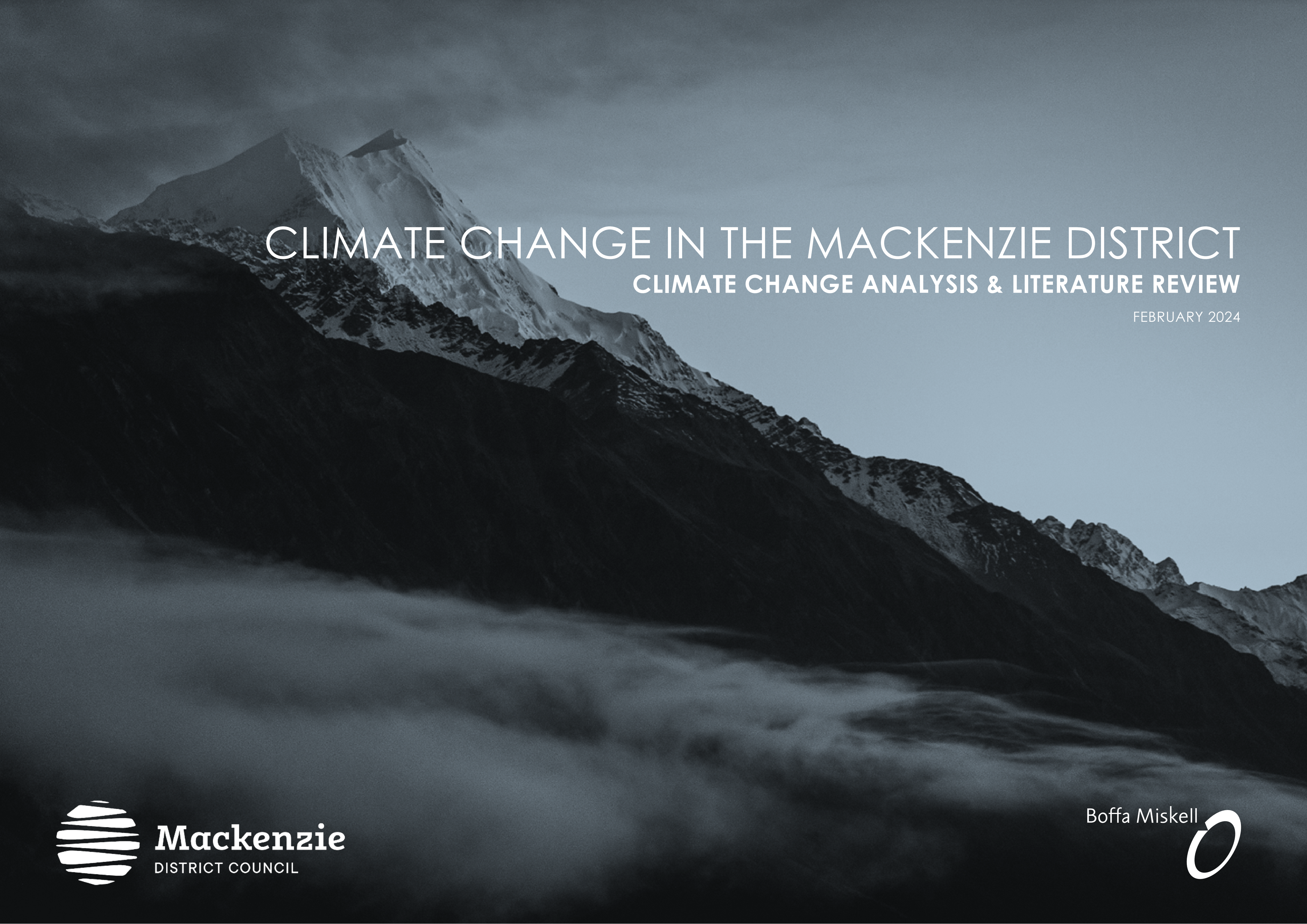

CLIMATE CHANGE IN THE MACKENZIE DISTRICT

CLIMATE CHANGE ANALYSIS & LITERATURE REVIEW

FEBRUARY 2024

Mackenzie DISTRICT COUNCIL

Boffa Miskell

DOCUMENT QUALITY ASSURANCE

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Cover photograph: Aoraki Mount Cook National Park, © Miles Holden

MACKENZIE DISTRICT CLIMATE 2100

Projected climate changes in the Mackenzie District by 2100 compared to present day

TEMPERATURE

Annual mean temperature is projected to increase across the Mackenzie District by 0.9-3.4°C

HOT DAYS ≥ 25°C

The number of hot days above 25°C experienced in the Mackenzie District (excluding Aoraki Mt. Cook area) will increase by 9 to 52 additional days on average, with Twizel projected to experience the highest number of hot days annually

DROUGHT

Drought potential is likely to increase across the Mackenzie basin and Fairlie (excluding Aoraki Mt. Cook area), with severely dry and extremely dry conditions projected to increase.

FIRE

Wildfire risk conditions are projected to increase within the Mackenzie District, both in the expected length of the fire season and the intensity of the fires that may take hold

SNOW + ICE

Snow and ice coverage in alpine environments within the Mackenzie District are projected to shrink and retreat, with glacier ice volume projected to reduce by 50-90%

FROST DAY ≤ 0°C

The number of days below 0°C experienced in the Mackenzie District is projected to decrease by 19 and 74 days on average, with Aoraki Mt. Cook area expected to experience the most significant decrease in days annually

EXTREME RAINFALL

Extreme rainfall events are likely to become more frequent and intense across the Mackenzie District, with rainfall depths received over a 24-hour period during a one-in-100-year storm event projected to increase by 6-23%

GROWING DEGREE DAYS

Growing degree days across the Mackenzie District are expected to increase with base threshold temperature conditions for good pasture growth (4°C and 10°C) likely to occur more frequently

CONTENTS

INTRODUCTION

PURPOSE

The Mackenzie District can thrive in the coming decades if it takes action to adapt its people, its places, and its economic and cultural assets to the impacts of climate change, starting now.

The purpose of this report is to detail the projected climate change scenarios and impacts for the Mackenzie District. The key outcomes include:

- Analysis of the projected physical climate change hazards for the Mackenzie District
- Analysis of the transitional climate-related hazards for the Mackenzie District
- Assessment of the potential climate-related impacts and implications for the Mackenzie District

Understanding the physical and transitional impacts that climate change will have on the Mackenzie District under different scenarios is important to ensuring actions taken today are responsive and remain resilient in a changing environment. This Climate Change Analysis and Literature Review for the Mackenzie District will support the development of a climate change response strategy, providing a climate change lens to inform decision making and action in the Mackenzie District across the coming decades.

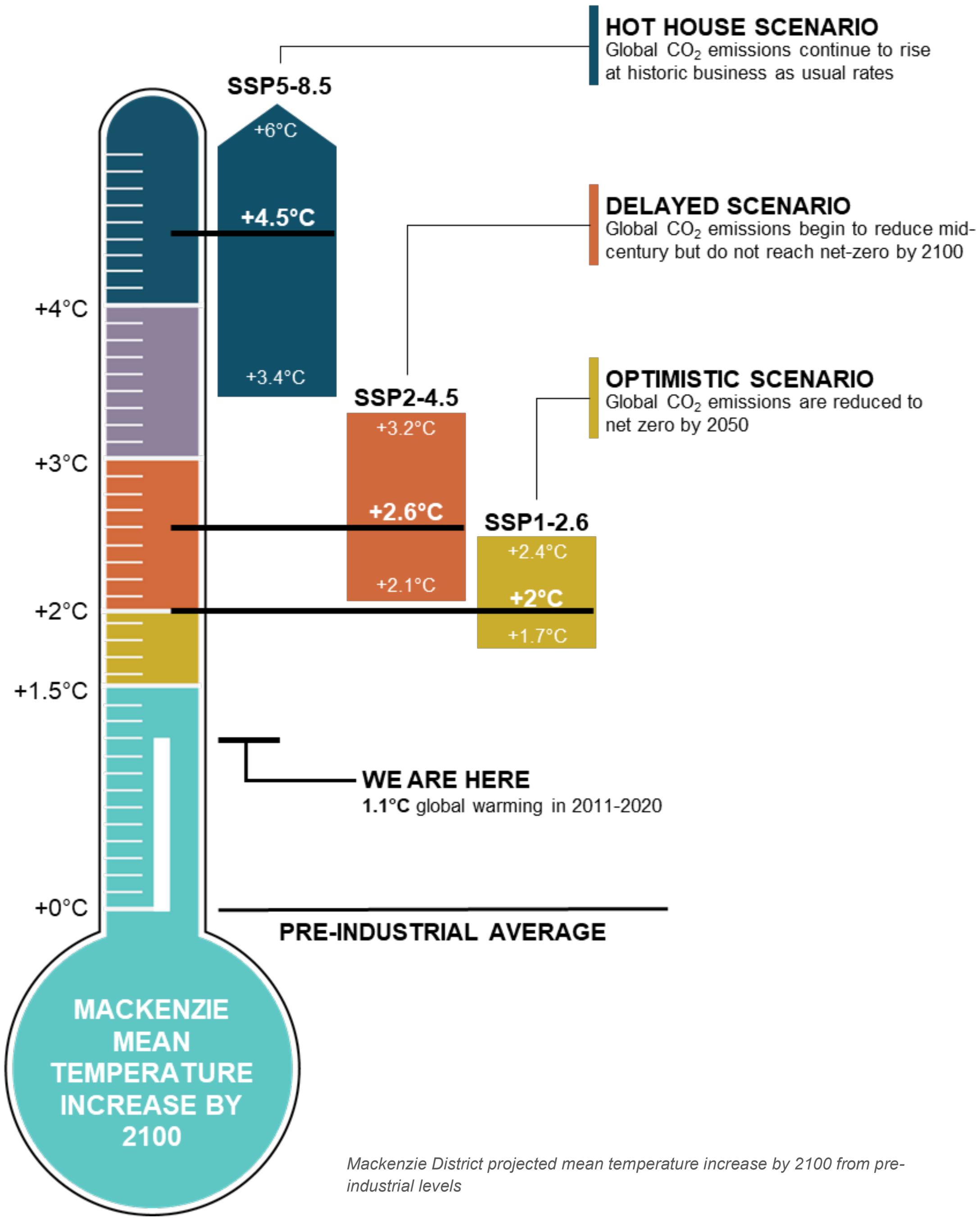
OUR CHANGING CLIMATE

The impacts and challenges of climate change is here, in the Mackenzie District, now. As the century progresses, the effects of climate change will grow

Globally, human activities, principally through the emission of greenhouse gases, have unequivocally caused global warming of 1.1°C above pre-industrial levels. Widespread and rapid changes in the atmosphere, water, and land continue to occur resulting in more frequent and more intense extreme weather events in every region of the world.[1]

Deep, rapid, and sustained greenhouse gas emission reductions must be achieved within this decade to limit global warming to 1.5°C or 2°C. However, current national and international climate change mitigation policies and laws continue to fall short of the emission reduction pathways required, making it likely that global warming will exceed 1.5°C during the 21st century and making it far harder to limit warming below 2°C. Every increment of global warming will continue to intensify hazards across all environments, sectors, and communities.

