✓
Matamata-Piako	✓✓✓	N/A	✓✓✓	✓✓✓	✓✓✓	✓✓✓	N/A	✓	N/A	✓
South Waikato	✓	N/A	✓	✓✓	✓✓	✓✓	N/A	✓	N/A	✓✓
Waipā	✓✓	N/A	✓	✓✓	✓✓	✓	N/A	✓✓	N/A	✓
Ōtorohanga	✓✓	✓✓	✓✓✓	✓✓	✓	✓	✓	✓✓✓	✓	✓✓
Waitomo	✓✓✓	✓✓	✓✓✓	✓	✓	✓	✓	✓✓✓	✓	✓✓
Taupō	✓✓	N/A	✓✓	✓	✓✓✓	✓	N/A	✓✓✓	N/A	✓✓✓
Rotorua Lakes (WRC area)	✓	N/A	✓✓	✓	✓✓	✓	N/A	✓✓	N/A	✓✓✓

✓✓✓ Territorial authority (TA) has a large exposure to this climate hazard now and into the future with the potential to impact significant areas.

✓✓ TA has presence of hazard and exposure to this climate hazard now and into the future with the potential to impact localised areas.

✓ Limited presence and exposure of hazards and/or limited impact areas are impacted.

**Waikato Regional Council and/or other district councils provide and manage flood protection and land drainage schemes throughout the region. Waikato Regional Council manages flood protection and land drainage in Waikato District, Hauraki District, Thames Coromandel District, Matamata-Piako District, Waipā District and Taupō District. Hauraki and Ōtorohanga District Councils manage their own flood protection and land drainage for parts of their districts.*

Waikato District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Coastal communities like Port Waikato and Raglan face isolation risks from flooding and land instability, which can cause injuries and affect well-being, alongside low-lying inland communities such as Ngaruawahia and Huntly. Many marae near the Waikato River and low-lying coastal areas are at risk of flooding. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Natural environment

Whangamarino Wetland, a key Ramsar site, faces climate hazards affecting water quality and biodiversity. Warmer temperatures disrupt ecosystems, while increased rainfall, flooding and erosion cause vegetation loss and sedimentation, impacting wildlife. Coastal erosion and sea level rise at Port Waikato and Raglan also threaten coastal ecosystems, causing coastal squeeze and increased sedimentation.

Economy

Increased temperature, drought and heavy rainfall threaten Franklin's horticultural industry, straining production. Severe weather events can cause significant economic costs for homeowners. Additionally, increased river and ponding flooding will financially strain lower Waikato farmers, affecting their economic sustainability.

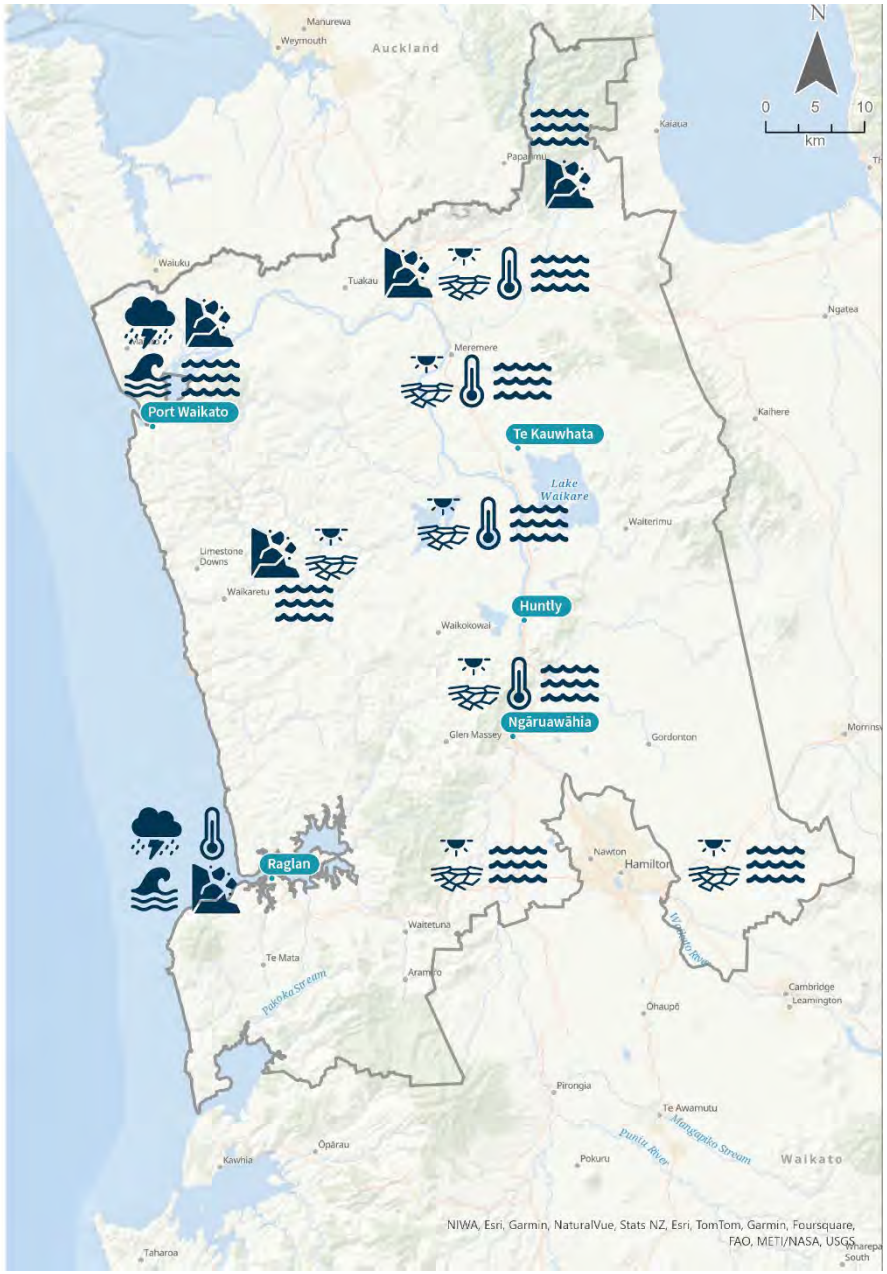
Built environment

Roading networks in the district are vulnerable to land instability, potentially isolating communities like Raglan and Port Waikato. SH1 and the North Island Main Trunk are at risk of managed flooding at Rangiriri during high river flows in the Waikato River. Many communities, such as Huntly and Rangiriri, face critical infrastructure failure from possible stopbank failure or overtopping. Coastal community assets, like the Sunset Beach carpark, are at risk of coastal inundation and erosion.

Hazards

- Extreme weather
- Drought
- Rainfall and flooding
- Land instability
- Higher temperature
- Coastal hazards

#7657



Hauraki District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Increased temperature may lead to risks to human health from heat related illness and make outdoor activities less viable impacting social and mental wellbeing, alongside community isolation and economic stress from drought. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Increased temperature, drought conditions and river flooding will affect the rural sector by reducing stock productivity, raising agricultural costs and impacting animal welfare. Reduced water availability poses a significant risk as the district relies heavily on this resource.

Natural environment

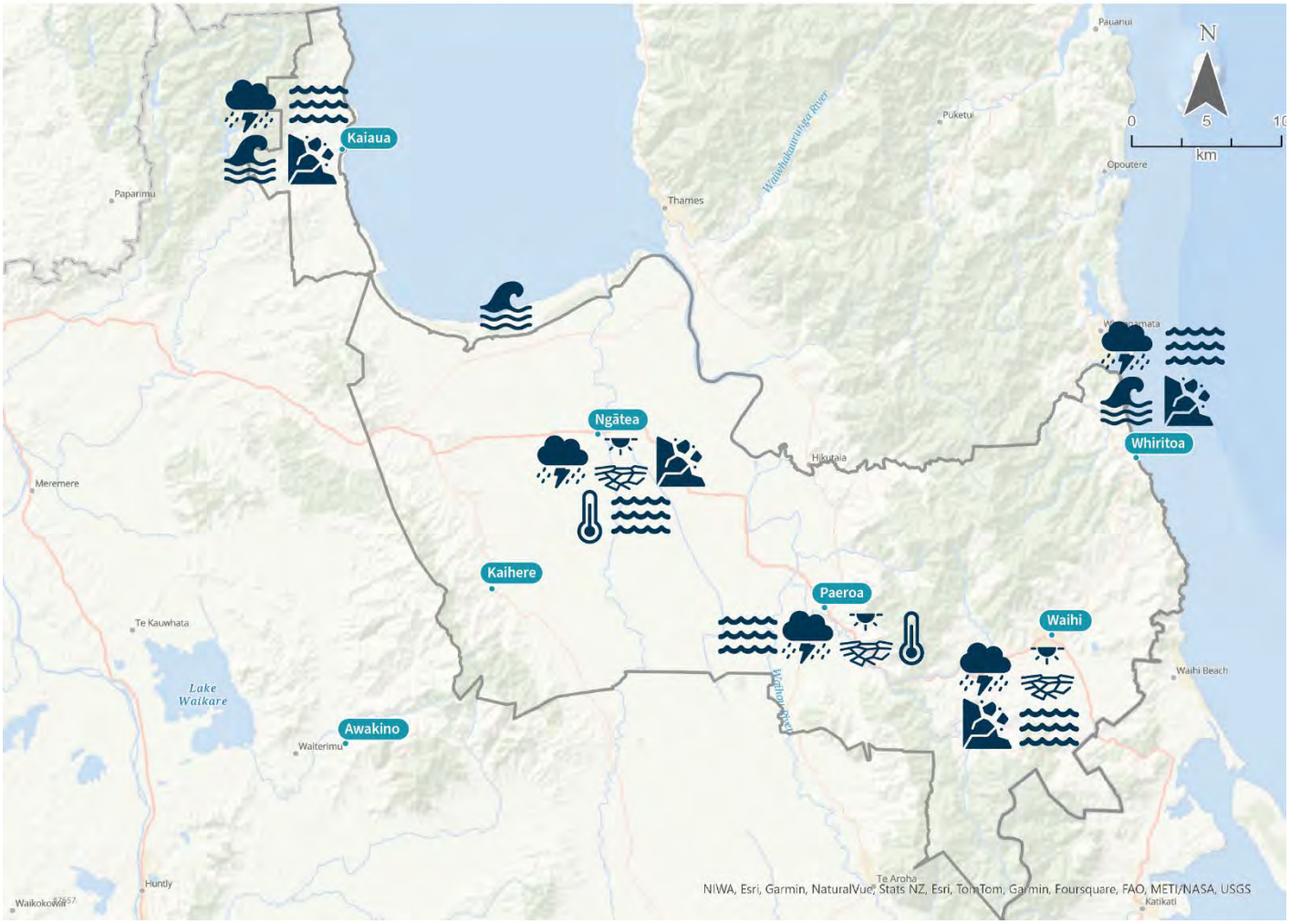
The district faces increased risks in coastal and terrestrial environments such as the Pūkorokoro-Miranda and Kopuatai Wetland Ramsar sites. Water quality across the district is also at risk from increased coastal and inland flooding, higher temperatures and drought conditions.

Built environment

SH2 is a significant transport route at risk from flooding (inland and coastal) and land instability, which would reduce the community's ability to move across the district. Flood risk management infrastructure risks being overwhelmed by extreme weather events leaving critical infrastructure and buildings vulnerable to damage.

Hazards

- Extreme weather
- Rainfall and flooding
- Higher temperature
- Drought
- Land instability
- Coastal hazards



Thames-Coromandel District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Community isolation is a significant risk for the district, leading is access issues to community, critical services and education. Isolation and loss of community cohesion can impact community wellbeing. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Tourism, a key contributor to the district's economy, faces significant risks from various hazards. Continuous impacts on critical infrastructure can increase the economic burden on the community and lead to higher inflation for transported produce and goods. Homeowners may also face increased economic costs due to higher maintenance and insurance expenses. Additional impacts may affect the aquacultural industry.

Natural environment

The Hauraki Gulf, a significant marine reserve for the region and New Zealand, is among the most at-risk ecosystems. Increased marine temperatures and ocean acidification have already caused sponge bleaching and disrupted marine food chains and wildlife.

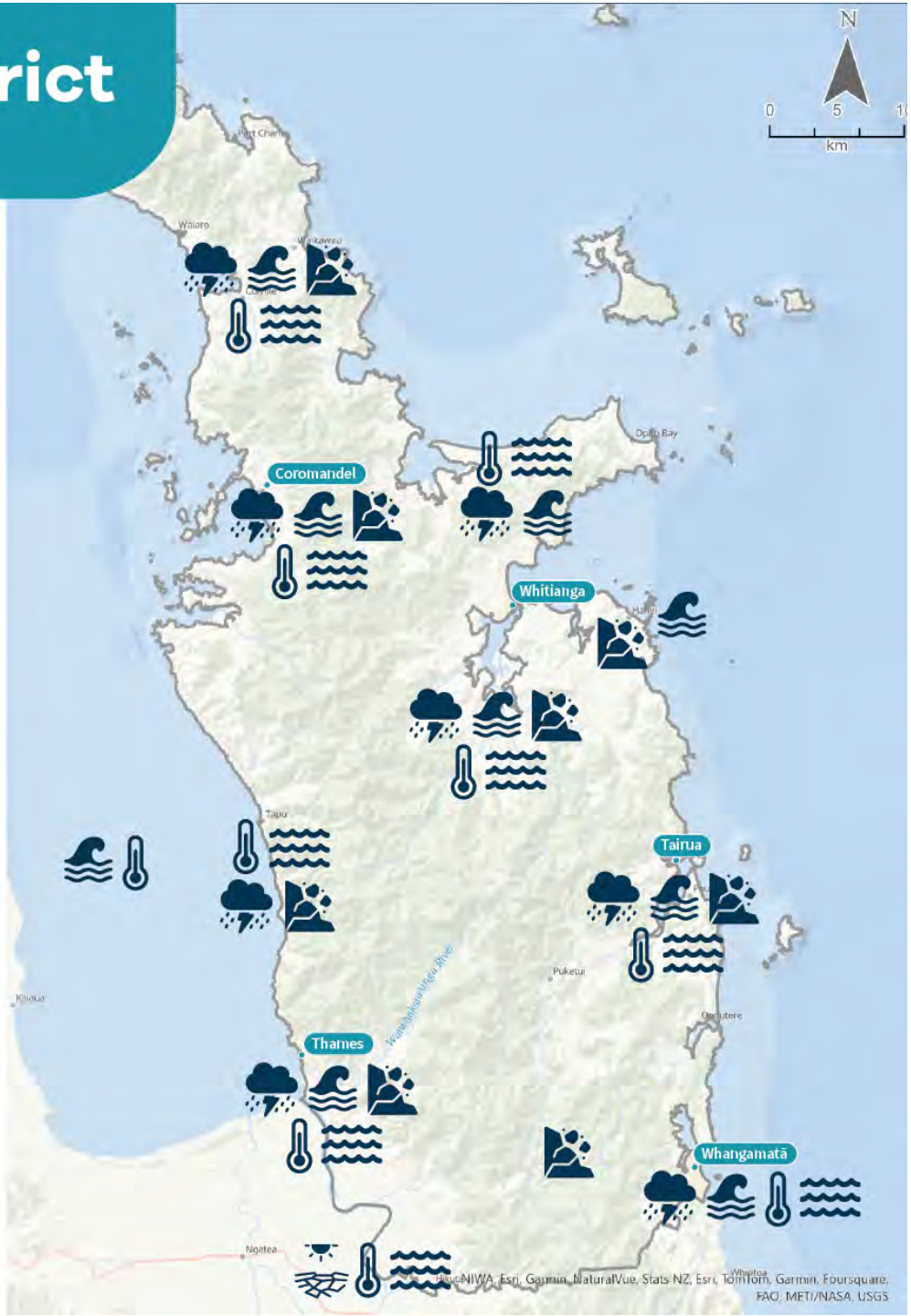
Built environment

All roading networks in the district are at risk from multiple hazards, isolating communities and disrupting regional connections. Key impacts are driven by land instability, flooding and sea level rise. SH25 at Coroglen, Manaia, Kūaotunu, Tairua, Whangamatā and Thames is highly vulnerable to several hazards influencing transport across the district. Buildings and critical infrastructure across the district are also at high risk from flooding and land instability impacts.

Hazards

- Extreme weather
- Rainfall and flooding
- Higher temperature
- Drought
- Land instability
- Coastal hazards

#7657



Matamata-Piako District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Higher temperatures may harm vulnerable communities, increase heat-related illness and impact outdoor activities (work, recreational, walking and cycling). Extreme weather and flooding may cause injury, isolate communites, and impact physical and mental wellbeing. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Higher temperatures, drought and flooding may reduce rural sector productivity and impact animal welfare. Extreme weather will influence the cost of properties and business owners from direct damage, loss of essential services and loss of tourism. Changes in temperature, seasonality changes, rainfall and water availability impact farming and horticulture systems, which affects the overall economic wellbeing of the district.

Natural environment

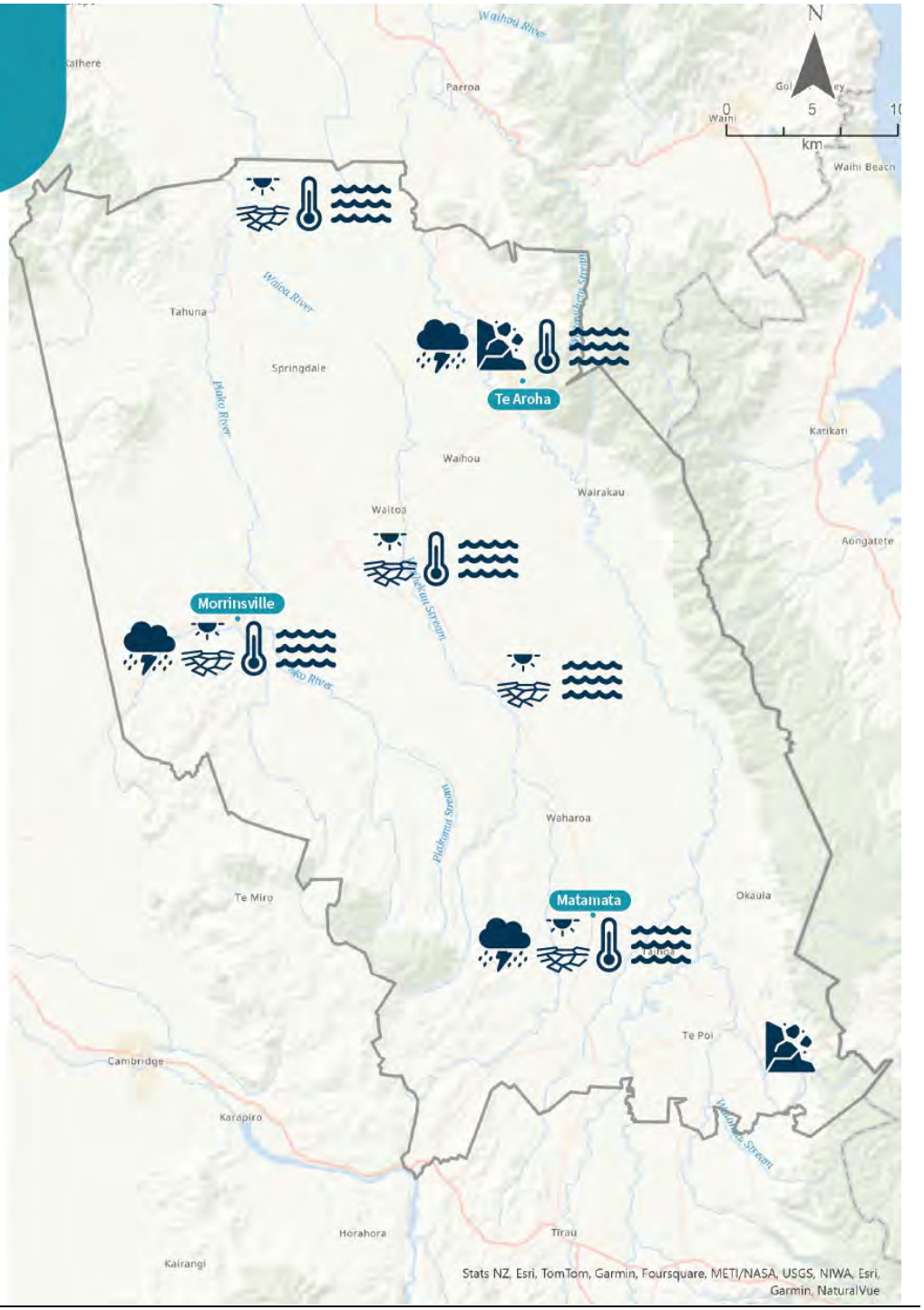
Kopuatai Dome is a significant Ramsar wetland site for the district and is at risk from multiple climate hazards including threats to water quality and biodiversity. Warmer temperatures can disrupt ecosystems, while increased rainfall, flooding and erosion can lead to vegetation loss and sedimentation, impacting wildlife.

