Wellington Regional Climate Change Impact Assessment

Final Report

Prepared for Wellington City Council and Partner Councils
Prepared by Beca Limited in association with NIWA Ltd, GNS Science, Dr Judy Lawrence and Dr Ilan Noy

12 February 2024

Creative people together transforming our world

Contents

Appendices

Revision History

Revision Nº	Prepared By	Description	Date
1	Azura Patterson, Naira de Gracia, Erin Connolly, Laura Robichaux, Claire Webb, Mike Allis, Ilan Noy, Paula Blackett, Judy Lawrence, Matt Raeburn, John Blyth, Cushla Loomb	Interim Draft	6/03/2023
2	Azura Patterson, Erin Connolly, Laura Robichaux, Claire Webb, Mike Allis, Ilan Noy, Paula Blackett, Judy Lawrence, John Blyth, Cushla Loomb	Final Draft for client review	25/08/2023
3	Erin Connolly	Final	12/02/2024

Document Acceptance

Action	Name	Signed	Date
Prepared by	Erin Connolly, Laura Robichaux, Claire Webb, Michael Allis, Ilan Noy, Paula Blackett, Judy Lawrence, John Blyth, Cushla Loomb		09/02/2024
Reviewed by	Michael Allis, Cushla Loomb		25/08/2023 09/02/2024
Approved by	Cushla Loomb		12/09/2024
on behalf of	Beca Limited		

Authors

This Final Report and accompanying Risk Register (**Appendix A**) have been prepared by various sustainability and climate change advisory staff from Beca and associated technical specialists, in particular, the following key subject matter experts:

Name	Organisation and title *Qualifications* Hapū or iwi	Role
Claire Webb	Senior Associate – Ecology, Beca *MSc Botany, BSc (Hons), BSc*	Subject Matter Expert Natural Environment Domain – Risk Scoring & Technical Verification
Michael Allis	Senior Associate – Coastal Engineering, Resilience and Adaptation, Beca *PhD Ocean Engineering, BE (Hons) Civil Engineering*	Subject Matter Expert Built Domain – Risk Scoring & Technical Verification
Ilan Noy	Chair in the Economics of Disasters and Climate Change School of Economics and Finance, Victoria University of Wellington *PhD & MA International Economics, BA*	Subject Matter Expert Economic Domain – Risk Scoring & Technical Verification
Paula Blackett	Environmental Social Scientist, NIWA *PhD, Geography & Environmental Science* *MSc (Hons), Resources & Environmental Planning, BSc*	Subject Matter Expert Human Domain – Risk Scoring & Technical Verification Co-author - Cascading Risks and Technical Verification
Judy Lawrence	Director PS Consulting Ltd *PhD Public Policy, MA Geography, BA (Hons) Geography, COP Planning Law*	Subject Matter Expert Governance Domain – Lead Author Governance Assessment
Matt Raeburn	Senior Associate – Sustainability Advisory, Beca *U.S. law degree (Juris Doctor), BA*	Transition Risk Lead
Laura Robichaux	Senior Associate – Civil Engineering and Adaptation Planning *Doctorate of Philosophy, Environmental Science*	Cascading Risks co-author
John Blyth	Māori Business Lead, Beca *BSc Earth Science* Te Atihaunui a Pāpārangi, Ngāti Tūpoho	Te Kaiwhakatere – Technical Review
Cushla Loomb	Business Director – Climate Resilience, Beca *MSc Earth Science, BSC, CEnvP NZPI*	Project Director

Acknowledgements

The development of this Final Report for the Wellington Regional Climate Change Impact Assessment has been made possible by the contributions of the Council Project Team listed below. We would also like to acknowledge the time and inputs provided by mana whenua representatives, and staff from councils, and external stakeholder organisations including in the collation of data and attendance at workshops. In particular, we thank Wellington Water Ltd for the provision of flood data used in the detailed assessment stage.

It is noted that iwi and hapū who have mana whenua in their own rohe across this region have unfortunately not been able to be directly involved in the development of the climate risk and impact methodology or assessment as part of this stage of the project. The Council Project Team, Beca and our partners acknowledge the importance of partnership in accordance with Te Tiriti o Waitangi and the need to continue to engage in a way that best suits mana whenua in regards to this important kaupapa. Throughout the document we have identified particular topics that can form part of the wider ongoing discussions and partnership with mana whenua but note that it will be mana whenua that ultimately express their expertise and knowledge around potential topics of interest to them.

Council Project Team

Jamuna Rotstein, Wellington City Council

Suze Keith, Greater Wellington Regional Council

Kylie Robinson, Upper Hutt City Council

Nienke Itjeshorst, Kāpiti Coast District Council

Melanie Barthe, Carterton District Council

Sky Halford, Carterton District Council and South Wairarapa District Councils

Ben Fountain, Porirua City Council

Lisa McLaren, Masterton District Council

Dalila Gharbaoui, Hutt City Council

Angela Sutherland, Porirua City Council

Sedigheh Mousavipour, Wellington City Council

Iain Dawe, Greater Wellington Regional Council

Report Summary

Introduction

To support the Wellington Region to transition to a low-carbon future that is resilient to climate impacts, the Wellington Regional Leadership Committee has commissioned a Wellington Regional Climate Change Impact Assessment (WRCCIA). The assessment offers insights into potential risks and impacts associated with climate change across the Wellington Region, in a regionally consistent method at both regional and local authority scales. The WRCCIA has been designed to inform decision making across the region. The WRCCIA involved a qualitative assessment of the potential climate change risks and their impacts across the region, followed by a more detailed assessment of selected risks and impacts to the specific elements of the built environment, natural environment, human / social domain and the economy.

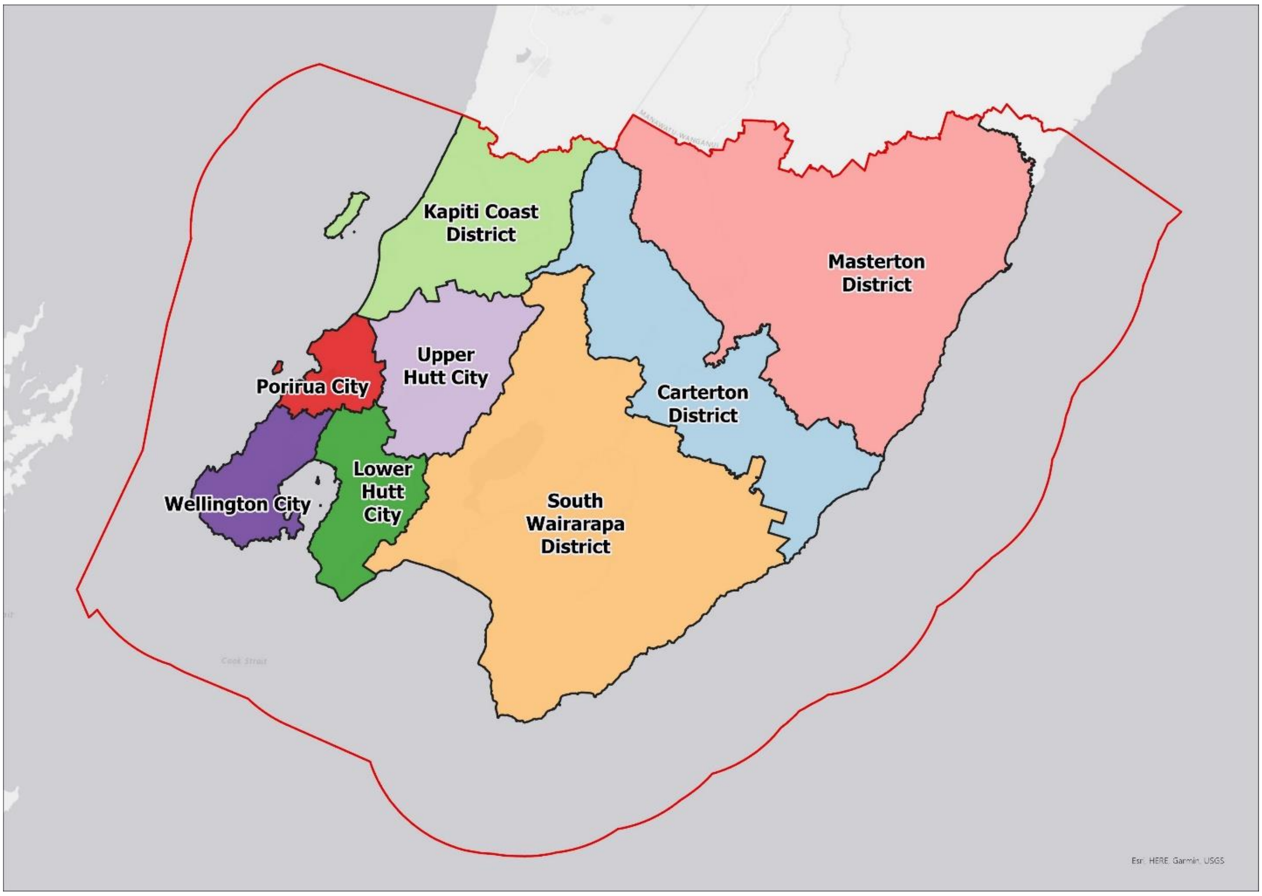


Figure 1: The Wellington Region with Council Partners of the WRCCIA. Contains Data from LINZ, Stats NZ, Eagle Climate Projections for Wellington Region Technology, Esri, HERE, Garmin, FAO, METI / NASA, USGS

Climate Projections for the Wellington Region

The Wellington Region is exposed to a wide range of climate stressors and hazards that will increasingly impact the built environment, economy, natural environment, governance and human domains. Assessing possible changes for the future climate due to human activity is difficult because climate projections depend strongly on estimates for future greenhouse gas concentrations. This range of uncertainty has been addressed by the International Panel of Climate Change (IPCC) through consideration of 'scenarios' that describe possible future concentrations of greenhouse gases in the atmosphere. These scenarios are called Representative Concentrations Pathways (RCPs) or, more recently, Shared Socio-economic Profiles (SSP).

Regional downscaled climate projections for Wellington are available for RCPs, abbreviated as RCP2.6, RCP4.5, RP6.0, and RCP8.5, in order of increasing radiative forcing by greenhouse gases.

Exposure to changing climate hazards and drivers varies by geographic location in the Wellington Region. For example, climate projections differ on either side of the Remutaka / Tararua ranges where both sides are predicted to become hotter, but the east will grow dryer while the west will be wetter. There are many other geographic differences in future climate hazard exposure including urban / rural, topography (hill / valley), coastal / inland, and it is important that the partner councils and strategic planners recognise that these differences will drive the varied levels of risk and urgency to implementing adaptation measures, and thus required levels of support to address spatial differences. Climate projections for the Wellington region are discussed further in the NIWA reports (NIWA 2017, 2019).

Methodology

The WRCCIA methodology is aligned with best practice risk assessment methodology guidance, including:

- National Climate Change Risk Assessment (NCCRA, 2020);
- Ministry for the Environment (MfE) Guidance for Local Climate Change Risk Assessments; and,
- ISO14091 Standard (2021).

The WRCCIA has consisted of Phase 1, a Qualitative Assessment and Phase 2, a Detailed Assessment. A full description of the methodology is provided in the *Wellington Regional Climate Change Impact Assessment Methodology Framework Report (8 June 2022*).

The first step in the Qualitative Assessment was an initial risk screening by Subject Matter Experts (SMEs) to identify whether or not elements at risk will be exposed to climate hazards or drivers under a RCP8.5 climate scenario by the end of the century. The purpose of the screening was to remove risks and impacts from further consideration that are not relevant for the Wellington Region (for example the risk of ocean chemistry changes on terrestrial ecosystems). Through this process opportunities were also identified where a climate hazard/driver may have a positive impact for the element at risk in the future (for example, there may be an opportunity for outdoor activities associated with the tourism industry in the future from warmer and drier conditions). The results identified a total of 375 risks and opportunities regionally across the built, human, natural environment and economic domains.

The screened risks were then collated into a Risk Register (see Appendix A) and risks and impacts were qualitatively assessed and scored. Risk is comprised of the exposure of an element-at-risk (or 'element') combined with the vulnerability of the element to the particular climate hazard or driver (see **Error! Reference source not found.**).

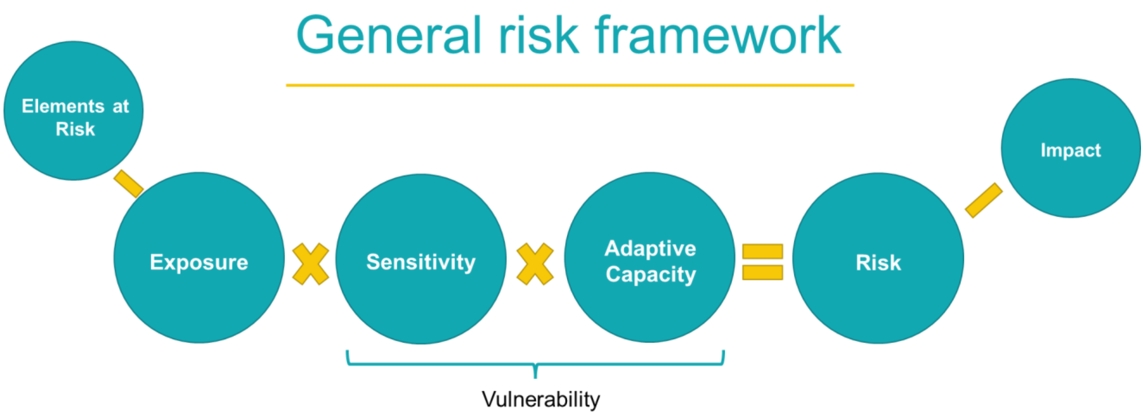


Figure 2: Risk Assessment Framework. Adapted from MfE's Guide to Local Climate Change Risk Assessments (2021)

Understanding the *exposure* of a particular *element-at-risk* to an identified climate change driver was determined using a GIS viewer where data was available or qualitatively using SME experience.

The vulnerability of an element encompasses the *sensitivity* to harm and *adaptive capacity* of the element to respond to climate pressures (Figure 2). Each of these elements informs the final risk scoring. The *impact* is then determined considering the risk and its potential consequences.

The impacts may be direct, indirect, compounding or a complex interconnected cascade of impacts across many domains (see Figure 3 below). There will also be transitional impacts associated with the move to a low emissions and climate resilient society, including international influences such as changing migration patterns, shifts in supply chains, less international travel and shift in consumer preferences.

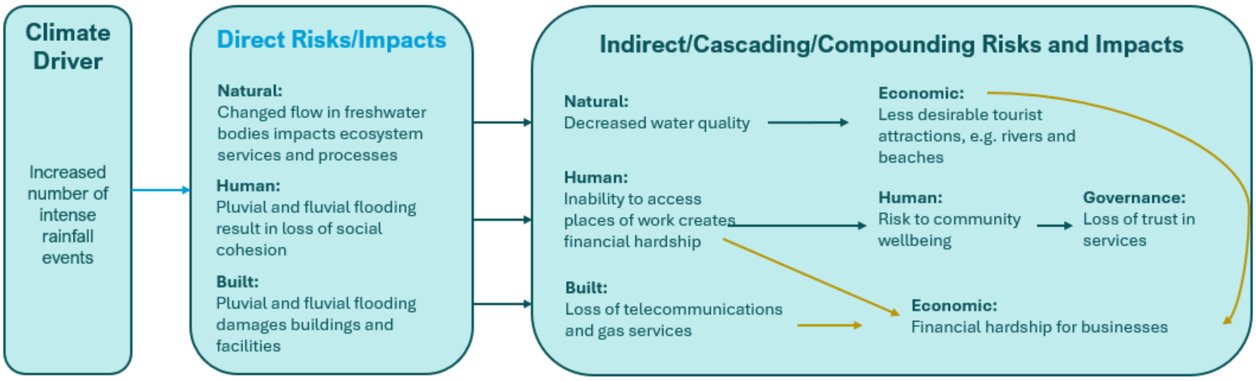


Figure 3: Relationship Diagram Showing an Example of the Direct Risks and Associated Impacts Associated with a Climate Driver (Increase Number of Rainfall Events) and How Direct Impacts Can Lead to Indirect and Cascading Impacts

Key Findings

The initial screening of potential risks and opportunities identified 363 risks and 12 potential opportunities (see Table 1).

Table 1: Number of Risks and Opportunities Identified by Domain / Type Across the Region

Value Domain	Number of Risks	Number of Opportunities
Natural Environment	73	2
Human	69	4
Built Environment	128	
Economy	93	5
Governance	6	
Transition	5	1
Total	**363**	**12**

The Regional Climate Risk Register (Appendix A) displays all of the screened risks and scores them under three different timeframes (present day, mid century and end of century) and under different future climate warming scenarios (i.e. a moderate emissions RCP4.5 or high emissions RCP 8.5 scenario). A consequence (or impact) rating for each risk was applied from 'Insignificant' to 'Catastrophic' (Table H6, Appendix H). Many of these impacts may 'cascade' through other domains. For example, damage to residential buildings from coastal inundation may result in financial costs of repairs, increased insurance premiums (economic impacts) and health and wellbeing impacts (human / social). These impacts will be greatest across the region where exposure to the hazards (determined using spatial data where possible) is greatest and vulnerability to the hazard is high (such as lower socio-economic areas that may be less able to cope with financial impacts). Climate change will affect the exposure to climate related hazards over time and the degree of the hazard is dependent on future levels of global warming.

The **top five risks in each domain for the region**, selected based on their risk severity and impact score, are summarised below. As there were many extreme risks by 2100 under a RCP8.5 high emissions scenario, risks were sorted in the following order:

1. Risk level in 2100 under RCP8.5.
2. First-pass impact score.
3. Risk level in 2100 under RCP4.5.
4. Risk level in 2050 under RCP8.5.
5. Risk level in 2050 under RCP4.5.

The most significant climate drivers / hazards for the region are coastal hazards (such as coastal inundation and coastal erosion that are exacerbated by sea level rise), rainfall induced landslides, pluvial and fluvial flooding (from extreme weather events) and drought. These hazards can compound to create greater exposure, for example high groundwater levels in low lying coastal areas (from rising sea levels) will exacerbate flooding from extreme rainfall events. The Wellington Region is particularly exposed to sea level rise as the land is subsiding (downward vertical movement) due to tectonic activity. This means that in parts of the Wellington Region (such as South Wairarapa) local sea level will rise faster than other parts of New Zealand and many coastal impacts relating to flooding and erosion will be experienced sooner.

Built Environment Domain Results – Top 5 Risks (Out of 128 Total)

The Built Environment Domain refers to physical infrastructure, transport, and buildings sectors including housing, public amenity, water, wastewater, stormwater, energy, transport, communications and coastal defences.

Five key risks were identified for the Built Environment Domain as set out in Table 2. In addition to the top 5 risks identified below, there is also extreme risks to future drinking water supply predicted by the end of the century due to longer summers and drought periods. However, as alternative water supplies are potentially available, the impacts of this risk are scored as moderate.

Table 2: Top Five Risks Identified - Built Environment Domain

Risks	Risk Rating			Impact Rating
	Present	Long 2100 RCP4.5	Long 2100 RCP8.5	
Risk to buildings and facilities (public and private) due to coastal erosion: cliffs and beaches	High	Extreme	Extreme	Catastrophic
Risk to transport (road and rail) landslides and soil erosion	High	Extreme	Extreme	Major
Risk to buildings and facilities (public and private) due to coastal and estuarine flooding	Moderate	High	High	Catastrophic
Risk to buildings and facilities (public and private) due to increasing landslides and soil erosion	Moderate	High	High	Catastrophic
Risk to flood and coastal defences due to river and pluvial flooding	Moderate	High	High	Major

Most built environment impacts relate to damage to public and private buildings or structures or disruption to transport networks (road/rail) from coastal inundation, fluvial and pluvial / flooding, coastal erosion and landslides. These impacts can have catastrophic impacts as significant structural damage and extensive costs of repairs or relocations away from affected areas can result in significant financial costs (including potentially the need for temporary housing in the case of residential buildings). There are potentially major impacts from landslides damaging transport infrastructure (rail and road) across the region. The impacts will be greatest where single access roads are affected as this may mean complete loss of access to work, residences or important cultural or social sites of significance. In addition, if roads that are major arterials conveying large numbers of people and potentially goods around the region are affected by landslides the potential economic and social impacts can be high. The following describes the potential risks to the built environment further.

Fluvial and pluvial flooding driven by increasingly intense rainfall is one of the most significant risk to buildings across the Wellington Region with over 60,000 buildings and facilities currently impacted and is projected to increase by approximately 100,000 by end of century. The key areas that will be impacted the most by pluvial flooding are Petone, where the stormwater system is already under pressure, a range of suburbs in Wellington City including the CBD and historical infill areas Miramar and Kilbirnie, and parts of Porirua such as the CBD and recreational areas. While the predominate (82%) impacts will be on residential buildings, there are more than 2,500 commercial buildings and more than 1,800 publicly owned buildings projected to be exposed to extreme flood events at the end of the century. Many buildings have a higher vulnerability due to their use (such as schools, aged care facilities and childcare facilities), age, and existing condition (e.g. damp or mouldy homes). The potential risks to these buildings can cause significant social impacts and even health and safety concerns (either through direct impacts associated with exposure to flood waters, or through increase damp and mouldy buildings that are frequently subject to water damage). Although there is no data available for finished floor levels, foundations (piles or slabs) or building types (e.g. timber versus concrete) for buildings across the region, older building stock not constructed in accordance with modern building code regulations (with finished floor levels above the floodplain) may be more vulnerable to damage than modern buildings.

The impacts of **coastal erosion** on buildings and facilities are significant across the region, with areas of Wellington City, Porirua City and Kāpiti Coast District particularly vulnerable to erosion of cliffs and beaches, exacerbated by rising sea levels and increasing severity of storms. The 2019 Greater Wellington report on *Preparing Coastal Communities for Climate Change* evaluated regional coastal vulnerability with a focus on sea level rise and coastal erosion and identified the following geographic units as the most vulnerable in a district by district assessment: Paraparaumu and Raumati (Kāpiti Coast District), Porirua and Pāuatahanui (Porirua City Council), Seaview and Petone (Hutt City Council), and Palliser and Whakataki (for the joint Wairarapa Districts). It is difficult to quantify the scale of impact of coastal erosion on the Wellington region due to lack of a region-wide coastal erosion model and due to the fact that Wellington City was not included in the Greater Wellington Vulnerability study. However, it is expected that impacts will occur and continue to get worse in most areas with infrastructure development along natural (e.g. no engineered structures) coastal margins. Even in areas where there is existing erosion protection, increases in water levels over time are fundamentally different from the historic design assumptions for these structures, and further engineering and construction would be required to maintain functionality in the long term. An increase in coastal erosion will begin to undermine buildings and facilities prompting increasing demand by the community for increased protection. This will affect homes, property, business and facilities, and without coastal protection, risks are likely to cascade into social and economic impacts as buildings become more costly or harder to insure and occupiers forced to eventually retreat (if costs become too high).

Landslides already have and will continue to have, a notable impact on road and rail transport as well as buildings around the region. There is currently only data for rainfall-induced landslide susceptibility for the Wellington City area. In general, areas more prone to landslides have slopes greater than 35 degrees, cut slopes or areas with removed vegetation, fracturing of rock strata weakening slopes, or historic landslides that may resume or continue to shift over time. Whilst there are many buildings exposed to landslides, according to the Wellington City landslide information (GNS Science, SLIDE programme), five[1] buildings have been assessed as having higher landslide risk (including a consideration of vulnerability) under present conditions (residential in Karori), increasing to approximately 210 buildings by mid-century (94% residential, one supermarket) and approximately 3,400 buildings by late century. There are 27 roads with high landslide risk of rainfall-induced landslides under present conditions, increasing to approximately 210 roads by mid-century and approximately 990 by late century. Key arterial roads impacted by late century (approximately 120 in total) include State Highway 1 through Ngauranga and up to Grenada, State Highway 2 along the coast connecting Petone to Wellington, and connections from Brooklyn to the City and the Aro Valley to Northland. These are major road connections that if blocked by landslide, can cause significant impacts on connectivity between main parts of the Wellington Region, and limiting people's ability to commute for work or social reasons. Landslides require time, resource and effort to clear and may directly damage infrastructure resulting in costly repairs.

Although there are currently no transport routes at high risk to rainfall-induced **landslides** (above the selected threshold) in Wellington City, by mid-century there are 14 high risk locations and this increases to 52 locations by late century. Key impacted transport routes by end century include the Johnsonville line through Ngaio and between Wadestown and the sea, the Kāpiti line between Onslow and the sea and near its intersection with State Highway 1 in Ngauranga and between Grenada Village and Grenada North. Disruptions caused by landslides on rail tracks will impact freight, commuter and passenger transport causing economic impacts, commercial and supply chain disruptions and costly repairs to damaged infrastructure.

Human Domain Results – Top 5 Risks (Out of 69 Total)

The Human Domain refers to people's skills, knowledge and physical and mental health (human); the norms, rules and institutions of society (social), and the knowledge, heritage, beliefs, arts, morals, laws and customs that infuse society; including culturally significant buildings and structures (cultural).

Five key risks were identified for the Human Domain as set out in Table 3. The main risks across the region relate to a loss of social cohesion due to flooding, cultural heritage risks due to sea level rise (particularly as many culturally significant sites are near the coast) and risks to existing inequities from flooding (pluvial, fluvial and coastal) and coastal erosion. The impacts from these risks can be catastrophic if the community cannot recover from acute events in the future or where cultural and social practices are severely compromised or no longer possible.

Table 33: Five Key Risk Identified - Human Domain

Risks	Risk Rating			Impact Rating
	Present	Long 2100 RCP4.5	Long 2100 RCP8.5	
Risk to social cohesion due to coastal and estuarine flooding	Moderate	Extreme	Extreme	Catastrophic
Risk to cultural heritage due to sea-level rise and salinity stresses on brackish and aquifer systems and coastal lowland rivers	Moderate	Extreme	Extreme	Catastrophic
Risk to existing inequities due to river and pluvial flooding	Low	High	Extreme	Catastrophic
Risk to existing inequities due to coastal and estuarine flooding	Moderate	Extreme	Extreme	Major

[1] Note that there are many more exposed buildings – however the assessment factors in all components of risk, including vulnerability (adaptive capacity and sensitivity) of the elements

Risks	Risk Rating			Impact Rating
	Present	Long 2100 RCP4.5	Long 2100 RCP8.5	
Risk to existing inequities due to increasing coastal erosion: cliffs and beaches	Moderate	Extreme	Extreme	Major

An increased incidence of **flood events, coastal inundation** and **coastal erosion** associated with a changing climate will affect homes, property, businesses and facilities and over time will erode the desire and ability of people to remain in affected communities. Displacement can cause trauma linked to disruption and dislocation from familiar surroundings and breaking of social and cultural bonds, and the challenges of resettlement. The breakdown of communities and the social bonds and connections to special places is important because fractured less cohesive communities can result in conflict and feelings of isolation and loss. Less cohesive communities can also be less resilient following a disaster event.

Displacement impacts are particularly acute for Māori because of the reciprocal relationship and kinship connections between people and places at the centre of Te Ao Māori. As such, there is a risk to the spiritual and cultural attachment to place that is essential to maintaining connections to the land and traditional practices and wellbeing, which will impact the maintenance of traditional skills and identity. A reduced ability to maintain a relationship with land / places will likely affect almost all aspects of Māori wellbeing.

Groups within society that are already marginalised, at an economic disadvantage or are potentially more vulnerable to climate hazards (such as those living with disabilities) may be at risk of being made more vulnerable as a result of being increasingly exposed to the hazard. The constant damage to infrastructure and services may exacerbate existing vulnerabilities such accessibility, underlying health issues and mental health. With more frequent, repeat events some infrastructure and services may potentially not be replaced or become increasingly unreliable (for example power and clean water) causing loss of social cohesion and further increasing the impacts on vulnerable parts of the community.

Natural Environment Domain Results – Top 5 risks (Out of 73 Total)

The Natural Environment Domain refers to all aspects of the natural environment that support the full range of our indigenous species, he kura taiao (living treasures), indigenous & taonga species, and the ecosystems in terrestrial, freshwater and marine environments.

Five key risks were identified for the Natural Environment Domain as set out in Table 4. The main risks in the Wellington Region is to the services and processes of freshwater ecosystems from higher mean water temperatures and river and pluvial flooding which can change the mixing regimes and can fundamentally alter the dynamics. Many freshwater ecosystems in the Wellington Region are already degraded or fragmented with threatened species and so are sensitive to further changes. The distinctive ecosystems of sub-alpine and alpine lakes, like those found in the Tararua Range, will also be subject to on-going change in temperatures, allowing invasion by species normally restricted to lower elevations. These risks may cause catastrophic impacts if they ultimately lead to a loss of habitat and breeding locations for a number of organisms.

Table 44: Five Key Risks Identified - Natural Environment Domain

Risks	Risk Rating			Impact Score
	Present	2100 RCP4.5	2100 RCP8.5	
Risk to freshwater ecosystems, services and processes due to higher mean water temperatures	Moderate	Extreme	Extreme	Catastrophic
Risk to freshwater ecosystems, services and processes due to river and pluvial flooding	Extreme	Extreme	Extreme	Major

Risks	Risk Rating			Impact Score
	Present	2100 RCP4.5	2100 RCP8.5	
Risk to terrestrial and forest ecosystems, services and processes due to reducing snow and ice cover	Moderate	Extreme	Extreme	Major
Risk to freshwater ecosystems, services and processes due to increasing landslides and soil erosion	Moderate	Extreme	Extreme	Major
Risk to coastal and marine ecosystems, services and processes due to sea-level rise and salinity stresses on brackish and aquifer systems and coastal lowland rivers	Moderate	Extreme	Extreme	Major

The Wellington Region has a relatively small tidal range and therefore even small changes in sea level may have impacts on the size, scale and distribution of coastal ecosystems. As rising sea level shifts the high-water mark inland in low lying areas, coastal ecosystems (such as salt marsh) and the biota they support may be lost or irreversibly altered if they are prevented from migrating inland due to natural or man-made barriers reducing the scale of the intertidal zone (such as where there is a hard infrastructure edge to the coastal marine area). Areas where saltmarsh may be particularly impacted by coastal squeeze are Pāuahautanui Inlet in Porirua as there is hard infrastructure in the form of roading and residential development that will prevent the landward migration of saltmarsh over time. Dunelands at Lake Ōnoke and along the eastern Wairarapa coastline are also likely to be impacted with changing coastal processes as landform and infrastructure will prevent dune formation. More frequent inundation of low-lying river mouths and estuaries in Lower Hutt, Porirua and Kāpiti Coast will have cascading impacts on wader bird habitats and migrant coastal birds to due changing locations and extents of intertidal habitats and their ecosystems.

A range of forest types are supported by the Wellington Region's diverse geography. Risks and associated impacts will be higher for sensitive forest ecosystems, such as regionally endangered forests. The most pronounced potential climate change risks for regionally endangered forests occur in the South Wairarapa, Carterton and Masterton Districts where the greatest change in temperature and soil moisture deficits are likely to occur by mid-century and beyond (i.e. annual temperature change of 2ºC or more). The fragmented nature of the remaining forest and scrub and the lack of connectivity with other natural areas as well as increased pest pressures and acute disturbance events (wildfires) means that these areas have a higher vulnerability to risks associated with warming temperatures. These impacts will manifest as a lack of seedling and sapling regeneration as well as canopy dieback within the remnants and an overall reduction in the number and extent of lowland forest remnants present.

Economic Domain Results – Top 5 Risks (Out of 93 Total)

The Economic Domain refers to the set and arrangement of inter-related production, distribution, trade and consumption that allocate scarce resources.

Five key risks were identified for the Economic Domain as set out in Table 5. The key risks reflect the scale of the economic sector in regards to GDP and the adaptive capacity (as a measure of vulnerability). Economic risks relate mostly to international disruptions to the regional economy from customer preferences which is a particular impact given the reliance on high carbon transport for international tourism (cruise ships, aeroplanes). Whilst this risk may be extreme in the future the impact is only moderate as the regional economy is not heavily reliant on tourism. The public services sector is a key economic sector for the Wellington Region and whilst the risk of international influences on the public sector is scored 'high' risk in the future, the impact will be major given the contribution of the public services sector to the Wellington Region GDP. There will also be high risks to insurance coverage in the future due to more frequent and damaging extreme weather events.

Table 55: Five Key Risks Identified – Economic Domain

Risks	Risk Rating			Impact Rating*
	Present	Long 2100 RCP4.5	Long 2100 RCP8.5	
Risk to tourism and hospitality due to international influences from climate change and greenhouse gas mitigation preferences	Low	Extreme	Extreme	Moderate
Risk to public services due to international influences from climate change and greenhouse gas mitigation preferences	Low	High	High	Major
Risk to forestry economic sector due to increasing fire–weather conditions: harsher, prolonged season	Moderate	High	High	Moderate
Risk to insurance coverage and credit provision due to increasing fire–weather conditions: harsher, prolonged season	Low	High	High	Moderate
Risk to insurance coverage and credit provision due to increased storminess and extreme winds	Low	High	High	Moderate

Other economic sectors important at a district scale are not reflected in the key economic risks for the region above if they are not a significant contributor to overall regional GDP. Primary industry is very important in the agricultural and horticultural areas of South Wairarapa (with agriculture, forestry and fishing contributing 8.7% to Wairarapa GDP, Infometrics 2023) and will have a higher risk and associated impacts when considered at a district level.

More and longer **dry spells and drought weather** pose a risk to the productivity of pastoral farming, horticulture, viticulture and drive the risk of increasing **fire-weather** conditions which will impact the forestry industry and subsequently impacting local economic activities. Seasonal rainfall is expected to decrease in Spring by 5% for the eastern Wellington Region by 2040, resulting in increased risk of **drought.** In particular, the Wairarapa will be increasingly dryer with up to 10% reduction in seasonal rainfall in spring, summer and autumn in 2090. Agricultural water is already fully allocated in the Wairarapa, and the Wairarapa Economic Growth Strategy estimates water scarcity will reach crisis proportions by 2040 (Wairarapa Economic Development Strategy, 2022 - 2030). It is expected there will be significant economic impacts for the agricultural sector in the Wairarapa in the future as competition for water for irrigation increases. However, studies have shown that grapes have very high adaptive capacity in conditions of drought and so increasing dry spells in the eastern region may have a positive impact on the quality of grapes, enhancing economic productivity in the viticulture sector (however other factors such as supply chain costs etc will also play a part on whether this positive economic impact is realised).

Increasing frequency and duration of dry spells and warmer temperatures increase the chance of **forest fire**. In particular, large tracts of forestry in the Wairarapa support the local economy and if subject to fire damage will cause local economic impacts associated with direct loss of productive forest and loss of wages for people employed in the local industry. Not only can forest fires be deadly, forest fires can have far reaching economic impacts if property or infrastructure is damaged or even indirectly through poor air quality and reduction in tourism. Forest fires adjacent to roads may also restrict commutes for work or transport of goods within the Wellington Region, resulting in loss of income for those who need to be physically present at their place of employment (such as those employed in manufacturing).

Flooding will impact the low-lying industrial areas of Lower Hutt, Porirua, and Miramar in Wellington City. There are approximately 1,170 industrial buildings in the Wellington Region that are at risk from flooding and coastal inundation by end century, including the low-lying industrial areas of Lower Hutt (approximately 445 buildings), Porirua (approximately 145 buildings), Miramar (Wellington City, approximately 110 buildings). In addition to industrial buildings and land directly impacted, there may be industrial areas where access may be inhibited due to **flooding** of roads. There is a lack of information on who is directly employed in industrial areas and the exact nature of business and so it is not possible to quantify economic impacts. The adaptive capacity of industrial land to flooding hazard is typically low as it is difficult to find alternative suitable (flat, away from residential areas) hazard free locations. There will be potential economic impacts associated with a decline in production from these industrial sites from more frequent flooding and personal income losses for wage earners employed in this industry (from temporary closures). These impacts may cascade further into the natural environment due to releases of contaminants from flooded industrial areas.

Governance Risks

Governance risks and opportunities refer to the architecture and processes in and between governments, iwi and hāpu, and economic and social institutions. Institutions hold the rules and norms that shape interactions and decisions, and the agents that act within their frameworks.

Effective governance in a rapidly changing and uncertain world in the face of climate change will require a shift from our current relatively static approaches to a proactive approach. The most significant governance risks for the Wellington Region are shown in Table 6.

Table 6: Governance Risks

Risk ID	Risks	Rating
Gov. Risk 1	The inability of the institutional arrangements to be applied to the increasing complexity of climate change impacts, including their cascading and compounding effects	Extreme
Gov. Risk 3	Weak central / local government relationship driven by conflicting priorities from central government including political change, lack of continuity of political leadership, numerous points of adaptation entry for local government and central government creating barriers to adaptation action	Major
Gov. Risk 4	Failure of coordination between local government agencies and with central government due to a short-term focus on local jurisdictional interests and the 3-year electoral cycle	Major
Gov. Risk 2	Inadequate council partnership and engagement mechanisms with iwi, hapū and iwi / Māori	Major
Gov. Risk 6	Ongoing uncertainty, slow adaptation and potential maladaptation and litigation arising from slow implementation of the resource management law reform	Major

Summary of Regional Findings

The following is a summary of the assessment by domain. The summary below indicates the key risks and their associated impacts by domain and where in the region they are most significant. It is noted that the detailed assessments of risks and their associated impacts was constrained by the availability of regionally consistent data.

Built Environment Impacts

- Increased **sea levels** will drive an increase in the persistence, frequency and magnitude of coastal and estuarine flooding. The impacts of coastal erosion on **buildings** and facilities are significant across the region, with Wellington City, Porirua City and Kāpiti Coast District particularly vulnerable to erosion of cliffs and beaches, which is exacerbated by rising sea levels. This will significantly impact the built environment in Wellington City CBD, large portions of Lower Hutt City and buildings near and around Lake Wairarapa.
- **Flooding** of rivers and streams as well as surface water flooding driven by increasingly intense rainfall is one of the most significant climate risks to **buildings** across the Wellington Region. The key areas that will be impacted the most by flooding are Petone, where the stormwater system is already under pressure, suburbs in Wellington City including the CBD and historical infill areas Miramar and Kilbirnie, and parts of Porirua such as the CBD and recreational areas.
- **Landslides** will have an impact on road and rail transport as well as buildings around the region, causing disruption to travel, costly repairs / recovery and potential impacts on health and safety. Wellington region's hilly topography, particularly in and around Wellington City, means there have been shifts in the natural landscape to accommodate the development of housing and transport routes. These shifts, combined with natural challenges to slope stability and increasingly intense rainfall put buildings and transport infrastructure at risk. Impacts will be most severe in Wellington City where many roads are already exposed to landslides and over 25 roads are at high present day risk (considering both exposure as well as vulnerability), and it is expected that approximately 990 roads and over 50 railway locations will be impacted by the end of the century. A landslide assessment has shown thousands of buildings in Wellington City will also likely be impacted by the end of the century.

Economic Impacts

- The public services sector is a key economic sector for the Wellington Region and whilst the risk of **international influences** on the public sector is scored 'high' risk in the future, the impact will be major given the contribution of the public services sector to the Wellington Region GDP. There will also be high risks to insurance coverage in the future due to more frequent and damaging **extreme weather events**.
- More and **longer dry spells and drought weather** pose a risk to the productivity of pastoral farming, horticulture, viticulture and drive the risk of increasing fire-weather conditions which will impact the forestry industry. The direct impacts will be concentrated where there are large tracts of agricultural and forestry land, such as in Wairarapa and Kāpiti Coast, while the indirect impacts of reduced productivity and loss of income may be felt around the Wellington Region.
- During workshops council staff noted the particular vulnerability of industrial land across the region as it is not easy to find suitable alternative industrial land. The risk of **coastal and estuarine flooding** to existing low lying industrial areas in the Wellington Region is high given the low adaptive capacity of industrial land. Flooding will impact the low-lying industrial areas of Lower Hutt, Porirua and Miramar in Wellington City. This will have impacts on the manufacturing sector, including those employed in the manufacturing sector, in particular.

Natural Environment Impacts

- Impacts to Wellington Region's coastal ecosystems due to **sea level rise** vary across the region but are most prevalent within harbours, estuaries and river mouths where the most vulnerable ecosystems are found. For example, Pāuatahanui Inlet in Porirua, dunelands at Lake Ōnoke in Wairarapa and the eastern Wairarapa coastline are most likely to be impacted by changing sea levels. More frequent inundation of low-lying river mouths and estuaries in Lower Hutt and Porirua will have cascading impacts on wader bird habitats and migrant coastal birds.

- A range of forest types are supported by the Wellington Region's diverse geography. The western part of the region has extensive tracts of native forest ecosystems and increasing temperatures of 2ºC or more could change forest composition and distribution. Coupled with increased wildfire risk and soil moisture deficits these endangered forest ecosystems are at extreme risk of being lost along with associated ecosystem services and habitat provision. The most pronounced impacts will be in the South Wairarapa, Carterton and Masterton districts where the greatest change in temperature and soil moisture deficits are likely to occur.

Human Impacts

- The human / social impacts of climate change are often indirect and may occur together within the same community. Many social impacts will be similar no matter the specific climate driver.
- The impacts of these climate drivers can cause the breakdown of communities and social bonds within them (social cohesion) and to places of importance (cultural heritage) as well as impacting how quickly communities may recover from extreme events. There is a lack of social vulnerability information to quantify where the particular impacts will be greatest across the region. However, the social impacts of climate change will be felt around the region, with bisected, fragmented or cut off communities, such as those with single access roads, and lower socio-economic communities likely to experience more severe impacts.
- Social cohesion and cultural heritage are at risk due to **flooding** and **coastal erosion** and existing inequities will be exacerbated by flooding and coastal erosion driven by sea level rise.

1 Introduction

1.1 Purpose

The Wellington Region is prone to ongoing changes in the climate and many natural hazards which are likely to be exacerbated by climate change. To support the Wellington Region to transition to a low-carbon future that is resilient to climate impacts, the Wellington Regional Leadership Committee has commissioned a Wellington Regional Climate Change Impact Assessment (WRCCIA). The assessment is intended to offer insights into potential risks and impacts associated with climate change across the Wellington Region, in a regionally consistent method, at both regional and local authority scales.

The WRCCIA involved a qualitative assessment of the potential climate change risks and their impacts across the region, followed by a more detailed assessment of selected risks and impacts (quantified where data allowed) to the specific elements of the built environment, natural environment, human domain and the economy.

The purpose of this WRCCIA is to support climate change adaptation planning activities across the region, including the Wellington Regional Climate Change Adaptation Plan that will be developed by the Wellington Regional Leadership Committee in 2024. The WRCCIA can be used to inform decision making across the region. However, due to the evolving nature of climate science and the potential for unforeseen events, the actual outcomes of climate change impacts may differ from those described in this assessment. Therefore, users of this assessment are cautioned against making decisions solely based on the information provided herein. Decisions related to planning and investment, adaptation, and policy-making should consider a wide range of sources, expert opinions, and ongoing research.

1.2 Scope of the Assessment

As shown by the map below (Figure 4), the assessment covers the geographic area of the nine councils in the Wellington Region. The assessment provides an analysis of the risks and impacts of climate change on social, environmental, cultural, and economic issues over the coming century that are likely to affect the region. In addition, the indirect, cascading and compounding risks and associated impacts have been considered as well as transition risks (those risks caused by a rapid shift to a low carbon economy) and governance risks.

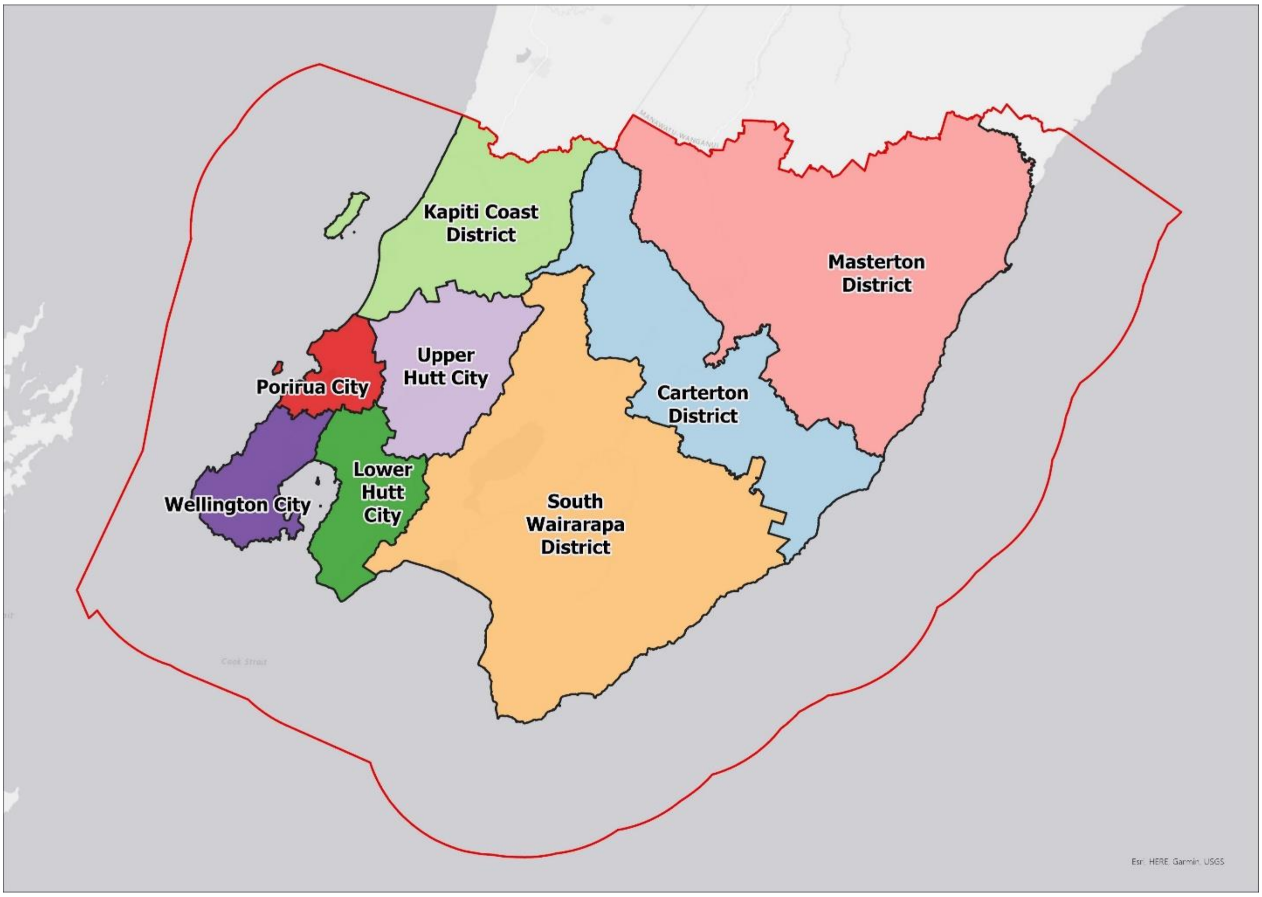


Figure 4: The Wellington Region with Council Partners of the WRCCIA. Contains Data from LINZ, Stats NZ, Eagle Climate Projections for Wellington Region Technology, Esri, HERE, Garmin, FAO, METI / NASA, USGS

1.3 Structure of this Report

The WRCCIA report is structured into four parts as shown and described below:

- **Part A** provides an overview of the methodology for the WRCCIA. A full description of the methodology is provided in *Wellington Regional Climate Change Impact Assessment Methodology Framework (8 June 2022)*
- **Part B** of this report provides background to and commentary on the Qualitative Assessment stage of the WRCCIA. This report is intended to be read with reference to the WRCCIA Qualitative Climate Risk Register (**Appendix A**)
- **Part C** of this report covers the Prioritisation stage of the project, including the process for how risks / impacts were selected for Detailed Assessment
- **Part D** of this report covers the results of the Detailed Assessment. Appendix C and Appendix I covers the limitations and data gaps encountered within district and regional information within the study and assumptions made in the assessment.

Appendices provide additional information about the process of the analysis, data sources and details of the analysis, as follows:

A. Qualitative Climate Risk Register
B. Glossary
C. Limitations and Assumptions
D. Maps
E. Methodology Summaries and Workshop Details
F. Cascading Impacts
G. Climate Driver & Elements at Risk Tables
H. Scoring Considerations – Direct & Indirect Risk / Impacts
I. Details of Detailed Assessment (Data & Assumptions)

Part A – Methodology Summary

2 Climate Change Risk and Impact Assessment Methodology

The WRCCIA methodology, outlined in this section, is aligned with best practice risk assessment methodology guidance, including:

- National Climate Change Risk Assessment (NCCRA, 2020);
- Ministry for the Environment (MfE) Guidance for Local Climate Change Risk Assessments; and,
- ISO14091 Standard (2021).

It involves an assessment of the potential climate change risks and their impacts across the region within the five value domains in the MfE guidance; natural environment, built environment, human, economy, and governance. This has been followed by a more detailed assessment of selected risks and associated impacts to specific elements in the domains.

The assessment offers insights into potential risks and associated impacts with climate change across the Wellington Region, and specific considerations at local authority level. 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 completely eliminated. Appendix C documents the limitations and assumptions used in this assessment. Appendix I contains specific data and assumptions used in the detailed assessment of risks and impacts.

A full description of the methodology is provided in the *Wellington Regional Climate Change Impact Assessment Methodology Framework* Report (8 June 2022). Further details on methodology workshops are in Appendix E.

2.1 Climate Change Scenarios and Timeframes

In alignment with the projections in the NCCRA framework and MfE guidance, the climate change scenarios used for this assessment were derived from the four representative concentration pathways (RCPs) used by the Intergovernmental Panel on Climate Change (IPCC) in its fifth Assessment Report, AR5 (IPCC, 2014). These scenarios are presented in **Error! Reference source not found.**5**Error! Reference source not found.**.

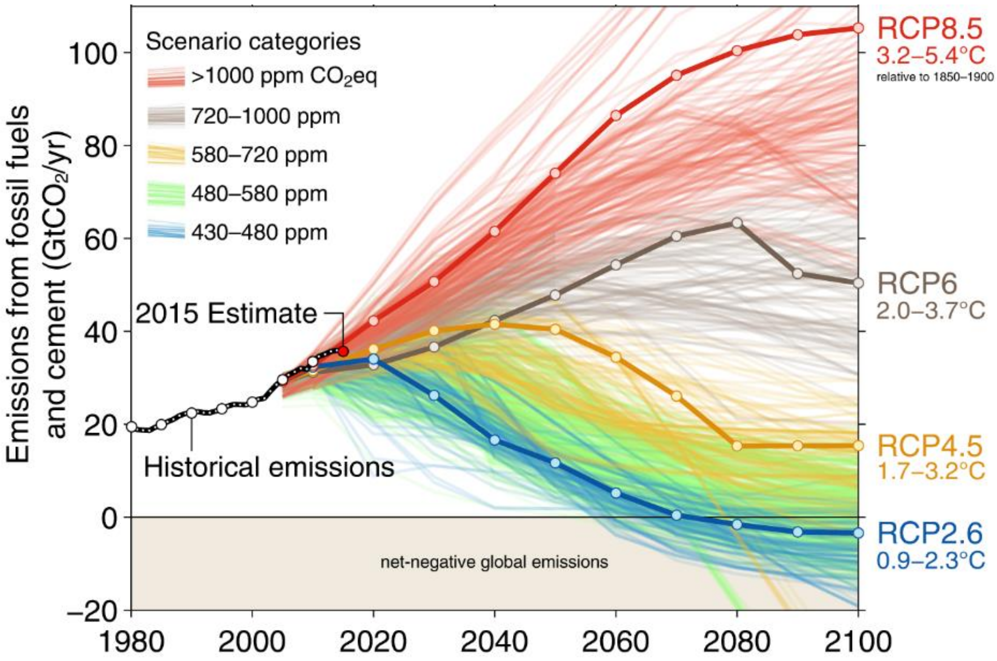


Figure 5: RCP Scenarios Showing Annual Emissions per Year

Further details on the selection of the climate change scenarios used in the assessment is in Appendix E.

2.1.1 Scenarios for Physical Risk and Opportunities Assessment

For the physical risk and opportunities assessment, two RCP scenarios were used, RCP4.5 and RCP8.5:

- **RCP 4.5:** This is a lower mid-range scenario, where greenhouse gas emissions are stabilised. It leads to a range of mean annual temperature projected across New Zealand of 0.5 - 1.0°C by 2031 – 2050 and 0.7 - 1.7°C by 2081 – 2100 (NIWA, 2017a). The RCP 4.5 scenario is useful to identify risks under a more realistic ambitious reduction pathway, where emissions peak around 2040 and then decline.
- **RCP 8.5:** This is a 'high-end' emissions scenario with high global emissions. It leads to a range of mean annual temperature projected across New Zealand of 0.6 - 1.2°C by 2031 – 2050 and 2.0 - 3.2°C by 2081 – 2100 (NIWA, 2017a). The RCP 8.5 scenario is useful to identify the most significant risks if warming continues unabated. The RCP 8.5 'high-end' scenario is a worst-case assumption for a risk assessment (Hausfather, 2019)).

2.1.2 Scenarios for Transition Risk and Opportunities Assessment

For the transition risk and opportunities assessment, RCP4.5 and RCP8.5 were used along with an additional, 'swift transition' scenario, RCP2.6:

- **RCP2.6:** this scenario represents a swift transition to a carbon-neutral economy, with strict policy changes to reduce emissions that lead to net-negative global emissions by 2070. Mean annual temperature increases in the Wellington area are limited to 0.4 - 0.9°C by 2031 - 2050 and 0.2 - 1.0°C by 2081 - 2100 (MfE, 2018). This scenario represents the extreme in transition risk and is used to test an organisation's transition resilience.

2.1.3 Timeframes

Three main timeframes were used assessing physical and transition risks and opportunities from climate change. There is a fourth timeframe for coastal hazard risks resulting from rising sea levels (MfE, 2021a).

Present day (1986 - 2005): The impacts already occurring from climate change are a starting point for considering the urgency of the risks identified. This is also a useful starting point when seeking feedback, before considering future impacts.

Mid-century (2031 - 2050): This covers the next few cycles of council long-term plans, and 30 years is the planning timeframe for local government infrastructure strategies (Local Government Act 2002, section 101B) and asset management plans. It also aligns with the longer terms granted for resource consents (up to 35 years).

End-century (2081 - 2100): Typically used as the juncture for detailed climate change projections. A limitation of this timescale is that some decisions (e.g. land-use planning) require at least 100-year timeframes. However, this timeframe enables projections for a wide range of climate variables without the need for extrapolation.

2150: For coastal hazard risks related to sea-level rise, given that:

- The *New Zealand Coastal Policy Statement 2010* has a requirement to assess coastal hazard risks (including climate change) to “at least 100 years”
- A set of New Zealand-specific sea-level rise projections to 2150 is available in the *Coastal Hazards and Climate Change Guidance for Local Government* (MfE, 2017, p 105, Figure 27)
- Regional coastal flooding risk exposure mapping has been completed for coastal areas with up to five metres of sea-level rise (GWRC, 2021)
- The NZSeaRise results were recently released (May 2022) providing vertical land motion and sea-level rise projections for this timeframe around the New Zealand coast (NZSeaRise, 2022). MfE guidance (2017) recommends accounting for vertical land motions in future projections.

2.2 Identification of Climate Hazards

Climate hazards and the associated climate related variables (or drivers) have been pulled from the NCCRA to align the regional approach with the national approach. The relative importance of each hazard, and the way they combine to create compounding risks, is determined through the risk screening and scoring process. Table 8**Error! Reference source not found.** presents the climate hazards that are considered in the WRCCIA.

Table 86: Climate Hazards Considered in the WRCCIA

Hazard (Arising from Climate Change)	Primary Climate-Related Variables	Secondary Climate-related Variables
Higher mean temperatures: air and water	• Higher day and night temperatures • Higher mean water (freshwater and marine) temperatures	• More heatwaves and warm spells • Fewer frosts or cold days
Heatwaves: increasing persistence, frequency and magnitude	• Higher day and night temperatures • Increase in persistence of maximum daily temperatures above 25°C	• Changes in seasonal winds • Humidity changes from changes in cloudiness
More and longer **dry spells** and **drought**	• Low seasonal rainfall • Change in seasonal wind patterns • Interannual variability (eg, ENSO)	• Higher day and night temperatures
Changes in climate seasonality with longer summers and shorter winters	• Fewer frosts or cold days • Higher day and night temperatures • Changes in seasonal rainfall	• Changes in seasonal wind
Increasing **fire–weather** conditions: harsher, prolonged season	• Low seasonal rainfall • Change in seasonal wind patterns	• Higher day and night temperatures • Interannual variability (e.g., ENSO)

Hazard (Arising from Climate Change)	Primary Climate-Related Variables	Secondary Climate-related Variables
	• Increase in persistence of maximum daily temperatures above 25°C • Humidity changes from changes in cloudiness	
Increased **storminess and extreme winds**	• Increase in storminess (frequency, intensity) including tropical cyclones • Changes in extreme wind speed	• Changes in wind seasonality • Interannual variability (e.g., ENSO) • Increase in convective weather events (tornadoes, lightning)
Change in **mean annual rainfall**	• Higher or lower mean annual rainfall in sub-national climate zones • Changes in seasonal winds	• Humidity changes from changes in cloudiness
Reducing **snow and ice cover**	• Higher day and night temperatures • Changes in rainfall seasonality • Change in seasonal wind patterns • Receding snowline • Reduced snow and glacier cover • Earlier snow melt	• Increase in avalanches • Interannual variability (e.g. ENSO)
Increasing **hail** severity or frequency	• Increase in hail severity or frequency • Increase in convective weather events (tornadoes, lightning)	• Humidity changes from changes in cloudiness
River and pluvial flooding: changes in frequency and magnitude in rural and urban areas	• Changes in extremes: high intensity and persistence of rainfall • Increase in hail severity or frequency • Interannual variability (e.g. ENSO) • Increased storminess and wind • Relative sea-level rise (including land movement) • Rising groundwater from sea-level rise	• Humidity changes from changes in cloudiness • Changes in rainfall seasonality • Change in seasonal wind patterns • More and longer dry spells and droughts (antecedent conditions)
Coastal and estuarine flooding: increasing persistence, frequency and magnitude	• Relative sea-level rise (including land movement) • Change in tidal range or increased water depth • Permanent increase in spring high-tide inundation • Rising groundwater from sea-level rise • Changes in extremes: high intensity and persistence of rainfall • Increase in storminess (frequency, intensity) including tropical cyclones	• Changes in waves and swell • Changes in extreme wind speed • Changes in sedimentation (estuaries and harbours)

Hazard (Arising from Climate Change)	Primary Climate-Related Variables	Secondary Climate-related Variables
Sea-level rise and salinity stresses on brackish and aquifer systems and coastal lowland rivers	• Relative sea-level rise (including land movement) • Permanent and episodic (low river flow) saline intrusion • Low seasonal rainfall • Rising groundwater from sea-level rise • Permanent increase in spring high-tide inundation	• Changes in sedimentation (estuaries and harbours) • Interannual variability (eg, ENSO)
Increasing **coastal erosion:** cliffs and beaches	• Relative sea-level rise (including land movement) • Changes in waves and swell • Changes in extreme rainfall: high intensity and persistence • Changes in sedimentation from catchment run-off • Increased storminess and extreme winds • Interannual variability (eg, ENSO)	• Rising groundwater from sea-level rise • Changes in rainfall seasonality • Change in seasonal wind patterns
Increasing **landslides and soil erosion**	• Changes in extreme rainfall: high intensity and persistence • Changes in rainfall seasonality • More and longer dry spells and droughts (antecedent conditions)	• Interannual variability (eg, ENSO)
Marine heatwaves: more persistent high summer sea temperatures	• Higher mean ocean temperatures • Increase in persistence of maximum daily temperatures e.g. above 25°C • Change in seasonal wind patterns • Ocean circulation changes	• Interannual variability (eg, ENSO) • Changes in waves and swell
Ocean chemistry changes: nutrient cycling and pH changes	• Changes in ocean nutrient cycling – upwelling and carbon • Ocean acidification (pH decreasing) • Higher mean surface-water temperatures • Change in seasonal wind patterns	• Ocean circulation changes • Interannual variability (eg, ENSO)
International influences from climate change and greenhouse gas mitigation preferences	• Immigration • Markets (pricing, preferences) • Pacific Island countries (disaster responses, development)	

2.3 Regional Climate Change Projections

NIWA's 2019 report *Wellington Region climate change extremes and implications* and 2017 report *Climate change and variability – Wellington Region* explore projections for a number of climate factors that could pose hazards to the Wellington region. They both consider the climate scenarios used in this risk assessment (RCP4.5 and RCP8.5) in mid-century and end-century.