Climate change modelling shows a future for the Mackenzie District that is generally warmer and more volatile. Regardless of actions to reduce emissions today, our environment will continue to warm throughout the 21st century along with other changes in our climate. Warming will continue to drive more intense and frequent extreme rainfalls, decreasing snow and ice in alpine zones, and more regular heatwave and drought events.



Mackenzie District projected mean temperature increase by 2100 from pre-industrial levels

GEOGRAPHIC SCOPE

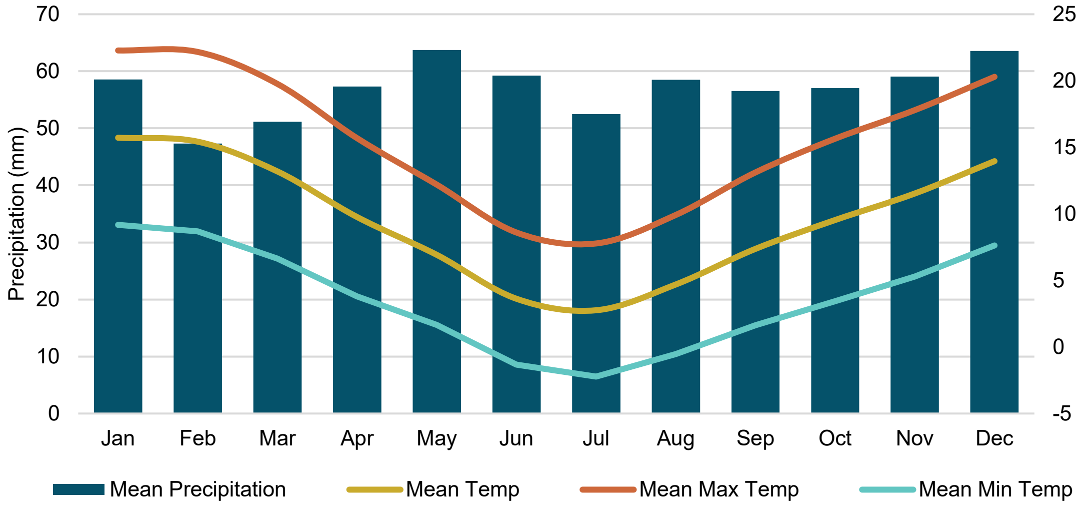
The Mackenzie District is a vast and varied landscape with nationally significant alpine and dryland environments. Covering an area of 7,339km², the district's boundaries stretch from the Hopkins and Ohau rivers in west, up to the Two Thumbs Range and Ōpihi River Catchment in the east. The district has strong and distinctive communities and is home to over 5,100 people. For Te Rūnanga O Ngāi Tahu and Papatipu Rūnanga, the Mackenzie District provides a deep cultural connection through a long line of whakapapa and history.

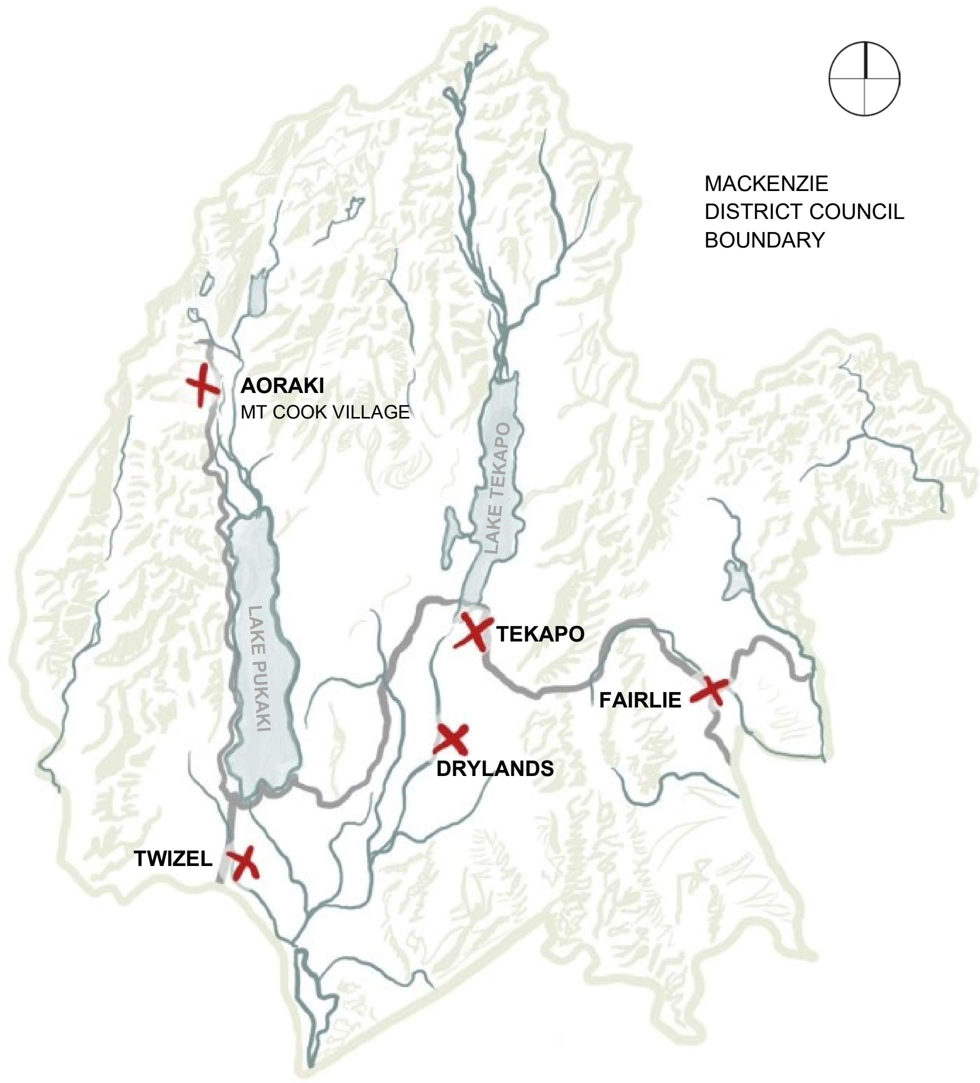
As a large inter-montane basin, the present-day climate of the Mackenzie District is dominated by the influence of the Southern Alps. With the Southern Alps receiving heavy rainfall from the west, Aoraki Mount Cook National Park receives the highest average rainfalls each year, and with the village located approximately 750m above sea level, experiences cooler temperatures than the rest of the district, with snow and frost frequent during winter and early spring.

The Mackenzie basin and eastern Mackenzie district, with the 'rain shadow' effect of the Southern Alps, is comparatively drier with average rainfalls between 600-700mm. Summer months in the basin are typically mild, with maximum summer temperatures averaging between 20-22°C presently. Winters are cold, with snow and frost conditions experienced regularly. Winter temperatures across the basin at present average between 2-5°C, with minimum temperatures usually falling below 0°C overnight.

To assess the current and future climate of the Mackenzie Basin, climate change projections were generated for five representative locations across the district as illustrated in the map to the right.

Average monthly mean, maximum, minimum temperature, and precipitation for the Mackenzie District 1991-2020 (excludes Aoraki Mount Cook)





TANGATA WHENUA

For Te Rūnanga o Ngāi Tahu and Papatipu Rūnanga, Te Manahuna and the wider Mackenzie District is a place of cultural significance. The landscape is woven with traditional trails, nohoaka sites, taonga species, mahika kai sites that have sustained whānau for generations, and home to Te Waka o Aoraki – the Canoe of Aoraki.

Three Papatipu Rūnanga have their rōhe within the Mackenzie District: Te Rūnanga o Arowhenua based at Arowhenua, Temuka; Te Rūnanga o Waihao based north of the Waitaki River, South Canterbury; and Te Rūnanga o Moeraki based at Moeraki, North Otago. While historical land purchases and land use changes have displaced tangata whenua from much of the area, Te Manahuna remains of immense significance to Papatipu Rūnanga.

The connection of Te Rūnanga o Ngāi Tahu to Te Manahuna is one of whakapapa from Te Kauwae-rangoe (the celestial world) through to Te Kauwae-raro (the realm of man), with Aoraki an entity with his own mauri. For Ngāi Tahu whānau, Aoraki and his surrounding peaks are tūpuna, providing an unbreakable connection to the past.