Built environment

SH 29 across the Kaimai Range is vulnerable to land instability, affecting transportation to the Bay of Plenty and local roads and buildings in Te Aroha. Heavy rainfall can render critical infrastructure inoperable, leading to loss of services in vulnerable communities like Te Aroha. These communities also face building damage from ponded water when stormwater systems are overwhelmed and increased energy demand for cooling on hot days.

Hazards

- Extreme weather
- Drought
- Rainfall and flooding
- Land instability
- Higher temperature



Hamilton City

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the city. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Increased coastal and riverine hazards may lead people to migrate within the region to areas perceived as less risky, such as Hamilton. Consequently, this influx will place additional pressure on Hamilton City's services and housing, affecting social wellbeing. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Increased temperature, seasonality changes and increased rainfall may impact industries across the city as certain ones become less or more viable, affecting commercial and private income. Impacts from severe weather events on private and public property may also create economic costs for homeowners.

Natural environment

Hamilton lakes and the Waikato River are highly vulnerable to climate change, facing threats to water quality and biodiversity. Warmer temperatures can disrupt ecosystems, while increased rainfall, flooding and erosion can lead to vegetation loss and sedimentation, impacting wildlife.

Built environment

Hamilton's critical infrastructure risks being inoperable during heavy rainfall, impacting critical services across the city. Vulnerable communities face building damage from ponded water when stormwater infrastructure is overwhelmed and increased energy demand for cooling in hot days.

Hazards

- Extreme weather
- Rainfall and flooding
- Higher temperature
- Drought
- Land instability

Waipā District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Higher temperatures in urban centres can harm vulnerable communities, increase heat-related illness, strain hospital systems and make outdoor activities less viable. Urban flooding can also cause injury loss of livelihood, impacting wellbeing and mental health. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Increased temperature, droughts and flooding will affect the rural sector by reducing stock productivity, raising agricultural costs and impacting animal welfare. Severe weather events can cause significant costs for homeowners along the Waipā, Puniu and Mangapiko Rivers. Additionally, changes in temperature, seasonality and rainfall may make gardening less viable, straining commercial production.

Natural environment

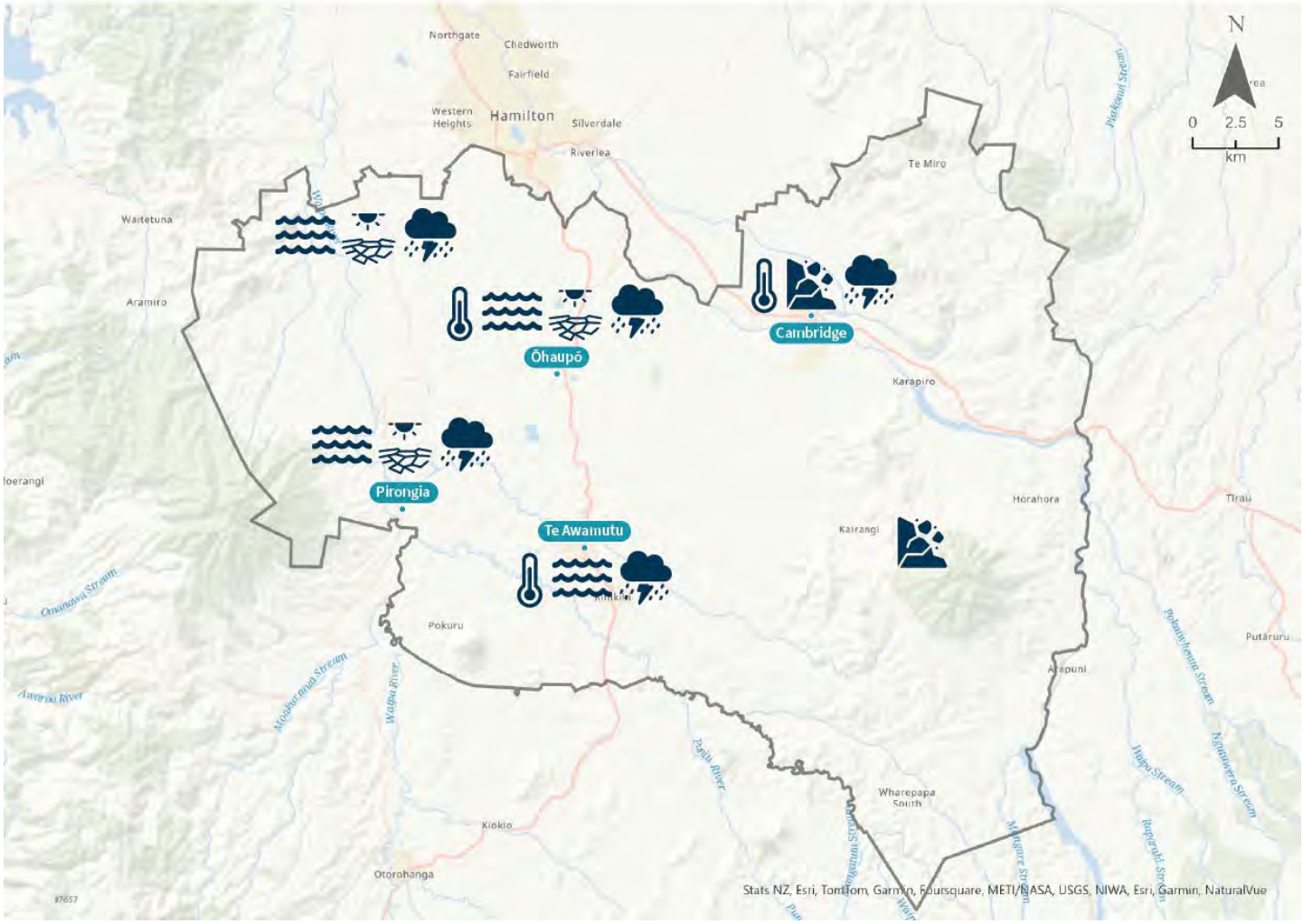
Waipā lakes and associated rivers are highly vulnerable to climate change, facing threats to water quality and biodiversity. Warmer temperatures can disrupt ecosystems, while increased rainfall and flooding can cause erosion, vegetation loss and sedimentation, impacting wildlife. Increased run-off from rural land can further decrease water quality in waterways across the district.

Built environment

Waipa's critical built infrastructure risks being inoperable during heavy rainfall, impacting critical services across key communities, like Cambridge and Te Awamutu. Vulnerable communities face building damage from ponded water when stormwater infrastructure is overwhelmed and increased energy demand for cooling on hot days. SH1 near Karāpiro is at risk of land instability, disrupting national transport.

Hazards

- Extreme weather
- Rainfall and flooding
- Higher temperature
- Drought
- Land instability



Ōtorohanga District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Vulnerable communities around Kāwhia and Aotea Harbours risk potential isolation driven by hazards like flooding and land instability. Flooding can also cause injury, impacting wellbeing and mental health in local communities, Ōtorohanga, Kāwhia and Aotea. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Increased temperature, droughts and increased flooding will economically impact the rural sector by reducing stock productivity, raising agricultural costs and impacting animal welfare. Severe weather events can also create significant economic costs for homeowners in vulnerable communities like Ōtorohanga and Kāwhia where flooding risk is highest.

Natural environment

High country in Ōtorohanga is highly vulnerable to erosion and land instability, impacting native biodiversity. Kāwhia and Aotea Harbours may experience increasing sedimentation, marine heatwaves, acidification and sea-level rise impacting coastal ecosystems.

Built environment

Critical infrastructure in Ōtorohanga is at risk of damage from flooding, particularly from possible failure/overtopping of stopbanks protecting the township. Additionally, local roads and state highways across the district are vulnerable to flooding and land instability, isolating communities, particularly in the west of the district.

Hazards

- Extreme weather
- Rainfall and flooding
- Higher temperature
- Drought
- Land instability
- Coastal hazards

Waitomo District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Vulnerable communities like Awakino, Mōkau and Marakopa face isolation risks from flooding and land instability, making access to critical services difficult and impacting community cohesion. Coastal erosion and flooding can cause injuries, alongside economic stresses impacting wellbeing, and mental health. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Waitomo Caves is vital to the Waitomo District's economy. It provides jobs but also faces risks from heavy rainfall and land instability. Increased temperature, droughts and flooding affect the rural sector by reducing stock productivity, raising agricultural costs and impacting animal welfare. Severe weather events can also create significant costs for homeowners.

Natural environment

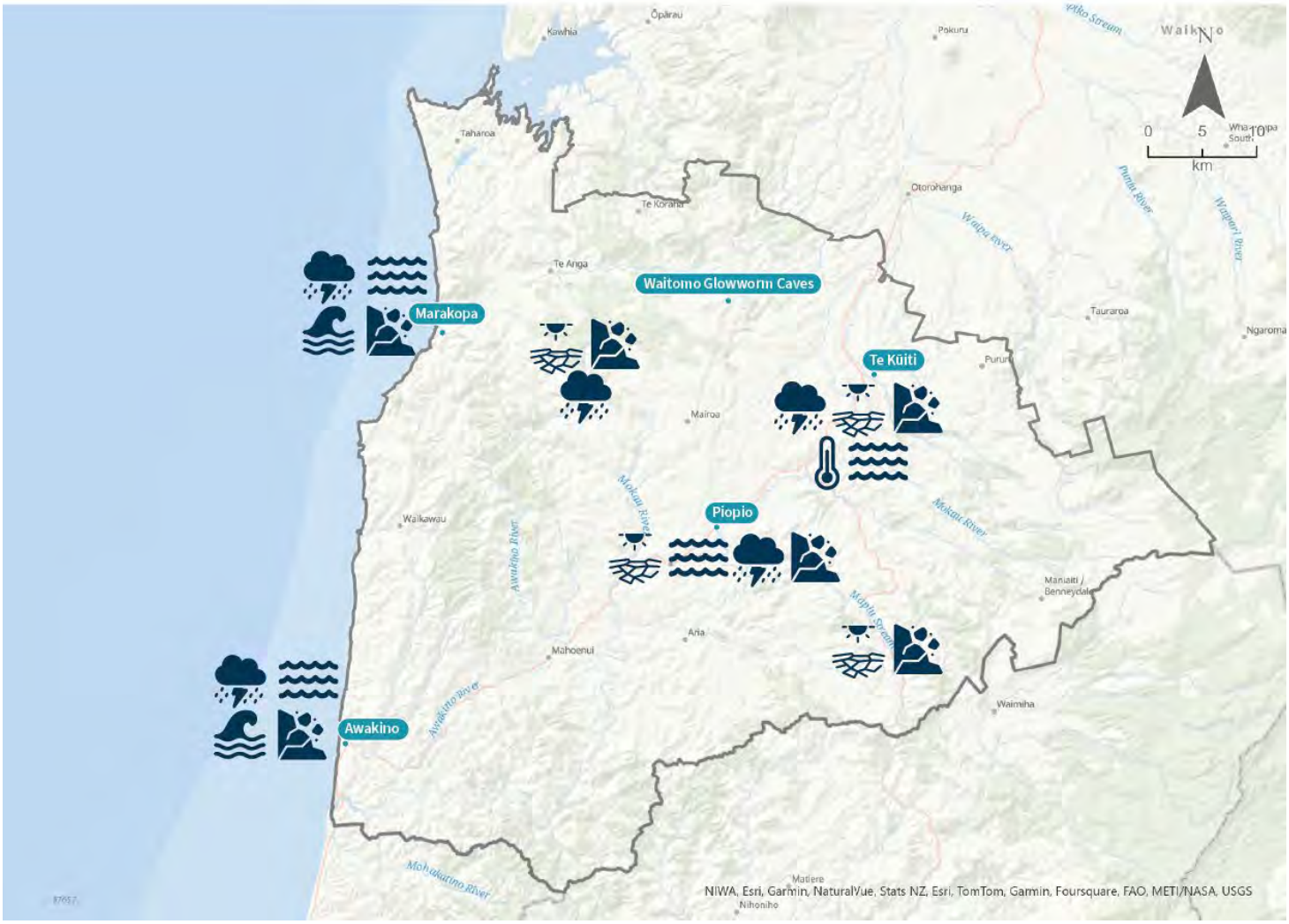
King Country is highly vulnerable to erosion and land instability, affecting native biodiversity and bush. Coastal erosion and sea-level rise at river inlets like Marakopa and Mōkau threaten coastal ecosystems, leading to coastal squeeze, increased sedimentation, marine heatwaves and acidification.

Built environment

Roading networks across the district are vulnerable to land instability, potentially isolating communities such as Awakino, Mōkau, and Marakopa. The North Island Main Trunk faces flood risk north of Te Kūiti. Te Kūiti and Piopio face building damage from ponded and river flooding when stormwater infrastructure is overwhelmed.

Hazards

- Extreme weather
- Rainfall and flooding
- Higher temperature
- Drought
- Land instability
- Coastal hazards



South Waikato District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Impact on the forestry industry reduce wellbeing in communities that work in the industry. Urban flooding can cause injury and loss of livelihood impacting wellbeing and mental health. Demand on marae and community facilities may increase with possible damage to urupā and other places of cultural significance.

Economy

Increased temperature, droughts and river flooding will economically impact the rural sector by reducing stock productivity, raising agricultural costs, and affecting animal welfare. Seasonal changes and severe weather can also impact the forestry industry through reduced rainfall, wind damage to trees, and increased fire risk.

Natural environment

Increase in severe weather can lead to increased run-off from urban, forestry and native bush reducing water quality and impacting tourist destinations across the district, like the Blue Springs. Native vegetation, biodiversity and forestry is at risk of fire from increased temperatures.

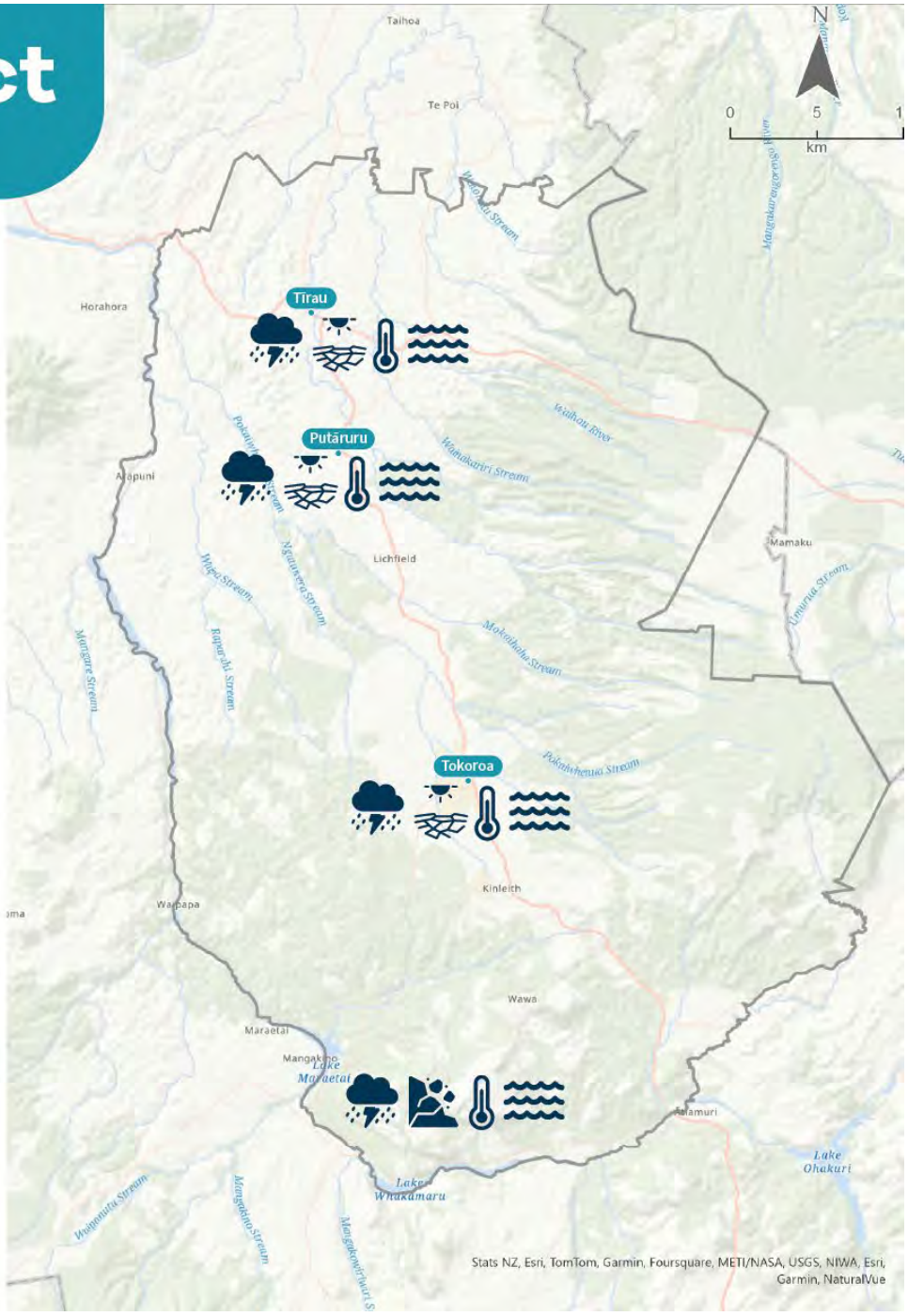
Built environment

South Waikato's critical infrastructure may fail during heavy rainfall, affecting services in Tīrau, Putāruru and Tokoroa. Vulnerable communities risk building damage from overwhelmed stormwater systems. Waikato River power generation is at risk from severe weather, drought and seasonal changes.

Hazards

- Extreme weather
- Drought
- Rainfall and flooding
- Land instability
- Higher temperature

#7657



Rotorua District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

Increased temperature may lead to risks to human health from heat-related illness and make outdoor activities less viable impacting social and mental wellbeing, alongside community isolation and economic stress from drought.

Natural environment

Increase in severe weather can lead to increased run-off from forestry and native bush, which reduces water quality. Native vegetation, biodiversity and forestry are at risk of fire from increased temperatures.

Economy

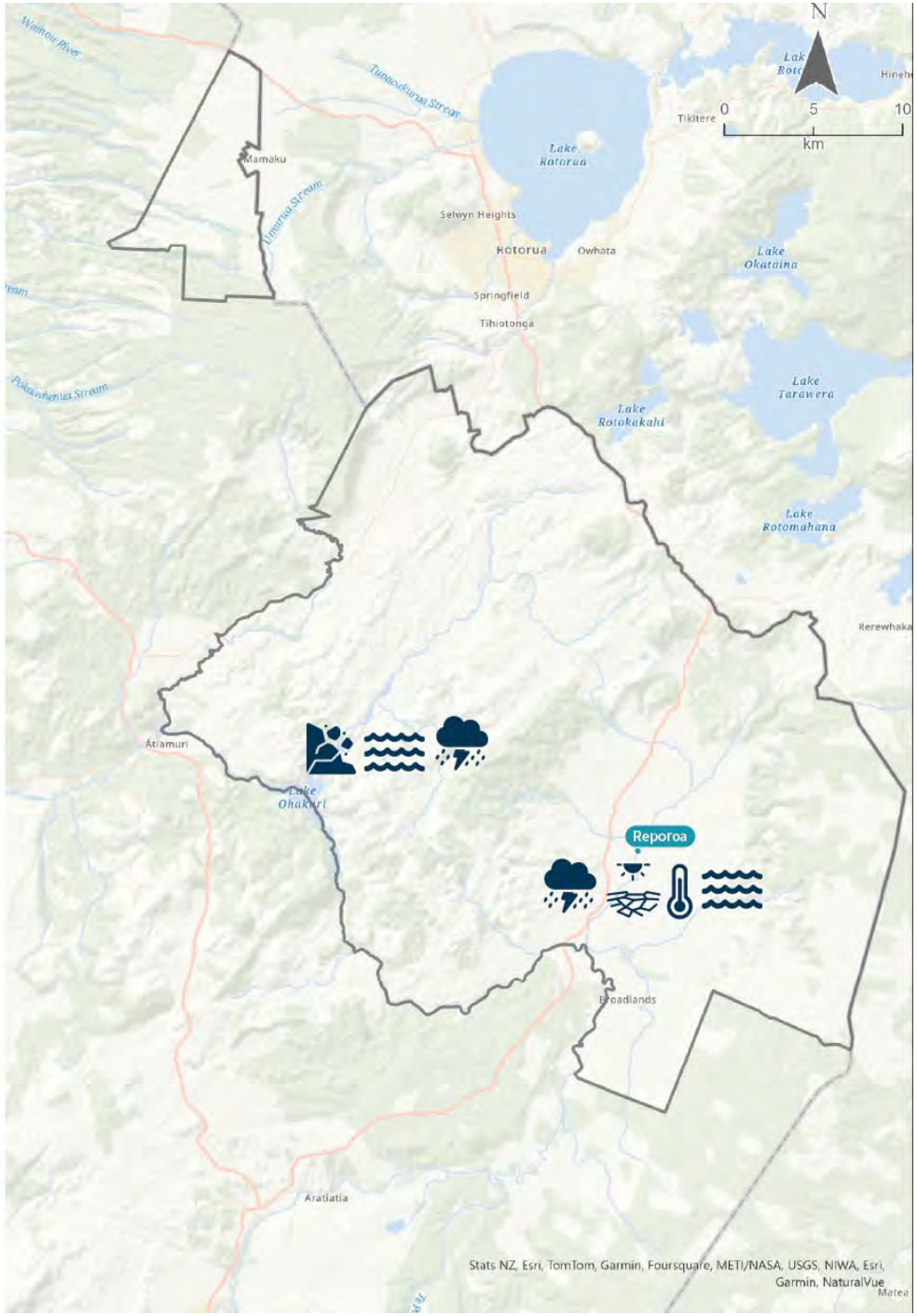
Increased temperature, droughts and increased flooding will economically impact the rural sector by reducing stock productivity, raising agricultural costs and impacting animal welfare.

