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Climate Change Guideline: Integrated Catchment Management

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Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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1 Introduction

The climate is changing. While climate change is a natural process, increased greenhouse gas concentrations are projected to exacerbate the drivers of our climate in ways that may be irreversible. Even if significant global action is taken now to reduce greenhouse gas concentrations, a degree of climate change is inevitable in our lifetime.

Experts agree that there is no longer any doubt that the Earth's climate is warming. Nationally and internationally 2016 has been recorded as the warmest on record. Despite the cooling effects of a strong La Niña, 2011 was globally the ninth warmest year since 1880, reinforcing a trend which shows that nine of the 10 warmest years on modern record happened after 2000.

Climate change is often described as the biggest challenge we face. The effects of climate change carry tough economic and social implications for central government, councils and communities, with increased risks to settlements, infrastructure and ecosystems from rising seas, storms and flooding.

New Zealand, as a country heavily dependent on agriculture and tourism for its revenue, can expect to be affected by even small changes in climate. There is uncertainty in what climatic changes will occur over future decades. The uncertainty is due to both levels of future greenhouse gas emissions and incomplete knowledge about the processes governing climate and natural climate variability. However, the trend of change is well accepted.

Thus, councils and communities need to give serious consideration to the potential future impacts of climate change on their functions and services. Particularly important are infrastructure and developments that will need to cope with climate conditions in 50–100 years' time. Climate change may also bring opportunities to which councils and communities may need to respond.

For the Waikato Regional Council's (WRC) Integrated Catchment Management Directorate (ICM) the potential impacts of climate change need to be considered across almost all areas of business. Core ICM functions in relation to flood scheme maintenance and management, catchment management, biosecurity and biodiversity, drainage and the provision infrastructure along coastlines will all be impacted by climate change.

1.1 Purpose

The purpose of this Climate Change Guideline (CCG) is to assist ICM staff in planning for climate change adaptation in relation to the many and varied operational activities delivered through the Directorate. The document builds on climate change related work that has been completed and/or is underway within the WRC, and will assist in further co-ordinating efforts internally.

The CCG includes the following:

- A set of guidelines (in line with statutory requirements) that ICM will adopt and apply in addressing the challenge of climate change adaptation.
- A summary of key national and regional policy guidance to assist staff when planning for adaptation.
- A summary of the projected effects of climate change on the Waikato Region and the key areas of impact in relation to ICM activities, as guide to key planning considerations.
- Adopted numerical values and thresholds to inform modelling and scenario analysis.
- An assessment framework, consistent with national guidance, to support staff decision making in reference to climate change adaptation.
- A programme of actions for the Directorate over the next 3 years to embed climate change adaptation planning into business as usual.

1.2 Scope

The CCG is focussed on climate change adaptation actions. Adaptation refers to addressing the impacts of climate change. Adaptation involves taking practical actions to manage risks from climate impacts, protect communities and strengthen resilience. Adaptation is required on one hand to consider long-term changes to secure long term protection from climate change. On the other hand, it needs to deal with new or more often extreme events in the short term (hazard/disaster management).

Adaptation is distinct from mitigation. Mitigation means dealing with the drivers of climate change by reducing greenhouse gas emissions. The CCG does not include any WRC actions in relation to climate change mitigation. However, WRC is working on initiatives that mitigate climate change and seek to reduce emissions.

The CCG applies on a regional basis and is most applicable to the following ICM business areas:

- Catchment Management - including sustainable land management advisory services, soil conservation and river management activities.
- Flood protection - including provision of infrastructure and maintenance of flood management schemes.
- Land drainage - including provision of infrastructure and maintenance of land drainage schemes.
- Asset Management – setting standards, performance, levels of service.
- Emergency and hazard management – managing hazard threats and responding to natural hazard events.
- Biosecurity – pest management.
- Biodiversity – maintaining and enhancing indigenous biodiversity within the Region.

The CCG has been developed using published research and climate change guidance available nationally and internationally. The development of the CCG has not undertaken primary climate change research and does not seek to vary from the accepted national policy framework.

ICM staff with a range of expertise in climate change science and adaptation actions have had significant input into the development of the CCG and the work programme contained within.

1.3 Assumptions

The following assumptions have informed the development of this guideline:

- ICM acknowledge the risks and potential impacts of climate change to its activities, based on current science and projections.
- ICM accepts the climate change projections set out in Central Government guidance.
- The guideline is based on current Central Government projections.
- Central Government will continue to take the lead on advising Regional Councils of the latest climate change projections relevant for NZ.
- WRC's key stakeholders and communities will continue to engage in climate change and understand the associated risks.

1.4 Status and strategic fit

The CCG is a non-statutory document developed to support the implementation of statutory policies, objectives and methods in relation to climate change contained within the Regional Policy Statement, Regional Plan and Long Term Plan.

The guideline will inform a range of statutory and non-statutory WRC and ICM policy documents. Its relationship to key national and regional policy documents is summarised in Figure 1 below.

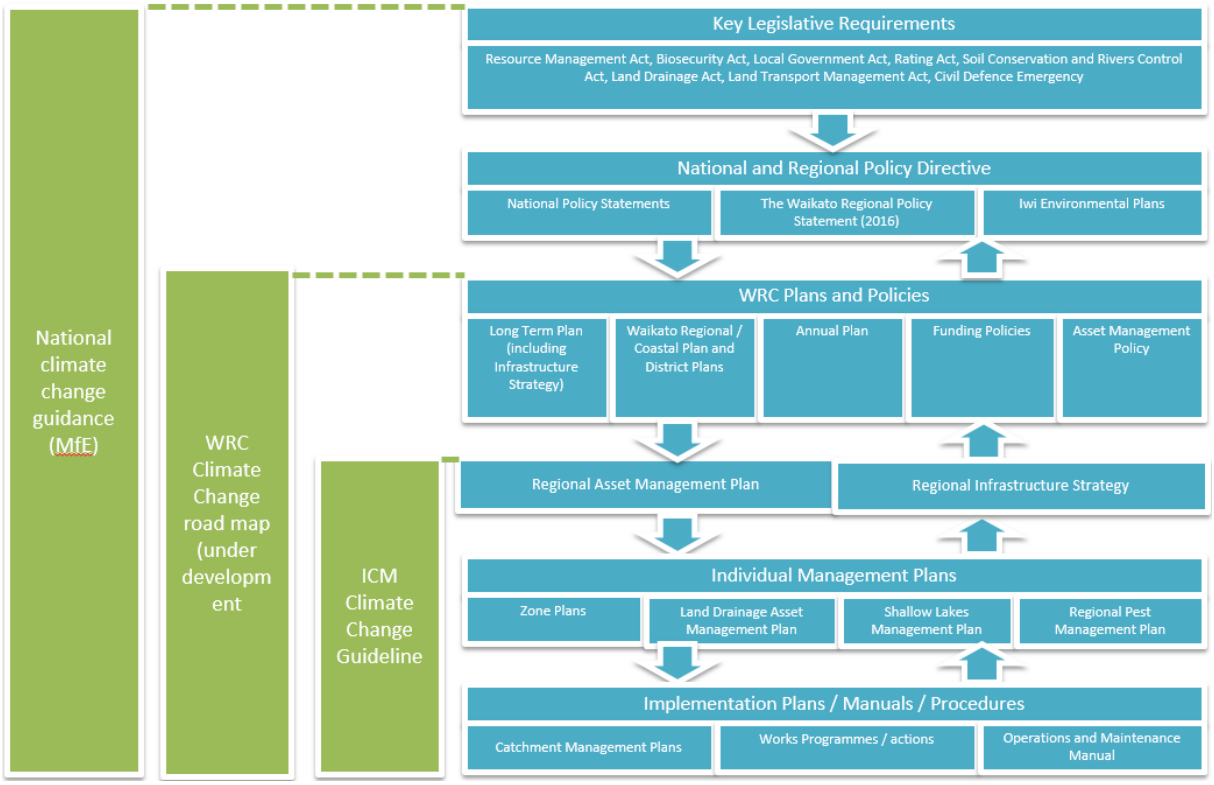

Figure 1: Climate Change Guidance Note – Strategic Fit

2 Principles

ICM will adopt the following guiding principles for climate change adaptation planning through its business:

Adaptive management, planning for uncertainty:
ICM acknowledges that climate change impacts are still uncertain and will continue to take shape over the long term, but that impacts are already emerging. ICM therefore commits to an approach that enables decisions to be made by Council in the face of uncertainty, but has the ability to revise and improve over time. ICM aims to ensure any adaptation approach is one that finds a balance between immediate and long-term needs.