Annual mean temperature is projected to increase, particularly in inland areas, with an increase of 1.2°C under RCP4.5 and 2.7°C under RCP8.5 in 2090. Additionally, the daily temperature range is expected to increase across the region.

The number of hot days (T_{max}>25°C), extreme hot days (T_{max}>30°C) and heatwaves (>3 consecutive days T_{max}>25°C), is projected to increase across the region. The western side of the region is expected to experience the largest increase in hot days, extreme hot days and heatwaves in both climate scenarios and in mid-century and end-century with up to 25 more extreme hot days and 70 more heatwave days for parts of the Wairarapa in 2090 under RCP8.5.

Changes in the **annual number of days with more than 20mm of rainfall** varies across the region. Areas currently experiencing high numbers of days with >20mm rainfall will have a reduction in number of days, such as the Tararua and Remutaka ranges and South Wairarapa. The eastern areas are projected to have a maximum increase of 4 days with >20mm of rain in 2090 under RCP8.5.

Conversely, areas currently experiencing **fewer rain days** and lower levels of rain during extreme rainfall events, such as central Wairarapa and the southwest (Wellington City and Hutt Valley) are projected to have more frequent lengthy dry spells. The entire region, apart from the Tararua Ranges, is projected to experience an increase in drought frequency while inland Wairarapa will experience the greatest Potential Evapotranspiration Deficit, making it more drought prone in the future.

The number of **snow days** will reduce across the region and high elevation areas in the Tararua Ranges where there are the largest number of snow days will experience the largest decreases.

The number of **windy days** is projected to increase across the region with over eight more days per year expected for the central and southern parts in 2090 under RCP8.5.

For more detailed information on projected climate change in the Wellington Region (e.g. number of hot days, wet days, sea-level rise) refer to the national / regional information provided by NIWA (2017, 2019, and within the GWRC website[2]) and MfE (2018) which downscale and distil the international guidance from the various Intergovernmental Panel on Climate Change (e.g. IPCC 2022 WG1 Physical Science Basis) to the Wellington Region.

2.4 Process of the Assessment

The WRCCIA was undertaken in 3 key stages:

Phase 1 – Risk Screening and Qualitative Assessment

This phase involved an initial screening of relevant risks for the Wellington Region, removing risks that will never eventuate, such as the risk of ocean chemistry changes to terrestrial ecosystems.

Screened risks were developed into risk statements and included in a comprehensive Risk Register (Appendix A). These risks were scored through a combination of workshops with key stakeholders and SME knowledge.

Phase 2 – Priority Risks Assessment

A 'prioritisation' of the over 300 risks identified for the Wellington Region was undertaken to reduce the number for a detailed assessment of risk and impact.

Phase 3 – Detailed Assessment of Prioritised Risks

[2] https://mapping1.gw.govt.nz/gw/ClimateChange/

A deeper dive into selected risks was undertaken. This detailed assessment stage was to try to quantify impacts where possible using a GIS viewer and available literature. The extent of the data gaps (see Data Gap Report dated 10 August 2023) meant that the detailed assessment was mostly qualitative.

2.4.1 Phase 1: Initial Screen and Qualitative Assessment

The first step in the qualitative assessment was an initial risk screening by SMEs to identify whether or not elements-at-risk, within the natural environment, human, built environment and economic value domains, will be exposed to a climate hazard or stressor under a 2100 'high end' emissions scenario (RCP8.5).

The definitions of the value domains is provided below.

Oranga Whenua	**Natural Environment**	All aspects of the natural environment that support the full range of our indigenous species, he kura taiao (living treasures), indigenous & taonga species, and the ecosystems in terrestrial, freshwater and marine environments.
Oranga Tangata	**Human**	People's skills, knowledge, and physical and mental health (human); the norms, rules, and institutions of society (social); and the knowledge, heritage, beliefs, arts, morals, laws, and customs that infuse society, including culturally significant buildings and structures (cultural).
Taiohanga	**Built Environment**	The set and configuration of physical infrastructure, transport, and buildings sectors including housing, public amenity, water, wastewater, stormwater, energy, transport, communications, waste and coastal defences.
Whairawa	**Economy**	The set and arrangement of inter-related production, distribution, trade, and consumption that allocate scarce resources.
Kāwanatanga	**Governance**	The governance architecture and processes in and between governments, and economic and social institutions. Institutions hold the rules and norms that shape interactions and decisions, and the agents that act within their frameworks.

Although the focus of the initial risk screening was on direct risks, indirect risks were also considered in this initial binary (yes or no) screen, with the screening tables used to focus discussion and conversation with workshop attendees.

Preliminary lists of governance and transition risks were also developed by SMEs and discussed then confirmed with council representatives throughout the workshop process. Refer to Appendix E for further details on the risk screening process.

Once the risks were screened a Risk Register (Appendix A) was established and risks were qualitatively assessed, along with a consideration of associated impacts. The process of assessing climate change risks started with understanding the *exposure* of a particular *element-at-risk* to an identified climate change driver.

Table 9 presents the elements-at-risk included within each domain. Considerations and definitions of each element-at-risk are in Appendix D.

Table 9 7: Elements-at-Risk in the Five Domains

Domain	Element
Natural Environment Oranga Whenua	Indigenous & Taonga Species
	Terrestrial & Forest Ecosystems, Services and Processes
	Wetland Ecosystems, Services and Processes
	Coastal Ecosystems, Services and Processes
	Freshwater Ecosystems, Services and Processes
Human Oranga Tangata	Human health
	Social cohesion and community wellbeing
	Existing inequities
	Social infrastructure and amenities
	Cultural heritage
	Sports and recreation
Built Taiohanga	Airports and Seaports
	Buildings and Facilities (public and private)
	Energy
	Flood and Coastal Defences
	Transport (Road and Rail)
	Solid Waste Management
	Communications
	Drinking water
	Stormwater infrastructure
	Wastewater infrastructure
	Marae and cultural sites, Māori owned assets

Domain	Element
Economy Whairawa	Forestry
	Horticulture
	Viticulture
	Fisheries
	Pastoral Farming
	Tourism
	Public Services (including government, scientific research, and education)
	Insurance coverage and credit provision
	Māori Enterprise
	Information technology and creative industries
Governance Kawanatanga	Partnership Strategy and Framework with Iwi and hapū
	All governing and institutional systems
	Legislation and Policy
	Climate related Litigation
	Emergency Management

The vulnerability of an element encompasses the *sensitivity* to harm and *adaptive capacity* of the element to respond to climate pressures. Each of these components inform the final risk scoring (see Appendix A for risk scoring). The *impact* is then determined considering the risk and its potential consequences. This approach is presented in **Error! Reference source not found.**6.

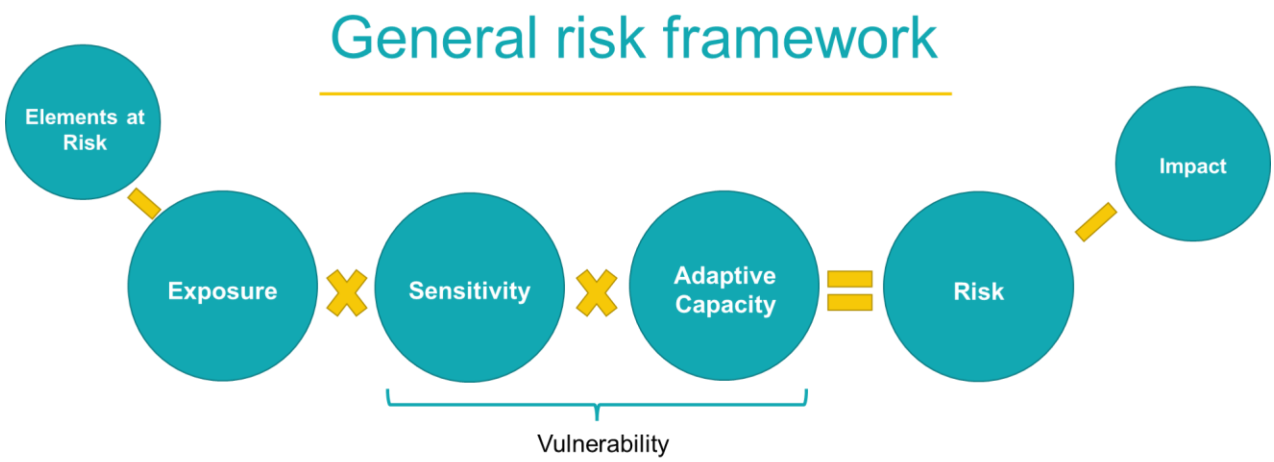


Figure 6: Risk Assessment Framework. Adapted from MfE's Guide to Local Climate Change Risk Assessments (2021)

A single climate driver / hazard may initially have a **Direct** risk and associated impact on an element (e.g. the risk to a wastewater pipe from increased coastal erosion). However, it is well understood that climate-driven risks do not occur in isolation, and a single climate driver / hazard can have ramifications across multiple value domains outside of the initial direct impact (e.g. the impact on community wellbeing from the loss of wastewater services). These types of risks can be classified as **Indirect** risks or impacts.

Governance-related risks are distinct because they are crosscutting and indirect, emerging from other domain risks. Indirect risks also include **Compounding** risks which are the overlapping of risks to a specific element (e.g. the coastal erosion also damages telecommunications and gas supplies or coastal inundation combined with pluvial flooding to exacerbate flooding risk on buildings), and **Cascading** risks which are dynamic sequence of interrelated risks (e.g. the businesses which are dependent on the gas supply that has been damaged experience financial hardship and have to lay off workers which then has a social impact).

Risks to the Wellington Region may also emerge from the transition to a lower-carbon global economy and a climate resilient community. This may entail extensive policy, legal, technology and market changes to address mitigation and adaptation. Such **Transition** risks include higher pricing of greenhouse gas (GHG) emissions or costs of transitioning to lower emissions technology (Task Force on Climate-related Financial Disclosures, TCFD, 2017) and the implementation of climate change adaptation plans. Transition risks may combine with physical risks to affect different sectors.

The Qualitative Assessment covers Direct, Indirect, Governance, Transition, Cascading, and Compounding risks. An example is shown in Figure 7.

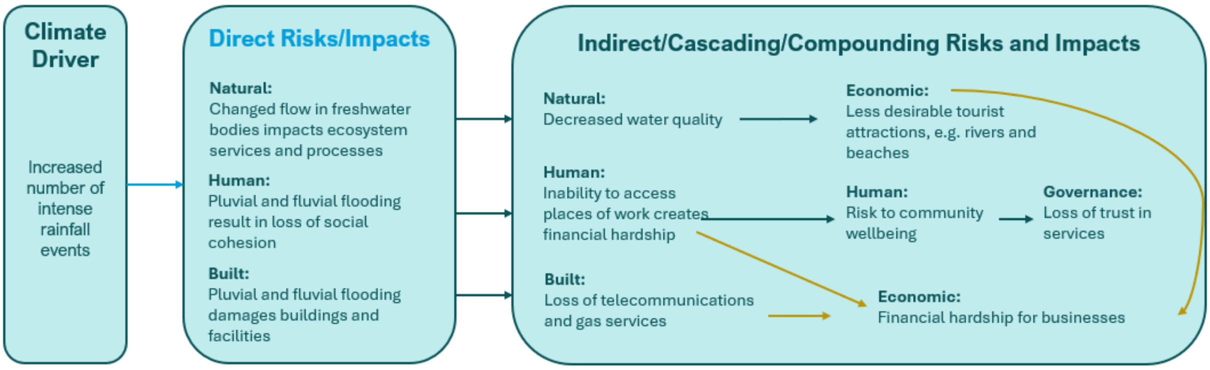


Figure 7: Example of Risk and Impact Types Assessed

2.4.2 Prioritisation for Detailed Assessment

Prioritisation of risks was undertaken in workshops with council representatives with the aim of reducing the number of risks and impacts considered in the detailed assessment. Prior to these workshops, an impact and uncertainty assessment was undertaken by SMEs for all risks and opportunities assessed in the qualitative risk assessment.

Selection of the risks for the detailed assessment required balancing of many factors in combination with the qualitative risk assessment ratings. Factors that were considered throughout the workshop process include:

- Primary risk rating (exposure, vulnerability) in relation to timeframe from the qualitative assessment stage (with higher consequence scores being given additional weight)
- Level of uncertainty of the risk (i.e. how much evidential basis supported the risk scoring)
- Specific location / community inequities or vulnerabilities that may drive a higher priority for further detailed assessment
- The ability for that risk to be assessed using quantitative and geospatial methods based on existing information sources (noting that the creation of new data is outside the scope of the WRCCIA)
- Whether pre-existing hazard studies are available spatially and supporting information on vulnerability to inform the impacts assessments.

The impacts with the highest primary risk ratings were determined via progressively sorting within each domain, based on the following order:

1. Risk score at 2100, RCP8.5.

2. First pass impact score.
3. Risk score at 2100, RCP4.5.
4. Risk score at 2050, RCP8.5.
5. Risk score at 2050, RCP4.5.
6. Risk score at present day.

A list of the top 50 risks / impacts (top 10 from each of the five domains) was included in the workshops for consideration. However, the level of detail of the assessment for selected risks was dependent on the data available, so the risks / impacts with the highest risk ratings were not automatically selected for the detailed assessment (as described above).

2.4.3 Detailed Assessment

The aim of the detailed risk assessment was to further quantify (where data permits) the priority risks and associated impacts identified through the prioritisation process. In order to quantify risks and their associated impacts spatial information is needed on the level of exposure, the nature of the vulnerability and the extent of the impact. Using GIS analysis where data availability allowed enabled the SME team to evaluate the risks and impacts quantitatively. Where quantitative analysis wasn't possible, the risks and associated impacts were explored further with in depth qualitative analysis using available relevant studies and SME knowledge.

The process of undertaking a detailed assessment, for quantifiable risks is as follows:

- Select risk, noting dependencies
- Review data layers and identify limitations
- Determine target outputs and aggregation level
- Prepare input layers
- Determine hazard-vulnerability-risk relationship model
- Undertake analysis (using software platforms including ArcGIS and FME) [3]
- Develop a visual interface mock up for discussion and agreement with CPT
- Configure GIS to visualise and interact with risk and impact analysis.

The methodology of the detailed assessment is included in Appendix E.

.

[3] The Beca Methodology Report, 2022, notes that RiskScape® will be used for the analysis of risk for the WRCCIA in the detailed assessment stage. RiskScape® is a propriety tool developed by NIWA, GNS Science and Catalyst IT. RiskScape® requires specific data types and formats and the results are required to be transported for spatial display in tools such as GIS. Due to programme, lack of consistency in data across the region and requirement for substantial manipulation of existing datasets it was agreed with the CPT to use existing software platforms commonly used by the councils (ArcGIS).

Part B – Qualitative Assessment Findings

3 Initial Risk Screening

This section includes the results of the initial risk screening followed by the results from the qualitative risk assessment.

The results of the initial risk screening provide the basis for the qualitative risk assessment by identifying the potential risks across the Wellington Region. Table 10**Error! Reference source not found.** displays the number of risks identified through the initial risk screening for the natural environment, human, built environment and economic value domains. Risks that were originally 'screened out' but received substantial commentary throughout the workshop process have been included as they were identified as relevant to the Wellington Region, along with opportunities. These risks and opportunities were collated into a risk register for the qualitative risk assessment (see Appendix A).

Table 10 8: Elements-at-Risk in the Initial Risk Screening

Value Domain	Number of Risks	Number of Opportunities
Natural Environment	73	2
Human	69	4
Built Environment	128	
Economy	93	5
Governance	6	
Transition	5	1
Total	**363**	**12**

Whilst the initial risk screening has identified the largest number of potential risks associated with the built environment, this is due to there being many different built elements at risk and this is not indicative of the scale of risks (this is addressed in the Risk Register, Appendix A). All natural environment elements are potentially exposed to many different hazards.

The initial risk screen indicates that **elements** potentially at risk to the greatest number of total hazards (those that are potentially exposed to 13 or more hazards) include:

- Buildings and facilities (13 relevant hazards)
- Energy infrastructure (14 relevant hazards)
- Transport, road and rail (13 relevant hazards)
- Drinking water (13 relevant hazards)
- Wastewater infrastructure (13 relevant hazards)
- Indigenous species (16 relevant hazards)
- Terrestrial and forest ecosystems (16 relevant hazards)
- Wetland ecosystems (13 relevant hazards)
- Coastal and marine ecosystems (15 relevant hazards)
- Freshwater ecosystems (14 relevant hazards)
- Human Health (16 relevant hazards)
- Existing Inequities (14 relevant hazards)
- Public services (14 relevant hazards)
- Māori enterprise (13 relevant hazards) *

**Information from the BERL 2018 report on Māori Economy in the Greater Wellington region has been used for the screening. Māori enterprise in the Greater Wellington Region has many dimensions. The BERL report considers the Māori population (employment and income), Māori business, Māori collective assets as well as Māori freehold land as Māori enterprise.*

The results indicate that the **climate hazards** likely to pose risk across the widest range of elements include:

- River and pluvial flooding
- Coastal and estuarine flooding
- Sea-level rise
- Increasing coastal erosion
- Increasing landslides and soil erosion.

3.1.1 Natural Environment Domain | Oranga Whenua

Results from the initial risk/opportunity screen for the natural domain indicate that higher mean air temperatures, change in seasonality, storminess and extreme winds, coastal flooding, sea-level rise, and coastal erosion are potentially relevant hazards or stressors across almost all most natural elements at risk (Table 9). At the initial screening stage, indigenous and taonga species and terrestrial and forest ecosystems were identified as having the highest number of relevant hazards, closely followed by coastal and marine ecosystems. A change in climate seasonality was identified as a potential opportunity for indigenous species (i.e. those that prefer longer summers).

3.1.2 Human Domain | Oranga Tangata

Results from the initial screen for the human domain indicate that fire weather, river and pluvial flooding, coastal and estuarine flooding, sea level rise, coastal erosion and landslides are relevant risks across almost all most human / social elements at risk (Table 10). At the initial screening stage, the elements of Human Health, and Existing Inequities were human elements identified as having the highest number of potentially relevant hazards, these were closely followed by Social Cohesion and Community Wellbeing. There are opportunities identified for Human Health and Social Cohesion / Community Wellbeing associated with changing seasonality and increased air/water temperatures (and conversely less snow and ice) in consideration of many health concerns deriving from cold conditions and the enhanced ability to enjoy outdoor activities. However, this can also present a Human Health risk for those with underlying health conditions made worse by warmer temperatures.

3.1.3 Built Environment Domain | Taiaohanga

Results from the initial screen for the built environment indicate that flooding, coastal erosion, and landslide hazards are relevant across almost all built domain elements at risk (Table 11). At the initial screening stage, buildings and facilities, transport (road and rail), energy infrastructure, drinking water and wastewater infrastructure were identified as having the highest number of relevant hazards.

3.1.4 Economic Domain | Whairawa

Results from the initial screen for the economic domain indicate that storminess and extreme winds is a potential risk across almost all economic elements at risk (Table 12). At the initial screening stage, the primary industry sectors of Māori Enterprise, Public Services, Manufacturing and Tourism and Hospitality were identified as having the highest number of relevant hazards. Whilst Tourism and Hospitality had 12 potential hazards that are potential risks to that sector, it is noted that there were also opportunities for Tourism and Hospitality associated with higher mean air temperature, changes in climate seasonality and changes in mean annual rainfall (i.e. prolonged warmer and drier 'tourist weather'). Higher mean air temperatures can also present an opportunity for the forestry sector.

Table 9: Results of initial screening – Natural Environment Domain. Purple squares are 'yes' from the initial screening and grey squares are a 'no' from the initial screening. Pink squares were initially 'no' but added back to the risk register post-workshop and are counted as a relevant hazard for that element. Green stars indicate potential opportunities identified. Total hazards is a count of potential risks only (i.e. only purple or pink squares). It is noted in some instances an opportunity may be present in addition to a potential risk.

Natural Environment Oranga Whenua	Higher mean air temperatures	Higher mean water temperatures	Heatwaves	Dry spells and drought	Changes in climate seasonality	Increased fire weather	Storminess and extreme winds	Changes in mean annual rainfall	Decreases in snow and ice cover	Increasing hail severity	River and pluvial flooding	Coastal and estuarine flooding	Sea level rise (and slinity stresses)	Increasing coastal erosion	Increasing landslides and soil erosion	Marine heatwaves	Ocean chemistry changes	International influences & GHG mitigation	TOTAL HAZARD COUNT
Indigenous species	Purple	Purple	Purple	Purple	Grey ★	Purple	Purple	Purple	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Pink	**15**
Terrestrial and forest, ecosystems, services and processes	Purple	Pink	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Pink	Pink	Purple	Purple	Purple	Purple	Grey	Grey	Purple	**16**
Wetland, ecosystems, services and processes	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Purple	Purple	Purple	Purple	Pink	Grey	Grey	Grey	**13**
Coastal and marine ecosystems, services and processes	Purple	Purple	Pink	Pink	Purple	Pink	Purple	Grey	Grey	Pink	Purple	Purple	Purple	Purple	Grey	Purple	Purple	Pink	**15**
Freshwater ecosystems, services and processes	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Pink	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	**14**

Table 10: Results of Initial Screening – Human Domain. Purple squares are 'yes' from the initial screening and grey squares are a 'no' from the initial screening. Pink squares were initially 'no' but added back to the risk register post-workshop and are counted as a relevant hazard for that element. Green stars indicate potential opportunities identified. Total hazards is a count of potential risks only (i.e. only purple or pink squares). It is noted in some instances an opportunity may be present in addition to a potential risk.

Human Oranga Tangata	Higher mean air temperatures	Higher mean water temperatures	Heatwaves	Dry spells and drought	Changes in climate seasonality	Increased fire weather	Storminess and extreme winds	Changes in mean annual rainfall	Decreases in snow and ice cover	Increasing hail severity	River and pluvial flooding	Coastal and estuarine flooding	Sea level rise (and slinity stresses)	Increasing coastal erosion	Increasing landslides and soil erosion	Marine heatwaves	Ocean chemistry changes	International influences & GHG mitigation	**TOTAL HAZARD COUNT**
Human health	Purple	Purple ★	Purple	Purple	Purple ★	Purple	Purple	Purple	Grey ★	Pink	Purple	Purple	Purple	Purple	Pink	Pink	Grey	Purple	**16**
Social cohesion & community wellbeing	Grey ★	Grey	Pink	Pink	Grey	Purple	Purple	Grey	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Pink	**10**
Existing inequities	Purple	Grey	Pink	Pink	Purple	Pink	Pink	Pink	Grey	Grey	Pink	Pink	Pink	Pink	Pink	Purple	Grey	Pink	**14**
Social infrastructure & amenities	Grey	Grey	Pink	Purple	Grey	Purple	Grey	Purple	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Pink	**10**
Cultural & historic heritage	Grey	Grey	Grey	Grey	Pink	Purple	Purple	Grey	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Pink	Grey	Grey	**9**
Sports & recreation	Grey	Grey	Pink	Grey	Grey	Purple	Purple	Purple	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Pink	**10**

Table 11 Results of initial screening - Built Environment Domain. Purple squares are 'yes' from the initial screening and grey squares are a 'no' from the initial screening. Pink squares were initially 'no' but added back to the risk register post-workshop and are counted as a relevant hazard for that element. Total hazards is a count of potential risks only (i.e. only purple or pink squares).

Built Environment Taiohanga	Higher mean air temperatures	Higher mean water temperatures	Heatwaves	Dry spells and drought	Changes in climate seasonality	Increased fire weather	Storminess and extreme winds	Changes in mean annual rainfall	Decreases in snow and ice cover	Increasing hail severity	River and pluvial flooding	Coastal and estuarine flooding	Sea level rise (and slinity stresses)	Increasing coastal erosion	Increasing landslides and soil erosion	Marine heatwaves	Ocean chemistry changes	International influences & GHG mitigation	**TOTAL HAZARD COUNT**
Airports & seaports	Purple	Purple	Purple	Grey	Grey	Grey	Purple	Grey	Grey	Purple	Purple	Purple	Grey	Purple	Grey	Grey	Grey	Grey	**8**
Buildings & facilities (public and private)	Purple	Purple	Purple	Grey	Purple	Purple	Purple	Grey	Purple	Pink	Purple	Purple	Grey	Purple	Purple	Grey	Pink	Grey	**13**
Energy	Purple	Purple	Purple	Purple	Grey	Pink	Purple	Purple	Purple	Pink	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Purple	**14**
Flood & coastal defences	Pink	Grey	Grey	Pink	Grey	Grey	Purple	Purple	Grey	Grey	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Grey	**8**
Transport (road & rail)	Pink	Grey	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Pink	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Grey	**13**
Solid waste management	Pink	Pink	Pink	Pink	Pink	Purple	Pink	Purple	Grey	Grey	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Grey	**12**
Communications	Grey	Grey	Purple	Grey	Grey	Purple	Purple	Grey	Purple	Grey	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Grey	**8**
Māori assets	Purple	Grey	Purple	Grey	Grey	Purple	Grey	Grey	Grey	Grey	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Grey	**7**
Drinking water	Purple	Pink	Purple	Purple	Purple	Pink	Pink	Purple	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	**13**
Stormwater infrastructure	Pink	Purple	Pink	Purple	Grey	Pink	Grey	Purple	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	**11**
Wastewater infrastructure	Purple	Purple	Purple	Pink	Purple	Grey	Pink	Purple	Grey	Pink	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	**13**
Marae & cultural sites	Purple	Grey	Purple	Grey	Grey	Purple	Purple	Grey	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	**9**

Table 12: Results of initial screening – Economy Domain. Purple squares are 'yes' from the initial screening and grey squares are a 'no' from the initial screening. Pink squares were initially 'no' but added back to the risk register post-workshop and are counted as a relevant hazard for that element. Green stars indicate potential opportunities identified. Total hazards is a count of potential risks only (i.e. only purple or pink squares). It is noted in some instances an opportunity may be present in addition to a potential

Economy Whairawa	Higher mean air temperatures	Higher mean water temperatures	Heatwaves	Dry spells and drought	Changes in climate seasonality	Increased fire weather	Storminess and extreme winds	Changes in mean annual rainfall	Decreases in snow and ice cover	Increasing hail severity	River and pluvial flooding	Coastal and estuarine flooding	Sea level rise (and slinity stresses)	Increasing coastal erosion	Increasing landslides and soil erosion	Marine heatwaves	Ocean chemistry changes	International influences & GHG mitigation	TOTAL HAZARD COUNT
Forestry	Pink ★	Grey	Grey	Purple	Grey	Purple	Purple	Purple	Grey	Grey	Grey	Grey	Grey	Grey	Purple	Grey	Grey	Grey	**6**
Horticulture	Purple	Grey	Purple	Purple	Purple	Pink	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Grey	Grey	Grey	Grey	Grey	**9**
Viticulture	Grey	Grey	Purple	Purple	Purple	Grey	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Grey	Grey	Grey	Grey	Grey	**7**
Pastoral farming	Purple	Grey	Purple	Purple	Purple	Grey	Purple	Purple	Grey	Grey	Purple	Grey	Grey	Grey	Purple	Grey	Grey	Grey	**8**
Tourism & hospitality	Grey ★	Purple	Purple	Grey	Grey ★	Purple	Purple	Grey ★	Pink	Grey	Pink	Pink	Pink	Pink	Pink	Purple ★	Grey	Pink	**12**
Public services	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Purple	**14**
Insurance coverage & debt provision	Grey	Grey	Grey	Pink	Grey	Purple	Purple	Grey	Grey	Purple	Purple	Purple	Grey	Grey	Purple	Grey	Grey	Grey	**7**
Māori enterprise	Grey	Purple	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Grey	**13**
Manufacturing	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	Purple	Purple	Purple	Purple	Purple	Grey	Grey	Grey	**12**
IT & creative industries	Pink	Grey	Pink	Grey	Grey	Pink	Purple	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Pink	**5**

4 Qualitative Risk Assessment

The qualitative risk assessment took place through a series of five structured workshops (one for each domain) with council representatives and SMEs, in which participants were asked to discuss and document the exposure and vulnerability of each element-at-risk (as identified in the initial risk screening) to the climate hazards. Post-workshop, the SMEs used workshop outputs to produce scores for exposure and vulnerability in the climate scenarios and timeframes (see Section 22.1).

Further details on the workshop process and assessing exposure and vulnerability is included in Appendix E.

The following subsections present a qualitative description of regional risks (exposure and vulnerability) and impacts in each of the value domains and is based on available information (see Bibliography, Section 7). It is not intended to be an exhaustive assessment of all risks (as these are presented in the Risk Register in Appendix A) but provides discussion of where the elements may be most exposed across the region and the nature of vulnerability to inform the associated impact assessment. The top five risks and impacts identified through the qualitative assessment are assessed in more detail in Part 4 – Detailed Assessment.

4.1 Natural Environment Domain | Oranga Whenua

Domain Description

Natural Environment Oranga Whenua	Description
	All aspects of the natural environment that support the full range of our indigenous species, he kura taiao (living treasures), indigenous & taonga species**,** and the ecosystems in terrestrial, freshwater and marine environments.

The ecology of the Wellington Region is remarkably varied and diverse, and includes alpine, wetland, coastal and lowland forest biomes. A total of 44 ecosystem types have been identified in the Wellington Region (Singers et al, 2018) many of which are under pressure from human activity. The Tararua mountain range divides the region in two and causes climatic differences between the east and the west (NIWA 2017). The eastern side of the Tararua mountain range has largely been cleared for pastoral farming with the western hillsides outside of urban areas being largely bush covered. The Wellington Region encompasses a number of threatened species and ecosystem types, including kahikatea and pukatea forest, birds (e.g. banded dotterel), herpetofauna (e.g. barking gecko) and rimu, mataī, and hīnau forest remnants.

Climate change is likely to pose a variety of risks to the natural environment of the Wellington Region. Ecosystems are complex systems with interconnected processes that make it difficult to predict the full risks and impacts of direct climate hazards like rainfall and temperature. During the cascading risks workshop, ecosystem impacts were classified into four types to assist with the analysis as illustrated in **Error! Reference source not found.**8**Error! Reference source not found.**.

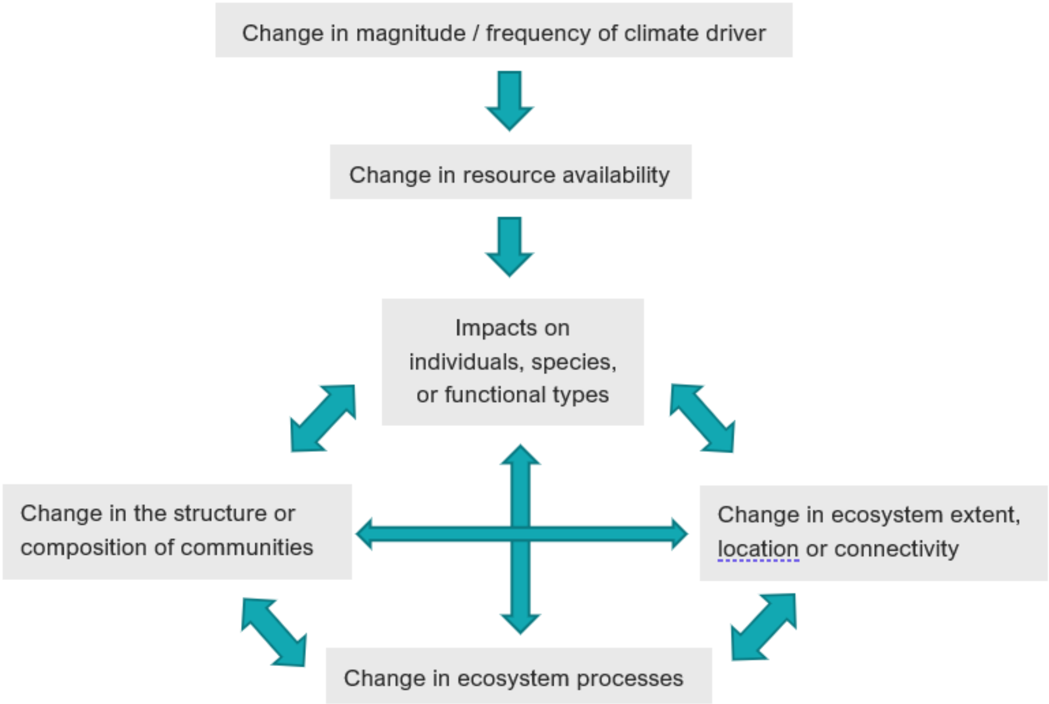


Figure 8: Ecosystem Impacts Identified in Cascading Workshops

The above impact types and mechanisms are explored in more depth below for each biome in the Wellington Region. Key points drawn from the assessment that have informed the vulnerability scoring:

- Many of the region's biomes are already under stress and highly fragmented which increases their sensitivity to climatic drivers and hazards
- There is limited ability of native and natural ecosystems to adapt to climate change due to high disturbance and pressure from human activities.
- The adaptive capacity of the natural environment depends on an ecosystem's capacity to shift and spread, which is highly constrained by human development.

4.1.1 Top Risks for Natural Environment Domain

The elements-at-risk identified for the natural environment domain through the initial risk screening were:

- Indigenous species
- Terrestrial and forest ecosystems, services and processes
- Wetland ecosystems, services and processes
- Coastal and marine ecosystems, services and processes
- Freshwater ecosystems, services and processes.

A total of 73 risks and 2 opportunities were included in the natural environment qualitative assessment (Appendix A). These were sorted to determine the most significant impacts. To find the top five risks for the Natural Environment Domain the risk register was sorted in this order:

1. Risk level in 2100 under RCP8.5.
2. First-pass impact score.
3. Risk level in 2100 under RCP4.5.
4. Risk level in 2050 under RCP8.5.
5. Risk level in 2050 under RCP4.5.

Impacts were scored for the natural environment on the following basis:

- **Catastrophic:** Major widespread loss of environmental amenity and progressive irrecoverable environmental damage
- **Major**: Severe loss of environmental amenity and a danger of continuing environmental damage
- **Moderate:** Isolated but significant instances of environmental damage that might be reversed with intensive efforts
- **Minor:** Minor instances of environmental damage that could be reversed.

The order in which the risks are sorted determines which ones are identified as the top five (Table 15).

Table 15: Top Five Risks Identified - Natural Environment Domain

Risk ID	Risk Statement	Vulnerability	Risk					First-pass impact score
			Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
ND74	Risk to freshwater ecosystems, services and processes due to **higher mean water temperatures**.	Extreme	Moderate	High	Extreme	Extreme	Extreme	Catastrophic
ND83	Risk to freshwater ecosystems, services and processes due to **river and pluvial flooding**: changes in frequency and magnitude in rural and urban areas.	Extreme	Extreme	Extreme	Extreme	Extreme	Extreme	Major
ND27	Risk to terrestrial and forest ecosystems, services and processes due to reducing **snow** and ice cover.	Extreme	Moderate	Extreme	Extreme	Extreme	Extreme	Major
ND87	Risk to freshwater ecosystems, services and processes due to increasing **landslides and soil erosion**.	Extreme	Moderate	Extreme	Extreme	Extreme	Extreme	Major
ND67	Risk to coastal and marine ecosystems, services and processes due to **sea-level rise** and salinity stresses on brackish and aquifer systems and coastal lowland rivers.	High	Moderate	High	Extreme	Extreme	Extreme	Major

The following sections provide a qualitative description of the potential climate change risks and impacts across the natural environment elements-at-risk. The assessment of top risks is described in the detailed assessment (Section 6).

4.1.2 Indigenous and Taonga Species

Many of the region's indigenous ecosystems already face high pressure from introduced species, including plants, vertebrates, invertebrates and pathogens. Impacts include predation, competition and, in some cases, mortality. These combine to reduce both native dominance in ecosystems, and the abundance of vulnerable species.

Threats posed by climate change to many of New Zealand's migratory, coastal and river-nesting birds include **ongoing sea-level rise, alteration to river flows and decline in ocean productivity**. Sea-level rise will threaten the stability and productivity of important breeding, feeding and roosting habitats impacting indigenous and taonga species that rely on these habitats. Ongoing gradual changes in climate and **extreme weather events** will exacerbate the threat of invasive or exotic species. Disruptions to ecosystem structure and composition are likely to provide greater opportunities for competing introduced species to establish (Thuiller, 2007).

The diverse range of threatened and at risk species that are dependent on the region's offshore islands for their continued survival are susceptible to climate risk due to ongoing **sea-level rise, changes in terrestrial climates, and changes in ocean chemistry and productivity**. Matiu Island, Mana Island and Kāpiti Island, for example, are scientific and nature reserves respectively. These islands are inhabited by a range of indigenous species, such as the little brown spotted kiwi and several threatened herpetofauna species. These islands are actively managed to maintain indigenous species populations with a focus on predator control which will reduce future impacts on these species (as they will be less vulnerable if they are healthier ecosystems). Climate change risks such as **sea-level rise** and **more frequent storm events** impacting islands, as well as warmer temperatures increasing pest burden will undermine the sustainability of viable populations without additional conservation interventions.

Only a limited degree of adaptive capacity can be expected for most coastal, migratory and river-nesting birds, due to the high pressure they already experience from predation, habitat loss and human disturbance. Other species may be vulnerable for similar reasons. The northern spotted skink, for example, has very fragmented and isolated populations in the Wellington Region and is particularly vulnerable to climate hazards as a result. While migratory and dispersal ability may be high in most of these species, their ability to adapt to climate change will be limited by lack of suitable alternative habitats, feeding areas and breeding sites.

4.1.3 Freshwater Ecosystems

The primary risks to freshwater ecosystems in the Wellington Region are **salinity intrusions, altered patterns of flow variability, gradual change in rainfall and water temperatures, and an increase in the frequency and intensity of more severe extreme weather events**.

Saline water intrusion (caused by **sea level rise**) into coastal lakes such Lake Onoke, Kohangapiripiri and Kohangatera and mixing regime shifts in shallow lowland lakes are likely to significantly alter ecosystem composition and function. **Temperature and wind-induced changes** to the mixing regimes of deeper lakes (those deeper than 4m such as Lake Pounui with a maximum depth of 9.6m[4]) could fundamentally alter their dynamics, with consequences including the deoxygenation of bottom waters and release of nutrients stored in lake sediments. The distinctive ecosystems of sub-alpine and alpine lakes, like those found in the Tararua Range, will also be subject to ongoing **change in temperatures**, allowing invasion by species normally restricted to lower elevations.

Rivers are likely to be most affected by alterations to annual and seasonal river flows as a result of **changing rainfall,** reflecting the importance of flow variability in structuring the composition and functioning of riverine ecosystems. Increased peak flows in rivers and streams caused by **more intense rainfall** are likely to increase rates of channel sediment transport and bed instability. Conversely, predicted **increases in intensity and duration of dry periods** are likely to result in more extended periods of low flow and reduced flow variability across freshwater ecosystems in the Wellington Region. Riverine ecosystems that are already fragmented, and species that are already threatened, are likely to be more sensitive to the predicted changes in river flow, particularly due to their limited ability for unassisted distribution and recolonisation (Robertson et.al., 2016). This may ultimately lead to a loss of habitat and breeding locations for a number of organisms.

Adaptive capacity of the Wellington Region's lake and river ecosystems is likely to be significantly impaired by the high pressure they are already exposed to from human activities. The fragmentation and vulnerability of

[4] https://www.lawa.org.nz/explore-data/wellington-region/lakes/lake-pounui/

these ecosystems will make shifts in distribution difficult for a number of aquatic organisms. This difficulty will be further compounded by the fragmented nature of Wellington's riverine ecosystems, where human-made barriers restrict migration ability and reduce adaptive capacity (Weeks et al, 2016). These barriers are most present in urban areas like Wellington City and in areas of high pastoral use. Projects like Zealandia's "Kia Mouriora te Kaiwharawhara" (also known as Sanctuary to Sea) is a restoration project that takes a catchment view and can serve to support the climate resilience of the Wellington Region's freshwater ecosystems.

The sensitivity of many lowland freshwater ecosystems to **drought and increased temperatures** is likely to be increased by:

- existing degradation of lakes;
- rivers and streams resulting from flow obstructions (dams, diversions, culverts);
- abstraction for irrigation with resulting change to natural flow variability; and,
- elevated inputs of sediments and nutrients; and pressures from introduced species including aquatic plants, fish and algae.

4.1.4 Coastal and Marine Ecosystems

Coastal ecosystems, such as salt marsh, are under very high risk of sea-level rise and **coastal inundation**, coastal squeeze, **ocean acidification**, and storm events (direct physical damage due to storm surges). All marine ecosystems are expected to experience more persistent, **higher summer sea temperatures, and marine heatwaves** are projected to increase in both frequency and intensity.

Assessing the sensitivity of the oceans around the Wellington Region to projected declines in their productivity is difficult due to the complex linkages and interrelationships between ecosystems and species, and the complexity of the physical environment. The sensitivity of some oceanic ecosystems is likely to be increased by the impacts of human activity. NIWA has identified twelve sites or habitats of significant marine biodiversity, only one of which is protected (the Kāpiti Island rhodolith beds) (NIWA, 2012). The sites range from the shallow Porirua Harbour to methane seeps lying in 1100 m of water at the south-east extremity of the region. Significant marine biodiversity in the Wellington region is located in either shallow coastal areas (Porirua Harbour, Wellington Harbour freshwater springs and Adamsiella beds, Kapiti Island rhodolith beds, Mataikona reefs, giant kelp beds, subtidal reefs, exposed reef kelp beds) or deep water areas (Cook Strait Canyons, methane seeps, sunken wood habitat) as stated in the NIWA report.

The adaptive capacity of opportunistic species is high (e.g. jellyfish, salpae, some algae). For many marine invertebrates, not enough is known enough about their physiology to make predictions of their adaptive capacity to climate hazards. However, many algal species are already demonstrating that they can adapt well and exploit changing conditions like seasonality.

Broader ecosystem sensitivity will be heightened by effects from **ocean acidification** that are particular to individual species, where each of these effects and changes will contribute to overall community dynamics in complex ways. Small or slight variations in species response to changes in **ocean acidification** may be amplified over successive generations, potentially driving major reorganisation, and restructuring of ecosystems.

In the absence of human-induced pressures, many coastal ecosystems and species would be able to adapt in some way. However, most are exposed to the effects of introduced species, inputs of nutrients and sediments, for example from agricultural practices (Wilcock et al, 2011), and direct disturbance from activities such as subdivisions and the construction of buildings, roads, marinas, and other structures. This is likely to reduce their adaptive capacity substantially, particularly where there is intensive human activity such as around towns and cities.

4.1.5 Terrestrial Ecosystems

Projected **reductions in both annual and seasonal rainfall** are likely to result in more intense and prolonged dry spells and droughts, particularly on the eastern coast of the Wellington Region (South Wairarapa, Masterton and Carterton). These projected changes in climate are also expected to increase the risk and severity of **wildfires** in the Region, particularly in the east.

The relative lack of evidence of contemporary change in forest composition and species range adjustments suggests the most visible impacts of climate change on indigenous forest ecosystems will become apparent through the reduced ability of ecosystems and species to recover from disturbance events.

There are risks to sub-alpine ecosystems due to **changes in temperature and a reduction in snow cover** in mountain ranges like the Tararua and Remutaka. With a warming of 3 degrees Celsius under RCP8.5, alpine vegetation zones are expected to rise 500 metres.

Figure 9: The Delicate Alphine Biome of the Tararua Forest Park. Credit NZ Geographic

New Zealand's sub-alpine ecosystems and species are likely to be highly sensitive to **increasing temperatures**, in part reflecting the highly fragmented distribution of subalpine environments. These are widely scattered habitat 'islands' on range crests that are often distant from other similar habitats. This isolation has resulted in high levels of species endemism both nationally and locally, and these ecosystems are highly vulnerable to climate change (Halloy & Mark, 2003), with very limited ability to spread into new geographic locations as temperatures rise (Thuiller *et al*, 2007). For example, subalpine scrub is found in the northern edge of the Tararua Forest Park and occurs at or near the tree line. The composition of this cold-tolerant biome varies with altitude but often includes *Olearia* and *Pseudopanax* species.

Low adaptive capacity to human-induced pressures is a common feature of island biotas, and particularly those that have experienced long genetic isolation (Williams et al, 2008). In particular, the forested areas in the central Wairarapa forests are fragmented and degraded, making them more vulnerable to climate impacts. Coupled with the geographic isolation of many subalpine habitats which is sometimes intensified by clearance of surrounding indigenous cover, this indicates that many sub-alpine ecosystems and their species will have low adaptive capacity to climate change.

4.1.6 Wetland Ecosystems

Significant wetland ecosystems in the region include (but are not limited to) large wetland areas on the east of Lake Wairarapa and wetlands to the north of Lake Kohangatera (eastern tip of Wellington City harbour), Turakirae Head wetlands (Wainuiōmata), and wetlands around the Waikanae River mouth in Kāpiti.

Climate change is predicted to alter **annual and seasonal rainfall** distribution, which, combined with **higher temperatures and increased windiness**, will affect the moisture status of many of New Zealand's freshwater wetland ecosystems and species, particularly those of lowland wetlands in eastern and northern parts of New

Zealand, including the Wellington Region. New Zealand's wetland ecosystems and species are already vulnerable due to widespread land-use changes, with about 90 percent of their former cover lost since European settlement in the 1840s, most notably in lowland environments (Robertson et al, 2019). There are only 3% wetlands remaining in the Greater Wellington Region[5].

The sensitivity of the Region's wetland ecosystems and species to climate-related change in **moisture status** will vary, with those in the drier climates of the east coast likely to show higher sensitivity than those in the wetter climates of the west. Ephemeral wetlands that support high numbers of threatened species may show high sensitivity to these changes in moisture status, given the natural fluctuations in moisture status they currently experience (Johnson & Rogers, 2003).

Adaptive capacity of wetland ecosystems will mainly rely on effective governance. The Greater Wellington Regional Council Sea Level Rise Modelling has shown that the topography allows estuarine wetlands some ability to retreat as **sea levels rise** except that urban development and hard infrastructure, like sea walls, is largely going to prevent this.

4.2 Human Domain | Oranga Tangata

Human Oranga Tangata	Description
	People's skills, knowledge, and physical and mental health (human); the norms, rules, and institutions of society (social); and the knowledge, heritage, beliefs, arts, morals, laws, and customs that infuse society, including culturally significant buildings and structures (cultural).

While increases in temperature and heat wave events pose a direct risk to human health, most other risks and impacts assessed in the human domain can be classified as indirect. Indirect risks and impacts stem from or are 'downstream' to other risks (often from other domains). For example, stresses, and downstream mental and physical risks linked to damages to housing (built domain) or loss of ecosystem services (natural domain).

4.2.1 Top Risks for Human Domain

The elements-at-risk identified for the human domain through the initial risk screening were:

- Human health
- Social cohesion & community wellbeing
- Existing inequities
- Social infrastructure & amenities
- Cultural & historic heritage
- Sports & recreation.

There were a total of 69 risks and 1 opportunity included in the human domain qualitative assessment. These were sorted to determine the most significant impacts. The risk register was sorted in this order:

1. Risk level in 2100 under RCP8.5.
2. First-pass impact score.
3. Risk level in 2100 under RCP4.5.
4. Risk level in 2050 under RCP8.5.
5. Risk level in 2050 under RCP4.5.

[5] https://www.gw.govt.nz/environment/our-natural-environment/our-unique-ecosystem-types/wetlands/wetlands-in-our-region/

The order in which the risks are sorted determines which ones are identified as the top five (Table 16).

Impacts were scored for the human domain on the following basis:

- **Catastrophic:** The region would be seen as very unattractive, moribund, and unable to support its community and / or large numbers of serious injuries or loss of lives
- **Major:** Severe and widespread decline in services and quality of life within the community and / or isolated instances of serious injuries or loss of lives
- **Moderate:** General appreciable decline in services and / or small numbers of injuries
- **Minor**: Isolated but noticeable examples of decline in services and / or serious near misses or minor injuries.

Table 16: Top Five risks Identified - Human Domain

Risk ID	Risk Statement	Vulnerability	Risk					First-pass impact score
			Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
HD30	Risk to social cohesion due to coastal and estuarine **flooding**: increasing persistence, frequency and magnitude.	Extreme	Moderate	High	High	Extreme	Extreme	Catastrophic
HD85	Risk to cultural heritage due to **sea-level rise** and salinity stresses on brackish and aquifer systems and coastal lowland rivers.	Extreme	Moderate	High	High	Extreme	Extreme	Catastrophic
HD47	Risk to existing inequities due to river and pluvial **flooding**: changes in frequency and magnitude in rural and urban areas.	High	Low	Moderate	Moderate	High	Extreme	Catastrophic
HD48	Risk to existing inequities due to coastal and estuarine **flooding:** increasing persistence, frequency and magnitude.	Extreme	Moderate	High	Extreme	Extreme	Extreme	Major
HD50	Risk to existing inequities due to increasing **coastal erosion:** cliffs and beaches.	Extreme	Moderate	High	Extreme	Extreme	Extreme	Major

The following sections provide a qualitative description of the potential climate change risks and impacts across the human / social elements-at-risk. The assessment of top risks is described in the detailed assessment (Section 6).

4.2.2 Human Health, Social Cohesion & Community Wellbeing

The most extreme risks identified relate to **acute flooding events and landslides**. These hazards pose a direct risk to human health and safety. People have a limited ability to adapt in situ to these types of acute events. Impacts can potentially be catastrophic, including injury and loss of life, with significant economic and social disruption if the extent of the impact is widespread. These hazards also pose an extreme risk to social cohesion and community wellbeing which can be catastrophic if whole neighbourhoods or suburbs are deemed undesirable or large-scale events result in injury and loss of life.

Sea-level rise and coastal erosion, while chronic (incremental) hazards, pose indirect risks to human health due to the stresses associated with property and amenity loss. The impacts of these risks have the potential to be catastrophic or major, with regard to long term severe reduction in quality of life, the area being considered undesirable (or unaffordable) and potentially services withdrawal. Sea-level rise and coastal erosion also pose extreme risks to social cohesion and community wellbeing, particularly for those directly affected by property and amenity damage or indirectly affected by insurance retreat.

Overall risk of **drought** to human health is relatively low, largely because there are measures that can reduce human health impacts such as alternative water sources and drought management plans. However, indirect impacts of water scarcity on human health if it were to occur could be major, leading to loss of life, and major social and community unrest.

Fire weather poses a high risk to social cohesion and a moderate risk to human health. Although Wellington region's urban centres are not located in areas where the risk of fire weather is significant (i.e. low exposure), urban centres are not designed with fire resilience in mind and so they have extreme vulnerability to fire weather. If this risk were to occur, impacts are potentially major, including loss of life, and displacement of affected communities placing pressure on public services.

4.2.3 Existing Inequities

It is well recognised in the international literature that climate change is already, and will continue to, disproportionately affect socially disadvantaged and marginalised people (IPCC, 2014). Climate change is expected to exacerbate existing inequities in three main ways: (a) due to higher exposure of disadvantaged groups to climate hazards, (b) higher sensitivity of these groups to climate hazards, and (c) lower adaptive capacity of these groups (i.e. less ability and resources to cope and recover). Further, new inequities may arise as the climate changes and resource use and access issues occur.

In the Wellington Region there are existing inequities with people who identify as Pacific people and Māori being over-represented in areas of high socio-economic deprivation (e.g. Porirua and Lower Hutt) and having disparate health risk factors, use of health services and health outcomes (Pacific Perspectives, 2019). Wellington's Pacific communities, clustered around Porirua Harbour (the Waitangirua-Titahi bay arc), the Hutt River (the Lower Hutt Valley), the southern suburbs of Wellington (the Strathmore to Berhamphore corridor) and the suburb of Wainuiomata are resilient with strong cultural and spiritual connections, locally, nationally and internationally. However, these communities experience high levels of socio-economic deprivation and poor access to education, employment and home ownership (Pacific Perspectives, 2019) which increases vulnerability to climate hazards.

Inequities in relative housing affordability show that more residents spend over the median income on housing in Porirua and Kapiti Coast, particularly compared to residents of Wellington City. The high cost of housing relative to income may make ongoing repairs and maintenance more difficult financially over time, resulting in lower quality of living standards. Damp and mould are a significant issue for households in Porirua; and for Pacific and Māori households across the region (Regional Community Profile, Wellington Community Trust, 2020). Large **intense rainfall** and more frequent **flooding** will make these conditions worse if ongoing maintenance is not undertaken.

Acute events, such as **flooding and landslides**, as well as the chronic hazards of sea-level rise and coastal erosion, and the risk these pose to existing inequities, are highly significant risks for the Wellington Region. The assessment has identified that many lower socio-economic communities are reasonably isolated with limited access points (e.g. Stokes Valley, Wainuiomata, Castlepoint). These communities may be more sensitive to and less able to recover quickly to events such as floods and landslides. The extent of the social and economic impact will depend on the scale of the flooding or landslide and whether people are impacted financially (such as through damage to property) and whether alternative access is available so that people can continue to access services and places of employment. Flooding is likely to have an extreme risk on existing inequities by the end of the century under all emissions scenarios and by mid-century under a high emissions scenario. The impacts on existing inequities can be catastrophic if flood risk is such that insurance becomes unaffordable for lower socio-economic areas, resulting in people moving out of the area or losing the ability to own homes, or rent properties.

Sea-level rise and coastal erosion will also exacerbate existing inequities and create new ones in coastal communities that are already fragmented (for example Porirua). Those with fewer resources, or those already marginalised in a variety of ways will have less ability to plan for and respond to coastal erosion and sea-level rise. Relocating out of coastal flood zones, or acquiring insurance, for example, may be less accessible options to these groups. Tenants already struggling with cost of living could find that rents increase (in association with insurance premium rise and higher maintenance costs) or houses become increasingly damp or mouldy.

Drought and **heatwaves** expected to be greatest in inland areas near Masterton and Martinborough, pose a higher risk of exacerbating existing inequities than they do to human health or social cohesion more generally for the region. This is because socially disadvantaged or marginalised groups typically have higher sensitivity and lower adaptive capacity to deal with these hazard types. For example, older people or those with disabilities may be more sensitive to heat stress and less able to avoid the impacts. Those working in primary industries or construction may be more exposed to drought and heatwaves, which may overlap with pre-existing lower socio-economic demographics within these industries.

International influences from **greenhouse gas mitigation preferences** are also a high to extreme risk of exacerbating inequities by the end of the century. The costs of mitigation actions are likely to fall disproportionally on those who can least afford them. The costs are twofold: the cost of taking the action and the cost of not taking the action (i.e. additional charges or tax burden). For example, the implementation of certain mitigation strategies may lead to changes in traditional livelihoods and cultural practices. This can affect communities that rely on activities such as agriculture, fishing, or forestry for their sustenance and cultural identity. Exacerbation of existing inequities was also identified as a priority transition risk as part of the transition risk assessment. This risk is discussed in further detail in the Transition Risk section of this report (Section4.7 4.7).

Māori Cultural Infrastructure

The following is a description of the potential impacts on Māori cultural infrastructure based on a review of the literature - the specific local impacts and their significance need to be discussed and confirmed by iwi and hapū themselves.

There are many sites of significance to Māori throughout the region. The assessment has identified a number of potentially significant risks related to repeated acute flood events and ongoing coastal erosion, and sea-level rise causing damage to things of importance to Māori (indigenous biodiversity, mahinga kai, taonga, tīpuna, marae, urupā, and other cultural assets).

The impact of pluvial flooding events has been assessed as major, due to the potential for significant loss of taonga, marae, etc. and the impact on quality of life, and holistically impacting the health of those affected.

The impact of inundation of cultural sites due to sea-level rise has the potential to be catastrophic, leading to loss of significant sites or coastal areas. This loss along with other risks such as marine heatwaves may inhibit the ability to undertake cultural practices, development of mātauranga, and maintain connection with significant places. In many ways this would mean a loss of Māori cultural infrastructure where the elements of that infrastructure are not pipes, bridges, etc but are of equal importance in the connectivity of a culture.

4.2.4 Infrastructure & Amenities, Sports & Recreation

Key risks to infrastructure and amenities, and sports and recreation for the region include those related to **landslides**, in addition to the chronic risks of **sea-level rise and coastal erosion**. Social infrastructure, amenities, and recreational facilities are vulnerable to be damaged by these hazards with limited adaptive capacity to recover (without relocation). The key distinction for these two elements at risk, is that impacts resulting from damage to and loss of social infrastructure and amenities (e.g. community support and healthcare facilities) have the potential to be major. The loss of these assets and amenities could mean significant impact on quality of life, loss of immediate healthcare access and service provision for those affected. Meanwhile, the impacts caused by damage to sports and recreation facilities are comparatively moderate, leading to reduced enjoyment of these facilities and the long-term physical and mental health implications of the temporary loss of these facilities.

4.3 Built Environment Domain | Taiaohanga

Built Environment Taiaohanga	Description
	The set and configuration of physical infrastructure, transport, and buildings sectors including housing, public amenity, water, wastewater, stormwater, energy, transport, communications, waste and coastal defences.

The Built Environment | Taiaohanga domain is key to the climate resilience of the Wellington Region. Communities within the Wellington Region rely on critical infrastructure and lifeline utilities such as transport, water, wastewater, telecommunication, gas, electricity, road, rail and solid waste management. These are essential services that play a vital role in the safety and security of the community. A reliable electricity supply is a critical service as almost all other services and many economic sectors rely on it, including communication, health services, agriculture, manufacturing, transportation and water. Communities are reliant on a clean and reliable water supply for everyday use influencing both health and hygiene. Solid waste management and wastewater infrastructure are critical within a community to ensure waste is managed in a way that minimises the adverse effects on the environment and public health. Transportation and accessibility routes are critical in their role of connecting communities and allowing the movement of people, goods, and services throughout and outside the region. Flood and coastal defences are critical in their provision of safe and reliable land for buildings, ports, transport, agriculture, and natural environments. For these reasons, the risks of climate hazards and drivers on elements of the built environment can have catastrophic or major impacts if damaged.