Built environment

Agricultural infrastructure and buildings in and around Reporoa are at risk from flooding.

Hazards

- Extreme weather
- Drought
- Rainfall and flooding
- Land instability
- Higher temperature



#7657

Taupō District

Climate change hazards and risks

This map provides a high-level overview of key climate hazards and risks for the district. It should not be interpreted as showing all climate hazards, risks and all locations.

Human

The loss of winter tourism will significantly impact Taupō communities, influencing communities' mental well-being. Vulnerable communities, such as those on the eastern and southern lakefront, face potential isolation risks driven by hazards. Land instability in Waihi Village poses a risk to iwi/Māori as demand increases on marae and community facilities with possible damage to urupā and other places of cultural significance.

Economy

Increased temperature and fewer snow days will affect winter tourism in Taupō, while increased droughts will economically impact the rural sector by reducing stock productivity and raising agricultural costs. Seasonal changes and severe weather can also harm the forestry industry through reduced rainfall, wind damage to trees and increased fire risk.

Natural environment

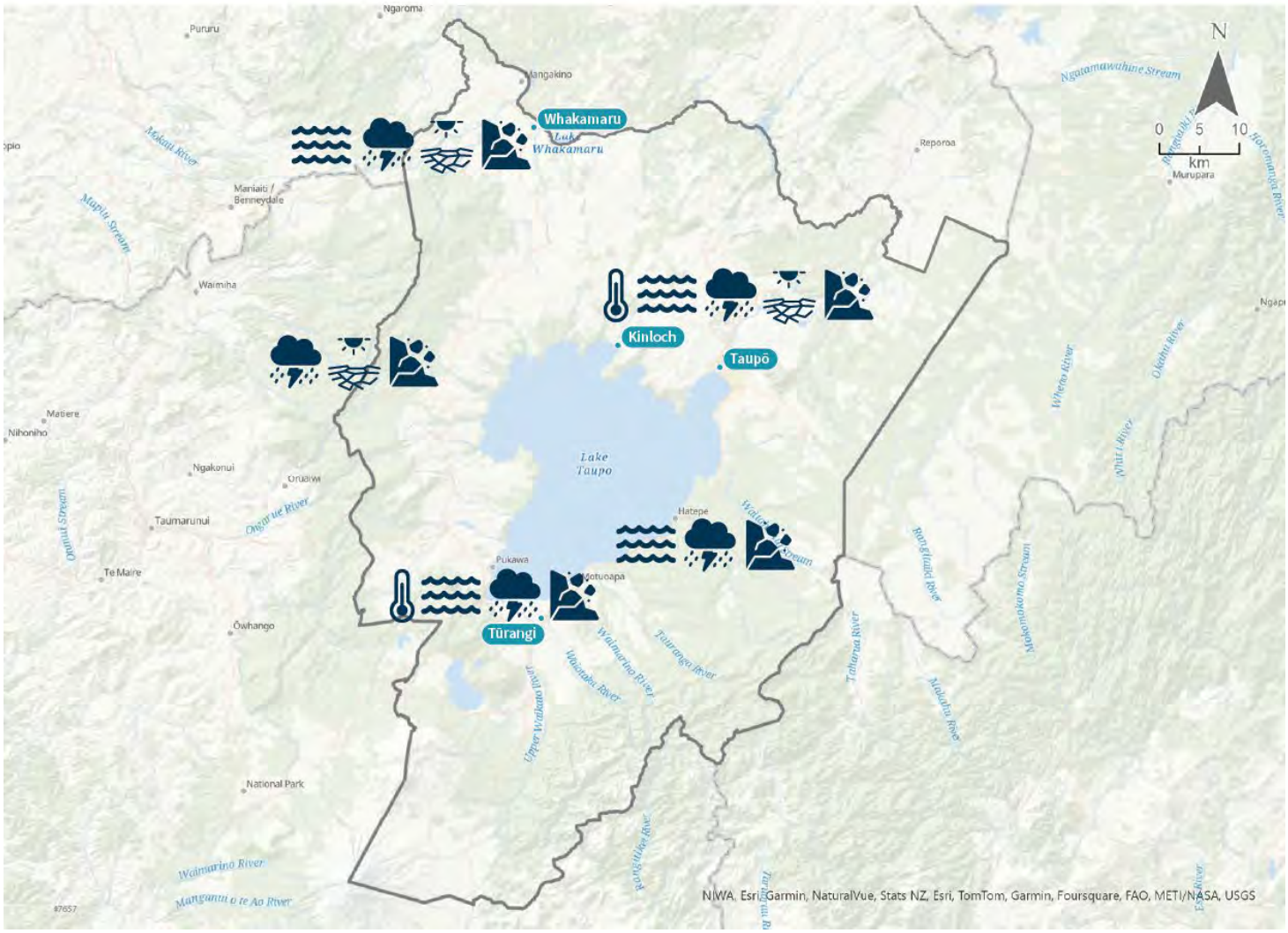
Warmer temperatures can negatively impact Lake Taupō's ecosystems, increasing algal blooms and biodiversity both in and around the lake. Increased rainfall and erosion can reduce water quality alongside increased run-off from urban centres like Taupō township and forestry areas.

Built environment

Critical infrastructure along SH1 and SH43 is vulnerable to flooding and land instability, and buildings along the eastern and southern shores of Lake Taupō are at risk of flooding, such as in Tūrangi, Tokaanu and Tauranga Taupō communites. Lake Taupō power generation is at risk during both high and low lake levels due to severe weather, drought and seasonality changes.

Hazards

- Extreme weather
- Rainfall and flooding
- Higher temperature
- Drought
- Land instability



5 Climate risks to Māori

In 2021, *He huringa āhuarangi, he huringa ao: a changing climate, a changing world* was produced by a multidisciplinary Māori research team working across many research institutions. Using a novel kaupapa Māori risk assessment approach to climate change, this substantial piece of work synthesises the latest climate change research through a Māori lens and identifies the potential impacts, implications, mitigation and adaptation strategies for whānau, hapū, iwi and Māori business (Awatere et al., 2021).

Drawing on *He huringa āhuarangi, he huringa ao*, as well as Waikato-specific engagement with iwi Māori during the regional climate risk identification project, the following points represent a summary of key themes:

- Climate change is likely to have significant impacts on Māori.
- Māori well-being across the domains of environment, Māori enterprise, healthy people and Māori culture will be moderately impacted by 2050. By 2100, the risks to ecosystems are likely to show severe impact, compromising many aspects of Māori well-being.
- Climate change not only threatens the tangible components of Māori well-being, but also the spiritual components and, most importantly, the well-being of future generations. The production and ecology of fresh water, terrestrial and coastal-marine ecosystems and biodiversity in New Zealand will be challenged by projected warming temperatures and reductions in rainfall.
- Vulnerable flora and fauna may face habitat loss and in some cases extinction. Any decline in the quantity and quality of keystone species like pāua, kina and koura, will adversely impact Māori customary practice, cultural identity, social cohesion, and well-being. Cultural infrastructure, especially in exposed areas such as river valleys and coastal areas, will be particularly vulnerable to climate change impacts, and some marae and papa kāinga may have to be moved, along with urupā in low lying and coastal areas prone to flooding and erosion. Limited land availability for moving marae at risk is a concern.
- Iwi/Māori have a role as kaitiaki (guardians) of the whenua and will therefore be impacted by risks posed to the natural environment to which they have an innate connection.
- Māori maintain a critical concern for Papatūānuku and recognise the fragility of ecosystems and the disruption that humans can cause.
- Tohu (indicators) may change with climate change – such as when is best to collect kai, and how future seasons and weather patterns may change, e.g. severe drought. This has the potential to create physical, spiritual and cultural implications for Māori. Hukanui was named for 'the big frost', but iwi Māori no longer see this.
- Climate change threatens culturally significant land, taonga species and resources, thereby impacting mātauranga and tikanga Māori.
- Impacts on coastal marae are of concern, as well as those near flood plains – as marae are of fundamental importance and hold generations of knowledge and traditions, and impacts would create broader implications for Māori health and well-being. The impact of climate change on critical infrastructure servicing marae is also relevant.
- Climate-related adverse health impacts are expected to become more severe and be borne disproportionately by groups like Māori who already suffer health inequities. Baseline health statistics are poor with generations of poor well-being.
- Many socio-economically deprived areas will be exposed to coastal and flooding hazards. Generally, these communities have limited ability to respond (i.e. poor access to transport, lack of reserve food supplies, inequitable distribution of infrastructure etc.), therefore

increasing their vulnerability. Higher temperatures can impact health, particularly in kaumatua, ageing and other vulnerable groups (including babies).
- Risks to cultural practices can include implications for intergenerational knowledge sharing, and cultural rituals and ceremonies – with impacts to cultural and spiritual well-being as well as impacts on tikanga, kawa and te reo Māori. An example was given of Taupiri Maunga during summer, where increasing temperatures will require earlier services.
- Implications of transition will be significant and could create new risks.

6 Waikato region climate projections and hazards

6.1 An introduction to global climate scenarios and projections

The main driver of climate change relates to emissions of carbon dioxide into the atmosphere, which has been extensively modelled by the Intergovernmental Panel for Climate Change (IPCC).

The Fifth Assessment Report (AR5), released in 2014, explores five different Representative Concentration Pathways (RCPs). Each RCP corresponds with a level of radiative forcing (and degree of global warming) by 2100.

The IPCC's sixth assessment report (AR6), released in 2021, introduced the Shared Socio-economic Pathways (SSPs), which outline how global society, demographics and economics might change over the next century, which establish 'baselines' in the absence of specific climate mitigation policy.

AR6 explores five different SSPs combined with RCPs (which contain a range of specific mitigation targets and policy assumptions). There are five commonly used SSP-RCP ('SSPX-Y') scenarios:
- SSP1-1.9
- SSP1-2.6
- SSP2-4.5
- SSP3-7.0
- SSP5-8.5

The first number 'X' in the SSPX-Y acronym refers to the baseline SSP scenario. The second number 'Y' refers to the RCP radiative forcing levels. For example, 'SSP1-1.9' is a scenario that combines SSP1 with 1.9 W m-2 radiative forcing in 2100 (RCP1.9).

Climate change projections are modelled representations of the potential future climate over the next century. NIWA and Ministry for the Environment (MfE) have recently released downscaled climate change projections for New Zealand using the latest AR6 data (Ministry for the Environment, 2024). These provide the region with the most current understanding of how the climate may change across the region into the future (Ministry for the Environment, 2024).

Three scenarios were used in these projections (Ministry for the Environment, 2024).
- The 'Sustainability' scenario, SSP1-2.6, assumes that the world shifts gradually toward a more sustainable path, emphasising more inclusive development that respects environmental boundaries. It assumes that warming stays below 2˚C, with net zero CO_2 emissions reached by 2050.
- The 'Middle of the road' scenario, SSP2-4.5, assumes that the world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. It assumes that warming reaches 2.7˚C by 2100.

- The ‘Regional rivalry’ scenario, SSP3-7.0, assumes the world becomes more focused on national and regional security issues, and there is no additional climate policy. It assumes CO_2 emissions approximately double from current levels by 2100 and warming reaches 3.6˚C by 2100.

At time of finalising this report, NIWA and Ministry for the Environment have not released downscaled SSP5-8.5 projections for the country, but the report will be updated to include these on release. SSP5-8.5+ for sea-level rise projections have been included in this report as this information is already available through NZ Sea Rise (2024).

6.2 Climate change projections and hazards in the Waikato

The following section is a discussion of the key climate exacerbated hazards expected in the Waikato region, followed by tables 2-4 which summarises the range of expected changes across these hazards and provides the range of projected climate change futures that can be expected across the Waikato region for two time periods, mid-century and end of century.

6.2.1 Key climate hazards in the Waikato

Climate change is expected to increase the frequency, severity and impact of many natural hazards in the region. Over the next century, the Waikato region can expect rising sea levels, more extreme weather, warmer summers and milder winters with seasonal rainfall shifts. It is projected that drought risk will increase in the north and east over spring and summer, and there may be seasonal changes in rainfall and wind in the west.

Severe weather and flooding: The Waikato region is highly vulnerable to severe weather events, which are expected to become more frequent and intense due to climate change. The region's steep river catchments and low-lying flood plains, such as the Coromandel Peninsula and Hauraki Plains, are particularly prone to flooding from heavy rainfall and storms. Increased rainfall can overwhelm rivers and drainage systems, leading to widespread flooding in both urban and rural areas. Coastal inundation and elevated coastal water levels can also exacerbate river flooding in tidal areas and hinder the discharge of river systems.

The Waikato region has extensive flood management schemes and land drainage networks, all built to provide agreed levels of service. However, with climate change these may be unable to maintain historic levels of protection without considerable additional investment. Ongoing development in flood-protected areas also further increases exposure to flood risk.

Landslides and erosion: Intense rainfall and river flooding drive increased land instability, including landslides and erosion. Longer dry periods can exacerbate land instability as dry, cracked ground is more prone to failure during intense rainfall. Landslides are common in steep catchments with weak geology, particularly when soils become oversaturated. The Coromandel Peninsula is highly vulnerable, as seen during Cyclone Gabrielle in February 2023, where landslips caused significant road damage including the closure of State Highway 25A. Additionally, western Waikato hill country is highly erodible and prone to land instability risks. Riverbank erosion is also common on outer river bends during flood events due to high-energy flows. Erosion can also have secondary impacts on water quality, as a result of sediment loads.

Coastal inundation and erosion: Coastal inundation and erosion are significant risks for the Waikato region, particularly as climate change exacerbates these hazards. Coastal areas, including Port Waikato, Mōkau, Aotea Harbour and various Coromandel communities, are highly susceptible to both

short term erosion from storms and long term erosion driven by long term costal processes such as sea-level rise and sediment changes.

Sea-level rise is expected to accelerate coastal erosion and increase the frequency and severity of inundation events. Currently, coastal inundation risks 8,000 people, $1.46 billion worth of buildings, and 540 square kilometres of productive land. A 1-metre rise in sea level could significantly increase these impacts, potentially affecting over 11,000 residents, $2.2 billion worth of buildings, and 630 square kilometres of land if no future protection measures are taken (Waikato Regional Council, 2023b).

King tides and storm events exacerbate coastal erosion and inundation, causing the loss of natural buffers like sand dunes. This can make properties, infrastructure and eco-systems more vulnerable. Sea-level rise also affects groundwater levels, increasing the water table, impacting buried infrastructure and foundations, and increasing liquefaction risk.

Vertical land movement impacts coastal inundation by altering local sea levels. Subsiding land increases the relative sea-level rise, exacerbating flooding, while uplifting land can mitigate some impacts. In the Waikato region, our greater likelihood of subsidence in many coastal and low-lying locations may amplify inundation risks over time.

Droughts: The Waikato region, traditionally known for its plentiful water resources, is increasingly facing the prospect of more frequent and severe droughts due to climate change. Rising temperatures and less consistent rainfall are expected to increase the incidence and intensity of droughts. Northern and eastern parts of the region are particularly at risk, which will significantly impact agricultural and horticultural industries. Areas like the Hauraki Plains, which relies heavily on reticulated water for farming, will likely experience reduced water availability during prolonged dry periods. This can lead to economic burdens due to heat stress on animals and reduced pasture feed, affecting food production. The region has already experienced severe droughts, such as the dry conditions in 2019 and the record-breaking low rainfall in the summer of 2020. The North Island drought of 2007-2008, which cost the New Zealand economy $2.8 billion, highlights the potentially significant economic impacts of drought (Connolly et al., 2021). Drought events can have secondary risks on the environmental domain in terms of water quality and eco-systems.

Temperature increase: Extreme heatwaves are becoming more common and intense in the Waikato region as national temperatures rise. These heatwaves can have wide-ranging effects on human health, animal welfare, the marine environment and economic productivity. Additionally, warmer air can hold more moisture, which can result in more intense rainfall. Recent summers have seen record-breaking temperatures, with many more warm days (≥ 25°C) than usual. High afternoon temperatures and humidity in the Waikato can cause significant heat stress, with extreme events often persisting for several days with little respite overnight. The impacts of extreme heat include increased demand for water and energy, degradation of infrastructure such as roads, and challenges for agriculture due to heat stress on livestock and reduced crop yields. Additionally, fewer frost days are expected, which can affect winter recreational activities and tourism, as seen with the record-breaking low snowfall in Tongariro National Park in 2022.

Increased fire weather: Climate change predominantly increases the risk of wildfires by increasing temperatures and reducing moisture. Higher temperatures reduce relative humidity and prolong droughts, making fire fuels more available. Changing rainfall patterns also result in increased rainfall in some areas but drier conditions in others. Projections for the Waikato region indicate that the highest fire danger areas are in the Matamata-Piako and Hauraki Districts, including Matamata, Morrinsville, Waihi, Thames, Te Aroha, and Paeroa, which have a mix of exotic plantations, native

forests and other land uses. The area around Te Aroha, particularly the Kaimai-Mamakū forest park, is at risk of extreme fire danger ratings. Climate change is expected to increase fire weather risk in Waikato by about 3 per cent per decade until 2050. The high-end scenario (RCP8.5) predicts a 10 per cent increase per decade in fire danger metrics from 2050 onwards, with the worst years showing double the current fire danger levels (Melia N et al., 2022).

Sea-level rise and groundwater: Sea-level rise affects groundwater levels in coastal aquifers, raising the water table and impacting the structure and functionality of buried infrastructure, such as public water services and private septic tanks. It can also affect the foundations of infrastructure like highways, rail and stopbanks, increase liquefaction risk and land drainage requirements, shift the freshwater–saltwater interface of rivers, and increase saltwater intrusion into groundwater bores.

6.2.2 Expected changes across key climate hazards

Using NIWA's downscaled climate projections, Tables 2 to 4 summarise the range of expected changes across these hazards and provides the range of projected climate change futures that can be expected across the Waikato region for two time periods, mid-century and end of century across different SSP projections.

The climate change projection data in Tables 2 to 4 is the mean change expected across the whole region. Therefore, it is possible for a larger or smaller range to occur than what is provided below. Several sources have been used to inform Tables 2 to 4, including Ministry for the Environment (2024), NZ Sea Rise (2024) and Yi et al., (2021).

For a greater level of detail on the potential future climate that will impact the Waikato region and our districts, see the updated 2024 Climate Projections Map (Ministry for the Environment, 2024). The NIWA downscaled dashboard includes projection descriptions and maps broken down for each territorial authority.

Table 2 Temperature increased and drought climate change projections and hazards across the Waikato region.

Hazard	Description	Present day (baseline 1995-2014)	Mid-century (2040 - 2060)		End of century (2080 - 2100)		Spatial variation across the region
			SSP2-4.5	SSP3-7.0	SSP2-4.5	SSP3-7.0	
Average temperatures	• The average daily air temperature per year or season.	8°C to 10°C on average per year	+ 1.1° to 1.2°C temperature increase	+ 1.3° to 1.4°C temperature increase	+ 1.9° to 2.1°C temperature increase	+ 2.9° to 3.1° C temperature increase	• Average daily temperature is expected to increase across the whole region, however Hamilton City, Ōtorohanga, Rotorua and Taupō Districts are expected to see a significant increase in the number of hot days, particularly by end of century. • My mid-century three out of four summers in Hamilton will include a 15-day hot spell more intense than those occurring once a decade in the recent past (1984-2015). • By mid-century, significant multi-week heatwaves with temperatures at or above 30°C for several weeks could occur in Hamilton.
Hot days (>25deg)	• The number of days per year or season with a maximum daily air temperature over 25°C or greater and very hot as 30°C. • Significant increases are expected in summer, especially by end of century. • By mid-century, summer temperatures are projected to rise by +0.9°C – 1.8°C and up to 3.8°C by end of century.	10 to 38 hot days on average per year	+ 12 to 30 more hot days per year	+ 17 to 39 more hot days per year	+ 25 to 54 more hot days per year	+ 48 to 82 more hot days per year	
Frost days	• The number of days per year or season with a minimum daily air temperature below 0°C. • These will significantly decrease in the southern parts of the Waikato region, particularly by end of century.	6 to 45 frost days on average per year	3 to 12 fewer frost days per year	3 to 14 fewer frost days per year	5 to 22 fewer frost days per year	5 to 29 fewer frost days per year	• Taupō District will see the largest decrease in estimated frost days followed by Rotorua District. • There is a smaller decrease in the number of frost days seen across the northern Waikato Districts.
Drought	• Dry days are days where rainfall is less than 1mm per day. • Potential evapotranspiration deficit (PED) is a drought index (expressed in mm) representing drought exposure. • An increase in PED indicates an increase in drought severity. • By the end of century, the time spent in drought ranges from minimal change through to more than double, depending on the climate model and emission scenario considered.	213 to 242 dry days on average per year 42mm to 144mm PED	-2 to +1 more dry days per year +21mm to +36mm of PED	-2 to +1 more dry days per year +2mm to +44mm of PED	+1 to +3 more dry days per year +27mm to +66mm of PED	+6 to +8 more dry days per year +48mm to +87mm of PED	• Drought risk is expected to increase across the whole region, but particularly in north-eastern districts.
Increased fire weather	• Fire weather index is dependent on temperature, precipitation, relative humidity and wind speed. • The number of days with very high and extreme fire danger could increase significantly across the country.	*No projection information available					• The highest fire danger in Waikato is projected for the Matamata-Piako and Hauraki districts, including Matamata, Morrinsville, Waihi, Thames, Te Aroha, and Paeroa. • Districts and locations identified above will experience higher temperatures could see increased fire weather. • However, the Waikato region is not expected to see a significant increase in wind, which is an exacerbator of fire risk.