Stakeholder collaboration:
ICM acknowledges the complexity of climate change drivers and impacts means that many stakeholders will need to be engaged to develop a robust approach to managing those drivers and impacts. The coordination of a large number of stakeholders, both within and outside our region can be extremely challenging. ICM is committed to undertaking adaptation initiatives that influence our region.

3 Climate Change Policy Guidance

There is an overwhelming body of national and international research and guidance dedicated to addressing climate change adaptation. This research is often complex, highly technical, and at times, the sheer volume of information can be a barrier to practically addressing climate change adaptation.

Fortunately, New Zealand has a well-focussed body of research regarding climate change adaptation. A summary of key areas of guidance is provided below and direct links to the guidance are provided in section 8 of this CCG.

3.1 Central Government Policy Guidance

The guidance sources below are regarded as the best current source of information. The links to updated or new guidance will be updated and guideline amended as required (refer Section 9). Full hyperlinks to all central government guidance are provided in Section 8 of the CCG.

Guidance Manuals

The Ministry for the Environment (MfE) reviewed the three guidance manuals and their summary publications on adapting to climate change during 2014. The guidance was reviewed in response to significant developments in international science and domestic policy relating to climate change adaptation since the current guidance was published. This guidance is provided in three broad areas described as follows.

Climate change effects and impacts assessment

This guidance provides projections of the expected physical impacts of climate change, both at the national level and for regions around New Zealand.

It is designed to help identify and quantify opportunities and risks that climate change poses for local authorities' functions, responsibilities and infrastructure. It also demonstrates how to incorporate climate risk assessment into local government regulatory, assessment and planning processes to reduce vulnerability to the impacts of climate change.

New climate projections for New Zealand were published in June 2016 to replace the projections in the manual which are now out-of-date. The rest of the manual which provides guidance on how to

interpret and apply the climate projections, undertake risk assessments and incorporate the projections into planning decisions remains relevant to the new set of projections.

Coastal hazards and climate change

This guidance highlights the impacts that climate change is expected to have on coastal hazards. It details the climate change impacts that are expected not only through sea-level rise but also through storm surge, wind and waves.

The publications also discuss a risk management framework in which to consider the consequences of these hazards. An updated version of this guidance is due to be released in late 2017.

Tools for estimating the effects of climate change on flood flow

This guidance details the key effects of climate change on flooding and presents methods for estimating changes in rainfall, flow rates and inundation. It also includes some best practice case studies to illustrate these methods.

The summary publication also provides good practice information, guidance and examples to help local authorities incorporate climate change impacts into flood risk assessments.

3.2 Regional Policy Guidance

3.2.1 Regional Policy Statement

WRC's Regional Policy Statement (WRPS) provides a sound basis for planning for and undertaking climate change adaptation actions.

The WRPS acknowledges the need to manage natural hazards, such as flooding, landslides and large-scale rock/soil mass movements, severe weather events, drought and fire. Climate change will increase the risk from these hazards and make their management even more important.

The key policies within the Regional Policy Statement relevant to climate change adaptation are contained below:

The effects of climate change (including climate variability) may impact our ability to provide for our wellbeing, including health and safety. While addressing this issue generally, specific focus should be directed to the following matters:

a) *increased potential for storm damage and weather-related natural hazards; and*
b) *long-term risks of sea level rise to settlements and infrastructure such as through increased coastal flooding and erosion.*

3.6 Adapting to climate change Land use is managed to avoid the potential adverse effects of climate change induced weather variability and sea level rise on:

a) amenity;
b) the built environment, including infrastructure;
c) indigenous biodiversity;
d) natural character;
e) public health and safety; and
f) public access.

4.1.13 Incorporating effects of climate change

Local authorities should, and regional and district plans shall, recognise and provide for the projected effects of climate change, having particular regard to:

a) historic long-term local climate data;
b) projected increase in rainfall intensity, taking account of the most recent national guidance and assuming a minimum increase in temperature of 2.1°C by 2090 (relative to 1990 levels); and
c) projected increase in sea level, taking into account the most recent national guidance and assuming a minimum increase in sea level of 0.8m by 2090 (relative to 1990 levels).

Note that 4.1.13 b) and c) are minimum values and current guidance on projected temperature and sea level rise shall be used.

3.2.2 WRC Strategic Direction 2016-2019

The Council has recently adopted its strategic direction for 2016-2019 period (https://www.waikatoregion.govt.nz/assets/PageFiles/19184-strategic-direction/5304-Strategic-Direction-DOCUMENT-WEB2.PDF).

The strategic direction sets out the vision, mission and key priorities for Council over the next 3-year governance term and is summarised in Figure 2 below.

Figure 2: Waikato Regional Council Strategic Direction 2016-2019 Summary

The Strategic Direction identifies climate change as a key driver of change in the region as follows:

- REGIONAL RISKS - Our major risks are natural hazards (including flooding), biosecurity incursions and climate change impacts.

Climate change (and the importance of climate change adaptation) is relevant to almost all Council's identified priority areas and the following specific priorities within the Strategic Direction:

- **Support communities to take action on agreed outcomes**
    - Our data and information is more readily accessible so communities can use it to make good decisions.
- **Positively influence future land use choices to ensure long term sustainability**
    - We advocate more strongly for coastal development to take into account natural hazards and predicted impacts of climate change.
- **Increase communities' understanding of risks and resilience to change**
    - We plan and make decisions on land use based on multiple values and benefits, including economic and non-economic.
    - We are all better informed of risks and drivers for change affecting communities.
    - We more actively reduce long term risks to communities from storm damage and weather-related natural hazards; and long term risks of sea level rise to settlements and infrastructure.
    - If shown to be feasible, we create an entity in partnership with others to buy land, enter into joint ventures and incentivise good land use practices so land use can be changed to better suit the land's long term sustainability.
- **Enhance the value of the region's coasts and marine area**
    - We play an active role in implementing SeaChange.

3.2.3 WRC climate change adaptation roadmap (under development)

WRC is preparing a comprehensive Climate Change Response Roadmap. It will include existing statutory adaptation responsibilities in the support of communities and the exercise of resource allocation decisions. It will also identify opportunities available by leveraging central government policy tools, in particular the increasing price for Carbon to effect land-use change that contributes to core functions of achieving biodiversity, catchment security and freshwater quality objectives. It will build upon existing information, and integrate with current work programs to identify gaps in knowledge and opportunities for action to create the conditions for a low-emission regional economy. The content of this CCG has taken account of the development of the roadmap and is consistent with its proposed direction.

4 Regional Climate Change Effects

In planning adaptation actions, ICM accepts the climate change impacts as currently projected at a national level. A summary of these projected impacts is set out below.

It is important to note there are still many gaps in knowledge about regional and local detail, along with the uncertainties that exist about future changes in climate. However, the Directorate does not consider this a barrier to pursuing adaptation planning.

4.1 Summary of potential effects

The potential effects of climate change on key areas of ICM business areas are summarised in Figure 3. Further detail on the potential effects is provided is below.