Infrastructure within the region is owned and operated by various stakeholders including local and central government, private entities (such as power companies, telecommunications, ports), Waka Kotahi New Zealand Transport Agency, and KiwiRail. This diverse ownership can influence how risks within the region are prioritised and funded (see Governance Section 4.5).

The table in section 4.3.1 summarises the key built environment risks for the region. Further to that summary table, the risks and associated impacts identified for the built environment include (but are not limited to):

- Those associated with damage to built assets due to acute **flooding and landslides**, particularly buildings and transport, but also co-located assets within underground infrastructure corridors (water, wastewater, roads, energy, communications etc)
- Unavoidable critical threshold around mid-century (300mm relative sea-level rise (RSLR)) where gravity stormwater outlets will be impacted by **sea-level rise** significantly reducing performance of associated stormwater networks (kool et al., 2020)
- Unavoidable increasing risk of damage to coastal assets towards the end of the century and beyond, due to ongoing incremental **sea-level rise** driving increased **coastal flooding and erosion**

- Damage to sea walls and coastal defences due to **storminess** and **extreme winds** (including damage to rock revetment).

This section provides high level commentary from the scoring of exposure and vulnerability within the built environment elements.

4.3.1 Top Risks for Built Domain

The elements-at-risk identified for the built environment domain through the initial risk screening were:

- Buildings & facilities
- Airports & seaports
- Energy
- Flood & coastal defences
- Transport (road & rail)
- Solid waste management
- Communications
- Māori assets
- Drinking water
- Stormwater infrastructure
- Wastewater infrastructure
- Marae & cultural sites.

There are over 100 risks identified for the Built Domain - many of these risks are extreme by 2100 under a RCP8.5 scenario. In order to determine what the most significant risks may be from the long list and refine to the top five risks for the Built Domain, within the risk register risks were sorted from high to low following the following sequence:

1. Risk level in 2100 under RCP8.5.
2. First-pass impact score.
3. Risk level in 2100 under RCP4.5.
4. Risk level in 2050 under RCP8.5.
5. Risk level in 2050 under RCP4.5.

It is noted that risks to drinking water due to **longer dry spells**, **changes in climate seasonality** with longer summers and shorter winters and changes in mean annual rainfall (risk IDs BD130, BD131, BD134 respectively) were identified as extreme risks by 2100. The first pass rating determined, however, that they are moderate impacts for the region, with higher adaptive capacity in the engineered networks and systems (see Appendix A), and so they were removed from the top risks for the built domain.

Impacts were scored for the built environment domain on the following basis:

- **Catastrophic:** Service restoration takes greater than 1 month or major prosecution
- **Major:** Service restoration within 1 month or minor prosecution
- **Moderate:** Service restoration within 2 - 3 weeks or infringement notice
- **Minor:** Service restoration within 1 week or consent compliance notice.

Table 17: Top Five Identified Risks - Built Environment Domain

Risk ID	Risk Statement	Vulnerability	Risk					First-pass impact score
			Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
BD32	Risk to buildings and facilities (public and private) due to **coastal erosion**: cliffs and beaches.	Extreme	High	Extreme	Extreme	Extreme	Extreme	Catastrophic
BD87	Risk to transport (road and rail) **landslides** and soil erosion.	High	High	High	High	Extreme	Extreme	Major
BD30	Risk to buildings and facilities (public and private) due to coastal and estuarine **flooding**: increasing persistence, frequency and magnitude.	High	Moderate	High	High	High	High	Catastrophic
BD33	Risk to buildings and facilities (public and private) due to increasing **landslides** and soil erosion.	High	Moderate	High	High	High	High	Catastrophic
BD65	Risk to flood and coastal defences due to river and pluvial **flooding**: changes in frequency and magnitude in rural and urban areas.	High	Moderate	High	High	High	High	Major

The following sections provide a qualitative description of the potential climate change risks (exposure and vulnerability) and impacts across the built environment elements-at-risk. The assessment of top risks is described in the detailed assessment (Section 6).

4.3.2 Exposure Within the Built Environment

Intra-region and external transport linkages are key lifelines to support the regional and national function of Wellington as a region and the seat of government. These transport linkages are already exposed to a myriad of natural hazards such as **landslides** (e.g. SH1 Ngauranga Gorge, SH2 Rimutaka, SH2 and SH58 in the Hutt Valley), coastal flooding (e.g. SH58/59 Porirua and Pāuatahanui Harbour), **coastal erosion** (e.g. SH59 Pukerua Bay) and river (fluvial) **flooding** (e.g. SH2 Wairarapa), with climate change further increasing these risks into the future. Compromised transport linkages will have widespread cascading impacts across the Wellington Region and nationwide. There are several streams of work addressing the future exposure of this transport network including the Let's Get Wellington Moving (LGWM) and utilities provider studies (Waka Kotahi, KiwiRail), coordination between these programmes is required for effective climate adaptation, alongside working with Wellington Region Emergency Management Office (WREMO) for disaster risk management.

4.3.3 Vulnerability of the Built Environment

Elements at risk within the built environment have the benefit of owners and asset managers being able to manage the sensitivity of their assets and incrementally improve the adaptive capacity of these elements over time. These vulnerabilities within the built domain can be improved through mechanisms such as:

- Condition assessment and maintenance programmes

- Planned asset renewal cycles, and
- Building codes and environmental standards.

A key dependency of *future* vulnerability within elements of the built environment is the reliance on central government, councils, regulatory authorities and industry bodies, to ensure that codes and standards accurately reflect the potential for climate change effects over the design lifetimes.

However, despite this incremental improvement potential in the built environment, there are groups of assets that typically have very low adaptive capacity and thus are highly vulnerable. The critical assets with typically low adaptive capacity include:

- Very large assets, those inaccessible for condition assessments (buried, remote) or those on very long renewal cycles (e.g. stopbanks, airport defences, port wharves)
- Assets that were / are constructed with a 'once and forever' mentality (e.g. permanent land creation through reclamation at coast for ports / industry) are at risk from historic underestimation for the future effects of climate change
- Assets which are not subject to frequent inspections or a formal and comprehensive asset management process (e.g. private water storage dams).

Existing risk management systems in a climate change context are commonly reactive and intervene as a result of failure after a **severe weather event**. For example, a common theme in the workshop comments was that seawalls are typically left to weather the elements and are maintained as needed. Then, once seawalls reach a certain age and maintenance requirements are more frequent, the wall is replaced. Except for Centerport, Wellington International Airport (WIAL) and the Paekākāriki seawall (due to be replaced in 2024), the workshop participants did not highlight current examples in the Wellington Region of seawall assets being replaced / upgraded through an asset management cycle. This may be a process gap to address in future work programmes.

Figure 10: CentrePort, in the Wellington City Waterfront. Copyright 2023 WT

4.3.4 Indirect Risk / Impacts

Many aboveground assets are at indirect risk from external drivers damaging assets and networks via acute hazards of **wind and storms** causing vegetation treefall / uprooting (e.g. aerial / buried cabling), but also through chronic (slow) **mean annual change of temperature** causing excess vegetation growth or vegetation die back which may lead to additional occurrence of vegetation debris and damage during storms. Often, vegetation maintenance is on private land and outside the network operator's control (e.g. Council, Waka Kotahi, lines companies) limiting the owner's ability to act proactively (such as preventative pruning). In these cases, the owner is restricted to reactive responses after the damage occurs (a Governance risk). These challenges also apply to slips and erosion which begins in areas that cannot be maintained on Council / public land and flow downhill to impact people, property and assets.

International supply chain interruptions can be an indirect risk to the built environment as identified by workshop participants**. International influences associated with changing consumer preferences** (shifts to lower emissions construction and manufacturing products such as timber) will increase competition for materials and supplies and increase costs and limit availability. Many necessary physical activities / processes such as asset replacement and repairs across many of the built environment elements will not be able to be completed efficiently without reliable, cost effective, access to building materials and construction equipment. This will lead to cascading social and economic impacts from loss of services and increased building and manufacturing costs.

4.4 Economic Domain | Whairawa

	Description
Economic **Whairawa**	The set and arrangement of inter-related production, distribution, trade, and consumption that allocate scarce resources.

The key Wellington Region **economic** services at risk from a changing climate are the public sector, and light manufacturing. These sectors are less sensitive and have a higher level of adaptive capacity to climate hazards than some of the economic sectors in other regions. However, there are indirect risks for the local economic sectors in the Wellington Region particularly related to the impacts of **severe weather events** and **sea level rise** on the mobility of goods going to port at Wellington and goods coming into the region at Seaview petrochem fuel wharf for the lower half of the North Island and the Wellington Region. Disruption to the main transportation networks of SH2 Hutt to Wellington and from Seaview to the rest of the region from ongoing **sea level rise** and **more intense storms** is an economic risk.

The results of the risk and first-pass impact scoring for the economic domain are provided In Appendix A.

This report section provides high level commentary on considerations for the exposure and vulnerability of the economic domain elements for the Wellington Region.

Exposure considerations for elements at risk within the economic domain have been framed relative to the proportion of the total Wellington Region economy that each element makes up. The risk scores therefore reflect distillation of the higher and lower risks relative to risk to the overall economy.

4.4.1 Top Risks for Economic Domain

The elements-at-risk identified for the economic domain through the initial risk screening were:

- Forestry
- Horticulture
- Viticulture
- Pastoral farming
- Tourism & hospitality
- Public services

- Service coverage & debt provision
- Māori enterprise
- IT & creative industries.

There were a total of 93 risks and 5 opportunities identified for the economic domain. These were sorted to determine the most significant impacts. The risk register was sorted in this order:

1. Risk level in 2100 under RCP8.5.
2. First-pass impact score.
3. Risk level in 2100 under RCP4.5.
4. Risk level in 2050 under RCP8.5.
5. Risk level in 2050 under RCP4.5.

The order in which the risks are sorted determines which ones are identified as the top five (Table 18).

The impacts were scored on the following basis:

- **Catastrophic:** Regional decline leading to widespread business failure, loss of employment, and hardship
- **Major:** Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth
- **Moderate:** Significant general reduction in economic performance relative to current forecasts
- **Minor:** Individually significant but isolated areas of reduction in economic performance relative to current forecasts

Table 18: Top Five Risks Identified - Economic Domain

Risk ID	Risk Statement	Vulnerability	Risk					First-pass impact score
			Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
ED59	Risk to tourism and hospitality due to **international influences** from climate change and greenhouse gas mitigation preferences	High	Low	Moderate	High	Extreme	Extreme	Moderate
ED77	Risk to public services due to **international influences** from climate change and greenhouse gas mitigation preferences	Moderate	Low	Low	Moderate	High	High	Major
ED4	Risk to forestry due to increasing **fire**–weather conditions: harsher, prolonged season	Moderate	Moderate	Moderate	High	High	High	Moderate
ED79	Risk to insurance coverage and credit provision due to increasing **fire**–weather conditions: harsher, prolonged season	High	Low	Moderate	Moderate	High	High	Moderate
ED80	Risk to insurance coverage and credit provision due to increased **storminess and extreme winds**	High	Low	Moderate	Moderate	High	High	Moderate

4.4.2 Public Services, Manufacturing, and IT

Generally, climate risks to public services, manufacturing, and IT are low in the Wellington Region at present but may increase to high by the end of the century. These elements at risk have low vulnerability to climate hazards and are industries with an inherent ability to adapt compared to others (such as primary industries).

Professional and public services are less dependent on a fixed location for operations (as evidenced by rapid shifts in working arrangements during the COVID-19 pandemic). Both public services and manufacturing are less sensitive to adverse weather events by comparison to other industries.

The manufacturing industry has good insurance provision generally, so is able to recover relatively easily from acute climate related events such as **severe weather events**. However, there are some commercial and industrial locations across the region that are high risk. For example, the low lying land in the Seaview industrial area in the Lower Hutt is on reclaimed land and includes infrastructure associated with contaminants. There is already some outward migration from the area as flooding has impacted these sites, and the risk will increase significantly in the medium term from **rising groundwater** caused by **sea level rise**.

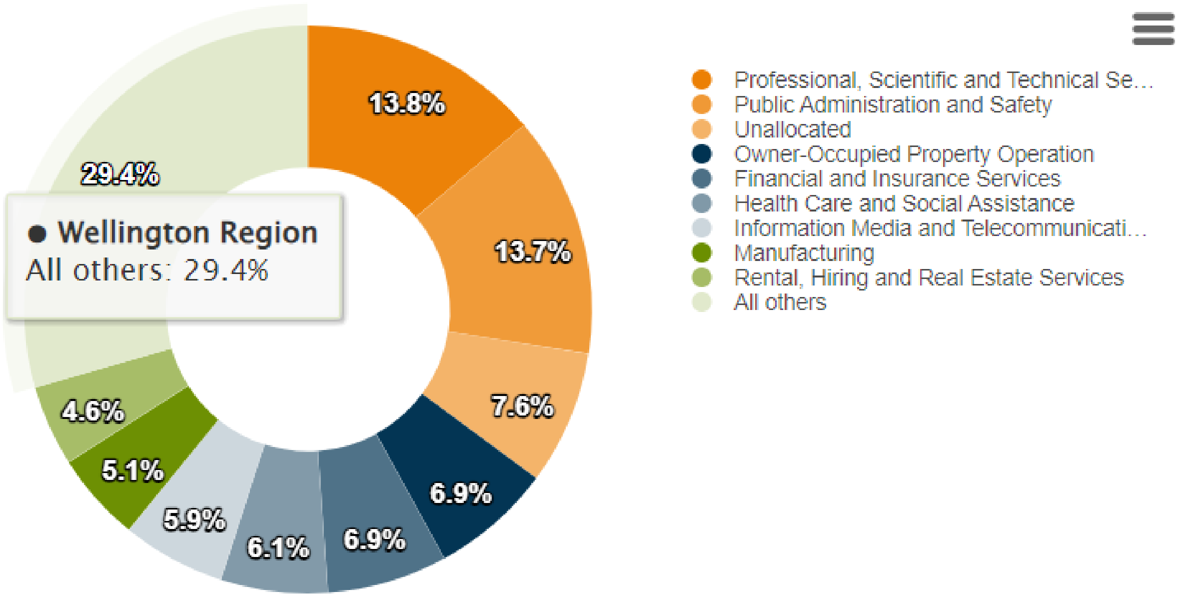


Figure 11: Proportion of GDP by Australian and New Zealand Standard Industrial Classification, 2023 (source Infometrics)

4.4.3 Primary Industries

As shown in Figure 11**Error! Reference source not found.**, primary industries do not contribute significantly to the Wellington Region's overall GDP. However, primary industries are more significant for rural districts (in particular the Wairarapa, where agriculture, forestry and fishing contributes 8.7% of the GDP, Infometrics 2023) and rely on transport routes including road, rail and the port. Primary industries like horticulture, forestry and pastoral farming are generally vulnerable to climate risks due to their reliance on ecosystems and climatic patterns. **Severe weather events** and climatic changes are expected to disrupt these industries to varying extents.

The direct climate risks to forestry are, for the most part, well researched and understood in New Zealand. The management of fire risk and biosecurity threats are already common practice. As the **mean annual temperatures rise**, there is a risk that pest species may more readily establish and may cause changes in environments and species of trees planted in the forestry industry requiring further refining of practices. However, vulnerability of plantations to **landslides and soil erosion** is an important consideration within the forestry sector. Overall, climate impacts associated with forestry are, in large part, moderate for the region.

Climate risks for other primary industries (viticulture, horticulture, and pastoral farming) are relatively low overall. Primary industries have a high vulnerability to hazards such as **heatwaves, drought, changes in**

climate seasonality, and fire weather. However, the exposure of the overall economy to these risks is generally low to moderate by mid-century, given that primary industries constitute a small proportion of the total economy in the Wellington Region**. Drought and seasonal change** risks become high for horticulture and pastoral farming overall by end century under an RCP8.5 scenario. The economic impacts of identified primary industry climate risks are generally insignificant to minor regarding the Wellington Region's overall economy (Appendix A).

For the east coast of the Wellington Region, the economic risks and impacts of climate change on primary industries is likely to be a lot higher at the district scale. It was noted in the workshops, for example, that the Wairarapa is already experiencing drought and seasonal changes under present conditions. Droughts are projected to intensify and become more frequent on the east coast, and therefore increase the impacts to east coast district economies.

4.4.4 Insurance Coverage & Credit Provision

An increase in **extreme weather events** has significant implications for the availability of insurance and credit. Increases in insurance premiums is already being experienced in the Wellington Region due to higher earthquake risk[6]. It is likely that those in high hazard areas will see similar trends in insurance premium rises[7]. Soaring insurance premiums or total insurance retreat from high-hazard zones could exacerbate inequality by making insurance unavailable for the region's most vulnerable communities. As **severe weather events** destabilise the economy, credit could become less available. People will struggle to insure assets in high hazard zones like flood plains and low-lying coastal areas. It is not possible to identify the scale of this potential impact for the region as details on what is insured are kept confidential by insurance companies.

One of the primary challenges for New Zealand insurers is the cost of reinsurance on the international market. Large catastrophic events, such as earthquakes or floods, can result in substantial claims that need to be covered by reinsurance. Depending on the severity and frequency of these events, obtaining affordable reinsurance coverage may become more difficult and costly for insurers, again resulting in insurance retreat or very high premiums under future climate change scenarios. Councils' ability to insure assets for service delivery to the public will become increasingly limited over time. It may be that councils will need to consider self-insurance of some of their assets in the future.

4.4.5 Tourism & Hospitality

Direct physical climate hazards do not currently pose a high risk to the tourism and hospitality industries in relation to the region's total economy (tourism contributes approximately $1 million of the total regional GDP of approximately $50 million, Infometrics 2023). These industries both have a high adaptive capacity in their ability to rely on insurance and recover or relocate from extreme weather events. There are also potential opportunities arising for tourism and hospitality sectors associated with outdoor activities in the Wellington Region from **warmer drier conditions and longer summer seasons**.

In the table above **international influences from climate change and GHG emission mitigation preference** is noted as an extreme risk to tourism and hospitality sector by the end of the century. The primary modes of transport in New Zealand (to arrive in the country and once within it) are carbon-heavy: cruise ships, air travel and personal vehicles. In the future, carbon pricing or the inclusion of international aviation in climate accords could lead to changes in travel patterns, including a shift towards more sustainable transportation options. This could impact the tourism industry in Wellington, as visitors might prioritise low-carbon modes of

[6] https://www.nzherald.co.nz/business/insurance-council-defends-skyrocketing-wellington-premiums/2RTP5KFVLFUZ3ZDUXZLTHS2Q4Q/

[7] https://www.insurancebusinessmag.com/nz/news/breaking-news/kiwis-can-expect-more-premium-increases-in-highrisk-areas-166313.aspx

travel such as trains or electric vehicles over traditional air travel. This change could potentially affect the number and types of tourists visiting the region. It is noted that this will be a risk across New Zealand as well as for the Wellington Region. Growing environmental awareness among travellers means that there is likely to be an increasing demand for sustainable practices in the tourism and hospitality sector. Visitors may seek out accommodation, dining, and activity options that prioritise energy efficiency, waste reduction, and other sustainable initiatives. Businesses in the Wellington region will need to adapt to meet these preferences, potentially requiring investments and adjustments to their operations.

International immigrants are key to staffing the hospitality and primary industries, which became very apparent through staffing shortages during the recent COVID-19 pandemic-related closure of New Zealand's borders. In 2020, 29% of New Zealand's hospitality workforce was comprised of recent migrants or migrant visa holders (Hospitality New Zealand, 2021). Higher costs of air travel as a result of **international influences from climate change and GHG emission mitigation preference** described above could decrease the number of immigrants that decide to travel to and settle in New Zealand, with impacts on the hospitality and tourism workforces.

4.4.6 Māori Enterprise

Māori-owned business make up approximately 6% of all businesses in New Zealand. A recent study (Te Puni Kōkiri & Nicholson Consulting, 2019) identified a total of 537 Māori-owned businesses in the Wellington Region. In most regions of the country, including Wellington, there are more Māori-owned construction businesses than any other business type. A total of 738 businesses in the Wellington Region were identified in 2019 as 'significant employers of Māori' (defined as a business where at least 75% of the total number of employees are individuals of Māori ethnicity or descent). At present, there is limited data available on the make up on Māori owned businesses or 'significant employers of Māori' in the Wellington Region. Better insights are likely to emerge in future years due to the recent addition of a Māori identifier to the data collected for the NZBN Register.

As Māori enterprise has many dimensions, available information at a regional scale was used to determine what may be the most relevant hazards for the Wellington Region. The scoring of risks (exposure and vulnerability) to Māori enterprise and associated impacts has been based on the limited data available and has been undertaken in the absence of local iwi / Hapū input to the WRCCIA.

We do know that the proportion of Māori owned businesses in the primary industries and tourism is lower in Wellington compared with other regions in New Zealand (such as the South Island, Gisborne, or Hawkes Bay). We also know that four of the six iwi in the region have settled with collective assets of $300 million – mostly invested in property[8]. Assuming, based on available data, that Māori owned businesses in the Wellington Region are largely construction and services, these business types typically have low to moderate exposure to climate hazards and low vulnerability. Data does indicate, however, that Māori-owned businesses appear to be generating margins less than 70% of that of non-Māori-owned businesses in NZ overall (Te Puni Kōkiri & Nicholson Consulting, 2019). Māori enterprises may typically have lower cash reserves and therefore fewer financial resources to recover from climate-related events. For these reasons the vulnerability of Māori enterprise to climate hazards and drivers is scored higher and risks are also therefore higher (Appendix A).

Māori Enterprise

Māori businesses and enterprise support a wider community than what might be experienced in non-Māori businesses. Incomes from Māori business may likely flow through marae to community in a more connected and integrated way, so while direct impacts on Māori Enterprise may be moderate, there are cascading social and economic impacts on communities that may be more

[8] https://www.tematarau.co.nz/current-state-of-play/

significant and much broader. Further exploring and working with Mana Whenua is essential to better understand the nature of local Māori-owned enterprise and the potential impacts.

4.5 Governance Risks

Governance Kawanatanga	Description
	The governance architecture and processes in and between governments, iwi and hapū, and economic and social institutions. Institutions hold the rules and norms that shape interactions and decisions, and the agents that act within their frameworks.

4.5.1 Context

The New Zealand National Climate Change Risk Assessment (MfE 2020) identified the top two governance risks as:

1. That climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for adaptation; and,
2. That there would be a flow-on risk that maladaptation will occur across all domains due to practices, processes and tools that do not account for uncertainty and change over long-time frames.

These risks were rated extreme.

The IPCC Sixth Assessment Report Working Group II, Chapter 11 Australasia (IPCC 2022), identified as a key implementation risk*, the inability of institutions and governance to adapt to changing risk profiles (high confidence)* and with consequences that are major now, extreme in 2050, and extreme in 2100.

4.5.2 Why is Understanding Governance Risk Important?

As climate hazards intensify in place and across space, the complexity levels will challenge existing, planned and evolved governance arrangements and the speed with which they can adapt to the ongoing and changing conditions. This places governance risks at the heart of addressing climate risks and impacts. The ability to change governance instruments and practices across scales and domains through collaboration is fundamental to implementing adaptation plans.

Governance permeates all aspects of New Zealand society, including Te Tiriti partnership between Māori and the Government (the Crown), intertribal relationships (iwi to iwi), relationships between local government and communities and between levels of local government, with the economy, the built environment, and the natural environment across many ecosystems. Governance risks broadly arise due to mandate, institutional arrangements (laws, inter-tribal lore, regulations, professional practice codes), engagement with community and sector interests across the region, partnerships with iwi / Māori, and by the manner in which they are operationalised by the key decision makers and advisors.

In 2023 the Government launched an inquiry into managed retreat and adaptation funding in New Zealand, including an issues and options paper (November 2023) as part of future Climate Adaptation Bill that was proposed as part of wider legislative reform. The Issues and Options paper considers options for an enduring and comprehensive system for community led retreat, including a section on Te Tiriti based adaptation. At the time of writing this report it is not clear whether the incoming National led Government will proceed with a Climate Adaptation Act. However, the Government has signalled that an adaptation framework is required for New Zealand and this will likely address a number of existing Governance risks at a national scale.

Te Tiriti & Te ao Māori

Inclusion of te ao Māori is critical in climate change risk decision making as an expression of Te Tiriti. Māori tribal organisations have an important role in defining climate risks and policy responses (Awatere et al., 2021), as well as entering into strategic partnerships with business, science, research and government to address these risks (Beall and Brocklesby, 2017).

The social-cultural networks and conventions and practices through collective action and mutual support amongst Māori communities are invaluable for initiating responses to, and facilitating recovery from, climate stresses and extreme events.

The conversations, issues, and resolutions that happen in a Māori world that are underpinned by kaitiakiatanga and intergenerational care for ecosystems and people (at the centre of the Māori worldview), are forms of Māori governance. For example, Māori governance includes processes where points of view are debated and discussed across a public space and actions can be determined collectively. Future engagement with iwi on this project should explore the adoption of this approach, i.e. where iwi-only governance is applied to determine how joint iwi would like to come together to contribute.

Governance risks in this report are those that affect the ability for decisions to be made and for effective implementation of broader risk responses and adaptation to be taken on climate change risks across all domains. They impinge on our planning for climate risk avoidance and pre-empting risk impacts, identifying cascading impacts across scales, exercising kaitiakitanga, conveying risk to communities, gathering and accessing the right data and information and connecting between agencies on risk reduction and building resilience.

The way governance systems operate now, and how they operate in future, will determine whether risk reduction and the ability to manage the forthcoming risks and associated impacts can be achieved. Risk reduction measures will not be able to address all risks, due to their timing, spatial location, and the scale of the risks as they compound and cascade across the region and from outside the region within New Zealand and internationally.

Effective governance in the face of climate change will require a shift from our current relatively static approach to adaptation, to governance that enables us to be proactive. Governance systems will have to anticipate the known ongoing chronic changes in **temperature, rainfall and sea-level rise** that will reach coping thresholds soon (some in the next few decades) and which will require adaptive actions in the near-term to anticipate what is known to be coming. Governance systems will also need to address the more acute changes that result in extreme events from increases in **rainfall intensity, fire and coastal storm flooding** and may require rapid response.

Key Regional Governance Risks

The assessment derived 6 key governance risks for the Wellington Region. It is noted that the first governance risk is the primary regional risk as it leads to the other 5 risks. The governance risks have been scored based on how bad the impact is in terms of delaying / preventing / weakening Councils' and stakeholders adaptation planning / responses to the other domain risks. The scores are as follows:

- **Extreme:** entirely halts or prevents any meaningful adaptation planning / work from taking place (i.e. 'fatal for adaptation')
- **Major:** creates significant problems, delays or inefficiencies in adaptation planning / responses (but doesn't entirely prevent all action)
- **Moderate:** creates minor delays or inefficiencies in delivering adaptation planning / response.

Gov. Risk 1	**The inability of the institutional arrangements to respond to the increasing complexity of climate change impacts, including their cascading and compounding effects**
Consequence	The uncertain scale and scope of projected climate impacts overwhelm the capacity of institutions, organisations and systems to provide the necessary policies, services, resources and coordination to address socioeconomic impacts and build resilience across communities in the region. The result is failure of adaptation due to reactive and short-term decision making that locks in existing exposures and vulnerabilities and unaddressed systemic impacts generating high costs and fiscal impacts. Inequities across different groups in the region result and iwi/ Māori rights and interests are not upheld, and litigation risks are increased.
Rating	Extreme

Gov. Risk 2	**Inadequate council partnerships and engagement mechanisms with iwi and hapū and Māori communities**
Consequence	Culturally inappropriate adaptation which exacerbates inequities and pre-existing vulnerabilities with potential for litigation and slow adaptation action. It is noted that there may be further consequences that need to be discussed and explored further with iwi / hapū themselves (see limitations in Appendix C)
Rating	Major

Gov. Risk 3	**Weak central /local government relationship driven by conflicting priorities from central government including political change, lack of continuity, numerous points of entry for local government and central government creating barriers to adaptation action**
Consequence	Funding inadequacies, and funding models used by different agencies and availability of new funding mechanisms being constrained, leads to uncoordinated action leading to inadequate adaptation responses that cannot build proactivity and preparedness. For example, via inadequate funding levels and different funding models used by different agencies and unavailability of new funding mechanisms.
Rating	Major

Gov. Risk 4	**Failure of coordination between local government agencies and with central government on climate-relevant policies and their implementation, due to a short-term focus on local jurisdictional interests and the 3-year electoral cycle.**
Consequence	Duplication, lack of integration and barriers to implementation of adaptation leading to an inability to get regional coherence in climate change risk reduction.
Rating	Major

Gov. Risk 5	**Legislative mandates and policy misaligned across land use planning, infrastructure planning, flood risk management and biodiversity and biosecurity management**

Consequence	Duplication, lack of integration and barriers to implementation of adaptation leading to an inability to get regional coherence in climate change risk reduction.
Rating	Major

Gov. Risk 6	**Ongoing uncertainty, delayed adaptation and potential maladaptation and litigation arising from slow implementation of the resource management law system.**
Consequence	Disruption and delay in effectively addressing climate change risks as they compound and become more extreme and missing implementation mechanisms such as funding and community relocation.
Rating	Major

4.5.3 Adaptation Planning Considerations

Addressing the identified governance risks determines the ability to adapt effectively across the Wellington Region in the context of rising risks from climate change (noting that climate risks can never be reduced completely and that there are limits to adaptation measures). Finding effective entry points for addressing the governance risks is imperative to reducing the other domain risks, and avoiding decisions in all domains that make the risks worse (and their ability to be managed even harder). The following adaptation entry points were identified from the workshops. No one entry point will be sufficient in itself - a suite of coordinated actions will be necessary based on a collective understanding of the governance risks and their criticality.

- Honouring Te Tiriti, supporting tino rangatiratanga and co-governance
- Indigenous knowledge at community level could enable preparedness and resilience by taking a long-term view and through connection to nature
- The resource management system reform, in particular the Strategic Planning Act for spatial identification of risk areas and the Natural and Built Environment Act for potential regulatory actions on adaptation options
- The Cyclone Gabrielle Inquiry recommendations on managing landscape scale adaptation actions
- The proposed Climate Change Adaptation Act through funding arrangements and by using managed retreat criteria
- NAP actions that address accessible, consistent and usable data and information
- Initiating engagement opportunities on a regional scale
- Showcasing what can be done, using case studies and discussing learning from them.

4.6 Compounding Risks

4.6.1 Approach

Compounding risks arise when multiple climate-related factors, such as extreme weather events, rising temperatures, sea-level rise, and ecosystem changes, interact and reinforce each other, amplifying the overall impact of the individual hazards (and potentially leading to amplified and compounding effects0).

For this assessment, compound risks are defined as risks that "arise from the interaction of hazards / stressors, which can be characterised by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors" (Collins et al., 2019). For example, compounding risks in the low-lying coastal areas of the Wellington Region include **high rainfall events** and **storm-tides with sea-level rise** coinciding, resulting in extents of flooding and impacts greater than both coastal flooding and fluvial / pluvial flooding if evaluated individually. This is a common compounding risk for coastal areas in New Zealand (and Wellington) as pluvial / fluvial flooding and storm induced sea level changes (coastal inundation) usually occur together as they are normally tied to the same weather system.

Understanding and addressing compounding risks in climate change is important for effective risk management, adaptation planning, and policy development. It requires integrated approaches that consider the interconnected nature of climate-related hazards and their potential cumulative impacts on both natural and human systems.

The purpose of this compounding risk calculation is to assess which of the identified elements at risk in the Wellington Region are exposed to the greatest number of climate change hazards, resulting in an overall multi-hazard risk scoring for that element. This will illustrate which domain or elements are a potential 'hot-spot' for compounding climate change risks and where an integrated or multi-pronged approach to risk management is likely to be required. As described above there are hazards that more commonly occur together as they are tied to the same weather system (such as pluvial and fluvial flooding and coastal inundation) or to similar drivers (such as heat and drought resulting in increased risk of fire weather). Therefore, the multi-hazard risk scoring is just an indication of which elements may be exposed to more variable risks than others (but does depend on the hazards occurring together).

Further details on the methodology of determining compounding risks are included in Appendix E.

4.6.2 Compounding Risk Scores

Table **Error! Reference source not found.**illustrates the number of identified risks (e.g. elements-at-risk exposed to hazards) and compounding risk score for each element at risk from the qualitative risk register. This provides a quantitative measure that consolidates both the severity of risks and the number of hazards (and therefore risks) previously identified for elements within a domain. This information and calculations are included within the qualitative risk register spreadsheet tab 'Compounding Risks' (Appendix A).

As described above, the counting of risks does not signal the overlapping occurrence of the hazards (e.g., drought and rainfall are not likely to occur in the same place at the same time). Rather, compounding risk identifies the degree to which an element is exposed to multiple climate change hazards, which could compound the effects on the element at risk over the assessment timeframes (e.g. drought followed by intense rainfall can increase flood risk).

The compounding risk score supports the identification and prioritisation of specific risks and elements and in the future, can be used by councils in the application of cascading risk assessment archetypes where multiple hazards can be explored together (see Appendix F for Cascading Risks and Impacts Archetypes).

An understanding of the compounding risks to each element and domain can be drawn by considering both the measure of the number of hazards the element at risk may be exposed to and the average risk score (which includes consideration of exposure, sensitivity and adaptive capacity).

Table 19: Compounding risk assessment. Note, the higher the average risk score, the greater the potential severity of risk and impact

Domain and Te Taiao aspect	Element at Risk	Number of Hazards	Average risk score at each scenario/timeframe where: Low (1), Moderate (2), High (3), Extreme (4)				
			Present	Mid 2050 RCP4.5	Mid 2050 RCP8.5	Long 2100 RCP4.5	Long 2100 RCP8.5
Ec on o m	Forestry	6	1.2	1.5	1.7	1.7	2.2

Domain and Te Taiao aspect	Element at Risk	Number of Hazards	Average risk score at each scenario/timeframe where: Low (1), Moderate (2), High (3), Extreme (4)				
			Present	Mid 2050 RCP4.5	Mid 2050 RCP8.5	Long 2100 RCP4.5	Long 2100 RCP8.5
	Horticulture	9	1.0	1.3	1.6	2.0	2.3
	Viticulture	7	1.0	1.0	1.0	1.4	1.6
	Pastoral farming	8	1.0	1.0	1.1	1.3	1.5
	Tourism and hospitality	12	1.0	1.1	1.2	1.3	1.3
	Public Services (including government, scientific research, and education)	14	1.0	1.0	1.1	1.1	1.1
	Insurance coverage and credit provision	7	1.0	1.4	1.9	2.3	2.7
	Māori Enterprise	13	1.0	1.0	1.3	1.4	1.5
	Manufacturing	12	1.0	1.0	1.0	1.0	1.0
	Information technology and creative industries	5	1.0	1.0	1.0	1.0	1.0
Built Environment Taiohanga	Airports and Seaports	8	1.1	1.5	1.5	1.9	2.0
	Buildings and Facilities (public and private)	13	1.5	1.9	1.9	2.3	2.4
	Energy	14	1.1	1.4	1.4	2.1	2.0
	Flood and Coastal Defences	8	1.5	2.4	2.4	2.5	2.5
	Transport (Road and Rail)	13	1.6	2.1	2.1	2.2	2.2
	Solid Waste Management	12	1.1	1.8	1.8	2.2	2.2
	Communications	8	1.4	1.9	1.9	2.6	2.6
	Drinking water	13	1.5	2.0	2.0	2.6	2.6
	Stormwater infrastructure	11	1.1	1.6	1.6	2.4	2.4
	Wastewater infrastructure	13	1.0	1.6	1.6	2.1	2.1
	Marae and cultural sites*	8	1.1	1.6	1.8	2.1	2.1
	Māori Assets*	7	1.1	1.7	1.7	2.1	2.3
Human Oranga Tangata	Human health	16	1.3	1.5	1.6	1.8	2.1
	Social cohesion and community wellbeing	10	1.4	1.9	2.1	2.4	2.5

Domain and Te Taiao aspect	Element at Risk	Number of Hazards	Average risk score at each scenario/timeframe where: Low (1), Moderate (2), High (3), Extreme (4)				
			Present	Mid 2050 RCP4.5	Mid 2050 RCP8.5	Long 2100 RCP4.5	Long 2100 RCP8.5
	Existing inequities	14	1.4	1.8	2.0	2.4	2.8
	Social infrastructure and amenities	10	1.3	1.6	1.6	2.1	2.1
	Cultural heritage	9	1.6	2.0	2.0	2.7	3.0
	Sports and recreation	10	1.3	1.4	1.8	2.1	2.2
Natural Environment Oranga Whenua	Indigenous and Taonga species	15	1.5	2.4	2.6	3.3	3.7
	Forest Ecosystems, Services and Processes	16	1.3	2.1	2.3	2.9	3.2
	Wetland Ecosystems, Services and Processes	13	1.3	2.1	2.1	2.9	3.2
	Coastal Ecosystems, Services and Processes	15	1.6	2.0	2.1	2.7	2.9
	Freshwater Ecosystems, Services and Processes	14	1.5	2.2	2.4	2.9	3.2

** Disclaimer. One of the issues identified and acknowledged through preparation of these tables is iwi and hapū have not been involved in the assessment and outcomes indicated above are likely to change when this occurs.*

While assessing intersections of elements and hazards during initial screening, opportunities were identified as well as risks. The number of climate hazards above is associated with risks only and does not include the number of hazards that may drive opportunities for each element.

The number of risks highlights the breadth and diversity of risks, while the average risk score provides a quantitative assessment of the overall risk level, accounting for the severity and importance of each risk, and shows how the risk changes over time. The compounding risk scores also serve as a proxy for the scale of complexity associated with managing and adapting to multiple climate-driven risks. Elements with a higher count of hazards or higher risk scores are likely to face greater challenges in understanding the various interconnecting risks, and also in creating an effective adaptation plan to address a larger number of processes and risks.

Together these measures contribute to a more nuanced characterisation of the compounding risks faced by a domain or element. For example, Table illustrates that the Natural Environment elements are consistently exposed to a higher number of climate change risks (between 13 and 16, of a possible 18), as well as having higher average scores (min 1.3, max 3.7) compared to other domains. This reflects the sensitivity of the natural environment to multiple climate change drivers, the limited adaptive capacity given natural timeframes of physical adaptation or constraints on adaptability (e.g. land use), as well as the growing risk severity as the exposure to the climate driver change (e.g. temperature increase, sea-level rise) increases over time.

When comparing some of the natural elements (e.g. forests as ecosystems) to the economic elements (e.g. forestry industry), there is a disparity between the number of hazards (15 vs 6) and scale of associated impacts (max 3.7 vs max 2.2 for forest ecosystems and forestry economic sector respectively). While the scoring between domains is varied, SMEs in the individual domains used robust processes to identify risks (exposure and vulnerability) and score potential impacts. Further, the assessments were careful to differentiate between direct and indirect risks. Therefore, using the example above, impacts on forest ecosystems (related to loss of habitats/species) is not directly related to impacts on the forestry industry (which is relative to the scale of the contribution to regional GDP).

While the compounding risks in the built environment are significant, in general, these built systems have been designed with some level of risk in mind. The most severe compounding risks are associated with drinking water (13 hazards, maximum score of 2.6) and communications infrastructure (8 hazards, maximum score 2.6). However, as noted earlier in the assessment there is higher adaptive capacity for the management of drinking water supply which means that while the compound risk is high, the impact is low. Conversely, airports and seaports have relatively low severity scores and number of compounding risks (8 hazards, maximum score of 2), potentially because of the associated design requirements of these assets. Māori assets, marae and cultural sites are shown to have relatively low numbers of risks and severities (compared to for example public and private buildings and facilities) however, caution should be applied in their use as one of the issues identified and acknowledged in these tables is iwi and hapū have not been consulted which may well likely change the outcomes when this occurs. Other possible reasons including that historically, iwi and hapū shifted communities and assets as required in response to known hazards (e.g. erosion, flooding) and seasonality with reduced exposure to current risks than the general built environment. Further work on risks and impacts to Māori and cultural assets and sites is required in partnership with iwi and hāpu.

Within the human domain, human health has the greatest number of total hazards while cultural heritage (maximum 3.0) followed by exacerbation of existing inequities (maximum of 2.8) has the greatest severity scoring. Health is vulnerable to a range of risks, and society as a whole is not likely to adapt evenly. While high heat can drive negative health outcomes, some people work indoors while others work outdoors, and those able to afford air conditioners will use them. These types of factors result in an uneven distribution of impacts of climate change, largely along existing lines of inequity further exacerbating negative outcomes.

Future strategic decisions within the Wellington Region's climate change adaptation program are able to consider adaptation planning resource allocation, policy formulation, and resilience-building efforts using these compounding risk scores. The high numbers or collated severity of risks represents a likelihood of compounding hazards which can drive uncertainties and decisions placed in the "too hard" basket. The ability to respond to these hazards in the face of uncertainty will need to be managed in the governance domain, where existing institutional frameworks may become barriers to adaptation due to the incompatibility of current polices and plans with making decisions in the face of uncertainty.

4.7 Transition Risks and Opportunities

Transition risks differ from physical risks from climate change. The New Zealand External Reporting Board (XRB) defines them as "risks related to the transition to a low-emissions, climate-resilient global and domestic economy, such as policy, legal, technology, market and reputation changes associated with the mitigation and adaptation requirements relating to climate change".

4.7.1 Priority Transition Risks and Opportunities

Five priority risks and one priority opportunity were identified in the transition risk workshop (Appendix E).

Transition Risk 1	Exacerbated social inequity **(due to inequitable outcomes from climate mitigation / adaptation)**	Medium term (2032-2050) RCP2.6	Long term (2081-2100) RCP2.6
		Moderate	Moderate

Consequence	Climate mitigation and adaptation policies could lead to inequitable outcomes, further disadvantaging the Wellington Region's most vulnerable communities. Even a transition that limits warming could be achieved through inequitable policies that leave people behind. Climate change could amplify the challenges facing vulnerable communities, including Māori communities. Exacerbation of existing inequalities from Council policies could also have cascading effects, including disparate educational impacts, decreased access to work, and increased mental illness and addiction. As climate impacts become more severe, affordable insurance access may not be equal, with only those who can afford sufficient coverage having their assets protected. Changes in the insurance market may also hinder the ability of people in vulnerable communities to move from hazardous areas. The unequal impacts of climate change and climate policy have the potential to further social division among the Wellington Region's residents, separating people along socioeconomic lines, rural/urban divide, or cultural groups. In contrast, equitable outcomes could foster a sense of unity, supporting councils' work to serve residents.

Transition Risk 2	**Lack of investment and funding for mitigation and adaptation**	**Medium term (2032-2050) RCP2.6**	**Long term (2081-2100) RCP2.6**
		High	Moderate
Consequence	Councils are concerned about a lack of investment and funding, including insufficient resources to support Councils' responsibilities for emissions reduction or for comprehensive adaptation planning. Climate change mitigation and adaptation require massive investment to fund infrastructure and public services. Continued lack of investment could significantly delay decisive action, with Councils reacting to climate-related impacts rather than taking a strategic and proactive approach. In some situations, Councils could have adaptation funding for Councils' assets but not to support private asset owners with their adaptation. Councils could need to use public revenue to increase the resilience of for-profit lifeline utilities. Either situation could cause a backlash with reputational impacts for Councils. With more frequent or extreme climate-related events, such as Cyclone Gabrielle in 2023, emergency funding is under strain. It will be more important to balance funds going towards preventative adaptation and for post-event disaster relief. A comprehensive approach could lead to different funding streams for disaster relief and for climate mitigation and adaptation, so that they don't occur at each other's expense. Costs from investing in mitigation and adaptation will be high, but the reactive costs of inaction will be greater. The value in investing in adaptation, particularly in nature-based solutions, could also include the ways in which communities are enriched by these programmes. Councils should emphasise these messages in conversations with ratepayers and stakeholders when large investment decisions are made.		

Transition Risk 3	**Transport and mobility risks (including transport poverty, insufficient public transport, risks to freight, and increased need for electricity due to EVs)**	**Medium term (2032-2050) RCP2.6**	**Long term (2081-2100) RCP2.6**
		High	Moderate
Consequence	Transport and future mobility will become a key lever and focus of climate mitigation and adaptation in a transition scenario. Elements of this broad risk include:		

	• Transport poverty and access to affordable public transportation. • Limits to freight and the transport of goods. • Uptake of EVs widens the wealth gap (public transportation is unequitable). • Lack of EV charging infrastructure. • Increased need for electricity supply due to electrification of transport. • Insufficient/unreliable public transport systems lower public trust in them (results in more private vehicles and demand for more roads). • Lack of safe active transport options increases risk to cyclists and pedestrians and impacts uptake (private vehicles and roading continue to be the priority). • Cultural impediments such as inhibiting iwi and hapū from accessing marae. Changes to urban form will play a large part in shifting rapidly to a low carbon future, particularly if they occur in concert with adaptation measures (e.g. flood risk reduction and managed retreat). For an equitable transition, inclusive development must respect environmental boundaries. Once this infrastructure is in place, risks associated with transport decrease over time. Even in a climate scenario in which warming is limited to 1.5ºC above pre-industrial temperatures, many physical impacts will be "locked in" and continue to impact the Wellington Region for decades. Transport must transition to a low-carbon form and become more resilient to extreme weather events. Transport could exacerbate inequalities if public transport is disrupted by climate-related events. An increase in the cost of typical modes of transport like private vehicles will disproportionally impact economically disadvantaged communities. In addition to moving people, disruptions in transport will also impact freight, which can have knock-on effects to the availability of supplies and business operations.

Transition Risk 4	**Increased climate litigation (from decisions around managed retreat, ineffective adaptation plans, failure to meet reduction targets)**	**Medium term (2032-2050) RCP2.6**	**Long term (2081-2100) RCP2.6**
		High	Moderate
Consequence	As discussed in the transition risks and opportunities workshop, the fear of litigation seems to be a sufficient, significant threat to the Wellington Region's transition to a more resilient, low carbon economy. This fear can paralyse climate mitigation and adaptation activities. These decisions are particularly difficult due to the paucity of evidence to support adaptation or mitigation decisions. Councils must often make decisions with uncertain data that might expose them to litigation but are the best option for supporting the climate resilience of their communities. Litigation could arise from: • Decisions around managed retreat. • Failure to meet climate emissions reduction targets (at the regional or local level). • Insufficient disclosure of material climate-related risks or their financial impacts. • Exposure around changing levels of service to account for climate impacts (e.g. flood protection assets, access to parks, transport/three waters infrastructure, etc.) • Inefficient adaptation action plans (e.g. councils make decisions based on the information available and may face criticism based on the updated data). New Zealand is also among a select few countries that have an additional dimension to the litigation risk: the legal personhood of some of the country's most significant natural features (e.g. Whanganui Awa). Entities that can file a suit on behalf of these natural features could drive climate action, where these natural features and adjacent communities are affected by climate change. Whilst there are currently no situations of 'legal personhood' in the Wellington region, in the future there may be. Recent legal ramifications of climate policies have come to the fore in conversations with developers for some of the councils in the Wellington Region. There is potential for litigation against the councils		

	where landowners cannot develop their properties. On the other hand, councils could also perceive a litigation risk if development is approved and the property is severely impacted by an extreme weather event. The fear of litigation, despite whether councils allow for development or don't, can also be a significant driver of inaction. Litigation is more likely to occur when communities feel that their freedoms are being curtailed by councils' decisions or where councils are perceived as not acting quickly enough or at a large enough scale. In these cases, the importance of engagement with ratepayers and stakeholders would be critical in a collaborative approach that respects and integrates the agency of affected communities. Involving communities in the decision-making process can lessen the chances of litigation once decisions are made.

Transition Risk 5	**Increased acute event-related costs and chronic events reaching thresholds of tolerance**	**Medium term (2032-2050) RCP2.6**	**Long term (2081-2100) RCP2.6**
		High	Moderate
Consequence	As climate impacts become more severe, the costs of recovering assets and supporting communities through natural disasters will grow. This will compound over time with changes from chronic events reaching thresholds of tolerance. Event-related costs can include: • Insurance retreat from high hazard zones. • Maintaining / insurance for climate-exposed council assets. • Damage cost of recovering assets due to frequent and extreme weather events. • Financial impact from loss of ratepayers (due to residents' departures). • Failure to consider impacts of foreseeable climate change risks on Council-owned infrastructure and projects (e.g. decreasing the level of services and increasing damage costs). • Damage to infrastructure due to climate-related extreme events can lead to tipping points where assets and infrastructure are no longer recoverable. In these instances, costs also include replacing infrastructure and decommissioning stranded assets. New Zealand's relatively small population can constrain funding for disaster relief and mitigation/adaptation due to limited resources – including from Central Government. Existing disaster relief and infrastructure repair funds are likely to be allocated towards where they can be most effective for the highest number of people. In a future with more frequent climate-related events, tipping points could occur where roads used by smaller communities become too expensive to maintain and repair. As discussed under "Risk: Lack of investment and funding for mitigation and adaptation", competition over funding for emergency response needs and adaptation/mitigation could occur if that funding comes from the same sources. Presenting costs of inaction when weighing the costs of adaptation and mitigation is also key. To support these discussions, councils could invest in assessing the costs of inaction. Recent floods in the North Island could serve as an example. Actions taken to increase resilience and to adapt to the impacts of climate change could have added benefits like making infrastructure more resilient to earthquakes.		

Transition Opportunity	**Investment in ecosystem restoration or additional forestry leading to broader biodiversity, resilience, economic and social outcomes**	**Medium term (2032-2050) RCP2.6**	**Long term (2081-2100) RCP2.6**

		High	Moderate
Consequence	One of the adaptation opportunities available to councils in the Wellington Region is nature-based solutions and habitat restoration or land use change. This includes potentially providing for more forestry as international markets change as a result of greenhouse gas mitigation preferences (i.e. stronger demand for wood products as a construction material over concrete, or changing preferences in regards to reduced demand for meat and dairy). Investing in the region's biodiversity and ecosystems has benefits, including: Adaptation • Increased resilience from floods due to the water absorption qualities of native plantings • Buffering heat waves and urban heat island effects through trees and native ecosystem areas Mitigation • Increased carbon absorption of healthy ecosystems compared with lawns or built structures • An increase in the biodiversity of the region and more habitat available for rare and threatened species • Wellbeing benefits • Mental health benefits from more green spaces • Stronger community connections to nature (especially within urban areas) and the Region's unique biodiversity, with public support for Council actions to protect them • Increased availability of local and culturally significant foods • Sequestration of permanent forestry Economic • Appeal of the region for tourists who prioritise biodiversity • Increase in ratepayers who might want to move to these regions. • Maximising existing wood product production to create a competitive advantage in the Wellington Region as shifting international preferences (as a result of greenhouse gas mitigation preferences) change demand for building materials. **Prioritising the natural domain when addressing significant climate challenges can have flow-on benefits across the four well-beings (environmental, social, economic and cultural outcomes).** By investing in the functionality and resilience of the Wellington Region's ecosystems, councils have the co-benefit of investing in the region's people, economy, and biome. However, care is needed that in many cases nature-based solutions will only offer short term adaptation and will need to be partnered with other options as part of a long-term adaptation pathway. During the workshop, it was mentioned that New Zealand's residents are particularly connected with the country's natural landscape. Working with this cultural focus and New Zealand's unique natural landscape can lead to a variety of nature-based solutions that serve purposes besides climate resilience. There are many international examples of nature-based solutions that can serve as inspiration and adapted to New Zealand's unique natural context (Figure 12). Natural features tend to have softer boundaries than built infrastructure, and when ecosystems are healthy and diverse, can often absorb the impacts of extreme weather events. However, nature-based solutions, like other adaptation options, are still subject to failure during severe events as has been experienced in China, with sponge cities unable to cope with the extreme rainfall intensities being experienced. Recent work on planetary boundaries could be used by councils when creating strategies around nature-based solutions and gathering supporting evidence. In this case, New Zealand's small population and expansive natural landscapes is a huge advantage in the journey towards climate mitigation and adaptation.		

Figure 12: Nature-based Solutions like this Vertical Forest Designed by Stefano Boeri in Milan can Offer Myriad Opportunities to Improve the Climate Resilience and Liveability of New Zealand's Cities

4.7.2 Materiality

After discussing the priority transition risks and opportunity, workshop participants assigned materiality ratings to each risk across three timeframes. 'Materiality' was defined using the XRB's definition in its final climate standards: *information is material if omitting, misstating, or obscuring it could reasonably be expected to influence decisions that primary users make on the basis of an entity's climate-related disclosures*.

Materiality ratings were simplified to three categories. The short, medium, and long-term timeframes were the same ones used in the assessment for non-transition risks.

Table 20: Materiality ratings assigned during the transition workshop

Rating	Action
High	Most material risks. These should be the focus of risk management efforts.
Moderate	Should be closely monitored but considered 'under control' to some degree.
Low	Are lower priority compared to 'moderate' risks but should still be monitored.

After the workshop, participants noted that materiality ratings should be assessed separately for how the risks related to mitigation and adaptation. Similarly, urban and rural transport risks bring different challenges, so materiality ratings should be determined separately for urban and rural transport. This is reflected in Table 21 below.

Table 21: Materiality Ratings Assigned During the Transition Risk Workshop

Transition Risk / Opportunity	Specification	Short term (2023-2028)	Medium term (2031-2050)	Long term (2081-2100)
	Mitigation	High	Moderate	Moderate

Transition Risk / Opportunity	Specification		Short term (2023-2028)	Medium term (2031-2050)	Long term (2081-2100)
Exacerbated social inequity (due to inequitable outcomes from climate mitigation / adaptation)	Adaptation		Moderate	High	Moderate
Lack of investment & funding for mitigation and adaptation	Mitigation		High	High	Moderate
	Adaptation		High	High	Moderate
Transport risks (including transport poverty, insufficient public transport, risks to freight, and increased need for electricity due to EVs)	Urban	Mitigation	Moderate	Moderate	Moderate
		Adaptation	Moderate	High	Moderate
	Rural	Mitigation	Moderate	High	Moderate
		Adaptation	High	High	Moderate
Fear of Litigation (from decisions around managed retreat, inefficient adaptation plans, failure to meet reduction targets)			Moderate	High	Moderate
Increased event-related costs (e.g. damage costs of recovering assets)			High	High	Moderate
Investment in **ecosystem restoration** leading to broader biodiversity, resilience, economic and social outcomes			High	High	Moderate

Part C – Prioritisation for the Detailed Assessment

5 Prioritisation

The aim of the prioritisation process was to short-list 10-20 risks for the Detailed Assessment that are high priority for the councils based on both significance of the risk and associated impact and other factors such as the level of uncertainty, other projects or programmes of work that the detailed assessment would inform and aspects of greatest interest to the councils. The prioritisation process is described in Appendix E.

5.1 Prioritisation Outcomes – Scope of the Detailed Assessment

Table 2213 includes the list of the risks originally selected through the prioritisation stage to take through to Detailed Assessment.

Table 2213: Short-listed Risks Selected for Detailed Assessment through the Prioritisation Stage

Domain	Risk ID(s)	Risk Statement	Included in Detailed Assessment?	Reason for not Including (if Applicable)
Natural Environment	ND66	Risk to **vulnerable coastal ecosystems** (dunelands, saltmarshes, coastal turf) due to **coastal squeeze** (caused by existing infrastructure, storm surge, and coastal flooding)	Yes	
Natural Environment	ND19	Risk to critically endangered forest types (all warm forest) due to changes in mean annual temperature	Yes	Originally a change in mean annual rainfall was selected but there was no suitable spatial data available to support an assessment of the potential impacts and so mean annual temperature was selected instead.
Human	HD84, HD86	Risk to **cultural heritage** due to climate change hazards (with a focus on coastal flooding and coastal erosion)	Yes	
Human	HD30 HD31, HD32	Risk to social cohesion due to climate change (with a focus on flooding, sea-level rise, coastal erosion)	Yes	
Human	HD47, HD48, HD50	Risk to existing inequities due to climate change (with a focus on flooding, sea-level rise, coastal erosion)	Yes	
Built Environment	BD32	Risk to **buildings and facilities** (public and private) due to increasing **coastal erosion**	Yes	
Built Environment	BD87	Risk to **transport** (road and rail) due to **increasing rainfall induced landslides** and soil erosion	Yes. Qualitatively for most of region (see comment)	Data through the GNS Sciences Stability of Land in Dynamic Environments (SLIDE) project on landslides susceptibility is only available for the Wellington City area at

Domain	Risk ID(s)	Risk Statement	Included in Detailed Assessment?	Reason for not Including (if Applicable)
				this time. There is landslide information available for earthquake-induced landslides but this was not considered by technical specialists to accurately reflect the climate change potential risks (that are associated with rainfall). See the Data Gaps Report (Beca 2023) for further information.
Built Environment	BD30	Risk to **buildings and facilities** (public and private) due to **coastal and estuarine flooding:** increasing persistence, frequency and magnitude due to SLR	Yes	
Built Environment	BD33	Risk to **buildings and facilities** (public and private) due to **increasing rainfall induced landslides** and soil erosion	Yes. Qualitatively	Data through the GNS Sciences Stability of Land in Dynamic Environments (SLIDE) project on landslides susceptibility is only available for the Wellington City area at this time. There is landslide information available for earthquake-induced landslides but this was not considered by technical specialists to accurately reflect the climate change potential risks (that are associated with rainfall). See the Data Gaps Report (Beca 2023) for further information.
Built Environment	BD29	Risk to **buildings and facilities** (public and private) due to **river and pluvial flooding:** changes in frequency and magnitude in rural and urban areas	Yes	
Economic	ED13, ED23, ED33	Risk to **primary industries** (pastoral farming, horticulture, viticulture) due to more and longer **dry spells and drought**	Yes	
Economic	ED79, ED80	Risk to insurance coverage and credit provision due to increasing fire–weather conditions; storminess	No	Although this was a moderate rated impact for the Wellington Region, it is difficult to further quantify this risk in a useful way that will guide future council decision making and so it was taken

Domain	Risk ID(s)	Risk Statement	Included in Detailed Assessment?	Reason for not Including (if Applicable)
				out of the detailed assessment in agreement with the council project team. Threshold information that triggers insurance or credit retreat is the decision of private insurers and banks, and due to confidentiality of the data in a contract between the insurance company and the property owner, there is no way to access this information. Information on entities / properties that don't have insurance is also not accessible (held confidentially by insurers).
Economic	ED4	Risk to **forestry** due to increasing **fire–weather conditions**: harsher, prolonged season	Yes	
Economic		Opportunity for **forestry** due to international influences from climate change and **greenhouse gas mitigation preferences**	No	Covered as a transition risk
Economic	ED116	Risk to manufacturing (industrial land) due to coastal inundation and flooding)	Yes	

Part D – Detailed Impact Assessment

6 Detailed Assessment

The following section describes the potential regional impacts of the risks selected during prioritisation for a detailed analysis of the potential impacts of climate change. Appendix F contains more detail on the particular elements of risk and impact scoring used in the Detailed Assessment. As data is extremely limited most of the detailed assessments, except for the built environment domain, was qualitative by necessity. The following provides a summary at the regional level.