The impacts of climate change on the cultural, social, environmental, and economic wellbeing of Te Rūnanga o Arowhenua, Te Rūnanga o Waihao, and Te Rūnanga o Moeraki are potentially profound. It is expected that under existing structures, Māori will be highly impacted by climate change.[2] Impacts include:

- Exposure of people to potentially harmful climate-related events such as heatwaves, wildfires, and floods
- Diverse risks to Māori capital, enterprise, and employment, particularly to assets and investments in the primary and tourism sectors
- Risks to infrastructure and significant sites such as wāhi tapu and nohoaka sites, particularly in low-lying areas and areas threatened by flood inundation
- Loss of vulnerable indigenous flora and fauna obstructing access or provision of long-held customary practices, degrading mahika kai, and driving extinction of taonga species

The cumulative impacts of climate change threaten to fundamentally alter the way Papatipu Rūnanga interact with the natural environment, each other, and other communities across Te Manahuna. The impacts on Te Rūnanga o Ngāi Tahu cultural identify, as the resources, taonga, and places that are woven into Ngāi Tahutanga are threatened, presents significant risks to social cohesion, well-being, and the prosperity of future generations.

METHODOLOGY

CLIMATE CHANGE DATA

This climate change analysis was conducted using CMIP6 (*Coupled Model Intercomparison Project, phase 6*) climate modelling. CMIP6 is a climate modelling activity from the World Climate Research Programme, coordinating and archiving climate model simulations. The simulations are a combination of historic climate models and simulations of plausible future climates. The simulations are selected based on expert knowledge and validation. The simulations are then combined to formulate a series of climate change projections, known as 'Climate Scenarios'. This collation of the international climate simulations creates bell-curve distributions of data points for each climate variable, ranging from a 5th percentile to 95th percentile. The variation is due to different climate models producing slightly different results; hence a range is produced. The climate data in this analysis for the Mackenzie District is primarily based on the 50th percentile of the CMIP6 findings.

SCENARIO ANALYSIS

The future is inherently uncertain, particularly in the context of climate change. By exploring a range of plausible futures, climate change scenario analysis allows us to understand how this uncertain future may look, and to build resilience to the challenges that may come.

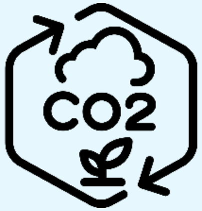
CMIP6 developed a set of emission scenarios named the Shared Socioeconomic Pathways (SSPs). The SSPs outlined in the IPCC Sixth Assessment Report (AR6) are intended to update the previously used Representative Concentration Pathways (RCPs), complementing the RCP scenarios with models of how socio-economic factors such as population, education, and urbanisation can influence emission reduction pathways. SSPs are driven by different socioeconomic assumptions.

SSPs are applied in this assessment to provide a range of plausible outcomes when analysing the future climate for the Mackenzie District. Low, mid, and high climate change scenarios have been used in this assessment with climate variables generated across four timeframes: present-day, 2040, 2070, and 2100. The 'present day' time slice for the Mackenzie District shows a 30-year average of mean temperature and precipitation over 1991-2020, in alignment with the World Meteorological Organisation and IPCC AR6 report baseline period.

These timeframes were selected to reflect the likely timeframe for undertaking the adaptation of the Mackenzie Districts' at-risk values and acknowledge the future climate conditions long-life assets and infrastructure will likely experience.

The climate change scenarios assessed in this report are detailed in Box 1.

BOX 1: CLIMATE CHANGE SCENARIOS



SSP1-2.6: SUSTAINABILITY ACHIEVED SCENARIO

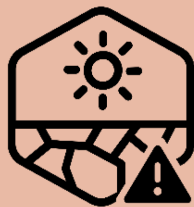
This 'Sustainability Achieved' scenario represents the low emissions plausible future, where global CO_2 emissions are reduced to net-zero by 2050 in line with global targets.

Global warming surpasses 1.5°C above pre-industrial levels but stabilise around 1.8°C thanks to stringent climate policies restricting GHG emissions, decarbonization of global energy systems, restoration of natural carbon sinks.

SSP2-4.5: SUSTAINABILITY DELAYED SCENARIO

This 'Sustainability Delayed' scenario represents ongoing delays in delivery of meaningful emission reduction policies that bridge the global ambition gap. It assumes that CO_2 emissions hover around current levels before starting to reduce around mid-century but do not reach net-zero by 2100.

Global warming surpasses the 2°C above pre-industrial threshold, rising by approximately 2.7°C by 2100.



SSP5-8.5: HOT HOUSE SCENARIO

This 'Hot House' scenario represents the fossil-fueled development pathway, where global CO_2 emissions continue to rise at historic business as usual rates, roughly doubling by 2050. Global targets remain unachieved as economic growth is fueled by exploiting fossil fuels and energy intensive lifestyles.

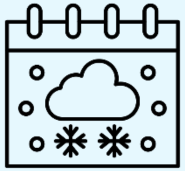
By 2100, global warming is has risen to 4.4°C above pre-industrial levels.

CLIMATE CHANGE VARIABLES

The climate change projections presented for Fairlie, Tekapo, Aoraki Mount Cook, Basin Drylands, and Twizel in the following section provide an overview of how key climate variables relating to temperature and precipitation are projected to change over the course of this century.

While the Mackenzie District frequently experiences extreme daily temperature highs and lows far exceeding the temperatures listed in the climate change projections, these projections display the annual average over a long time period (i.e., 30 years) to describe the change in climate trends and cycles of variability.

BOX 2: THE DIFFERENCE BETWEEN CLIMATE & WEATHER



WEATHER

Weather shows how the atmosphere behaves and can change over short timeframes (e.g. from minute-to-minute, hour-to-hour and day-to-day). There are many components to weather, which include temperature, rain, wind, hail, snow, humidity, flooding, thunderstorms, and heatwaves.

CLIMATE

Climate is the weather in a specific area over a long period of time – usually 30 years of more. When assessing climate, trends or cycles of variability is referred to, such as changes in temperature, humidity, precipitation, ocean-surface temperature, and other weather phenomena that occur over longer periods of time in a specific location

Although closely related, weather and climate are not the same – the difference between the two is simply a matter of time

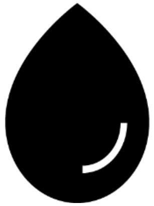
While weather refers to the short-term changes in the atmosphere, climate refers to the atmospheric changes over longer periods of time, defined as a 30-year period by the World Meteorological Organisation. This is why areas can still experience significantly cold spells, even though average temperatures are continuing to rise – while the cold spell may take place over a number of days, the long-term trends (i.e. annual frequency and duration of cold spells) indicate an overall change in climate.

The climate change projections presented in the following section are detailed in the table below. These climate change variables were selected to provide a representative overview of how climate indicators relating to temperature and precipitation are projected to change across the Mackenzie District. Additionally, for each location, a full range of climate variables were generated and analysed. These variables are listed in Appendix 1 with results for each location available in the Technical Appendices.

ANNUAL TEMPERATURE

Mean Maximum Temperature	The annual mean maximum temperature in degrees celsius
Mean Annual Temperature	The annual mean temperature in degrees celsius
Mean Minimum Temperature	The annual mean minimum temperature in degrees celcius

PRECIPITATION



Mean Annual Precipitation	The annual mean precipitation depth in millimetres
Extreme 24-hr Rainfall	The depth of rainfall received for a 1-in-100-year extreme rainfall event during a 24-hour period in millimetres
Extreme 48-hr Rainfall	The depth of rainfall received for a 1-in-100-year extreme rainfall event during a 48-hour period in millimetres

CHANGE EVENTS

Days ≤ 0°C:	The number of days in a year on average when the minimum air temperature falls below freezing (less than 0°C)
Days ≥ 25°C:	The number of days on average with daily maximum temperature above 25°C.
Heatwave Days:	A heatwave event is when a daily maximum and minimum temperature simultaneously exceeding their respective 90th percentiles for at least three consecutive days. Heatwave days are the total number of days that occur in heatwave events.

CLIMATE CHANGE PROJECTIONS

FAIRLIE

Located at approximately 301m above sea-level within the Ōpihi River Catchment at the junction of State Highway 79 and State Highway 8, Fairlie has acted as a rural hub for the Mackenzie District for generations. Situated at the eastern extent of the district, Fairlie is largely regarded as the gateway to the Mackenzie.

PRESENT DAY

TEMPERATURE

Maximum:	15.8°C
Mean:	9.8°C
Minimum:	3.8°C

PRECIPITATION*

Mean Annual:	758mm
Extreme 24hr:	147mm
Extreme 48hr:	184mm

CHANGE EVENTS

Days ≤ 0°C:	85
Days ≥ 25°C:	20
Heatwave Days:	2

*Extreme rainfall depths are based on a 100-ARI rainfall event

SSP1-2.6 SSP2-4.5 SSP5-8.5

2040

TEMPERATURE

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	16.5°C	16.6°C	16.7°C
Mean	10.4°C	10.6°C	10.7°C
Minimum	4.4°C	4.5°C	4.7°C

PRECIPITATION

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	772mm	774mm	777mm
Extreme 24hr	153mm	156mm	157mm
Extreme 48hr	188mm	189mm	190mm

CHANGE EVENTS

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-14	-16	-19
Days ≥25°C	+7	+8	+10
Heatwave Days	+6	+7	+9

2070

TEMPERATURE

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	16.7°C	17.2°C	17.9°C
Mean	10.6°C	11.1°C	11.8°C
Minimum	4.6°C	5.1°C	5.8°C

PRECIPITATION

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	776mm	786mm	803mm
Extreme 24hr	155mm	160mm	167mm
Extreme 48hr	190mm	194mm	199mm

CHANGE EVENTS

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-18	-29	-48
Days ≥25°C	+9	+14	+24
Heatwave Days	+8	+16	+33

2100

TEMPERATURE

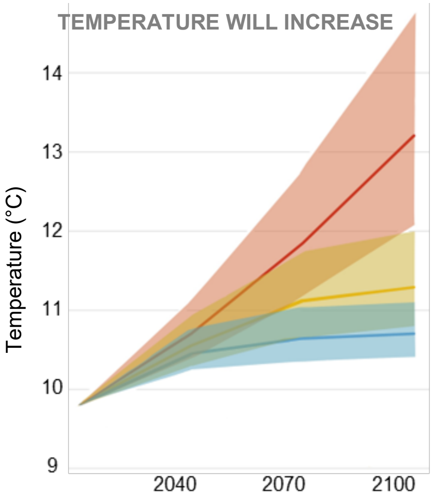
	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	16.7°C	17.3°C	19.3°C
Mean	10.7°C	11.3°C	13.2°C
Minimum	4.7°C	5.3°C	7.1°C

