Climate Change Risk and Adaptation Assessment Framework for Infrastructure Projects

March 2020

Queensland Government

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Glossary

Terms, abbreviations and acronyms	Meaning
BoM	Bureau of Meteorology
CCRAA	Climate Change Risk and Adaptation Assessment
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Design Rating	An Infrastructure Sustainability rating type assessed at the end of detailed design (as applicable to the Contract). Assessed based on the inclusion of design elements and construction requirements for sustainability in the project documentation.
Infrastructure Sustainability (IS)	Infrastructure that is designed, constructed and operated to optimise environmental, social and economic outcomes over the long term.
Infrastructure Sustainability Accredited Professional (ISAP)	A person who has completed the ISCA Infrastructure Sustainability for Professionals training and successfully passed the examination.
ISCA	Infrastructure Sustainability Council of Australia

1 Introduction

1.1 Background

This document provides a strategic framework for considering and responding to climate change risks on infrastructure projects. The framework compliments the engineering policy EP170 *Climate Change Risk Assessment Methodology*.

The document provides guidance on typical adaptation and resilience risk treatments to address potential climate change risks.

The framework provides guidance on evidence requirements outlined within the Infrastructure Sustainability Council of Australia (ISCA) Infrastructure Sustainability (IS) Rating Tool version 1.2 (v1.2), credits Cli-1: Climate Change Risk Assessment and Cli-2: Adaptation measures.

The document is structured to provide:

- policy context at the international, national, state and the Department of Transport and Main Roads levels
- the purpose and intent of the document in support of an ISCA rating
- climate change exposure, hazards and projections specific to the programs
- the methodology and assessment criteria used to rate risks and provide a risk rating
- the findings of typical baseline climate risk assessment completed on a number of major projects to date.
- a selection of overarching adaptation actions required to help mitigate the identified climate risks, and
- a set of next steps providing instruction on how programs and projects should take the findings presented in this document and apply them at the project level.

This document is not intended to limit the potential adaptation and resilience treatments that could be applied by programs and projects. It is to provide guidance on what treatments might typically be applied. There are network operation benefits to having consistent treatments, as these can assist with maintenance processes.

The findings and instructions outlined within this document must be reviewed and applied at an individual program/project level to form the necessary supplementary information required to evidence compliance with the IS Rating Tool v.1.2. Cli-1 and Cli-2 credits, and must be provided by the project team in support of the ISCA credit verification process.

2 Policy context

2.1 International policy

In 2015 the Commonwealth government announced its commitment to a target of reducing greenhouse gas (GHG) emissions by 26 to 28% below 2005 levels by 2030, building on its previous target of five per cent below 2000 emission levels by 2020, irrespective of what other countries do. The Commonwealth government submitted this new target as its intended nationally determined contribution to the United Nations Framework Convention on Climate Change for negotiation at the 21st Conference of the Parties (COP21) held in Paris in December 2015.

A global climate agreement was reached by all 196 countries in Paris on 14 December 2015. The Paris Agreement provides a framework for all countries to take action on climate change post 2020. Key outcomes of the Paris Agreement include (Department of Foreign Affairs and Trade, 2016):

- a target to keep global temperature increase to well below 2°C and pursue efforts to keep warming below 1.5°C above pre-industrial levels
- all countries to set emissions reduction targets from 2020, with an agreement to review and strengthen targets every five years
- transparency and accountability rules to provide confidence in countries' actions and track progress towards targets
- promoting action to adapt and build resilience to climate impacts, and
- financial, technological and capacity building support to help developing countries implement the Agreement.

2.2 National policy

The Australian Government's *Direct Action Plan* sets out how the 2030 emissions reduction target will be achieved. The Emissions Reduction Fund, as part of the *Direct Action Plan*, aims to reduce Australia's GHG emissions by creating positive incentives to adopt better technologies and practices to reduce emissions. The Government has considered the 2030 target policy framework in detail in 2017-2018 and is confident in achieving the identified reduction targets through the implementation of the Renewable Energy Target, Minimum Energy Performance Standards and the 20 Million Trees programme.