The Detailed Assessment covers the following for each domain:

a. Potential impacts
b. Key areas of impacts (geographical)
c. Considerations for adaptation planning.

6.1 Natural Environment Impacts

As described in Section 4.1, ecosystems are complex systems with interconnected processes that make it difficult to predict the full risks and impacts of direct climate stressors like changes in rainfall and temperature (Keegan et al., 2022). There is also limited information to inform a regional impact assessment such as when impacts may become so significant, they reach a 'threshold for change'. This level of assessment is highly dependent on the nature and composition of specific habitats, the existing state of the ecosystem, how it has changed over time and whether the impacts can be attributed to any one hazard. This level of assessment is therefore best done at a site-specific scale as part of local adaptation planning.

It has been identified that potentially more significant impacts from climate change are likely when the ecosystem is already under pressure or sensitive in some way. Therefore, for the detailed assessment, coastal ecosystems (salt marsh and dunelands) and regionally threatened forest ecosystems (Singers et al., 2018) were identified as vulnerable ecosystems to be explored further. Coastal ecosystems were selected to assess more fully the potential impacts from rising sea levels, particularly as it relates to coastal squeeze and regionally threatened forest types were investigated for potential impacts of a warming climate on distribution and coverage. Table 23 below shows the broad risks that were selected for the detailed assessment.

Table 2314: Risks selected for natural environment detailed assessment

Risk ID	Risk Statement
ND66	Risk to coastal and marine ecosystems, services and processes due to coastal and estuarine flooding: increasing persistence, frequency and magnitude
ND19	Risk to terrestrial and forest, ecosystems, services and processes due to higher mean air temperatures

6.1.1 Risk to Coastal and Marine Ecosystems, Services and Processes Due to Coastal and Estuarine Flooding: Increasing Persistence, Frequency and Magnitude

Table 2415: Qualitative risk scores for ND66, see Appendix A for more detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
ND66: Risk to coastal and marine ecosystems, services and processes due to coastal and estuarine flooding.	Moderate	Moderate	Moderate	High	Moderate	Major

a. Potential Impacts

The Wellington Region has a relatively small tidal range and therefore even small changes in sea level may have impacts on the size, scale and distribution of coastal ecosystems. As rising sea level moves the high-water mark inland in low lying areas, coastal ecosystems and the biota they support may be lost or irreversibly altered if they are prevented from migrating inland due to natural or man-made barriers (such as where there is a hard infrastructure edge to the coastal marine area). Particularly sensitive ecosystems at higher risk from sea-level rise and inundation are those that occupy nearshore environments such as salt marsh, coastal turf, dunes, intertidal sand and mudflats and their associated fauna namely coastal avifauna, marine mammals and invertebrates. As naturally uncommon ecosystems (Wiser et al., 2013), the vulnerability (sensitivity and adaptive capacity) of these ecosystems is high exacerbating the risk and potential impacts. The resultant impacts of this ‘coastal squeeze’ includes loss of ecosystem extent and value, and a decrease in ecosystem services such as food provision (mahinga kai), reduction in carbon sequestration, decline in water quality (Keegan et al., 2022).

b. Key Areas of Impact

Within the Wellington Region, the impacts from sea-level rise and storm surge will be most prevalent within the region’s harbours, estuaries and river mouths as these are the locations most of these vulnerable ecosystems are found. The areas where saltmarsh may be particularly impacted by coastal squeeze are Pāuatahanui Inlet as there is hard infrastructure in the form of roading and residential development that will prevent the landward migration of saltmarsh over time. Dunelands at Lake Ōnoke and along the eastern Wairarapa coastline are also likely to be impacted with changing coastal processes, landform and infrastructure prevent dune formation.

With rising sea level, more frequent coastal inundation of low-lying river mouths and estuaries will impact coastal wetlands and wader bird habitat in Hutt City and Porirua City inner harbour inlets. Impacts may include a loss of productivity and carbon sequestration of coastal wetlands and cascading population level impacts on resident and migrant coastal birds. Cascading impacts on coastal birds is due to the loss of wetland extent and subsequent increasing pressure on remaining coastal wetlands.

The eastern coastline of the Wellington Region has several river mouths, coastal wetlands and dunelands that are at risk from increasing storm surge associated with rising sea levels. Lake Kohangatera and Ōnoke are already exposed to saltwater intrusion and changes in salinity gradients from sea-level rise (Perrie & Milne, 2012). This change in salinity will impact aquatic fauna distribution within the associated waterways and have cascading impacts on habitat, and potentially cultural practices (mahinga kai gathering). The impacts are expected to occur as early as mid-century.

c. Consideration for Adaptation Planning

Identification and protection of sites with suitable coastal processes and existing coastal ecosystem values is needed to retain representative, self-sustaining coastal ecosystems. Setting of regional targets for minimum viable ecosystem extent could also form part of adaptation planning for long-term coastal biodiversity outcomes and this can inform ongoing monitoring programmes. More specifically, investigation of existing locations and immediate surrounding areas would help to identify sites for protection and enhancement. This may include areas currently earmarked for managed retreat that have suitable characteristics to allow the natural or facilitated establishment of ecosystems like dunelands, saltmarsh and coastal turf. Programmes of coastal management including restoration and habitat creation will be required in the long-term as well as monitoring of the extent and condition of these vulnerable ecosystems to identify trends related to climate change early and allow for adaptation measures to be implemented.

6.1.2 Risk to Terrestrial and Forest, Ecosystems, Services and Processes Due to Higher Mean Air Temperatures

Table 2516: Qualitative risk scores for ND19, see Appendix A for more detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
ND19: Risk to terrestrial and forest ecosystems, services and processes due to higher mean air temperatures	Moderate	High	High	Extreme	Extreme	Major

a. Potential Impacts

The diverse geography of the Wellington Region supports a range of forest types including alpine and sub-alpine, mild forests and lowland broadleaf forests throughout the region. Forest types are generally distributed along an east-west moisture gradient as well as along elevation gradients associated with the Tararua and Aorangi Ranges (Singers et al., 2018). The western part of the region (Wellington, Porirua, Upper Hutt, Lower Hutt) has extensive, contiguous tracts of native and plantation forests on ridgelines and hillslopes associated with the Tararua and Remutaka Ranges. Similarly, contiguous mild forest and scrub types are found along the Aorangi Range (South Wairarapa, Carterton, Masterton districts).

Fragmented lowland forest and scrub types are found on the Wairarapa plains and within the Wellington and Porirua City districts (Singers et al., 2018). Due to past vegetation clearance for agricultural and urban development, lowland forest types are categorised as 'Regionally Endangered' in the Wellington Region. Increasing temperatures of 2ºC or more (RCP 8.5) could change forest composition and distribution coupled with an increased risk of wildfire, soil moisture deficits and the cascading, indirect impacts causing increased pest abundance (Sheppard, 2013; Macinnis-Ng et al., 2021). This means that the Region is at risk of losing these endangered forest ecosystems along with associated ecosystem services, habitat provision for native fauna and humans (Keegan et al., 2022).

b. Key Areas of Impact

The most pronounced potential climate change risks specifically for Regionally Endangered Forests (as opposed to general forest types across the region) occur in the South Wairarapa, Carterton and Masterton Districts where the greatest change in temperature and soil moisture deficits are likely to occur by mid-century and beyond (i.e. annual temperature of 2ºC or more). The fragmented nature of the remaining forest and scrub increases the vulnerability of these ecosystems to both direct and indirect climate change impacts. The adaptive capacity of these remnants is constrained by lack of connectivity with other natural areas as well as increased pest pressures and acute disturbance events (wildfires). These impacts will manifest as a lack of seedling and sapling regeneration as well as canopy dieback within the remnants and a reduction in the number and extent of lowland forest remnants present.

c. Considerations for Adaptation Planning

Bolstering the adaptive capacity of regionally threatened ecosystems is an important consideration for future planning. This involves the protection and enhancement of existing forest remnants and target setting of minimum extents needed for forest and scrub ecosystems to remain in the region long-term. Examples of actions include regulatory mechanisms, pest control and fencing as well as identifying suitable areas / corridors for the expansion of forest. Importantly, monitoring of other, non-threatened terrestrial ecosystems is also important to keep track of the extent native forest cover within the region and to prioritise ecosystem management within the region.

6.2 Human Impacts

The social impacts of climate are often indirect and may occur together within the same community. For this reason, the risk to social cohesion and the risk of increasing existing inequities are described separately, but then covered together for various communities across the region.

A number of risks were combined for assessment in the detailed assessment stage. This is in acknowledgement that many of the social impacts will be similar no matter the specific climate hazard or driver. The information sources as described in Appendix H have been used to inform the assessment. However, available information sources relate to indicators of vulnerability (such as Mason., et. al, 2021) and to determine impacts on social cohesion, existing inequities and cultural heritage requires SME interpretation of the data in terms of what those vulnerabilities might mean in regard to the selected hazards.

Table 2617: Risks Selected for Social / Human Domain Detailed Assessment

Risk ID	Risk Statement
HD30 HD31 HD32	Risk to social cohesion and community wellbeing due to coastal and estuarine flooding, increasing coastal erosion and sea level rise.
HD47 HD48 HD50	Risk to existing inequities due to river and pluvial flooding, coastal and estuarine flooding and coastal erosion.
HD84 HD86	Risk to cultural heritage due to coastal and estuarine flooding and coastal erosion.

6.2.1 Risk to Social Cohesion Due to Coastal and Estuarine Flooding: Increasing Persistence, Frequency and Magnitude and Increased Coastal Erosion: Cliffs and Beaches

Table 2718: Qualitative risk scores for HD30, HD31 and HD32, see Appendix A for more detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
HD30: Risk to social cohesion due to coastal and estuarine flooding.	Moderate	High	High	Extreme	Extreme	Catastrophic
HD31: Risk to social cohesion due to sea-level rise.	Low	Moderate	Moderate	High	Extreme	Major
HD32: Risk to social cohesion due to coastal erosion.	Moderate	High	Extreme	Extreme	Extreme	Minor

a. Description of Potential Impacts

There is limited information on existing social cohesion in the Wellington Region. Social cohesion is described as the bonds that link communities and people together, these may be physical place based, cultural or social connections. From a social perspective, well-being is considered a measure of happiness or satisfaction and the ability to achieve personal and collective aspirations. It will change over time as communities are dynamic and so detailed assessments of social cohesion are normally undertaken at a site specific level as part of a localised adaptation planning process. The following assessment draws on SME expertise and utilises vulnerability information outlined in Appendix H to provide a regional assessment.

An increased incidence of flood events, coastal inundation and coastal erosion associated with a changing climate will affect homes, property, business and facilities and over time erode the desire and ability of people to remain in affected communities. The National Climate Change Risk Assessment describes two aspects to the risks, first the impacts associated with displacement and second the impacts on the parts of the community left behind (MfE, 2020).

Displacement can cause trauma linked to disruption and dislocation from familiar surroundings and breaking of social and cultural bonds, and the challenges of resettlement. Movement between communities within the Wellington Region may change the composition of communities, affect housing availability and affordability, change demand for social services, change demand for recreational facilities and schools, alter commuting patterns and competition for other resources. Conflict may arise between existing residents and relocated households as disagreements about social norms and practices emerge. With less ties to support networks and opportunities, poorer health and well-being outcomes are likely.

Over time, affected communities will see a decrease in the local population as the affected residents relocate or are relocated to areas of lower risk. A likely drop in property value of properties at high risk may result in these properties being increasingly occupied by those who can't afford to live anywhere else, increasing vulnerability and increasing overall risk and potential social impacts. Households who remain within the affected communities may experience feelings of loss and abandonment as the community diminishes. As households leave, the community will reduce in size and essential services may be slowly withdrawn (for example education facilities, job opportunities or community service). Similar to displaced households, those who remain may experience trauma due to the breaking of family, social and cultural bonds, and poorer health and well-being outcomes are likely.

The breakdown of communities and the social bonds and connections to special places is important because fractured less cohesive communities can result in conflict and feelings of isolation and loss. Less cohesive communities can also be less resilient following a disaster event as often it is your immediate neighbour / community who is able to offer help in the first instance if required.

Increased flood risk and communities cut in half (or fragmented) by events or repeat events. Key infrastructure and services, physical connections, social infrastructure within the community, and between the community and other communities may be damaged and potentially not replaced. Relocation of affected households may be (formally) required, or some households may find the stress associated with living with flood hazard too high and leave on their own. Either way, community cohesion could be suddenly affected probably after an event as the desirability of the community is reduced by both the hazard and the diminishing provision of or access to support, education, job and education opportunities and social services. Social relationships, support networks and connections may be diminished affecting well-being (Campbell, 2019; Boege, 2018).

Slow onset sea-level rise and coastal erosion making areas of the community unliveable due to the risk of storm damage or semi-permanent or permanent inundation. Sea-level rise will probably affect social cohesion at a slow pace as the sea slowly rises affecting coastal homes, assets and key infrastructure and access routes. A few households at a time may relocate after an event or due to the on-going stress of living with coastal hazards, or isolation. The result of relocations will be a slowly reducing population size and essential services and opportunities. Impacts in terms of mental health and well-being will be felt across the community and the affect those who have relocated.

b. Key Areas of Impact

Social cohesion impacts are more likely to occur where existing communities are already cut off from key services and infrastructure, bisected or fragmented due to inundation or flood hazard zones and communities where social infrastructure could be lost or damaged (schools' sports facilities, medical facilities, shops and supermarkets etc).

Where single access roads connect communities to other parts of the region any damage to the road goes beyond just a physical impact on the transport infrastructure it will:

- Impact on social cohesion because the community is at risk of isolation which may lead to the slow erosion of services and infrastructure. Either the community is isolated from key social and / or physical network for example schools, hospitals, places of work
- Exacerbate existing inequities or create new ones as isolation leads to loss of residents, services and erodes the sense of community cohesion
- Limit the ability to practice tikanga and connect with valued places having cultural impacts.

Examples of areas in the region that are more likely to be impacted by being cut off, bisected or fragmented include:

- **Cut Off:** Eastbourne, South Wainuiomata, Stokes Valley, Whiteman's Valley, Otaki, Rural Eastern Wairapapa (cut off)
- **Bisected:** Masterton
- **Fragmented:** Featherston, Greytown, Carterton, Paraparaumu.

c. Considerations for Adaptation Planning

There are some key indicators for adaptation planning that may signal social cohesion impacts are increasing. These include decreasing house prices, social conflict and anti-social behaviour, increasing turnover of residents and rates of property abandonment, population change and accessing support and education services / youth.

6.2.2 Risk to Existing Inequities Due to Coastal and Estuarine Flooding, Coastal Erosion and River and Pluvial Flooding: Increasing Persistence, Frequency and Magnitude

Table 2819: Qualitative risk scores for HD47, HD48 and HD50, see Appendix A for more detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
HD47: Risk to existing inequities due to river and pluvial flooding.	Low	Moderate	Moderate	High	Extreme	Catastrophic
HD48: Risk to existing inequities due to coastal and estuarine flooding.	Moderate	High	Extreme	Extreme	Extreme	Major
HD50: Risk to existing inequities due to coastal erosion.	Moderate	High	Extreme	Extreme	Extreme	Major

a. Potential Impacts

There are existing inequities in society around the ability to access services and resources (e.g. clean water, work, finance, insurance, safe and dry homes) to maintain and support well-being that can be exacerbated by climate hazards. Also new inequities can be created through the action (or inaction) taken to respond to the impacts and implications of a changing climate.

Groups within society that are already marginalised, at an economic disadvantage or are potentially more vulnerable to climate hazards (such as those with disabilities) may be at risk of being made more vulnerable as a result of being increasingly exposed to the hazard. International literature suggests that areas of known hazard where damage and loss has already been experienced, such as flood prone areas, tend to be occupied by those of lesser economic means because they can't afford to live anywhere else (Beck, 1992).

In the Wellington region there are existing inequities with people who identify as Pacific people and Māori being over represented in areas of high deprivation (e.g. Porirua and Lower Hutt) and having disparate health risk factors, use of health services and health outcomes (Pacific Perspectives, 2019). Wellington's Pacific communities, clustered around Porirua Harbour (the Waitangirua-Titahi bay arc), the Hutt River (the Lower Hutt Valley), the southern suburbs of Wellington (the Strathmore to Berhamphore corridor) and the suburb of Wainuiomata are resilient with strong cultural and spiritual connections, locally,nationally and internationally. However, these communities experience high levels of socioeconomic deprivation and poor access to education, employment and home ownership (Pacific Perspectives, 2019). Inequities in relative housing affordability show that more residents spend over the median income on housing in Porirua and Kapiti Coast, particularly compared to residents of Wellington City. Damp and mould are a significant issue for households in Porirua; and for Pacific and Māori households across the region (Regional Community Profile, Wellington Community Trust, 2020).

Increased flood risk and coastal inundation can increase existing inequities by fragmenting communities, reducing support networks and increasing social impacts (described in the social cohesion section above). Key infrastructure and services, physical connections, social infrastructure within the community, and between the community and other communities may be damaged by coastal and estuarine flooding events and repeat events. The constant damage to infrastructure and services may exacerbate existing vulnerabilities such accessibility, underlying health issues and mental health. With more frequent, repeat events some infrastructure and services may potentially not be replaced or become increasingly unreliable (for example power and clean water) further increasing the impacts on vulnerable parts of the community.

Known coastal, erosion and estuarine flood risk zones that are already be occupied by those with lesser economic means or those who are already marginalised, including Wainuiomata, western side of State Highway 59 including parts of Tawa, Linden, Porirua and Porirua City Centre, Otaki and Otaki Beach, Featherston, Naenae, Taita and Moera, Trentham, Stokes Valley, Māori Bank. A failure to manage the hazards faced by already marginalised residents will result in on-going loss and damage to an already struggling portion of the community making their lives harder and reducing well-being. An increasing frequency of flood events will likely exacerbate the situation triggering a downward spiral of living conditions and access to services. Affected properties may be sold cheaply or rented out drawing in others of lesser means who are seeking cheaper housing. Over time the residents may be trapped in low quality risky rental properties or unable to sell their homes and move to safer locations. Given existing housing issues, prices in safer locations may increase and become less affordable.

New inequities may be created or existing inequities exacerbated through the response to managing the hazard. For example, an increasing frequency of severe flood events may result in additional, previously safe and unmanaged locations, experiencing flood hazards. Slow onset sea-level rise and coastal erosion making areas of the community unliveable due to the risk of storm damage or semi-permanent or permanent inundation. Inaction (or maladaptation) may create new equalities by resulting in a devaluing of properties at risk and those with resources leaving, starting a transition to those with lesser resources moving into high-risk areas. Maladaptation such as providing a certain level of protection may create inequalities by encouraging more development and affordable housing in areas that have short term protection but lack the long-term, large event, protection from floods (for example stopbanks that are overtopped by severe storm events).

Coastal erosion and inundation may cause transport networks to become inaccessible. This is already occurring as evidenced in rainfall induced landslides and flooding that cut off road access along Masterton-Castlepoint Rd in February 2023. Where this occurs in areas of existing inequities, the communities may find themselves more frequently isolated leading to a loss of ability to obtain services and access employment. This may lead to a loss of social cohesion as people leave for less isolated areas.

Existing Inequities in Relation to Māori Health

A range of factors, with roots in historic and ongoing forms of political marginalisation, underlie the disproportionate risks facing Māori public health (Harris et al. 2012; Cormack et al. 2018). These factors include existing Māori health disparities (Ministry of Health 2019b); poorer access to and quality of health care (Brown 2018; Graham & Masters-Awatere 2020); socio-economic deprivation (Jones et al. 2014; Jones 2019); and political marginalisation (Harris et al. 2012; Lewis et al. 2020).

Increased frequency of flooding may impact those with existing underlying health issues more and exacerbate these existing inequalities.

b. Considerations for Adaptation Planning

It will be difficult to identify what indicators of changes to existing inequities may be directly caused from the impacts of a changing climate. However the following are general indicators that could signal existing inequalities are being exacerbated:

- Changes in the deprivation index of hazard prone areas
- Change in the demographics and income range of hazard prone areas
- Loss of infrastructure and services to hazard prone areas.

6.2.3 Risk to Cultural Heritage Due to Coastal and Estuarine Flooding and Coastal Erosion: Increasing Persistence, Frequency and Magnitude

Table 2920: Qualitative risk scores for HD84 and HD86, see Appendix A for more detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
HD84: Risk to cultural heritage due to coastal and estuarine flooding.	Moderate	High	High	Extreme	Extreme	Major
HD86: Risk to cultural heritage due to coastal erosion.	Moderate	High	High	Extreme	Extreme	Major

The following has been written based on the general knowledge of the project team in regards to the potential impacts on cultural heritage from climate change. According to the Parliamentary Commissioner for the Environment (1996) cultural heritage includes places of significance to Māori, archaeological sites, historic buildings and structures, and cultural landscapes. These sites of value and significance to the heritage, daily life and well-being in New Zealand can include things like Māori assets (Marae, papakāinga), cultural sites (e.g. wāhi tapu), resources (customary resources), ability to express kaitiakitanga, practice tikanga and apply and perpetuate mātauranga Māori.

Outside of the Parliamentary report mentioned, it is acknowledged that for Māori the whenua manifests whakapapa (genealogical links) from past to present and into the future so in that context all of the whenua is considered to be of value to Māori in that Tīpuna are in the whenua and are the whenua (Mountains, Rivers, Forests among other elements).

Iwi and hapū across the region have not provided input into the following discussion and therefore this reflects general impacts that may occur to cultural heritage only. Further engagement should occur with iwi and Hapū to identify more fully the potential impacts on cultural heritage across the region. For this reason, specific locations of the potential impacts have not been described.

a. Potential Impacts

There are three potential aspects regarding the risk to cultural heritage:

- The physical loss of a site of significance and value due to coastal inundation, flood damage, or coastal erosion
- The loss of the opportunity to interact and maintain a relationship with a significant location generally through loss of access (e.g., road) to the location
- Passing on mātauranga via practices related to coastal, moana, roto and river aspects such at Mahinga kai.

These risks are particularly acute for Māori because of the reciprocal relationship and kinship connections between people and places at the centre of Te Ao Māori (Hyslop et. al., 2023). As such, there is a risk to the spiritual and cultural attachment to place that is essential to maintaining connections to the land and traditional practices and wellbeing and affect the maintenance of traditional skills and identity (King and Penny, 2006; King et al., 2012). An erosion of the ability to maintain a relationship with land / places will likely affect almost all aspects of Māori well-bring (Awatere et. al., 2021).

Of particular concern are the aspects of holistic health, whānau, spiritual, physical and mental health issues, loss of identity and community cohesion and the exacerbation of inequality and disparities already experienced by Māori (NCCRA in MfE, 2020).

Climate hazards such as coastal inundation, flooding and coastal erosion can directly impact on cultural heritage sites causing damage and resulting in the need for costly repairs. Many marae are located on the coast, or within flood hazard zones and in low lying areas.

Marae are not just a physical structure but a place where culture is practiced. Tikanga is upheld and connections with people and land are experienced and maintained. Therefore, impacts can be many and complex and may relate to losing special features of the area such as loss of physical spaces to meet connect and interact with the land and environment. Furthermore, with inundation and flooding a loss of traditional customary practices (such as mahinga kai), impacts on cultural identity, ability to share mātauranga within customary practices and impacts on health and well-being and social cohesion.

Loss of wāhi tapu and other significant sites affect the relationship between living and tīpuna and the environment affecting traditional practices, food gathering and impacting on identity and social cohesion centred on those practices.

b. Key Areas of Impact

There will be sites of cultural significance across the Wellington Region that will be affected either directly (loss or damage) or indirectly (loss of access) by coastal and river flooding. However, we have not identified such sites in this assessment as these sites and associations are the domain of iwi and hapū who have not been specifically engaged with in the creation of this report. We note that there will be regional nuances that should be explored further with iwi / hapū.

c. Considerations for Adaptation Planning

This study and the corresponding report recognises that each iwi and hapū focus on the aspects of their own people and whenua in the rohe (geographic area) pertaining to that iwi. This is at the heart of rangatiratanga. It presents as a different lens to that of a Regional Project and so creates some further need to look closely at the aims and outcomes of Treaty Partnership with iwi and hāpu.

Further work is needed alongside iwi and hapū in the region to identify the potential impacts on cultural heritage pertaining to each iwi and hapū. However, in the interim there are aspects that can be monitored that may be indicators of impacts occurring such as significant sites or assets being lost or isolated (road access is lost) due to coastal inundation, flood hazard zones or coastal erosion.

6.3 Built Environment Impacts

The risks to the built environment selected for detailed assessment in the prioritisation are shown in the table below. In the sub-sections that follow, descriptions of impacts, key areas of impact, and considerations for adaptation planning are provided for each risk assessed in detail.

Table 3021: Risks selected for built environment detailed assessment

Risk ID	Risk Statement
BD32	Risk to buildings and facilities (public and private) due to coastal erosion
BD87	Risk to transport (road and rail) due to increasing landslides and soil erosion
BD30	Risk to buildings and facilities (public and private) due to coastal and estuarine flooding
BD33	Risk to buildings and facilities (public and private) due to increasing landslides and soil erosion
BD29	Risk to buildings and facilities (public and private) due to pluvial and fluvial flooding

6.3.1 Risk to Buildings and Facilities (Public and Private) Due to Pluvial and Fluvial Flooding (Risk ID #BD29)

Table 3122: Qualitative risk scores for BD29, see Appendix A for more detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
BD29: Risk to buildings and facilities (public and private) due pluvial and fluvial flooding	Moderate	High	High	High	High	Major

a. Description of Potential Impacts

Fluvial (river) and pluvial (surface water) flooding is perhaps the most significant risk to buildings across the Wellington Region. Even at present day, the combined regional flood modelling from GWRC and analysis against council GIS layers indicate over 60,000 properties being at risk (Figures 13 – 15), with 82% being residential. In the coming decades there will be increasing exposure of flood-prone buildings and communities around the region with further increases in the scale of risk in coastal catchments. Gravity driven stormwater networks at the coast will have reduced ability to discharge as groundwater rises with increasing sea levels. This will create backwater effects in river systems and increase compound flooding potential.

Table 3223: Summary of buildings exposed to fluvial / pluvial flood risk

Buildings Exposed	Present Day	Late Century (RCP4.5)
Total buildings (i.e. those below plus residential, commercial, etc)	61,674	69,483
Childcare facility buildings	195	205
School buildings	794	847
Aged care facility buildings	29	31
Hospital buildings	45	45
Supermarkets	75	81
Religious facility buildings	175	180

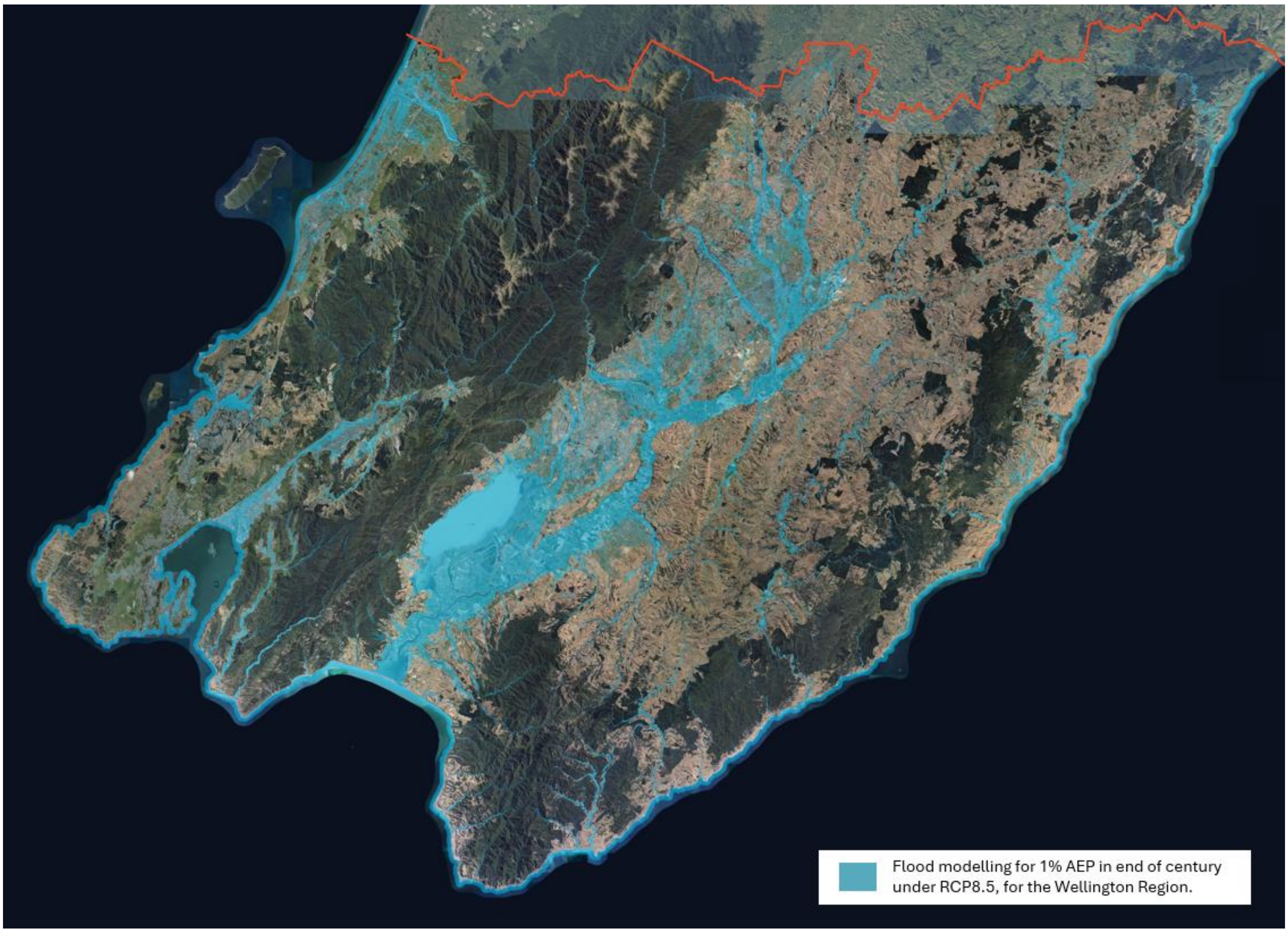


Figure 13: Flood Modelling for a 1% AEP at End of Century Under RCP8.5 for the Wellington Region (GWRC Regional Flood Exposure Model Viewer) – a Large Scale Copy of this Map is in Appendix D

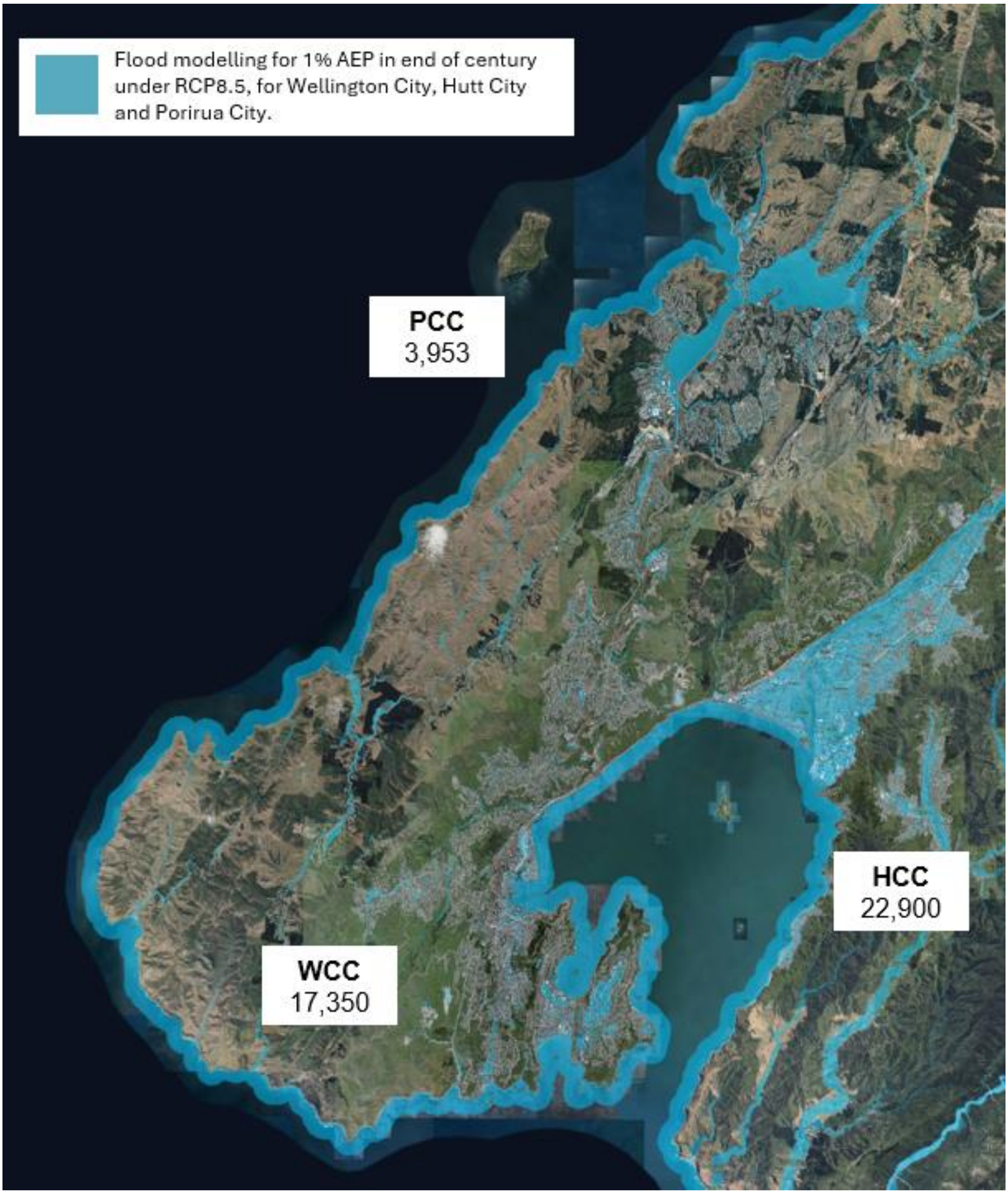


Figure 14: Pluvial Flood Modelling for 1% AEP in End of Century Under RCP8.5 and the number of buildings impacted in Wellington, Hutt City and Porirua (GWRC Regional Flood Exposure Model Viewer)

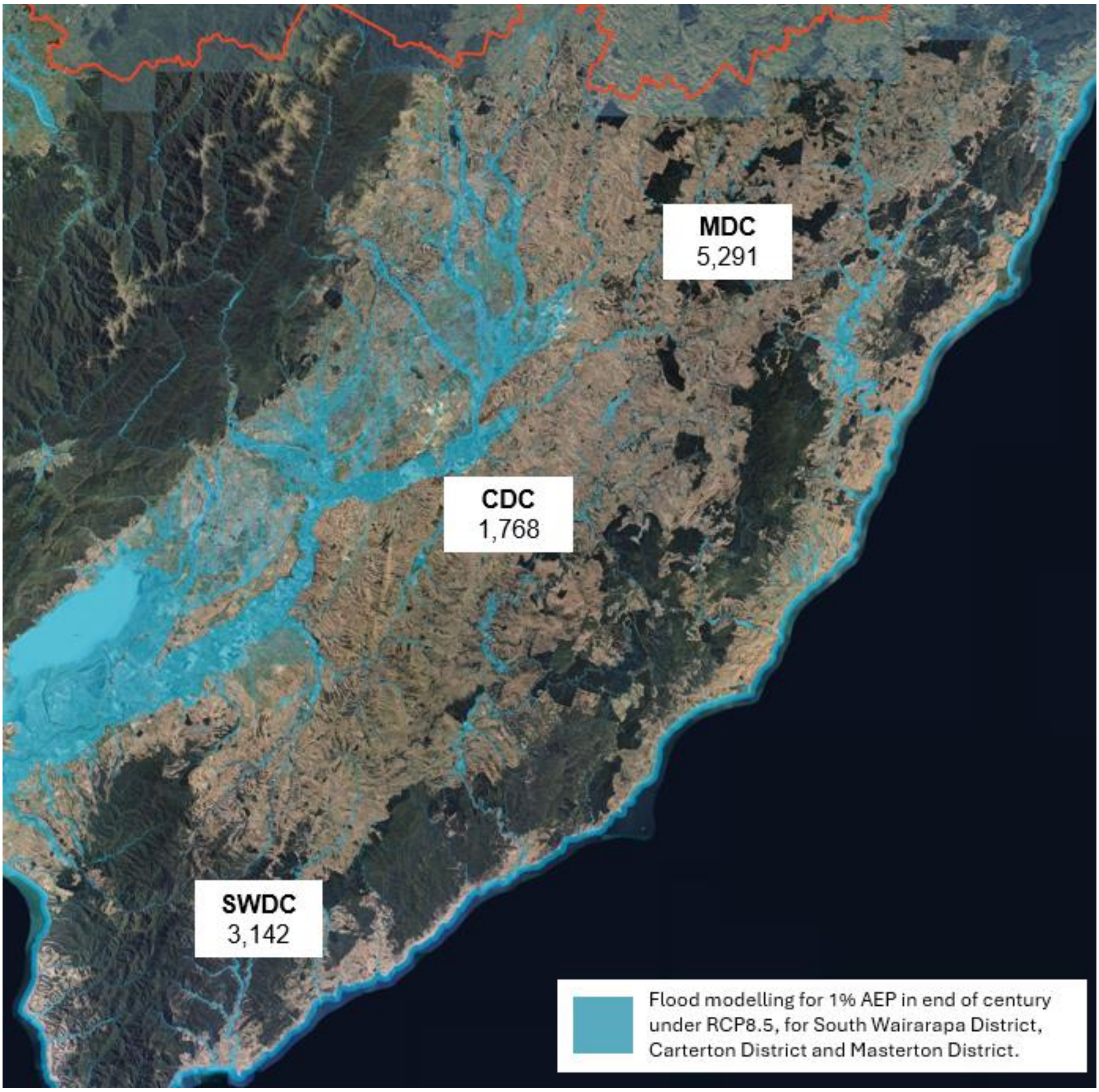


Figure 15: Pluvial Flood Modelling for 1% AEP in End of Century Under RCP8.5 and the Number of Buildings Impacted in South Wairarapa, Carterton and Masterton (GWRC Regional Flood Exposure Model Viewer)

While the predominate (82% by number of buildings) impacts will be on residential buildings, there are more than 2,500 commercial buildings and more than 1,800 publicly owned buildings that will be exposed to extreme flood events at the end of the century. Most buildings are highly sensitive and will be damaged by flooding. Although there is no region-wide data available for finished floor levels, foundations type (piles or slabs) or building types (e.g. timber versus concrete), older building stock not constructed in accordance with modern building code regulations (with finished floor levels above the floodplain) may be more vulnerable to damage than modern buildings. Similarly, because of the useable life of buildings and the infrequent updates of the building code, the adaptive capacity of buildings is slow to change over time because there is not necessarily a frequent "turnover" of buildings where structures are removed and rebuilt.

The increasing exposure of commercial and industrial buildings will cause impacts to the contributing communities over time, with impacts cascading into the economic and human domains. When industrial areas are exposed to flooding, chemicals or contaminants may discharge into floodwaters and cause environmental damage. Because of the scale of impacts particularly on the commercial and industrial areas, there is likely to be a regional level impact from severe flooding due to shifts in economic, community and lifestyle patterns. This may be felt particularly in the immediate aftermath of flooding due to lack of local emergency accommodation or shelter capacity in the region while flooded houses are repaired or rebuilt. In other places (e.g. post-Katrina New Orleans, Christchurch post-earthquakes), when there was not local housing available for those with damaged homes, many relocated temporarily to another city / town (e.g. from Christchurch to Rolleston, Rangiora), and ultimately for some, that relocation becomes permanent because by the time the house is repaired, they have settled into a new lifestyle and do not want to uproot nor return to a hazard area.

These flooding impacts will affect all councils with suburbs in floodplains, in valley floors, along rivers and streams, and in low lying coastal areas as the intensity of extreme events increases and sea levels rise resulting in less infiltration, detention, and efficient drainage. In general, areas without existing overland flow paths (e.g. where rainwater can drain naturally) will have increasing difficulty to manage pluvial flooding over time due to increasing rainfall, and this will compound with sea-level rise in near-coastal areas.

b. Key Areas of Impact

There will be significant impacts to buildings from **fluvial and pluvial flooding** across the Wellington Region, with the number of buildings at risk increasing as the climate changes. The key areas of impact at the end of the century (RCP 4.5) are presented in Table 33Table (from most to fewest buildings impacted by district).

Table 3324: Number of buildings impacted by the end of the century under RCP4.5, from most to fewest buildings impacted by district, highlighting buildings of interest *from within* the total number.

	Districts						
	HCC	WCC	UHCC	MDC	PCC	SWDC	CDC
Hospital Buildings	13	13	-	7	12	-	-
Aged Care Facility Buildings	7	6	4	7	1	1	-
School Buildings	270	220	40	62	142	9	-
Childcare Facility Buildings	59	83	23	12	14	2	-
Supermarkets	19	29	6	11	11	-	-
Religious Facility Buildings	58	69	18	17	17	2	-
Total	22,900	17,350	7,582	5,291	3,953	3,142	1,768

This analysis focused on risk to buildings, however flood water poses serious threats to human life as well as damage to property and assets, interruption of commerce and essential services such as drinking water and power. Further work is required to quantify the risk and impact of flood modelling on broader asset classes and beyond the built domain in the future.

c. Considerations for Adaptation Planning

Similar to the considerations of responses to erosion, it is useful to have a regional scale understanding of the existing risks and a local understanding of where the regional scale flood model may be too conservative or not conservative enough. Additionally, an understanding of the existing levels of protection in the area needs to be incorporated into flood models across the region. Maintaining a consolidated single ‘source of truth’ for regional pluvial and flood hazard is recommended to allow for consistent exposure and risk analysis. This assessment of risk may then be combined with assessment of social and economic drivers which consider the ability to effectively mitigate risk, and the locations that require intervention be triaged and addressed.

While pluvial risk is generally managed by city and district councils via overland flow path regulations, stormwater systems and other drainage networks, flood risk for large river catchments is managed by the

Regional Council. Many stormwater or drainage systems in New Zealand are designed to a maximum 5% AEP return period event.

This assessment has identified that the level of service of the river management systems varies across the region as shown below:

River	Management System
Waiwhetū Stream, Lower Hutt	2.5 AEP (present day).
Mangatarere Stream, Carterton	No information.
Ruamāhanga River, Wairarapa	5% AEP in upper reaches, 1% AEP in lower reaches (present day) with protection by the Lower Wairarapa Valley Development Scheme protecting 41,000 hectares with 190km of stopbanks.
Waiōhine River, Wairarapa	A 70-year adaptive management plan was developed (GWRC, 2021) intending to provide a 1% AEP level of protection to Greytown (plus 16% climate change) and a 5% AEP level of protection to the rural areas using primarily stopbanks and groynes while providing room for natural variation in river morphology where possible.
Pinehaven Stream, Upper Hutt	4% AEP level of protection with structural protection and 1% AEP level of protection via building elevation (GWRC, 2016)
Te Awa Kairangi Hutt River	0.2% AEP level of protection by stopbanks.
Mangaroa River, Upper Hutt	No information.
Wainuiomata River, Hutt City	No information.

Adaptation responses to flooding can include a mixture of approaches including protection (via stopbanks, pumping, pipe networks, detention or spillways, etc.), accommodation (e.g. raising buildings above flood levels) and retreating. Additionally, areas with known flood exposure which cannot be managed should not be further developed for residential purposes without detailed assessment and mitigation strategies. As demonstrated in the Hawke's Bay Region during Cyclone Gabrielle, while stopbanks are useful to protect against more frequent flooding, stopbanks can be overtopped or can be breeched resulting in significant damage to buildings and potentially loss of life.

Large scale flood protection works can provide a false sense of security and can encourage additional development or intensification which can manifest as maladaptation if or when an extreme event beyond the design criteria occurs and the residual risk is realised. Te Wai Takamori o Te Awa Kairangi (RiverLink) is a transformative project that will provide protection from a one in a 440-year flood event, far safer travel along State Highway 2, improved public transport connections, and urban rejuvenation through housing and other development activity. This level of protection will be sufficient for most large scale weather events, however it is not completely risk free and should be used in combination with other adaptation measures.

It is recommended to use the "10 Golden Rules of Flood Management" (Sayers, et.al., 2015) for flood adaptation planning across the region. These include: accepting some flooding and uncertainty; planning for design thresholds to be exceeded; understanding that the future will be different than the past; using a range of layered approaches to manage flood risk; using resources efficiently and fairly; having clear roles and responsibilities; communicating risk (and residual risk) clearly; placing communities at the heart of flood risk management; and integrating flood risk management with local planning and processes.

6.3.2 Risk to Buildings and Facilities (Public and Private) Due to Coastal and Estuarine Flooding: Increasing Persistence, Frequency and Magnitude (Risk ID #BD30)

Table 3425: Qualitative risk scores for BD30, see Appendix A for more detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
BD30: Risk to buildings and facilities (public and private) due to coastal and estuarine flooding.	Moderate	High	High	High	High	Catastrophic

a. Description of Potential Impacts

There is high mid and end century risks to buildings and facilities projected due to coastal and estuarine flooding with increasing persistence, frequency and magnitude due to sea-level rise combined with land subsidence. Most of the Wellington Region is subsiding, with the south east coast subsiding the fastest and in some places up to 9mm/year (such as coastal Wairarapa, see NZSeaRise[9]), which further exacerbates local sea-level rise effects beyond global sea-level rise. For areas with (for example) vertical land movement (VLM) of -6mm/year, an increase in sea level of 500mm by 2050 above a 2005 baseline can be expected, and there is a tipping point around 300mm (estimated around 2030 for much of the Wellington Region) where gravity driven stormwater systems will experience reduced performance. This means that the impacts of high intensity rainfall will be further compounded as stormwater will no longer be able to discharge effectively.

These coastal flooding impacts on buildings and facilities will compound with groundwater level increases and increases to extreme rainfall. Increasing pressures on horizontal infrastructure from more intense rainfall events is expected, reducing the level of service to buildings and exacerbating coastal flooding. This will present buoyancy challenges to both buried horizontal structures (e.g. pipes) as well as building foundations and will also result in increased challenges to damp-prone buildings, and exposing new buildings to damp and mould issues. The rising dampness in low-lying coastal buildings can potentially lead to adverse health impacts for residents, increase electricity usage for dehumidification, and accelerate building decay where unmanaged.

Across the region, the analysis shows there are presently 165 buildings at risk (exposed and vulnerable) to the 1% Annual Exceedance Probability (AEP) coastal flood level, where 1% AEP refers to a flood with a 1-in-100 change of occurring in any one year (Ecan 2023). The number and types of buildings at risk in the range of scenarios and timeframes are:

Table 3526: Number and type of buildings impacted by 1% AEP coastal flood levels

Scenario and Timeframe	Number of Buildings at risk	Types
Present Day	165	Boat sheds, buildings near boat launches or marinas.
RCP4.5, mid century	742	Present day plus school buildings and childcare facility buildings.
RCP4.5, end century	5,450	RCP4.5, mid century plus aged care facility buildings, supermarkets and religious facility buildings.
RCP8.5, end century	7,200	

[9] https://www.searise.nz/

b. Key Areas of Impact

A large number of buildings are at risk of coastal flooding impacts under present and future 1% AEP coastal storm events. A 1% AEP event occurring at the end of the century under RCP4.5 (+0.9m SLR as projected) will impact these areas the most:

Table 3627: Number and Example locations of buildings impacted by 1% AEP coastal flood levels across districts

District	Number of Buildings at risk	Details
Lower Hutt	4,690	Predominately in Petone area (**Error! Reference source not found.Error! Reference source not found.**).
Wellington City	219	Harbour side bays, primarily mixed use or commercial and including the Wellington Railway Station.
Porirua	172	Paremata, Plimmerton and Paekākāriki, primarily residential with some recreational facilities.
Masterton	125	Riversale Beach, primarily residential.
South Wairarapa	39	Aorangi Forest and Kahutara (via flooding of Ruamāhanga River and Lake Wairarapa).
Carterton	3	Rural zoned buildings.

These areas, and the number of buildings within them, increase in size and locations under higher relative sea-level rise (RLSR) trajectories and longer timeframes.

While there will be significant impacts of coastal flooding during coastal storms (with storm surge and waves) as outlined above, there are significant inundation risks which will occur *every day* at high tide (e.g. permanent high tide flooding) due to permanent sea-level rise. The GWRC mapper[10] shows that high tides with 1m of sea-level rise (occurring approximately 2085 combined with -6 mm/year VLM under a moderate RSLR scenario (RCP4.5) for large parts of the Wellington region) will see inundation in the Wellington CBD, across large portions of built environment in the Lower Hutt, areas of the Wairarapa near Lake Ōnoke, as well as the low-lying land around upper Porirua Harbour and Pāuatahanui Inlet. The extent of this every-day high-tide flooding will be further increased when coastal storm events occur or if combined with extreme rainfall events.

[10] https://mapping1.gw.govt.nz/GW/SLR/

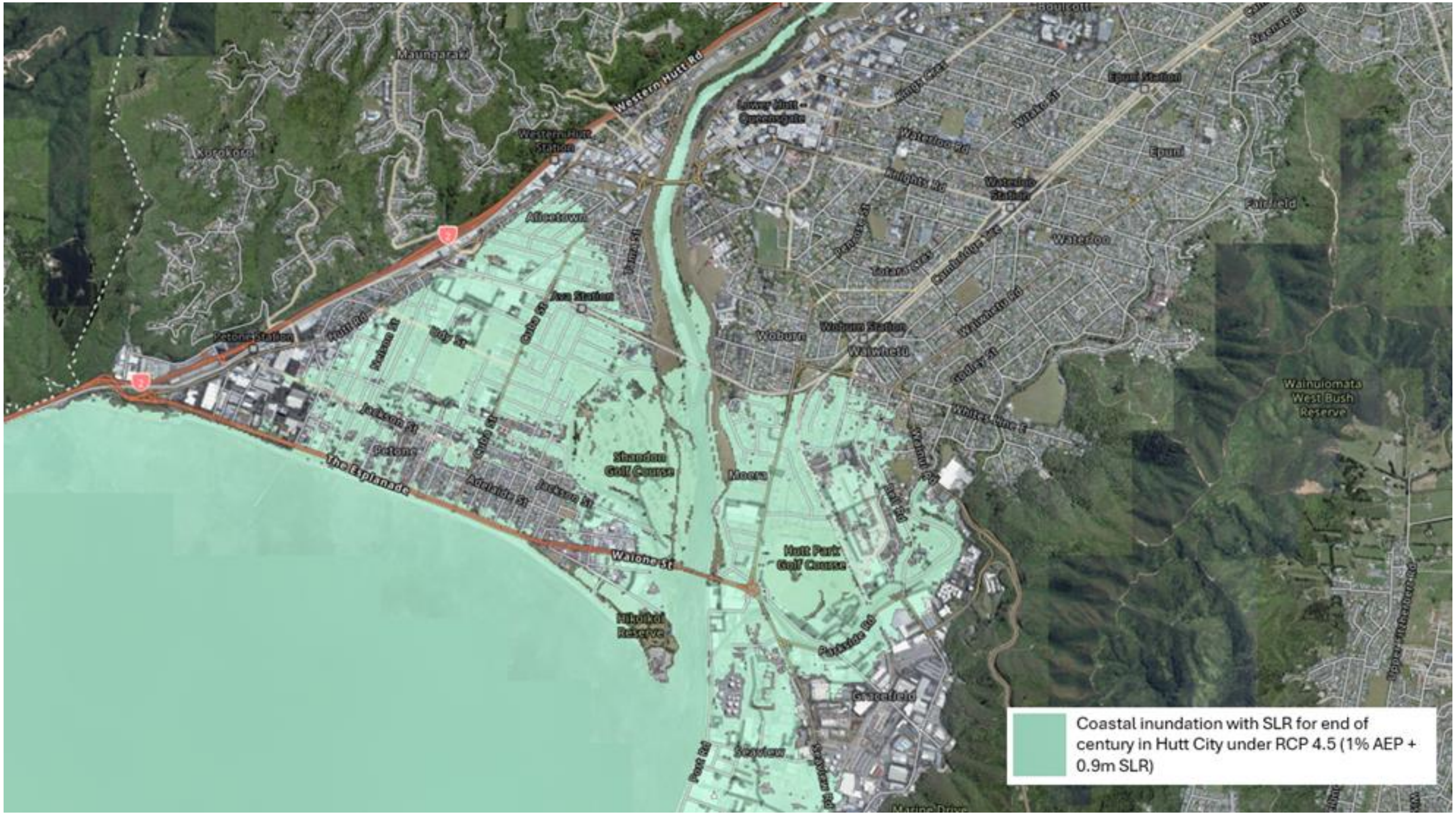


Figure 16: Coastal Inundation Modelling for a 1% AEP (+0.9m SLR) at End of Century in Hutt City Under RCP4.5 (source: Paulik, et al. 2023)

c. Considerations for Adaptation Planning

The MfE (2017) guidance for coastal hazards and climate change sets out an adaptive management approach to identify, manage and adapt to coastal hazards. This national guidance is being updated (due for release in 2024) and is expected to reinforce precautionary and proactive management of coastal hazards with a long term (potentially beyond 100 years) perspective, especially related to land use, community needs, and hazards management. Recently, two coastal communities in the Wellington Region have been the subject of adaptation planning (Makara Beach[11], and the underway KCDC Takutai Kāpiti Programme[12]), drawing on community adaptation process within the 2017 guidance. The guidance, the local examples, and other studies from around New Zealand, form a library of lessons and concepts to support the pressing need for a widespread coastal adaptation programme in most Councils, and across the wider Wellington Region coastal area.

From a built environment perspective there are many well understood engineering interventions to reduce the risk of coastal flooding to the built environment. While construction of seawalls and continuous pumping of groundwater, rainfall and overtopping is technically possible, and there are cities all over the world that exist below sea level, this is increasingly not recommended unless there are significant economic, cultural, or other factors justifying the built environment to remain in at-risk coastal locations. Decisions to follow this route should be thoroughly evaluated alongside other options and pathways.

Importantly for adaptation planning, even though engineers can design coastal infrastructure for a 50- or 100-year design life, sea levels will continue to rise over the next 200+ years, so careful consideration of the viability of investments in coastal infrastructure in low-lying coastal areas is strongly recommended. A precautionary approach is also recommended when opening up new areas for land development, avoiding investment on land which is at risk shortly after the 100-year New Zealand Coastal Policy Statement (NZCPS) coastal hazards planning timeframe. This precaution avoids the future generations having to deal with the impacts of these investment decisions just as the Wellington region's councils are grappling with impacts from decisions in the previous century (and since development began).

Consideration of adaptative actions to reduce coastal flooding impacts to the built environment should also consider the associated emissions impacts of both the capital costs of the initial work as well as the costs to operate and maintain over time. Further, coastal flood protection structures will cause coastal squeeze of foreshore areas, resulting in impacts to coastal ecosystems, and also to cultural and recreational values if access and amenity and biodiversity at the foreshore is affected.

6.3.3 Risk to Land Transport (Road and Rail) Due Landslides and Soil Erosion (Risk ID #BD87)

Table 3728: Qualitative Risk Scores for BD87, see Appendix A for More Detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
BD87: Risk to land transport (road and rail) due to landslides and soil erosion	High	High	High	Extreme	Extreme	Major

a. Description of Potential Impacts

The risks to transport, namely roadway and rail links, due to landslides and soil erosion have been increasingly visible over the recent years. In 2022 there was 670 slips in Wellington City in the seven week period starting

[11] https://wcc.maps.arcgis.com/apps/MapSeries/index.html?appid=57e797777a96430c8074182984622a6a

[12] https://takutaikapiti.nz/

1 July 2022, causing people to evacuate homes and causing road closures including the Main Road in Tawa, the Pass of Branda, and Southerland Crescent in Melrose[13]. During the same period a slip on the Kāpiti Coast closed the coastal road between Pukerua Bay and Paekākāriki highlighting significant impacts in the Wellington Region in periods of heavy rainfall. Under climate change scenarios, rainfall induced landslides and their associated impacts are expected to increase (Crozier 2010).

The hilly topography of the Wellington Region, particularly Wellington City, parts of Hutt City and Porirua, posed challenges to building in the mid 1900s where many areas had bulk earthworks (cut and fills) to provide flat land for building transport routes and structures throughout the region. These shifts in the natural landscape coupled with natural challenges to slope stability (e.g. earthquake) have resulted in slip prone land, further exacerbated by the weight of the built environment and increasing groundwater levels. During a 2004 rainfall event that caused 74 landslides throughout the Wellington Region, more than two thirds occurred on slopes that were already weakened by earthworks. These slips have increased in recent years due to climate change and can result in future road and rail damage, delays, lengthy closures and costly repairs.

In future, with considerations of increasing extreme rainfall intensity, analysis of NIWA's High Intensity Rainfall Design System (HIRDS) projections, a 250-year rainfall event (present day) is likely to be more like a 100-year rainfall event by the end of the century under conservative climate change assumptions, while a 100-year rainfall event (present day) will be more like a 50-year event under a conservative, end of century scenario (refer to the Details of Detailed Assessment in Appendix F for calculations).

While road slips are more common and clearing slips from roads can be straightforward, the rail network is more vulnerable to damage, and slopes of historic cuts to enable rail lines are already vulnerable. With climate change, these risks will increase, both in likelihood and in consequence.

When these slips occur, communities with limited access roads (such as Makara Beach, the eastern Wairarapa coastal communities, as well as Wainuiomata and other urban suburbs) can be isolated. This can cause disruption to economies, wellbeing, and supply chains. For more rural communities, this may also pose health risks if there are not healthcare facilities in the isolated region.

b. Key Areas of Impact

GNS Science provided rainfall-induced landslide hazard data (SLIDE), which at the time of writing only covers Wellington City, therefore it has been used to undertake quantitative geospatial analysis for Wellington City only. Once regional data is available a similar assessment is recommended for the wider region.

Wellington City

The quantitative analysis using a GIS viewer and GNS Science SLIDE data (see Appendix I for data analysis) shows that rainfall induced landslide risks (exposure and vulnerability) impact 27 roads under present conditions, increasing to 212 roads by mid-century and 990 by late century under a moderate / high emissions scenario (RCP 8.5). The number of roads exposed to landslides will be considerably more than these values. Cascading social and economic impacts are greatest when slips block key routes, limiting peoples ability to access places of work, community facilities or sites of cultural significance. Key arterial roads expected to be at higher risk by late century (127 total) include SH1 through Ngauranga Gorge and up to Grenada, SH2 along the coast connecting Petone to Wellington, and connections from Brooklyn to the City and the Aro Valley to Northland.