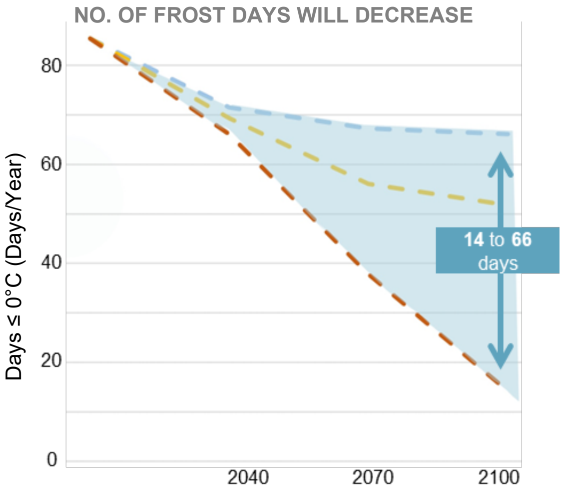
PRECIPITATION

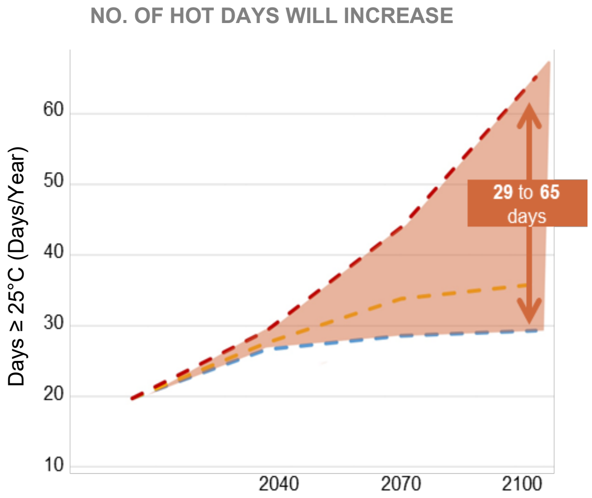
	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	777mm	790mm	832mm
Extreme 24hr	156mm	161mm	180mm
Extreme 48hr	190mm	195mm	210mm

CHANGE EVENTS

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-19	-34	-71
Days ≥25°C	+10	+16	+45
Heatwave Days	+9	+20	+83







SSP1-2.6 | SSP2-4.5 | SSP5-8.5

TEKAPO

Located at approximately 720m above sea-level on the shores of Lake Tekapo on State Highway 8, the alpine village of Tekapo is a popular destination for domestic and international visitors. Situated in the heart of the Mackenzie District, the population of Tekapo has grown significantly over the past decade.

PRESENT DAY

TEMPERATURE

Maximum: 14.6°C

Mean: 8.9°C

Minimum: 3.2°C

PRECIPITATION*

Mean Annual: 663mm

Extreme 24hr: 124mm

Extreme 48hr: 151mm

CHANGE EVENTS

Days ≤ 0°C: 91

Days ≥ 25°C: 15

Heatwave Days: 3

*Extreme rainfall depths are based on a 100-ARI rainfall event

2040

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	15.3°C	15.4°C	15.5°C
Mean	9.5°C	9.6°C	9.8°C
Minimum	3.8°C	3.9°C	4.1°C

PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	678mm	681mm	685mm
Extreme 24hr	129mm	130mm	131mm
Extreme 48hr	158mm	159mm	160mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-21	-24	-28
Days ≥25°C	+5	+6	+11
Heatwave Days	+4	+6	+8

2070

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	15.4°C	15.9°C	16.7°C
Mean	9.7°C	10.2°C	10.9°C
Minimum	4.0°C	4.5°C	5.2°C

PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	683mm	695mm	713mm
Extreme 24hr	131mm	135mm	141mm
Extreme 48hr	160mm	165mm	172mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-26	-38	-50
Days ≥25°C	+7	+11	+20
Heatwave Days	+7	+15	+37

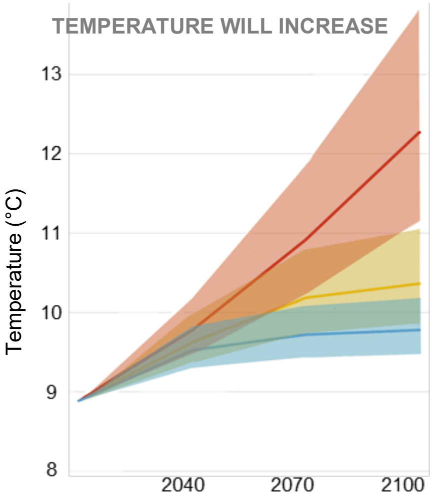
2100

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	15.5°C	16.1°C	18.1°C
Mean	9.8°C	10.4°C	12.3°C
Minimum	4.1°C	4.6°C	6.5°C

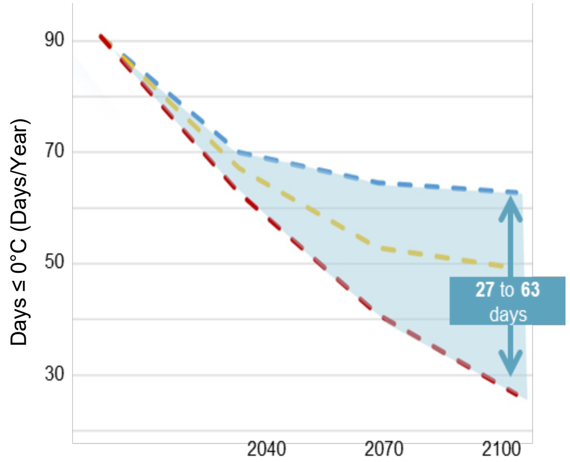
PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	685mm	699mm	746mm
Extreme 24hr	131mm	136mm	152mm
Extreme 48hr	160mm	166mm	185mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-28	-42	-64
Days ≥25°C	+7	+13	+41
Heatwave Days	+8	+20	+99

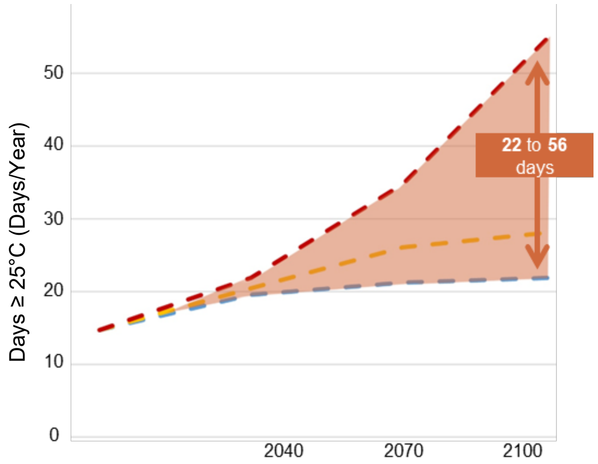
TEMPERATURE WILL INCREASE



NO. OF FROST DAYS WILL DECREASE



NO. OF HOT DAYS WILL INCREASE



AORAKI MT. COOK

Located at the western extent of the Mackenzie District at the end of State Highway 80, Aoraki Mount Cook National Park is an extreme and dynamic environment with over 19 mountain peaks over 3,000m including New Zealand's highest mountain, Aoraki Mount Cook. As New Zealand's premier alpine park, Aoraki Mount Cook attracts a significant number of visitors each year.

PRESENT DAY

TEMPERATURE

Maximum:	10.1°C
Mean:	5.7°C
Minimum:	1.3°C

PRECIPITATION*

Extreme 24hr:	479mm
Extreme 48hr:	646mm
Extreme 72hr:	743mm

CHANGE EVENTS

Days ≤ 0°C:	128
Days ≤2°C:	202

*Extreme rainfall depths are based on a 100-ARI rainfall event

SSP1-2.6 | SSP2-4.5 | SSP5-8.5

2040

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	10.8°C	10.9°C	11.1°C
Mean	6.3°C	6.4°C	6.6°C
Minimum	1.9°C	2.0°C	2.1°C

PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Extreme 24hr	496mm	498mm	502mm
Extreme 48hr	670mm	674mm	680mm
Extreme 72hr	781mm	787mm	796mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-17	-19	-23
Days ≤2°C	-24	-28	-34

2070

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	11.0°C	11.5°C	12.2°C
Mean	6.5°C	7.0°C	7.7°C
Minimum	2.1°C	2.5°C	3.2°C

PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Extreme 24hr	501mm	513mm	532mm
Extreme 48hr	678mm	695mm	722mm
Extreme 72hr	793mm	821mm	865mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-21	-32	-47
Days ≤2°C	-32	-48	-72

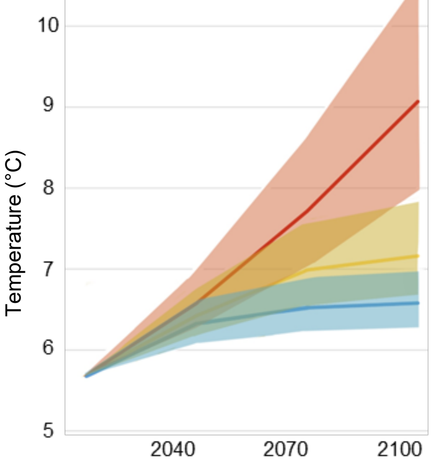
2100

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	11.1°C	11.7°C	13.6°C
Mean	6.6°C	7.2°C	9.1°C
Minimum	2.1°C	2.7°C	4.5°C