The Australian Government's *National Climate Resilience and Adaptation Strategy* was released on 2 December 2015 and provides a set of principles to guide effective adaptation and build the resilience of communities, the economy and the environment. The guiding principles include priorities for shared responsibility, climate change risks factored into decision making, a risk management approach based on the best available scientific data, assisting the vulnerable, collaboration with stakeholders, and the need to revisit decisions and outcomes over time.

2.3 Queensland policy

The Queensland Government's Pathways to a climate resilient Queensland, *Queensland Climate Adaptation Strategy* 2017-2030 serves as a core component of Queensland's climate change response to help guide a transition to a zero net emissions economy.

The strategy aims to deliver this guidance through four clearly defined pathways; people and knowledge, state government, local governments and regions, and sectors and systems.

In particular, the Strategy has set out a number of commitments for Transport and Main Roads including to 'manage risks to property, assets, infrastructure and services'.

In making Queensland more resilient to a changing climate, the Queensland Government have committed to implementing a number of key actions including:

- Action 1.3 – Educate using the best climate science
- Action 2.2 – Manage risks to property, assets, infrastructure and services
- Action 2.4 – Incorporate sustainability objectives into infrastructure projects.

The *Climate Change Risk and Adaptation Framework for Infrastructure Projects* supports these key actions by:

- using several climate scenarios informed by the latest science as provided by the Intergovernmental Panel on Climate Change (IPCC), Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology (BOM)
- providing a risk assessment to manage both direct and indirect risks to the QTRIP program including assets, infrastructure and surrounding properties, and
- describing measures to meet ISCA climate change risk assessment credits, while satisfying sustainability objectives.

2.4 Transport and Main Roads Climate Change Risk Assessment Methodology

The departments EP170 *Climate Change Risk Assessment Methodology* aims to provide governance for the consideration and assessment of impacts associated with climate change across its network and infrastructure projects.

The engineering policy identifies a number of opportunities to integrate climate change into assessment to achieve maximum benefits including:

- through specifications and standard drawings
- risk profiles
- risk registers, and
- investment.

This engineering policy builds off recommendations and findings from Infrastructure Australia around the effects of climate change, including the recognition of three categories:

- direct effects on an asset that alter its ability to deliver the intended services or increases its costs to function; these may be acute (for example, increasing disaster impacts from natural hazards such as flooding) or chronic (for example, trends towards higher average temperatures promoting faster corrosion)
- indirect effects of climate that alter benefits flows even if the infrastructure itself is working as intended (for example, changing temperatures and rainfall altering demand for agriculture-related commercial transport), and
- transitional risks where changes in technology, policy or sentiment occur in response to climate change, altering the relevance of the services delivered by the infrastructure whether or not climate change itself eventuates (for example, changing fuel markets which reduce the demand for coal transport to export ports, driverless truck technology or improved telework which reduce the demand for transport).

3 Purpose of this document

This framework has been developed to guide teams and provide a consistent approach to climate change risk assessment and adaptation measures across the Queensland Transport and Roads Investment Program (QTRIP). The intent being to drive efficiency of process, building of capacity internally and generation of consistency of adaptation treatments. While it may not always be suitable to have consistent adaptation, there are also benefits where it is practical. Consistency of adaptation will engender greater uptake of methodology as well as efficiencies during operational phase maintenance.

This document presents the commonly identified baseline climate risk assessment and outlines the approach for how these risks are currently addressed by business as usual processes and additional treatments that could be applied at a project level.

3.1 Framework context

This framework and corresponding template for Climate Change Risk and Adaptation Assessment (CCRAA) serves to provide a baseline for projects seeking to address climate risk and adaptation in alignment with the requirements outlined in v.1.2 of the ISCA IS Rating Scheme for Cli-1 and Cli-2. Cli-1 aims to reward the assessment of climate change risks, while Cli-2 aims to reward the assessment and implementation of climate change adaptation measures.