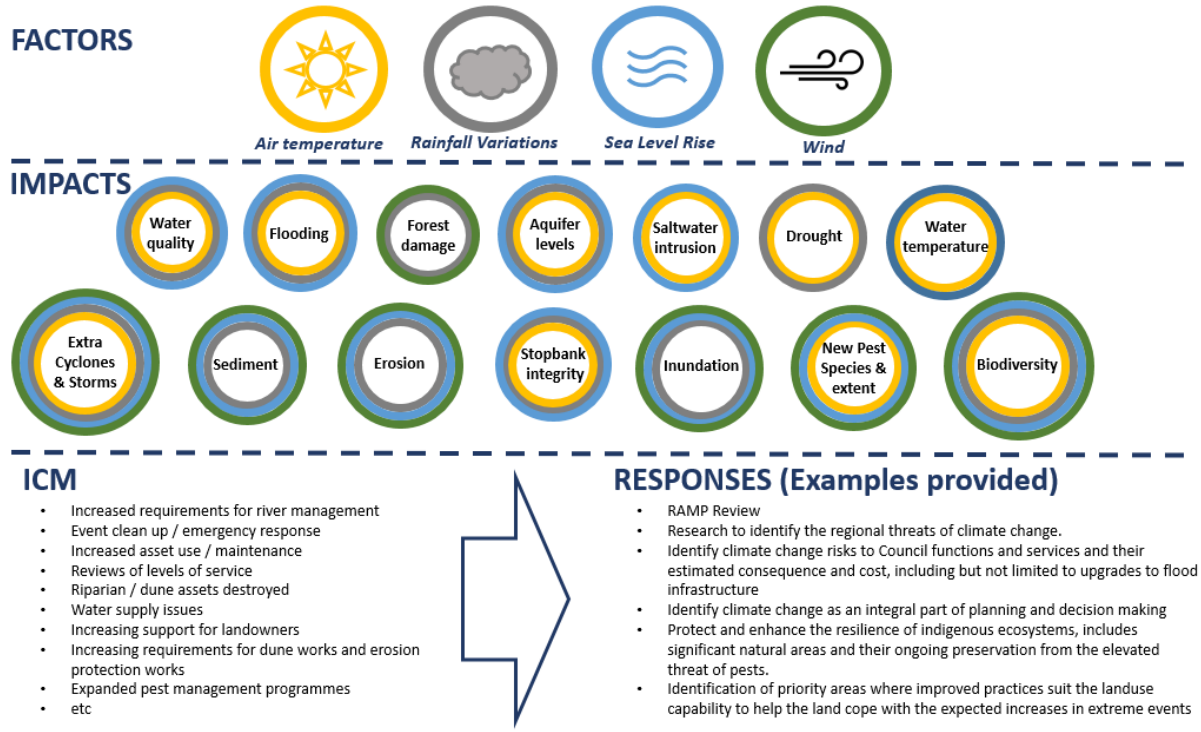

Figure 3: Summary of climate change impacts

Drought – By 2090, the time spent in drought ranges from minimal change through to more than double, depending on the climate model and emissions scenario considered. Parts of the Hauraki district, Matamata and Thames-Coromandel are especially likely to experience increased drought risk. More frequent droughts are likely to lead to water shortages, increased demand for irrigation and increased risk of wild fires.

Flooding – More frequent and intense heavy rainfall will increase the risk of inland flooding.

Coastal Inundation - Rising sea levels and storm surges will increase the risk of inundation of low lying coastal areas. Increased sea levels will also affect river flooding in upper catchments. Water takes from both ground water and rivers near the coast may also be affected by salt water intrusion.

Erosion and landslides – More frequent and intense heavy rainfall events are likely to lead to more erosion and landslides, as much of the soil in the region is volcanic and prone to erosion.

Disease – Tropical diseases may become established in areas where they currently do not exist.

Biosecurity – Warmer, wetter conditions (particularly in the south and west of Waikato) could increase the risk of invasive pests and weeds.

Lakes – Higher temperatures and changes in rainfall are likely to result in higher lake levels, on average, in western and central parts of New Zealand such as Lake Taupo. Warmer water temperatures could lead to more algal blooms, a reduced range of trout and the spread of pest species like carp.

Agriculture – Warmer temperatures, a longer growing season and fewer frosts could provide opportunities to grow new crops. Farmers might benefit from faster growth of pasture and better crop growing conditions. However, these benefits may be limited by negative effects of climate change such as prolonged drought, reduced water availability, increased flood risk, or greater frequency and intensity of storms.

Biodiversity - Higher temperatures and changes in rainfall are likely to result in impacts on biodiversity.

Water quality – extended droughts will mean waters are likely to reduce the volume of flowing waters which will be influenced by groundwater thorough springs and seeps Surface waters are likely to become warmer reducing the ability to contain dissolved gasses (e.g. oxygen) and availability to indigenous biodiversity. This can affect the metabolism of indigenous biota meaning that some contaminants become toxic at lower concentrations.

5 Modelling and scenario testing

The latest climate projections for New Zealand were published by Ministry for the Environment in June 2016 and can be found here:

http://www.mfe.govt.nz/publications/climate-change/climate-change-projections-new-zealand .

Projections are based on modelling and draw heavily on climate model simulations from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

For adaptation modelling and scenario testing purposes ICM will adopt national level projections as produced by MfE. A summary of the projections at a national scale, including thresholds is provided below. Regional projections are contained within Appendix A and should be used for all planning.

Climate change projections are likely to be updated periodically. The information in this document will be updated accordingly (refer Section 9).

5.1 Climate projections to assist modelling

Table 1 provides a summary of projected numerical values and thresholds at a national scale. Detailed regional projections including numerical values for a range of climate change effects are provided in Appendix A to this CCG. The regional projections contained in Appendix A have been adopted for modelling and scenario testing to assist adaptation planning.

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Mean temperature	Progressive increase with concentration. Only for RCP2.6 does warming trend peak and then decline.	By 2040, from +0.7°C [RCP2.6] to +1.0°C [RCP8.5]. By 2090, +0.7°C to +3.0°C. By 2110, +0.7°C to +3.7°C.	Warming greatest at higher elevations. Warming greatest summer/autumn and least winter/spring.

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Minimum and maximum temperatures	As mean temperature.	Maximum increases faster than minimum. Diurnal range increases by up to 2°C by 2090 (RCP8.5).	Higher elevation warming particularly marked for maximum temperature.
Daily temperature extremes: frosts	Decrease in cold nights (minimum temperature of 0°C or lower).	By 2040, a 30% [2.6] to 50% [8.5] decrease. By 2090, 30% [2.6] to 90% [8.5] decrease.	Percentage changes similar in different locations, but number of days of frost decrease (hot day increase) greatest in the coldest (hottest) regions.
Daily temperature extremes: hot days	Increase in hot days (maximum temperature of 25°C or higher).	By 2040, a 40% [2.6] to 100% [8.5] increase. By 2090, a 40% [2.6] to 300% [8.5] increase.	
Mean precipitation	Varies around the country and with season. Annual pattern of increases in west and south of New Zealand, and decreases in north and east.	Substantial variation around the country (see section 3.6.1), increasing in magnitude with increasing emissions.	Winter decreases: Waikato, Gisborne, Hawke's Bay and Canterbury. Winter increases: Nelson, West Coast, Otago and Southland. Spring decreases: Auckland, Northland and Bay of Plenty.
Daily precipitation extremes: dry days	More dry days throughout North Island, and in inland South Island.	By 2090 [8.5], up to 10 or more dry days per year (~5% increase).	Increased dry days most marked in north and east of North Island, in winter and spring.
Daily precipitation extremes: very wet days	Increased extreme daily rainfalls, especially where mean rainfall increases.	More than 20% increase in 99th percentile of daily rainfall by 2090 [8.5] in South West of South Island. A few percentage decrease in north and east of North Island.	Increase in western regions, and in south of South Island. Decrease in extremes in parts of north and east of North Island.
Snow	Decrease.	Snow days per year reduce by 30 days or more by 2090 under RCP8.5.	Large decreases confined to high altitude or southern regions of the South Island.
Drought	Increase in severity and frequency.	By 2090 [8.5], up to 50mm or more increase per year, on average, in July–June PED.	Increases most marked in already dry areas.
Circulation	Varies with season.	Generally, the changes are only a few hectopascals, but the spatial pattern matters.	More northeast airflow in summer. Strengthened westerlies in winter.
Extreme wind speeds	Increase.	Up to 10% or more in parts of the country.	Most robust increases occur in southern half of North Island, and throughout the South Island.
Storms	Likely poleward shift of mid-latitude cyclones and possibly also a small reduction in frequency.	More analysis needed.	See section 3.7.

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Solar radiation	Varies around the country and with season.	Seasonal changes generally lie between -5% and +5%. (See section 3.9.1.)	By 2090 [8.5], West Coast shows the largest changes: summer increase (~5%) and winter decrease (5%).
Relative humidity	Decrease.	Up to 5% or more by 2090 [8.5], especially in the South Island. (See section 3.9.1.)	Largest decreases in South Island in spring and summer.

Table 1: Main features of New Zealand climate change projections (reference: MFE CLIMATE PROJECTIONS FOR NEW ZEALAND JUNE 2016)

5.2 High intensity rainfall projections

NIWA has produced an online tool that estimates rainfall frequency at any point in New Zealand. It can be used to estimate rainfall depths for hydrological design purposes, and to assess the rarity of observed storm events.