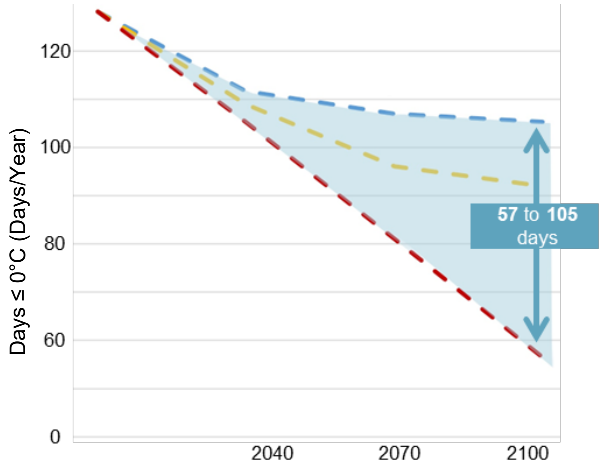
PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Extreme 24hr	502mm	517mm	567mm
Extreme 48hr	680mm	702mm	773mm
Extreme 72hr	796mm	832mm	947mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-23	-32	-72
Days ≤2°C	-34	-54	-106

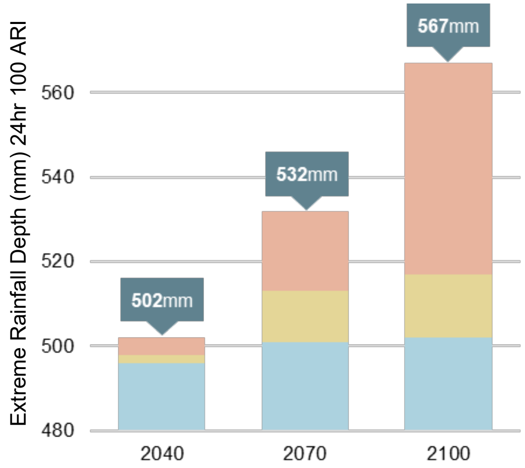
TEMPERATURE WILL INCREASE



NO. OF FROST DAYS WILL DECREASE



RAINFALL WILL BECOME MORE INTENSE



BASIN DRYLANDS

Located in the heart of the Mackenzie Basin, the Drylands is home to some of the iconic landscapes and threatened environments in New Zealand. Comprised of an extensive intermontane basin, ringed with mountains, the Drylands is unique in its size, naturalness, landforms, and pastoral heritage.

PRESENT DAY

TEMPERATURE

Maximum:	15.1°C
Mean:	9.2°C
Minimum:	3.3°C

PRECIPITATION*

Mean Annual:	638mm
Extreme 24hr:	125mm
Extreme 48hr:	151mm

CHANGE EVENTS

Days ≤ 0°C:	96
Days ≥ 25°C:	19
Heatwave Days:	2

*Extreme rainfall depths are based on a 100-ARI rainfall event

SSP1-2.6 | SSP2-4.5 | SSP5-8.5

2040

TEMPERATURE

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	15.8°C	15.9°C	16.0°C
Mean	9.8°C	9.9°C	10.1°C
Minimum	3.9°C	4.0°C	4.2°C

PRECIPITATION

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	652mm	655mm	658mm
Extreme 24hr	131mm	132mm	133mm
Extreme 48hr	158mm	159mm	160mm

CHANGE EVENTS

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-22	-25	-30
Days ≥25°C	+6	+7	+9
Heatwave Days	+5	+6	+8

2070

TEMPERATURE

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	16.0°C	16.4°C	17.2°C
Mean	10.0°C	10.5°C	11.2°C
Minimum	4.1°C	4.6°C	5.3°C

PRECIPITATION

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	657mm	668mm	684mm
Extreme 24hr	133mm	137mm	143mm
Extreme 48hr	160mm	165mm	172mm

CHANGE EVENTS

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-28	-42	-58
Days ≥25°C	+8	+13	+23
Heatwave Days	+7	+14	+33

2100

TEMPERATURE

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	16.0°C	16.6°C	18.6°C
Mean	10.1°C	10.7°C	12.6°C
Minimum	4.2°C	4.8°C	6.6°C

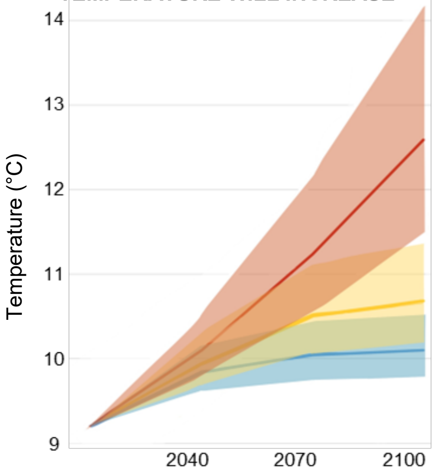
PRECIPITATION

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	658mm	672mm	715mm
Extreme 24hr	133mm	138mm	155mm
Extreme 48hr	160mm	166mm	186mm

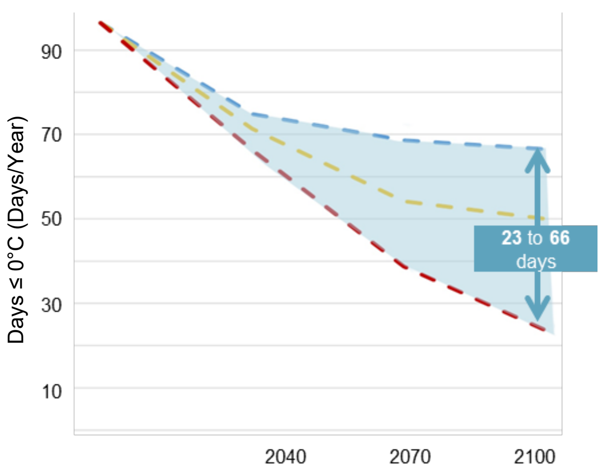
CHANGE EVENTS

	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-30	-47	-74
Days ≥25°C	+9	+15	+45
Heatwave Days	+8	+19	+98

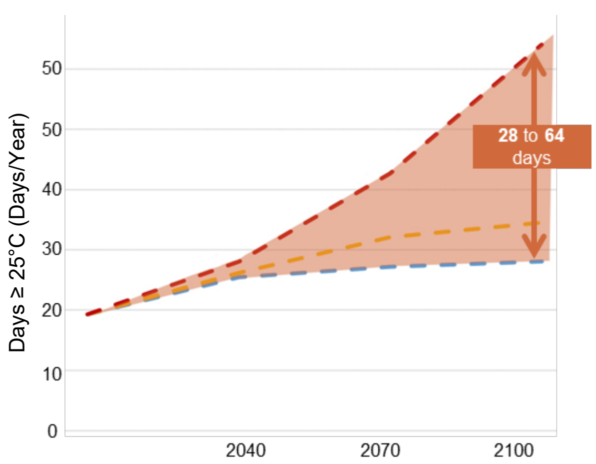
TEMPERATURE WILL INCREASE



NO. OF FROST DAYS WILL DECREASE



NO. OF HOT DAYS WILL INCREASE



SSP1-2.6 | SSP2-4.5 | SSP5-8.5

TWIZEL

Located at approximately 470m above sea-level, between Lake Pukaki and Lake Ruataniwha on State Highway 8, Twizel sits at the centre of the Waitaki Catchment. Founded as a hydro construction town in 1968, Twizel is now the largest town in the Mackenzie District and has experienced significant population growth over the past decade.

PRESENT DAY

TEMPERATURE

Maximum: 16.2°C

Mean: 10.3°C

Minimum: 4.3°C

PRECIPITATION*

Mean Annual: 680mm

Extreme 24hr: 120mm

Extreme 48hr: 143mm

CHANGE EVENTS

Days ≤ 0°C: 71

Days ≥ 25°C: 30

Heatwave Days: 2

*Extreme rainfall depths are based on a 100-ARI rainfall event

2040

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	16.9°C	17.0°C	17.1°C
Mean	10.9°C	11.0°C	11.1°C
Minimum	4.9°C	5.0°C	5.2°C

PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	695mm	698mm	701mm
Extreme 24hr	126mm	127mm	128mm
Extreme 48hr	149mm	150mm	151mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-17	-20	-23
Days ≥25°C	+8	+9	+11
Heatwave Days	+4	+6	+7

2070

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	17.1°C	17.6°C	18.3°C
Mean	11.1°C	11.6°C	12.3°C
Minimum	5.1°C	5.6°C	6.3°C

PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	700mm	711mm	729mm
Extreme 24hr	127mm	131mm	137mm
Extreme 48hr	151mm	155mm	162mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-22	-33	-43
Days ≥25°C	+11	+18	+29
Heatwave Days	+7	+15	+35

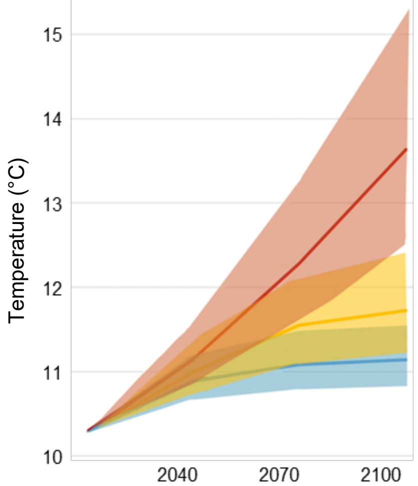
2100

TEMPERATURE	SSP1-2.6	SSP2-4.5	SSP5-8.5
Maximum	17.1°C	17.7°C	19.7°C
Mean	11.1°C	11.7°C	13.6°C
Minimum	5.2°C	5.7°C	7.6°C