In alignment with the IS Rating Tool requirements for Cli-1 and Cli-2, this framework document identifies relevant climate effects in the context of relevant time horizons and relevant climate scenarios and provides an assessment of the potential climate change risks to the project. It further identifies appropriate risk management and adaptation measures to be incorporated into the construction and operation phases to build the resilience of the proposed works to changing climate conditions.

3.2 Cli-1 – Climate change risk assessment

The Cli-1 ISCA Credit: Climate Change Risk Assessment aims to reward proponents for assessing climate change risks. Within this credit, there are three levels with associated criteria. These are detailed in Table 3.2.

Table 3.2 – IS Rating Tool v.1.2 Cli-1: Climate Change Risk Assessment Criteria

Benchmark	Level 1	Level 2	Level 3
	Readily available climate change projection identified & adopted over asset useful life. AND Direct climate risks are identified and assessed.	Achieve Level 1 AND A number of readily available climate change projections AND Consider indirect climate change risks AND Multi-disciplinary team participate in identifying risks and issues.	Achieve Level 2 AND Undertake modelling to characterise likely impacts of projected climate change for all High and Extreme priority risks AND Comprehensive set of affected external stakeholders participated in identifying risks and issues.
Evidence	Climate change study report showing identification and adoption of suitable projection. Risk register or report.	Evidence as per Level 1. Minutes of risk assessment meeting.	Evidence as per Level 2. Model(s) of impacts from High and Extreme priority risks.

Use of the baseline CCRAA provided in this framework and completion of supplementary risk testing at the project level supports evidence requirements in line with Level 2 requirements, subject to verification and submission of supporting evidence.

For Cli-1 this is demonstrated by the following:

- The CCRAA has considered two sets of readily available climate change projections (Queensland Climate Futures and the CSIRO / BOM Climate Futures Tool) as well as provided the rationale for consideration of two-time horizons (for example, 2030 and 2070).
- The CCRAA identified a range of direct and indirect risks and undertook an assessment of those identified risks, and
- A multidisciplinary workshop was held with program and package representatives to validate and refine risk statements as well as refine risk ratings.

3.3 Cli-2 – Adaptation measures

The Cli-2: Adaptation measures credit aims to reward the assessment and implementation of climate change adaptation measures in response to identified climate change risks.

Within this credit, there are three levels of associated criteria. These are detailed in Table 3.3.

Table 3.3 – IS Rating Tool v.1.2 Cli-2: Adaptation Options Criteria

Benchmark	Level 1	Level 2	Level 3
	Adaptation options to treat all high and extreme risks are identified and assessed with appropriate measures implemented. AND After treatment, no extreme residual risks.	Achieve Level 1 AND Adaptation options to treat 25-50% of all medium risks are identified and assessed with appropriate measures implemented.	Achieve Level 2 AND Optimal scale and timing of options are addressed. AND Adaptation options to treat at least 50% of all medium risks are identified and assessed with appropriate measures implemented. AND After treatment, no high residual risks.
Evidence	Risk register or report. Report / management plans demonstrating implementation of measures from risk register.	Evidence as per Level 1.	Evidence as per Level 2.