The tool is available here https://hirds.niwa.co.nz/.

5.3 Coastal projections

MfE has also produced sea level rise projections for adaptation within coastal areas; Coastal Hazards and Climate Change: A Guidance Manual for Local Government in New Zealand (2008). The latest projections and related commentary from this guidance is provided below. The projections contained in Table 2 have been adopted by ICM for planning purposes in coastal areas.

Baseline sea-level rise recommendations for different future timeframes

Timeframe	Base sea-level rise allowance (m relative to 1980–1999 average)	Also consider the consequences of sea-level rise of at least: (m relative to 1980–1999 average)
2030–2039	0.15	0.20
2040–2049	0.20	0.27
2050–2059	0.25	0.36
2060–2069	0.31	0.45
2070–2079	0.37	0.55
2080–2089	0.44	0.66
2090–2099	0.50	0.80
Beyond 2100	10 mm/year	

Table 2 sourced from Coastal Hazards and Climate Change MfE (2008)

Coastal Hazards and Climate Change: A Guidance Manual for Local Government in New Zealand (2008) Section 2.3 provides guidance on future sea level as follows:

For planning and decision timeframes out to the 2090s (2090–2099):

a. a base value sea-level rise of 0.5 m relative to the 1980–1999 average should be used, along with

b. an assessment of the potential consequences from a range of possible higher sea-level rises (particularly where impacts are likely to have high consequence or where additional future adaptation options are limited). At the very least, all assessments should consider the consequences of a mean sea-level rise of at least 0.8 m relative to the 1980–1999 average. Guidance on potential sea-level rise uncertainties is provided within the Guidance Manual to aid this assessment.

For planning and decision timeframes beyond 2100 where, as a result of the particular decision, future adaptation options will be limited, an allowance for sea-level rise of 10 mm per year beyond 2100 is recommended (in addition to the above recommendation).

It should be noted that the above guidance is due to be updated in 2017. Once available, the revised projections contained within will be adopted by ICM.

WRC has an interactive tool to provide guidance on areas susceptible to sea level rise. The Coastal Inundation Tool is available here: (https://www.waikatoregion.govt.nz/services/regional-services/regional-hazards-and-emergency-management/coastal-hazards/coastal-flooding/coastal-inundation-tool)

6 ICM climate change adaptation framework

The following section provides a summary of a best practice climate change adaptation framework to assist ICM staff in assessing the potential risks climate change and/or determining potential adaptation actions.

6.1 Risk management approach

In New Zealand, a risk management approach to managing climate change risks is promoted. There is a range of guidance as to how to undertake risk assessments for a number of potential climate changes effects (and more specifically for coastal issues).

At a regional and local scale, councils seeking to manage climate change effects using a risk management approach need to understand uncertainties about both the likelihood and consequences that make up the risk.

Adaptation decision making frameworks are therefore based on assessing the scale of risks and possible adaptation that may be required to address the risks identified. The framework described below provides a stepped approach to assessing risk.

6.2 Adaptive management approach

Adaptive management provides an approach to identify possible actions based on scenarios of climate change. The adaptations are based on specific climate change scenarios to provide a range of possible outcomes. To provide more certainty on which climate change scenario and therefore what management outcome is likely, regular reviews and establishment of 'trigger points' will need to be established for the project.

Trigger points identify at what point over the life of the project changes to the climate change adaptation is required.

The key to adaptive management is the transparency of possible adaptation options based on specific scenarios and methodology to reassess and review periodically.

6.3 Framework overview

Figure 4 sets out the six key steps for assessing risk, including climate change, in relation to ICM projects.

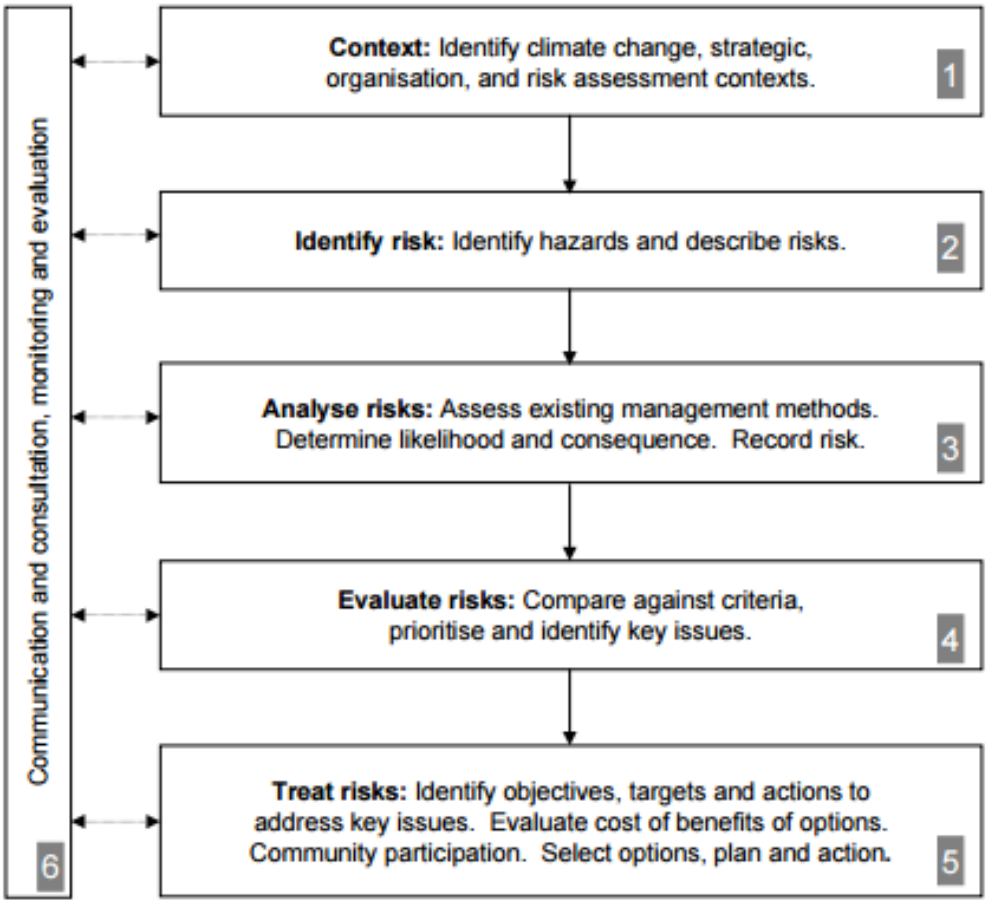

Figure 4: Decision making framework to assess significance (reference MfE)

6.4 ICM climate change assessment framework

As part of assessing context, identifying and analysing risks the significance of the risk needs to be determined. Figure 5 provides a decision making framework to assess whether an activity is likely to be affected in a significant way by climate change risks and whether further analysis maybe required.