In Wellington City, landslide risks do not impact rail under present conditions (above the selected risk threshold of greater than 2% RIL and slip size greater than 1,000m^2), however this increases to 14 locations by mid-century and 52 locations by late century. As shown in Figure 17**Error! Reference source not found.**, these

[13] https://www.rnz.co.nz/news/national/473258/wellington-landslides-670-slips-in-seven-weeks

late century impacts include the Johnsonville line through Ngaio and along the coastal escarpment between Wadestown and the sea, the Kāpiti line between Onslow and the sea and near its intersection with SH1 in Ngauranga and between Grenada Village and Grenada North. These impacts to rail can cause prolonged impacts beyond the Wellington City limits as commuter trains are interrupted increasing pressures on the road networks, potentially reducing the number of people in the city as rail commuters may opt to work from home, with cascading impacts on reduced workday traffic for CBD retail and food merchants. Freight lines are also vulnerable with closures potentially causing cascading supply chain impacts to businesses, increased freight on roads causing congestion and with higher carbon emissions. This would further exacerbate existing inequities, similar to how the COVID-19 response demonstrated that impacts of changing work requirements affected groups unequally.

Wellington Region

While rainfall induced landslides are caused by several factors as discussed above, two of the key geologic drivers are slope angle and underlying rock type. These two elements were assessed in 2019 to inform the Regional Soil Plan for Erosion Prone Land[14] (Greater Wellington Regional Council, 2022). Additionally, the Ministry for the Environment commissioned a study of Highly Erodible Land Area[15] in 2012 which is defined as "land at risk of severe mass-movement erosion (landslide, earthflow, and gully) if it does not have protective woody vegetation" (MfE, 2019) (Dymond et al., 2006). The study includes satellite image based land cover, slop and rock type.

While these regional layers have not been incorporated into the quantified assessment as they are not specifically related to climate change and rainfall induced landslides, they have been used to geospatially analyse potential landslide impacts across the region, specifically relating to key transport corridors.

A high-level review of at risk transport routes across the region identified is shown in Table 38.

---

[14] https://data-gwrc.opendata.arcgis.com/datasets/GWRC:rsp-erosion-prone-land/explore

[15] https://statisticsnz.shinyapps.io/highly_erodible_land/

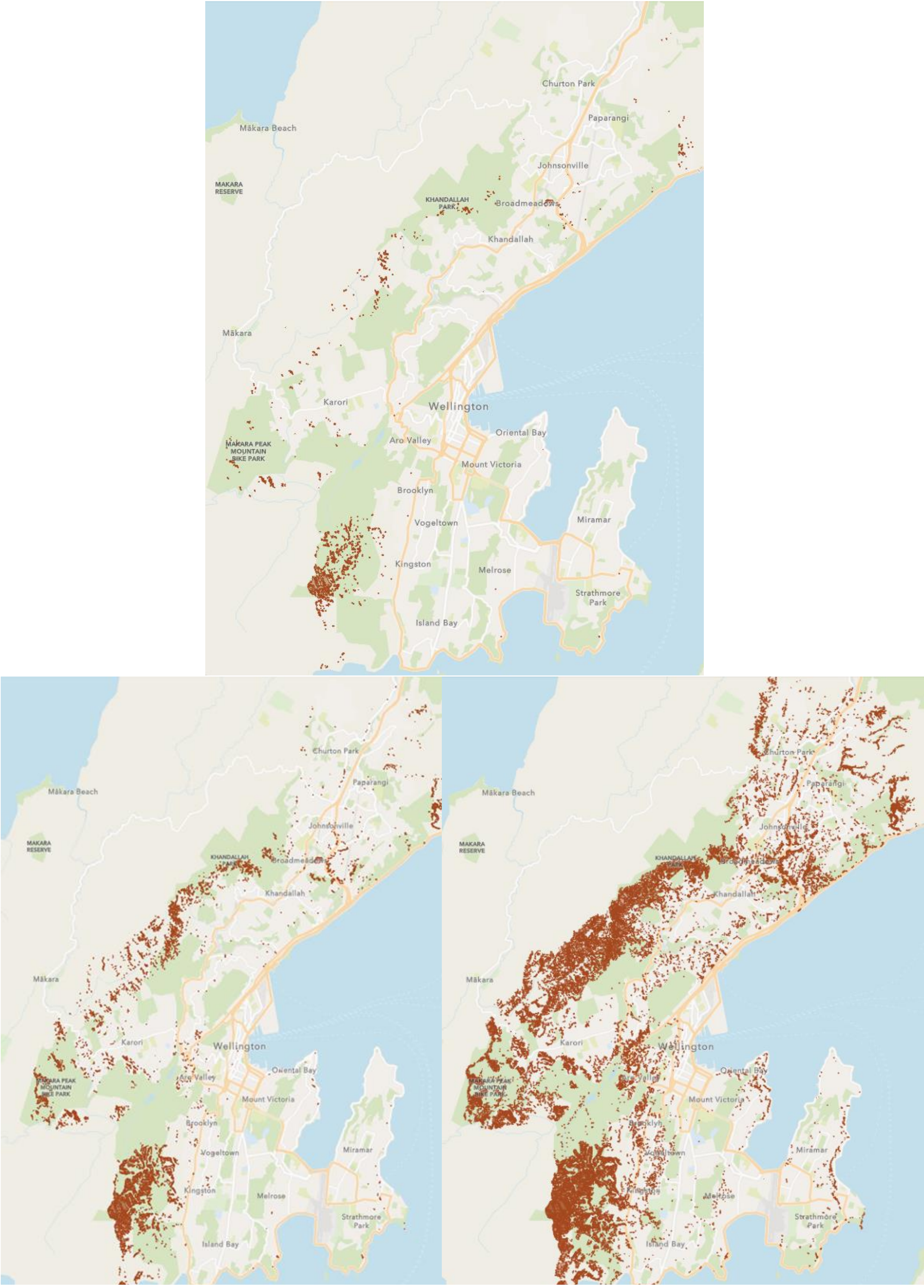


Figure 17: Rainfall Induced Landslide locations in Wellington City (Brown). Top: Present Day, Bottom Left: Mid Century, Bottom Right: End Century (GNS Science). See Appendix D for Large Scale Map.

Table 38: Locations of potentially impact transport routes across the region

Masterton
SH2 near Mount Bruce
Along the Masterton-Castlepoint Road between Tīnui and Whakataki
Carterton
Along Ngāhape Road between Stronvar and Ngāhape
South Wairarapa
SH2 between Pākuratahi and Featherston (Remutaka Hill)
Wairarapa Line where it emerges from the Remutaka tunnel near Featherson
Upper Hutt
SH2 through Upper Hutt
Lower Hutt
Along Western Hutt Road between Haywards and Belmont
SH58 between Mt Cecil Road and Harris Road
SH58 near the Western Hutt Road Roundabout
Porirua
SH1, Transmission Gully south of Paekākāriki
SH1 58 near Belmont Road
SH59 between Paekākāriki and Pukerua Bay

Landslides are more likely to occur on erosion prone land in areas of high slope and weak soils (Figure 18**Error! Reference source not found.**). Landslides that occur on coastal and single access roads along the edges of hills or cliffs that connect remote communities are likely to have greater impacts due to the loss of access and connectivity between the community and other key areas and services.

Recent slips on SH58 can provide a useful case study to evaluate impacts on slips on transport routes. When there was a slip on Hayward Hill in August 2022, the highway was closed temporarily, and residents were re-routed either via SH1 through Pāuatahanui or via SH2. This added extra time of at least half an hour onto residents' journeys. When SH58 was closed early in 2023 for planned repairs, tens of thousands of car journeys were disrupted, and Wellington residents were asked to travel outside of peak times to reduce congestion. This further caused delays on public transport due to the increased number of people avoiding travelling into the city by car (Radio New Zealand, 2023).

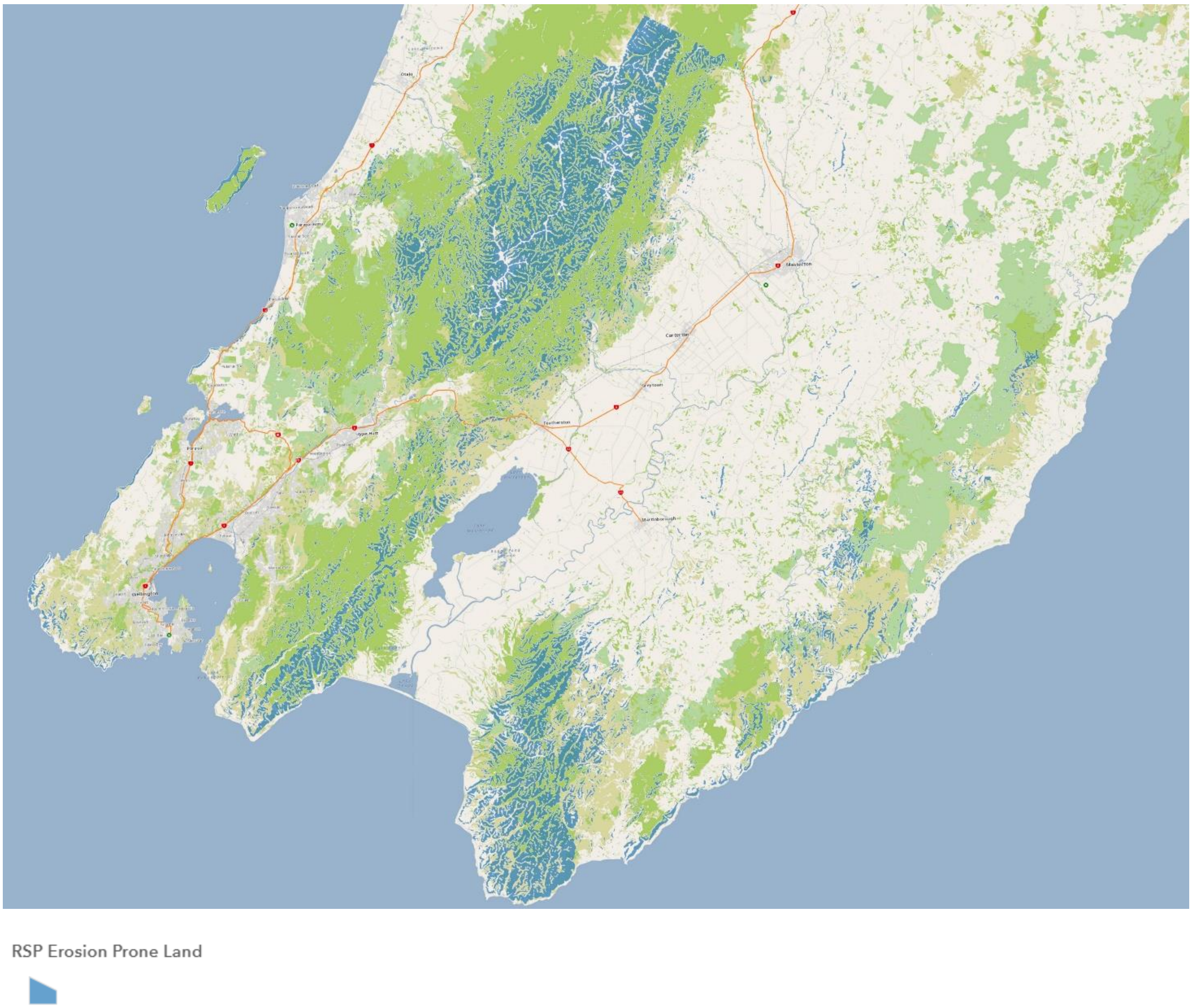


Figure 1817: Erosion Prone Land from the GWRC Regional Soil Plan, Based on Slope Angle and Underlying Rock Type. A Large Scale Copy is in Appendix D

c. Considerations for Adaptation Planning

For adaptation planning to cope with increasing landslide risks, monitoring is recommended to identify shifts in slope due to small landslides to proactively identify the initial signs of slips before significant events occur. As stated above, a regional scale assessment of landslide risk is recommended. This would provide an understanding of potential “hot spots” for landslides; however, site specific assessments for critical assets in hot spot areas would be recommended to better understand the specific nature of the landslide hazard and risk to life, property and transport assets. Specifically, whether the slip would occur above (e.g. depositing material onto the assets) or below (e.g. undermining) can significantly impact ability and time to restore transport access.

Certain types of vegetation can alter the risk of landslides by increasing the strength of the soil due to roots (reducing risk), reducing the saturation of the soil due to uptake and vegetation cover (reducing risk), and / or destabilising the slope due to wind loads on trees (increasing risk). The use of vegetation should be evaluated as soft protection against landslides, and existing vegetated slopes should not be disturbed if possible.

While there are hard engineering measures to manage landslides, they are costly and residual risk still remains. Adaptation planning for slip prone transport routes may include proactive investigation of alternative means of access or detour planning if a slip occurs, infrastructure to either reduce susceptibility of the adjacent slopes, shift drainage patterns.

Many roads and railway routes are increasingly susceptible to landslides; however, of particular concern is the roads serving the Hutt Valley (SH58, SH2 (north and south) and the interregional connections of these transport routes. Managing landslide risk along these key routes transport of freight and people would be an important first-step towards more resilient transport routes, not only for climate change hazards but also for seismic events.

The exposure of buried assets (e.g. three waters, communications, electricity, gas) are critically reliant on seawall / earth retaining structural protection, which is almost always provided by transport facilities (road / rail). Exposure of many buried assets is therefore dependent on the operations and maintenance of other service providers. If condition assessment monitoring and maintenance are not resourced by asset owners (e.g. road corridors) then the exposure of the other co-located assets increases. This creates a cross-cutting and compounding risk. The Governance risk assessment (Section 4.5) identified that coordinating mechanisms are better fit for purpose at the CEO level (through mechanisms such as the Wellington Regional Leadership Committee (WRLC)) but are lacking at the planning and implementation level. Knowledge sharing about co-located assets (public / private), a systems thinking approach which includes cost sharing to maintain, upgrade or reinstate structures are key considerations for successful adaptation and to mitigate future exposure.

6.3.4 Risk to Buildings and Facilities (Public and Private) Due to Increasing Landslides and Soil Erosion (Risk ID #BD33)

Table 3929: Qualitative Risk Scores for BD33, see Appendix A for More Detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
BD33: Risk to buildings and facilities (public and private) due to increasing landslides and soil erosion	Moderate	High	High	High	High	Catastrophic

a. Description of Potential Impacts

The risks to buildings and facilities due to landslides and soil erosion have been increasingly visible over the recent years, with 2022 highlighting significant impacts in the Wellington Region (Jakob 2022). Under climate change scenarios, rainfall induced landslides and their associated impacts are expected to increase (Crozier 2010). In a coastal environment, increases in sea level and changes in marine and storm activity may also result in greater coastal erosion and landslides (Jakob 2022).

The hilly topography of the Wellington Region, particulary Wellington City, parts of Hutt City and Porirua, have posed challenges to building since the mid 1900s where many areas had cuts and fills to provide flat land for building structures throughout the region. These shifts in the natural landscape coupled with natural challenges to slope stability have resulted in slip prone land, further exacerbated by the weight of the built environment and increasing groundwater levels near the coast caused by sea level rise.

When buildings and facilities are on or near slip prone land, Toka Tū Ake EQC will cover land damage for the value of insured land up to 8m around the home; however, this may not be sufficient to repair properties if the landslides are complex. While there is not a risk of insurance retreat from landslide damage at present, there is a risk of underinsurance and therefore impacts cascade into the economic and human domains.

Over time, with considerations of increasing extreme rainfall, a 250-year rainfall event (present day) is likely to be more like a 100-year rainfall event by the end of the century under conservative climate change assumptions, while a 100-year rainfall event (present day) will be more like a 50-year event under a conservative, end century scenario. This means that rainfall-induced landslides will become more likely, and the scale of landslides may increase, including increasing exposure and risk to buildings and facilities.

b. Key Areas of Impact

This section includes regional analysis and local analysis for Wellington City as the rainfall-induced landslide hazard information is only available for Wellington City.

Wellington City Council Results: There is rainfall-induced landslide hazard information available for Wellington City only, and a similar assessment is recommended to be undertaken for the wider region. When this exposure data is applied to vulnerability (adaptative capacity and sensitivity scores, see Appendix I), this research indicates that five buildings have higher landslide risk under present conditions (residential buildings in Karori), increasing to 212 buildings by mid-century (94% residential, one supermarket and no health centres or schools affected) and 3,399 buildings by late century. In the late century scenario, risks to vulnerable buildings and infrastructure may start to cause social cohesion impacts.

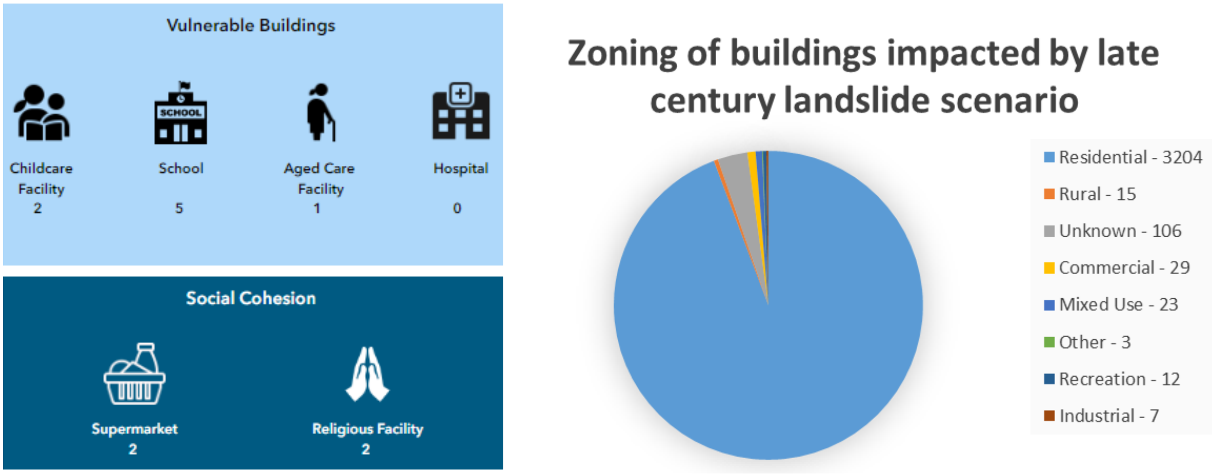


Figure 1918: Summary of Buildings Affected by End of Century Landslides Scenario (RCP4.5). Vulnerable Building Data Refers to the Number of Individual Buildings, Not the Number of Facilities (e.g. 5 School Buildings, not 5 Schools) and Reflects Exposure Combined with Vulnerability

While presently the greatest risk to buildings of landslides in Wellington City is concentrated in the hillsides of Karori, by mid-century, the risk in Karori increases and other areas also emerge as hot spots (Aro Valley, Kelburn, Brooklyn, some isolated locations in the CBD, and along the fringes of the suburbs where they abut alongside the steep hillsides). By late century, large portions of many central suburbs will have landslide risk similar to the risk in Karori today in terms of likelihood of occurrence.

GWRC's Regional Soil Plan for Erosion Prone Land and the MfE-commissioned study of highly Erodible Land Area have informed regional scale analysis. Areas with large amounts of potentially impacted buildings include:

- Porirua
  - Coastal fringes of Titahi Bay
  - Upper Hutt
  - Parts of the Pinehaven

  - Edges near hills of Riverstone Terraces
  - Parts of Birchville
- Fringe areas of urban hillside suburbs around Wellington City

c. Considerations for Adaptation Planning

Landslide management approaches are covered in the Guidelines for Assessing Planning, Policy and Consent Requirements for Landslide-prone Land (GNS, 2007). The recent draft update to these landslide planning guidelines (GNS 2023) emphasises that the effects of climate change will exacerbate landslide hazards and risk over time, and that risk-based approaches should be applied in policy and plan development to manage the hazards and reduce risks from landslides. The draft guidelines also identify that landslide susceptibility, hazard and risk maps should provide information for developing regional and district policy and plans as well as any broad scale spatial plans or growth strategies. The guidelines should be used for future adaptation planning.

As mentioned above, due to the lack of regionally available data at the time of this assessment, we recommend a regional scale assessment of the changing scale and impact of rainfall induced landslide risks with climate change effects is the first step in adaptation planning. The regional scale landslide risk assessment would provide an understanding of potential "hot spots" for landslide impacts on the built environment, and the emergence of new areas at risk as rainfall intensity increases. If landslide risks are above a tolerable risk threshold (explored in GNS 2023), active intervention and monitoring may be required, however this should be informed by site specific assessments of the landslide probabilities (time, space, hazard), the number and vulnerability of the elements at risk as advised in GNS (2023).

While there are hard engineering measures to manage landslides (such as soil stabilisation, retaining walls, drainage systems for stormwater and groundwater), they can be costly and residual risk will often remain (e.g. a retaining wall has a specified design condition and design life, there is residual risk should events larger than the design conditions occur). Certain types of vegetation can alter the risk of landslides by increasing the strength of the soil due to roots (reducing risk), reducing the saturation of the soil due to uptake and vegetation cover (reducing risk), and / or destabilising the slope due to wind loads on trees (increasing risk). As such, the use of vegetation should be evaluated as soft protection to adapt to landslide hazards, and existing vegetated slopes should not be disturbed if possible. Other general flood reduction measures such as reducing impervious surfaces will also have benefits in minimising the risk of landslides on certain areas.

Adaptation planning for critical assets (e.g. hospitals or schools), new / existing subdivisions, may need to include proactive investigation and relocation to alternative, less slip prone locations for the Wellington Region due to changes in the climate.

Education about practical steps to identify landslide risks such as sticky doors, cracks in foundation, or water or gas leaks is a low-regret adaptation consideration for managing landslide risks to buildings and people.

6.3.5 Risk to Buildings and Facilities (Public and Private) Due to Coastal Erosion: Cliffs and Beaches (Risk ID #BD32)

Table 4030: Qualitative Risk Scores for BD32, see Appendix A for More Detail

Risk Statement	Risk					First-pass impact score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
BD32: Risk to buildings and facilities (public and private) due to coastal erosion	High	Extreme	Extreme	Extreme	Extreme	Catastrophic

a. Description of Potential Impacts

Coastal erosion occurs due to a combination of wave and current energy, water levels including sea-level rise and storm surge, geology and sediment supply, and the effect of manmade structures on natural beach sediment transport processes. As the climate continues to change, the balance of energy along the coast will continue to shift, likely resulting in more erosion (in absence of increased sediment supply) due to increased interaction between the sea and the land caused by higher sea levels[16].

Coastal erosion impacting cliffs and beaches (soft shores) will have direct impacts on buildings and facilities in areas where the shoreline is not hardened. If unprotected, the buildings themselves are highly vulnerable and they likely will not withstand substantial wave-attack or erosion of the land beneath them. Waves will have increased interaction with cliffs increasing toe scour (erosion of the base of the cliff that can cause instability higher up) and erosion rates over time. Along softer shorelines such as sandy or cobble beaches, erosion rates are likely to increase unless there is a robust sediment supply within the system to offset the landward migration of the shoreline associated with sea-level rise. In areas with dunes or gravel barrier systems, there is the risk of a tipping point being breached resulting in dune or barrier collapse and rapid erosion which then leaves the built environment behind the dunes or gravel barriers more vulnerable to both erosion and coastal flooding. Refer to the National Guidance on Coastal Hazards and Climate Change (MfE 2017) for further explanation of erosion and climate change.

It is difficult to quantify the scale of impact of coastal erosion on buildings around the Wellington Region due to lack of a regionally consistent coastal erosion projections (see the Limitations section of this report, Appendix C). However, it is expected that impacts will begin in areas where erosion is already apparent (such as coastal Wairarapa and Porirua), and in areas with infrastructure and buildings alongside natural (i.e. no engineered protection structures) beaches and coastal margins. Even in areas where there is existing erosion protection, the increases in sea levels over time are fundamentally different from the historic design assumptions for these structures, and further engineering and construction (e.g. toe protection for additional scour, crest raising) would be required to maintain functionality in the long term.

An increase in coastal erosion will begin to undermine buildings and facilities prompting calls for increased protection. This will affect homes, businesses and facilities, and without coastal protection, buildings may be forced to retreat, or owners / council forced to pay for upgrades. Beyond the physical environment, if erosion is mitigated by coastal protection, coastal squeeze is likely to cascade into impacts on the natural environment by reducing the location, extents and character of coastal habitats.

While coastal property is presently desirable and generally high value, erosion pressures may either reduce the value of these properties or further exacerbate inequalities because if insurance retreats or becomes unaffordable, properties will likely only be bought outright reducing the portion of the population that is financially able to purchase property on the coast. In addition, there are inequities that may be generated or exacerbated by the general ratepayer base subsiding continuing services to at risk properties (which is likely to become more costly in the future due to higher maintenance as a result to climate hazards).

b. Key Areas of Impact

The 2019 Mitchell Daysh report on Preparing Coastal Communities for Climate Change evaluated regional coastal vulnerability (excluding Wellington City) with a focus on sea-level rise and coastal erosion and identified the following geographic units as the most vulnerable in a district-by-district assessment: Porirua and Pāuatahanui (Porirua City Council), Seaview and Petone (Hutt City Council), and Palliser and Whakataki (for the joint Wairarapa Districts). Specifically as it relates to coastal erosion, only one coastal cell scored a

[16] https://wellington.govt.nz/-/media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/spatial-plan/coastal-hazards-report---august-2021.pdf?la=en&hash=E70B002B5D515679482B867E649FD90D3D74FB5C

vulnerability of 4 (out of a maximum of five); Palliser South in South Wairarapa, where 1 is 'low vulnerability' and 5 is 'very high vulnerability'.

Due to the lack of regional data, workshops identified a number of known locations where coastal erosion is *already* impacting the built environment including:

- Areas across Porirua City (including Pukerua Bay, Plimmerton, Hongoeka Bay, Titahi Bay and some inner harbour shorelines)
- The coastal embayments around the fringes of Wellington City's open coast (including Lyall Bay, Ōwhiro Bay, Mākara Beach)
- Hutt City (Petone, Eastbourne and the Eastern Bays beaches)
- The Wairarapa coastal communities of Mataikona, Riversdale Beach and Castlepoint.

These existing erosion areas are a starting point for future assessments, however new areas may emerge, and it is important to understand these areas to avoid *future* impacts by putting buildings in at risk areas.

c. Considerations for Adaptation Planning

There is a lack of consistent regional data on coastal erosion so to prioritise areas requiring adaptive actions, a regional scale evaluation of coastal erosion rates and future shoreline projections is recommended to address the sparse and inconsistent coastal erosion exposure information and address the district-scale gaps for the major urban areas (including Wellington City, Lower Hutt (Petone to Eastbourne)) and the smaller communities of the Wairarapa coastal councils (e.g. Mataikona, Riversdale Beach, Castlepoint). Erosion projection methodologies can vary from the comprehensive probabilistic approach (such as the KCDCs example above) but may also begin with an intentionally simple mapping exercise as a way to "triage" areas potentially at risk (as undertaken in a 2021 NIWA report for Wellington City, NIWA, 2021) before completing a more detailed study.

Overall, prioritising a work programme to consistently identify future coastal erosion areas is recommended as this will inform identification of at-risk communities which may require prioritisation for adaptation programmes, and areas suitable for future developments outside of at-risk areas across the region.

We also note that there are national research programmes underway which will look to digitise and document coastal change (via shoreline position digitisation) around the Region. The Coastal Pillar component of the Resilience to Nature's Challenges 2 (RNC2) research results are expected to be available for the Wellington Region in 2024 (pers. comm. Prof Mark Dickson, University of Auckland). The RNC2 outputs may not include erosion projections, however the shoreline position data is likely to be suitable to base future studies on.

While understanding whether erosion is occurring and if there are already structures in place to manage impacts of erosion is a critical first step to adaptation planning, further considerations should include factors beyond solely protection of the built environment. Coastal erosion is one key hazard impacting coastal margins, but over time, there will be a range of other hazards emerge including increased inundation via rising groundwater levels in low lying areas *behind* coastal protection structures. Evaluation of structural coastal protection should also include an understanding of the viable lifetime of both the adaptive action and the buildings, considering the range of hazards and residual risk to land and assets behind such structures.

Further, coastal protection structures can accelerate erosion due to end effects or increased wave reflection reducing the beach width and the width of other coastal environments. This well documented coastal squeeze[17] can not only result in ecological impacts but also cultural and recreational values if access to the foreshore is impeded.

[17] https://niwa.co.nz/natural-hazards/research-projects/future-coasts-aotearoa

6.4 Economic Impacts

Economic impacts can be directly attributed to climate hazards (such as flood damage) and stressors (such as drought) where primary industries will be directly impacted, or indirectly through a cascade of impacts from other risks (such as personal economic loss suffered from property damage from climate hazards such as flooding). The impacts from risks being realised in the economic sector depend on how significant the industry is to the total regional or district economy (in terms of % of contribution GDP). Therefore risks assessed as high may only have minor impacts. The following economic risks were selected for further detailed assessment.

Table 4131: Risks Selected for Economic Domain Detailed Assessment

Risk ID	Risk Statement
ED13 ED23 ED33	Risk to pastoral farming, viticulture and horticulture due to more and longer dry spells and drought.
ED116 / BD30	Risk to manufacturing / industrial buildings due to coastal and estuarine flooding.
ED4	Risk to forestry due to increasing fire–weather conditions: harsher, prolonged season (drought).

6.4.1 Risk to Primary Industries (Pastoral Farming, Horticulture and Viticulture) and Forestry from Drought and Increased Fire Weather

Table 4232: Qualitative Risk Scores for ED13, ED23 and ED33, see Appendix A for More Detail

Risk Statement	Risk					First-pass Impact Score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
ED13: Risk to horticulture due to more and longer dry spells and drought	Low	Moderate	Moderate	Moderate	High	Minor
ED23: Risk to viticulture due to more and longer dry spells and drought	Low	Low	Low	Moderate	Moderate	Minor
ED33: Risk to pastoral farming due to more and longer dry spells and drought	Low	Low	Moderate	Moderate	High	Moderate

a. Potential Impacts

Rainfall is expected to decrease in spring by 5% for the eastern Wellington Region by 2040. In particular, the Wairarapa will be increasingly dryer with up to 10% reduction in rainfall in spring, summer and autumn in 2090. Dry weather and drought conditions can negatively impact crops and grassland, particularly fodder crops used to feed animals. These conditions can also cause a compounding risk where intense rainfall events occur immediately after a drought. In particular, dry and hard ground has less absorption capacity, so when intense rainfall follows dry conditions, the impacts associated with runoff and flooding can be exacerbated.

Low yields of fodder crop can lead to reduced profits in the pastoral farming industry. A decrease in annual rainfall can also impact horticulture productivity which typically relies on stored water for irrigation throughout the year. These impacts will not increase national prices sufficiently to counteract the productivity decline and so this will be an increasingly significant economic impact for affected industries, for example in South Wairarapa where primary industries make up a large portion of the district GDP. If these conditions are experienced more frequently than income derived from primary industries will reduce but also costs of production will increase. For example, pasture may need to be supplemented with feed, and water imported or drawn from other sources at potentially unsustainable levels.

Increasing dry spells in the eastern region may have a positive impact on the quality of grapes. Studies have shown that grapes have very high adaptive capacity in conditions of drought (Charrier et al., 2018), and therefore the projected increased dry spells may benefit wine production in the eastern region, having a positive economic impact both for the growers as well as through tourism spend associated with visits to the region (noting however that tourists visit the region for more than just the boutique wineries). However, the positive impacts of droughts on grape quality is dependent on suitable conditions over all growing seasons, including enough water during winter to support root health and the absence of intense rainfall occurring between dry periods. As part of long-term adaptation planning there is an opportunity to encourage alternative farming practices that suits the forecast future climate.

b. Key Areas of Impact

There are large tracts of agricultural land in the Wellington Region, mainly focused in the Wairarapa and around Kāpiti, approximately 139,145ha and 9,888ha respectively, (see Figure 20

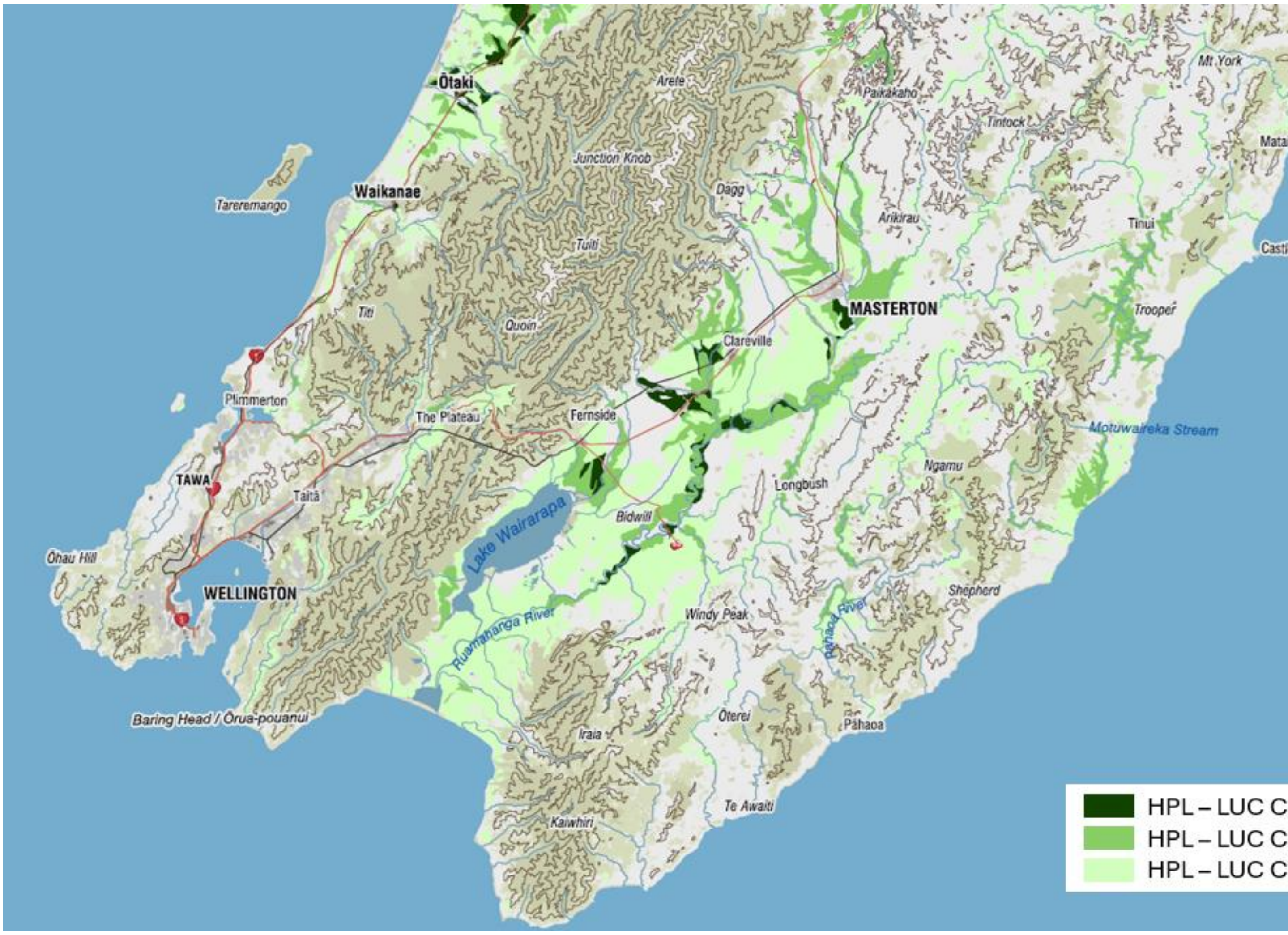


Figure 20: Existing Agricultural Land in the Wellington Region (Manaaki Whenua Our Environment). Dark Green is HPL – LUC Class 1: the Most Versatile Multiple Use Land, Minimal Limitations, Highly Suitable for Cropping, Viticulture, Berry Fruit, Pastoralism, Tree Crops and Forestry. Light Green is HPL – LUC Class 2: Very Good Multiple-use Land, Slight Limitations, Suitable for Cropping, Viticulture, Berry Fruit, Pastoralism, Tree Crops and Forestry. Pale Green is HPL – LUC Class 3: Moderate Limitations, Restricting Crop Types and Intensity of Cultivation, Suitable for Cropping, Viticulture, Berry Fruit, Pastoralism, Tree Crops and Forestry

).

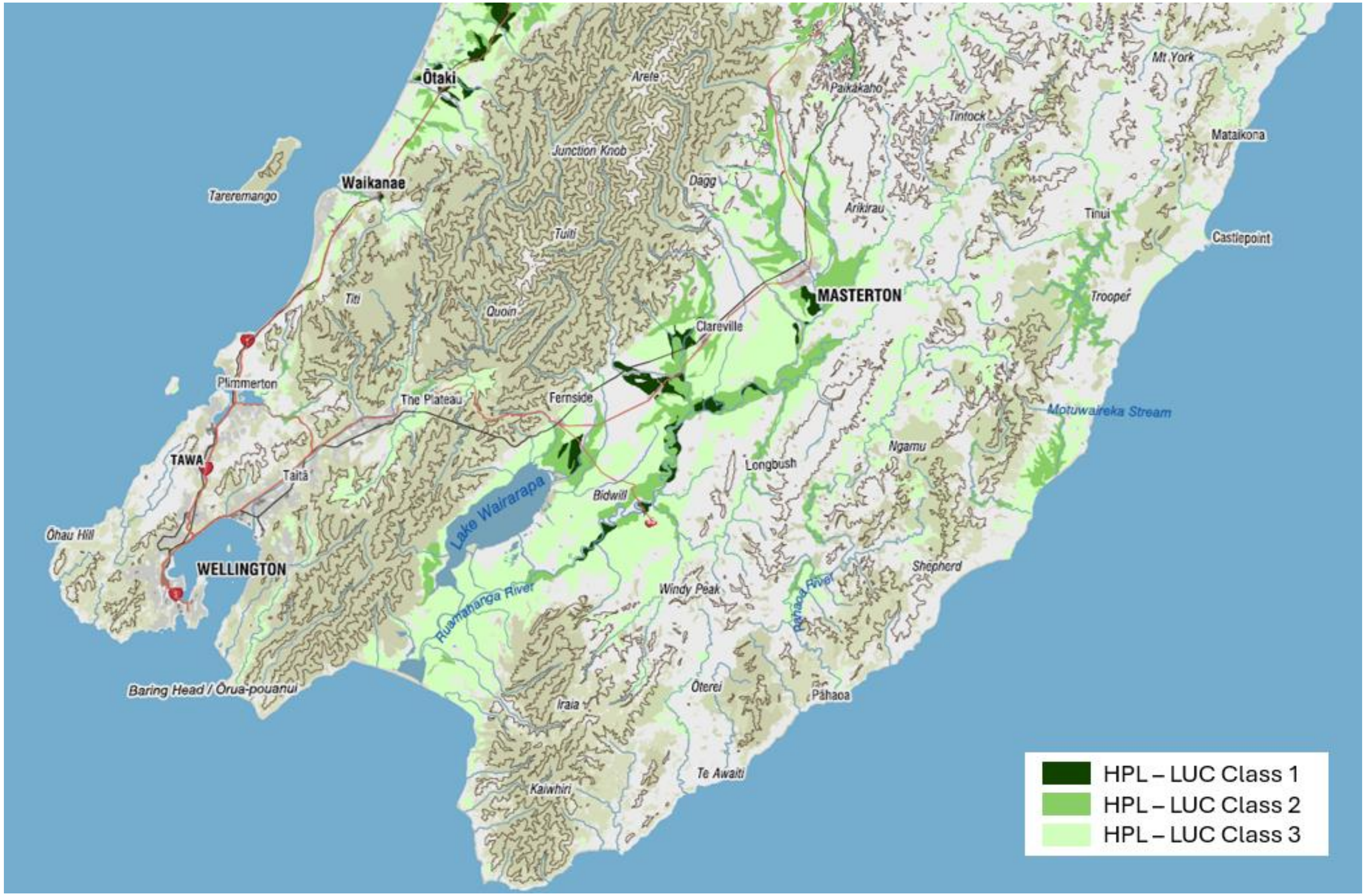


Figure 20: Existing Agricultural Land in the Wellington Region (Manaaki Whenua Our Environment). Dark Green is HPL – LUC Class 1: the Most Versatile Multiple Use Land, Minimal Limitations, Highly Suitable for Cropping, Viticulture, Berry Fruit, Pastoralism, Tree Crops and Forestry. Light Green is HPL – LUC Class 2: Very Good Multiple-use Land, Slight Limitations, Suitable for Cropping, Viticulture, Berry Fruit, Pastoralism, Tree Crops and Forestry. Pale Green is HPL – LUC Class 3: Moderate Limitations, Restricting Crop Types and Intensity of Cultivation, Suitable for Cropping, Viticulture, Berry Fruit, Pastoralism, Tree Crops and Forestry

As the Wairarapa is a key area with large tracts of productive land, the potential impacts of drought are most significant in this area from an economic perspective. Future shortages of water will increase competition for the scare resource and combined with increased demand from a growing population, will mean that future restrictions in water supply may be the limiting factor for further growth of this sector. Agricultural water is already fully allocated in the Wairarapa, and the Wairarapa Growth Strategy estimates water scarcity will reach crisis proportions by 2040 (Wairarapa Economic Development Strategy, 2022 - 2030).

Wairarapa is not the only agricultural area at risk, with climate change impacts to productivity in the agricultural areas and market gardens of Porirua valleys, and Upper Hutt's Mangaroa Valley.

Increasing dry spells and warmer temperatures predicted to occur in the eastern parts of the Wellington Region can increase the chance of forest fire. In particular, the Wairarapa has large tracts of forestry that support the local economy and if impacted will cause local economic impacts associated with direct loss of productive forest and loss of wages for people employed in the local industry. Not only can forest fires be deadly, forest fires can have far reaching economic impacts if property or infrastructure is damaged or even indirectly through air quality and reduction in tourism. Forest fires adjacent to roads may also limit commute for work for people within the Wellington Region, resulting in loss of income for those who need to be physically present at their place of employment (such as those employed in manufacturing). As was experienced in the catastrophic 2023 Hawaii wildfires, forest fires can even cause loss of life.

c. Considerations for Adaptation Planning

As described above, there are certain types of primary industry that may be more suitable for the predicted future warm, dry conditions in the eastern parts of the Wellington Region. South Wairarapa, Carterton and Masterton already support viticulture and grape crops in particular suit warm dry conditions (noting they will still be subject to damage if severe storms occur). Water shortages experienced in the eastern parts of the Wellington Region will become more severe and competition for scarce water resources is likely to increase. Future regional economic planning should incorporate considerations around the future climate and adaptation planning should look to maximise economic opportunities for the region.

6.4.2 Risk to Manufacturing / Industrial Buildings Due to Coastal and Estuarine Flooding

Table 4333: Qualitative Risk Scores for ED116 and BD30, see Appendix A for More Detail

Risk Statement	Risk					First-pass impact score
	Present	2050 RCP4.5	2050 RCP8.5	2100 RCP4.5	2100 RCP8.5	
ED116: Risk to manufacturing due to coastal and estuarine flooding.	Low	Low	Low	Low	Low	Minor
BD30 Risk to buildings and facilities (public and private) due to coastal and estuarine flooding.	Moderate	High	High	High	High	Catastrophic

a. Potential Impact

Industrial areas in the Wellington Region play an important role in supporting a local employment base and supporting economic activities. Wholesale trade accounted for $1,891.5 million (3.8%) of the regions GDP and manufacturing accounted for $2,548.7 million (5.1%) in 2023 (Infometrics, 2024). Areas of existing industrial land may be increasingly impacted by flood and coastal inundation associated with rising sea levels. The adaptive capacity of industrial land is low as it is difficult to find alternative suitable and hazard free locations within the region as industrial activity has specific requirements such as good access for heavy vehicles and to main transport hubs such as ports and airports. Industrial activity may not be suitable to be located adjacent to residential areas given the potential nuisance effects (noise, air quality, traffic movements) and often it is important to site industrial activities together. This means large land areas are required. Industrial land also typically needs to be on flat land and this is the main reason it is currently located on flood prone land (as the main flat areas within the region are flood prone). The hilly nature of the Wellington City area means that finding suitable alternative industrial land will be severely limited.

Flooding of industrial / manufacturing sites can damage buildings and products stored on site resulting in costs for repairs and lost productivity. Disruptions to manufacturing and industrial activities can impact on the local economy and may have personal economic impacts if wage earners cannot access their place of work due to flooding. Flood waters on industrial sites can potentially cause contamination of the environment if flood waters come in contact with hazardous substances.

b. Key Areas of Impact

There are approximately 1,170 industrial buildings in the Wellington Region that are at risk (exposure and vulnerability) from flooding and coastal inundation by end century, including the low-lying industrial areas of Lower Hutt (approximately 445 buildings) and Porirua (approximately 145 buildings), Miramar (Wellington City, approximately 110 buildings). In addition to industrial buildings and land directly impacted, there may be industrial areas where access may be inhibited due to flooding of roads. There will be potential economic impacts associated with a decline in production from these industrial sites from more frequent flooding and personal income losses for wage earners employed in this industry (from temporary closures). There is a lack of information on who is directly employed in industrial areas and where they live and so it is not possible to quantify the spatial location (i.e. suburb) of downstream economic impacts.

c. Considerations for Adaptation Planning

It is suggested that a long-term plan be prioritised for at risk industrial areas, including potentially identifying future industrial sectors best suited to the districts and location of climate hazards. For example, the flat land of the Wairarapa that is currently in agriculture may be better suited to industrial land in the future, however this comes with risks of relying on Remutaka Hill road / rail networks (as described above) and has implications for food production economy and the protection of highly productive soils. Other important considerations for future planning include whether existing economic sectors be maintained or is there a need to have a gradual shift to alternative economic sectors that better align with Wellington’s comparative economic advantages (e.g. knowledge economy, tourism) and can be accommodated given the constraints in the region’s hilly geography.

7 Bibliography

Awatere, S., Reid, J., Masters-Awatere, B., Tassell-Matamua, N., Eastwood, K., Jackson, A-M., Ngaru King, D., Williams, L., Harris, P., Jones, R., Pirker, J. (2021). *He huringa āhuarangi, he huringa ao: a changing climate, a changing world*. Ngā Pae o te Māramatanga. www.maramatanga.co.nz

Beall, E., & Brocklesby, J. (2017). *Exploring with Māori organizations comparative advantage in the context of climate change.* Journal of Management & Organization, 23(6), 821-838. doi:10.1017/jmo.2017.65

Beca. (2023). Data Gaps Report for Wellington Regional Climate Change Impact Assessment.

Beca. (2022). Wellington Regional Climate Change Impact Assessment Methodology Framework Report.

Beck, U. (1992). *Risk Society: Towards a new modernity*. London, Sage Publications.

Bodeker Scientific, et al. (2022). *New ZealandNew Zealand New Zealand climate change projections guidance: Interpreting the latest IPCC WG1 report findings*. Retrieved from: https://environment.govt.nz/publications/New ZealandNew Zealandnew-zealand-climate-change-projections-guidance/

Boege, V. (2018). *Climate Change and Conflict in Oceania: Challenges, Responses, and Suggestions for a Policy-Relevant Research Agenda.* Toda Peace Institute.

Brown, R.M. (2018). *Surviving the system: Māori and Pacific whānau coping strategies to overcome health system barriers.* Auckland: Auckland University of Technology.

Campbell, J. R. (2019). *Climate Change, Migration and Land in Oceania*. Toda Peace Institute

Charrier, G. et al. (2018). *Drought will not leave your glass empty: Low risk of hydraulic failure revealed by long-term drought observations in world's top wine regions*. Science Advances. DOI: 10.1126 / sciadv.aao6969.

Collins M., M. Sutherland, L. Bouwer, S.-M. Cheong, T. Frölicher, H. Jacot Des Combes, M. Koll Roxy, I. Losada, K. McInnes, B. Ratter, E. Rivera-Arriaga, R.D. Susanto, D. Swingedouw, and L. Tibig, (2019). Extremes, Abrupt Changes and Managing Risk. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 589–655. https://doi.org/10.1017/9781009157964.008.

Cormack, D., Stanley, J., Harris, R. (2018). *Multiple forms of discrimination and relationships with health and well-being: findings from national cross-sectional surveys in New ZealandNew Zealand/New Zealand.* International Journal for Equity in Health, 17. http://doi.org/gc3qmm

Crozier MJ. (2010). Deciphering the effect of climate change on landslide activity: a review. Geomorphology. 124(3–4):260–267. doi:10.1016/j.geomorph.2010.04.009.

Dymond, J.R., Ausseil, A-G., Shepherd, J.D., Buettner, L. (2006). *Validation of a region-wide model of landslide susceptibility in the Manawatu–Wanganui region of New Zealand.* Geomorphology,Volume 74, Issues 1–4, Pages 70-79, ISSN 0169-555X. Retrieved from: https://doi.org/10.1016/j.geomorph.2005.08.005

Environment Canterbury Regional Council (ECan) (2023). *Flood Probabilities.* Retrieved from: https://www.ecan.govt.nz/your-region/your-environment/natural-hazards/floods/flood-probabilities/

Environmental Health Intelligence New Zealand (EHINZ). (2018). *Socioeconomic Deprivation Profile.* Retrieved from: https://www.ehinz.ac.nz/indicators/population-vulnerability/socioeconomic-deprivation-profile/#nzdep-for-2018-nzdep2018

GNS Science (2007). *Guidelines for assessing planning, policy and consent requirements for landslide-prone land, GNS Science Miscellaneous Series 7. Compiled by Saunders, W, & P. Glassey.* 78p. Available from: https://www.qualityplanning.org.nz/sites/default/files/Guidelines%20for%20assessing%20planning%20policy%20and%20consent%20requirements%20for%20la.pdf

GNS Science (2023), Landslide planning guidance: reducing landslide risk through land-use planning. By de Vilder SJ, Kelly SD, Buxton R, Allan S, Glassey PJ. 2023. Lower Hutt (NZ): GNS Science. 38 p. (GNS Science miscellaneous series; 144). doi:10.21420/R2X8-FJ49. Consultative draft available from: https://planning.org.nz/Attachment?Action=Download&Attachment_id=1000565

Graham, R., Masters-Awatere, B. (2020). *Experiences of Māori of New ZealandNew Zealand New Zealand's public health system: a systematic review of two decades of published qualitative research.* Australian and New Zealand Journal of Public Health, 44(3): 193–200. https://doi.org/10.1111/1753-6405.12971

Greater Wellington Regional Council (GWRC). (Accessed 2023). *Sea Level Rise and Storm Surge Modelling.* https://mapping1.gw.govt.nz/GW/SLR/.

Greater Wellington Regional Council (GWRC). (1998). *Otaki Floodplain Management Plan; The Community's Plan for the Otaki River and its environment*. Retrieved from: https://www.gw.govt.nz/assets/Documents/2021/11/FP-Otaki-FMP.pdf

Greater Wellington Regional Council (GWRC). (2016). *Pinehaven Stream: Floodplain Management Plan vol.1*. Retrieved from: https://www.gw.govt.nz/assets/Documents/2021/11/Pinehaven-printing-FMP-volume-1-update-6-September-2016.pdf

Greater Wellington Regional Council (GWRC) (2021). *Climate Change Mapping: 3D viewer prototype*. https://mapping1.gw.govt.nz/GW/SLR/

Greater Wellington Regional Council (GWRC). (2021). *The Waiōhine I Rakahanga River Plan*. Retrieved from: https://www.gw.govt.nz/assets/Documents/2022/06/The-Waiohine-Rakahanga-River-Plan

Greater Wellington Regional Council (GWRC). (2022). *Regional Soil Plan - Regional Rules*. Retrieved from: https://www.gw.govt.nz/your-region/plans-policies-and-bylaws/plans-and-reports/environmental-plans/regional-soil-plan/regional-soil-plan-regional-rules/

Greater Wellington Regional Council (GWRC). (2023a). *The community's plan for the Waikanae River and its environment.* Retrieved from: https://www.gw.govt.nz/assets/Documents/2021/11/FP-Waikanae-FMP.pdf

Greater Wellington Regional Council (GWRC). (2023b). *Lower Ruamahanga Valley.* Retrieved from: https://www.gw.govt.nz/your-region/emergency-and-hazard-management/flood-protection/our-work/rivers-and-schemes/lower-ruamahanga-valley/

Halloy, S. R. & Mark, A. F. (2003). *Climate-change effects on alpine plant biodiversity: A New Zealand perspective on quantifying the threat*. Arctic, Antarctic and Alpine Research, 35(2), 248–254.

Harris, R., Cormack, D., Tobias, M., Yeh, L-C., Talamaivao, N., Minster, J., Timutimu, R. (2012). *The pervasive effects of racism: experiences of racial discrimination in New Zealand over time and associations with multiple health domains.* Social Science & Medicine, (0) https://doi.10.1016/j.socscimed.2011.11.004.

Hospitality New Zealand. (2021). https://www.productivity.govt.nz/assets/Submission-Documents/immigration-settings/DR-139-Hospitality-New-Zealand.pdf

Hyslop, J., Harcourt, N., Awatere, S., Hikuroa, D., Blackett, P., & Heron, R. L. (2023). *Kia aiō ngā ngaru, kia hora te marino: smoothing the waters in natural resource management to mitigate risk and uncertainty.* AlterNative: An International Journal of Indigenous Peoples, 19(2), 229–239. https://doi.org/10.1177/11771801231174317

Infometrics. (2024). *Wellington Region – Regional Economic Profile* https://ecoprofile.infometrics.co.nz/wellington%20region

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.

IPCC (2014). Sixth Assessment Report (AR5): *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Retrieved from: https://www.ipcc.ch/report/ar5/wg3/

IPCC. (2018). Annex I - Glossary.

IPCC. (2019). *Climate Change influences on Abrupt Changes, Irreversibility, Tipping Points and Extreme Events*. Retrieved from: https://www.ipcc.ch/srocc/chapter/chapter-6/#:~:text=Cascading%20impacts%20from%20extreme%20weather,larger%20than%20the%20initial%20impact

IPCC (2019). *Special Report on the Ocean and Cryosphere in a Changing Climate*. Annex I - Glossary. Retrieved from: https://www.ipcc.ch/srocc/

IPCC. (2021). AR6, Annex VII - Glossary.

IPCC (2021). Sixth Assessment Report (AR6): *Climate Change 2021: The Physical Science Basis, the Working Group I contribution to the Sixth Assessment Report.* Retrieved from: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

IPCC. (2022): *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

IPCC. (2022). Annex II – Glossary.

ISO 14091:2021: *Adaptation to climate change — Guidelines on vulnerability, impacts and risk assessment (2021).* Retrieved from: https://www.iso.org/standard/68508.html

Jacobs (2022) Takutai Kāpiti – Coastal Science and Engineering Services Kāpiti Coast Coastal Hazards Susceptibility and Vulnerability Assessment Volume 2: Results. February 2022. 192p.

Jakob M. 2022. Landslides in a changing climate. In: Davies T, Rosser N, Shroder JF, editors. Landslide hazards, risks, and disasters. 2nd ed. Amsterdam (NL): Elsevier. p. 505–579.

Johnson, P. & Rogers, G. (2003). *Ephemeral wetlands and their turfs in New Zealand*. Science for Conservation, 230, 109.

Jones, R. (2019). *Climate change and indigenous health promotion.* Global Health Promotion, 26(3_suppl): 73–81. https://doi.org/10.1177/1757975919829713

Jones, R., Bennett, H., Keating, G., Blaiklock, A. (2014). *Climate change and the right to health for Māori in New ZealandNew Zealand/New Zealand.* Health and Human Rights Journal, 16(1): 54–68.

Keegan, L.J., White, R. & Macinnis-Ng, C. (2022). *Current knowledge and potential impacts of climate change on New Zealand's biological heritage.* New Zealand Journal of Ecology, 46(1), 3467. Retrieved from: https://doi.org/10.20417/nzjecol.46.10

King, D., Dalton, W., Home, M., Duncan, M., Srinivasan, MS. Bind, J., Zammit, C., McKerchar, A., Ashford-Hosking, D., and Skipper, A. (2012). *Māori Community Adaptation to Climate Variability and Change*: *Examining risk, vulnerability and adaptive strategies with Ngāti Huirapa at Arowhenua Pā, Te Umu Kaha (Temuka), New Zealand.*

King, D., and Penny, G. (2006). *The 2nd Māori Climate Forum - Hongoeka Marae, Plimmerton (24 May 2006): Summary Report.* NIWA Report prepared for the Foundation for Research, Science and Technology (FRST): AKL2006-099. 23.

Kingi, T. (2005). *Māori landownership and land management in New Zealand.* Reconciling customary ownership and development. Retrieved from: https://www.dfat.gov.au/sites/default/files/MLW_VolumeTwo_CaseStudy_7.pdf

Kool, R., Lawrence, J., Drews, M., Bell, R. (2020). *Preparing for Sea-level Rise through Adaptive Managed Retreat of a New Zealand Stormwater and Wastewater Network.* Infrastructures 5 (11), 92. Retrieved from: http://dx.doi.org/10.3390/infrastructures5110092

Lawrence, J., Blackett, P., Cradock-Henry, N., Nistor, B.J. (2021). *Climate Change: The Cascade Effect Cascading impacts and implications for New ZealandNew Zealand New Zealand*. National Science Challenges: The Deep South. Retrieved from: https://deepsouthchallenge.co.nz/wp-content/uploads/2021/01/Climate-Change-The-Cascade-Effect-Final-Report.pdf

Lawrence, J., B. Mackey, F. Chiew, M.J. Costello, K. Hennessy, N. Lansbury, U.B. Nidumolu, G. Pecl, L. Rickards, N. Tapper, A.Woodward, and A.Wreford, 2022: Australasia. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1581–1688, doi:10.1017/9781009325844.013.

Lewis, D., Williams, L., Jones, R. (2020). *A radical revision of the public health response to environmental crisis in a warming world: contributions of Indigenous knowledges and Indigenous feminist perspectives.* Canadian Journal of Public Health, 111: 897–900. https://doi.org/10.17269/s41997-020-00388-1

Macinnis-Ng, C., Mcintosh, A. R., Monks, J. M., Waipara, N., White, R. S. A., Boudjelas, S., Clark, C. D., Clearwater, M. J., Curran, T. J., Dickinson, K. J. M., Nelson, N., Perry, G. L. W., Richardson, S. J., Stanley, M. C., & Peltzer, D. A. (2021). *Climate-change impacts exacerbate conservation threats in island systems: New Zealand as a case study.* Frontiers in Ecology and the Environment, 19(4), 216–224. Retrieved from: https://doi.org/https://doi.org/10.1002/fee.2285

Manaaki Whenua Landcare Research. (2023). Our Environment Land Capability, Baseline Highly Productive Land

Ministry for the Environment (MfE). (2012). *Highly erodible land 2012.* Wellington: Ministry for the Environment. Retrieved from: https://data.mfe.govt.nz/table/99877-highly-erodible-land-2012/

Ministry for the Environment (MfE) (2017) Coastal hazards and climate change: Guidance for local government. December 2017. 279p.

Ministry for the Environment (MfE). (2018). *Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, 2nd Edition*. Wellington: Ministry for the Environment.