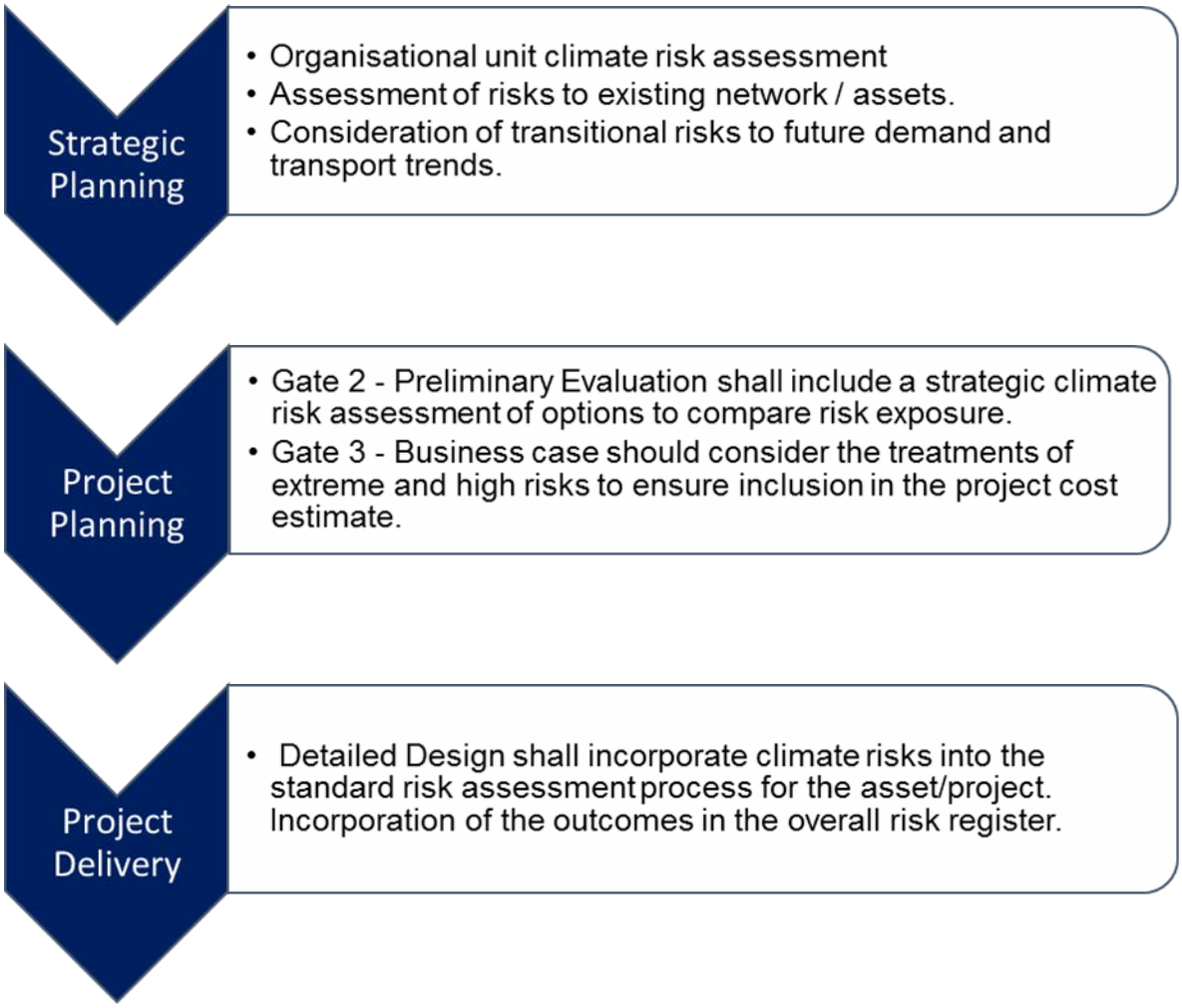
Use of the baseline CCRAA provided in this framework and completion of supplementary adaptation action review supports evidence requirements in line with the Level 2 requirements within each credit, subject to verification and submission of supporting evidence.

For Cli-2 this is demonstrated by the following:

- adaptation actions and current controls were identified (and discussed for practicality / implementation) for treating all high and extreme risks
- following application of the adaptation actions, the residual risk assessment resulted in no high or extreme residual risks, and
- adaptation actions and current controls were identified (and discussed for practicality / implementation) for treating all of the identified medium rated risks.