Table 3 Flooding, extreme rainfall and storms climate change projections and hazards across the Waikato region.

Hazard	Description	Present day (baseline 1995-2014)	Mid-century (2040 - 2060)			End of century (2080 - 2100)			Spatial variation across the region
			SSP2-4.5	SSP3-7.0	SSP5-8.5	SSP2-4.5	SSP3-7.0	SSP5-8.5	
Annual rainfall	• The total amount of rainfall per year or season. • Slight increase expected overall, but potential for a 11% decrease by end of century. • Rainfall intensity is expected to increase, so while seasonality of rainfall may decrease, more intense rainfall is expected to fall over shorter periods.	1160 – 2260mm total rainfall per year on average 122 to 152 rainy days per year	-3% to +0.4% change in annual rainfall -1 to +1 very rainy days per year	-3% to -2% change in annual rainfall -1 to +1 very rainy days per year	N/A	-5% to -2% change in annual rainfall -2 to +1 very rainy days per year	-8% to -6% change in annual rainfall -4 to +1 very rainy days per year	N/A	• Overall Rainfall: Projected to decrease in many districts, especially in spring. • Significant Decreases: Notable in Waikato, Thames-Coromandel, Hamilton City, Waipā, Ōtorohanga, Rotorua, and Taupō during spring. • Hauraki and Matamata-Piako: Show significant variability in winter rainfall, with decreases up to 16% and slight increases around 3%. • Taupō District: Largest projected change in rainfall by end of century, with annual rainfall expected to change between -11 and 1%. Spring rainfall could decrease by -22% to -3%. • Flooding Risk: Varies across the region, with flood-susceptible areas in all districts. Highly susceptible districts include Waikato, Hauraki, Matamata-Piako, and Coromandel. Taupō District also has flood-susceptible communities, especially in lakeshore areas like Tūrangi.
Extreme rainfall	• 1% AEP, 24 hour duration rainfall depth (mm) • A rainfall amount that has a 1% chance of being exceeded in any given year. • Likely to become more intense, leading to more extreme flooding. Projections taken from CMIP6 report (**Yi, et al., 2021**) where projections are provided for SSP2-4.5 and SSP5-8.5	197mm (24hr, 100year)	+13% rainfall depth (24hr, 100year)	N/A	+16% rainfall depth (24hr, 100year)	+19% rainfall depth (24hr, 100year)	N/A	+39% rainfall depth (24hr, 100year)	
Extreme weather events (wind & storms)	• Increase in cyclone frequency and intensity • Extreme precipitation intensity is projected to increase. • Windy days are defined as days with >10m/s. • The reduction in windy days tends to be more significant by end of century compared to mid-century. • Frequency of extreme winds is expected to increase in winter and decrease in summer • Increase in storm intensity predicted by end of century will result in an increase in gale force westerly winds. • This may mean that longer dry spells are followed by more intense rainfall events.	1 to 82 windy days on average per year	0 to 7 fewer windy days per year	0 to 7 fewer windy days per year	N/A	0 to 12 fewer windy days per year	0 to 20 fewer windy days per year	N/A	• North and eastern parts of the region, particularly the Coromandel Peninsula, Hauraki, Matamata-Piako and Waikato Districts are likely to experience more frequency and more intense cyclones. • Most districts are projected to experience a decrease in the number of windy days by both mid-century and end of century. • Taupō District could experience 13 fewer to 1.2 more windy days, which contrasts with the overall trend of decrease across the region. • North-eastern districts such as Coromandel, Hauraki and Matamata-Piako could experience more extreme cyclone activity into the future.
Increased land instability and soil erosion	• Increasing rainfall intensity will increase the probability of landslides occurring. • Changes in rainfall intensity could also lead to a broader geographical area susceptible to landslide risk. • Increases in earthflow, gully, sheet, and bank erosion are expected with increased rainfall and temperature.	*No projection information available							• The Coromandel Peninsula is highly susceptible to land instability, as well as Northern Waikato surrounding Port Waikato, Wharekawa, Hunua Rangers, and along King Country in the west of the region. • Land instability is also likely surrounding Lake Taupō due to the weaker volcanic ash and pyroclastic flow deposits. • These locations are also susceptible to soil erosion alongside land use areas highly populated by agriculture and horticulture, such as Hauraki Plains, Lower Waikato, Matamata-Piako and Tūākau/Pukekohe.

Table 4 Coastal hazards and sea level rise projections across the Waikato region.

Hazard	Description	Present day (baseline 1995-2014)	Mid-century (2040 - 2060)			End of century (2080 - 2100)			Spatial variation across the region
			SSP2-4.5	SSP3-7.0	SSP5-8.5 H+	SSP2-4.5	SSP3-7.0	SSP5-8.5 H+	
Coastal inundation and sea level rise	• Extreme sea levels that are expected to be reached once every 100 years (on average) at present-day MSL, will occur at least once per year or more (on average) by 2050 - 2070 and will occur earlier in areas with smaller tidal ranges. • Exposure to extreme storm tides will increase with further sea-level rise. • Vertical land movement (VLM) should be considered when understanding sea-level rise across the region. • VLM is highly influenced by the compaction of weak geological rock (e.g. peat) and larger scale tectonic processes.	SSP2-4.5: less than +0.12 m SSP3-7.0: less than +0.12 m SSP5-8.5 H+: less than +0.13 m	+0.15m to +0.30m	+0.15m to +0.32m	+0.18m to +0.43m	+0.27m to +0.55m	+0.35m to +0.66m	+0.52 to +1.41m	• Sea-level rise will have long lasting impacts and associated risks across all our coastal districts, including Coromandel, Hauraki, Waikato, Ōtorohanga and Waitomo. • Due to large scale tectonic processes, the Hauraki Plains and Thames foreshore are highly susceptible to VLM subsidence. • The Kaiaua coastline is also susceptible to VLM subsidence. • West coast communities such as Raglan, Kāwhia and Mōkau are also at risk of VLM subsidence. • The Hauraki Plains is highly exposed to the impacts of coastal inundation; however, the risk is currently mitigated through a foreshore stopbank. • Communities along the Coromandel Peninsula, Wharekawa Coastline, and low-lying West coast communities are all at risk of coastal inundation exacerbated by SLR • The extent and intensity of coastal inundation is expected to increase due to SLR, particularly in low lying estuary environment.
Coastal erosion	Coastal erosion will increase in frequency, intensity and extent because of sea-level rise and changes to extreme weather events. Exposure of coastlines to extreme storm tides will increase with further sea-level rise.								• The location and severity of coastal erosion will vary across the region depending on location, coastal process and conditions. • West Coast areas such as Port Waikato, Raglan, Mōkau and Aotea Harbour are all highly vulnerable to coastal erosion. • Additionally, all eastern coromandel communities are vulnerable to coastal erosion, eroding property, infrastructure and the natural environment, such as Whitianga and Whangamatā.
Groundwater rise and salinity	• Groundwater levels will be influenced by sea-level rise and rainfall runoff. • Changes to salinity will depend on rainfall and runoff patterns. • VLM has a significant influence on the effects of groundwater rise								• The Hauraki Plains is highly vulnerable to the impact of a rising groundwater because of both sea-level rise and more intense rainfall and ponding. • Thames is vulnerable to groundwater rise due to vertical land movement. • Increases of saltwater intrusion in aquifers within coastal areas, e.g. Hauraki Plains and Hahei.

7 Climate risks in the Waikato region

This section provides overview of climate change risks for the region. The risks were identified through a regional high-level risk identification and screening project led and funded by the Waikato Regional Council.

The aim of the high-level risk identification and screening was to create a long list of potential climate change risks, drawing on knowledge from council subject matter experts, iwi and external stakeholders. This was achieved through a combination of a desktop review of in-house information, SME and technical focus group input via workshops and surveys, and external stakeholder and iwi engagement through both surveys and workshops.

Risks were grouped within five domains, consistent with the National Climate Change Risk Assessment and further categorised by **risk focus area.** Risks were then presented according to both hazard (refer Tables 2 to 4), and specific risk element (i.e. what is being potentially affected by the hazard). **Direct** and **indirect** risks were identified separately, with indirect (cascading) risks being either:

- An upstream risk that could have a consequential impact within a particular domain, or
- A downstream consequence of a direct risk (for example, across the economic, social, cultural or environmental well-being areas).

A total of 231 **direct** risks were identified across 44 elements (e.g. terrestrial ecosystems and species, horticulture/productivity of the land, buildings, biosecurity) and 55 **indirect** risks were identified across 37 elements.

Tables in Section 7 summarise the identified risks and provides selected geographic examples. The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region. Additionally, where geographical examples have been provided, this does not mean that is the only location where that risk is present. Consequently, the geographic examples may appear incomplete for places across the region where risks are present but were not identified in this work.

Although some transition risks were provided in the survey, the project was focused on identifying the direct and indirect risks from physical climate hazards. An overview of transition risks can be found in Appendix 1 for completeness.

7.1.1 Natural environment domain

Table 5 Overview of natural environment domain direct risks.

Natural environment domain direct risks				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographical examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Coastal marine environment 	• Marine heatwaves and ocean chemistry changes • Sea-level rise and coastal inundation • Extreme weather (wind, storms, extreme rainfall) • Increased landslides and soil erosion • Increased fire weather • Increased inland flooding (fluvial and pluvial) • Higher temperature (including increased hot days) • Changes in variability and seasonality of rainfall • Dryness and drought	• Biosecurity (including pests and diseases) • Coastal ecosystems and species • Marine ecosystems, estuaries and species • Water quality • Taonga species • Wetland ecosystems and species • Contaminated land	**Coastal erosion and sea-level rise**: • Coastal erosion has potential to expose land to invasive species and destroy dune ecosystems. • Sea-level rise can inundate coastal habitats, impacting species with limited mobility and altering critical habitats. • Hard defences against sea-level rise can exacerbate coastal squeeze, leading to species loss. **Extreme weather and oceanic changes**: • Extreme weather and oceanic heatwaves can damage intertidal habitats, reduce food availability, and increase the risk of invasive species. • Ocean acidification from reduced CO_2 absorption threatens marine species and ecosystem function. **High temperatures**: • Rising temperatures and changing ocean chemistry reduce ecosystem resilience and threaten marine species. **Increased rainfall and flooding**: • Extreme rainfall can introduce pollutants and sediments into marine environments, causing algal blooms and ecosystem disruption. This is exacerbated following prolonged dry periods.	All territorial authorities with a coastline are potentially at risk from these identified coastal marine risks. 1. **Coastal erosion and habitat risks**: • Sand dunes and cliffs: Erosion is worse in the **Waikato District**, while the **Coromandel** is more stable. Sand dunes are affected across the region. • Beach access and infrastructure: Erosion impacts beach access roads and infrastructure, such as internet cables at **Ngarunui Beach**. • Specific locations: **Kāwhia, Mōkau, Port Waikato, Buffalo Beach, Wharekawa Coast, and Sunset Beach are notably affected.** 2. **Invasive species and habitat degradation**: • Foreshore habitats: At risk from invasive species like Spartina, alligator weed, and saltwater paspalum, especially in areas like the **Firth of Thames** and **Whitianga**. • Shorebird habitats: Impacted by invasive species and poor conditions, such as diseased whitebait in **west coast estuaries.** • **Mercury Bay/Islands (TCDC)**: Also affected by invasive species and habitat degradation. 3. **Estuaries and coastal wetlands**: • Estuaries: All estuaries in the Waikato and open coast beaches are at risk. The internationally recognised bird sanctuary at **Miranda (HDC)** is crucial for migrating Godwits. • Freshwater Wetlands: Loss of these wetlands impacts international bird migration and local settlements along the **Kaiaua coastline (HDC).** 4. **Marine heatwaves and ocean changes**: • **Firth of Thames:** Bleaching of sponges and other sensitive taxa in shallow waters. • Coastal Marine Area (CMA): Affected by changes in sediment plumes and heat stress, leading to mass die-offs in estuaries and shallow coastal areas. • **Kāwhia, Raglan, Aotea Harbours** along with the **Firth of Thames and Coromandel Peninsula** harbours and estuaries, are particularly vulnerable.

Natural environment domain direct risks				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographical examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
				• Estuaries: Impacts are most pronounced within estuaries, affecting the entire coastal management area.
Freshwater environment	• Changes in variability and seasonality • Dryness and drought • Extreme weather • Groundwater rise and salinity stress • Higher temperatures • Increased coastal erosion • Increased fire weather • Increased inland flooding • Increased landslide and soil erosion • Sea-level rise and coastal inundation	• Freshwater (lakes) ecosystems and species • Riverine ecosystems and species • Water quality • Wetland ecosystems and species	**Wildfires:** • Wildfires can produce ash and runoff which damage freshwater and wetland ecosystems, altering water pH and disrupting ecosystems. They can also introduce contaminants through ash and fire suppressants, decreasing dissolved oxygen and causing eutrophication. **Increased rainfall and Flooding:** • Flooding can lead to increased landslides and soil erosion, mobilising sediments and nutrients, altering estuarine salinity regimes and increasing risks of sedimentation and eutrophication. • Flooding can cause stream and topsoil erosion, impacting fish behaviour, breeding, and migration. **Variability in Rainfall:** • Extended dry periods cause low flows, stressing ecosystems, impacting native fish health and promoting invasive species. • Changes in hydrology affect migration cues for species like whitebait and tuna, reducing populations. **Drought conditions:** • Drought can cause reduced surface and groundwater levels, which can affect rivers and wetlands, leading to fish kills and avian botulism outbreaks. **Higher temperatures:** • Higher air temperatures can increase water temperatures, damaging native fish health and promoting algal blooms. • Increased temperatures can expand the range of invasive species and reduce suitable habitats for native species. **Increased flows and erosion:** • Increased flows can cause erosion along riverbanks leading to vegetation loss,	All territorial authorities are potentially at risk from the identified Freshwater environment risks. Risk to water quality due to changes in variability and seasonality of rainfall in **Firth of Thames** and **all major estuaries** in the region Risk to water quality due to dryness and drought throughout **Waipā and** recently seen at **Lake Ngā Roto (Waipā DC)** (freshwater fish and invertebrate die-off). Risk to freshwater ecosystems and species due to multiple climate hazard drivers across all lakes in the region. A few lakes identified includes: • **Lake Taupō** • **Whangamarino (Waikato DC)** • **Lake Ngā Roto (Waipā DC)** Risk to terrestrial ecosystems due to dryness and drought particularly the **Hauraki District** (Waihou and Piako Rivers). Risks to wetland ecosystems and species to multiple climate hazards across the whole region, particularly in peat lands such as the **Whangamarino and Kopuatai wetlands.** Risk to riverine ecosystems and species from Increased landslides and soil erosion in highly susceptible land instability district cross the region, particularly **West Waikato** and the **Coromandel**.

Natural environment domain direct risks				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographical examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			sedimentation, and impacts on wildlife nesting locations. • Changes in hydrology can impact fish migrations and reduce ecosystem recovery from floods. **Rising sea levels:** • Rising sea levels can, over time, impact river salinity and ecosystems, causing biodiversity loss and reduced carbon sequestration in wetlands. • Rising sea levels can impact ecosystems with hydrological connectivity between surface water and groundwater bodies. These points highlight the various impacts of wildfires, rainfall variability, drought, and temperature changes on ecosystems, water quality, and biodiversity.	
Terrestrial Environment 	• Changes in variability and seasonality • Dryness and drought • Extreme weather • Higher temperatures • Increased fire weather • Increased inland flooding • Increased landslide and soil erosion • Sea-level rise and coastal inundation	• Biodiversity • Biosecurity • Native planting/reserves • Taonga species • Terrestrial ecosystems and species • Wetland ecosystems and species	**Wildfires:** • Wildfires can damage ecosystems, alter water pH, and introduce contaminants. • Wildfires can increase disease and disrupt food chains, leading to biodiversity loss. **Increased rainfall and flooding:** • Increased rainfall / flooding can cause landslides and erosion, mobilise sediments, and lead to habitat loss **Variability in rainfall:** • Rainfall variability can cause low stream flows, stress ecosystems, and impact in-stream species health. • Rainfall variability can alter wetland water levels and degrade wetland habitats. **Drought conditions:**	All territorial authorities are potentially at risk from the identified terrestrial environment risks. Risk to biosecurity due to higher temperatures throughout the **Waipā District** and **Kaingaroa Forest (TDC).** Risk to taonga species due to increased fire weather in **Whangapoua (TCDC)** as Kauri Die Back. Risk to terrestrial ecosystems and species to increased fire weather identified throughout **Waipā District** and **Thames**. Risk to native planting/reserves from increase fire weather identified in **Maungatautari**, **Pirongia** and **Kakepuku (Waipā DC)**; all peat lakes; as well as across the region where riparian planting has taken place on private land.

Natural environment domain direct risks				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographical examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			• Drought can stress ecosystems, increase fish mortality, and promote invasive species. It can also lead to greater soil erosion. **Higher temperatures:** • Higher water temperatures can promote algal blooms and expand the range of invasive species. • Higher temperatures can cause heat stress and disrupt biological processes. **Pests and diseases:** • Warmer and wetter conditions can encourage migration of pests and diseases, impacting biodiversity and human health. These points highlight the various impacts of wildfires, rainfall variability, drought, temperature changes, and biosecurity challenges on ecosystems, water quality, and biodiversity.	Risk to increased peat fires as a result in increased fire weather identified on the **Kopuatai** and **Whangamarino wetlands.**

Table 6 Overview of Natural environment domain indirect risks.

Natural environment indirect risks
• **Climate risks** are interconnected with natural systems, leading to the reduction or loss of indigenous biodiversity. This is worsened by factors like land use, resource depletion, and pollution. • **Preventative fire safety measures**, such as felling vegetation, can negatively impact natural ecosystems. This creates a dilemma for asset owners between protecting infrastructure and preserving native flora and fauna. • **Conversion of native forests** to plantation forests, driven by carbon markets, poses a risk to native biodiversity. • **New chemicals** will be introduced into the environment due to climate change, such as pesticides to combat new pathogens. There is limited knowledge about their ecotoxicity, and tools are needed to help regulators prioritise research on the most critical chemicals. Examples include PFAS, PFOS, and polyfluorinated compounds. • **Economic impacts:** Climate impacts on terrestrial, freshwater and marine ecosystems can have cascading impacts on economic sectors (e.g. aquaculture) and human health (e.g. food gathering). These impacts, in turn, can have broader implications for community wellbeing.

7.1.2 Built environment domain

Table 7 Overview of Built domain direct risk.

Built domain direct risks[1]				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Transport 	• Dryness and drought • Extreme weather • Groundwater rise and salinity stress • Higher temperature • Increased coastal erosion • Increased inland flooding • Increased landslides and soil erosion • Sea-level rise and coastal inundation	• Active modes of transport • Airports • Rail infrastructure • Roads	**Air transport:** • **High winds** can disrupt air services, impacting accessibility and freight. • **Salinity exposure** in coastal areas can corrode airport foundations, reducing lifespan. • **High temperatures** can melt tarmac, disrupting operations. • **River and coastal flooding** can damage airports, especially coastal ones like Raglan and Thames. **Rail transport:** • **Extreme weather** can lead to treefall and debris which can disrupt services. • **High temperatures** can distort rail lines, leading to damage, disruption to services, reduced speeds and potential accidents. • **Flooding** can lead to disruption, especially in low-lying and coastal areas. **Road transport:** • **Extreme weather** can cause washouts, slips, and surface damage. This can cause road damage and closures, impacting access, especially in rural or isolated communities. • **High groundwater** can compromise road integrity, requiring maintenance. • **High temperatures and drought** can lead to melting, cracking and subsidence of roads, especially in areas of peat. • **Flooding and landslides** can lead to risk of culvert washouts and bridge scour, making roads impassable, increasing accident rates. This can	All territorial authorities are potentially at risk from the identified transport risks. **Air transport**: • Fog in **Hamilton**: Affects air services. • **Raglan** Airstrip: At risk from groundwater rise • **Thames** and **Hamilton** Airports: At risk from sea-level rise and flooding. Road Transport: • **SH25 (TCDC), SH23 (Waikato DC)** and **SH3 (Waitomo DC) SH2 through Karangahake Gorge (HDC)**: Vulnerable to extreme weather, flooding and land instability. • Low-Lying Areas: **Raglan** waterfront, **Thames** coast highway, and others at risk from sea-level rise and flooding. • **Coromandel Peninsula (TCDC)**: Roads susceptible to flooding (coastal and inland) and land instability and impacts occurring now and expected to be exacerbated with climate change. • Roads throughout the **Hauraki** Districts susceptible to inland flooding from rainfall and the Waihou and Piako Rivers, as well as subsidence and cracking from increased temperature and drought. • Roads across the **Waikato** District at risk from flooding (SH2 – **Mangatāwhiri** River), (SH1 at **Rangiriri** from Waikato River) and rural roads surrounding the Waipā River, including in the **Waipā, Ōtorohanga** and **Waitomo** Districts • **SH3 (Waitomo DC)** vulnerable to flooding from the **Awakino river**, both from inland flooding but also influenced by sea-level rise. Additionally, **SH37 (Waitomo DC)** at risk to flooding to Waitomo village (tourist attraction). • **Port Waikato, Manu Bay Car Park (Waikato DC), East Coast Road (TCDC)**: At risk from sea-level rise and coastal erosion. • **Marokopa, Awakino, Coromandel Peninsula**: Vulnerable to flooding and slips.