Ministry for the Environment (MfE). (2019). *Highly erodible land 2012.* Wellington: Ministry for the Environment. Retrieved from: https://data.mfe.govt.nz/table/99877-highly-erodible-land-2012/

Ministry for the Environment. (2019). *Arotakenga Huringa Āhuarangi: A Framework for the National Climate Change Risk Assessment for New ZealandNew Zealand New Zealand*. Wellington: Ministry for the Environment.

Ministry for the Environment (MfE). (2020). *National Climate Change Risk Assessment for New ZealandNew Zealand New Zealand: Main report – Arotakenga Tūraru mō te Huringa Āhuarangi o Āotearoa: Pūrongo whakatōpū.* Wellington: Ministry for the Environment.

Ministry for the Environment (MfE) (2021a). *A guide to local climate change risk assessments.* Retrieved from: https://environment.govt.nz/publications/a-guide-to-local-climate-change-risk-assessments/

Ministry for the Environment (MfE). (2021b). *The Ngaa Rauru Kiitahi Climate Change Strategy*. Wellington: Ministry for the Environment. Retrieved from: https://environment.govt.nz/assets/publications/ngaa-rauru-kiitahi-climate-change-strategy.pdf

Ministry for the Environment (MfE) 2022. Interim guidance on the use of new sea-level rise projections. Available from: https://environment.govt.nz/publications/interim-guidance-on-the-use-of-new-sea-level-rise-projections/

Ministry of Health. (2019b). *WAI 2575 Māori Health Trends Report*. Wellington: Ministry of Health.

Mitchell Daysh. (2019). *Greater Wellington. Preparing Coastal Communities for Climate Change*.

NIWA. (2012). *Sites of significance for indigenous marine biodiversity in the Wellington region,* May 2012. Prepared for Greater Wellington Regional Council.

NIWA (2017a). *Climate change and variability - Wellington Region: Prepared for Greater Wellington Regional Council.* Retrieved from: https://www.gw.govt.nz/assets/Documents/2017/06/Climate-Change-and-Variability-report-Wlgtn-Regn-High-Res-with-Appendix.pdf

NIWA (2017b). *Report Summary: Wellington Region climate change projections and impacts.* Retrieved from: https://niwa.co.nz/sites/niwa.co.nz/files/Well_NCC_projections_impacts2017.pdf

NIWA (2019). *Wellington Region climate change extremes and implications.* Retrieved from: https://niwa.co.nz/sites/niwa.co.nz/files/GWRC%20NIWA%20climate%20extremes%20FINAL2.pdf

NIWA. (2021). *Coastal hazards and sea-level rise in Wellington City; Supporting the 2020-2021 district plan process*. Retrieved from: https://wellington.govt.nz/-/media/your-council/plans-policies-and-bylaws/plans-and-policies/a-to-z/spatial-plan/coastal-hazards-report---august-2021.pdf?la=en&hash=E70B002B5D515679482B867E649FD90D3D74FB5C

NZSeaRise (2022). Maps. Retrieved from: https://www.searise.nz/maps-2.

Paulik, R., Wild, A., Stephens, S., Welsh, R., Wadhwa, S. (2023) National assessment of extreme sea-level driven inundation under rising sea levels. Frontiers in Environmental Science, 10, 2633, https://doi.org/10.3389/fenvs.2022.1045743

Pacific Perspectives, 2019. Pacific Population Health Profile. Analysis to support localities planning by CCDHB. A report prepared for Capital and Coast District Health Board, November 2019.

Parliamentary Commissioner for the Environment. (1996). *Historic and Cultural Heritage Management in New Zealand*. Accessed 12 February 2020, from https://www.pce.parliament.nz/media/1526/historic-and-cultural-heritage-management-in-newzealand-june-1996-small.pdf.

Paulik, R., Horspool, N., Woods, R. et al. (2022). *RiskScape: a flexible multi-hazard risk modelling engine.* Natural Hazards. Retrieved from: https://doi.org/10.1007/s11069-022-05593-4

Perrie, A., & Milne, J. R. (2012). *Lake water quality and ecology in the Wellington region*. Greater Wellington Regional Council, Publication No.GW/EMI-T-12/139. Retrieved from: http://www.gw.govt.nz/

Porirua City Council. (2020). *Porirua City Council's Climate Change Strategy 2021-2024*. Retrieved from: https://storage.googleapis.com/pcc-wagtail-media/documents/Porirua_City_Council_Climate_Change_Strategy_2021-2024-ONLINE.pdf

Quiggin, D., De Meyer, K., Hubble-Rose, L., Froggatt, A. (2021). *Climate change risk assessment 2021*. Chatham House. Retrieved from: https://www.chathamhouse.org/sites/default/files/2021-09/2021-09-14-climate-change-risk-assessment-summary-quiggin-et-al_0.pdf

Radio New Zealand. (2023). *Wellington's Haywards Road to close for work.* Retrieved from: https://www.rnz.co.nz/news/national/488525/wellington-s-haywards-road-to-close-for-work

Roberts, R., Carpenter, N., Klinac, P., Knook, P., Westgate, B., Haughey, R., Shand, T., Reinen-Hamill, R. (Auckland Council). (2021). *Predicting Auckland's exposure to coastal instability and erosion.* Retrieved from: https://www.knowledgeauckland.org.nz/publications/predicting-auckland-s-exposure-to-coastal-instability-and-erosion

Robertson, H., Bowie, S., Death, R. & Collins, D. (2016). *Freshwater conservation under a changing climate*. Proceeding of a workshop hosted by the Department of Conservation. (p 87). Wellington: Department of Conservation.

Robertson, H.A., Ausseil, A.G., Rance, B., Betts, H. & Pomeroy, E. (2019). *Loss of wetlands since 1990 in Southland, New Zealand.* New Zealand Journal of Ecology, 43(1), 1–9.

Sayers, P., Galloway, G., Penning-Rowsell, E., Yuanyuan, L., Fuxin, S., Yiwei, C., Kang, W., Le Quesne, T., Wang, L. & Guan, Y. (2015). *Strategic flood management: ten 'golden rules' to guide a sound approach*. International Journal of River Basin Management, 13:2, 137-151, DOI: 10.1080/15715124.2014.902378 Retrieved from: https://eponline.com/Articles/2014/05/27/10-Golden-Rules-of-Flood-Management.aspx

Sheppard, C. S. (2013). *Potential spread of recently naturalised plants in New Zealand under climate change.* Climatic Change, 117(4), 919–931. Retrieved from: https://doi.org/10.1007/s10584-012-0605-3

Singers, N., Crisp, P. & Spearpoint, O. (2018). *Forest Ecosystems of the Wellington Region*. Greater Wellington Regional Council, Publication No. GW/ESCI-G-18-164, Wellington.

Singers, N.J.D., & Rogers, G.M. (2014). *A classification of New Zealand's terrestrial ecosystems*. www.doc.govt.nz

Stats NZ. (2012). *Highly erodible land area*. Retrieved from: https://statisticsnz.shinyapps.io/highly_erodible_land/

Takutai Kāpiti. (n.d.). *Community-focused coastal adaptation programme*. Retrieved from: https://takutaikapiti.nz/

Task Force on Climate-related Financial Disclosures (TCFD), *Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures* (2017); TCFD, *Guidance on Risk Management Integration and Disclosure* (2020).

Te Puni Kōkiri & Nicholson Consulting. (2019). https://www.tpk.govt.nz/docs/tematapaeroa2019-insightsmaoribusiness.pdf

Thuiller, W. (2007). *Climate change and the ecologist*. Nature 448.7153: 550-552.

Thuiller, W., Richardson, D.M., Midgley, G.F. (2007). *Will climate change promote alien plant invasions?* Ecological Studies, 193, 197–211.

Todd, D., Macdonald, K. and Debski, D. (2022). *Kāpiti Coast Coastal Hazards Susceptibility and Vulnerability Assessment Volume 2: Results.* A report by Jacobs commissioned by Kāpiti Coast District Council.

Wairarapa Economic Development Strategy 2022-2030. Retrieved from: www.thrivewairarapa.nz

Waka Kotahi (2022) Tiro Rangi: our climate adaptation plan 2022-2024. December 2022. 33. Available from: https://www.nzta.govt.nz/resources/tiro-rangi-our-climate-adaptation-plan-2022-2024/

Weeks, E.S., Death, R.G., Foote, K., Anderson-Lederer, R., Joy, M.K. & Boyce, P. (2016). *Conservation Science Statement 1. The demise of New Zealand's freshwater flora and fauna: a forgotten treasure*. Pacific Conservation Biology, 22(2), 110–115.

Wilcock, R. J., Nash, D., Schmidt, J., Larned, S.T., Rivers, M.R. & Feehan, P. (2011). *Inputs of nutrients and faecal bacteria to freshwaters from irrigated agriculture: Case studies in Australia and New Zealand.* Environmental Management 48, 198–211.

Williams, S.E., Shoo, L.P., Isaac, J.L., Hoffmann, A.A. & Langham, G. (2008). *Towards an integrated framework for assessing the vulnerability of species to climate change*. PLoS Biology, 6(12), 2621–2626.

Wiser, S.K., Buxton, R.P., Clarkson, B.R., Hoare, R.J.B., Holdaway, R.J., Richardson, S.J., Smale, M.C., West, C., & Williams, P.A. (2013). New Zealand's Naturally Uncommon Ecosystems. Ecosystem Services in New Zealand – Conditions and Trends, 49–61. http://www.biodiversity.govt.nz

WREMO (2019). *Wellington Lifelines Project: Protecting Wellington's Economy Through Accelerated Infrastructure Investment Programme Business Case*. Revision 3, 04 October 2019. Available from: https://www.wremo.nz/assets/Library/Reports/Wellington-Lifelines-PBC-MAIN-Combined-20191009.pdf

A

Appendix A – Qualitative Climate Risk Register

Qualitative Climate Risk Register - Excel

B

Appendix B – Glossary

Glossary

We note that the councils have chosen to refer to this project as an ‘impact’ rather than a ‘risk’ assessment to emphasise the focus on practical implications. Climate ‘risks’ and ‘impacts’ are conventionally defined as below.

Most definitions below come from the IPCC AR6, Annex VII – Glossary (2021) or the MfE: A Guide to local climate change risk assessments (2021)

Adaptive capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2021).

Cascading effects: Effects that flow on from a primary hazard, propagating as impacts across other human or natural systems in a dynamic manner (MfE, 2021).

Cascading risk: Cascading risks are those that develop due to a hazard and its impacts in situ to the systems affected, flowing out to other domains (Lawrence et al., 2020).

Climate driver: A changing aspect of the climate system that influences a component of a human or natural system (IPCC, 2022).

Coastal erosion: Removal of soil and rock at the coastline. It’s a complex process that can be caused by a number of factors including wave energy, high rainfall, changes to sediment availability and land use, or sea-level rise. It occurs differently for beaches and cliffs, and can occur rapidly due to storm events or more gradually over time. This is often a permanent loss, although beaches can re-establish if conditions are appropriate (Roberts, et al., 2021).

Coastal instability: The movement of land (typically as a landslide) resulting from the loss of support caused by coastal erosion. The effects last for a long time or may be permanent (Roberts, et al., 2021).

Coastal inundation: Flooding of coastal areas by the sea, also known as coastal flooding. Can be caused by a number of processes including high astronomical tides, low atmospheric pressur4e (storm surge) and wind direction and strength. Climate change induced sea-level risk will exacerbate this process over time (Roberts, et al., 2021).

Compound risk: Arise from the interaction of hazards, which may be characterised by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors (IPCC, 2019).

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).

Direct risk: Where there is a direct link between a hazard and an element at risk that is exposed and vulnerable. For example, storms and flooding damaging buildings and infrastructure, droughts leading to crop failure, or extreme temperatures causing heat stress.

Elements at risk: People, values, taonga, species, sectors, assets etc that are potentially vulnerable to climate change impacts.

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by a change in external stresses that a system is exposed to.

Fluvial flooding: The flooding that occurs when rivers and streams break their banks and water flows out onto the adjacent low-lying areas.

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. In this assessment, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Impacts: The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather / climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial.

Indirect risk: Indirect risks are further removed from a hazard – for example, impacts on mental health, disruptions to supply chains, migration, social wellbeing, and cohesion. They are the result of direct risks elsewhere, which can be local or distant.

Pluvial flooding: The flooding that occurs when the amount of rainfall exceeds the capacity of urban storm water drainage systems or the ground to absorb it. This excess water flows overland, ponding in natural or man-made hollows and low-lying areas.

Sensitivity: Refers to the degree to which an element at risk is affected, either adversely or beneficially, by climate variability or change. Sensitivity relates to how the element will fare when exposed to a hazard, which is a function of its properties or characteristics.

Te Taiao narrative: Te Taiao is a unique and integrated model for viewing the environment from a Māori perspective. The overarching Te Taiao Narrative of this assessment looks at climate change risk from a holistic 'all of environment' perspective. Te Taiao presents an ideal framework for an integrated view on climate risks, enabling integration of western risk frameworks with Te Ao Māori values.

Transition risks: Risks occurring due to a swift transition to a net zero carbon economy and may entail extensive policy, legal, technology, and market changes to address mitigation and adaptation requirements related to climate change. Depending on the nature, speed, and focus of these changes, transition risks pose varying levels of financial and reputational risk to organisations. (Task Force on Climate-related Financial Disclosures, 2017, 2020).

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 types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts). (IPCC, 2018).

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. See also Contextual vulnerability and Outcome vulnerability.

C

Appendix C – Limitations and Assumptions

Limitations and Assumptions

General

This climate change risk and impact assessment is subject to the inherent limitations of predictive modelling and data analysis in the field of climate science. The assessment is intended to offer insights into potential risks associated with climate change across the Wellington Region, and specific considerations at local authority level. 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, uncertainties inherent in climate modelling, data collection, and future scenario projections cannot be completely eliminated.

The assessment presented in this report involves a qualitative judgment of potential climate-related risks and impacts and where possible quantify risks and impacts in the detailed assessment. It is essential to understand that qualitative assessments inherently involve subjectivity and expert interpretation. Different experts or stakeholders may arrive at different conclusions based on their perspectives and the assumptions they make. Furthermore, due to the evolving nature of climate science and the potential for unforeseen events, the actual outcomes of climate change impacts may differ from those described in this assessment. Therefore, users of this assessment are cautioned against making decisions solely based on the information provided herein. Decisions related to planning and investment, adaptation, and policy-making should consider a wide range of sources, expert opinions, and ongoing research.

This report and the associated services performed by the Beca-led team documents the Wellington Climate Risk and Impact Assessment in accordance with the scope of services set out in the contract between Beca and the Wellington City Council ('the Client'). That scope of services has been further refined through the development of a regionally consistent risk and impact assessment methodology developed as part of the services. The Detailed Assessment stage has focussed on the risks selected for further investigation with the Council Project Team during the prioritisation stage and as documented in this report. The following section identifies particular limitations and assumptions made as a result of data availability and suitability for a regionally consistent impact assessment at the time of the services delivery.

In preparing this report, the Beca-led team has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Beca has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate, or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

The Beca-led team has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures, and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full, and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Beca for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of, the Client, and is subject to, and issued in accordance with, the provisions of the contract between Beca and the Client. Beca accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

Appendix F summarises the data used in the Detailed Assessment and the assumptions made in regards to scoring or risk / impact.

Built Environment

Compared with the other domains, the Built Environment of the Wellington Region is relatively well supported by spatial data for the various elements of risk. For example, the location of residential buildings, schools, Three Waters infrastructure etc. However, information held by councils in regard to privately-owned assets may be incomplete or lacking in detail.

Although locations of buildings and facilities is well known, there is limited data available to inform vulnerability (such as building floor levels, structural condition, etc). The following documents the particular limitations and assumptions made in the conducting of this risk and impact assessment. The Data Gaps Report (Beca, 2023) described in more detail the data assessed and used for the WRCCIA.

Risk to Building and Facilities Due to Coastal Erosion

Coastal erosion has been assessed and considered very differently across districts. This has implications for the regional consistency of risk / impact assessments (and therefore not able to be relied on for prioritising/advancing regional adaptation planning).

However, coastal erosion risk to buildings was identified as a key risk for the region on the basis of its risk scoring. The higher risk rating reflects the inevitability of the erosion (via RSLR), the broad exposure within multiple districts around the region, sensitivity of buildings to erosion, the lack of effective and long-term adaptation measures (rebuilding coastal defences is limited by cost and environmental effects), the degree of uncertainty in available assessments (i.e. data gaps), and the broad impact on the region (e.g. economic losses, perception about risk from negative media attention, and complicated governance steps to re-zoning at risk land). Hence, the assessment proceeded with hazard information which was already available to qualitatively introduce and explain the coastal erosion context around the region.

The nature of coastal erosion information varies across the region. Table C1 provides an overview of coastal erosion information available. Refer to the Data Gaps Report (Beca, 2023) for further summary of data available and gaps.

Table C1: Overview of Coastal Erosion Data Availability for Present Day and Future Scenarios in the Wellington Region

Council	Present Day Erosion Hazard Information	Future **E**rosion **H**azard
Region-wide (i.e. via GWRC)	None.	None.
Porirua	Selected areas only.	Single scenario of +1m SLR in selected areas only.
Kapiti (KCDC requested this dataset not be used within the assessment)	District wide, comprehensive probabilistic assessment of erosion. Long-term coastal monitoring programme.	Probabilistic erosion assessment with relative SLR at 0.4, 0.8, 1.2 and 1.6m above present-day sea levels.
Wairarapa councils (South Wairarapa, Masterton, Carterton)	Simple 50m wide zone of 'foreshore protection area' within district plan. Some erosion protection structures at Riversdale Beach.	None.
Wellington City	Coastal erosion overlays not available at district scale or included within District Plan. No detailed erosion projections at district scale but known coastal hazards along South Coast and Makara Beach.	Localised erosion projections at south coast pocket beaches associated with hazard studies (e.g. Owhiro Bay, Island Bay, Lyall Bay, Makara Beach).

Council	Present Day Erosion Hazard Information	Future **E**rosion **H**azard
Hutt City (Lower Hutt)	No coastal erosion layers available but known coastal hazard risks along Eastern Bays and Eastbourne.	None.
Upper Hutt	NA – non-coastal.	NA – non-coastal.
Other (e.g. NIWA)	Coastal Sensitivity index, region wide but outdated (circa 2011) and was methodologically too simple for hazards assessment and spatial planning.	None.

Overall, there is sparse and inconsistent coastal erosion data to support a detailed climate change risk and impact assessment. Future scenarios are only available for Porirua and Kapiti Coast however these are inconsistent between districts. There are district-scale gaps in coastal erosion hazard knowledge for the major urban areas of Wellington City, Lower Hutt (Petone to Eastbourne) and the smaller communities of the Wairarapa coastal councils (e.g. Mataikona, Riversdale Beach, Castlepoint). Prioritising a work programme to consistently identify future coastal erosion areas is recommended as this will inform identification of at-risk communities which may require prioritisation for adaptation programmes, and areas suitable for future developments outside of at-risk areas across the region.

We also note that there are national research programmes underway which will look to digitise and document coastal change (via shoreline position digitisation) around the Region. The Coastal Pillar component of the Resilience to Nature's Challenges 2 (RNC2) research results are expected to be available for the Wellington Region in 2024 (pers. comm. Prof Mark Dickson, University of Auckland). The RNC2 outputs may not include erosion projections, however the shoreline change data is likely to be suitable to base future studies on.

Risk to Buildings Due to Coastal Inundation and Sea-Level Rise

a. Element at Risk: Buildings

The National Buildings database information is available from LINZ and has been used in the assessments. This dataset provides the building footprint which has been combined with available data from councils and central government to indicate building usage. Attributes include land use zoning (source: council district plans grouped into residential, rural, commercial, mixed use, recreation, industrial and other), Public/Private (source: LINZ ownership data), Childcare facility (source: MoE), School (source: MoE), Hospital (source: MoH), Aged care facility (source: MoH), Religious facility (source: OpenStreetMap), and Supermarkets (source: LINZ).

However, this building information does not include specific information about the buildings which would be useful to inform a more detailed vulnerability assessment. Information such as building age, materials, floor level primary/secondary uses, and floor level above ground level, was not able to be sourced for this assessment.

Consolidation of built environment data into building and property specific information with consistent terminology, metadata and definitions across the region is recommended to further facilitate regionally consistent assessments and support adaptation planning. The key focus to be on building characteristics and building usage which inform the parameters of sensitivity and adaptive capacity within risk assessments.

b. Hazards Data: Coastal Inundation

Coastal inundation has been defined differently across districts with an imbalance in detail of information available. Rising sea levels are a major hazard to the region, however the rate of SLR is locally affected by the geology and Vertical Land Motion (VLM) which is the slow uplift or subsidence of the land not directly associated with earthquakes. Together, the combined SLR + VLM is the Relative SLR (RSLR) where VLM either accelerates (subsidence) or offsets (uplift) sea-level rise.

National-scale VLM and RSLR information only became available in March 2022 via the NZSeaRise research programme but is recommended for inclusion in coastal hazards mapping by the interim update to the MfE Coastal Hazards guidance (June 2022). As such, inundation mapping delivered prior to NZSeaRise release typically does not include local VLM (WCC being the exception with the 2020 district plan mapping by NIWA including VLM). More recent assessments by KCDC (Takutai Kapiti) and HCC (released June 2023) do include VLM.

Table C2 provides an overview of coastal inundation information available. Refer to the Data Gaps Report (Beca, 2023) for further summary of data available and gaps.

Table C2: Overview of Coastal Inundation Data Availability for Present Day and Future Scenarios in the Wellington Region

Council	Present Day Coastal Inundation Hazard Information	Future Inundation Hazard Information
Region-wide (i.e. via GWRC)	Publicly available regional scale storm surge and MHWS mapping. Analysis by NIWA mapping by GWRC.	MHWS includes +0.1 m increments of SLR. Storm-surge includes +0.5m increments. Does not include vertical land motion from NZSeaRise.
Porirua	District Plan layers 1% AEP at present day.	Single +1m SLR layer. No VLM.
Kapiti (KCDC requested this dataset not be used within the assessment)	Detailed probabilistic coastal inundation modelling via Takutai Kapiti mapping project.	Probabilistic inundation assessment with relative SLR at multiple scenarios.
Wairarapa councils (South Wairarapa, Masterton, Carterton)	Simple 50m wide zone of 'foreshore protection area' within district plan.	None.
Wellington City	District Plan Inundation Hazard overlay – high resolution storm and wave modelling by NIWA in 2021 for open coast areas (outside harbour). Simple bathtub mapping within the Harbour.	Includes specific RSLR scenarios related to 100-year planning timeframe for the district plan.
Lower Hutt	Detailed high-resolution storm and wave modelling by NIWA with mapping by NIWA (released June 2023).	Includes specific RSLR scenarios related to 100-year planning timeframe for the district plan.
Upper Hutt	NA (non-coastal).	
Other (e.g. NIWA)	National Coastal inundation hazard mapping.	0.1m increments of SLR from 0-2m. No VLM inclusion.

To use only these datasets would limit the regional consistency of any risk / impact assessment (and therefore not able to be relied on for regional adaptation planning). This issue was anticipated in the Phase 1 Data Gaps analysis. Further, only the KCDC, HCC and WCC results explicitly account for vertical land motion, but not using exactly the same method.

This data inconsistency was addressed by selecting NIWA's latest coastal inundation mapping which was released publicly (May 2023)[18]. These maps provide the inundation under 1% AEP + wave setup storm events, and include 0.1m SLR increments from 0-2 m above present day (i.e. 20 layers with each layer related to a 0.1 m increment of SLR). This information is regionally consistent; however it does not include VLM. All assumptions, limitations and disclaimers from the NIWA analysis and flood models apply.

Following the latest MfE (2022) interim guidance on coastal hazards and climate change, the SLR layer can be adjusted to account for local VLM by adjusting 'up' a 0.1m layer (for subsidence where SLR gets worse) or 'down' a 0.1m layer (for uplift).

For this assessment, the SLR layer for each RCP/timeframe (mid and end-century, RCP4.5 and RCP8.5) was adjusted up/down to account for VLM based on three broad groups of regional subsidence across region as indicated below (-1 mm/year: East, -3 mm/year: Central, -5 mm/yr: West – images from NZSeaRise). This approach was agreed with GNS Science as suitable for region and district scale assessments.

Overall, the inclusion of VLM at the mid-century timeframe adds between 0 (west) and 2 (east) layers to the SLR mapping, increasing to 1 (west) and 4 (east) at the end of century timeframe.

Future assessments could improve future hazards knowledge by utilising the local VLM (i.e. at 2km coastal scale rather than splitting region into three broad areas), and mapping results across the region with a consistent approach to the wave-driven component of inundation (i.e. dynamic vs bathtub modelling). Updating this information is important in future detailed assessment, but not critical for regional spatial planning as NIWAs regional-scale information is considered adequate with inclusion of conservative allowances of higher RSLR rates (as per Ministry for the Environment Coastal Guidance).

Risk to Buildings Due to Pluvial Flooding

c. Element at Risk: Buildings

The National Buildings database information has been used in the assessments.

d. Hazard: Pluvial and Fluvial Flooding

Flooding hazards mapping within the Wellington Region is available from a variety of studies by Wellington Water, GWRC and some individual district councils detailed flood modelling (e.g. KCDC). However, the various models are not wholly consistent in resolution, inclusion of future climate scenarios, or level of detail such as inclusion of protection measures (e.g. stormwater network, stopbanks).

For the purpose of this assessment, the flood modelling sources have been grouped as follows:

- **Local-scale flood models**. These have been developed by WWL or individual councils for predominantly urban catchments to simulate stormwater flooding hazard extents for district plans and other planning purposes. The local-scale models cover most, but not all, catchments within WCC, PCC, HCC, HCC, UHCC but excludes KCDC and the three Wairarapa councils (South Wairarapa, Masterton and Carterton). KCDC are underway developing their own local model. Model simulations are available for a range of extreme events (e.g. 10% or 1% AEP events) and some climate change scenarios (e.g. a combination of % rainfall increases and SLR). Gaps in the data in rural locations include:
  - Western Hills North of Harbour View (Lower Hutt)
  - Eastern Bays South of Point Howard (Lower Hutt)
  - South Wainuiomata (South of Wainuiomata Rugby Club) (due to be available 2024)
  - Whitby (due to be available late 2023 or 2024)

[18] https://niwa.co.nz/natural-hazards/our-services/extreme-coastal-flood-maps-for-aotearoa-new-zealand

- South Wairarapa models

- **Sub-regional priority catchments flood models** are available on the GWRC public GIS server. Coverage is of only those catchments where GWRC provide flood risk management advice for GWRC flood protection schemes including some tributary rivers. Specific catchments and rivers include Otaki River, Waikanae River, Hutt River and tributaries, Porirua Stream, Wainuiomata River, Ruamahanga River and tributaries within Wairarapa Valley, and some smaller Wairarapa Rivers (Whareama River, Awhea River). Modelling includes some climate change scenarios across the region. The flood modelling method differs from the other models, with the model outputs not including depth of flood waters[19]
- **Regional flood exposure models** (released 2023, modelled by T+T for GWRC) were developed as a high-level model for the purpose of understanding flood exposure across the entire region. However, we understand the methodology does not resolve protective features of stormwater networks to the same extent as the WWL and GWRC models. Mapping includes 1% AEP events and climate change scenarios (RCP6.0 and RCP8.5) at mid-century and end-century timeframes including SLR allowances[20].

The local, sub-regional and regional flood maps were produced using a range of different hydrodynamic flood inundation modelling software and methods over recent years.

On the advice of GWRC and based on the objectives of the WRCCIA to provide a regionally consistent impact assessment we adopted an approach for this assessment to include local flood model results (consolidating the various model outputs, excluding KCDC) with the GWRC Regional Flood Exposure model. This approach meets the project objectives by allowing a regional perspective of the increasing risk from climate change on flooding hazards and allows improved resolution of potential building and transport impacts through use of flood depths in the exposure calculation.

For this assessment:

- The Wellington Water flood models were consolidated together from the multiple sub-catchment model results. The common model simulations available were a 1% AEP event which includes a single future climate change scenario (+20% rainfall with + 1m SLR – equivalent to RCP4.5 at end-century timeframes). Note the local KCDC flood model data was unable to provide flood depths within the project timeframe and KCDC are developing another detailed flood model but this is not due until the end of 2024.
- The GWRC Regional Flood Exposure which covers the whole region. This also includes 1% AEP events and climate change scenarios (RCP6.0 and RCP8.5) at mid-century and end-century timeframes.
- Where there are gaps in WWL flood data (see above), the GWRC flood vulnerability assessment data has been used.

[19] https://mapping.gw.govt.nz/gw/floods/

[20] https://www.gw.govt.nz/your-region/emergency-and-hazard-management/flood-protection/flood-hazard-advice/regional-flood-hazard-assessment/

e. Limitations

Flood hazard maps developed using higher resolution modelling methods are considered to provide a more accurate representation of flood hazard areas, however until the entire region is modelled in a single consistent manner, there will be differences such as:

- Input parameters (e.g. rainfall, surface roughness) at the time of model development
- Inclusion / exclusion physical features (e.g. stopbanks, culverts, bridges) that influence flood hazard characteristics
- Residual flood hazards (e.g. stopbank failures) are often excluded in modelled flood scenarios
- Inconsistent inclusion of the influence of climate change (e.g. rainfall and sea-level rise), or land use change on flood hazard characteristics in modelled flood scenarios.

All limitations and disclaimers from the local and regional flood models apply.

Human / Social

In general, there is less geospatial and other information available in literature to help assess human domain risks and impacts as some elements are more abstract compared to the built environment, for example. Risk scoring for the human domain therefore typically requires a greater level of qualitative judgement and assumptions (e.g. compared to the built domain).

The following is the specific limitations noted for the Detailed Assessment.

Risk to Cultural Heritage Due to Coastal and Pluvial Flooding and Coastal Erosion

f. Element at Risk Data

For the GIS **Viewer**, publicly available datasets in the Natural Resources Plan 2019 were used including:

- Schedule B - Ngā Taonga Nui a Kiwa
- Schedule C - Sites with significant iwi and hapū values
- Schedule E - Sites with significant historic heritage values
- Marae locations (Te Kāhui Māngai - TKM).

This assessment has only used existing data contained in the Natural Resources Plan 2019 to identify sites of significance. There has been no engagement with iwi and hapū to identify new sites and / or re-verify the sites contained in the Natural Resources Plan 2019. Therefore, the sites identified are non-exhaustive and do not necessarily represent all potential sites of significance in the region.

Risk to Social Cohesion Due to Coastal and Pluvial Flooding and Coastal Erosion

Social cohesion is a difficult concept to measure and there are few indicators and data sets that provide clear information on how to assess the potential risks. This assessment uses measures that provide the best available proxy for social cohesion, including easy access to social infrastructure that provides places for people to meet, secure services and to undertake activities that enable their daily lives. In addition, cohesion would be reduced if residents struggled to physically move around the community or large tracts of the community were permanently relocated.

g. Element at Risk Data

Social cohesion was linked to the local buildings, roads, important local places such as schools, supermarkets and religious facilities and the ease with which the community could connect with each other and the rest of the region. To this end, the following data sets were used:

LINZ Building Outlines with attributes below:

- High level zone (source: council district plans grouped into residential, rural, commercial, mixed use, recreation, industrial, other)
- Public / Private (source: LINZ ownership data)
- Childcare facility (source: Ministry of Education)
- School (source: Ministry of Education)
- Hospital (source: Ministry of Health via LINZ)
- Religious facility (source: OpenStreetMap)
- Supermarket (source: LINZ).

Single access point roads that may be impacted by flooding and landslides as well roads where large areas of flooding would fragment or disconnect key towns were identified manually and added to the GIS maps for use in determining areas where access and isolation may be an impact.

Average Annualised Loss (source: RiskScape®) was generated for buildings and coastal inundation risk but was not used in the assessment at CPT request as data considered sensitive for public release.

The risk assessment was undertaken by overlaying flood and inundation models for 2100 on the current configurations of buildings and roads. Clearly, buildings and roads will be redesigned and (potentially) relocated in this timeframe, however, it provides a baseline set of assessments against which future change can be monitored.

Further social cohesion indices and indicators need to be developed to better describe change within the community so more direct measures can be monitored over time. This is potential future research opportunity (potentially under the Deep South Challenge) for the research community who can assist to bridge the gap between a qualitative concept and quantitative measures.

The most important aspect for adaptation planning is to monitor the changes within the community over time including any changes in access to social infrastructure that provides places for people to meet, secure services and to undertake activities that enable their daily lives in known and emerging hazard zones.

Risk to Existing Inequities Due to Coastal and Pluvial Flooding and Coastal Erosion

h. Element at Risk Data

EHINZ social vulnerability indicators based on 2018 Census has been used to determine where there may be existing inequities. The population information used in GIS analysis is presented at the meshblock level which is defined by StatsNZ[21] as

"both a geographic unit and a classification. It is the smallest geographic unit for which statistical data is reported by Statistics NZ. A meshblock is a defined geographic area, varying in size from part of a city block to large areas of rural land. Meshblocks are contiguous: each meshblock borders on another to form a network covering all of New Zealand, including coasts and inlets. The meshblock classification extends out to New Zealand's 200 mile exclusive economic zone (EEZ)"

A meshblock is typically no more than 120 dwellings and has specific rules regarding how its constructed and what it contains. However, because the size of a meshblock varies so does the spatial resolution of data available for different communities. As a result, the overlay of flood hazard zones and coastal inundation maps with meshblock data may not reveal accurate information regarding the community potentially impacted because of the difference in the spatial extent of the hazard zone and meshblock.

[21] Statistical standard for meshblock (stats.govt.nz) (https://www.stats.govt.nz/assets/Uploads/Retirement-of-archive-website-project-files/Methods/Statistical-standard-for-meshblock/stats-stnd-meshblock.pdf

Data used includes:

- Percentage of renters
- NZ deprivation index
- Percentage of crowded households
- Percentage of damp and mouldy houses
- Percentage of 65+ older adults
- Percentage of young children (under 5)
- Percentage of school age children (5 - 17)
- Percentage of unemployed people
- Percentage of people able to work from home.

All data is from the 2018 census, so it is static data that is approximately six years old and does not account for future changes / projections and social change that has occurred in the preceding period. This means that when undertaking the risk assessment, flood and inundation models for 2100 are overlayed on census data from 2018 in order to make assessments about potential risk. Clearly, social conditions will change in this timeframe, however, it provides a baseline set of assessments against which future change can be monitored.

The most important aspect for adaptation planning is to monitor the changes within the community over time including any changes in social deprivation in known and emerging hazard zones. Adaptation actions should be carefully integrated to insure they do not increase inequity or create new inequities.

i. Hazard Data: Coastal and Pluvial Flooding and Coastal Erosion

Refer to Appendix I for discussion on this hazards data used and its limitations.

Natural Environment

General

Unlike damage to the built environment, negative impacts to the natural domain are harder to classify. Changes to an ecosystem are not inherently "positive" or "negative," and require a definition of what is valued (e.g. biodiversity) and the baseline against which change will be measured.

Much of the assessment is based on national assessments and data, due to the paucity of regionally specific information for the Wellington Region.

The dynamics of complex systems like ecosystems can make it difficult to predict the full extent of climate-related risks and impacts. While the initial exposure and vulnerability of coastal ecosystems to sea-level rise can be estimated, for example, the downstream ecological impacts are much harder to predict.

From a te ao Māori perspective, the natural domain is not separate from the "Human Domain" or any other element of human society that we have categorised here (e.g. governance or built environment). For the assessment, we have separated out the Natural Domain from the others, but it is important to note that this is a western worldview and western framing. The cascading risk section specifically examines the interconnection between the value domains.

Risk to Coastal Ecosystems from SLR / Storm Surge

j. Elements at Risk: Vulnerable Coastal Ecosystems

For the purposes of this report, a qualitative assessment of pre-determined vulnerable coastal ecosystems was undertaken using existing data sets on the advice of GWRC. Vulnerability was determined by expert judgement and supported by scientific literature. The lack of data to represent the full range of threatened and naturally rare / uncommon ecosystems is a limitation of the analysis. Climate change impacts were inferred by assessing exposure to SLR / storm surge mid and late century scenarios (RCP4.5 and RCP8.5) on these datasets. Adaptive capacity was inferred by proximity (100m) to built infrastructure and/or topographical constraints e.g. coastal cliffs.

Limited data was sourced from Greater Wellington Regional Council representing vulnerable coastal ecosystems as below:

- Scientific dunelands 2022 (supplied by Roger Uys, GWRC)
- Saltmarshes as identified by DOC ("Coastal marine habitats and marine protected areas in the New Zealand Territorial Sea: a broad scale gap analysis" report of 2011.)
- Geospatial data from the Natural Resources Plan 2019.

k. Hazard Data: Coastal Inundation

Refer to Appendix I for discussion on the hazard data and its limitations.

Risk to Regionally Threatened Forests from Rainfall Changes

l. Element at Risk: Regionally Threatened Forest (Warm)

For the purposes of this report, a qualitative assessment of pre-determined vulnerable forest ecosystems was undertaken using existing data sets on the advice of GWRC. Expert judgement, supported by scientific literature review, determined ecosystem vulnerability with regionally threatened forest chosen for the detailed assessment.

Data was sourced from Greater Wellington Regional Council representing vulnerable coastal ecosystems as below:

- Singers, N.; Crisp, P and Spearpoint, O (2018) *Singers Forest Classification (GWRC)* Geospatial layer.

m. Climate Hazard

Climate change impacts were inferred by assessing exposure to changes in annual temperature, potential evapotranspiration deficit >300mm and rainfall for mid- and late century scenarios (RCP4.5 and RCP8.5). NIWA modelled climate change indicators used:

- Total rainfall (changes in % per year)
- Potential evapotranspiration deficit (PED) days over 300mm (changes in days per year)
- Mean temperature (annual changes in degrees C).

For temperature, a change of 2ºC or greater was assumed to be a threshold for impact realisation based on class or isotherm limits for New Zealand forest types (Singers & Rogers, 2014).

Thresholds for rainfall and drought impact realisation could not be inferred using the available data, however the comparative change between present day, mid-century and late-century was used as an indicative guide to where the greatest change may occur spatially across the region over this time period.

This is a simplistic approach where topographical influence, species ecology, thermal and soil moisture tolerances were not considered beyond that inherently factored into the assigning of isotherm limits in Singers and Rogers (2014).

Economic Domain

General

Regional GDP data used:

- Stats NZ, 2019
- Infometrics Regional Economic Summary (based on 2022 or 2023 prices as identified in report).

GDP has been used to indicate the relative importance of certain industries to a district or the region. The data has been used alongside exposure to provide a qualitative description of the potential economic impact.

Risk to Primary Industries Due to Drought

n. Element at Risk Data

Landcover database:

- Orchard, Vineyard or Other Perennial Crop
- Short-rotation Cropland
- High Producing Exotic Grassland
- Low Producing Grassland.

New Zealand business demography statistics: February 2022 (Stats NZ):

- A01 Agriculture Category

Gross domestic product by industry, by region (Stats NZ):

- 'Wellington', 'Agriculture' (2019)

There is limited publicly available data on the relationship between dry spells / droughts and horticulture productivity, making it difficult to understand and quantify the extent of economic impacts.

There is no information available on industry-specific income indicators, so it is not possible to determine the scale of the economic impact on the various primary industries.

o. Hazard: Drought

- >300mm PED used as drought threshold: refer here: https://niwa.co.nz/climate/information-and-resources/drought/charts.

Risk to Forestry Due to Fire Weather

p. Element at Risk Data

Landcover database:

- Deciduous Hardwoods
- Exotic Forest
- Forest – Harvested.

New Zealand business demography statistics: February 2022 (Stats NZ).

A03 Forestry and Logging category.

q. Hazard

- >300mm PED used as fire weather proxy threshold (https://niwa.co.nz/climate/information-and-resources/drought/charts) (% forestry exposed to >300mm PED).

Risk to Industrial Land from Flooding and Coastal Inundation

r. Element at Risk Data

- Industrial zoned land (Council District Plans)
- New Zealand business demography statistics: February 2022 (Stats NZ)
- Manufacturing category.

Assessment of industrial buildings exposed to flood zones as a proxy for industrial land at risk. Since there is no detailed footprint /value data within each industrial property parcel, the required assumption is that industrial assets are distributed evenly across the parcelled land. This is clearly unwarranted, and well may yield in an over-estimation of the risk, as it is likelier that highest risk areas were less intensively developed.

s. Hazard Data: Coastal and Pluvial Flooding and Coastal Erosion

Refer to Section 13.2.3 for discussion on the hazard information and its limitations.

Governance

The Governance risks were assessed with participation of all councils in the Wellington Region and some of the relevant regional agencies which make decisions affected by climate change risks. Only some iwi and hapū representatives were available to participate in the workshops and this assessment does not include an assessment of governance risks of importance to iwi / Māori.

D

Appendix D - Maps

E

Appendix E – Methodology Summaries and Workshop Details

This appendix summarises the key methodologies used throughout the impact assessment. For more details please refer to the WRCCIA Methodology Framework Report (Beca, 2022).

Selection of Climate Change Scenarios and Timeframes

Selection of Climate Change Scenarios and Timeframes

The climate change scenarios used for this assessment were derived from the representative concentration pathways (RCPs) used by the Intergovernmental Panel on Climate Change (IPCC) in its fifth Assessment Report, AR5 (IPCC, 2014).

The IPCC's 6th Assessment Report, AR6, released in 2021/2022, presents a modified set of scenarios titled Shared Socioeconomic Pathways (SSPs). SSPs build on the RCP scenarios by considering a number of different climate policy pathways. Climate information relevant for the scale of this assessment using updated SSP scenarios has not yet been developed for New Zealand. However, investigations indicate the differences between RCP and equivalent SSP climate projections are not significant (Bodeker et al., 2022):

> *"… overall future regional projections using CMIP6 [IPCC AR6] global projections over New Zealand, excluding extremes, are expected to be similar to previous versions, but perhaps with areas of improved confidence and clarity. The projections detailed in MfE (2018) can therefore likely be used with reasonable confidence that the improved knowledge represented in the AR6 report do not fundamentally change key findings."*

As such, RCP scenarios are considered appropriate for this assessment but could be updated when downscaled SSP projections become more available as a future piece of work.

The points discussed when selecting suitable RCP scenarios included:

- **Data availability:** Not all climate hazards are assessed with the full range of RCPs (e.g. WCC Draft District Plan mapping for coastal hazards with climate change used RCP8.5 (median) and RCP8.5 (83rd percentile) for sea level rise projections, as per MfE guidance (MfE 2017).
- Feasibility: RCP2.6 is a very stringent pathway which requires that carbon dioxide (CO2) emissions start declining by 2020 and go to zero by 2100 (IPCC, 2014). This is considered ambitious based on the latest IPCC AR6 report (IPCC, 2021), latest emissions reductions pathways and Paris Accord promises. It is therefore considered to be an unrealistic scenario for the purposes of a physical climate risk assessment and for informing adaptation planning.
- Efficiency: The proposed qualitative assessment methodology involves workshopping with domain experts and council representatives on the climate hazard exposure. To add RCP2.6 (dramatic emissions reduction) and RCP6.6 (mid-range emissions reductions) would increase workshop assessment time for not much gain in climate risk resolution.
- Consistency: MfE (2021) guidance recommends the use of RCP4.5 and 8.5. These RCPs were used by neighbouring *Manawatū-Whanganui Regional Climate Change Risk Assessment* (Horizons, 2021). The use of these scenarios promotes consistency in how regional risks have been assessed.

Workshop Processes and Outcomes

Workshop Process

The Beca-led team hosted a series of four workshops for the direct and indirect risk domains (built, economic, human, and natural environment). The purpose of these workshops was to gather information to inform the scoring of risks and impacts and for validation. Attendees at each workshop typically included the WRCCIA Council Project Team in addition to a wide range of Council and external stakeholders identified as knowledgeable about the given domain or a subset of elements at risk within a domain. Details and outlines of the workshop activities for each domain are shown in the following subsections.

Workshop participants were presented with a Miro Board matrix matching the pre-screening tables. Attendees were asked to select one to two elements at risk within the domain that related most closely to their area of knowledge. Working through each climate hazard / driver (stressor), attendees were asked to input commentary on exposure, sensitivity, adaptive capacity, and impacts for their element(s) at risk.

The following subsections outline the workshop activities and outcomes for the natural environment, human, built environment and economic domains, the governance domain, transition risks and cascading risks. They use the following format:

a. Workshop Activity

b. Workshop Outcomes.

Natural Environment, Human, Built Environment, and Economic Domain Workshops

t. Workshop Activity

In each workshop, participants were asked to choose one to two elements at risk they were most familiar with or knowledgeable about. Facilitators then stepped participants across a Miro board table introducing each of the climate hazard / drivers covered in this assessment. A GIS viewer was used to aid commentary on each hazard / driver. Participants were then asked to spend time recording commentary related to the exposure, sensitivity, adaptive capacity, and impacts associated with their chosen element(s) at risk for each hazard.

Squares on the Miro table were greyed out where element-at-risk / hazard combinations had been identified as low risk during the pre-screening conducted be SMEs. Workshop participants were encouraged to add relevant commentary and their views on relevancy of elements at risk to all boxes regardless of whether it had been greyed out in pre-screening conducted by SMEs. In this way workshop participants validated all SME pre-screened elements at risk.

u. Workshop Outcomes

The output of each domain workshop was a populated matrix hosted on Miro. The Beca-led team reviewed and synthesised these outputs following each domain workshop. Miro board comments were reorganised and provided to each domain SME to inform their qualitative risk and impact scoring. They were also used to develop the initial risk screening tables included in Section 3.

Governance Risk Workshop and Additional Methodology

v. Workshop Process

In the governance risk workshop, participants discussed the key risks in each council territory, the criteria for identifying regional risks and identified regional risks.

Additional methodology included:

- Gathering of reports and documents requested of councils. Answers from councils to a set of questions provided on a Miro board, see Figure E1 below
- A meeting with several regionally based agencies in the transport and infrastructure sectors
- Assessment of the risk material against the set of criteria discussed at the workshop, see Figure E2 below
- Assessment of the consequences of not addressing the risks
- Assessment of the entry points for adaptation that enable the regional risks to be addressed
- Rating the risks according to their adaptive capacity and consequences, see Section 4.5.
- Recording of the reasons for the risk levels and consequences.

Q1. Describe the elements of your council's risk management system and how known risks and emerging ones are documented and acted upon.

Q2. How are climate risks considered in your risk management system?

Q3. What are your council's arrangements for partnering with iwi / Māori and what are they delivering for iwi / Māori and council that is relevant to climate risk management?

Q4. What are the key elements your council has (e.g. resources, people, policies and plans) to manage climate risks?

Q5. What are the coordinating mechanisms that exist between councils and key agencies (e.g. Waka Kotahi, DOC) across the region to address changing climate risks? How are these functioning for effective and timely risk reduction?

Q6. How are climate emergencies managed where interconnectivity is interrupted? For example, there are emergency management plans, Lifelines Group and Plans / Regional CEO Group. Do these deliver timely risk reduction?

Q7. What process is currently used to enable climate related emergency response actions to be included in decisions about replacement of assets and people in situ or for other options to be examined?

Q8. What currently triggers a change in management / governance operations in councils or regionally related to climate change impacts / vulnerability and adaptation?

Q9. How are different council functions integrated within and across councils?

Q10. What elements are missing to enable integrated risk management and climate change adaptation to reduce climate risks?

Figure E1: Set of Questions Provided to Councils on Governance Risks

w. Workshop Outcomes

The material provided by the councils and agencies and collected during the workshop formed the basis of the council evidence for their answering of the questions in Box 1. It gave a preliminary guide to where gaps lay in governance risks in the Wellington Region.

Summary of Council Answers to the Set of Governance Risk Questions

Q1. Describe the Elements of Your Council's Risk Management System and how Known Risks and Emerging Ones are Documented and Acted Upon?

Councils in the region have internal risk management processes set up with reporting to senior leadership teams and Council on a quarterly basis using a risk register with climate change risks included to varying degrees based on some of the current knowledge of hazards and risk levels. The Greater Wellington Regional Council has embedded risk champions to review existing risks and alert of emerging risks and are also upgrading their climate change reporting and audit functions. Council-owned and separately mandated companies like Wellington Water and CentrePort are beginning to develop their awareness of the breadth and scale of climate risks. Waka Kotahi have developed Tiro Rangi-Climate Change Adaptation Plan (Waka Kotahi, 2022) based on a resilience risk assessment with links to the National Adaptation Plan. Lifelines groups (through WREMO) have done a comprehensive resilience assessment for the Wellington Region (WREMO 2019) based solely on earthquakes but have a long-term strategic role and a lifelines coordination role.

Emerging theme*:* *Variations in risk management systems and processes across the region.*

Evidence: Council processes in place are based on old ISO standards for risk assessment that do not adequately account for changing risk and uncertainty. For example, risk 'likelihood' assessments are inappropriate for climate risks where there is high uncertainty or ongoing change due to the temporal nature of how climate change risks play out over time. Many organisations are doing slightly different reporting and processes, which are not compatible for a regional systems view of risk.

Q2. How are Climate Risks Considered in Your Risk Management System?

Climate change is considered by most councils as a major risk. Work is in progress across the region to consider climate change risks. Most are in the identification of climate projections and hazards assessments which are to be integrated into infrastructure and land use planning at the regional level or long-term plans (LTPs) at the local level, as well as high-level strategies. Climate risks are integrated into three waters planning and investment recommendations to most councils. The Waka Kotahi resilience assessment which incorporates climate risks is a national product, and this has informed their operating programme for the Wellington Region. The Wellington Lifelines Project (WREMO 2019) has limited resource for considering climate change risks.

Emerging theme*:* *Climate change is inadequately addressed in the systems and processes currently deployed across the region.*

Evidence: climate risk management is dominated by emergency response, rather than strategic actions for changing risks or increasing scale of risks (prevention, reduction), although this is starting to change.

Q3. What are Your Council's Arrangements for Partnering with Iwi / Māori and What are They Delivering for Iwi / Māori and Council that is Relevant to Climate Risk Management?

Councils vary in the level of engagement and partnership with iwi / Māori. Some work is in progress, and other work is longstanding with liaison mechanisms in place. Some iwi are represented on councils so have a governance role. Some advisory groups and Māori standing committees of council are in place. Some co-design of strategies and partnership agreements are in place. The regional council has a Te Tiriti o Waitangi Committee in place, whaitua group under the NPS Freshwater, which is related to climate change implicitly, and acknowledged in the RPS.

Emerging theme*:* *Adequacy for climate risk management from a Māori perspective has not been assessed through this risk assessment as iwi and hapū have not been involved and the themes indicated in the governance workshops and surveys are likely to change when this occurs.*

Evidence: Indications from councils are that while resourced partnerships are in place, capacity constraints for iwi / Māori mean that priorities may not be on the risks and adaptation most important to them.

Q4. What are the Key Elements Your Council has (e.g. Resources, People, Policies and Plans) to Manage Climate Risks?

Councils have dedicated people and resources to focus on climate change with the council's climate responses embedded in some council processes as intentions, in strategy documents such as the Regional Policy Statement and some associated climate action plans. There is generally a greater focus on emission reduction efforts than climate change adaptation across councils in the region. There is some disjunct between strategy and action, but work is in progress to fill the gaps. Risk management planning varies across the region and the use of traditional flood protection measures for flood risk management is the focus. More recently a risk-based approach has been appearing in some proposed district plans and proposed plans under an operative regional plan, recently strengthened. However, even though climate change is a qualifying matter under the national direction for housing intensity because it is a matter of national importance (e.g. NPS-Urban Development), housing intensity has dominated. The private sector companies are lagging in their focus on climate risks affecting their businesses (e.g. CentrePort and associated companies across utilities, transport and telecommunications). The recent mandatory climate related disclosures (TCFD) requirements may help shift this focus.

Emerging theme*: The intentions and processes are in place at councils, but resourcing and coordination is light across councils at a regional level and of mixed maturity.*

Evidence: protection actions are the focus with less on avoidance strategies and action that is forward looking built into the statutory planning system at regional level to guide local land use decision making.

Q5. What are the Coordinating Mechanisms that Exist Between Councils and Key Agencies (e.g. Waka Kotahi, DOC) Across the Region to Address Changing Climate Risks? How are these functioning for effective and Timely Risk Reduction?

Coordination is strong for operational emergencies at regional and district level through WREMO and the Wellington Regional Leadership Committee. However, greater coordination across forward planning for climate change risks would strengthen more effective and timely risk reduction via land use planning and consenting as impacts worsen and for strategic management of lifeline utilities and three waters infrastructure. Waka Kotahi needs, for their spatial planning, to know where future development is going at a regional level.

Emerging theme*: There are many different coordination groups with overlaps, but there are gaps for effective coordination on forward looking strategic planning for climate change risks for Councils individually and as a region.*

Evidence: There have been attempts at coordination and failures to reach political agreement across council and at regional level. Little attention to climate risks that are evolving and few statutory plans that effectively control or manage existing and new developments that will be affected by chronic and acute climate risks.

Q6. How are Climate Emergencies Managed where Interconnectivity is Interrupted? For Example, There are Emergency Management Plans, Lifelines Group and Plans / Regional CEO Group. Do These Deliver Timely Risk Reduction?

Emergency management institutions and hierarchy is in place with a response, recovery, rebuild ethic that has reinforced the status quo. *"Investment decisions remain biased towards the most recent crisis with a tendency to replace / reinforce the status quo".* WREMO includes readiness (from a response basis), and councils note this does not reduce climate risks and that only land use planning can. Owner responsibility, insurance and council asset planning are the main tools currently. Councils acknowledge they are not so good at preparing and planning to reduce climate risk and their investments are skewed to infrastructure solutions (capex rather than rates). Part of the region (Wairarapa) risks being cut off within the region and from Wellington from earthquakes and slips on the Remutaka Hill. Increasingly, other parts of the region risk being cut off from

Wellington City (northern suburbs, Kapiti, Hutt Valley and Eastbourne) by different climate hazards (landslips, coastal storms with sea-level rise) .

Emerging theme: *Immature strategic focus and systems to deliver integrated risk reduction. Integrated funding mechanisms and capacity are key barriers.*

Evidence: Focus is on emergencies, which gets in the way of strategic plans. Investment in capex being used instead of rates to manage risks which have limitations without strategic planning to avoid risky areas.

Q7. What Process is Currently Used to Enable Climate Related Emergency Response Actions to be Included in Decisions About Replacement of Assets and People in Situ or for Other Options to be Examined?

"*Reduction involves identifying and analysing risks to life and property from hazards, taking steps to eliminate those risks if practicable and, if not, reducing the magnitude of their impact and the likelihood of their occurrence to an acceptable level*". This demonstrates a mitigation response is inherent in council thinking and a focus on risk to life, not the connectivity of functioning communities. Competing priorities defines a governance approach which impacts as LTP priorities and resourcing constraints. Sustainability implications of asset investment are highlighted by councils using climate change models, but land use planning has gaps and are insufficient. This is further exacerbated by lack of institutional linkages with asset planning. At the regional level, climate change is integrated into planning, but question remains whether these are rules that must be given effect in district plans and whether district councils include rules that address the rising risks adequately.

Emerging theme: *Disjunct between asset and land use planning via different legislation.*

Evidence: An example that exemplifies the misalignment of different statutory functions in different agencies is that port planning is dominated by commercial drivers reflected in the Port Company Act. Under emergency recovery structural protection gets priority and limits planning approaches to complement them. This is an issue across infrastructure agencies and between them and councils. This makes adaptation to the long term more difficult to implement. There is little head space after emergencies for engagement on finding alternative development spaces as options or on staged retreat of infrastructure and housing.

Q8. What Currently Triggers a Change in Management / Governance Operations in Councils or Regionally Related to Climate Change Impacts / Vulnerability and Adaptation?

LTP process is the place where these issues are resourced or not. Competing priorities are a barrier and there is a project investment rather than strategic conversation in LTP discussions. Infrastructure 30 year plans are not integrated with land use planning conversations and have a focus on capital assets and not the spatial or specific risk exposure of sites. A silo issue is generated by legislation and insurance issues limiting open spaces for waterways versus pipes. Tension around quantifying the risk and how cost-benefit-analysis discounts future benefits. Response is focused on processes and procedures and guidance, but these do not integrate climate change into systems across parts of organisational functions. This manifests as a practice gap. This is despite climate change committees being in place.

Emerging theme*:* *Integrating and coordination mechanisms not working to join up mandates across different legislation and functions within councils.*

"Climate change is a signal that the systems that we have built are currently incompatible with the world we live in. How do we as a region encourage a decolonialisation discussion and explore ways to reconstruct governance systems that are more appropriate for our taiao?"

Evidence: Different agencies working with different mandates and funding models means lower investment in building adaptive capacity and long-term adaptive plans and strategic planning for reducing risk. Often there is agreement on strategic direction, but funding is not committed to whole system and proactive adaptation.

Q9. How are Different Council Functions Integrated Within and Across Councils?

The challenge of climate change risks is that it affects all functions across councils and the resourcing constraints are so large that climate change risks have not been well embedded in priorities whereas emergency management response is to get communities functioning after the climate events. Preventative strategies are not well embedded or started in some councils. There have been some mixed results from attempting greater integration. Managing climate risks, a 'nice to have' and no capacity for strategic thinking about the consequences and what is coming. Regional council reorganisation is underway to strengthen integration and delivery of services and build staff capacity and use the coordinating mechanism to effect change to better support risk reduction. How this manifests at district council level remains uncertain and constitutes a risk.

Emerging theme*: organisational integration gaps have emerged as a resourcing and staff capacity issue relating to overall funding issues for all councils.*

Evidence: It is early days in developing new ways of working and application of new tools. Resourcing is generally prioritised to traditional status quo ways of working in discrete silos within organisations. Funding constraints continue to be fundamental to gaps identified.

Q10. What Elements are Missing to Enable Integrated Risk Management and Climate Change Adaptation to Reduce Climate Risks?

The funding, capacity and capability to prioritise climate adaptation is a missing ingredient for reducing climate risks. Overlapping and unaligned legislation is also creating complexity and creating a barrier. There is a need for more effective relationships between central and local government and for meaningful iwi partnerships to facilitate effective adaptation. A better understanding of the scale of the climate impacts is seen as requiring time and information in a usable and accessible form. Spatial planning tools and measures that enable reduction of building in risky places and to move people where necessary by provision of 'safe' sites for housing developments are critical. Mandate between regional and district councils needs clarification to reduce overlaps and increase the coordination through regional strategies for regional and local adaptation actions. There are funding streams and mandates that are not aligned with land use planning e.g. infrastructure via Waka Kotahi and commercial operators of ports and airport and utilities.

"The issue is so large and transcends responsibilities; no one organisation can do it on its own. Needs rethinking of how we work (work 'across lanes'). As long as we take a 'staying in our lanes' approach (e.g. RPS refresh), we won't solve the problem. The magnitude of the problem demands an integrated response".

Emerging theme: *Funding capacity, adaptive capacity and capability are limited across the region. Central and local government governance is misaligned. A lack of local government political buy-in creates a barrier to strategic climate risk reduction. There is a need for meaningful iwi / Māori partnerships that can influence outcomes.*

Evidence: There is still building and intensification in risky locations and too much dependence on protection measures alone without consideration of residual and rising risks. There are many legislative mandates cutting across each other. Effective legislative coordination mechanisms are missing.