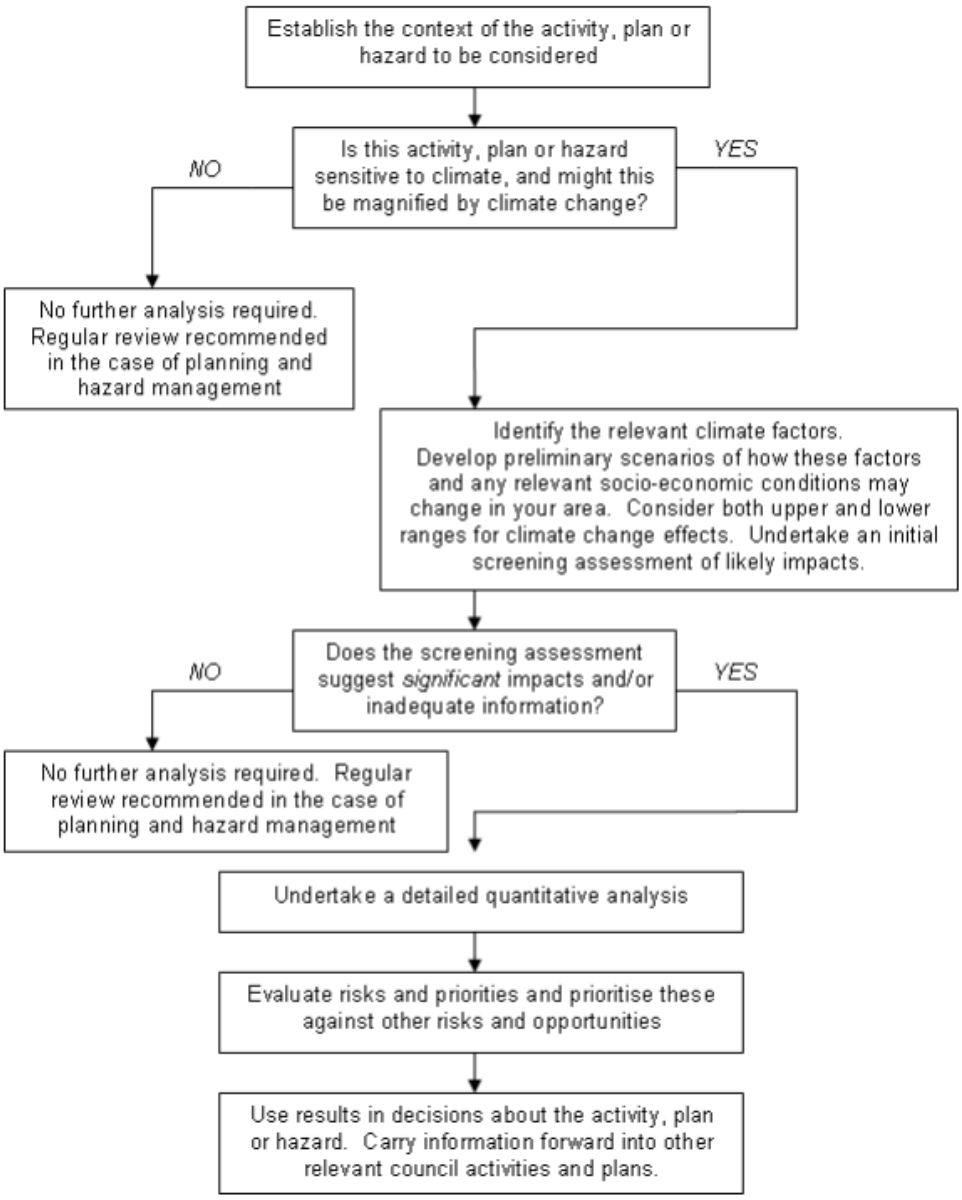

Figure 5: Decision making framework to assess significance (reference MfE)

The first step is to qualitatively identify whether a specific activity, hazard or plan could be significantly affected by climate change. Special consideration should be given to activities, hazards or plans which are vulnerable at present to climate and climate variability.

If a potentially significant climate change effect is identified at this stage, a brief quantitative assessment or 'screening' analysis can be undertaken. This consists of considering the expected climate change effect (for example, a rainfall increase of between 2%-10% by 2030) and any other relevant planning variables that may change over the period in question (for example, a projected population increase of 15% by 2030), to develop scenarios in order to test quantitatively the likely significance of the projected climate change.

From this screening analysis, further analysis can be made as to whether existing planning provisions and/or hazard management responses have a sufficient safety margin to cover any resulting change in risk or resource availability.

If it appears that existing provisions/responses do not adequately cover the future change in risk, a more complex technical risk assessment can be undertaken, followed by an analysis of response options to manage the risk over appropriate timeframes.

6.5 Management Timeframes

An important aspect for all scenario planning are the relevant time horizon/s. For ICM planning purposes 10, 20 and 50 year time horizons are considered to be most important and will be adopted for modelling. Timeframes can be tailored for projects on this basis.

Where risks are determined to be significant (see section 6.6. below), the effects of climate change on a project by project basis shall be assessed at periods of 50 and 100 years as a base line, but further time periods may be included as required, depending on the life of the project. The 50 and 100 year time periods are required to assess the possible impacts of climate change on the project and what adaptive management pathways may need to be identified.

In terms of time frames, each project should set 'review' and trigger point assessment periods. These review periods may already be set in place (i.e. Level of Service reviews). However, as guidance it is suggested that climate change reviews are undertaken in line with national guidance updates.

6.6 Key considerations in relation to significance

When assessing whether climate change is likely to have a **significant** impact on a particular activity, hazard or plan, the following key factors should be taken into account.

1 - Duration of activity. Decisions have a range of implications in terms of time horizons. Climate change should be considered for all climate-sensitive decisions with a long-term horizon (if the effects of the decision will last 30 years or more).

2 - Presence of a particular 'driver'. Any significant investment in infrastructure should be preceded by a risk assessment that includes climate change implications and a cost-benefit analysis. Climate change effects will be factored into infrastructure design where the resulting asset 'life-cycle' costs are less than the expected additional costs from premature retirement of the asset or unprogrammed upgrades. In some situations, the design of new infrastructure may 'lock in' resource requirements in a way that makes later upgrading virtually impossible.

3 - Location of activity. Some locations are particularly vulnerable to climate change. Decisions on significant activities near the coast should consider expected sea-level rise over the next century, as well as other consequential effects such as increased coastal erosion and salt water intrusion into aquifers. Development in flood plains should factor in potentially increased flood frequency and greater peaks.

4 - Extent of activity. Decisions that involve, for example, a small part of an infrastructure asset (unless the latter constrains the rest of the system) are less likely to have fundamental and long-term implications than decisions that affect larger areas. The exception is where a small development sets a precedent, leading to acceptance of subsequent applications.

5 - Nature of activity. An activity may be affected by a single climate variable, or by complex parameters with multiple effects and implications over time. The latter can best be addressed at the policy level, with decision-making applied consistently over time. Relatively general information may be adequate to start policy development and information can be refined over time within a generic policy context. For example, in planning an urban extension, if there are options, low-lying coastal areas should be avoided, and if flood plains are being considered, higher and more frequent floods than in the past should be assumed.

6.7 Further tools of assessment where impacts are significant

In cases where impacts are likely to be significant, more comprehensive analysis will be required.

Key steps include:

1. Identification of areas most vulnerable to climate change through climate and physical modelling.
2. Detailed mapping of high risk areas using multi criteria analysis. Further refinement needs to be included to use the respective climate change scenarios below for SLR, temp and Precipitation.
3. Development of adaptation options.
4. Assessment to determine a preferred option.

Figure 6 provides a guide for further analysis where this is the case.