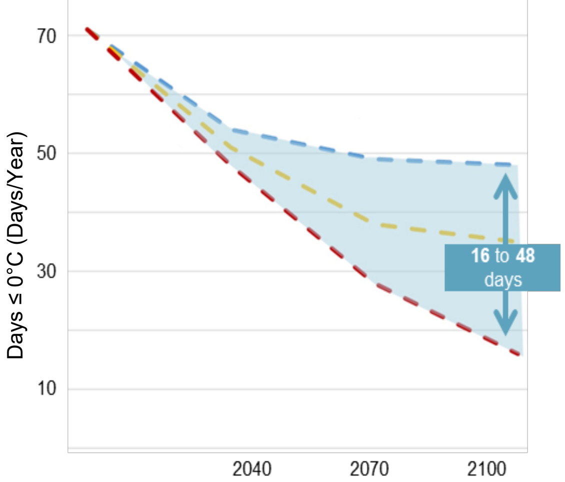
PRECIPITATION	SSP1-2.6	SSP2-4.5	SSP5-8.5
Mean Annual	701mm	715mm	761mm
Extreme 24hr	128mm	133mm	148mm
Extreme 48hr	151mm	157mm	175mm

CHANGE EVENTS	SSP1-2.6	SSP2-4.5	SSP5-8.5
Days ≤0°C	-23	-36	-55
Days ≥25°C	+11	+21	+52
Heatwave Days	+7	+20	+104

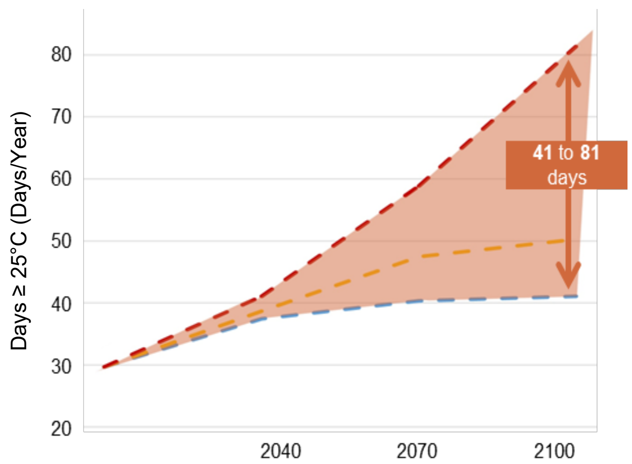
TEMPERATURE WILL INCREASE



NO. OF FROST DAYS WILL DECREASE



NO. OF HOT DAYS WILL INCREASE



CLIMATE-RELATED IMPACTS & IMPLICATIONS

NATURAL ENVIRONMENT & LANDSCAPE

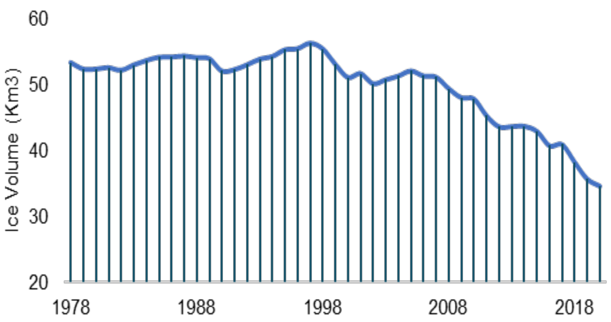
SNOW & ICE

Globally, continued warming has led to the widespread reductions in snow cover, shrinking of ice sheets and glaciers, and increased permafrost temperatures.[3] The Mackenzie District's unique alpine environments are equally exposed to these risks, with its glaciers in particular, acting as iconic indicators of the impacts of climate change. As large scale, highly sensitive indicators of environmental change, glaciers clearly demonstrate the effects global warming is having on the local natural environment.

In the Mackenzie District, climate change is causing summer snowlines to rise and glaciers to retreat. Between 1978 and 2020, the total volume of glacier ice in New Zealand has decreased by 35%, with Tasman Glacier, one of the Mackenzie's most visited glaciers, recording its highest end of summer snowline elevation on record in 2019.[4]

With the projected warming under a 'hot-house' scenario (SSP5-8.5) increasing mean temperatures by up to 3.4°C and decreasing the number of days under 0°C by almost 77% by 2100 in Aoraki Mount Cook National Park, alpine and sub-alpine ecosystems and landscapes in the Mackenzie District are at high risk of further loss, with a reduction of 50-92% in glacier ice volume projected to occur by the end of this century in the central Southern Alps.[5]

With many of the Mackenzie's iconic alpine and sub-alpine species found in relatively isolated populations in habitat 'islands' on mountain tops, rising temperatures will increase their vulnerability, as habitats become increasingly 'squeezed' between retreating ice and snow and the mountain summit.



New Zealand glacier ice volume 1978-2020 (Stats NZ)

RIVERS & LAKES

The iconic lakes, braided rivers, and waterways of the Mackenzie are nationally important, providing habitat for a diversity of endangered birds, fish, and invertebrates, a source of kai, and powering a number of major South Island hydroelectricity schemes.

The Mackenzie District is projected to observe moderate changes in future annual precipitation, with rainfall across the Waitaki catchment expected to increase in the coming decades and extreme rainfall events increasing in frequency and intensity. The Waitaki catchment, encompassing Lake Tekapo and Lake Pukaki, has the largest proportion of stored seasonal snow of any hydropower catchment in the country, with almost half of Lake Pukaki summer inflow coming from snow melt.

This moderate change in rainfall, coupled with the decline in seasonal snow melt sees the Waitaki catchment likely to receive higher inflows that present during winter months and lower inflows during summer. As a result, the annual flows are projected to increase slightly on average, with mean annual flood events becoming more extensive and volatile during extreme rainfall periods.[6]

While the projected changes in the Mackenzie Districts rivers and lake present opportunities for improved energy generation for hydroelectric providers; flow alterations, increasing temperatures, volatile river flood events, and increased nutrient inputs during rainfall events expose freshwater ecosystems to significant degradation.

With up to 74% of native freshwater fish in New Zealand classified as endangered or at risk, and the braided rivers of the Mackenzie District are home to threatened taonga bird species such as kakī/Black Stilt. Consequently, the Mackenzie Districts River and Lake environments are highly vulnerable to increased degradation with climate change.

FIRE

With New Zealand recording its warmest year on record consecutively in 2022 and 2021, the risk of extreme fire weather is becoming increasingly apparent, particulary within the Mackenzie Basin and surrounding areas. Notable wildfires in recent years include the Pukaki Downs and Lake Ōhau fires which burned across 3,100 ha and 5,032 ha respectively and destroyed 48 houses.

Across the Mackenzie, projected increases in high temperatures, combined with increased likelihood of severe or extremely dry drought conditions will see the average fire risk increase in the coming decades, both in season length of fire weather conditions and the intensity of fires that may take hold. As witnessed in the investigation following the neighbouring Lake Ōhau fire in October 2020, a combination of dry weather and low moisture content within the surround grasslands assisted in the ignition and rapid spread of the devastating fire.[7]

Analysis of fire weather, both since 2015 and from forward looking climate change projections, shows that wildfire risk conditions similar to those experienced during the devastating 2019-2020 'Black Summer' fires in Australia, are likely to occur more frequently in the Mackenzie District in the coming decades, with the observed highest risk areas found around Lake Tekapo, the Waitaki River, and nearby Lake Aviemore.[8]

Image: Lake Pukaki Fire 2020

INFRASTRUCTURE, BUILDINGS, & PLACES

TRANSPORTATION

Image: State Highway 80 to Aoraki Mount Cook

As an expansive and predominantly rural district, Mackenzie District residents and visitors remain heavily dependent on its linear transport network, both across the Mackenzie District and the wider Canterbury Region. Dependency on the transport network include access and delivery of supplies, access to critical services, and everyday living such as commuting between towns for work and school.

Canterbury roads have the highest national exposure to surface water flooding and erosion, with 3,947km of road at risk to flooding hazards.[9] With many of the region's transportation routes running adjacent or crossing the regions significant rivers, the effects of more intense extreme rainfall events across the Mackenzie District will likely increase the risk of damage and loss in the coming decades.

Increasingly intense and frequent extreme rainfall events are also expected to exacerbate the landslide risk along the district's transportation route, particularly within it's more mountainous environments. Extreme rainfall triggering land instability may include more frequent and severe debris flows and shallow landslides impacting the districts transportation network, with longer term effects possibly causing the reactivation of pre-existing large landslides.

With access to towns, villages, and many rural areas often reliant on a single road access route; roads and bridges, within the Mackenzie provide critical connections. As a result, many Mackenzie communities are vulnerable to the potential effects of flooding due to the implications of having roading access completely cut off or requiring multi-hour 'alternative route' detours.

THREE WATERS

The increase in intensity and frequency of extreme rainfall events and variable nature of seasonal rainfall will likely increase pressures of the Mackenzie District's stormwater and wastewater infrastructure in the coming decades.

Following national trends, extreme rainfall events are projected to increase across the Mackenzie District, with the depths of a 24-hour extreme rainfall event projected to increase by approx. 22-25% by the end of this century under a 'hot-house' scenario (SSP5-8.5). This change has the dual effect of increasing the physical depth of rainfall experienced during an extreme rainfall event (e.g., a one-in-100-year event) and increasing the frequency of historic extreme rainfall events.

The unprecedented nature of these increasingly intense extreme rainfall events presents the risk to existing stormwater systems, much of which was built prior to official guidance on climate change being included within the asset design. Increasing depths and duration of extreme rainfall events can overwhelm the designed capacity of these systems, overloading of existing stormwater systems causing flooding of surrounding areas via overland flow paths, damaging stormwater components, and restricting maintenance access routes (e.g., manhole covers and tunnels).

Wastewater systems most vulnerable to increasing extreme rainfall events are those with combined wastewater and stormwater lines. However, event when systems are separated, extreme rainfall events can result in rainfall dependent inflow and infiltration, where stormwater enters into wastewater pips overloading the ability of the system to transport waste.

Image: Flooded highway following extreme rainfall

ENERGY INFRASTRUCTURE

The Mackenzie District provides a significant contribution to the national electricity grid, generating a relatively high proportion of New Zealand's renewable energy through its major hydroelectric schemes in the Waitaki catchment. With a significant proportion of inflow into the Waitaki catchment coming from the surrounding alpine environments, the Waitaki catchment is sensitive to the effects of climate change as its river flows are influenced by water accumulation and runoff from snow and ice.