[1] The Waikato Lifelines Utility Group has undertaken a Waikato Infrastructure Resilience Project; an assessment of Waikato's critical infrastructure and its vulnerability to hazards. This project has been utilised by SMEs to understand the risks climate change poses on Waikato's critical infrastructure to inform this project. However, due to sensitivity and security reason of lifeline assets, this an internal piece of work and cannot be made public, particularly around locations of assets at risk.

Built domain direct risks[1]				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			impact freight movements across the region resulting in supply chain issues and secondary impacts on the economy and human domain. This is exacerbated by capacity issues in existing culvert infrastructure. • **Sea-level rise and coastal inundation** can damage coastal roads, cutting off communities. • **Drought related peat shrinkage** can cause subsidence, affecting roads and rail. Additionally, peat fires near roads can lead to thick smoke disrupting transport.	• **SH1** near **Tūrangi** suspectable from flooding from the **Tauranga-Taupō** an **Tongariro rivers** Various locations across the Waikato region are mapped in the Waikato Lifelines Resilience Study for resilience against natural hazards.
Energy and telecommunications 	• Dryness and drought • Extreme weather • Higher temperature • Increased fire weather • Increased coastal erosion • Increased inland flooding • Increased landslides and soil erosion • Sea-level rise and coastal inundation	• Data infrastructure • Energy • Telecommunication	**Hydropower schemes:** • **Drought** can lead to reduced inflow into hydro schemes affecting water availability and energy generation. • **Drought** can lead to low water levels in Lake Taupō and Waikato River, impacting on energy utilities and the national grid. • **Increased rainfall** will result in increased inflows into the hydro schemes and higher flows throughout the hydro system. This will increase the reliance on the Waikato River High Flow Management Plan to manage river/lakes levels within consenting conditions and reduce downstream flooding. **Electricity networks:** • **Extreme weather** (high winds, snow and storms) can damage above-ground infrastructure, causing widespread outages, especially in isolated communities. • **High temperatures** can increase conductor sag, fire risk, and reduce load ratings. Also, there is potential for increased load to power air conditioning and irrigation. • **Wildfires** can damage assets and increase fire risk from arcing/sagging lines. • **Flooding** can damage infrastructure, decrease ground stability, and expose assets. • **Landslides** can cause damage to infrastructure across the region, particularly those network elements on steeper terrain.	All territorial authorities are potentially at risk from the identified energy and telecommunication risks. **Hydropower**: • **Waikato Hydro System**: **Lake Taupō**, **Waikato River** (from **Taupō** to **Karāpiro**) and **Huntly Power** Station. • Risk of reduced inflow affecting water availability and energy generation and low water levels across the hydro scheme impact energy utilities and the national grid. • Risk of hydro scheme becoming overwhelmed due to increased rainfall resulting in the Waikato High Flow Management Plan being initiated more frequently and increased CDEM response. Coastal inundation: **Port Waikato, Wharekawa Coastline, Thames, SH25 (TCDC), Raglan, Awakino, Marakopa, Kāwhia** Wind farms near **Raglan** **Ngarunui beach (Waikato DC)** at risk from coastal erosion exposing telecommunication international cable. Risk to energy infrastructure in **Te Awamutu** from flooding. Rangitāiki Plains experienced a large snowstorm in 2016 impacting infrastructure, isolating the community.

Built domain direct risks[1]				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			• **Coastal inundation** can damage infrastructure, leading to outages. **Telecommunications:** • **Severe weather** (high winds and storms) can damage infrastructure, requiring repair leading to loss of power source for communities. • **Fire weather** can cause direct damage. • **Flooding and coastal inundation** can cause direct damage.	
Three-waters & flood protection infrastructure 	• Changes in variability and seasonality of rainfall • Dryness and drought • Extreme weather • Groundwater rise and salinity stress • Higher temperature • Increased coastal erosion • Increased fire weather • Increased inland flooding • Sea-level rise and coastal inundation	• Coastal defences and coastal flood protection • Flood defences/stopbanks • Stormwater infrastructure • Waste water infrastructure • Water availability (groundwater and surface water) • Water quality • Water supply infrastructure •	**Coastal and flood protection:** • **Coastal erosion and landslides** can damage flood protection infrastructure, including dunes and buffering systems, increasing storm impact. Reduced effectiveness of coastal protection structures due to sea-level rise. • **Variability in rainfall** can affect performance of flood protection and stopbank infrastructure through alternating dry and wet periods, compromising integrity during floods. Increased flood risk will require redesign and reconstruction, leading to higher costs. **Water supply and treatment:** • **Flooding and heavy rainfall** can damage in-stream infrastructure, storage dams, and water supply systems. Landslides can contaminate water supplies and increase sediment, putting additional demand on water treatment. **Stormwater and wastewater networks:** • **Extreme rainfall and flooding** can damage / overwhelm stormwater networks. This can lead to property flooding, causing damage, and increased insurance costs. Groundwater rise can also reduce capacity within 'leaky' stormwater and wastewater systems and increases maintenance costs. • **Extreme rainfall and flooding** can impact / damage wastewater networks. Flooding and high groundwater can increase inflow and infiltration, leading to overflows and reduced treatment effectiveness. In coastal areas, salinity can lead to damage to networks and treatment effectiveness.	All territorial authorities are potentially at risk from the identified water infrastructure risks. • **Hauraki/Firth of Thames Coastline**: Coastal erosion inundation and flooding risks for flood protection and coastal defences, managed by WRC and HDC • **Thames, Coromandel, Raglan**: Stormwater issues due to low lying environment and coastal inundation, as well as groundwater rise. • Urban centres across the **whole region** with three waters infrastructure is at risk from multiple hazards • Wastewater treatment plants identified at risk from multiple hazards include, **Matamata, Morrinsville, Te Aroha, Hauraki, Hamilton City** • Stormwater flooding risks identified across multiple main centres in the region from rainfall and rivers including **Morrinsville, Matamata, Te Aroha** • **Kaiaua and Whakatiwai (HDC)** has significant stormwater risks to both sea-level rise and inland fooding • **Paeroa** has a high stormwater risk, especially during high river levels and inland flooding events.

Built domain direct risks[1]				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			• **Coastal inundation and rising groundwater** can impact/damage septic tanks, causing contamination of surrounding water and land, impacting the environment and communities. **General infrastructure:** • **Higher temperatures** can affect the performance of biological wastewater treatment systems. • **Drought** can lead to dry ground conditions which could damage/crack buried infrastructure.	
Public Infrastructure and services 	• Increased inland flooding • Sea-level rise and coastal inundation • Increased coastal erosion • Higher temperature • Extreme weather	• Buildings • Community facilities • Landfills • Parks and reserves • Wharf and marinas	**Public buildings and facilities**: • **Flooding** can impact schools, hospitals (e.g. Thames Hospital), social buildings, prisons and council buildings in low-lying areas, leading to significant financial implications for councils and government. **Parks and reserves**: • **Flooding, coastal inundation and coastal erosion** can impact parks and reserves, especially DOC reserves used for tourism and recreation. **Wharfs and marinas**: • **Coastal erosion and sea-level rise** can lead to infrastructure damage / disruption, reduced maritime safety and increased operational costs. **Community facilities**: • **Coastal inundation** can impact schools, community buildings, public toilets, and other facilities in coastal areas. • **Higher temperatures** can potentially damage community facilities, and cause cracking of paving and degrading of playground materials. • **Flooding and extreme weather** can cause loss or damage to cultural and heritage buildings such as marae and historic buildings. **Landfills and hazardous sites:** • **High temperatures** can cause increased odour and fire risk near landfills	All territorial authorities are potentially at risk from the identified public infrastructure and services risks. Risk to parks and reserves and community facilities due to coastal erosion identified at **Sunset Beach (Port Waikato),** particularly the surf lifesaving club, ramp and carpark, as well as **Ngarunui Beach (Waikato DC)** where the surf lifesaving club **as well as Whiritoa Surf Club.** Risk to parks and reserves due to increase inland flooding across the whole region as generally these are designed as green spaces to accommodate flooding. Risk to cultural heritage sites due to extreme weather identified **Waharoa Park (HDC)** Wet Pond. **Thames Hospital**: At risk due to its coastal location. **Marine Precinct at Kopu Thames**: Vulnerable to coastal hazards. **Waikeria (Waipā DC)** and **Tongariro Prisons** are both susceptible to isolation due to flooding. **Karangahake Gorge** walkways at risk form land instability and increased river flooding.

Built domain direct risks[1]				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			• **Fire weather** increasing risk of landfill fires • **Flooding and coastal inundation / erosion** can cause leachate and waste exposure at landfills, contaminating waterways and affecting water quality, coastal ecosystems and aquatic ecology. Similarly flooding can mobilise contaminants at contaminated sites. **Green infrastructure and plant stress:** • **Increased variability in climate** can stress plants, compromising green infrastructure like flood defences, wetlands, and stormwater treatments. • **Higher temperatures, changing rainfall patterns, and drought** can reduce plant cover and affect the performance of these systems.	
Private property 	• Extreme weather • Groundwater rise and salinity stress • Increased coastal erosion • Increased fire weather • Increased inland flooding • Increased landslides and soil erosion • Sea-level rise and coastal inundation • Higher temperatures	• Buildings	• **High winds and storms** can cause damage to buildings and infrastructure. • **High groundwater and salinity stress** can damage building foundations, increase dampness, and cause health impacts. Increased risk of liquefaction during earthquakes. • **Coastal erosion** can cause loss of dunes and cliffs, exposing coastal properties to damage or loss, potentially making some coastal properties uninhabitable. • **Increased temperatures** can lead to higher likelihood of wildfires damaging properties. • **Flooding** can impact commercial and residential buildings in low-lying areas, causing significant potential for damage and financial implications. • **Landslides** can impact buildings near escarpments or riverbanks. • **Sea-level rise and coastal inundation** can impact residential properties, leading to potential	All territorial authorities are potentially at risk from the identified private infrastructure and services risks. **Coastal hazards:** Various coastal parts of the Waikato region, including: • **Mōkau**, **Whitianga**, **Kaiaua, Port Waikato, Raglan** (**Ngarunui Beach), and Sunset Beach in Port Waikato** all exposed to coastal erosion where buildings are at risk. • Specific risks include coastal erosion, flooding, and potential sinking of areas like **Raglan** and **Kāwhia**. • **Marine Precinct at Kopu**: Buildings vulnerable to coastal hazards. • **Moanataiari (Thames north)**: Low-lying residential area protected by a sea wall, which was overtopped during the January 2018 storm. Inland flooding: **Huntly, Kopu, Morrinsville, Te Aroha, Te Kowhai, Paeroa, Mercer, Ngātea, Te Kūiti, Pio Pio, Ōtorohanga, Te Awamutu, Reporoa, Tūrangi and the shores of Lake Taupō** are all communities where buildings are exposed to inland river flooding. Additionally, there are smaller communities across the whole region that are exposed. Additionally, private buildings are also at risk from urban stormwater flooding across all major town centres.

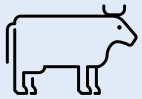
Built domain direct risks[1]				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			relocation or retreat and increased pressure on inland areas. • **Heatwaves** can lead to soil shrinkage, subsidence, concrete deterioration, and internal overheating of buildings. **Other:** • Existing early warning systems may not be sufficient.	Landslides: **Coromandel Peninsula** communities particularly along the western side of the Coromandel, as well as **Port Waikato**, **Raglan and Kāwhia** communities along the **southern shores of Lake Taupō** (Waihi landslide) and **Waharau (HDC)** communities are at risk of landslides impacting buildings. Additionally, villages in the **Karangahake Gorge**, such as **Mackaytown** (HDC) are vulnerable to isolation from land instability.

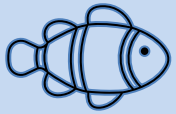
Table 8 Overview of Built domain indirect risks.

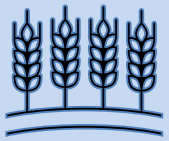
Built domain indirect risks
Increased generation of waste and contamination: o Extreme weather events can damage trees, bridges, buildings, and facilities, leading to significant recovery effort and costs. Also, can create large volumes of disaster waste, posing public health risks and significant clean-up costs. **Road damage and disruption:** o Increased climate variability can lead to loss, damage and disruption of roads, leading to higher operation and maintenance costs over time. o Acute climate events can lead put pressure on emergency management services. Communities can become isolated and there could be increased inability of emergency services to access these areas due to safety concerns **Water availability and quality:** o Over-irrigation during higher temperatures and drought can further reduce groundwater and surface water availability and quality. o Water quality can be impacted through the combination of reduced flows, higher temperatures, increased sedimentation, nutrient leaching, and agricultural runoff. **Other**: • Stopbanks may block ability for ecosystems to move inland due in response to sea-level rise. • Managing outdated building standards and codes of practice will be ongoing. Also, land use policy can allow development in areas that may be exposed to climate risk. • Damaged infrastructure may make it harder to access and manage storm-affected areas, impacting other activities like pest control. • Increased acute climate events can lead to increased insurance premiums or insurance retreat.

7.1.3 Economic domain

Table 9 Overview of economic domain direct risks.

Economic domain direct risks			
Sub-risk focus area	**Key climate hazards**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Agriculture/livestock 	• Changes in variability and seasonality of rainfall • Dryness and drought • Extreme weather • Groundwater rise and salinity stress • Higher temperature • Increased coastal erosion • Increased fire weather • Increased inland flooding • Increased landslide and soil erosion • Sea-level rise and coastal inundation	• **Changing rainfall** patterns can alter pasture growth and livestock productivity. Excessive rain can increase water tables, making land too wet for dairy farming. • **Drought** conditions can lead to increased fertiliser use to boost production after droughts or recover from flooding. • **Drought** reduces water availability for feed, stock water, and irrigation, impacting agricultural productivity. • **Drought and warmer temperatures** can lead to increased pests and diseases, reducing productive land and impacting biodiversity. Can also impact pastures and animal health. • **Extreme rain and flooding** can cause prolonged ponding, pasture damage, and nutrient loss. Sedimentation in waterways can impact agricultural activities and increase water treatment costs. Additionally, increased flooding can lead to excess water within irrigation storage ponds, which could result in dam failure, bank failure, overtopping and consequential flooding downstream and negative environmental impacts. • **Extreme rainfall** can lead to high water turbidity. This can affect milk processing during peak seasons, leading to potential disposal of milk. • **High temperatures can cause** heat stress in livestock, requiring more trees or shelters on farms. • **Rising groundwater** can compromise dairy farm effluent systems and affect pasture species due to changes in salinity levels. Shallow bores used for stock water may become unusable, and pumps used during floods may become insufficient. • **Wildfires** can destroy crops and landscapes, affecting local communities and economies. • **Coastal inundation** can cause loss of pasture, reduced productivity, and nutrient leaching. Saline intrusion from rising sea levels can affect agricultural land. • **Coastal erosion** can lead to loss of productive land and increased risk to livestock near erosion hotspots. • **Erosion and landslips** caused by extreme rainfall, can lead to nutrient loss and reduced soil fertility.	All territorial authorities are potentially at risk from the identified agriculture/livestock risks. Due to agriculture and livestock being a primary industry across the **whole of the Waikato region**, the risk is widespread, and impacts will be driven by the presence of the hazard or climate driver. However, a few specific locations identified in this assessment include: **Hauraki Plains and Waikato District:** Risk of drought and water availability, groundwater rise and salinity stress, heat stress, coastal inundation and inland river flooding. **Waipā**: increased risk from fire weather alongside drought and dryness, heat stress, inland river flooding. **Reporoa (RLDC)**: risk to inland river flooding. **Western Waikato (Marokopa**): Risk of increased landslide and soil erosion.

Economic domain direct risks			
Sub-risk focus area	**Key climate hazards**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Aquaculture and fisheries 	• Extreme weather • Increased Inland flooding • Increased landslides and soil erosion • Marine heatwaves and ocean chemistry changes • Sea-level rise and coastal inundation	• **Extreme weather** can lead to runoff from built environments impacting water quality in harbours, affecting fish quality and yield. This is exacerbated by increased nitrogen and phosphorus leaching - impacting freshwater species and algal growth. • **Increased extreme rainfall** can cause Upstream catchment erosion impacting seafood, particularly shellfish. • **Higher ocean temperatures** and increased CO_2 levels can reduce dissolved oxygen, and increased risk of algal blooms and deoxygenation of shallow coastal waters - impacting aquaculture viability. • **Acidification of oceans** reduces the ability of shellfish to secrete shells • The above could lead to potential collapse of food webs and coastal productivity, affecting fisheries and aquaculture, as well as loss of species that are tribal delicacies (kīnaki). • **Coastal inundation and sea level rise** can damage marine businesses and infrastructure in coastal areas. • **Inland flooding** transports silt and nutrients to coastal environments, impacting ecosystems and aquaculture	All territorial authorities with a coastline are potentially at risk from these identified aquaculture and fisheries risks. **Firth of Thames:** Aquaculture risks from all key hazard identified, particularly the mussel farms in the firth. In term this also stretches up into the Hauraki Gulf, impacting the whole of the **Coromandel** and **Hauraki** Coastline. **West Coast** environments identified as being at risk from marine heatwaves and ocean chemistry changes. Estuaries systems across the **whole region** are also vulnerable to the impacts from marine heatwaves and ocean chemistry changes as well as increased sediment load from inland flooding and land instability and is erosion.
Forestry 	• Changes in variability and seasonality of rainfall • Dryness and drought • Extreme weather • Groundwater rise and salinity stress • Higher temperature • Increase coastal erosion • Increased fire weather • Increased inland flooding • Increased landslides and soil erosion	• **Reduced rainfall and drought** can affect growth of radiata pine, increase tree stress and susceptibility to vector-borne diseases, lead to productivity loss and economic impact and raise fire risk. • **Extreme weather and wind** can damage infrastructure and crops, create forestry slash, impacting downstream environments, increase rainfall-induced landslips and sediment inundation. • **Saline intrusion** can cause salinity stress and higher groundwater tables. This can cause root disease and asphyxiation. • **Higher temperature**s can shorten planting windows • **Wildfire risk** is projected to increase which can damage crops and limit forest access. This has potential for financial impact on council-owned forestry and nearby rural areas. • **Flooding** can damage infrastructure and forestry operations and is exacerbated by landslides and forestry slash buildup. These factors collectively pose significant challenges to the Waikato's forestry sector, affecting productivity, economic stability and environmental health.	All Territorial authorities are potentially at risk from these identified Forestry risks. Key forestry locations identified across the region that are at risk include: • **Kaingaroa Forest** and **Taupō** Forests • Forestry in the **Coromandel** • **Waitetuna Valley / Otonga Valley** forests in the **Waikato** District • Forests along the **West Coast** of the region • **South Waikato** also has a large forestry industry.