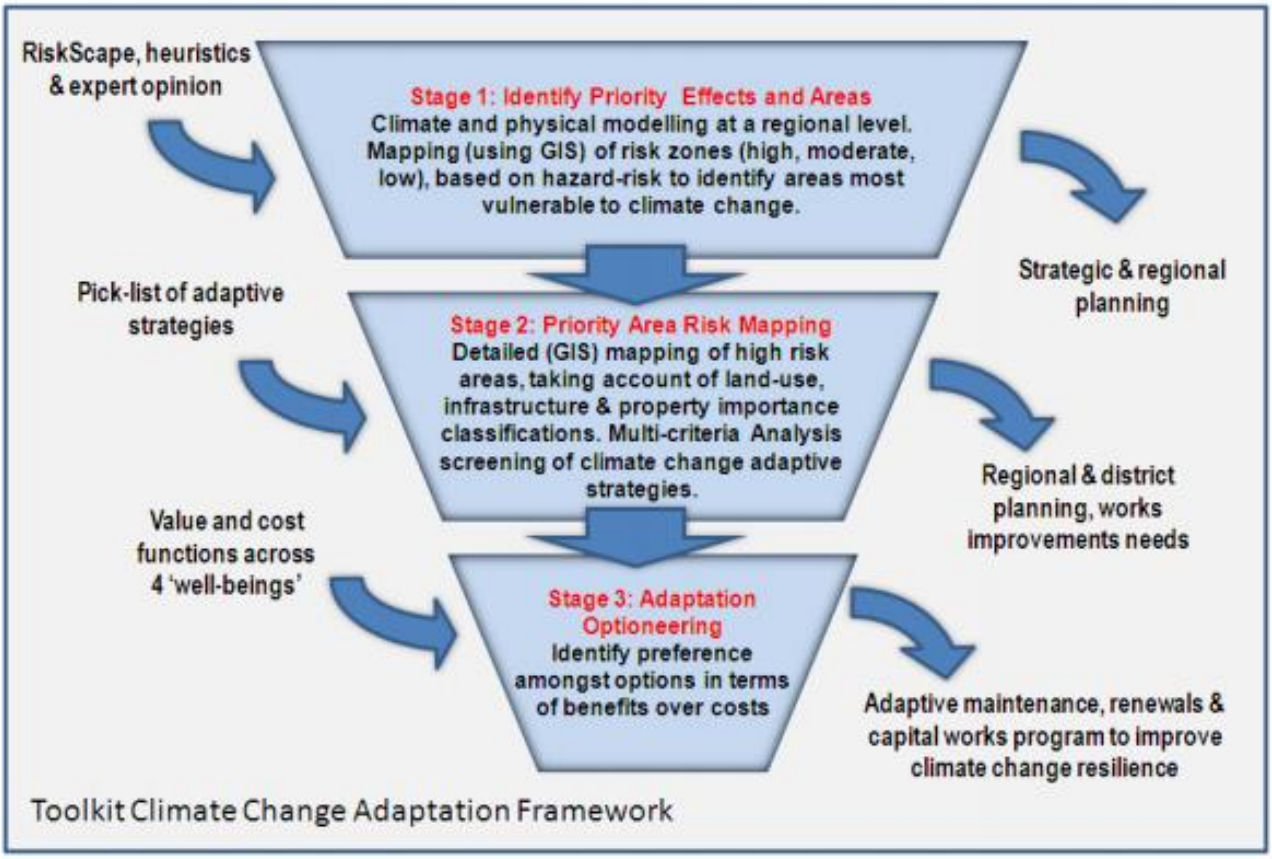

Figure 6: Adaptation framework where impacts are significant

6.8 Potential adaptation responses

Adaptation responses do not need to occur immediately, but needs to be accounted for and enacted when there is clear indication of climate change impacts.

Responses by decision-makers to a changing climate can be classified into eight different categories (also known as 'adaptation measures'). These categories are listed below in descending order from no action to proactive response:

- Bear losses - "Do nothing". The costs of adapting to climate change effects are considered too high in relation to the risk/expected damages.
- Transfer risks / losses - Work with the wider community to share the costs of any losses (i.e. through private insurance schemes, post-hazard reconstruction and rehabilitation of land)

- Modify the threat - Exercise control over the risk e.g. modify flood prevention works or seawalls.
- Prevent effects - Avoid exacerbating/creating new risks by "down-zoning", increasing restrictions/imposing prohibitions to avoid intensification or commencement of at-risk development, and designing assets to cope with future climate conditions.
- Change use - Encourage or require changes in land use away from high-risk use to uses not susceptible to a changing climate.
- Change location - Direct development away from areas susceptible to a changing climate.
- Research - Support research into new technologies to minimise risks from a changing climate and new methods of adaptation.

All of these responses are potentially valid and can be used as a basis for options analysis to determine preferred options for adaptation.

7 ICM Climate Change Work Programme

ICM is proposing to adopt to the following climate change work programme to further embed climate change adaptation planning and decision making across the Directorate over the next three year period.

Four broad programme aims have been identified along with high level actions and proposed implementation timeframes. Where needed, appropriate funding will be sought for the identified actions through the next Long Term Plan cycle (2018-2021).

A Cross Directorate Steering Group will oversee the Implementation Actions that are outlined in table 3. This Steering Group will meet at least four times annually to determine whether the actions are being embedded and delegate the work appropriately.

TABLE 3: Programme of climate change business improvements

Aim	**Actions**	**Status**	**Timeframe to complete**
Embed climate change adaptation considerations into operational planning.	• Advocate for stronger measures to assess climate change drivers and impacts with central government and other relevant parties. • Incorporate climate change priorities into all Council strategies and policies, including providing support to the climate change roadmap development. • Identify a team of climate change champions within ICM to provide technical support and publicise and celebrate climate change resilience success stories in the region to inspire positive behaviour change. • Build climate change adaptation planning framework into PMO function and project criteria.	In progress	Ongoing
Identify climate change risks to functions and services and their estimated consequence and cost, including but not limited to upgrades to flood infrastructure	• Map the major watercourses/floodplains in the region with allowances for climate change based on available data. • Develop a pilot programme within a defined geographic area to gain a greater understanding of the opportunities and risks to the region; communities, economy, key infrastructure and natural resources.	Planned	December 2018

	• Provide cost benefit analysis of the measures to adapt to climate change. Will include consultation with stakeholders, iwi and communities to understand the acceptable level of risk. (RAMP project already includes components of this). • Develop a long term environmental monitoring programmes to assess regional climate change. • Review current staffing levels in anticipation of increased levels of service across all ICM Service Areas.		
Protect and enhance the resilience of indigenous ecosystems, includes significant natural areas and their ongoing preservation from the elevated threat of pests	• Determine ICM priorities through existing programmes and through other pathways, for example, outcomes of Healthy Rivers. • Define biodiversity priorities and specific species threats as a result of climate change and adaptation to climate change.	In progress	December 2018
Identification of priority areas where improved practices suit the land use capability to help the land cope with the expected increases in extreme events	• Identify catchment works and land use practices that will benefit from increased investment to mitigate impacts of extreme events and better suit the land use capability. • Review scheme land for potential retirements/enhancements in advance of sea level rise impacts. • Support the work of local coastal care groups to assist in strengthening and protecting dunes and buffer areas.	Planned	Ongoing

8 Tools to assist planning and decision making

A summary of a range of useful tools to assist adaptation planning and decision making within a New Zealand context is provided below. An Intranet page will be developed for staff to readily access the information.

8.1 Links to national documents and tools

All documents listed below can be found at:
http://www.mfe.govt.nz/climate-change/climate-change-resources/guidance-local-government

Climate change effects and impacts assessment

- Climate change effects and impacts assessment: A guidance manual for local government in New Zealand
- Climate change projections for New Zealand snapshot
- Climate Change projections for New Zealand

Coastal hazards and climate change

- Coastal hazards and climate change: A guidance manual for local government in New Zealand
- Preparing for coastal change: A guide for local government in New Zealand (summary publication)

Tools for estimating the effects of climate change on flood flow

- Tools for estimating the effects of climate change on flood flow: A guidance manual for local government in New Zealand
- Preparing for future flooding: A guide for local government in New Zealand (summary publication)

https://www.gns.cri.nz/Home/RBP/Risk-based-planning/A-toolbox - A toolbox that aims to support risk-based land use policy and plan development in local government. It offers a new approach where consequences of natural hazard events are the focus. It presents techniques, practice steps and options for enabling local government to review multiple natural hazard risks, both within councils and with external stakeholders.

http://www.doc.govt.nz/Documents/science-and-technical/sap257.pdf - This framework focuses on land-based, or predominantly land-based, native species ecosystems and natural processes. It includes freshwater and coastal/estuarine ecosystems.

https://hirds.niwa.co.nz/ - The High Intensity Rainfall Design System is a web-based programme that can estimate rainfall frequency at any point in New Zealand. It can be used to estimate rainfall depths for hydrological design purposes, and to assess the rarity of observed storm events.
NIWA's High Intensity Rainfall Design System (HIRDS) offers planners and engineers more certainty about the frequency of high-intensity rainfalls, enabling them to better design stormwater drainage systems and other structures

8.2 Links to regional documents and tools

A summary of available regional guidance on climate change is provided below.

Ministry for the Environment

http://www.mfe.govt.nz/climate-change/climate-change-resources/resources-regions

Auckland Council
http://www.aucklandcouncil.govt.nz/EN/environmentwaste/naturalhazardsemergencies/hazards/Pages/climatechangehazards.aspx
http://www.aucklanddesignmanual.co.nz/project-type/infrastructure/codes-of-practice/stormwatercodeofpractice/guidance/General/climatechange

Greater Wellington Regional Council
http://www.gw.govt.nz/assets/Climate-change/WGNDOCS-1439979-v1-GWRCDraftClimateChangeStrategy.PDF
Bay of Plenty Regional Council
https://www.boprc.govt.nz/sustainable-communities/climate-change/

8.3 Links to internal documents and tools

The following internal documents

Document/Tool Title	Description	DM reference/link:
Infrastructure strategy 2015-2045 – flood protection and control works	Includes information climate change adaptation in relation to key flood control infrastructure	3233673
Freshwater Strategy (Let's talk about water)	Explores the strategic issues associated with climate change and the impacts within the Waikato Region.	3289404
Impacts of Climate Change on the Waikato Region	Explores the strategic issues associated with climate change and the impacts within the Waikato Region.	3433696
Coastal Inundation Tool	This guidance details the key effects of climate change on flooding and presents methods for estimating changes in rainfall, flow rates and inundation. It also includes some best practice case studies to illustrate these methods.	(https://www.waikatoregion.govt.nz/services/regional-services/regional-hazards-and-emergency-management/coastal-hazards/coastal-flooding/coastal-inundation-tool)

8.4 Staff with expertise in climate change adaptation

The Team Leader, Regional hazards, will maintain a list of WRC staff who will be able to support with information and advice in relation to climate change adaption. This list will be accessible via Intranet link.