The projected changes in total water inflows to hydroelectric waterways in the Mackenzie resulting from increasing annual and winter inflows (from overall increased mean precipitation) and decreasing summer flows (from decreasing snow and ice melt) will likely produce an overall net-rise in energy generation capacity and see possible supply shortfalls shifting from winter to summer.[10]

Generally, it is likely that high flows within the Mackenzie's hydro-electric waterways will increase across this century, while in the near term (2040) the number of extreme low-flow events may decrease, likely as a result of continued snow and ice melt in the coming decades. Once snow and ice within the catchment are considerably reduced though, extreme low-flow events may become more frequent.[11]

While climate change in the Mackenzie District presents an opportunity for improved energy generation capacity, generation and transmission in the Mackenzie remains adversely exposed to the more severe climate-related events such as extreme rainfall, fire, and high winds – all of which are expected to worsen in the coming decades.

The impacts of increasing intensity and frequency of extreme rainfall events in the Mackenzie District pose increasing risks of electricity generation infrastructure being damaged by silt and debris. During extreme rainfall events, this may require operators to lower dam water levels to remain resilient, temporarily reducing its energy generating capacity.[12]

CULTURE & COMMUNITY

COMMUNITY RESILIENCE

The effects of climate change in the Mackenzie District pose risks to community resilience and connectivity, with rural communities exposed to a range of hazards likely more vulnerable.

Over the 10-year period between 2007 and 2017, climate-related floods and drought events have cost the New Zealand economy significantly, with at least $120 million from privately insured damages from floods and $720 million from drought events.[13] These costs are likely to be conservative. Looking forward, delayed action on climate change mitigation and adaptation leading to an SSP2-4.5 'Sustainability Delayed' scenario could take up to $4.4 billion off New Zealand's GDP by 2050 (in net present-value terms).[14]

Destructive climate-related events such as extreme rainfall and fire, or slower climate-related impacts such as changing temperatures affecting industries, have the ability to disrupt communities, displace key community members, and degrade the social connections important to small and rural communities.

As communities and industries continue to respond and adapt to the impacts of climate change over the coming decades, further increases to the cost of living may likely occur. Increases in property insurance costs for newly identified hazard prone areas, or complete retreat of insurance services, may displace communities as certain areas become unaffordable.

Furthermore, goods and service industries managing decreased production due to increasingly severe climate events or more frequent disruptions in transport and distribution, may cause prices to increase or reduce availability of certain goods and services in isolated communities across the Mackenzie District.

EMERGENCY MANAGEMENT

Image: St. John Ambulance Twizel

With severe climate-related events such as flooding, wildfire, and heat-stress all expected to increase in frequency and intensity in the Mackenzie, the impacts of climate change will likely place more demands on emergency management and response services across the district.

The iconic Mackenzie landscape, with its diversity of outdoor recreation experiences in extreme and isolated environments, coupled with its widely disbursed rural communities, present unique challenges for emergency services in the district in responding to the growing risks. Particulary when coordinating community responses and providing aid to isolated community members during severe weather events.

In alpine areas, warming temperatures combined with extreme rainfall events (falling as snow at high altitudes) will likely increase the risk of avalanches and destabilise rock previously held by ice, causing more frequent rockfalls. At lower altitudes, across the Mackenzie Basin, the increasing frequency of wildfire conditions will continue to grow the risk of longer, more severe fire seasons and more intense fires.

With some emergency management and response services in the Mackenzie District dependant on volunteers, these structures may become inadequate in the coming decades to respond to the increasing demands for volunteer time and resources required.

INEQUALITIES

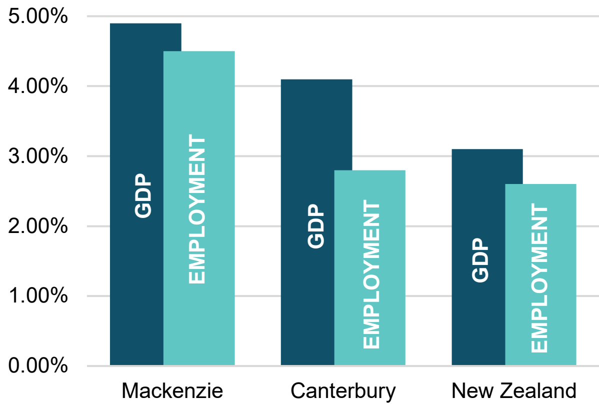
While communities, families, and individuals in the Mackenzie District are exposed to the same climate-related hazards in their area, the ability to cope or adapt to these hazards is different due to existing inequalities.

Demographic factors such as age, ethnicity, health, or household income strongly influences people's abilities to access resources, information, and support to adequately respond to the impacts of climate change. In New Zealand, Māori, Pacific, low-income, and disabled people are most at risk from being adversely affected by climate change hazards.[15]

With strong GDP growth following the Covid-19 pandemic recovery, low rates of unemployment, strong growth in employment of Mackenzie residents, and projected population growth across the district over the coming decade, the Mackenzie District is comparatively less exposed to social inequalities exacerbating the effects of climate change or limiting response options.[16] Furthermore, as New Zealand works to respond to climate change and reduce greenhouse gas emissions to net-zero by 2050, in the coming decades agricultural industries such as sheep, beef, and grain farming are expected to experience net-positive employment changes.

However, the disproportionate impacts from climate change on the resources, taonga, and places significant to Māori, presents profound risks to social cohesion, well-being, and the prosperity of future generations.

Mackenzie District GDP and Employment June 2023 (Infometrics)



ECONOMY & PRODUCTIVITY

PRIMARY INDUSTRIES

The expected increase in higher temperatures across the Mackenzie District and the increasing probability of extremely dry and severely dry drought conditions occurring each year will impact primary industries in the Mackenzie, in particular placing growing stresses on livestock and crops.

With all communities (excluding Mt. Cook Village) across the district expected to experience between 40 to 50 additional days over 25°C and heatwave events occurring more frequent by the end of this century under a SSP5-8.5 'hot house' climate, farming operation will likely face more severe and frequent heat-stresses on livestock and crops, along with reduced water availability for irrigation during drought periods.

The effects of increasing high temperatures, coupled with more volatile and extreme rainfall events also pose risks to aquaculture operations within the Mackenzie District. Surface water runoff across hot surfaces into surrounding waterbodies (e.g., a rainfall event after an extremely hot day) presents significant health risks to freshwater fish species. Sudden changes in water temperatures can alter the physical habitat conditions in freshwater environments (e.g., algal blooms) and cause a range of physical and behaviour responses, through to death in severe circumstances.[17]

Conversely, increasing average temperatures across the Mackenzie District, fewer frost days, and milder winter conditions present opportunities for primary producers, as growing seasons extend and growing degree days for pasture increase significantly in the coming decades. Combined with improved water management approaches and land uses to manage the effects of seasonal shortages in water supplies, these benefits may likely increase the productivity growers and producers across the district and open up new opportunities for different crop varieties in new locations.

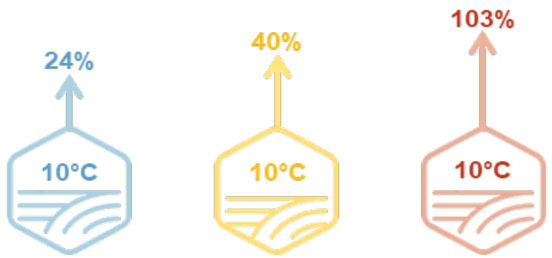


Image: Change in 10°C Growing Degree Days at 2100 compared to

TOURISM

With average temperatures increasing across the Mackenzie District and significant reductions in days below 0°C occurring in the coming decades, climate change will likely impact outdoor-based winter tourism in the Mackenzie.

Reducing availability and duration of snow and ice in the Mackenzie, home to a strong alpine recreation and tourism industry, will likely impact the quality of alpine experiences and length of the viable recreation season. Alpine recreation and tourism generally have few options to adapt to reducing snow and ice, particularly with Mackenzie ski fields being currently less equipped with snow making capabilities than their Southern Lakes counterparts.

More frequent and severe climate-related events such as wildfire, flooding, increasing avalanche risk, rockfalls, and landslides, also pose risks to a number of the Mackenzie's iconic outdoor recreation opportunities. Often located in the Mackenzie's highly dynamic landscapes, these destructive climate-related events risk damaging tourism infrastructure, restricting foot and vehicle access to backcountry locations, and closing visitation to certain experience due to an unacceptable visitor safety risk.

Consequently, tourism in the Mackenzie District may also see some benefits from the effects of climate change. Reducing frost conditions and warmer winter temperatures across the district will likely reduce winter driving risks often associated with 'black ice'.

Additionally, the draw of 'last chance tourism' and other lower altitude alpine regions being more significantly affected may counter the impacts that declining snow and ice conditions have on tourism operations. Anecdotally, during the warm winter of 2021 when the Southern Alps received unseasonably low snowfalls, ski and mount guide providers noted a significant increase in business as visitors from surrounding regions came to experience comparatively better snow conditions.

BIOSECURITY

Image: Wilding conifer in the Mackenzie District

As average temperatures continue to warm and winter months become less severe with decreasing days below 0°C, the Mackenzie Districts unique biodiversity, iconic high country and sub-alpine landscapes, and valuable freshwater environments will likely become more exposed and vulnerable to pest and disease. Warmer average temperatures and less severe winter conditions are beneficial to many existing pest species prevalent across the Mackenzie District, providing the conditions to out-compete less versatile native species more successfully for habitat and expand their range and distribution to higher elevations. With native species and ecosystems in the Mackenzie already under considerable pressure from introduced pest species such as wilding conifers, the pressures of climate change on native species combined with increasing pressures from introduced pests may drive localised extinctions.[18]

Rising temperatures in the Mackenzie District, particularly in dry tussock grasslands also pose significant threats to native herbs and shrubs, as conditions favour increased rabbit pressures on native ecosystems and pastoral farming operations. Frost sensitive pests, such as Argentine Ants may also become better established across the Mackenzie District as annual days below 0°C reduce considerably in the coming decades.