Economic domain direct risks			
Sub-risk focus area	**Key climate hazards**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Horticulture/productivity of the land 	• Changes in variability and seasonality of rainfall • Decreased frost • Dryness and drought • Extreme weather • Groundwater rise and salinity stress • Higher temperature • Increase coastal erosion • Increased fire weather • Increased hail frequency • Increased inland flooding • Increased landslides and soil erosion	• **Changing rainfall patterns** can alter growing times and conditions, making land productivity unpredictable. Also, can decrease pasture and plant growth, reducing soil carbon sequestration. • **Reduced frost days** can Impact fruit budding and native species germination, affecting yields and ecosystem functions. • **Drought and higher temperatures** can increase pest species due to insufficient frost to control their numbers. This expands home range and growing season for pests like alligator weed. • **Drought** can damage or kill trees and vines, especially shallow-rooted crops, cause soil erosion and loss of biodiversity, limit water availability, affecting production and leading to economic impacts. • **Higher temperatures** present specific issues for maize including reduced yield and pollination problems. • **Extreme weather** can damage crops like kiwifruit, avocado and grain, requiring improved wind breaks and shelter belts. Also, can cause nutrient loss from soils and affects pollination. • **High groundwater and saline intrusion** can reduce fertility of agricultural fields, particularly affecting kiwifruit and avocado farms. Higher groundwater tables risk root disease and asphyxiation. • **Higher temperatures** can push fruit crops out of optimal temperature bands, advancing flowering and increasing vulnerability to spring frosts. Also, can spread pests and diseases, reducing production. Higher temperatures increase demand for irrigation and competition for water resources and can affect pasture longevity, milk production, and animal welfare. • **Coastal erosion** can cause loss of coastal or peri-coastal orchards and productive land. • **Wildfire** can damage fruit crops and infrastructure, leading to economic losses. • **Hail event**s can cause crop loss and damage to produce. • **Flooding** can inundate land, reducing productivity and yield. Also, can cause nutrient leaching and waterlogging of ground. • **Landslides and erosion** can result in loss of fertile soils, reducing horticultural productivity and economic impact, especially on steep land. These factors highlight the significant challenges posed by climate change to New Zealand's agriculture and horticulture sectors, impacting productivity, economic stability, and environmental health.	All territorial authorities are potentially at risk from these identified horticultural/productivity land risks. The **Waikato District** has a very highly productive soils surrounding **Pukekohe,** which is a national key fresh produce growing location. **North Waikato** is highly vulnerable to drought and dryness. Additionally, the **Waikato District** is at risk from inland flooding and groundwater rise. **Hauraki**, **Matamata-Piako** and **Waipā** Districts are all highly productive land for dairying and at risk from dryness and drought, as well as inland river flooding. The **Hauraki District** is also prone to coastal inundation and groundwater rise that will highly impact the productivity of the soils. Home gardens **across the region**, can experience impacts from several climate drivers identified.

Economic domain direct risks			
Sub-risk focus area	**Key climate hazards**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Tourism 	• Changes in variability and seasonality of rainfall • Dryness and drought • Groundwater rise and salinity stress • Increase coastal erosion • Increased fire weather • Increased inland flooding • Marine heatwaves and ocean chemistry changes • Sea-level rise and coastal inundation	• **Drought** and lack of water availability can impact businesses like rafting and adventure tourism. Tourism businesses may become inoperable due to damage, safety concerns, and decline in natural beauty. • **Drought, fire, groundwater rise,and salinity** can degrade natural landscapes, affecting tourism. • **Fires** can destroy landscape features significant to tourism, leading to business failure, reduced income, and economic impacts. Loss of amenity values reduces tourist numbers over prolonged periods. • **Marine changes** and changing coastal environments and currents can affect recreational fishing operators.	All territorial authorities are potentially at risk from these identified tourism risks. Tourism risks in the following locations have been identified: • **Coromandel** – **Cathedral Cove, Mercury** and **Alderman** Islands – particularly around water-based activities • **Hamilton** Gardens • **Lake Taupō** and water-based activities • **First of Thames** and **Miranda** RAMSAR site • Coastal campsites across the region • **Raglan** and **Waihi** – surf locations • **Tongariro National Park** – reduction in snow activities

Table 10 Overview of Economic domain indirect risks.

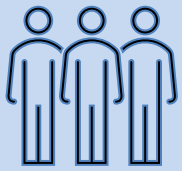
Economic domain indirect risks
Insurance and economic barriers: • Climate change may increase insurance premiums or lead to loss of insurance, especially in exposed areas like coasts and floodplains. Insurance is already costly for cultural sites like marae, which are crucial as evacuation centres during disasters. **Supply chains and cost of living:** • Climate risks can disrupt supply chains, increase insurance costs, and necessitate repairs and adaptation measures, raising the cost of living. • Extreme weather can increase transportation costs, power usage for cooling, and housing costs due to new regulations. • Water supply issues may increase need for alternative water sources, particularly in rural areas**.** **Job losses and economic activity:** • Electricity outages can disrupt businesses and communities. • Climate change can reduce productivity in agriculture, horticulture, fisheries, aquaculture and tourism, leading to job losses and economic decline. Ultimately this could lead to migration from coastal areas. • Extreme weather can damage farm assets and livestock, impacting the agricultural sector. • Contaminated reservoirs may increase need for alternative water supplies. • Industry growth may be limited by water supply constraints. **Agricultural and environmental impacts:** • Warmer, wetter conditions can increase pests, weeds, and diseases in crops, leading to economic losses and reliance on pesticides. • Soil carbon sequestration: Decreased pasture and plant growth reduce the soil's ability to sequester carbon.

Economic domain indirect risks

7.1.4 Human domain

Table 11 Overview of human domain direct risks.

Human domain direct risks				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Iwi/te ao Māori 	• Dryness and drought • Extreme weather • Groundwater rise and salinity stress • Increase coastal erosion • Increased fire weather • Increased inland flooding • Increased landslide and soil erosion • Sea-level rise and coastal inundation	• Cultural heritage sites • Māori Land • Wāhi tapu sites • Buildings	**Flooding risks**: • **Flooding** can impact Marae buildings, especially in low-lying areas, near lakes, and rivers. • **Flooding** can impact access to isolated communities as well as emergency services disruption. **Sea-level rise and coastal inundation**: • Damages property and infrastructure, affecting marae. • Loss of access and use of marae as cultural centres. • Loss of traditional connections, practices, and ability to hold events like tangihanga. • Financial strain on emergency responses and adaptation efforts. • Adverse impacts on community well-being and traditional hospitality (manaakitanga). **Coastal erosion**: • Increased risk to marae, with similar implications as coastal inundation. **Extreme rainfall**: • High river flows can erode banks, causing land loss and risks to marae and culturally significant sites. • Similar implications as coastal inundation. **Rising groundwater**: • Potential impact on low-lying urupā and cemetery sites.	All territorial authorities are potentially at risk from these identified iwi/te ao Māori risks. Cultural sites and marae identified in this study include: • Marae from **Orakei Korako** to **Port Waikato**. • Marae on the bank of the upper **Waikato River**. • **Wharekawa marae** (North of **Whakatīwai**). • **Waitomo** and **Waikato Districts** (Tōtara urupā). • **Kāwhia** (landing site of Tainui canoe), Kāwhia urupā. • **Wharekawa Coast** (**Whakatiwai**). • Tattooed Rock in **Manu Bay**. • All urupā and mahinga kai areas within projected sea inundation areas. • **Marokopa, Mōkau, Maketu**. • **Kāwhia harbour** access from Maketu Marae boat ramp. • **Port Waikato** (several Marae have moved uphill or inland). • **Coromandel Peninsula**, especially remote communities. • **Waharoa** Park Wet Pond.

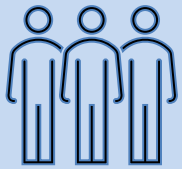
Human domain direct risks				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			• Risk to cultural heritage sites due to increased coastal erosion, fire weather, flooding, landslides, and soil erosion. **Drought**: • Significant impact on awa (rivers) tied to cultural heritage. • Deterioration of water quality affects cultural well-being. • Impact on traditional kai growing and gathering locations. **Increased landslides and soil erosion**: • Impacts Māori land used for farming and food production. • Long-term negative effects on iwi culture and land usability. • High rates of erosion on hilly-to-mountainous Māori land, exacerbated by extreme rainfall events. **Treaty obligations**: • Risk of breach by the Crown for failing to protect Māori from climate change impacts. • Implications for co-governance and the Takutai Moana Act.	
Social and Community well-being 	• Higher temperatures • Increased fire weather • Increased inland flooding • Extreme weather • Changes in variability and seasonality of rainfall	• Community health	**Higher temperatures**: • Impact health, especially for vulnerable groups (kaumatua, elderly, babies). • Increase heat-related illnesses (dehydration, heat stroke, sunburn, respiratory conditions). • Lead to more accidents from water activities and increased violence. • Extend pollen production, affecting allergy sufferers. • Cause food and waste purification, impacting community health. • Overload HVAC systems in hospitals, creating unacceptable conditions. • Make outdoor activities less comfortable or dangerous, affecting health and well-being. • Potentially cause population relocation due to discomfort and heat. • Reduce economic activity due to health impacts.	All territorial authorities are potentially at risk from these identified social and community well-being risks. **Thames** Hospital – risk of increased temperature and being cut off due to increased inland flooding and coastal inundation. Is also at risk of land instability issues due to proximity to steep terrain. **Waikato Hospital** (**Hamilton**) – risk of increased temperature **All urban areas across the region** – at risk from temperature rise, in particular **Hamilton City**

Human domain direct risks				
Risk focus area	**Key climate hazards**	**Elements**	**Risk overview**	**Geographic examples** *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
			• Affect physical health during traditional ceremonies (e.g., tangihanga). **Fire Weather**: • Direct risk to life, including injury, death, and respiratory conditions from ash. • Long-term health impacts from poor air quality. • Severe issues for isolated communities relying on single roads (e.g., Coromandel). **Increased rainfall and flooding**: • Increase drowning, injury, waterborne diseases, and community health decline from contaminants. • Cause property loss, livelihood loss, homelessness, stress, and reduced access to care. • Most common hazard in NZ with significant health impacts. **Extreme events**: • Reduce access to healthcare and emergency services. • Risk to critical facilities (e.g., Thames Hospital, Waikato Hospital). • Thunderstorm asthma events causing severe asthma-like symptoms. • Short and long-term mental health consequences (anxiety over future events). **Seasonal rain patterns**: • Impact seasonal pollen release from pest plants, affecting human health.	

Table 12 Overview of Human domain indirect risks.

Risk focus area	Direct risks (refer previous domain summaries)	Indirect risks	Geographic examples *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Iwi/te ao Māori	• Risks to Māori land, marae, access, cultural	**Treaty obligations**:	All territorial authorities are potentially at risk from these identified iwi/te ao Māori risks.

Risk focus area	Direct risks (refer previous domain summaries)	Indirect risks	Geographic examples *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
	sites (eg urupa), due to acute climate hazards such as flooding and extreme weather, and chronic climate hazards such as ongoing sea level risk and groundwater rise. • Risk to terrestrial, marine and freshwater ecosystems due to acute and chronic climate hazards. These in turn affect the ability to gather mahinga kai. • Risks to primary sector activities on land and in the marine environment ecosystems due to acute and chronic climate hazards.	• Risk of breach by the Crown for failing to protect Māori from climate change impacts. • Implications for co-governance and the Takutai Moana Act. **Cultural identity and taonga**: • Loss of traditional connections, practices, and ability to hold events like tangihanga. Climate change threatens the connection of tangata whenua to taonga, which supports Māori livelihood and identity. • Loss of water sovereignty due to impacts on water availability and quality. **Kotahitanga (unity and community)**: • Climate change can disrupt community cohesion, affecting kotahitanga. • Loss of taonga species central to Māori identity can lead to loss of knowledge and tikanga, impacting future generations. • Fragmentation and isolation within iwi may occur if cultural sites become inaccessible. **Manaakitanga (hospitality)**: • Increased climate stressors may hinder the ability of Māori to express manaakitanga to visitors at marae. **Physical and mental health**: • Climate change is likely to significantly impact Māori physical and mental health. **Traditional knowledge and practices**: • Traditional signs (tohu) used for environmental forecasting are becoming less reliable. • Loss of taonga species can lead to loss of knowledge and tikanga. • Coastal inundation and sea-level rise may force iwi to relocate, resulting in loss of stories and learnings. • Impacts on traditional mahinga kai, transmission of mātauranga, access to marae, and water sovereignty issues. • Climate anxiety and challenges in continuing traditional practices. **Mahinga kai and kaimoana**: • Reduced availability of traditional food sources due to species migration and algal blooms. • Decline in coastal species populations and increased closure of shellfish harvesting. • Ecosystem impacts affecting recreational and cultural activities.	Cultural sites and marae identified in this study include: • Marae from **Orakei Korako** to **Port Waikato**. • Marae on the bank of the upper **Waikato River**. • **Wharekawa marae** (North of **Whakatīwai**). • **Waitomo** and **Waikato Districts** (Tōtara urupā). • **Kāwhia** (landing site of Tainui canoe), Kāwhia urupā. • **Wharekawa Coast** (**Whakatiwai**). • Tattooed Rock in **Manu Bay**. • All urupā and mahinga kai areas within projected sea inundation areas. • **Marokopa, Mōkau, Maketu**. • **Kāwhia harbour** access from Maketu Marae boat ramp. • **Port Waikato** (several Marae have moved uphill or inland). • **Coromandel Peninsula**, especially remote communities. • **Waharoa** Park Wet Pond.

Risk focus area	Direct risks (refer previous domain summaries)	Indirect risks	Geographic examples *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
Social and Community well-being 	**Higher temperatures**: • Higher temperatures can impact health, especially for vulnerable groups (kaumatua, elderly, babies); lead to increased heat-related illnesses (dehydration, heat stroke, sunburn, respiratory conditions); lead to more accidents from water activities and increased anti-social behaviour. • Climate changes could extend pollen production, affecting allergy sufferers. • Fire weather could cause direct risk to life, including injury, death, and respiratory conditions from ash; impact long-term health impacts from poor air quality. • Increased rainfall and flooding could cause drowning, injury, waterborne diseases, and community health decline from contaminants, cause property loss, livelihood loss, homelessness, stress, and reduced access to care. • Climate events could impact critical infrastructure (e.g.	**Environmental and health impacts**: • Climate change will increase temperatures, flooding, sea-level rise, and deteriorate water quality, leading to various health impacts (communicable and non-communicable) such as infections, waterborne diseases, and psycho-social stressors. • Extreme weather can damage crops and contaminate water, leading to unhealthy food consumption and additional pressure on health services. **Exacerbation of inequities**: • Climate change will likely worsen existing social inequities and create new ones, impacting health, economic stability, and community cohesion. • Vulnerable groups may increasingly be forced to live in hazard-exposed areas further exposing them to climate impacts. **Regional capacity and climate migration**: • Climate migration may strain regional infrastructure, housing, healthcare, and social services. • Increased demand for resources and migration inland due to coastal hazards will put additional pressure on smaller inland communities and tourism resources. **Social cohesion and community well-being**: • Climate change hazards can lead to community displacement and managed retreat, causing economic issues, infrastructure pressure, and loss of social cohesion. • Displacement can have significant impacts on Māori connected to the land, exacerbating inequalities. • Relocation stress can adversely affect individuals, leading to fragmented communities and increased pressure on urban areas like Hamilton. **Employment and livelihoods**: • Climate change may impact employment, particularly for small businesses and land-based industries, affecting economic diversity and mental health. • Māori businesses, often land-based, will face significant risks impacting social and cultural success. **Drought and water shortages**: • Drought can lead to water shortages, dehydration, hygiene issues, infectious diseases and nutritional deficiencies. • Increased suicide rates among farmers during droughts have been observed globally. • Airborne dust can compromise air quality, and water shortages can undermine small communities and marae. **Groundwater rise and health**:	All territorial authorities are potentially at risk from these identified social and community well-being risks. **Thames** Hospital – risk of increased temperature and being cut off due to increased inland flooding and coastal inundation. Is also at risk of land instability issues due to proximity to steep terrain. **Waikato Hospital** (**Hamilton**) – risk of increased temperature **All urban areas across the region** – at risk from temperature rise, in particular **Hamilton City**

Risk focus area	Direct risks (refer previous domain summaries)	Indirect risks	Geographic examples *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
	roads, 3-waters, power), community infrastructure (e.g. parks, community centres) and facilities (e.g., Thames Hospital, Waikato Hospital). • Risks to primary sector activities on land and in the marine environment ecosystems due to acute and chronic climate hazards.	• Groundwater rise from sea-level rise can cause dampness around houses, leading to health issues like rheumatic fever, school sores, and asthma. • Increased mosquito presence can lead to more vector-borne diseases. **Coastal**: • Coastal erosion and poor water quality from runoff will affect coastal amenities. • Public access to beaches may be reduced, and coastal parks and reserves may face temporary or permanent inundation. **Food security risks:** • Climate change impacts on agriculture, horticulture, fisheries, biodiversity, and supply chains threaten food security for humans and livestock. • Increased demand for commercial food supply systems, higher food costs, and reliance on overseas exports could lead to reduced nutrition and social cohesion issues like stockpiling. **Job security risks:** • Managing climate change effects can increase costs for farmers, impacting their ability to maintain livestock and feed supplies during droughts. • This can lead to reduced family income, long-term economic losses, and potentially selling farms and losing livelihoods. • Reduced primary produce affects processing efficiency and viability, with negative impacts on employment and the regional economy. **Amenity and recreation:** • Climate change can degrade regional amenities through flooding, coastal erosion, loss of indigenous ecosystems, and reduced water quality, leading to a loss of recreational areas and connectedness to nature. • Extreme weather events pose risks to economic activities and events, damage and close community facilities, impacting social well-being. • Green spaces and biodiversity may be damaged or rendered unusable, negatively impacting community well-being. Parks and native species are crucial for health, well-being, and culture, especially in Hamilton. **Council and government challenges:** • Increased climate events can limit councils' ability to support communities and deliver services. • Acute climate events (emergencies) could lead to large-scale service loss and legal liability for councils.	

Risk focus area	Direct risks (refer previous domain summaries)	Indirect risks	Geographic examples *The geographic examples are limited to specific locations that were identified during the project, such as in survey responses and workshops, so should not be considered a conclusive list of "all risk" locations across the region.*
		• Councils may struggle to meet community needs and legislative responsibilities as extreme weather events become more frequent.	

7.1.5 Governance and institutional domain

Table 13 Overview of governance and institutional domain indirect risks.

Governance and institutional domain indirect risk
The following governance and institutional risks have been sourced from Ministry for the Enviornment (2020) National Climate Change Risk Assessment and are consistent with themes raised during the course of this project: • Risk of maladaptation across all domains due to the application of practices, processes and tools that do not account for uncertainty and change over long timeframes. • Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government, and funding mechanisms. • Risks to governments and businesses from climate change-related litigation, due to inadequate or mistimed climate change adaptation. • Risk of a breach of Treaty obligations from a failure to engage adequately with and protect current and future generations of Māori from the impacts of climate change. • Risks of delayed adaptation and maladaptation, due to knowledge gaps resulting from under-investment in climate adaptation research and capacity building • Risks to the ability of the emergency management system to respond to an increasing frequency and scale of compounding and cascading climate change impacts in New Zealand and the Pacific region. • Risk that effective climate change adaptation policy will not be implemented and sustained, due to a failure to secure sufficient parliamentary agreement. • Risk to the ability of democratic institutions to follow due democratic decision-making processes under pressure from an increasing frequency and scale of compounding and cascading climate change impacts. The following additional points were also noted during the project: • Climate change may lead to significant pressure on council finances, impacting local government's ability to fund usual activities and services, as well as adaptation, response and recovery efforts. • While Central Government is working on a national adaptation framework, responding to climate-related challenges across all domains may require high resource allocation from various agencies which can strain pre-existing funding schemes. • Funding flood risk management and maintaining levels of service for these assets, alongside funding managed retreat, can incur substantial costs. This could affect other services, as well as result in increased maintenance and operational expenses. • Councils may face various legal challenges related to historic planning and building consent decisions, infrastructure and maintaining levels of service. • The increasing frequency and scale of compounding and cascading climate change impacts will put pressure on the ability of the emergency management system and emergency services to respond to vulnerable Waikato communities. Changing hazard profiles may necessitate changes in land use zoning to maintain safe risk mitigation from hazards. Repeated extreme weather events can alter risk profiles.

7.2 Cascading and interconnected climate hazards and risks

Climate-induced hazards and their impacts do not occur in isolation. One hazard can compound with another, resulting in compounding and cascading risks. This interconnected nature of climate risks impacts all domains outlined in Section 7. The cascading effect of climate hazards can lead to multiple or ongoing short and long-term consequences across various domains, thereby affecting different well-being environments.

Furthermore, the impact on one element (or asset) at risk can have enduring consequences on another element within the same domain or across different domains. For example, an initial climate event can trigger a series of direct, indirect and cascading risks, creating a ripple effect across multiple domains. These cascading risks are influenced by the interdependence between different domains within our society, nature and the economy, propagating as cascades and causing often unforeseen or far-reaching impacts across geographical areas and various timeframes.