The WRC staff will have technical expertise in climate change adaptation and can be contacted to assist in relation to adaptation planning and decision making. The role of these staff is to provide

further guidance to the project lead. They are not intended to be used to undertake specific climate change assessments.

9 Monitoring and review of this document

This document will be reviewed on a three yearly cycle, one year prior to the Long Term Plan process. Updates to the document will also be undertaken as necessary due to staff changes and new or updated guidance from central government. The monitoring of new/updated guidance, staff changes and reviews shall be led or undertaken by the Team Leader of Regional Hazards and Environmental Compliance.

The actions set out within this document requiring funding for the 2018-2021 period are captured within the programme and will be monitored through the individual projects contained within the proposed programme.

Glossary of Terms

Adaptation - adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation (IPCC, 2007).

Anticipatory or proactive adaptation – adaptation that takes place before impacts of climate change are observed.

Autonomous or spontaneous adaptation – adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems.

Planned adaptation – adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Adaptation policy framework/guidelines - a structured process for developing adaptation strategies, policies, and measures to enhance and ensure human development in the face of climate change, including climate variability. The adaptation policy framework is designed to link climate change adaptation to sustainable development and other global environmental issues (UNDP, 2004).

Adaptive capacity (in relation to climate change impacts) - the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007).

Hazards - A physically defined climate event with the potential to cause harm, such as heavy rainfall, drought, flood, storm and long-term change in mean climatic variables such as temperature (UNDP, 2004).

Impacts (climate change) - the effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential impacts and residual impacts (IPCC, 2007).

Potential impacts: all impacts that may occur given a projected change in climate, without considering adaptation. This allows to assess all effects of climate change if no adaptation occurs for a specific sector or area.

Residual impacts: the impacts of climate change that would occur after anticipatory, planned and autonomous adaptation. This would allow to assess the actual need for intervention for a specific sector or area.

Autonomous adaptation residual impacts: impacts that may occur given a projected change in climate, considering only autonomous adaptation. This would allow to assess the actual need for public intervention for a specific sector or area

Indicators - quantitative or qualitative parameters that provide a basis for assessing change, they are logically tied to stated policy goals and chart progress towards policy targets.

Adaptation indicators - A measure of progress towards the implementation of adaptation measures (process-based) or a measure of effectiveness of adaptation policies and activities in general (EEA, 2008)

Index / indices – An aggregate indicator. An index combines several observable variables into one.

Likelihood – See probability

Measure - Technologies, processes, and practices that reduce GHG emissions or effects below anticipated future levels. Examples of measures are renewable energy technologies, waste minimization processes and public transport commuting practices (EEA, 2008).

Policies - Objectives, together with the means of implementation. In an adaptation context, a policy objective might be drawn from the overall policy goals of the country – for instance, the maintenance or strengthening of food security. Ways to achieve this objective might include, e.g., farmer advice and information services, seasonal climate forecasting and incentives for development of irrigation systems (UNDP, 2004).

Probability – the likelihood or possibility of an event or outcome occurring. Probability can range from being qualitative, using word descriptions such as likely or highly confident, to quantified ranges and single estimates, depending on the level of understanding of the causes of events, historical time series and future conditions (UNDP, 2004).

Risk - The combination of the probability of an event and its consequences (UNISDR, 2009). This definition is consistent with that used in ISO/IEC Guide 73. Some climate change glossaries consider vulnerability a part of risk, for example the UNDP guidance defines climate related risk as the result of the interaction of physically defined hazards with the properties of the exposed systems, i.e., their sensitivity or (social) vulnerability. Risk can also be considered as the combination of an event, its likelihood, and its consequences, i.e., risk equals the probability of climate hazard multiplied by a given system's vulnerability (UNDP, 2004).

Sensitivity - the degree to which a system is affected, either adversely or beneficially, by climate related stimuli. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise (IPCC, 2001).

Vulnerability - The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPPC, 2007).

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Regional Projections

For climate change adaptation modelling purposes, the following projections are to be adopted by ICM.

The Representative Concentration Pathways (RCP) scenarios are based on the graph below:

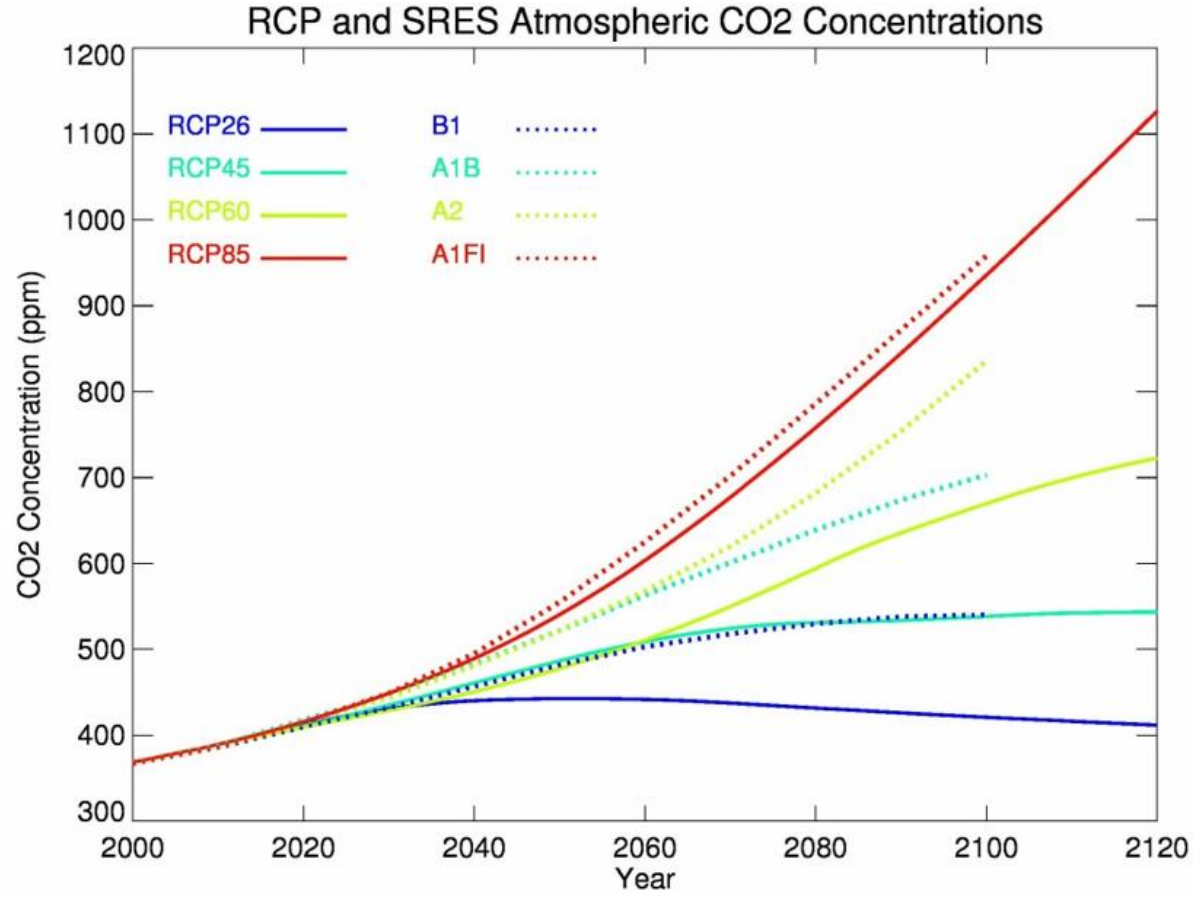

Table A1. Atmospheric carbon dioxide concentrations for the IPCC Fourth Assessment (dotted lines, SRES concentrations) and for the IPCC Fifth Assessment (solid lines, RCP concentrations). Source ('Climate Change Projections for NZ' http://www.mfe.govt.nz/publications/climate-change/climate-change-projections-new-zealand)

Temperature change

Projected temperature Changes for Waikato Region

The following data is from NIWA publication 'Climate Change Projections for NZ' http://www.mfe.govt.nz/publications/climate-change/climate-change-projections-new-zealand

Table 5: Projected changes in seasonal and annual mean temperature (in °C) between 1986–2005 and 2031–2050, by region, as derived from statistical downscaling. The changes are given for four

RCPs (8.5, 6.0, 4.5 and 2.6), where the ensemble-average is taken over (41, 18, 37, 23) models respectively

The values in each column represent the ensemble average, and in brackets the range (5th percentile to 95th percentile) over all models within that ensemble.