In the Mackenzie Districts freshwater environments, rising average temperatures and warmer waters will continue to provide the conditions for invasive algae and aquatic pests to thrive and spread. Aquatic pest species like didymo are likely to continue to spread within Mackenzie waterways as temperatures increase, inhibiting growth of native water plants and reducing spawning areas for many type of fish.

TRANSITION IMPACTS 2050

As New Zealand and the world respond to the impacts of climate change and seek to significantly reduce greenhouse gas emissions, the transition to a low-carbon and climate resilient economy in the coming decades may involve extensive market, policy, technology, and behaviour changes.

Transition impacts expose the expected parts of New Zealand's key value chains that could be impacted as New Zealand transitions to either a net-carbon zero economy by 2050 (SSP1-2.6: Sustainability achieved scenario) or remains fossil fuel dependant (SSP5-8.5: Hot House Scenario).

As a vast and largely dispersed district with strong economic connections to the land, landscapes, and natural resources, Mackenzie District communities and key economic sectors are vulnerable to the transition impacts of climate change.

As government and industry emission reduction targets and incentives become more influential through policy changes and consumer behaviour demands, New Zealand's price of carbon (i.e., carbon credits) and the availability of forestry carbon sinks that generate offsetting opportunities will likely impact how businesses such as agriculture and tourism successfully operate.

As modelled by the New Zealand Climate Change Commission in their advice to Central Government on the pathways towards meeting emission budget targets; the 'Tailwind' and 'Headwind' scenarios detail the plausible land use changes and carbon-related price responses likely to occur under the different climate change scenarios by 2050.[19,20]

Four key indicators for transition impacts based on Climate Change Commission modelling is found in Box 2 below.

BOX 2: TRANSITION IMPACTS FOR NEW ZEALAND IN 2050

INDICATOR	SSP1-2.6: SUSTAINABILITY ACHIEVED	SSP2-4.5: SUSTAINABILITY DELAYED	SSP5-8.5: HOT HOUSE
NEW ZEALAND EMISSIONS	6Mt CO_2e	24Mt CO_2e	40Mt CO_2e
GLOBAL EMISSIONS	26Gt CO_2e	57Gt CO_2e	103Gt CO_2e
HORTICULTURE & ARABLE LAND	↑ 34%	↑ 1%	↑ 1%
DAIRY HERD SIZE	↓ 30%	↓ 17%	↓ 13%
NATIVE FOREST LAND	↑ 704%	↑ 459%	↑ 134%
EXOTIC FOREST LAND	↑ 30%	↑ 40%	↑ 48%
CARBON PRICE (NZU)	$277 NZD	$369 NZD	$35 NZD
GLOBAL OIL PRICE (PER BARREL)	$43 NZD	$89 NZD	$157 NZD

*Percentage increase and decrease indicators are changes relative to 2020

GLOSSARY & REFERENCES

GLOSSARY

All climate change related terms and definitions have been sourced from the Intergovernmental Panel on Climate Change, Climate Change 2023: Synthesis Report, unless otherwise stated.[21]

TERM	DEFINITION
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.
Adaptation Options	The array of strategies and measures that are available and appropriate for addressing adaptation. They include a wide range of actions that can be categorized as structural, institutional, ecological, or behavioural
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
Biodiversity	Biodiversity or biological diversity means the variability among living organisms from all sources including, among other things, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems
Climate	In a narrow sense, climate is usually defined as the average weather -or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities- over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Organization (WMO). The relevant quantities are most often surface variables such as temperature, precipitation, and wind.
Climate Change	A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.
Drought	An exceptional period of water shortage for existing ecosystems and the human population (due to low rainfall, high temperature and/or wind).
Equality	A principle that ascribes equal worth to all human beings, including equal opportunities, rights, and obligations, irrespective of origins.
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.
Fire Weather	Weather conditions conducive to triggering and sustaining wildfires, usually based on a set of indicators and combinations of indicators including temperature, soil moisture, humidity, and wind. Fire weather does not include the presence or absence of fuel load.

TERM	DEFINITION
Global Warming	Global warming refers to the increase in global surface temperature relative to a baseline reference period, averaging over a period sufficient to remove interannual variations (e.g., 20 or 30 years). A common choice for the baseline is 1850–1900 (the earliest period of reliable observations with sufficient geographic coverage), with more modern baselines used depending upon the application
Greenhouse Gases	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the Earth's atmosphere. Human-made GHGs include sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs) and perfluorocarbons (PFCs); several of these are also O3-depleting (and are regulated under the Montreal Protocol).
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources
Impacts	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.
Mitigation	A human intervention to reduce emissions or enhance the sinks of greenhouse gases.
Net zero GHG emissions	Condition in which metric-weighted anthropogenic greenhouse gas (GHG) emissions are balanced by metric-weighted anthropogenic GHG removals over a specified period. The quantification of net zero GHG emissions depends on the GHG emission metric chosen to compare emissions and removals of different gases, as well as the time horizon chosen for that metric
Shared Socio-Economic Pathways (SSPs)	Shared socio-economic pathways (SSPs) have been developed to complement the Representative Concentration Pathways (RCPs). By design, the RCP emission and concentration pathways were stripped of their association with a certain socio-economic development. Different levels of emissions and climate change along the dimension of the RCPs can hence be explored against the backdrop of different socio-economic development pathways (SSPs) on the other dimension in a matrix.
Resilience	The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation.
Risk	The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social, and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure, and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making.
Emissions Scenario	A plausible representation of the future development of emissions of substances that are radiatively active (e.g., greenhouse gases (GHGs) or aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy, and land use) and their key relationships. Concentration scenarios, derived from emission scenarios, are often used as input to a climate model to compute climate projections.
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.

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APPENDICES

APPENDIX 1: CLIMATE CHANGE VARIABLES

Climate change variables applied in the analysis of the Mackenzie District, available in technical appendices.

VARIABLE	UNIT	DESCRIPTION
Mean Temperature	°C	The annual mean temperature is the degrees Celsius
Minimum Temperature	°C	The annual mean minimum temperature for a particular site.
Maximum Temperature	°C	The annual mean maximum temperature for a particular site.
Frost Days	Days/Year	The number of days in a year when the minimum air temperature falls below freezing (less than 0°C).
Minimum Temperature ≤ 2°C	Days/Year	The number of days per year with a minimum temperature lower than 2°C
Maximum Temperature ≥ 25°C	Days/Year	The number of days with daily maximum temperature above 25°C.
Maximum Temperature ≥ 30°C	Days/Year	The number of days with daily maximum temperature above 30°C.
Heatwave Days	Days	A heatwave event is defined as a daily maximum and minimum temperature simultaneously exceeding their respective 90th percentiles of time series in the baseline period for at least three consecutive days. Heatwave days are the total number of days that occur in heatwave events.
Heatwave Frequency	Times/Year	Heat Wave Frequency refers to the number of heat wave events over a year
Mean Precipitation	mm	The annual mean precipitation is in millimetres (mm).
Extreme Precipitation – 24 Hours	mm	Daily extreme precipitation represents 24-hour extreme rainfall in mm.
Extreme Precipitation – 48 Hours	mm	Extreme precipitation represents 48-hour extreme rainfall in mm.
Extreme Precipitation – 72 Hours	mm	Extreme precipitation represents 72-hour extreme rainfall in mm.
SPEI Drought Probability – 12 Months	%	Standardised Precipitation and Evapotranspiration (SPEI) considers precipitation and temperature to identify increases in drought severity linked with higher water demand by evapotranspiration. This variable examines changes over a 12-month period.
SPEI Drought Probability – 24 Months	%	Standardised Precipitation and Evapotranspiration (SPEI) considers precipitation and temperature to identify increases in drought severity linked with higher water demand by evapotranspiration. This variable examines changes over a 24-month period.
Monthly Solar Radiation	MJ/(m2*day)	The monthly median solar radiation in MJ/M2/day for the location for baseline (2005) and chosen future year(s). The result represents the statistical median derived from the GCM and RCM monthly solar radiation patterns
Monthly Wind Speed	km/h	The mean monthly wind speed in km/h
Extreme Wind Speed	km/h	The extreme daily wind speed is presented in kilometres or miles per hour. Extreme wind speeds could be derived from hurricanes, typhoons and other tropical depressions, but not tornado-related winds.
Growing Degree Days - 4°C	°C*day/year	The yearly growing degree days in cumulative degrees Celsius for the location for baseline (2005) and chosen future year(s) with a base temperature of 4°C.
Growing Degree Days - 10°C	°C*day/year	The yearly growing degree days in cumulative degrees Celsius for the location for baseline (2005) and chosen future year(s) with a base temperature of 10°C

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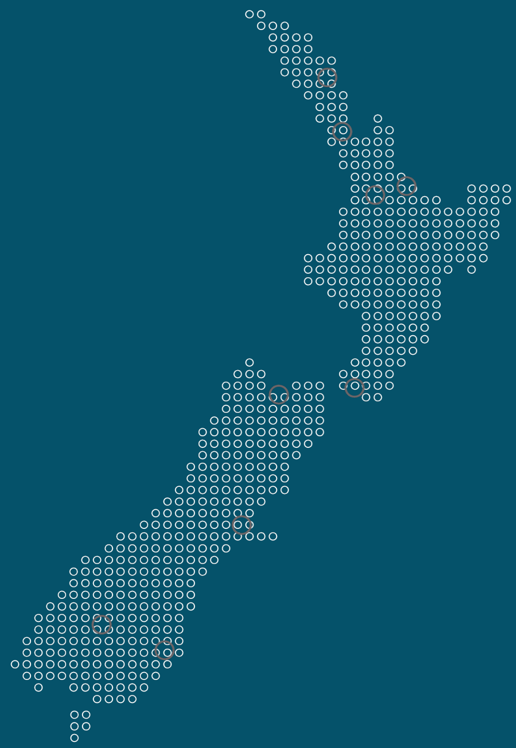

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