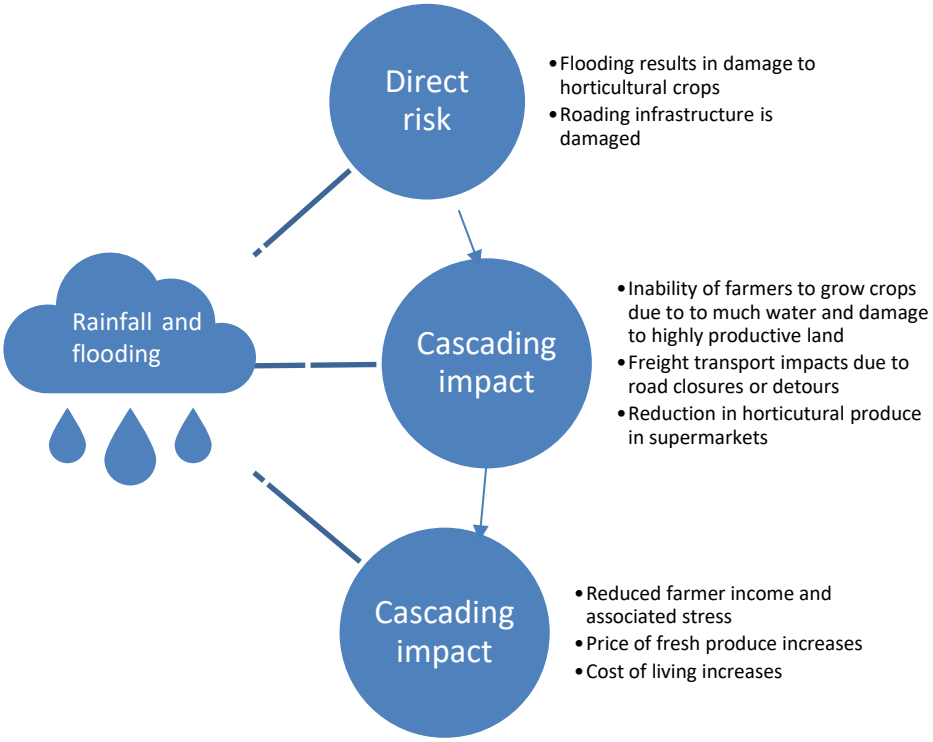


Figure 6 **Example of the interconnectedness of risks from rainfall on primary industry, roading infrastructure, society and economy.**

It is the council's understanding that this concept will be explored further in the next National Climate Change Risk Assessment, which is expected to be released by August 2026.

8 Case studies: Local community risk modelling for adaptation planning in the Waikato region

Across the Waikato, there are several community adaptation projects underway, each at different steps of the Dynamic Adaptive Pathways Planning 10-step decision cycle. These community adaptation projects across the region provide valuable case studies into undertaking localised climate change risk assessment.

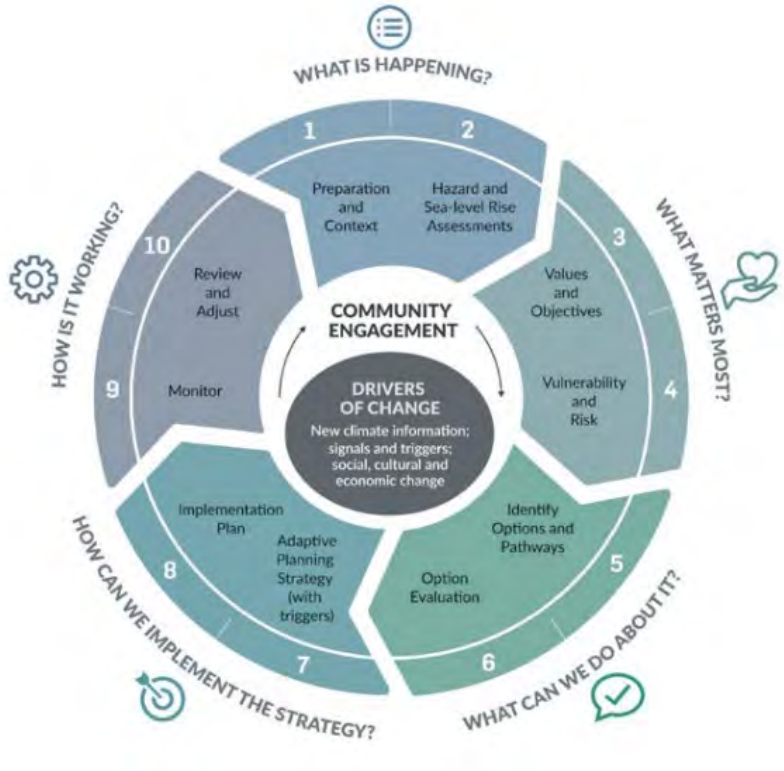


Figure 7 MfE Guidance 10-step decision cycle, grouped around five questions (Ministry for the Environment, 2024, p. 14).

8.1 Wharekawa Coast 2120

Currently at Step 8 of the DAPP cycle (implementation plan).

The Wharekawa Coast project area, which spans more than 20 kilometres from Waharau to Pūkorokoro/Miranda on the western side of the Firth of Thames, is steeped in the history of those who have gone before. The community and partner councils share the desire to leave the area in better shape for the generations to come.

The vision for Wharekawa Coast is:

"For community, mana whenua, and councils to come together to consider a range of issues and opportunities for the Wharekawa area, and to plan for a resilient and prosperous future for all.

Ko te pae tata, whakamaua kia tīnā, ko te pae tawhiti, whaia kia tata

Secure the horizons that are close to hand and pursue the most distant horizons so that they may become close."

One of the long-standing issues facing the Wharekawa Coast community is natural hazards exacerbated by climate change. Sea-level rise and changes in storm intensity due to climate change

are real issues for the Wharekawa Coast. The low-lying area has experienced approximately 14 floods and storm surges throughout the last 60 years, with the most recent being March and April 2017 and 5 January 2018, which caused widespread infrastructure, social, economic and environmental impacts.

Living along this coast presents many unknowns for those who live there, so it was decided to investigate the risks from stream flooding and coastal inundation and enable the community to evaluate their tolerance to those (risk thresholds). By knowing when these thresholds will be reached, factoring in sea-level rise, adaptation pathways can be developed and implementing accordingly (Hauraki District Council, 2024).

The natural hazard risk assessment allowed the Wharekawa communities to understand what their current risks were and to determine if and when their threshold would be reached in the future, indicating the risk has become intolerable.

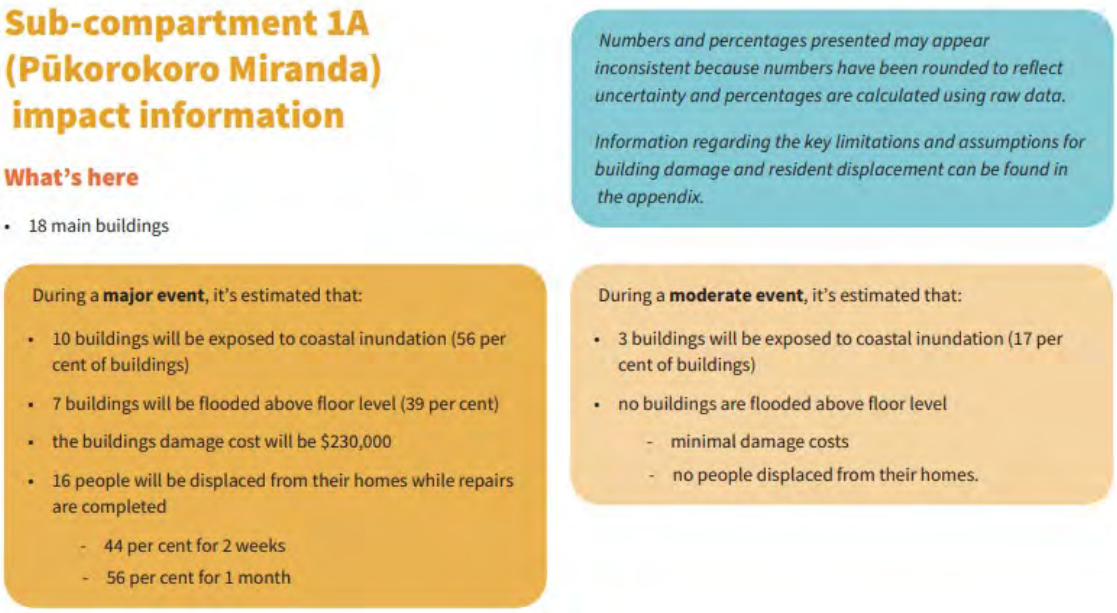


Figure 8 **Example of natural hazard risk information for impacts to homes and buildings, and disruption to residents' impact category for Sub-Compartment 1A (Pūkorokoro Miranda coast) for Wharekawa Coat 2120 (Waikato Regional Council, 2021).**

Results from this community engagement found that in some instances thresholds had already been reached; in others, we worked out how far into the future they will likely be reached, taking account of sea-level rise projections. This work was used to help inform adaptation pathways for the different communities.

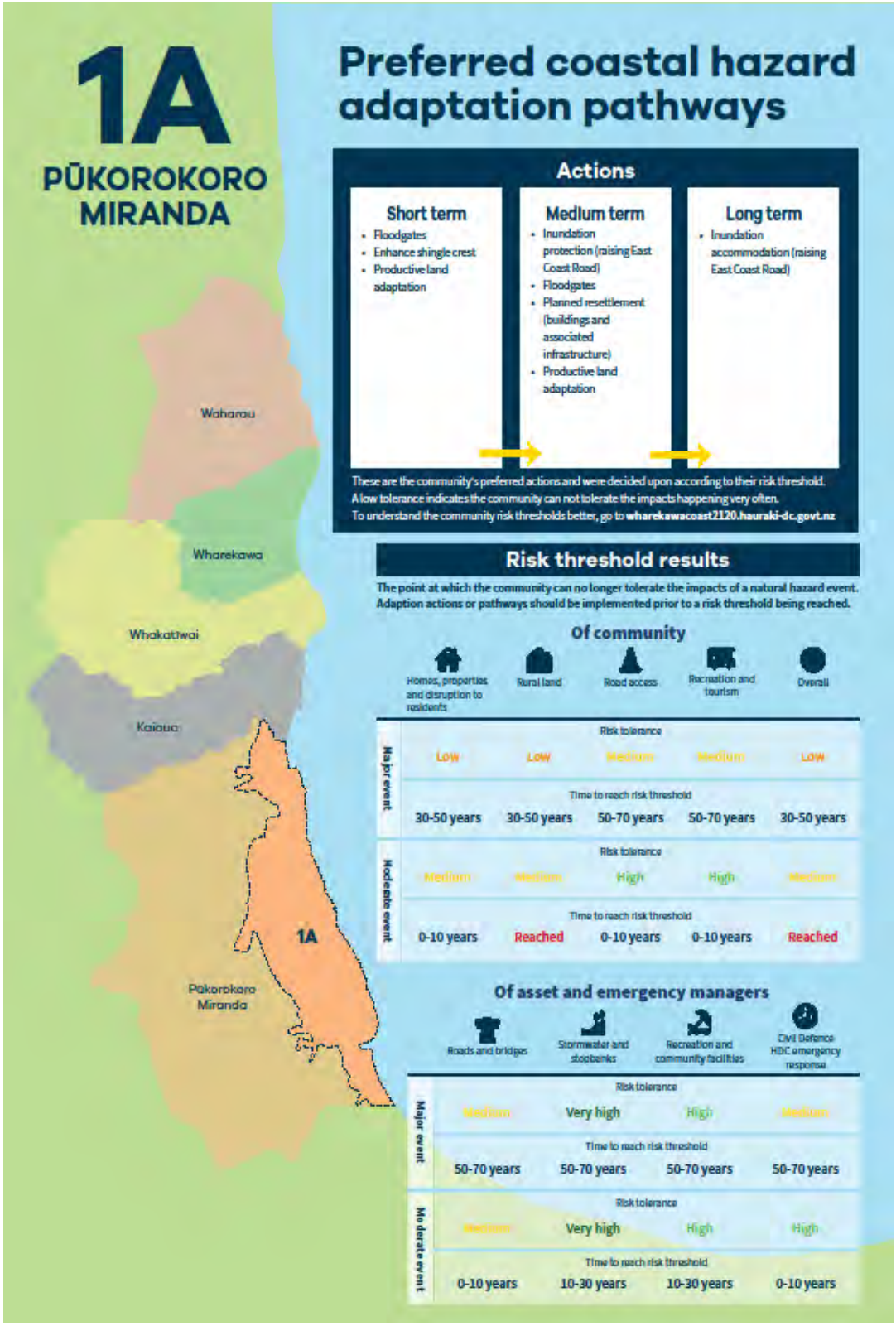


Figure 9 **Community risk threshold results for Sub-compartment 2a (Kaiaua township) (Waikato Regional Council, 2023a).**

Wharekawa Coast 2120 Community Plan is available online here.

8.2 Shoreline Management Pathways

Currently at Step 8 of the DAPP cycle (implementation plan).

The Shoreline Management Pathways (SMP) project, led by the Thames-Coromandel District Council with support from the Waikato Regional Council, aimed to develop community-led coastal adaptation strategies to address sea-level rise. The aim was to establish a framework for the sustainable management of risks to people, property, the environment and taonga associated with coastal hazards.

The project involved extensive community engagement and resulted in 138 specific adaptation pathways tailored to different sections of the coastline, that address more immediate short- and medium-term issues considering how communities may need to adapt in the longer term and was adopted in 2022.

These pathways are intended to reduce the risk from coastal hazards to an acceptable or tolerable level and develop tailored, flexible solutions to ensure the long-term sustainability and resilience of the Coromandel's coast communities. They build from the aspirations and concerns of TCDC's communities and the principles of kaitiakitanga.

These pathways include protection measures, accommodation strategies, managed retreat, ecosystem-based adaptation, and hybrid approaches. The project emphasised local input and kaitiakitanga principles, earning recognition for its innovative approach to managing coastal hazards.

Thames Coromandel District Council, along with Waikato Regional Council, is currently working through an implementation plan for the pathways by identifying the most urgent and important ones. They are also embedding outcomes alongside projects including asset management, combined river and coastal flood modelling for priority locations and civil defence (Thames Coromandel District Council, 2024).

Shoreline Management Pathways iReport can be online here.

8.3 Hauraki Plains Adaptation Plan

Currently at Steps 2 and 3 of the DAPP cycle (assess natural hazards and establish values and objectives).

This is a new adaptation project underway in the Hauraki Plains led by Hauraki District Council with support from Waikato Regional Council. The plan aims to create a future where everyone feels confident and safe, leveraging local knowledge about the land and weather. The community is collaborating with iwi and has formed a community panel to guide the development of a climate change adaptation plan. This plan will address the impacts of climate change, such as flooding, droughts, and changing weather patterns, and will focus on increasing resilience and exploring opportunities for growth.

The DAPP process will identify climate-related challenges and values and establish flexible strategies to adapt to changing conditions. This approach ensures that the community can respond to new signals and triggers, maintaining resilience and thriving in a changing climate (Hauraki Distrist Council, 2024).

Within the project, like other adaptation projects in the region, detailed flood modelling will inform a climate change risk assessment which the community will use to understand if the risk of natural hazards is either intolerable now or may become considering climate change (Hauraki District Council, 2024).

To find out more about the project, view the projects website here.

8.4 Waikato District Resilience Plan

We are beginning work with Waikato District to develop a district-wide resilience plan, which will undertake adaptation planning for communities at risk to multiple hazards. The plan will start with coastal adaptation planning for Port Waikato and Raglan, both highly vulnerable communities to multiple hazards, particularly coastal erosion, coastal inundation and land instability. The project will then move towards inland communities and plan for impact of increased river flooding and drought conditions along the Waikato River.

Sunset Beach at Port Waikato is a highly dynamic and high energy coastal environment that faces significant coastal erosion risks, which are increasingly threatening homes and infrastructure. Throughout 2024, multiple beachfront homes have felt the consequences of coastal erosion, with homes being removed, the car park being eroded and other infrastructure being impacted. This has had negative community consequences. Local homes are being impacted and the ability to access the beach for recreational purposes has been significantly reduced.

During Cyclone Gabrielle (2023), the Port Waikato community experienced landslides behind Maunsell Road, resulting in many properties being marked as unsafe. This event highlighted the risk of land instability in the community. Furthermore, a landslide impacted the only road into Port Waikato, isolating the community for several days. This landslide hazard is due to the local geology and steep catchments surrounding the community, which are prone to landslides during heavy rainfall events (Waikato District Council, 2024).

9 How can this report be used?

The project has generated a significant body of information, providing a central reference point for hazards and risks to consider when planning and responding to the impacts of climate change in the Waikato.

Individuals, organisation and sector will need to adapt and plan for climate change. It is hoped that this report will raise awareness of climate change hazards and risks in the Waikato and be utilised throughout the region by a range of parties—businesses, primary producers, communities, iwi/Māori, researchers, local government and public sector agencies—to aid the development of climate adaptation plans and the prioritisation of adaptation response and investment.

9.1 Further work to increase understanding of climate hazards and risks

This report can also be used to support:

- identifying domains and sectors where further effort is needed to understand, prioritise and manage climate change risks, which might include the acquisition of data or the commissioning of research
- initiating detailed risk assessments to provide an understanding of the relative severity of climate risks in different time periods under different emission scenarios. Detailed assessments assess risks on exposure, vulnerability, sensitivity and adaptive capacity and may be done across different timeframes and emission scenarios to rate and determine a risk rating[2]. They can:

[2] The Ministry for the Environment, (2019) Guide to Local Climate Change Risk Assessment provides a ponteial methodology for detailed assessments.

        - provide an indication of **when** risks may occur, consequences and urgency, helping to prioritise investment and action
        - be focused on specific species, environments, sectors or industries, or be at district, community or organisational scale.
    - initiating work to spatially understand and quantify **where** and **when** a risk may occur, which might include:
        - exposure modelling and analysis to spatially understand if elements in a geographic area may be exposed to climate change hazards over different time periods under different emission scenarios
        - quantitative spatial risk and vulnerability assessment of the physical impacts of climate change hazards in a geographic area.
    - initiating work to identify and assess cascading risks, taking a systems thinking approach to consider "and then what happens?" While beyond the scope of this report, evaluation of risks should not stop at a first pass risk screen or a qualitative assessment, particularly when cascades are likely.

Due to the evolving nature of climate science and the potential for unforeseen events, feedback loops and tipping points, the actual outcomes of climate change impacts may differ from those described in this report. Therefore, users of this report are cautioned against making decisions solely based on the information provided herein. Decisions related to planning and investment, adaptation and policymaking should consider a wide range of sources, expert opinions, ongoing research and quantitative analysis.

As a regional council, we will continue our work to provide modelling of key hazards and risks so that we can future-proof our decisions and pivot from basing resource management decisions on past measurements of our environment to one that includes modelled projections.

To view the current natural hazard information Waikato Regional Council hold across the Waikato region, view the Waikato Regional Hazards Portal and Coastal Inundation Tool.

9.2 Prioritising risks for adaptation action

Understanding of climate change risks for the Waikato region, and the supporting evidence base, will continue to grow over time. It may be informed through:

- detailed climate change risk assessments at district, community or organisational scale and
- research carried out by other organisations such as iwi or specific sectors
- the acquisition of natural hazards data and element information
- ongoing research
- quantitative spatial risk and vulnerability assessments
- community scale local adaptation planning projects.

This understanding and evidence base help identify the "where, what and who" for which the impacts of climate change may be significant, allowing for the prioritisation of resources and actions.

There are a range of methodologies available to support the prioritisation of resources and actions. The Climate Change Commission has indicated that it will use the proposed framework to assist with the prioritisation of risks in the second National Climate Change Risk Assessment (due by August 2026). It has been included in this report as one possible framework for use by other organisations also seeking to prioritise risks for adaptation investment and action (Climate Change Commission, 2025). However, it is noted that this is a proposed framework and whether it will usefully aid prioritisation at different scales is yet to be assessed.

Figure 10 Climate Change Commission methodology to support prioritisation of risks in the second National Climate Change Risk Assessment (Climate Change Commission, 2025).

To understand risk severity, factors that need to be considered include:

- The level or severity of the risk in different time periods under different emissions scenarios
- how the risk may compound and cascade
- whether the risk varies in different locations
- whether the risk has significant impacts for Māori
- potential lock-in risks (and at what point in time this will occur). "Lock-in" is where decisions made today are difficult to reverse and can increase exposure to subsequent risks long-term and/or will commit decision-makers to future interventions to manage exposure
- climate and non-climate aspects that may exacerbate or reduce the risk, such as thresholds, tipping points, socio-economic trends, climate mitigation action

To understand policy readiness, consider:

- what actions can be taken to address the risk, the potential impact of those actions on future risk, and the lead-in time for those actions
- what action is already being taken to address the risk and the impact it is having
- whether any actions could have or lead to mal-adaptation or when risks may become locked-in
- whether there are any barriers delaying action to address the risk
- shortfall in planned adaptation action – a sense of what further action is needed.

10 Conclusion

The Waikato region is already facing significant climate change impacts, posing risks to its economy, communities, infrastructure, and environment. This report, produced through a high-level risk identification and screening project led by the WRC, aligns with step 1 of the Ministry for the Environment's climate change risk assessment and adaptation process. It provides a comprehensive overview of the hazards and potential risks associated with climate change across five domains: human, natural environment, economy, built environment, and governance.

Key hazards identified include higher temperatures, drought, extreme weather, flooding, land instability, and coastal hazards and focuses on understanding the likely risks in the Waikato region as the climate changes.

The project aimed to list potential climate change risks through desktop reviews, workshops, and stakeholder engagement. Risks were categorised by hazard, risk elements, and domains, consistent with the National Climate Change Risk Assessment, however, were not rated through a quantitative risk assessment to identify the relative severity of climate risks in different time periods under different emission scenarios.

The presence and impact of climate hazards, both now and into the future, vary across the Waikato region. It is important to understand that each TA and consequently each community, will be affected by climate change and its associated risks differently. Therefore, each will need to plan for climate change in a unique way. Due to the presence and intensity of hazards across the region, some TAs have greater exposure to certain climate hazards than others. Consequently, the impact will vary across the region.