Key Regional Risks

Figure E2 shows the adequacy criteria for assessing the key regional risks, as discussed in the governance workshop.

6. **The ability of the current governance system to address uncertainty and changing risk.**
7. **The ability of the community to understand the scale and scope of the climate risks.**
8. **The ability of the current institutional system to reduce emerging and cascading risks and not create new risks through decision making.**
9. **The ability to build strong and new relationships across the community and to work with communities towards sustainable and flexible decision-making systems that reduce climate risks.**
10. **The ability of councils to work across time-inconsistent barriers that enable complex and changing risks across scales and functions to be addressed and managed in a sustainable and just manner.**

Figure E2: The Adequacy Criteria for Assessing the Key Regional Risks, as Discussed in the Governance Workshop

Transition Risk Workshop

a. Workshop Process

Prior to the workshop, Beca shared a preliminary list of transition risks and opportunities, categorised using the Task Force on Climate-Related Financial Disclosures (TCFD) framework. The Council project team rephrased and added to the list's risks and opportunities; that revised list was used in the workshop. The TCFD categories were also revised to better reflect councils' context, including the four well-beings.

Table E1: Categories used to organise transition risks and opportunities

TCFD Categories	WRCCIA Categories
Policy and legal	Policy and legal
Technology	Market & financial (economic well-being)
Market	Reputation
Reputation	Community / wellbeing / resilience (social, environmental, and cultural well-beings)
Resource efficiency	Technology / resource efficiency / products and services
Products and services	
Resilience	

During the workshop, the facilitators and Council project team provided context to the participants that had not been involved to date. The preliminary risk and opportunity list was summarised on a Miro board. Once participants confirmed there were no more risks or opportunities to add, a vote was used to identify participants' five highest priority risks and opportunities.

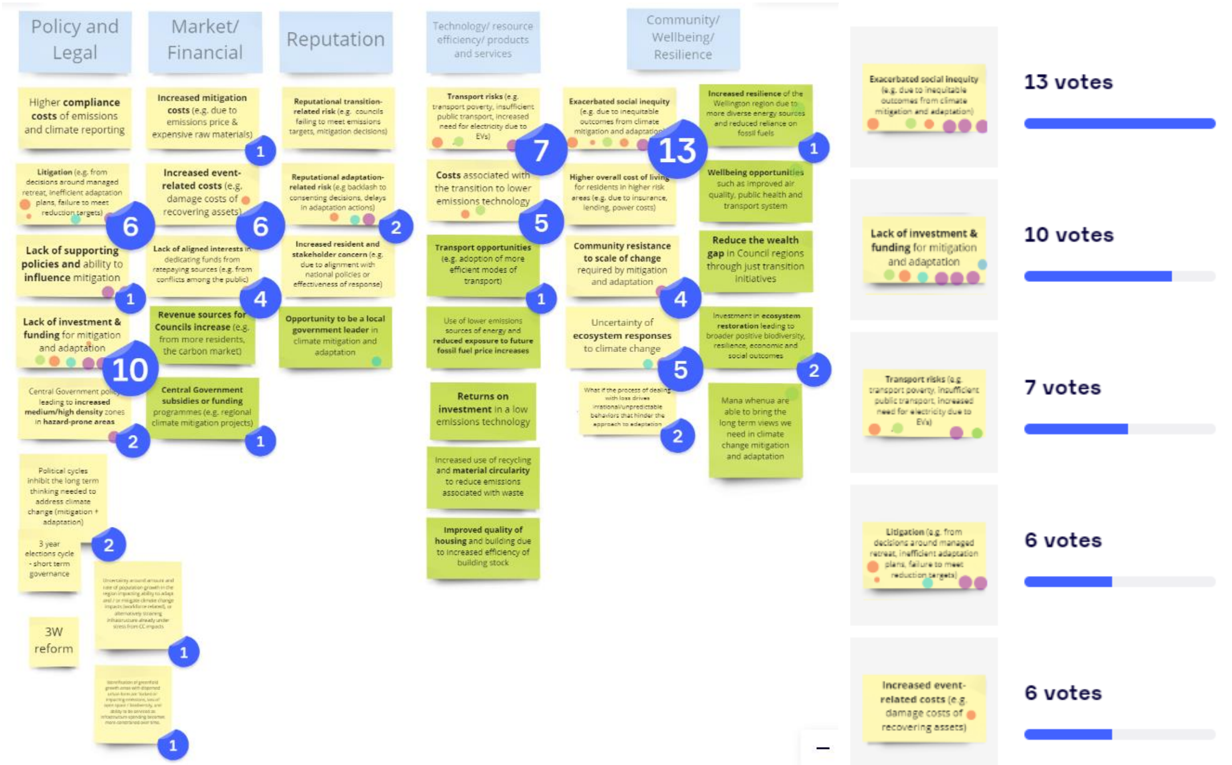


Figure E3: The Miro Board Used to Determine the Priority Transition Risks and Opportunities. Vote Results are Shown in Blue

Five risks received the most votes. No opportunities were initially selected, but a sixth priority opportunity was added by participants during discussion: investment in ecosystem restoration (i.e. as part of nature-based solutions).

The priority risks and opportunity were discussed in the context of a high transition risk climate scenario: Representative Concentration Pathway (RCP) 2.6 (The Assessment also uses RCPs for other types of risks). The scenario narrative also drawn from the RCP2.6-aligned Shared Socioeconomic Pathways scenario 1 (SSP1): Sustainability – Taking the Green Road.

Table E2: The IPCC projection used in the transition workshop

IPCC Scenario	Global Mean Temperature Increase	Transition Risk Severity	Physical Risk Severity	Description
RCP2.6	0.9 – 2.3°C (relative to a 1850 - 1900 baseline)	High	Moderate	RCP2.6 is representative of a scenario that would likely keep global warming below 2°C above pre-industrial temperatures.

After discussing the priority risks and opportunity, participants assigned materiality ratings to each across three timeframes. ‘Materiality’ was defined using the XRB’s definition in its final climate standards: information is material if omitting, misstating, or obscuring it could reasonably be expected to influence decisions that primary users make on the basis of an entity’s climate-related disclosures.

Materiality ratings were simplified to three categories. The short, medium, and long-term timeframes were the same ones used in the assessment for non-transition risks.

Table E3: Materiality ratings

Rating	Action
High	Most urgent risks. These should be the focus of risk management efforts.
Moderate	Should be closely monitored but considered ‘under control’ to some degree.
Low	Are lower priority compared to ‘moderate’ risks but should still be monitored.

Common interval for short-term →

Time horizons for physical risks – for consideration for transition risks

	Time interval
Short-term	2023 - 2028
Medium-term (Mid-century)	2031 - 2050
Long-term (end-century)	2081-2100

Figure E4: Time Horizons Considered in the Transition Workshop

After the workshop, the materiality ratings were circulated among workshop participants for review and confirmation. Several participants provided feedback with changes based on additional consideration and discussion. These were reconciled with existing ratings that were most selected by the group.

b. Workshop Outcomes

List of Preliminary Transition Risks and Opportunities

The list of preliminary transition risks used in the assessment is included below. Check marks indicate where Councils identified risks or opportunity as preliminary priorities (prior to official voting).

Policy and Legal Risks

- Higher compliance costs of emissions and climate reporting
- Litigation arising from:
  - decisions around managed retreat
  - failure to meet climate emissions reduction targets (regional/local level)
  - insufficient disclosure of material or financial climate-related risks
  - exposure around changing levels of service to account for climate impacts (e.g. flood protection assets, access to parks, transport / three water infrastructure, etc.)
  - inefficient adaptation action plans (council makes decision based on the information available and may face criticism based on the updated data)
- Lack of:
  - supporting policies and strategies to cope with climate change at the council level will cause poor planning for Wellington and increasing exposure to climate-related hazards
  - ability to influence decisions that could have the biggest impact on emissions
- Lack of investment / funding in:
  - New responsibilities for emissions reduction and adaptation
  - Adequate support for comprehensive adaptation planning
  - Central Government policy leading to increased medium to high density development in hazard prone areas.

Governance Risks (These are Covered by the Governance Risk Workstream)

- Integration between emergency management and risk reduction activities
- Long-term perspectives based on the election periods in councils
- Council governance changes every 3 years with the risk of changing appetites for climate action – both increased and reduced interest interrupting the potential for long term climate-related responses.

Inaction on Climate Adaptation Due to Policy Uncertainties Regarding the Funding of Adaptation

Policy and Legal Opportunities

Governance Opportunities

- Efficiencies in new regulation clearly identifying roles and responsibilities.

Market / Financial Risks

- Increased mitigation costs due to:
  - GHG emissions
  - Raw materials due to strict regulations
  - Stranded (critical) assets and early retirement of existing, emissions emitting infrastructure.
- Increased event-related costs due to:
  - Insurance retreat from high hazard zones
  - Maintaining / insurance for climate-exposed council assets
  - Damage cost of recovering assets due to frequent and extreme weather events
  - Financial impact from loss of ratepayers (due to residents' departures)
  - Failure to consider the impact of foreseeable climate change risks on WCC-owned infrastructure and projects causing a decrease in the level of services and increase damage cost
  - Lack of aligned interests in dedicating funds from ratepaying sources may potentially lead to conflicts among the public and affect the funding decisions by the council.

Market / Financial Opportunities

- Council revenue sources
- Increases in residents and ratepayers due to resident preference for regions that prioritise climate mitigation and adaptation
- Participation in carbon market as an opportunity for income from Council-held land
- Increased market valuation through resilience planning
- Central government subsidies or funding programmes
- Regional climate mitigation or adaptation projects (e.g. renewable energy or transition plans).

Reputation Risks

- Reputational transition-related risk of:
  - Councils failing to meet their emissions targets (e.g. GWRC's binding 2030 targets)
  - Emissions from planning decisions, public transport, grazing licenses, or other council activities.
- Reputational adaptation-related risk of:
  - Backlash to consenting decisions that continue to allow for development in hazard prone areas – community and business losing trust in council's regulatory processes.
- Delay in implementing meaningful adaptation actions (until 2025 for WCC) increases concerns among hazard-prone communities and the financial impact from the loss of ratepayers in the case of any catastrophic climate-related event. This will challenge the reputation of WCC in taking proper actions to respond to climate change
- Increased resident and stakeholder concern due to:
  - Councils' responses to climate change and alignment with national policies
  - Failure to respond effectively to climate change or to meet new requirements.

Reputation Opportunities

- Opportunity to be a local government leader in climate mitigation and adaptation:
  - Low emissions becomes a marketing tool for councils and businesses on all levels
  - Co-adaptation planning with communities will generate trust and increase willingness to pay for implementing adaptation actions among ratepayers and enhance community response capability (support to transition to community interconnectedness).
- Effective utilisation of technologies like digital twins to communicate climate-related data and develop adaption action plans would be an exceptional example of the transition to learning-empowered communities at regional and global scales.

Technology / Resource Efficiency / Products and Services Risks

- Transport risks:
  - Transport poverty and access to affordable public transportation (e.g. uptake of EVs and public transportation is unequitable and widens the wealth gap)
  - Increased need to electricity supply due to electrification of transport
  - Insufficient / unreliable public transport systems lower public trust in using these systems – increased private vehicle use and demand for roading increases
  - Lack of safe active transport options increases risk to cyclists and pedestrians and impacts uptake; private vehicles and roading continue to be the priority
  - Costs associated with the transition to lower emissions technology.

Technology / Resource Efficiency / Products and Services Opportunities

- Transport opportunities:
  - Adoption of more efficient modes of transport or energy use and reduced operating costs
  - Use of lower emissions sources of energy and reduced exposure to future fossil fuel price increases
  - Returns on investment in a low emissions technology
  - Increased use of recycling and material circularity to reduce emissions associated with waste
- Improved quality of housing and building due to increased efficiency of building stock.

Community/ Wellbeing/ Resilience Risks

- Exacerbated social inequity:
  - Inequitable outcomes from climate mitigation and adaptation policies, further disadvantaging most vulnerable communities in the Wellington region.
- Higher overall cost of living for residents in higher risk areas (lending, insurance, utility installations, three waters, power)
- Overall community resistance to change
- Uncertainty of ecosystem responses to climate change potentially resulting in the natural environment being of less concern in the transition to a low carbon / climate resilience society.

Community / Wellbeing/ Resilience Opportunities

- Increased resilience of the Wellington region due to more diverse energy sources and reduced reliance on fossil fuels
- Wellbeing opportunities:
  - Improved air quality and noise levels with electric transport
  - Improved public health due to uptake of public and active transport options
- Transition to low carbon living; land use planning rules change to require development of low carbon living options, requirements for 15 min neighbourhoods, people actively track their own emissions and make changes, education includes foot print education etc

- Reduce the wealth gap in Council regions through just transition initiatives that address climate change and empower & uplift historically marginalised communities
- Investment in ecosystem restoration / nature-based solutions due to mitigation needs leading to broader biodiversity, resilience, economic and social outcomes.

Cascading Risks Workshop

a. Workshop Process

Two workshops on cascading risks were held with participants including all nine councils with some additional specialists attending to support consideration of specific types of cascading risk patterns or archetypes in the second workshop.

The first workshop began with a group discussion of elements that make up a functioning city. Participants identified a range of social, physical, and environmental infrastructure that makes communities ideal places to live. A simplified, blank version of the circle tool similar to the populated one below depicting interconnected risks was then used to begin to identify connections. Participants were posed a series of questions – i.e. What happens if the ferry terminal is damaged by a wave event? What happens as a result of the ferry not being able to complete the route? What is impacted by the secondary impacts? – in order to begin to sketch the webs of connections and provoke systems thinking.

Participants were asked to bring places and spaces at risk within their jurisdictional area to begin cascades. They identified rural, agricultural areas, coastal communities, socio-economically deprived neighbourhoods in high hazard areas, a rail corridor, residential areas, water supply, and arterial roads. When these places and spaces were subjected to climate hazards, cascades extending into social, ecological, financial, and external (e.g. beyond the Wellington Region) systems occurred. Participants shared the narrative of these cascades while the team of SME listened to identify repeating patterns.

b. Workshop Outcomes

Themes and patterns that emerged from Workshop 1 were cascades beginning with too much of something, too little of something and cascades that were driven by change in baseline conditions (**Error! Reference source not found.**E4). Lower representation of cascades focused on the natural environment and cascades touching on cultural values, mātauranga and consequences were noted. Underrepresented cascades were furthered explored in Workshop 2 and further developed by Beca. There was comparatively less interrogation of impacts to natural environments and the consequences that they could have on communities. Cultural impacts, particularly on Māori communities, or narratives encapsulating mātauranga Māori were also underrepresented. These are explained in wider detail below, form the basis of the draft archetypes and presented in subsequent sections.

Table E4: Emerging cascading patterns from Workshop 1.

Emerging Patterns	Description
Too much (Workshop 1)	Pressures on infrastructure, culture, economies, governance, natural systems, and social factors caused by “too much” of something – e.g. rainfall, storm surge, landslide, or heatwaves.
Too little (Workshop 1)	Pressures on infrastructure, culture, economies, governance, natural systems, and social factors caused by “too little” of something causing resource contestation – e.g. rainfall (drought), available land (erosion or rezoning of hazard prone land), or other resources due to exogenous factors (supply chain disruptions).
Baseline shift (Workshop 1)	Pressures on infrastructure, culture, economies, governance, natural systems, and social factors caused by “baseline shifts” in the state of a system – e.g. mean sea-level rise or increases in average temperature.

Natural environments (Workshop 2)	While the three previous emerging patterns were the pressures on systems, there is a generic cascade system that depicts changes to environmental systems due to climate drivers.

c. Workshop Participants

Table E5**Error! Reference source not found.** presents the councils and organisations represented by participants in each workshop.

Table E5: The councils and organisations represented in each workshop

Natural Domain | Oranga Whenua Workshop Held online via MS Teams on 9 February 2022	
Participants	
Wellington City Council	Ngāti Toa Rangatira
Upper Hutt City Council	NIWA
Greater Wellington Regional Council	Department of Conservation
Carterton District Council	Victoria University of Wellington
Porirua City Council	Beca
Masterton District Council	
Kāpiti Coast District Council	
Hutt City Council	
Human Domain | Oranga Tangata Workhop Held online via MS Teams on 16 September 2022 Participants	
Wellington City Council	Wellington Region Emergency Management Office
Upper Hutt City Council	Ministry of Housing and Urban Development
Greater Wellington Regional Council	Wellington Water Ltd
Carterton District Council	Kāinga Ora
Porirua City Council	NIWA
Masterton District Council	Beca
Kāpiti Coast District Council	
Hutt City Council	
Built Environment Domain | Taiohanga Workshop Held online via MS Teams on 12 September 2022 Participants	
Wellington City Council	Wellington Regional Emergency Management Office
Upper Hutt City Council	Powerco
Greater Wellington Regional Council	Waka Kotahi
South Wairarapa District Council	CentrePort
Porirua City Council	Insurance Council of New Zealand
Masterton District Council	Wellington International Airport Ltd
Kāpiti Coast District Council	Kāinga Ora
Hutt City Council	Wellington Water Ltd
	Transport

	NIWA
	Beca
Economic Domain | Whairawa Workshop Held online via MS Teams on 13 September 2022 Participants	
Wellington City Council	Wellington NZ
Upper Hutt City Council	3R Group Ltd
Greater Wellington Regional Council	Victoria University of Wellington
Porirua City Council	NIWA
Masterton District Council	Beca
Kāpiti Coast District Council	
Hutt City Council	
Governance Domain | Kāwanatanga Workshop Held online via MS Teams on 16 February 2023 Participants	
Wellington City Council	Ngāti Toa Rangatira
Upper Hutt City Council	Wellington Water Ltd
Greater Wellington Regional Council	Victoria University of Wellington
Porirua City Council	Waka Kotahi (post-workshop interview)
Masterton District Council	Beca
Kāpiti Coast District Council	
Hutt City Council	
Carterton District Council	
South Wairarapa District Council	
Transition Risks Workshop Held online via MS Teams on 21 February 2023 Participants	
Wellington City Council	Waka Kotahi
Upper Hutt City Council	Wellington Water Ltd
Greater Wellington Regional Council	CentrePort
Porirua City Council	Beca
Masterton District Council	
Kāpiti Coast District Council	
Hutt City Council	
Carterton District Council	
South Wairarapa District Council	
Cascading Risks Workshops Held online via MS Teams on 16 February 2023 and 23 February 2023 Participants	
Wellington City Council	Victoria University of Wellington
Upper Hutt City Council	NIWA

Greater Wellington Regional Council	Wellington Water Ltd
Porirua City Council	Beca
Masterton District Council	
Kāpiti Coast District Council	
Hutt City Council	
Carterton District Council	
South Wairarapa District Council	

Direct and Indirect Qualitative Risks Screening Discussion

This section provides background on the risk scoring process and commentary on the results of the qualitative risk assessment across the four value domains. Note that the Risk Register (Appendix A) is intended to provide the main results of the qualitative assessment for direct and indirect risks. This report section is intended to provide additional commentary and observations where needed.

Risk Scoring Process

Post the domain workshops, SMEs scored each risk in their respective domains.

Exposure assessment: The qualitative framework used to assess exposure across all four value domains is provided in Appendix H. Note that the spatial data available to assess the built domain components was more substantive compared to other domains, but gaps were identified in data coverage.

Sensitivity and adaptive capacity assessment: SMEs applied the general criteria developed to assess sensitivity and adaptive capacity within each domain. These criteria are provided in Appendix H.

The assessment of exposure, sensitivity, and adaptive capacity drew on an amalgamation of:

- Available spatial data (in GIS Viewer) and previous literature review work undertaken
- Workshop commentary
- SMEs' own knowledge and qualitative judgements
- SMEs provided commentary in the Risk Register on assumptions and information underlying the assigned scores.

Risk scores: The risk register is coded to automatically assign risk scores under each timeframe and RCP scenario by combining the overall vulnerability score (sensitivity x adaptive capacity) and the exposure scores following the agreed WRCCIA Methodology report approach. The validation tables for these calculations are provided in the 'Validation' tab of the Risk Register (Appendix A).

First-pass Impact & Uncertainty Scoring

A *first-pass* impact and uncertainty scoring were completed immediately following the qualitative risk scoring. This first pass screen 'short-lists' the identified risks based on an aggregation of the potential impacts across any of the consequence categories (Economic, Community, Natural Environment, Governance, Built Environment) using the impact rating from Insignificant to Catastrophic as per the proposed impact / consequence scoring (Table 6H, Appendix H).

This initial screening of impacts was intended to provide a short list of higher risk and potential impacts to take into the prioritisation phase of the WRCCIA (Part C of this report).

SMEs also assigned an initial uncertainty score to each risk. Uncertainty was scored using a binary 'certain' or 'uncertain' framework. The certainty score indicates the overall level of certainty related to scoring of exposure, vulnerability, and impact(s) based on level of data that exists now and literature available to support the scoring[22]. SMEs provided comments, where relevant, related to the uncertainty of information and scoring for each risk / impact.

Compounding Risk Methodology

We combined the risk scores from the workshop-informed qualitative risk register (Section 0) across all climate hazards for each element at risk within a domain (excluding governance) using the following steps:

11. **Count of number of hazards for each element:** The number of hazards for each element is presented in Table **Error! Reference source not found.**. This count of the number of hazards indicates that elements are potentially more at risk due to exposure to a greater number of hazards and greater diversity of hazard drivers.
12. **Assign weighting of risk severity:** Weights were assigned based on their relative importance as judged by the SMEs and from workshop inputs with higher weights to more severe levels to reflect their increased impact (e.g. Low Risk weighting of 1, Moderate Risk = 2, High Risk = 3, Extreme Risk = 4). This weights 'extreme' risks as four times higher weighting than 'low' risks within the compounding risk scoring. No additional weighting was applied to the future scenarios / timeframes so that each risk is treated as equally important over timeframes / scenarios. This weighting approach recognizes that risk assessment and adaptation planning requires a balance between short term actions and long-term strategies.
13. **Calculate compounding risk score:** The weighted average risk score for each element at risk was determined dividing the total sum of the weighted scores (step 2 above) at each timeframe by the total sum of the weights. This provides the weighted average risk score as an aggregated score risk to each element for each future scenario/timeframe.

While the governance domain was excluded for counting the compounding risks, many of the impacts from compounding risks will cascade into the governance domain. Due to the uncertainty and general lack of modelled predictions of compounding risks, the complexity of these risks provides unique challenges for governance and legislation.

Prioritisation Methodology

Prioritisation of risks for the detailed assessment was undertaken in conjunction with the Council Project Team (CPT).

The first prioritisation workshop was held Tuesday 14 March 2023 with the CPT. Initially, the top fifty risks from the qualitative assessment were presented to the attendees to be discussed and ranked for inclusion in the detailed assessment (noting a maximum of 20 risks were to be assessed in the detailed stage of the WRCCIA project). Given a number of risks had similar scores, these top 50 risks / impacts were determined via progressively sorting within each domain, with the highest 10 - 15 scores based on the following order:

1. Risk score at 2100, RCP8.5.
2. First pass impact score.

[22] This use of uncertainty is different to the NCCRA in that it is the uncertainty that exists now, whereas the NCCRA used uncertainty over three timeframes to express the confidence in the assessment. Both methods allow a consideration of confidence in the assessment (and evidential basis to support).

3. Risk score at 2100, RCP4.5.
4. Risk score at 2050, RCP8.5.
5. Risk score at 2050, RCP4.5.
6. Risk score at present day.

The aim was to short-list risks for the Detailed Assessment that are high priority for the councils based on both significance of the risk and other factors such as the level of uncertainty, other projects or programmes of work (that the detailed assessment would inform) and aspects of greatest interest to the councils. The workshop featured a robust discussion on the selection process and selection criteria given the varying interests of the councils. The result of the discussion was a short list of the top 10 - 20 risks to be presented to the CPT in a second workshop.

During the shortlisting process, Governance, Transition and Cascading risks were removed from consideration for the Detailed Assessment with agreement with the CPT (for example, the CPT agreed they would explore the Governance risks further themselves building from the WRCCIA work in Section 4.5). The CPT agreed it would be good to have risks from each domain covered in the Detailed Assessment stage. Subject matter experts from the Beca-led team therefore refined shortlists of three to five recommended risks / impacts from each domain (Built Environment, Natural Environment, Human and Economic) based on their qualitative expert judgement of those of most significance to the Wellington Region to create the shortlist to carry forward for Detailed Assessment.

These shortlisted risks were presented to the CPT in a second workshop, held Wednesday 22 March 2023 and a targeted discussion held on the priority of the risks and the level of available information. The resulting prioritised risks, presented below, was confirmed post-workshop with the CPT via email.

The list of risks assessed were further investigated and modified as a more detailed assessment of the data available to support a quantified impact assessment was undertaken. Some risks were then removed or substituted due to a lack of suitable data.

Detailed Assessment Methodology

The detailed assessment was based on the well-established principles of risk quantification, expressed as:

$$R = fc(H_i, E, V_i w)$$

Where risk (R) is a function (f) of the consequences from a hazard event (H) impacting an exposure (E) (i.e. element at risk). Consequences are determined from the exposure's vulnerability (V) to an impact type and magnitude in response to either a single or, in the case of compounding risks, multiple hazard events (i), (Paulik et al., 2022).

This equation can be implemented geospatially but requires detailed understanding for each component of the selected risk R, the data and metadata supporting (H_i), (E) and (V_i), the relationship between the hazard event (i) and the element at risk (E).

Geospatial and quantitative analysis will be most beneficial where this information is clearly defined, such as where data from geospatial models can be combined with geospatial asset layers with a known vulnerability of the asset to the hazard. Depending on data availability this could enable:

- A detailed assessment of **exposure** in various hazard scenarios (e.g. for flooding this can be for various events with different average recurrence intervals)
- A detailed assessment of element at risk **sensitivity** based on data attributes (e.g. for infrastructure this may be related to the age, condition, or material of a network)

- An assessment of exposure to **vulnerable** populations (ecological species, demographics), which can be integrated with available vulnerability data, for a more granular view of risk
- An assessment of the potential **impacts** of the risk (e.g. transport network disruption, economic impacts, social impacts).

The material within existing datasets is critical to the detailed assessment phase as the scope of the WRCCIA did not include creation of new data. The level of detail in the quantitative risk assessment will be compromised if there is insufficient data available on H, E or V to support *each* step of the assessment for *each* of the selected risks R. For example, if the selected risk is regional then it is critical that *region-wide* data is available at a sufficient level of detail (i.e. consistent resolution). Similarly, if interrogation to suburbs or street level is required, then the underpinning information must be available at this level to begin with. The Data Gaps Report (Beca, 2023) describes the outcome of the assessment of the data for suitability during the detailed assessment stage. Where spatial data is not available or does not allow for a consistent application across the region, or where the risk is not able to be shown spatially, qualitative assessment and judgement by subject matter experts has been undertaken. It is noted that no matter how much data is available, there is always an element of qualitative judgement in the assessment of risk and the potential impacts and this qualitative assessment has been undertaken for the region in the comprehensive Qualitative Assessment Stage (Part A of this report) and is drawn on in the detailed assessment.

Assessment Process

The intention of the detailed assessment is to further describe and quantify (where possible, as described above) the risks and potential impacts from prioritised risks. Using GIS as a foundation where existing data has allowed, risks have been evaluated, aggregated, and displayed for a more targeted assessment.

The process of undertaking a detailed assessment of each risk R involved:

- Select risks through a prioritisation exercise (described in Part B of this report)
- Review data layers and identify limitations
- Determine target outputs and aggregation level
- Prepare input layers
- Determine hazard-vulnerability-risk relationship model
- Undertake analysis (using GIS software platforms including ArcGIS and FME (Feature Manipulation Engine))[23]
- Develop a visual interface mock up for discussion and agreement with the Council Project Team
- Configure GIS to visualise and interact with risk analysis.

[23] The Beca Methodology Report, 2022, notes that RiskScape® will be used for the analysis of risk for the WRCCIA in the detailed assessment stage. RiskScape® is a propriety tool developed by NIWA, GNS Science and Catalyst IT. RiskScape® requires specific data types and formats and the results are required to be transported for spatial display in tools such as GIS. Due to programme and requirement for substantial manipulation of existing datasets it was agreed with CPT to use existing software platforms commonly used by the councils.

F

Appendix F – Cascading Impacts

Cascading Risks

Climate change will not only result in direct impacts to communities and ecosystems but will cause impacts propagating outwards, like stones thrown in a pond producing interacting ripples. While traditional risk assessments are linear with a hazard causing a direct impact, a cascading risk assessment allows for the consideration of interactions between elements and impacts of the hazard event propagating outwards across different domains.

These interactions are caused by connections and dependencies within our communities. For example, an increase in loan interest rates would lead to mortgage price rise, and consequently homeowners would have less disposable income and thus buy fewer coffees, some cafes close, and some employees lose their jobs. Importantly, feedback loops may occur within cascades that exacerbate the effects of the initial disruption. For example, after some employees lose their jobs, they have less disposable income and therefore buy fewer things, and profitability of businesses continues to decrease.

Inter-related risks that are phrased as cascading risks feel inherently circular in notion because they are continuous, they run in to each other and continually reflect on each other. Seeing this in the context of te ao Māori may help visualise the notion that risk elements cannot be seen as isolated from each other and in much the same way the role that we have in human communities are seen as one continuous circular motion of elements.

Environmental and social systems can respond in a similar fashion. During Cyclone Gabrielle, damage to cellular network towers, caused by flooding, slips, or power outages, resulted in loss of contact with communities. This loss of communication resulted in the inability to request aid or to notify families that members of communities were safe. Even when first responders were able to reach isolated communities, they were not able to coordinate supply deliveries or additional aid without relying on satellite communications. This absence of communication reduced the ability to coordinate a response, reduced trust in government agencies, and allowed for misinformation to spread rapidly.

Te ao Māori

Marae are the core of the community and the community look to the protective qualities of the marae for many things, including following a hazard event. Focussing adaptation on areas that play an important role like this will enhance community resilience through principles of inter-relationship, connectivity, and protectiveness.For example, communities based around marae were the most prepared, and first to respond, to Cyclone Gabrielle. Marae became a central hub for support and connectivity.

In the risk management literature, these indirect risks that have a domino effect are termed “cascading risks”. Due to these cascades, what might appear to be a relatively tolerable risk, such as a few more days per year with average temperatures over 25°C, may cause a cascade ultimately resulting in an emergency, for example, increasing the likelihood of an algal bloom that damages a local ecosystem. Cascading risks have been an increasingly popular topic in international research; however, the generic risk cascades and systems produced (Quiggin et al, 2021) are largely focused on cascades likely to occur in vulnerable nations less insulated than parts of New Zealand from existing systemic challenges, such as widespread food insecurity, civil war, and large-scale migration.

A simplistic cascade, conceptualized by the Deep South Challenge, is presented below in Figure F1**Error! Reference source not found.**. In this cascade, a range of climate drivers cause cracks to form in wastewater pipes. These cracks allow saltwater intrusion which accelerates the rate which the pipes deteriorate causing additional leaks in the wastewater network. The salt water now in the pipes prevents treatment plants for performing at their design efficiency. The reduced capacity of the pipes to convey wastewater and the reduced capacity of the treatment plant led to negative health impacts on the community and ecosystem effects. People begin to notice these impacts and move from the area, and as a result, the ratepayer base decreases providing less funding for Council to maintain services for those who remain in the community. This example illustrates how direct impacts on an asset expand and cascade outward effecting community well-beings.

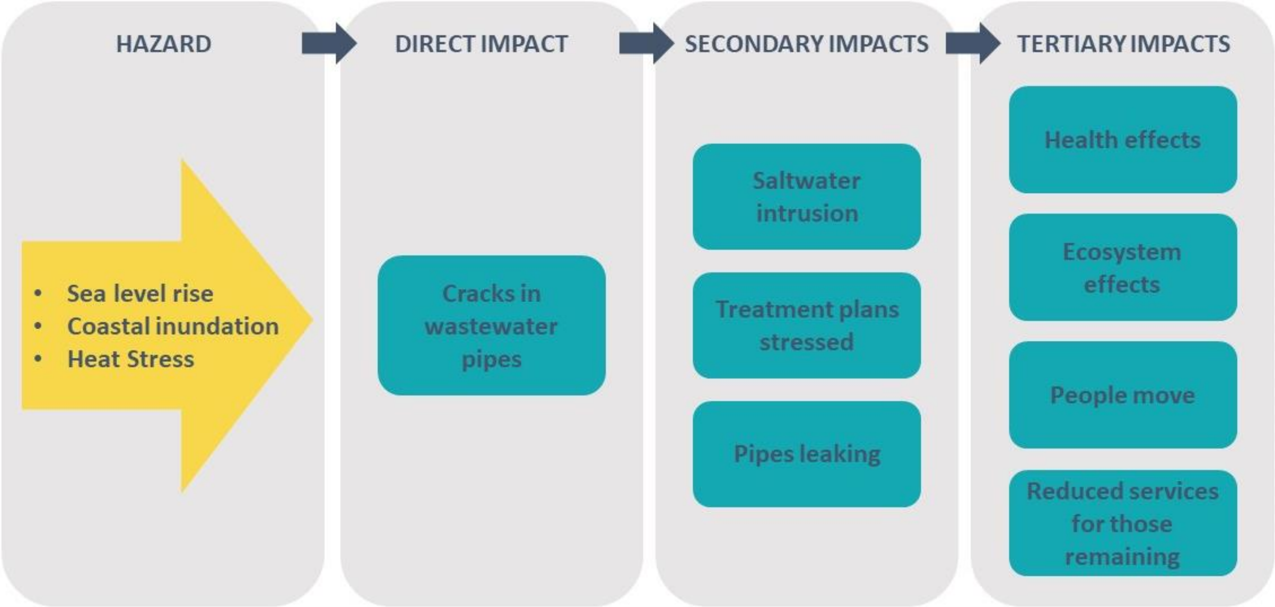


Figure F1: Simple Wastewater Pipe Cascade (modified from Lawrence et al, Deep South, 2021)

In the cascading risks workshops we aimed to identify some generally repeatable cascading risk patterns that we expect will emerge in the greater Wellington area due to direct climate change impacts. These cascading risk patterns, or archetypes, can be used as a tool to interrogate risks to specific places, spaces, ecosystems and people to continue to proactively assess indirect climate change impacts.

Cascading Risk (Draft) Archetypes

Building individual systems diagrams for cascades emanating from every risk identified in this report is beyond the scope of this study. However, researchers have noted that there are generally repeatable patterns that emerge when evaluating cascading risks. These repeatable cascading patterns are called archetypes and can be used to inform more complex future analysis.

Draft Archetypes, based on the cascades created in workshop 1 and tested and refined in workshop 2 are:

Draft "Too Much" Archetype

During Workshop 1, the "Too Much" pattern emerged in extreme rainfall leading to landslips impacting rail corridors, flooding in residential areas, and flooding damaging stopbanks or other flood protection works. In each of these, "too much" water impacted the built environment causing damage to infrastructure. This infrastructure damage compounded by affecting other infrastructure (e.g. slip over rail line affected transport networks, residential flooding increased pressure on three waters network, and stopbank failure resulting in property damage). These impacts then cascaded influencing social, environmental and economic domains resulting in mental health impacts due to isolation caused by disruption to transport, environmental impacts due to wastewater spills, and economic impacts due to business disruption.

See **Error! Reference source not found.** F4 for the "Too Much" archetype diagram.

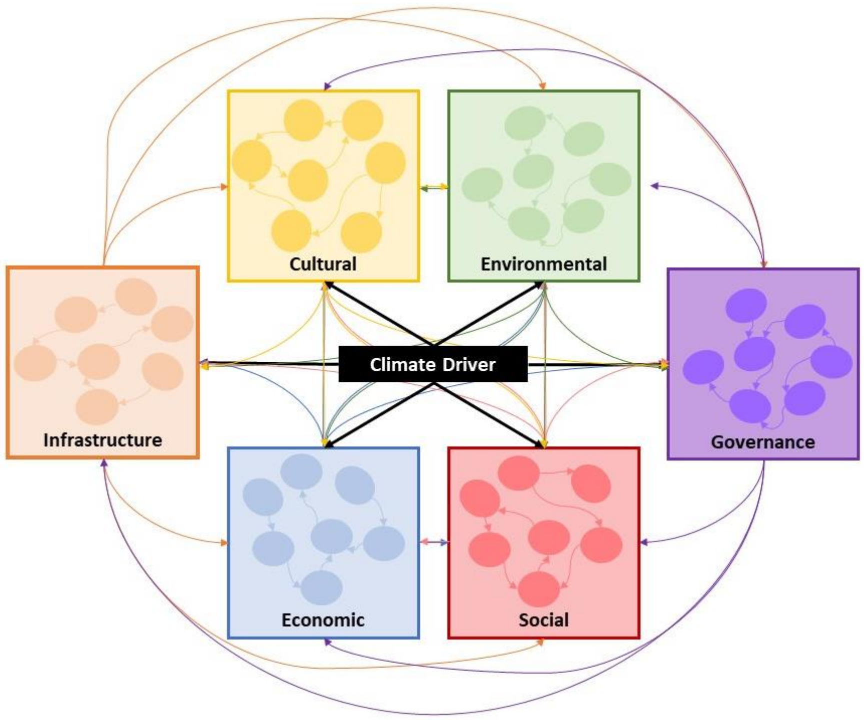
Draft "Too Little" Archetype

The "too little" cascade was developed following discussions of drought conditions in agricultural areas and effects of climate change on resource-constrained communities (see Figure F5**Error! Reference source not found.**). These resource constraints, whether water, investment into vulnerable (high hazard) areas, or economic resources to respond to hazards, result in pressure on infrastructure and further restrictions in resource. These infrastructure pressures and resource restrictions can result in individual financial hardship and then wider impacts to local economies. The pressure on infrastructure can result in non-compliance with environmental regulations and increase the likelihood of environmental impacts and ecosystem changes.

Te Ao Māori Archetype

Discussions regarding Māori impacts during Workshop 1 were primarily focused on effects on cultural practices like mahinga kai or rootshock caused by relocation away from places of turangawaewae. However, considerations of iwi values in cultural impact assessments frequently emphasize that impacts on Māori communities are not confined to impacts on marae, urupa, tapu spaces or species, and ability to gather kai but rather extend beyond into ability to make a living, spend time with family, and enjoy access to local amenities. These wider values are likely best connected and captured in the "too much", "too little" and "baseline shift" cascades.

These archetypes are presented in draft form and may be further simplified and refined through discussion with iwi / hapū.



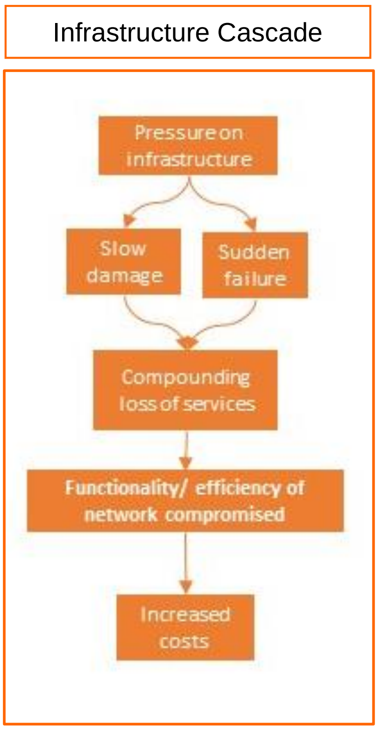


Figure F2: Generic Climate Risk Ecosystem (left) and Sample Infrastructure Cascade (right)

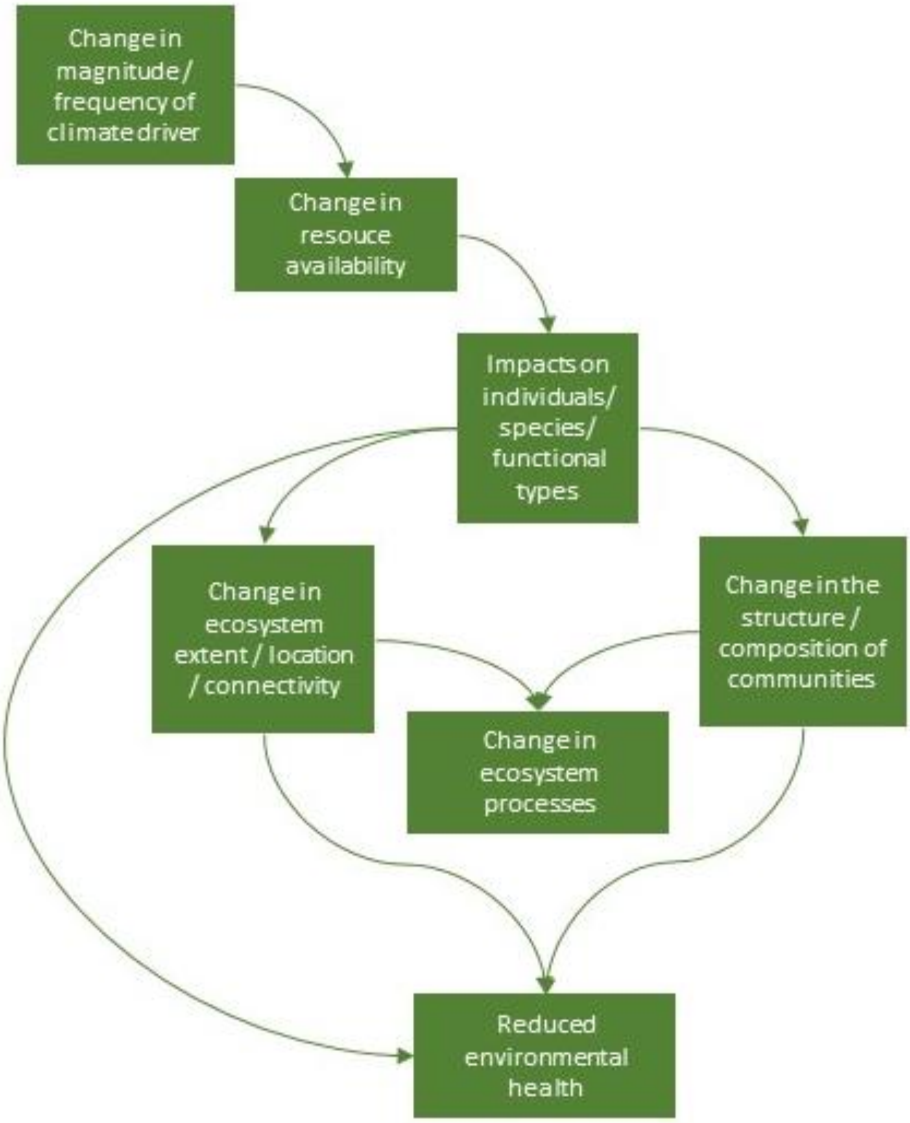


Figure F3: Generic Environmental Ecosystem Cascade

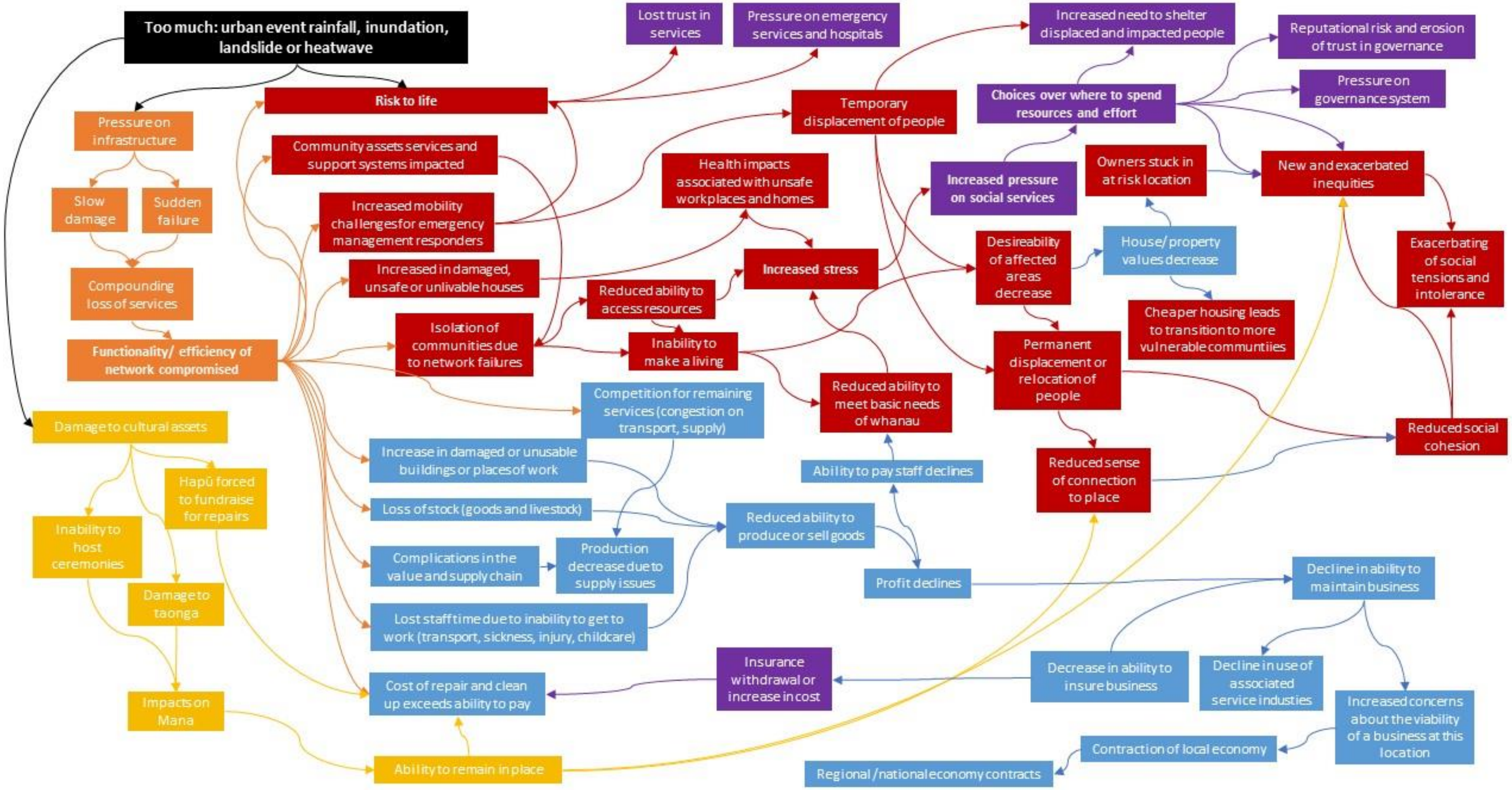


Figure F4: "Too Much" Cascading Risk Archetype

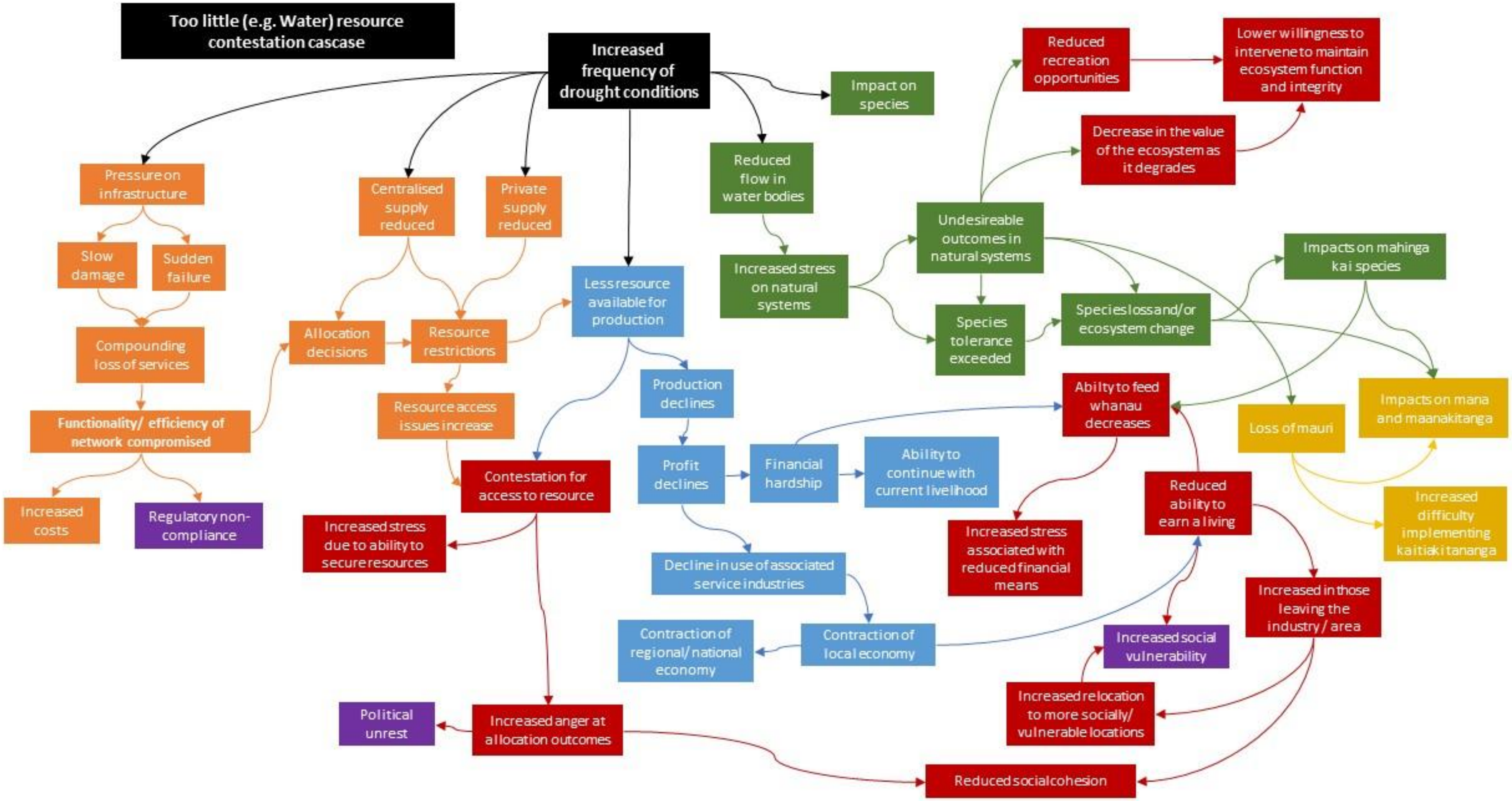


Figure F5: "Too little" Cascading Risk Archetype

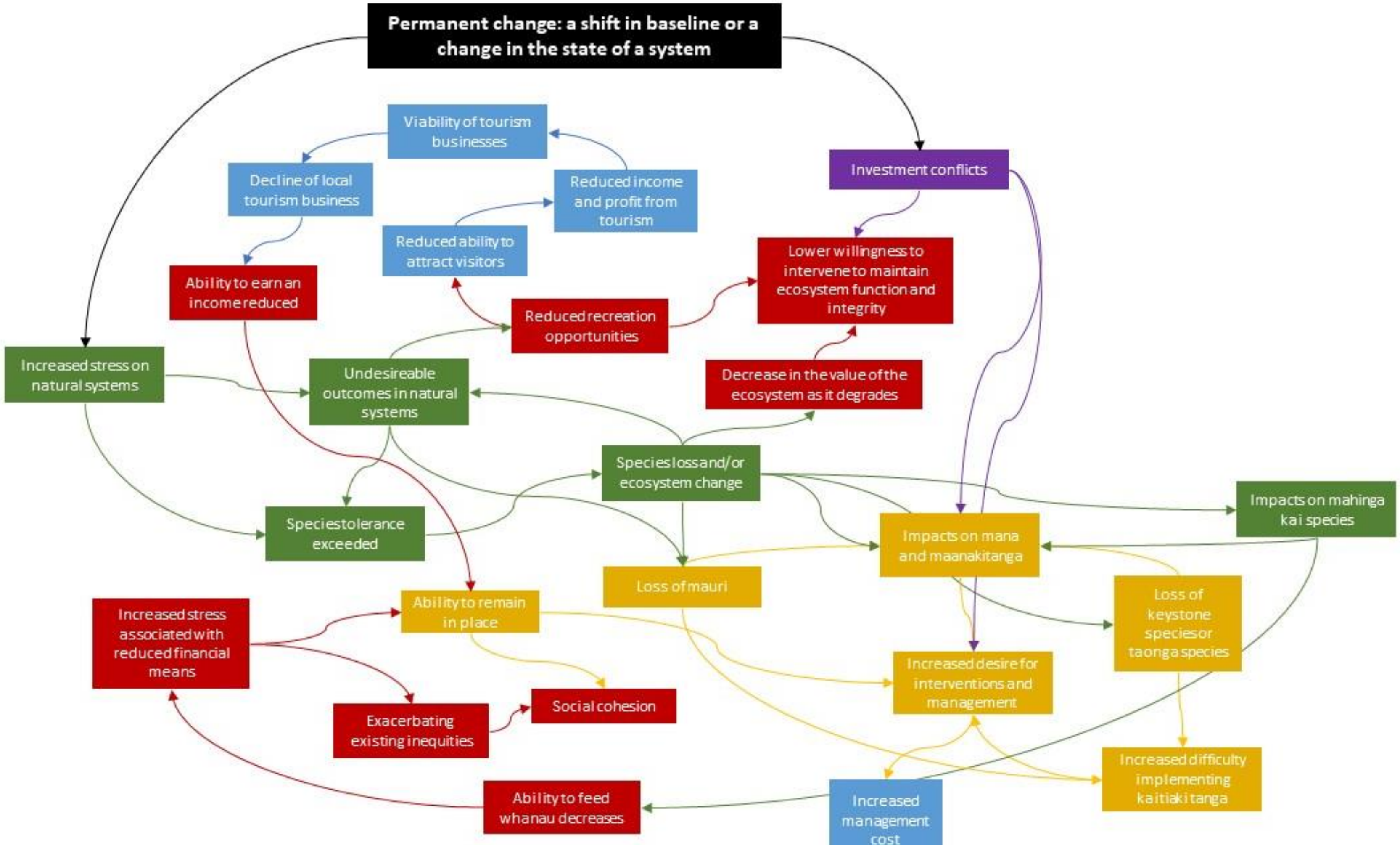


Figure F6: A “Permanent Change” or “shift in Baseline” Archetype

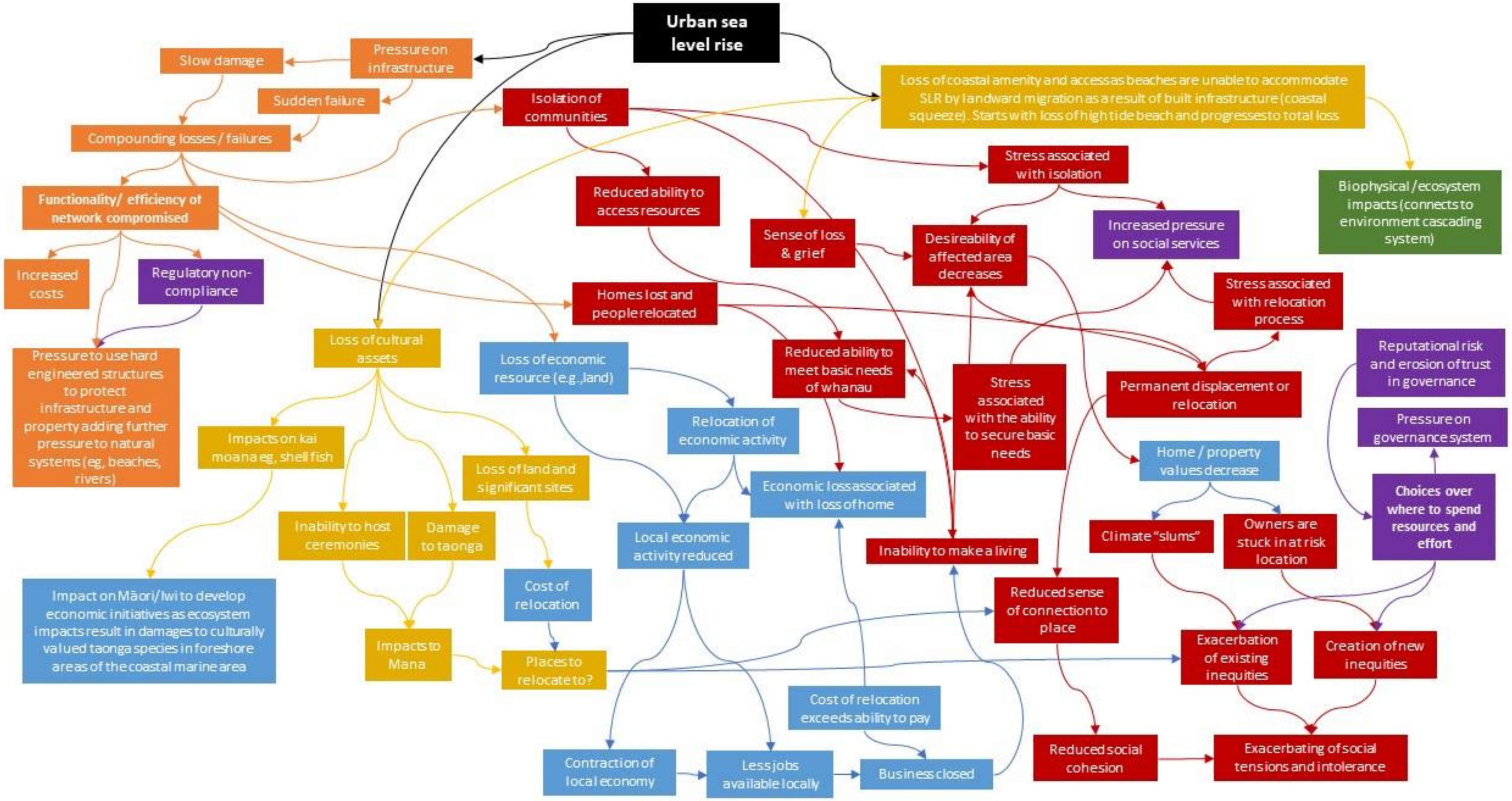


Figure F7: "Urban Sea-Level Rise" Cascading Risk Archetype

Draft "Baseline Shift" Archetype

The "baseline shift" cascade was discussed in Workshop 1 in the context of changes in sea level resulting in increased coastal hazard effects such as erosion and flooding (see Figure F7**Error! Reference source not found.**). Erosion can result in loss of access to coastal amenities either by erosion of the high tide beach or due to damage to coastal roads in addition to damage to properties. Members of communities with the resources to move may choose to do so leaving those without the means to move in a more vulnerable position resulting in exacerbation of the existing equity gap. Fewer people (e.g. ratepayers) are likely to result in declining levels of essential services reducing desirability of the area and cascading into reduced tourism. Those that remain will experience social isolation and may lose the ability to insure their properties. Beyond these socio-economic impacts, there may be losses of biodiversity (e.g. dunes and wetlands) which can have cultural impacts on food gathering.

Draft "Natural Systems Change" Archetype

The "natural system" cascade was generally underrepresented in the first workshop; however, participants identified that as baseline shifts occur, a tipping point may be reached whereby ecological communities change beyond a repairable threshold (see Figure F6). If this tipping point occurs, there may be ecosystem collapse or shifts in locations of ecosystems which may then cascade into affecting local economies and cultural practices.