Region		Summer	Autumn	Winter	Spring	Annual
Waikato						
	rcp 8.5	1.1 (0.5, 1.8)	1.1 (0.7, 1.6)	1.1 (0.7, 1.5)	0.9 (0.5, 1.3)	1.1 (0.6, 1.6)
	rcp 6.0	0.9 (0.4, 1.6)	0.9 (0.4, 1.2)	0.8 (0.4, 1.2)	0.7 (0.2, 1.2)	0.8 (0.3, 1.2)
	rcp 4.5	0.9 (0.4, 1.5)	0.9 (0.4, 1.4)	0.9 (0.6, 1.3)	0.8 (0.4, 1.1)	0.9 (0.5, 1.3)
	rcp 2.6	0.8 (0.3, 1.3)	0.8 (0.3, 1.2)	0.7 (0.3, 1.0)	0.7 (0.3, 1.1)	0.7 (0.3, 1.1)

Table 6: As Table 5, but for projected changes between 1986–2005 and 2081–2100. Also included are the 2081–2100 annual global projections from the IPCC (Collins et al, 2013)

Region		Summer	Autumn	Winter	Spring	Annual
Waikato						
	rcp 8.5	3.3 (2.2, 5.3)	3.2 (2.3, 4.5)	3.1 (2.4, 4.0)	2.7 (2.0, 3.5)	3.1 (2.3, 4.4)
	rcp 6.0	2.0 (1.1, 3.8)	2.0 (1.1, 2.9)	1.9 (1.2, 2.6)	1.7 (1.0, 2.3)	1.9 (1.2, 2.9)
	rcp 4.5	1.5 (0.7, 2.7)	1.5 (0.8, 2.2)	1.5 (0.9, 2.0)	1.3 (0.8, 1.8)	1.4 (0.9, 2.1)
	rcp 2.6	0.7 (0.2, 1.4)	0.7 (0.3, 1.4)	0.7 (0.4, 1.3)	0.6 (0.2, 1.1)	0.7 (0.4, 1.3)

Table 7: As Table 5, but for projected changes between 1986–2005 and 2101–2120

No results are shown for RCP6.0 because only two models in the NIWA CMIP5 archive have data available beyond 2100 for this RCP (see Table 2).

Region		Summer	Autumn	Winter	Spring	Annual
Waikato						
	rcp 8.5	4.2 (2.9, 6.2)	4.0 (3.0, 5.8)	3.7 (2.8, 4.7)	3.3 (2.6, 4.3)	3.8 (2.9, 5.2)
	rcp 6.0					
	rcp 4.5	1.8 (1.0, 3.1)	1.8 (1.2, 2.4)	1.6 (1.0, 2.2)	1.5 (0.9, 2.2)	1.7 (1.1, 2.3)
	rcp 2.6	0.7 (-0.1, 1.6)	0.8 (0.3, 1.4)	0.7 (0.4, 1.1)	0.7 (0.4, 1.1)	0.7 (0.4, 1.3)

Precipitation Change

Projected precipitation Changes for Waikato Region.
Note that extreme rainfall projections should use the Hirds tool (https://hirds.niwa.co.nz/) with the respective projected temperature changes.

The following data is from NIWA publication 'Climate Change Projections for NZ' http://www.mfe.govt.nz/publications/climate-change/climate-change-projections-new-zealand

Table 10: Projected changes in seasonal and annual precipitation (in percentage) between 1986–2005 and 2031–50, by region, as derived from statistical downscaling. The changes are given for four RCPs (8.5, 6.0, 4.5 and 2.6), where the ensemble-average is taken over (41, 18, 37, 23) models respectively

The values in each column represent the ensemble average, and in brackets the range (5th percentile to 95th percentile) over all models within that ensemble.

Region		Summer	Autumn	Winter	Spring	Annual
Waikato						
Ruakura						
	rcp 8.5	1 (-9, 12)	0 (-8, 8)	4 (-6, 13)	-2 (-11, 6)	1 (-5, 5)
	rcp 6.0	0 (-14, 13)	1 (-9, 11)	4 (-6, 12)	-1 (-7, 5)	1 (-3, 5)
	rcp 4.5	0 (-11, 9)	0 (-9, 7)	4 (-7, 14)	0 (-9, 8)	1 (-4, 6)
	rcp 2.6	0 (-6, 11)	1 (-7, 9)	3 (-5, 12)	0 (-8, 7)	1 (-3, 7)
Taupo						
	rcp 8.5	1 (-9, 12)	1 (-5, 8)	4 (-7, 13)	-3 (-11, 5)	1 (-3, 5)
	rcp 6.0	1 (-11, 16)	2 (-6, 9)	4 (-8, 13)	-2 (-9, 6)	1 (-2, 6)
	rcp 4.5	1 (-8, 10)	1 (-6, 9)	3 (-8, 12)	-1 (-8, 9)	1 (-3, 5)
	rcp 2.6	1 (-5, 12)	1 (-7, 7)	2 (-4, 9)	-1 (-9, 6)	1 (-4, 6)

Table 11: As Table 10, but for changes between 1986–2005 and 2081–2100

Region		Summer	Autumn	Winter	Spring	Annual
Waikato						
Ruakura						
	rcp 8.5	3 (-16, 23)	-3 (-16, 9)	5 (-10, 17)	-6 (-20, 4)	0 (-11, 7)
	rcp 6.0	4 (-18, 24)	2 (-13, 36)	8 (-10, 35)	-1 (-11, 9)	3 (-10, 26)
	rcp 4.5	2 (-13, 15)	1 (-8, 10)	4 (-7, 16)	-2 (-9, 7)	1 (-5, 7)
	rcp 2.6	2 (-6, 14)	2 (-7, 9)	4 (-4, 14)	2 (-5, 8)	3 (-3, 11)
Taupo						
	rcp 8.5	8 (-4, 26)	1 (-13, 11)	6 (-7, 18)	-6 (-20, 4)	2 (-7, 10)
	rcp 6.0	2 (-20, 22)	3 (-8, 13)	7 (-9, 23)	-3 (-12, 5)	2 (-7, 12)
	rcp 4.5	2 (-4, 13)	2 (-6, 11)	4 (-8, 13)	-2 (-9, 6)	2 (-4, 7)
	rcp 2.6	0 (-11, 10)	2 (-6, 9)	4 (-3, 12)	1 (-8, 7)	2 (-5, 8)

Table 12: As Table 10, but for changes between 1986–2005 and 2101–10

Region		Summer	Autumn	Winter	Spring	Annual
Waikato						
Ruakura						
	rcp 8.5	-2 (-28, 32)	-6 (-27, 9)	5 (-6, 24)	-7 (-18, 5)	-2 (-14, 11)
	rcp 6.0					
	rcp 4.5	2 (-13, 15)	-2 (-10, 6)	6 (-5, 16)	-1 (-9, 12)	1 (-5, 10)
	rcp 2.6	3 (-7, 15)	-1 (-5, 4)	4 (-4, 12)	1 (-2, 3)	2 (-1, 7)

Region		Summer	Autumn	Winter	Spring	Annual
Taupo						
	rcp 8.5	5 (-22, 37)	-1 (-20, 10)	5 (-7, 25)	-9 (-21, 7)	0 (-14, 12)
	rcp 6.0					
	rcp 4.5	3 (-8, 12)	0 (-9, 8)	6 (-6, 15)	-2 (-15, 12)	2 (-4, 10)
	rcp 2.6	2 (-8, 9)	-1 (-4, 8)	4 (-4, 12)	0 (-8, 6)	2 (-2, 6)