The report serves as a valuable resource for various stakeholders, including businesses, primary producers, communities, iwi/Māori, researchers, local government, and public sector agencies. It aims to support the development of climate adaptation plans, detailed risk assessments, and community awareness initiatives. However, due to the evolving nature of climate science and potential unforeseen events, users are advised to consider a broad range of sources and expert opinions when making decisions related to planning, investment, adaptation, and policymaking.

By understanding and addressing these risks, the Waikato region can better protect its economy, people, infrastructure, and environment from the adverse effects of a changing climate. The proactive approach to climate adaptation demonstrated by community projects across the region and work on regional spatial planning highlights the commitment to building a resilient and prepared Waikato.

11 References

Awatere S, King DN, Reid J, Williams L, Masters-Awatere B, Harris P, Tasset-Matamua N, Jones R, Eastwood K, Pirker J, Jackson A-M. 2021. He huringa āhuarangi, he huringa ao: a changing climate, a changing world. Manaaki Whenua Landcare Research report prepared for Ngā Pae o te Māramatanga.

Caldwell J. 2020. Internal series report on the causes of fish kill in the Aka Aka-Otaua Area. Waikato Regional Council Internal Report 2020/20. Hamilton, Waikato Regional Council.

Climate Change Commission. 2025. Webinar: National Climate Change Risk Assessment call for evidence - Academics and researchers. https://www.youtube.com/watch?v=jShoXA9pp68 [accessed 11 April 2025].

Connolly JD, Hackell M, Keenan B. 2021. Adapting to drought in the Waikato. Waikato Regional Council Technical Report 2021/28. Hamilton, Waikato Regional Council.

Edwards I, Yapp K, Mackay BL. 2020. Climate-related financial disclosures in the public sector. Nature Climate Change 10(7): 588-591.

External Reporting Board. 2024. Aotearoa New Zealand Climate Standards. https://www.xrb.govt.nz/standards/climate-related-disclosures/aotearoa-new-zealand-climate-standards/ [accessed 5 February 2025].

Hamling I, Naish T, Levy R, Hreinsdottir S, Bengtson S, Praveen K, Kopp B, Garner G. 2024. New Zealand Vertical land movement and sea rise projections. Zenodo. DOI 10.5281/zenodo.10976241.

Harrington LJ, Lewis H. 2025. Future changes in multi-week heat extremes over the Waikato region: a preliminary assessment. Zenodo. DOI 10.5281/zenodo.14962848.

Hauraki District Council. 2024. Hauraki Plains climate change adaptation planning. https://storymaps.arcgis.com/stories/0877b13b1fa14342b2e8a9f14e8b1eef [accessed 20 December 2024].

Hunt S, Jones HF. 2020. The fate of river-borne contaminants in the marine environment: Characterising Regions of Freshwater Influence (ROFIs) and estuary plumes using idealised models and satellite images. Marine Pollution Bulletin (156): 111169. DOI 10.1016/j.marpolbul.2020.111169.

Keenan B, Mackay S, Paragahawewa U. 2023. The economy of the Waikato region in 2022. Waikato Regional Council Technical Report 2022/17. Hamilton, Waikato Regional Council.

Livestock Improvement Corporation Limited & DairyNZ Limited. 2022. New Zealand Dairy Statistics 2021-22. Hamilton, Livestock Improvement Corporation Limited & DairyNZ Limited.

Melia N, Dean S, Pearce HG, Harrington L, Frame DJ, Strand T. 2022. Aotearoa New Zealand's 21st-century wildfire climate. Earth's Future 10(6): e2022EF002853. DOI 10.1029/2022EF002853

Ministry for the Environment. 2020. National climate change risk assessment for New Zealand. Wellington, Ministry for the Environment.

Ministry for the Environment. 2021. A guide to local climate change risk assessments. Wellington, Ministry for the Environment.

Ministry for the Environment. 2024a. Aotearoa New Zealand climate projections. https://environment.govt.nz/facts-and-science/climate-change/climate-change-projections/ [accessed 19 December 2024].

Ministry for the Environment. 2024b. Coastal hazards and climate change guidance. Wellington, Ministry for the Environment.

Ministry for the Environment. 2024c. Intergovernmental Panel of Climate Change SSP-RCP scenarios. https://environment.govt.nz/what-you-can-do/climate-scenarios-toolkit/climate-scenarios-list/ipccs-ssp-rcp-scenarios/ [accessed 10 January 2025].

Newnham RM. 2022. Monitoring airborne pollen in New Zealand. Journal of the Royal Society of New Zealand 52(2): 192-211.

NIWA. 2024. Regional Projections: Zone 1. https://niwa.co.nz/climate-change-adaptation-toolbox/projected-regional-climate-change-hazards/regional-projections-zone-1 [accessed 19 December 2024].

NIWA. 2025. Climate change scenarios for New Zealand. https://niwa.co.nz/climate-and-weather/climate-change-scenarios-new-zealand [accessed 7 April 2025].

NZ SeaRise. 2024. NZ Sea Rise. https://www.searise.nz/ [accessed 19 December 2024].

Statistics New Zealand. 2023. Infoshare table reference: RNA001AA. https://infoshare.stats.govt.nz/default.aspx?AspxAutoDetectCookieSupport=1 [accessed 24 March 2024].

Statistics New Zealand. 2023. 2023 Census. https://www.stats.govt.nz/2023-census/ [accessed 11 April 2025].

Thames Coromandel District Council. 2024. Shoreline Management Pathways Project. https://www.tcdc.govt.nz/Our-Community/Council-Projects/Current-Projects/Coastal-Management/Shoreline-Management-Pathways-Project [accessed 20 December 2024].

Waikato District Council. 2024. Port Waikato erosion. https://www.waikatodistrict.govt.nz/your-district/district-overview/towns/port-waikato/port-waikato-erosion [accessed 20 December 2024].

Waikato Regional Council. 2022. Waikato CCRA Survey. Hamilton, Waikato Regional Council. Document Number 23983585.

Waikato Regional Council. 2023a. 7338 - Wharekawa Coast 2120 maps RP no logos. Hamilton, Waikato Regional Council. Document number 26948628.

Waikato Regional Council. 2023b. Climate Action Roadmap. Waikato Regional Council Policy Series 2020/19. Hamilton, Waikato Regional Council.

Waikato Regional Council. 2023c. Te oranga o te taiao: He whakarāpopota A summary of the Waikato State of the Environment report 2022. Waikato Regional Council Policy Series 23/03. Hamilton, Waikato Regional Council.

Waikato Regional Council. 2024. Waikato Regional Plans. Hamilton, Waikato Regional Council. https://eplan.waikatoregion.govt.nz/eplan/rules/0/905/0/19963/0/157

Waikato Regional Council. 2025. Waikato Regional Hazards Portal. https://waikatoregion.maps.arcgis.com/apps/MapSeries/index.html?appid=f2b48398f93146e8a5cf0aa3fddce92c [accessed 24 April 2025].

Waikato Regional Council & Hauraki District Council. 2021. Wharekawa Coast 2120 Natural hazard risk assessment community risk thresholds : Sub-compartment 1A (Pūkorokoro Miranda). Hamilton, Waikato Regional Council. https://wharekawacoast2120.hauraki-dc.govt.nz/wp-content/uploads/2021/07/community_risk_thresholds-1a.pdf.

Wharekawa Coast 2120. 2024. Wharekawa Coast 2120. https://wharekawacoast2120.hauraki-dc.govt.nz/ [accessed 21 December 2024].

Yi Y, Urlich P, Yu J, Rogers H. 2021. Waikato regional climate impacts report applying CMIP6 data. Hamilton, Waikato Regional Council. Document number 22081522.

Yokahata T, Tanaka K, Nishina K, Emori S, Kiguchi M, Iseri Y, Honda Y, Okada M, Masaki Y, Yamamoto A. 2019. Visualizing the interconnections among climate risks. Earth's Future 7(2): 85-100.

Appendices

Appendix 1: Methodology

How this report fits within climate change risk assessment processes?

For this report, we have undertaken the first steps of Ministry for the Environment (2019) provided in Figure 5 to understand what climate risks are likely across the Waikato region and to start to understand the exposure of some of these risks. How this report can be used to support a detailed risk assessment, which includes the vulnerability aspects of risks, is discussed in Section 9.

Climate change risk assessments identify risks to things of value in communities ('elements at risk' or 'risk elements'), due to changes in the climate. A climate change risk assessment involves:

a. **Climate hazards** (which can be physical events or trends, such as sea-level rise or seasonal climate change)
b. The degree to which things we value (e.g. people, assets, taonga, ecosystems, infrastructure) are **exposed** to the hazard
c. Their vulnerability of its effects.

Waikato region climate change high level risk identification

This report is informed by a regional climate change risk identification project led by Waikato Regional Council, following the Ministry for the Environment, (2019) Guide to Local Climate Change Risk Assessments covering the first step of the climate change risk assessment and adaptation process (Figure 5).

High-level risk identification and screening

The aim of high-level risk identification and screening was to make a *long list* of potential climate change risks, drawing on knowledge from council subject matter experts, iwi and external stakeholders. This was achieved through a combination of a desktop review of in-house information, SME and technical focus group input via workshops and surveys, and external stakeholder and iwi engagement through a combination of surveys and workshops.

The risks were organised by hazard, then risk element. Domains consistent with the National Climate Change Risk Assessment were used as a further lens applied to the hazards and risk elements.

Hazard identification

The Waikato hazards of interest identified in Tables 2 to 4 were used to identify climate change risks, drive conversation and collate a long list of risks. The breadth of climate hazards comes from the National Climate Change Risk Assessment and the descriptors have been collated through literature review of the available regional projection information.

Risks domains

Risks were identified across the five domains used in the National Climate Change Risk Assessment (NCCRA) to allow for regional/national consistency and comparability (Ministry for the Enviornment, 2020).
The NCCRA domains are:

- human
- natural environment
- economic
- built environment
- governance
- any further local values as identified during the project.

Transition risks

Although some transition risks were provided in the survey, the project was focused on identifying the direct and indirect risks from physical climate hazards. An overview of transition risks are provided here for completeness. Transition risks typically refer to risks associated with "the transition to a low carbon economy" (in contrast to the physical risks associated with climate change). The language of transition risk has developed in recent years through the work of the international Task Force on Climate-related Financial Disclosures (TCFD) in the context of climate related financial disclosures. In a New Zealand context, transition risk is included in the Aotearoa New Zealand Climate Standards, (External Reporting Board, 2024), which were issued by New Zealand's External Reporting Board in December 2022 and establish a climate-related disclosure framework.

It is commonly used in relation to the business sector, i.e. to identify risks to a business or more broadly to an organisation. The purpose of these is to provide market signals to investors, so capital flows (in theory) favour low-carbon investments.

Transition risks are typically split into five types as outlined in the table 14 below:

Table 14 Transition risk types and what these could look like for the Waikato

Risk element	What could this look like for NZ
Policy	In coming years, central and local government policies will likely strengthen or appear, which will drive decarbonisation of the economy and carbon offsetting. These include the Emissions Trading Scheme, External Reporting Board climate disclosure requirements, incentives and regulations in various sectors etc.
Legal	The NZ External Reporting Board (XRB) has issued the Aotearoa New Zealand Climate Standards, which establish a climate-related disclosure framework for entities identified in the Financial Sector (Climate Related Matters and Other Matters) Amendment Act 2021. This includes changing legislative requirements in terms of decarbonisation of the economy and carbon offsetting. There is increasing activity from advocacy groups (e.g. Lawyers for Climate Action) at a national and regional level regarding both approaches to mitigation and adaptation. LGNZ prepared a legal opinion in 2019.
Technology	The need to substitute existing products and services with lower emissions options will likely increase in coming years. There is also a risk of unsuccessful investment in new technologies, and potential for stranded assets.
Market	This includes changing consumer behaviour and expectations, uncertainty through market signals, increase cost of and competition for raw materials.
Reputation	This includes shifts in consumer and citizen preferences, increased stakeholder concern/negative feedback (loss of social licence to operate) and resulting pressure on key regional sector(s).
Social	This is not commonly included (not identified in TCFD framework) but could be considered, e.g. the speed of change in some sectors will likely result in some businesses needing to reduce staff or close operations where they cannot keep up, resulting in unemployment, land use change…etc. This may be relevant in the context of a 'just transition' at a broader community level.

Risk identification and engagement

Three key inputs were used to develop the content of the risk identification workbook:

1. A desktop review of existing climate risk information held by council or submitted in the survey set out in item 2 below
2. An online risk identification survey (see Appendix 3)
    a. Engagement with the survey was extremely strong and a significant volume of information was shared

b. A total of 92 survey responses were received from a range of stakeholders and partners, including:
    i. local government
    ii. iwi Māori
    iii. energy, agriculture, forestry, aquaculture, tourism sectors
    iv. research institutions
    v. the Waikato District Health Board (now known as Health New Zealand)
    vi. non-governmental organisations and community groups.

3. Three workshops to discuss and refine risks:
    a. WRC subject matter expert workshop (50 attendees)
    b. general stakeholder workshop (33 attendees)
    c. iwi Māori hui (24 attendees).

Limitations and assumptions

High level risk screening:

- This is regional scale understanding of climate change hazards and risks for the Waikato region and therefore may not fully represent the potential risks across the region at a local scale. However, examples have been included where SMEs or stakeholders have identified a risk to be present but may not provide a comprehensive understanding of all climate hazards, risks and all locations.
- Climate change SSPs and sea-level rise projections are future modelled projections for the region and may not actually represent what the Waikato region will experience. However, they provide a good understanding of what the region may face to assist with planning purposes.
- Additionally, when considering the future at a specific point in time or when a climate risk may occur or be exacerbated, there are multiple different scenario projections and therefore different timeframes that could occur.
- The high-level risk screening identification has been informed by subject matter experts and stakeholders across the Waikato region, coordinated by the Waikato Regional Council.
- The risks identified by subject matter experts and stakeholders in this report have not been evaluated or confirmed, and therefore, some risks may appear incomplete.
- Risks have **not** been assessed on exposure, sensitivity and adaptive capacity across different timeframes and emission scenarios to rate and determine a risk rating. Consequently, this report does not provide an understanding of the relative severity of climate risks across the region over varying timeframes and emission scenarios. Rather, it offers an overview of known potential risks.
- Where geographical examples have been provided, this does not mean that is the only location where that risk is present. Consequently, the geographic examples may appear incomplete for places across the region where risks are present but were not identified in this work.
- The Waikato Lifelines Utility Group has conducted the Waikato Infrastructure Resilience Project, assessing the region's critical infrastructure and its vulnerability to hazards. This project has been utilised by SMEs to understand the risks to the region’s critical infrastructure and to inform this project. However, due to the sensitivity and security concerns regarding the location of critical lifelines assets, this is an internal document and cannot be made public.
- Waikato community adaptation projects provide a case study into localised climate change risk assessments; however, these were undertaken prior to this high-level risk identification being undertaken.

Appendix 2: Waikato Regional Climate Change Risk Identification workbook

To access the detailed climate change risk workbook this can be found here – Waikato Regional Climate Change Risk Identification Workbook (released with TR24-28).

Appendix 3: High-level risk identification stakeholder survey

The Waikato Climate change high level risk identification survey developed for engagement can be found here - Waikato Regional Climate Change Risk Survey.pdf

Appendix 4: Glossary

Definitions have been taken from the National Climate Changed Risk Assessment, unless referenced otherwise (Ministry for the Enviornment, 2020).

Table 15 Key terminology glossary.

Key term	Definition
Adaptation	Adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm, or to take opportunities. Intervention may facilitate adjustment
Annual exceedance probability (AEP)	The probability that an event of a particular magnitude will be exceeded in any given 12-month period (Waikato Regional Council, 2024). Additionally, a 1 per cent AEP is equivalent to a 100-yer average return period (ARP).
Assets	Adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm, or to take opportunities. Intervention may facilitate adjustment. These may also be called elements.
Cascading effects (of climate change)	Effects that flow on from a primary hazard to compound and affect other systems in a dynamic sequence.
Climate	The narrow definition is the average weather. More rigorously, the statistical description of the mean and variability of quantities over months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organisation. The quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.
Climate change	A change in the state of the climate identified (e.g., through statistical tests) by changes or trends in the mean and/or the variability of its properties, and that persists for an extended period, typically decades to centuries. Includes natural internal climate processes or external climate forcings such as variations in solar cycles, volcanic eruptions and persistent anthropogenic changes in the atmosphere or in land use.
Climate change projection	The simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario, which is in turn based on assumptions about, for example, socio-economic and technological developments that may or may not be realised.

Community	A geographic location (community of place), a community of similar interest (community of practice), or a community of affiliation or identity (such as industry).
Consequence	The outcome of an event that may result from a hazard. It can be expressed quantitatively (e.g., units of damage or loss, disruption period, monetary value of impacts or environmental effect), semi-quantitatively by category (e.g., high, medium, low level of impact) or qualitatively (a description of the impacts). It is also defined as the outcome of an event affecting objectives (ISO/IEC 27000:2014 and ISO 31000: 2009).
Domain	The NCCRA framework outlines five 'value domains' for assessing risks and opportunities. These represent values, assets and systems that may be at risk from climate-related hazards or could benefit (opportunities). They are a hybrid of Treasury's Living Standards Framework and those used in the National Disaster Resilience Strategy. They are interconnected and apply at the individual, community and national level. They include tangible and intangible values.
Exposure	Lack of protection, where people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings could be adversely affected by a change in external stresses that a system is exposed to. In the context of climate change, these are normally specific climate and other biophysical variables. Lack of protection against loss or harm in a hazard zone, affecting the number, density or value of people, property, services, or other things we value (taonga).
Extreme weather event	An event that is rare at a particular place and time of year. Rare is normally defined as 'as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. The characteristics of extreme weather will vary from place to place. When a pattern persists, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., a season of drought or heavy rainfall).
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.
Impacts (consequences, outcomes)	The effects on natural and human systems of extreme weather and climate events, and of climate change. Generally, refers to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events within a specific period, and the vulnerability of an exposed society or system.
Intergovernmental Panel of Climate Change (IPCC)	Intergovernmental Panel on Climate Change – a scientific and intergovernmental body under the auspices of the United Nations.
Land use	Human activities in a certain land cover type. Purposes for managing land (e.g., grazing, forestry, conservation). Urban land use has implications for city management, structure and form, and for energy demand, greenhouse gas emissions and mobility,
Likelihood	The chance of an outcome occurring, where this might be estimated probabilistically.

Representative concentration pathways (RCP)	A suite of future scenarios of additional radiative heat forcing at the Earth's surface by 2100 (in Watts per square metre), which is the net change in the balance between incoming solar radiation and outgoing energy, radiated back up in the atmosphere. Each RCP can be expressed as a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its Fifth Assessment Report (AR5) in 2014. Note that the Sixth IPCC Assessment report moved to Shared Socio-economic pathways.
Resilience	The capacity of social, economic and environmental systems to cope with a hazardous event, trend or disturbance by responding or reorganising in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation.
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. It also refers to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental) and infrastructure. Risk results from the interaction of vulnerability, exposure and hazard. To address the evolving impacts of climate change, it can also be defined as the interplay between hazards, exposure and vulnerability.
Risk assessment	The qualitative and/or quantitative process of identifying, analysing and evaluating risk, with entry points for communication and engagement, and monitoring and reviews (AS/NZS ISO 31000:2009, Risk Management Standard).
Shared Socio-economic pathway (SSP)[3]	IPCC's 6th Assessment Report (2021–22) shifted to a new core set of future representative scenarios, based on Shared Socio-economic Pathways (SSPs). These comprise different socio-economic assumptions that drive future greenhouse gas emissions. The scenarios span a wide range of plausible societal and climatic futures, based on greenhouse gas emissions, that result in the stabilisation of global warming at 1.5°C to over 4°C warming by 2100 (NZ Sea Rise, 2024). SSP1-1.9 and SSP1-2.6 are scenarios with very low and low greenhouse gas emissions, with CO2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO2 emissions. SSP2-4.5 is an intermediate greenhouse gas emissions scenario, with CO2 emissions remaining around current levels until the middle of the century. SSP3-7.0 and SSP5-8.5 are high and very high greenhouse gas emissions scenarios, with CO2 emissions that roughly double from current levels by 2100 and 2050, respectively (NIWA, 2025).
Stress	A long-term issue with an important and often negative impact for New Zealand.
Stressor (climate)	Persistent climatic event (e.g., change in seasonal rainfall) or rate of change or trend in variables such as the mean, extremes or the range (e.g., ongoing rise in mean ocean temperature or acidification), which occurs over a period of time (e.g., years, decades or centuries), with

[3] https://environment.govt.nz/what-you-can-do/climate-scenarios-toolkit/climate-scenarios-list/ipccs-ssp-rcp-scenarios/

	important effects on the system exposed. This in turn increases vulnerability to climate change.
Territorial authority	A city or a district council in the Waikato region - reference from RPS.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many sources, from imprecise data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour.
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm, and lack of capacity to cope and adapt (IPCC, 2014). Assessing vulnerability is broader than conventional risk assessments; it includes indirect and intangible consequences on the four well-beings, and adaptive capacity (e.g., communities, whānau, hapū and iwi may be resourceful but may lack the resources, insurance access and mandate or capacity to adapt).