In general, a climate driver can cause a change in resource availability, such as changing the salinity levels in an estuary due to sea-level rise. This causes impacts on individuals, species, and functional types whereby the mobile communities will shift to a location with their preferred salinity while the less mobile communities may slowly deteriorate. The change in location of the ecosystem results in changes in ecosystem processes, and depending upon the rates of this change, rapid change can result in reduced environmental health. These impacts would not be limited to the natural domain. The shift in ecosystem location could impact the ease of collecting kai moana, or deterioration of a habitat could affect the local economy due to impacts on tourism or on fisheries.

A similar cascade would result due to change in mean temperature, a wildfire or a flood event depositing contaminants. This generic cascade in Figure F3**Error! Reference source not found.** can be used as a thought prompt to evaluate changes in ecosystems due to a range of climate drivers.

Worked Example

To provide an example of how Council might use these cascade archetypes, the "baseline shift" archetype has been updated with black and yellow text in Figure F8 below to demonstrate how the generic archetype could be applied to a specific place, space, or element at risk.

In this example, a change in baseline temperature in Martinborough causes two direct impacts: increased stress on natural systems including the viticulture industry and investment conflicts whereby governments, institutions and businesses must begin to decide whether to invest resources to respond to this change or to allow the cascade to happen. As we move through the cascade, the existing grape species no longer grow as well, and the quality of the wine decreases. The vineyards then must decide whether and how to pivot, perhaps to a different species of grape. The new grapes might require more fertiliser or have different growing requirements which in turn have effects on the wider, natural environment and have the potential to impact mahinga kai species. These same shifts in grape species may, at least temporarily, decrease the quality of Martinborough wines and with less profit, there is less willingness to invest. With lower quality wines and perhaps fewer vineyards, fewer tourists visit. There is then reduced profit from tourism, decline of businesses, and ability to earn an income is reduced. This causes some residents to move which impacts social cohesion, stress, and inequalities.

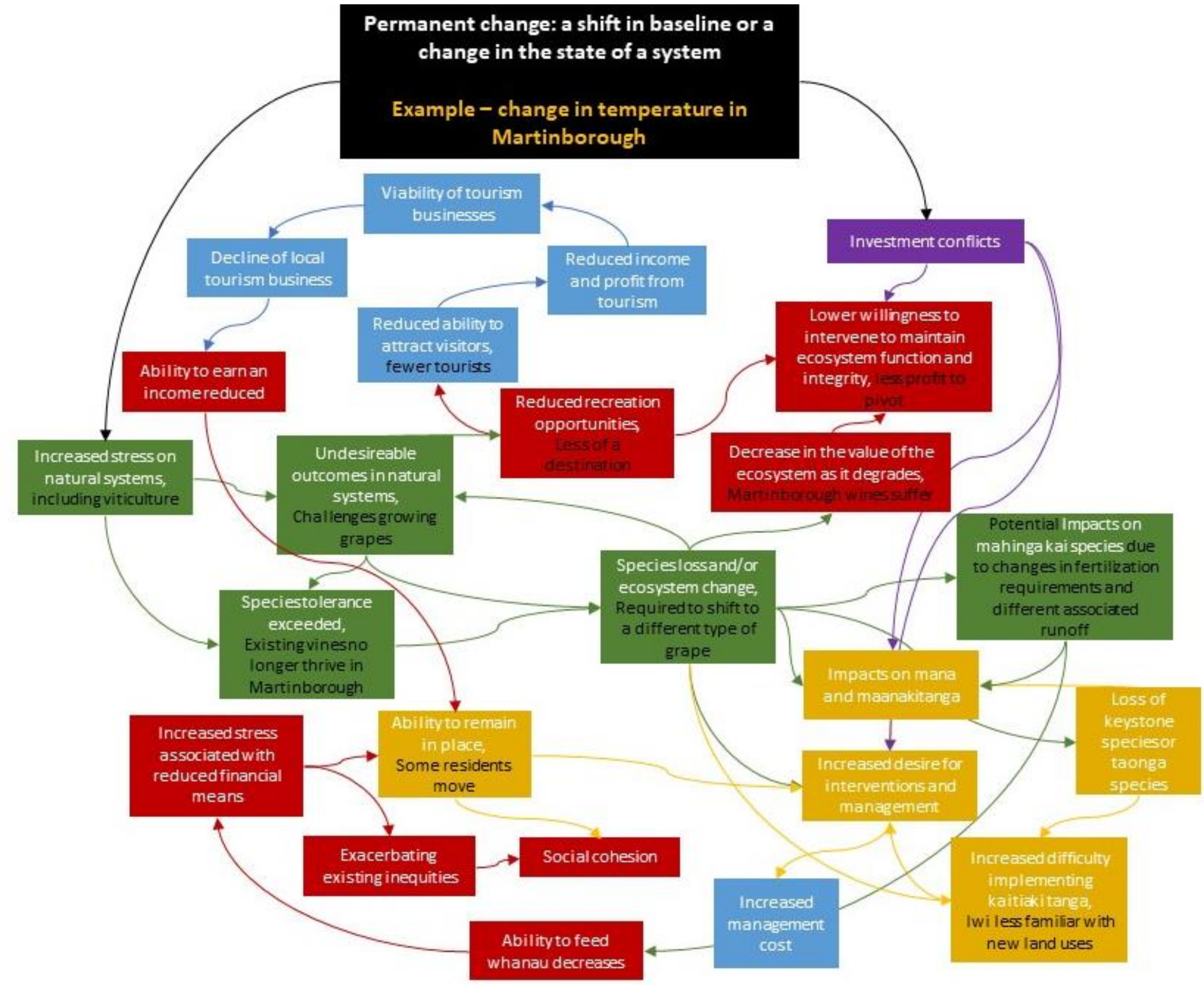


Figure F8: Example Cascading Risks Process for a Change in Average Temperature in Martinborough

Identifying and Assessing Cascading Risks

These cascades are not meant to be alarmist but are rather intended to provoke systems thinking, asking "and then what happens?" While beyond the scope of this assessment, evaluation of risks should not stop at a first pass risk screen or a qualitative assessment, particularly when cascades are likely.The archetypes above **provide a tool** for Council to use to expand the cascades that result from risks identified in earlier sections of this report. To continue this cascading risk thinking independently:

1. Select a place or space at risk.
2. Pair the place or space with a hazard.
3. Identify which archetype it fits within based upon the type of hazard.
4. Start with your directly-impacted place or space. It can be in the environmental, infrastructure, cultural, social, economic or governance domain.
5. Work through the selected archetype asking whether the prompt in each box is relevant. If so, add a qualitative statement (similar to the black text in Figure F8**Error! Reference source not found.**). If not, remove the box after confirming that there are no relevant cascades flowing from the box to be removed. If there are relevant cascades, reattach the arrows to your last relevant box before proceeding.
6. Continue until you work through the archetype.
7. Review the 'story' of your cascade. Ask yourself if there seems to be anything missing. These archetypes are meant to be a general guide and may not have all aspects of every scenario included. If there is anything missing (e.g. additional economic impacts), add them to the cascade diagram. Move on to the next climate driver relevant to that location.
8. Begin to consider "how bad" the impact within each sequence of the cascade is. Consider the following questions:
   - What size area is affected? Perhaps in terms of percentage of a network or local ecosystem?
   - How quickly can it recover, if at all?
   - How bad are the subsequent cascades?
9. Add some commentary of "how bad" the cascades are to your 'story'. Begin to evaluate whether the risk, including both the direct risk and the cascading risks, is tolerable. If the risk is intolerable, adaptive actions (beyond the scope of this work) should be considered and paired with the cascades to mitigate cascading disruption.

G

Appendix G – Climate Driver & Elements at Risk Tables

Climate Drivers

Table G1: Climate Hazards / Drivers

Hazard (Arising from Climate Change)	Primary Climate-Related Variables	Secondary Climate-Related Variables
Higher mean temperatures: air and water	• Higher day and night temperatures • Higher mean water (freshwater and marine) temperatures	• More heatwaves and warm spells • Fewer frosts or cold days
Heatwaves: increasing persistence, frequency and magnitude	• Higher day and night temperatures • Increase in persistence of maximum daily temperatures above 25°C	• Changes in seasonal winds • Humidity changes from changes in cloudiness
More and longer **dry spells** and **drought**	• Low seasonal rainfall • Change in seasonal wind patterns • Interannual variability (e.g. ENSO)	• Higher day and night temperatures
Changes in climate seasonality with longer summers and shorter winters	• Fewer frosts or cold days • Higher day and night temperatures • Changes in seasonal rainfall	• Changes in seasonal wind
Increasing **fire–weather** conditions: harsher, prolonged season	• Low seasonal rainfall • Change in seasonal wind patterns • Increase in persistence of maximum daily temperatures above 25°C • Humidity changes from changes in cloudiness	• Higher day and night temperatures • Interannual variability (e.g. ENSO)
Increased **storminess and extreme winds**	• Increase in storminess (frequency, intensity) including tropical cyclones • Changes in extreme wind speed	• Changes in wind seasonality • Interannual variability (e.g. ENSO) • Increase in convective weather events (tornadoes, lightning)
Change in **mean annual rainfall**	• Higher or lower mean annual rainfall in sub-national climate zones • Changes in seasonal winds	• Humidity changes from changes in cloudiness
Reducing **snow and ice cover**	• Higher day and night temperatures • Changes in rainfall seasonality • Change in seasonal wind patterns • Receding snowline • Reduced snow and glacier cover • Earlier snow melt	• Increase in avalanches • Interannual variability (e.g. ENSO)
Increasing **hail** severity or frequency	• Increase in hail severity or frequency • Increase in convective weather events (tornadoes, lightning)	• Humidity changes from changes in cloudiness
River and pluvial flooding: changes in frequency and magnitude in rural and urban areas	• Changes in extremes: high intensity and persistence of rainfall • Increase in hail severity or frequency • Interannual variability (e.g. ENSO) • Increased storminess and wind	• Humidity changes from changes in cloudiness • Changes in rainfall seasonality • Change in seasonal wind patterns

Hazard (Arising from Climate Change)	Primary Climate-Related Variables	Secondary Climate-Related Variables
	• Relative sea-level rise (including land movement) • Rising groundwater from sea-level rise	• More and longer dry spells and droughts (antecedent conditions)
Coastal and estuarine flooding: increasing persistence, frequency and magnitude	• Relative sea-level rise (including land movement) • Change in tidal range or increased water depth • Permanent increase in spring high-tide inundation • Rising groundwater from sea-level rise • Changes in extremes: high intensity and persistence of rainfall • Increase in storminess (frequency, intensity) including tropical cyclones	• Changes in waves and swell • Changes in extreme wind speed • Changes in sedimentation (estuaries and harbours)
Sea-level rise and salinity stresses on brackish and aquifer systems and coastal lowland rivers	• Relative sea-level rise (including land movement) • Permanent and episodic (low river flow) saline intrusion • Low seasonal rainfall • Rising groundwater from sea-level rise • Permanent increase in spring high-tide inundation	• Changes in sedimentation (estuaries and harbours) • Interannual variability (e.g. ENSO)
Increasing **coastal erosion:** cliffs and beaches	• Relative sea-level rise (including land movement) • Changes in waves and swell • Changes in extreme rainfall: high intensity and persistence • Changes in sedimentation from catchment run-off • Increased storminess and extreme winds • Interannual variability (e.g. ENSO)	• Rising groundwater from sea-level rise • Changes in rainfall seasonality • Change in seasonal wind patterns
Increasing **landslides and soil erosion**	• Changes in extreme rainfall: high intensity and persistence • Changes in rainfall seasonality • More and longer dry spells and droughts (antecedent conditions)	• Interannual variability (e.g. ENSO)
Marine heatwaves: more persistent high summer sea temperatures	• Higher mean ocean temperatures • Increase in persistence of maximum daily temperatures e.g. above 25°C • Change in seasonal wind patterns • Ocean circulation changes	• Interannual variability (e.g. ENSO) • Changes in waves and swell

Hazard (Arising from Climate Change)	Primary Climate-Related Variables	Secondary Climate-Related Variables
Ocean chemistry changes: nutrient cycling and pH changes	• Changes in ocean nutrient cycling – upwelling and carbon • Ocean acidification (pH decreasing) • Higher mean surface-water temperatures • Change in seasonal wind patterns	• Ocean circulation changes • Interannual variability (e.g. ENSO)
International influences from climate change and greenhouse gas mitigation preferences	• Immigration • Markets (pricing, preferences) • Pacific Island countries (disaster responses, development)	

Elements at Risk

Table G2: Elements at Risk

Domain	Element
Natural Environment Oranga Whenua	Indigenous & Taonga Species
	Terrestrial & Forest Ecosystems, Services and Processes
	Wetland Ecosystems, Services and Processes
	Coastal Ecosystems, Services and Processes
	Freshwater Ecosystems, Services and Processes
Economy Whairawa	Forestry
	Horticulture
	Viticulture
	Fisheries
	Pastoral Farming
	Tourism
	Public Services (including government, scientific research, and education)
	Insurance coverage and credit provision
	Māori Enterprise
	Information technology and creative industries
Built Taiohanga	Airports and Seaports
	Buildings and Facilities (public and private)
	Energy
	Flood and Coastal Defences
	Transport (Road and Rail)
	Solid Waste Management
	Communications
	Drinking water
	Stormwater infrastructure
	Wastewater infrastructure
	Marae and cultural sites, Māori owned assets
Human Oranga Tangata	Human health
	Social cohesion and community wellbeing
	Existing inequities
	Social infrastructure and amenities
	Cultural heritage
	Sports and recreation
Governance Kawanatanga	Partnership Strategy and Framework with Iwi and hapū
	All governing and institutional systems
	Legislation and Policy
	Climate related Litigation
	Emergency Management

Element at Risk Definitions

Element at risk definitions for the Natural and Economic domain are more self-explanatory than for the Built and Human domains. Further definitions / considerations for the Built and Human domain elements at risk are provided here.

Table G3 provides further definitions and considerations for the human domain elements at risk.

Table G3: Human domain elements at risk.

Elements at Risk	Consideration / Definitions
Airports and Seaports	Airports, airfields, seaports and marina, marine infrastructure.
Buildings and Facilities (public and private)	All buildings.
Energy	Consumption, generation, transmission and distribution. Includes pylons, poles, aerial / subterrain cables, substations, transformers, windfarm, Cook Strait cables, landfill gas generation.
Flood and Coastal Defences	River and coastal defence structures.
Transport (Road and Rail)	State highways, local roads, railway network. Includes lighting network, signals, intersections, foundations, supporting structures.
Solid Waste Management	Landfills, recycling centres.
Communications	Telecommunications, fibre, cellular, microwave, copper network, terminal boxes, distribution centres.
Drinking water	Supply, treatment, distribution. Includes reservoirs, groundwater bores, rainfall capture, pipes, plants, valves, treatment plants, pump stations.
Stormwater infrastructure	Network, treatment, disposal. Includes intakes, pipes, treatment methods, flood gates, pump stations, outlets.
Wastewater infrastructure	Collection, treatment, disposal. Includes pipes, pump stations, treatment plants, waste disposal, outlet pipes. Centralised systems, rural systems.
Marae and cultural sites	Marae, urupā, cemeteries, pā.
Māori Assets	Buildings, land.

Table G4**Error! Reference source not found.** provides further definitions and considerations for the human domain elements at risk.

Table G4: Human domain elements at risk.

Elements at Risk	Consideration / Definitions
Human health	This element covers both physical and mental health. It includes chronic and acute threats to life and health as well as mental health, identity, autonomy, sense of belonging and wellbeing.
Social cohesion and community wellbeing	This element is focused on the community level and includes aspects of community cohesion and well-being associated with living in a particular place.
Existing inequities	This element focuses on both existing inequities in society, as well as inequities potentially exacerbated by actions (or inactions) in response to climate change.
Social infrastructure and amenities	This element includes objects that keep society functioning, social support structures, community facilities, health care services, and the aesthetics and amenities of places where people live.
Cultural and historic heritage	Sites of value and significance to the heritage and daily life in New Zealand. This includes Historic Heritage sites and buildings as well as Māori cultural sites (e.g. wāhi tapu). It also includes the ability to practice tikanga, express kaitiakitanga and pass on mātauranga.

Sports and recreation	Locations and facilities that afford visitors and local residents the opportunity to enjoy and participate in organised sport, exercise and spend time in recreational pursuits (e.g. parks, sports clubs, etc.)

H

Appendix H – Scoring Considerations – Direct & Indirect Risks / Impacts

Scoring Considerations – Direct & Indirect Risks / Impacts

Appendix E provides the frameworks and considerations that SMEs used to score **exposure**, **sensitivity**, and **adaptive capacity** for each of the four value domains.

Exposure

Refers to the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by a change in external stresses that a system is exposed to.

The qualitative framework used for scoring 'exposure' of the elements to the climate hazard is presented in Table H1**Error! Reference source not found.**. The same framework for scoring exposure was applied similarly across all domains (excluding Governance and Transition risks).

Table H1: Exposure scoring for qualitative assessment

Score	Exposure	Description
Extreme	>75% of sector / element is exposed to the hazard	Significant and widespread exposure of elements to the hazard.
High	50 - 75% of sector / element is exposed to the hazard	High exposure of elements to the hazard.
Moderate	25 - 50% of sector / element is exposed to the hazard	Moderate exposure of elements to the hazard.
Low	5 - 25% of sector / element is exposed to the hazard	Isolated elements are exposed to the hazard.

Sensitivity

Refers to the degree to which an 'element' at risk is affected, either adversely or beneficially, by climate variability or change. Sensitivity relates to how the 'element' will fare when exposed to a hazard, which is a function of its properties or characteristics.

Sensitivity in relation to each domain include the considerations in Table H2**Error! Reference source not found.**.

Table H2: Sensitivity considerations for each domain.

Sensitivity Considerations – Natural Environment Domain
• **Environmental tolerance and geographic range:** Species and ecosystems that have a wide environmental tolerance – generally reflected in a wide geographic range – will likely be less sensitive to the impacts of climate change. By contrast, species and ecosystems that have narrow environmental ranges and / or are restricted to unusual combinations of environment are likely to be less tolerant (Thuiller et al, 2005). • **Species / ecosystems with specific climate requirements:** Ecosystems and species that have highly specific climate requirements (e.g. persistent winter snow cover, winter chilling for flower initiation or hibernation, frost for exclusion of competing tree species) will likely be more sensitive. • **Dispersal ability:** Species with poor dispersal ability and / or occupying environments with significant barriers to dispersal (e.g. lowland forest fragments) are likely to be more sensitive than those with good dispersal ability and / or those that occupy environments with fewer barriers to dispersal (e.g. many marine environments) (Williams et al, 2008). • **Abundance:** Species that are naturally rare may be more sensitive due to their limited population size. Species that are limited both in their distribution and abundance will likely be the most sensitive (Johnson, 1998). • **Geographic isolation:** Geographic isolation of species and ecosystems will render them more sensitive and susceptible. This is particularly relevant to endemic species that are restricted to a defined geographic location. • **Genetic diversity:** Species with less genetic diversity (e.g. threatened species that have passed through population bottlenecks) will likely be more sensitive because of their reduced capacity for adaptation (Reed and Frankham, 2003). • **Ocean acidification:** Species dependent on calcium carbonate for the maintenance of exoskeletons will be particularly susceptible to the effects of ocean acidification.
Sensitivity Considerations – Built Domain
• **Design (materials):** Types of construction materials are fundamental for considering asset sensitivity. • **Age:** This is often used as a proxy for condition; however, age is a key criterion in its own right. It should be considered along with design life to account for changing physical characteristics with time. • **Condition:** This is intrinsically linked to sensitivity. It provides accountability for the current physical state of an asset.
Sensitivity Considerations – Economic Domain
• **Dependence on ecological systems:** If elements or subcategories are dependent on ecological systems, they are likely to be highly sensitive to changes in such systems. • **Leverage and risk-taking:** Borrowed capital increases sensitivity to unexpected economic perturbations. • **Interconnectedness and common exposures:** Interconnectedness with other exposed and vulnerable elements, through supply chains for example, influences sensitivity. Multiple, concurrent or successive hazards will increase sensitivity. • **System characteristics:** In the primary sector particularly, different systems have differing sensitivities – for example, intensive livestock production may be more sensitive to heat stress than extensive systems. Certain crops are more sensitive to water stress.

Sensitivity Considerations – Human Domain
• **Debt levels:** Those who are overcapitalised may be more sensitive. • **Socio-economic status:** In general, people living in poverty are more exposed and sensitive than the wealthy to hazard impacts (Fothergill and Peek, 2004). • **Race and ethnicity:** Ethnic communities are often geographically and economically isolated from jobs, services and institutions. Discrimination also plays a major role in increasing the vulnerability of racial and ethnic minorities (Bolin, 2006; Fothergill et al, 1999). Where minorities are immigrants from non-English-speaking countries, language barriers can greatly increase vulnerability to a disaster and recovery (Trujillo-Pagan, 2007). • **Gender:** Following disasters, displaced women and children are often at greater risk of sexual violence. Unequal participation in labour markets and decision-making compounds inequalities (Enarson, 2007). Relocation due to slow-onset change may present similar challenges. • **Age:** Disruptions created by a disaster can have significant psychological and physical impacts on children. The elderly are likely to experience health problems and a slower recovery, and tend to be more reluctant to evacuate their homes in a disaster or move from their community due to slow-onset change. • **Disability and physical health:** People living with mental or physical disabilities are less able to respond effectively to disasters and additional stress and require additional help in preparing for and recovering from disasters, and adapting to slow-onset change (McGuire et al, 2007). • **The number of impacts** an individual, community or hapū is exposed to, either simultaneously or in a short period, affects their sensitivity. For example, a family may own property that is simultaneously affected by flooding and pests, or coastal inundation then drought in quick succession. • **Strength of identity** is linked to the ability to undertake cultural practices and assert kaitiakitanga or live in a particular place, or do a particular job (e.g. self-identity in farmers).

The qualitative framework used by the project team for scoring Sensitivity is presented in Table H3.**Error! Reference source not found.**

Table H3: Qualitative sensitivity scoring of elements to a given climate hazard.

Sensitivity Level	Definition	Score
Extreme	Extreme sensitivity to a given climate hazard	4
High	High sensitivity to a given climate hazard	3
Moderate	Moderate sensitivity to a given climate hazard	2
Low	Little to no sensitivity	1

Adaptive Capacity

Refers to the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Adaptive capacity relation to each domain include the considerations in Table H4.**Error! Reference source not found.**

Table H4: Adaptive capacity considerations for each domain

Adaptive Capacity Considerations – Natural Environment Domain
• **Genetic adaptation / evolutionary mechanisms:** Species that have historically been subjected to changes in the natural environment will have a capacity to adapt to future changes. Genetic adaptation at individual, population and species levels, including natural selection and gene flow, allows for greater population fitness and adaptive capacity (Lidner et al, 2010). • **Reproductive rates:** Reproductive rates are an important factor in the ability of species or ecosystems to adapt after a disturbance or climate hazards (Williams et al., 2008). Higher reproductive rates will allow for a greater ability to recover and adapt. • **Behavioural plasticity:** The ability of species and ecosystems to change behaviours based on environmental conditions will contribute greatly to adaptive capacity. Such behaviours involve shifts in distribution or seasonal activity, acclimation and changes in habitats (Williams et al., 2008). Behavioural changes favoured by natural selection through survival and reproduction may become fixed in populations over time.
Adaptive Capacity Considerations – Built Domain
• The **design life** and resilience of the asset to impacts (particularly if it is not a permanent asset or structure). • **Planning controls and design standards** for new infrastructure and facilities that take into account extreme weather, rising seas and groundwater. • The degree to which the asset can be **reconfigured or redesigned** to accommodate changes in climate, extreme weather events, and rising seas and groundwater. • Existing policies and procedures for **workplace health and safety**, for example, operations in storm, wind, wave, heat and low-visibility conditions. • **Technological changes:** including the ability to work longer and function during periods of more challenging conditions.
Adaptive Capacity Considerations – Economic Domain
• **Wealth:** National wealth and the state of the economy determine the ability to finance public sector adaptation. Similarly, in the private sector, financial performance, cash flow and solvency will affect the ability to cope with shocks and stressors. • **Innovation:** Elements with innovative potential are likely to be better positioned to adapt to change. • **Supply chain control:** The ability to exert influence over supply and distribution networks can bolster resilience to shocks. • **Sound macroeconomic management:** Macroeconomic stability (i.e. sustainable fiscal position, low price inflation and low unemployment) contributes to economic resilience. • **Liquidity:** The ability to liquidate assets can support adaptive capacity. • **Knowledge and skills:** Knowing the risks and adaptation options, and having the skills to implement them, are essential for adaptive capacity. This may man that there are existing adaptation strategies in place. • **Absence of barriers:** Behavioural, financial, structural and governance barriers may constrain adaptation. These may include physical barriers, such as the location of a business (or farm). • **Access to insurance:** The availability of insurance is an important component of the ability to adapt.
Adaptive Capacity Considerations – Human Domain

The qualitative framework that will be used for scoring Adaptive Capacity is presented in Table H5**Error! Reference source not found.**.

Table H5: Proposed Qualitative scoring adaptive capacity of elements to a given climate hazard.

Adaptive Capacity	Definition	Score
High	High capacity to adapt	1
Medium	Medium capacity to adapt	2
Low	Low capacity to adapt	3
Very low	Very low capacity to adapt	4

Impact

Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial.

Impact scoring will be informed by descriptions presented in Table H6**Error! Reference source not found.**.

Table H6: Impact / consequence scoring table

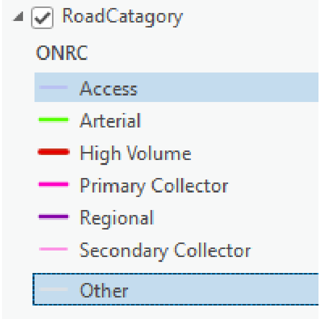
Rating	Consequence / Impact				
	Economic	Community	Natural Environment	Public Government	Built Environment
Catastrophic	Regional decline leading to widespread business failure, loss of employment, and hardship	The region would be seen as very unattractive, moribund, and unable to support its community OR Large numbers of serious injuries or loss of lives	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public administration would fall into decay and cease to be effective	Service restoration takes >1 month or major prosecution
Major	Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth	Severe and widespread decline in services and quality of life within the community OR Isolated instances of serious injuries or loss of lives	Severe loss of environmental amenity and a danger of continuing environmental damage	Public administration would struggle to remain effective and would be seen in danger of failing completely	Service restoration within 1 month or minor prosecution
Moderate	Significant general reduction in economic performance relative to current forecasts	General appreciable decline in services OR Small numbers of injuries	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Public administration would be under severe pressure on several fronts	Service restoration within 2-3 weeks or infringement notice
Minor	Individually significant but isolated areas of reduction in economic performance relative to current forecasts	Isolated but noticeable examples of decline in services OR Serious near misses or minor injuries	Minor instances of environmental damage that could be reversed	Isolated instances of public administration being under severe pressure	Service restoration within 1 week or consent compliance notice

I

Appendix I – Details of Detailed Assessment (Data & Assumptions)

Details of Detailed Assessment (Data & Assumptions)

<table>
<tr><th>Domain</th><th>Prioritised Risk</th><th>Element at Risk Data</th><th>Climate Data</th><th>Impact Assessment (Quantitative and / or Qualitative)</th></tr>
<tr><td>Built #BD32</td><td>Buildings and coastal erosion</td><td></td><td>N/A
No regional climate driver data for coastal erosion so spatial analysis removed from tool.</td><td>Qualitative commentary developed and provided in report where this risk is particularly important to a particular district.
In particular whether residential/commercial/industrial is most at risk. Local (district plan) coastal erosion used for narrative in report.</td></tr>
<tr><td>Built #BD87</td><td>Transport and landslides</td><td>
Wellington City Council provided road dataset with One Network Road classification as below:



KiwiRail Centrelines:

https://www.arcgis.com/apps/mapViewer/index.html?layers=13d266cb6dd141879daa76d993e2b0cc

Note road GIS database is centrelines data. We have applied a +/-15m buffer for State Highways, Arterial and HV, but a +/-10 m buffer to centrelines for all other road categories. Used a +/- 10m buffer for railway centrelines.

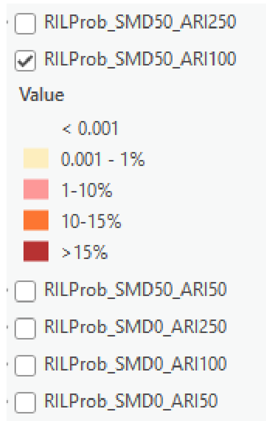
Rail centrelines split into segments of 250m. 250m selected as rail has fewer detour routes and landslides expose the route between stations.

Transport is considered exposed if the centreline + buffer intersects the RIL exposure layers.

Road risks node to node (as per source dataset from ONRC).
</td><td>
RIL Landslides Data provided by GNS Science for WCC area only.

DISCLAIMER: The Institute of Geological and Nuclear Sciences Limited (GNS Science) and its funders give no warranties of any kind concerning the accuracy, completeness, timeliness, or fitness for purpose of this dataset. The dataset is based on interpretation of imagery. Site-specific testing may result in a different determination at a given location than those contained in this dataset. GNS Science accepts no responsibility for any actions taken based on, or reliance placed on the dataset and GNS Science and its funders exclude to the full extent permitted by law liability for any loss, damage, or expense, direct or indirect, and however caused, whether through negligence or otherwise, resulting from any person's or organisation's use of, or reliance on, the dataset.

RIL Landslides Data is available from GNS Science for WCC area only with the following layers:



These layers are RIL source areas (where the landslide material comes from) not the landslide runout which is vastly more complicated to determine.

LAYER SELECTION

Soil Moisture Deficit (SMD): Select SMD of 0 as this conservatively assumes a wetter soil (i.e. lower deficit). This is because rainfall is projected to increase in the west of the Wellington Region and decrease in the east of the region. (NIWA 2018) for both RCP4.5 and RCP8.5. Specifically, Under RCP4.5 and RCP8.5 at 2040, increases in annual rainfall of up to 5% are projected for most of the region (NIWA, 2018) and at 2090, up to 5% more rainfall is projected in the western region for all four seasons, at the annual scale, and for the majority of the region in summer. (NIWA, 2018).

FUTURE ARI SCENARIOs

Used present day 50, 100 and 250 year ARI scenarios. The rarer present-day ARI events approximate more frequent ARI event (50 to 60
</td><td>
HAZARD EXPOSURE SCORE

P(RIL)<0.005 not exposed

<table>
<tr><th>RIL Probability (%) for Present and Future 50 to 60-year ARI Rainfall Events</th><th>Hazard Exposure</th><th>Score</th></tr>
<tr><td><0.02</td><td>Very low</td><td>1</td></tr>
<tr><td><0.04</td><td>Low</td><td>2</td></tr>
<tr><td><0.1</td><td>Moderate</td><td>3</td></tr>
<tr><td>>0.1</td><td>High</td><td>4</td></tr>
</table>

for 50 to 60-year ARI RIL maps at SMD=0

This utilises a semi-quantitative approach to exposure score and draws on the likelihood graduations from the Draft National Guidance on Landslide Management (2023): https://planning.org.nz/Attachment?Action=Download&Attachment_id=1000565

Exposure of transport:

<table>
<tr><th></th><th></th><th>ROAD</th><th>RAIL</th></tr>
<tr><td>Event</td><td>Duration of Outage</td><td>Exposure Score</td><td>Exposu Score</td></tr>
<tr><td>Slip < 1000m2</td><td>Less than 12hrs</td><td>1</td><td></td></tr>
<tr><td>Slip 1000m2 to 10,000m2</td><td>12-48hrs</td><td>2</td><td></td></tr>
<tr><td>Slip 10,000m2 to 100,000m2</td><td>2-5 days</td><td>3</td><td></td></tr>
<tr><td>Slip > 100,000m2</td><td>>5 days</td><td>4</td><td></td></tr>
</table>

NOTE:

Landslide sizes based on GNS categorization of large (100,000m2), moderate, and small (<10,000m2) landslides.

Landslides on railways considered to take longer to restore to full service than roads (which can return to partial service more rapidly).

EXPOSURE CLASSIFICATION:

<table>
<tr><th colspan="2">Exposure Classification</th></tr>
<tr><td>Yellow</td><td>1 to 2</td></tr>
<tr><td>Orange</td><td>2 to 3</td></tr>
<tr><td>Red</td><td>3 to 4</td></tr>
<tr><td></td><td></td></tr>
<tr><td>NOTES:</td><td></td></tr>
<tr><td colspan="2">Multiply hazard exposure and transport exposure and divide by 4 to get classification</td></tr>
</table>

VULNERABILITY SCORE
</td></tr>
</table>

Domain	Prioritised Risk	Element at Risk Data	Climate Data	Impact Assessment (Quantitative and / or Qualitative)
			(see below)	(see below)

Climate Data

year ARI) in the future as a result of increasing intensity of rainfall events based on HIRDS v4.

RIL Layer to Use	Present Day ARI	Equivalent Future Scenario (HIRDS v4 at Kelburn
SMD0_ARI250	250	approx. 60 year ARI, 2081-2100 RCP8.5
SMD0_ARI100	100	approx. 60-year ARI, 2031-2050 both RCP4.5 and RCP8.5
SMD0_ARI50	50	ARI50, Present day

By following the above methodology, we can show equivalent future '50 to 60-year ARI' rainfall scenarios and see how RIL impacts change in the future. There is uncertainty in the magnitude of these changes to extreme rainfall (NIWA 2018), with the standard error for present day 24 hour rainfall depths at the 50-250 year events is 12-24 mm. This degree of uncertainty means the intercomparison of present 50 and future 60-year equivalent ARI events is considered suitable and within the data confidence bounds. There is no alternative available currently which allows a regionally consistent comparison on climate change impacts on RIL.

Rationale

This uses HIRDS at Kelburn as the representative site for WCC mapped RIL as this is a central, long-term rainfall data source and NIWA report rainfall statistics as representative of Wellington CBD from this site in climate summaries.

Climate change will increase the depth of extreme rainfall events across the region (see HIRDS v4 data). Future extreme rainfall events can be approximated based on the increase in rainfall depth due to climate change.

Table 2: HIRDS extreme rainfall at Kelburn.

ARI	Historic Historical I	RCP4.5 2031-2050	RCP4.5 2081-2100	RCP8.5 2031-2	RCP8.5 2081-2100	Historical Standard error
1.58	67.4	70.9	73.1	71.4	79.6	1.2
2	73.6	77.5	80.0	78.1	87.2	1.1
5	94.7	100.0	104.0	101.0	114.0	2.8
10	110.0	117.0	121.0	118.0	133.0	4.8
20	127.0	134.0	139.0	135.0	153.0	7.5
30	136.0	145.0	150.0	146.0	165.0	9.3
40	143.0	152.0	158.0	154.0	174.0	11
50	149.0	158.0	164.0	159.0	181.0	12
60	153.0	163.0	169.0	164.0	187.0	13
80	161.0	171.0	177.0	172.0	196.0	15
100	166.0	177.0	184.0	178.0	203.0	17
250	190.0	202.0	209.0	203.0	232.0	24

HIRDS V4 Depth-Duration-Frequency Results
Sitename: WELLINGTON KELBURN
Site ID: E14272
Coordinate system: NZGD1949
Longitude: 174.767
Latitude: -41.286

The present day 24hr 100-year ARI rainfall (166mm) is equivalent to 60-year ARI rainfall depths (163mm and 164mm) of the 2031 - 2050 timeframe under both RCP 4.5 and 8.5.

Impact Assessment (Quantitative and / or Qualitative)

Vulnerability Classification	
Yellow	1 to 2
Orange	2 to 3
Red	3 to 4
NOTES:	
Multiply adaptive capacity score by sensitivity score and divide by 4.	

SENSITIVITY:

Sensitivity - degree transport system is affected, will specify based on approximate scale of wider impact (e.g. size).

Road Types	Sensitivity Score
Access	1
Secondary Collector	2
Primary Collector	3
Arterial	4
Regional	4
National	4
Rail networks	4

NOTE:

Based on ONRC classifications. More important roads = more sensitive to disruption from landslides.

Rail based on KiwiRail Centrelines. Freight and passenger rail equal high sensitivity (high economic disruption or high public disruption).

ADAPTIVE CAPACITY of transport system relative to connections / detours.

Road Types	Sensitivity Score
Neither cutoff, fragmented or bisected but is access, secondary or primary	1
Neither cutoff, fragmented or bisected but is arterial, regional or national	2
Fragmented road or bisected road	3
Cutoff road	4
Rail (all)	4

Note: Road sensitivity based on the qualitative connectivity manual work by Beca plus the connectivity descriptions in ONRC. All rail is has low adaptive capacity (higher score) due to limited detour options.

Cut off, fragmented and bisected roads were also identified manually. Where a landslide occurs intersecting the segment of a road identified as resulting in cutting off, fragmenting or bisecting communities, the entire segment (e.g. intersection to intersection) will be scored as identified above.

RISK IMPACT

Risk Impact Score = (vulnerability classification x exposure classification) / 4

Scoring 1 to 4, high score = high risk impact

Limitations

<table>
<tr><th>Domain</th><th>Prioritised Risk</th><th>Element at Risk Data</th><th>Climate Data</th><th>Impact Assessment (Quantitative and / or Qualitative)</th></tr>
<tr><td></td><td></td><td></td><td>The present day 24 hr 250-year ARI rainfall (190mm) is similar to the 60-year ARI rainfall depth (187mm) of the end century (2081 - 2100) RCP8.5.
Therefore, the present day higher ARI maps (100, 250) approximate the future more frequent ARI event (50 to 60 year ARI).
DATA COMMENTS
Limited only to WCC area.
The raw data and maps do not readily enable RCP separation of data, hence above approach required to consider future hazards with climate change.
All disclaimers from GNS apply to data used.</td><td>Reports a residual risk score as we are not including mitigating features or structures (retaining walls) as the dataset and method does not lend itself to this inclusion. i.e. no knowledge of integrity of retaining wall during RIL events.
The additional potential impact associated with RIL effects on bridges and other roading structures (retaining walls) are not included in Impact Viewer. This may be included at later version with information from Waka Kotahi and KiwiRail. Suggest that bridges have high sensitivity and low adaptive capacity.
Tool Output:
Display breakdown of results.
ONRC Class: number of km exposed by ONRC class.
Risk Impact Score: km of roads / rail in risk categories 1 - 4.</td></tr>
<tr><td>Built #BD33</td><td>Buildings and Landslides</td><td>National buildings database (LINZ) with uses / type:
<table>
<tr><th>Building Types</th></tr>
<tr><td>Schools</td></tr>
<tr><td>Early childhood centres</td></tr>
<tr><td>Hospitals</td></tr>
<tr><td>Aged care facilities</td></tr>
<tr><td>Supermarkets</td></tr>
<tr><td>Residential zone</td></tr>
<tr><td>Commercial zone</td></tr>
<tr><td>Industrial zone</td></tr>
<tr><td>Mixed-use zone</td></tr>
</table>
Refer to sensitivity and adaptive capacity scoring in Impact Assessment column</td><td>RIL data as per #BD87 (see above)</td><td>HAZARD EXPOSURE SCORE
As per #BD87 (see above)
EXPOSURE SCORES
<table>
<tr><th colspan="2">Exposure Classification</th></tr>
<tr><td>Yellow</td><td>1 to 2</td></tr>
<tr><td>Orange</td><td>2 to 3</td></tr>
<tr><td>Red</td><td>3 to 4</td></tr>
<tr><td></td><td></td></tr>
<tr><td>NOTES:</td><td></td></tr>
<tr><td colspan="2">Multiply exposure score by scale score by proximity score and divide by 16</td></tr>
</table>
SCALE OF IMPACT
<table>
<tr><th>Event</th><th>Exposure Score</th></tr>
<tr><td>Slip < 1000m2</td><td>1</td></tr>
<tr><td>Slip 1000m2 to 10,000m2</td><td>2</td></tr>
<tr><td>Slip 10,000m2 to 100,000m2</td><td>3</td></tr>
<tr><td>Slip > 100,000m2</td><td>4</td></tr>
<tr><td></td><td></td></tr>
<tr><td>NOTE:
Landslide sizes based on GNS categorization of large (100,000m2), moderate, and small (<10,000m2) landslides</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>PROXIMITY OF IMPACT</td><td></td></tr>
<tr><td>Event</td><td>Exposure Score</td></tr>
<tr><td>Intersects buffer</td><td>2</td></tr>
<tr><td>Intersects footprint</td><td>4</td></tr>
<tr><td></td><td></td></tr>
<tr><td>NOTE:
Buffers for building footprint selected as 8m (consistent with EQC impact zone. E.g. https://www.eqc.govt.nz/what-we-do/what-youre-covered-for/land-structures/).</td><td></td></tr>
</table>
VULNERABILITY SCORE</td></tr>
</table>

Domain	Prioritised Risk	Element at Risk Data	Climate Data	Impact Assessment (Quantitative and / or Qualitative)

Vulnerability Classification	
Yellow	1 to 2
Orange	2 to 3
Red	3 to 4
NOTES:	
Multiply adaptive capacity score by sensitivity score and divide by 4	

ADAPTIVE CAPACITY

Building Types	Adaptive Capacity Score
Schools	4
Early childhood centres	4
Hospitals	2
Aged care facilities	4
Supermarkets	3
Residential zone	4
Commercial zone	3
Industrial zone	3
Mixed-use zone	3
NOTES:	
Hospitals are designed with high Importance Level to cope during hazard events - high adaptive capacity (2)	
Supermarkets, commercial zones, industrial zones, and mixed-use zones are transient spaces and demand / use can often be shifted therefore more adaptive capacity than residential (3).	
Residential zones, aged care facilities, childcare centres and schools are where people live or are considered 'safe spaces' by young people and can serve as anchor points for communities where disruption would be significant (4).	
If a building were known to be on a significantly elevated platform or with a floodable ground floor, it would score a (1).	

SENSITIVITY

Building types	Building Metric	Sensitivity Score*			
		4	3	2	1
Schools	total roll	>500	100-499	=<100	-
Early childhood centres	total roll	-	>100	=<100	-
Hospitals	number of beds	>250	100-250	<=100	-
Aged care facilities	number of beds	>125	75-125	<=75	-
Supermarkets	square metres	>3750	1000-3750	<=1000	-

Domain	Prioritised Risk	Element at Risk Data	Climate Data	Impact Assessment (Quantitative and / or Qualitative)

Residential zones, Recreational and other zones (e.g. rural)	-	-	-	all	-
Commercial zone	square metres	-	>5000	=<5000	-
Industrial zone	square metres	-	>5000	=<5000	-
Mixed-use zone	square metres	-	>5000	=<5000	-

NOTE: All residential buildings score a 1 in sensitivity and that commercial / industrial / mixed can score a max of a 2 if quite large (>5000m2) otherwise are also a 1.

All residential buildings score a 2 in sensitivity and that commercial / industrial / mixed can score a max of a 3 if quite large (>5000m2) otherwise a 2.

Recreational and other zones are scored 2 in sensitivity. Many buildings in rural zones will be residential and data does not support differentiating between a farmhouse and an implement shed.

All schools are sensitive to flooding, sensitivity of disruption to the local community being related to roll. Larger schools roll (generally intermediate and above) having higher sensitivity via more potential disturbance to wider contributing catchment.

ECE centers are sensitive based on age of pupils and need for safe access/egress. ECE centers generally smaller than schools so can not score as high.

Aged care centers are more sensitive based on age of residents and need for safe access/egress.

Smaller supermarkets (1000 m^2 = 30*30 building) i.e. a corner dairy size. Less sensitive as there are likely to be alternatives nearby for community to use. Large supermarkets draw from wider buyer catchment, with consequential higher sensitivity.

RISK IMPACT (main score)

Risk Impact Score = (vulnerability classification x exposure classification) / 4

Scoring 1 to 4, high score = high risk impact

Reports a residual risk score as the regional flood model ((retaining walls) as the dataset and method does not lend itself to this inclusion. i.e. no knowledge of integrity of retaining wall during RIL events.

Tool Output:

Display breakdown of results as per mockups.

Zonation: high level zoning of commercial, residential, industrial and show as proportion of exposed buildings by different zone types

Building Use: Buildings exposed/not exposed for known building use types - specifically the sensitive receptors (supermarket, school, religious facility, hospital)

Domain	Prioritised Risk	Element at Risk Data	Climate Data	Impact Assessment (Quantitative and / or Qualitative)
				Private/Public use: Proportion of exposed buildings by public or private ownership Risk Impact Score: # buildings in risk categories 1-4
Built #BD30	Buildings and coastal flooding and SLR	National buildings database (LINZ) with uses / type: (see below)	NIWA latest coastal inundation with SLR layers (see below)	Used NIWA provided ARI 100 year depth (see below)

Domain: Built #BD30

Prioritised Risk: Buildings and coastal flooding and SLR

Element at Risk Data

National buildings database (LINZ) with uses / type:

Building Types
Schools
Early childhood centres
Hospitals
Aged care facilities
Supermarkets
Residential zone
Commercial zone
Industrial zone
Mixed-use zone

Refer to sensitivity and adaptive capacity scoring in Impact Assessment column.

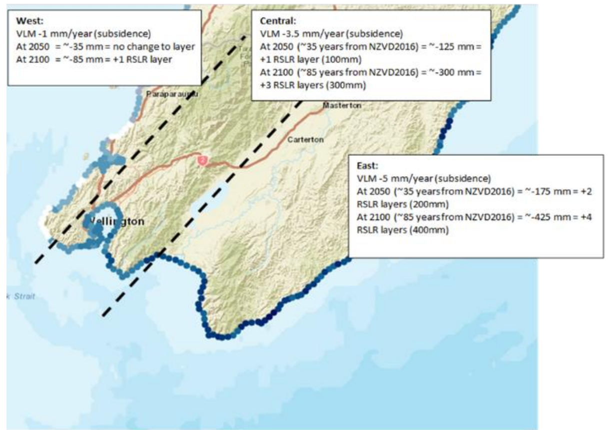
Limitation - no available and regionally consistent databases have QAd information on the vulnerability of the buildings themselves (e.g. materials, foundation type, age etc) hence their exposure is based on RiskScape exposure scoring linking damage state to depth for a pre-1970s house (see diagram column 6).

Climate Data

NIWA latest coastal inundation with SLR layers (1% AEP + wave setup at 0.1m SLR increments from 0 - 2m above present day). Refer to writeup:

https://niwa.co.nz/natural-hazards/our-services/extreme-coastal-flood-maps-for-New ZealandNew Zealand-new-zealand

Adjusted the layer used for each RCP/timeframe to account for Vertical Land Motion based on 3 areas around region (1mm/year east, 3mm/year Central, West=-5mm/yr).



And select the layer corresponding to the RSLR value as below.

			p50 from NZSeaRise						
			2050	2100					
scenario	year								
SSP2-4.5 (medium confidence)			0.22	0.57					
SSP3-7.0 (medium confidence)			0.24	0.74					
SSP5-8.5 (medium confidence)			0.26	0.84					
plus VLM allowance			2050	2100					
West	-1	mm/year	-0.034	-0.084	mm at timeframe				
Central	-3.5	mm/year	-0.119	-0.294					
East	-5	mm/year	-0.17	-0.42					
	West		Central		East		Kapiti		
	2050	2100	2050	2100	2050	2100	Takutai Kapiti results		
SSP2-4.5 (medium confidence)	0.254	0.654	0.339	0.864	0.39	0.99	0.2	0.65	
SSP5-8.5 (medium confidence)	0.294	0.924	0.379	1.134	0.43	1.26	0.4	1.25	
Layer to use	0.3	0.7	0.3	0.9	0.4	1	0.2	0.65	
	0.3	0.9	0.4	1.1	0.4	1.3	0.4	1.25	

Inundation depth around building = hazard

Impact Assessment (Quantitative and / or Qualitative)

Used NIWA provided ARI 100 year depth with future scenarios/timeframes as described in climate data column.

Exposure, vulnerability and risk impact scoring as below.

EXPOSURE SCORE (flood depth around building depth)

Riskscape			Correlate to a flood depth	Score
Damage state	Description	Damage Ratio		
DS0	Insignificant	0 to 0.02	<15mm	0
DS1	Light - non-structural damage or minor non-structural damage	0.02 to 0.1	15mm to 100mm	1
DS2	Moderate - repairable structural damage	0.1 to 0.5	100mm to 1400mm	2
DS3	Severe - Irreparable structural damage	0.5 to 0.95	1400mm to 3000mm	3
DS4	Collapse - Structural integrity fails	> 0.95	>30000mm	4

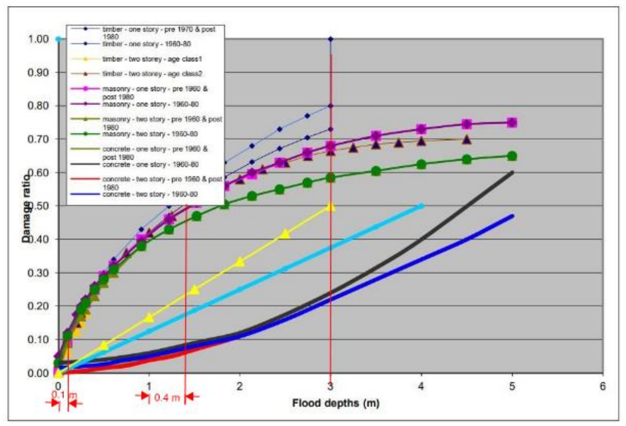


Figure 1 Flood fragility curves for various building types, with inundation depth above the floor level (m) along the horizontal axis and average damage ratio along the vertical axis.

Table 3: Summary of damage states, damage description, and damage ratio used within RiskScape.

Damage state	Description	Damage ratio
DS0	Insignificant	0–0.02
DS1	Light—Non-structural damage, or minor non-structural damage	0.02–0.1
DS2	Moderate—Reparable structural damage	0.1–0.5
DS3	Severe—Irreparable structural damage	0.5–0.95
DS4	Collapse—Structural integrity fails	> 0.95

VULNERABILITY SCORE

Vulnerability Classification

Domain	Prioritised Risk	Element at Risk Data	Climate Data	Impact Assessment (Quantitative and / or Qualitative)

Yellow	1 to 2
Orange	2 to 3
Red	3 to 4
NOTES:	

Multiply adaptive capacity score by sensitivity score and divide by 4

ADAPTIVE CAPACITY SCORE

Building Types	Adaptive Capacity Score
Schools	4
Early childhood centres	4
Hospitals	2
Aged care facilities	4
Supermarkets	3
Residential zone	4
Commercial zone	3
Industrial zone	3
Mixed-use zone	3
NOTES:	

Hospitals are designed with high ILs to cope during hazard events - high adaptive capacity (2)

Supermarkets, commercial zones, industrial zones, and mixed-use zones are transient spaces and demand / use can often be shifted therefore more adaptive capacity than residential (3).

Residential zones, aged care facilities, childcare centres and schools are where people live or are considered 'safe spaces' by young people and can serve as anchor points for communities where disruption would be significant (4).

If a building were known to be on a significantly elevated platform or with a floodable ground floor, it would score a (1).

SENSITIVITY SCORE

Building Types	Building Metric	Sensitivity Score			
		4	3	2	1
Schools	total roll	>800	500 - 799	100-499	=<100
Early childhood centres	total roll	-	-	>100	=<100
Hospitals	number of beds	>250	100-250	50-99	=<50
Aged care facilities	number of beds	>150	100-150	50-99	=<50
Supermarkets	square metres	>3750	2500-3750	1000-2499	=<1000
Residential, recreational and other zones	-				all
Commercial zone	square metres	-		>5000	=<5000
Industrial zone	square metres	-		>5000	=<5000

<table>
<tr><th>Domain</th><th>Prioritised Risk</th><th>Element at Risk Data</th><th>Climate Data</th><th>Impact Assessment (Quantitative and / or Qualitative)</th></tr>
<tr><td></td><td></td><td></td><td></td><td>
<table>
<tr><td>Mixed-use zone</td><td>square metres</td><td>-</td><td></td><td>>5000</td><td>=<5000</td></tr>
</table>
NOTE: All residential buildings score a 1 in sensitivity and that commercial / industrial / mixed can score a max of a 2 if quite large (>5000m2) otherwise are also a 1.
RISK IMPACT (main score)
Risk Impact Score = (vulnerability classification x exposure classification) / 4
Scoring 1 to 4, high score = high risk impact
Tool Output:
Display breakdown of results as per mockups.
Zonation: high level zoning of commercial, residential, industrial and show as proportion of exposed buildings by different zone types
Building Use: Buildings exposed/not exposed for known building use types - specifically the sensitive receptors (supermarket, school, religious facility, hospital)
Private / Public use: Proportion of exposed buildings by public or private ownership
Risk Impact Score: # buildings in risk categories 1 – 4.
</td></tr>
<tr><td>Built #BD29</td><td>Buildings and pluvial flooding</td><td>LINZ Building Outlines with attributes as per #BD30.</td><td>
WWL flood data for WCC, HCC, UHCC, PCC.
The Regional Flood Exposure solely used where WWL is not available. Building exposure linked to depth of flooding (see next column). With single building exposure score the maximum = max of exposure score for each building for each flood model.
LAYERS

WWL have confirmed available layers: +20% rainfall – linked to RCP4.5 project to 2130. Equivalent to RCP 6 to 2100. Confirmed we will use the one future scenario only for WWL data
10 year and 100-year ARI. Don’t have on hand data for 10 years with climate change so will use 100 year only.
Regional Flood Exposure model (aka T+T): 1%AEP present day and RCP8.5 scenario.
https://gwrc.maps.arcgis.com/apps/webappViewer/index.html?id=255ac9dd590a4d1cb347c56ecbb6376e

</td><td>
EXPOSURE
Intersect depth polygon layers with national buildings database for relevant scenarios (ARI/RCP)
Building Exposure is modified from above (Coastal flooding) to consider both Regional and Local flood modelling. Exposure score to be max score (per building) of either model’s score (as below). This means the building exposure is essentially the regional model (considered to be more conservative and hence deeper) with additional areas flooded by the more detailed WWL model.
<table>
<tr><th></th><th></th><th></th><th></th><th>WWL and KCDC flood model</th><th>T+T model</th></tr>
<tr><td>Riskscape</td><td>Riskscape</td><td>Riskscape</td><td rowspan="2">Correlate to a flood depth</td><td rowspan="2">Score</td><td rowspan="2">Score</td></tr>
<tr><td>Damage state</td><td>Description</td><td>Damage Ratio</td></tr>
<tr><td>DS0</td><td>Insignificant</td><td>0 to 0.02</td><td><15mm</td><td>0</td><td>0</td></tr>
<tr><td>DS1</td><td>Light - non-structural damage or minor non-structural damage</td><td>0.02 to 0.1</td><td>15mm to 100mm</td><td>1</td><td>1</td></tr>
<tr><td>DS2</td><td>Moderate - repairable structural damage</td><td>0.1 to 0.5</td><td>100mm to 1400mm</td><td>2</td><td>2</td></tr>
<tr><td>DS3</td><td>Severe - Irreparable</td><td>0.5 to 0.95</td><td>1400mm to</td><td>3</td><td>3</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>Domain</th><th>Prioritised Risk</th><th>Element at Risk Data</th><th>Climate Data</th><th>Impact Assessment (Quantitative and / or Qualitative)</th></tr>
<tr><td></td><td></td><td></td><td></td><td>
<table>
<tr><td></td><td>structural damage</td><td></td><td>3000m m</td><td></td><td></td></tr>
<tr><td>DS4</td><td>Collapse - Structural integrity fails</td><td>> 0.95</td><td>>30000 mm</td><td>4</td><td>4</td></tr>
</table>
Note: Exposure score = max of exposure score for each building for each flood model.
Building vulnerability scored as above for coastal flooding (#BD30)
<u>Limitations:</u>
The Local (WWL/KCDC) and Regional flood models were developed for different purposes and include different physical features and model assumptions. Disclaimers are included in The Impact Viewer tool.
Both model sources have a present day 100-year ARI flood scenario, and a single Climate change scenario. However, the CC scenarios are different (local = 20% rainfall RCP4.5 increase + 1m SLR, regional = RCP8.5+ including storm surge). Using different future scenarios is a limitation but there is no alternative data which provides a regional perspective of climate change projections.
Tool Output:
Zonation: high level zoning of commercial, residential, industrial and show as proportion of exposed buildings by different zone types.
Building Use: Buildings exposed/not exposed for known building use types - specifically the sensitive receptors (supermarket, school, religious facility, hospital).
Private / Public use: Proportion of exposed buildings by public or private ownership.
Risk Impact Score: # buildings in risk categories 1 – 4.</td></tr>
<tr><td>Human #HD84, HD86</td><td>Cultural heritage and coastal and pluvial flooding and coastal erosion</td><td>Cultural heritage sites in each district plan</td><td></td><td>Qualitative assessment in Final Report. High-level description of some potential impacts and/or considerations based on Qualitative Assessment e.g. possible social, cultural implications. The impact description is non-exhaustive and does not reflect engagement or views of mana whenua.</td></tr>
<tr><td>Human #HD30, HD32</td><td>Social cohesion and coastal and pluvial flooding and coastal erosion</td><td></td><td></td><td>Qualitative description of the considerations for these impacts (e.g. who is most impacted) developed and included in Final Report.</td></tr>
<tr><td>Human #HD50, HD48, HD47</td><td>Existing inequalities and coastal and pluvial flooding and coastal erosion</td><td></td><td></td><td>Qualitative description of inequities and how these may be exacerbated by climate change. This is high level for most places.</td></tr>
<tr><td>Natural Environment #ND66</td><td>Vulnerable coastal ecosystems (dunes, saltmarsh, coastal turf, mm haul outs) and SLR / storm surge</td><td></td><td></td><td>Qualitative description of vulnerable ecosystems (dunes, saltmarsh, coastal turf, coastal wetlands) and how these may be impacted by SLR / stormsurge.</td></tr>
<tr><td>Natural Environment #ND19</td><td>Forest and temperature change</td><td></td><td></td><td>Qualitative discussion about temperature effects on temperate forests and what this might mean for critically endangered areas in Wellington region.</td></tr>
</table>

Domain	Prioritised Risk	Element at Risk Data	Climate Data	Impact Assessment (Quantitative and / or Qualitative)
Economic #ED33, ED13, ED23 – grouped to primary industry	Primary industry and dry spells			Digital tool shows primary industry land uses. Qualitative discussion in Final Report about drought impacts on viticultural, horticulture, agriculture.
Economic ED4	Risk to forestry due to increasing fire–weather conditions: harsher, prolonged season			No data on fire weather so will feature a qualitative discussion under droughts / dry days climate hazard and in relation to economy what potential impacts maybe. Qualitative discussion in Final Report and narrative in tool on main considerations of fire risk to forestry in terms of GDP and potential impacts and opportunities to consider. Cascading impacts from international influence discussed.
Economic ED116 / Built BD30	Risk to manufacturing / industrial land due to coastal and estuarine flooding	• Industrial zoned land (Council District Plans) • New Zealand business demography statistics: February 2022 (Stats NZ) • C Manufacturing category	• Refer #BD30	

Beca

www.beca.com