4 Timing of climate change risk assessments

Climate change risk assessments should be incorporated into the risk assessments at various stages of planning and delivery. The level of detail in the risk assessment should be commensurate with the level of detail required at that phase of the project. That is, detailed design risk assessments are generally very detailed while the assessments at a strategic level are considering broader-scale consequences of impacts.



5 Approach and methodology

5.1 Approach

The overarching CCRAA has been developed in line with the following relevant standards and current guidelines.

These standards and guidelines are broadly aligned with best practice and also serve to address various requirements outlined within the IS Rating Tool v.1.2 Cli-1 and Cli-2 credits:

- AS 5334:2013 Climate change adaptation for settlements and infrastructure – A risk-based approach, following ISO 31000:2009
- Transport and Main Roads EP170 *Climate Change Risk Assessment Methodology*
- Australian Government's *Climate Change Impacts and Risk Management – A Guide for Business and Government* (Department of Environment and Heritage (DEH), 2006)
- *ISCA Climate Change Adaptation Guidelines* (AGIC, 2011), which have been reviewed and used to guide, confirm and validate measures to mitigate and adapt to climate change risks, and

- *ISCA IS v2.0 Climate and Natural Hazards Risk Guideline* which further supported the identification and implementation of relevant approaches in assessing climate risk and developing appropriate adaptation options to help reduce vulnerability and/or exposure.

5.2 Methodology

The adopted risk management framework for assessing the climate risks presented in this document has been developed in accordance with AS 5334:2013 *Climate change adaptation for settlements and infrastructure – a risk-based approach* and the departments EP170 *Climate Change Risk Assessment Methodology.*

The following steps shall be undertaken to complete the CCRAA in line with both AS 5334:2013 and the Australian Government's *Guide for Business and Government*:

1. Identification of key climate variables (e.g. temperature, rainfall and extreme events) and the climate variability that differentiates regional climate zones.
2. Development of potential climate change scenarios, based on the latest climate science, which describes how each variable may change over the design life of the proposed works.
3. Identification of broad climate-based risks that may impact on the proposed works.
4. Completion of a CCRA, with risk ratings, refer Table 5.2(c) evaluated using the AS 5334 *Risk management framework*, including likelihood, refer Table 5.2(a) and consequence criteria, Table 5.2(b).
5. Consequence ratings have been selected based on the highest rating for the risk categories.
6. Identification of measures to mitigate and adapt to the identified climate change risks.
7. Assessment of residual risks to the project, considering adaptation measures to treat high and very high risks.

   NOTE: The appetite for residual climate change risk will be dependent on the infrastructure, level of service requirements and feasibility of successful adaptation.

While it is not expected that project-specific reviews will need to reassess each of the identified risks presented in this framework, sensitivity testing in alignment with this methodology should be undertaken to verify the risk ratings at the project level.

Table 5.2(a) – Likelihood Criteria (Source: AS5334-2013 Climate change adaptation for settlements and infrastructure)

Likelihood	Description	Recurrent or Event Risks	Long Term Risks
Almost Certain	Could occur several times per year	Has happened several times in the past year and in each of the previous 5 years or Could occur several times per year	Has a greater than 90% chance of occurring in the identified time period if the risk is not mitigated
Likely	May arise about once per year	Has happened at least once in the past year and in each of the previous 5 years, or May arise about once per year	Has a 60–90% chance of occurring in the identified time period if the risk is not mitigated
Moderate	Maybe a couple of times in a generation	Has happened during the past 5 years but not in every year, or May arise once in 25 years	Has a 40–60% chance of occurring in the identified time period if the risk is not mitigated
Unlikely	Maybe once in a generation	May have occurred once in the last 5 years, or May arise once in 25 to 50 years	Has a 10–30% chance of occurring in the future if the risk is not mitigated
Very Unlikely (Rare)	Maybe once in a lifetime	Has not occurred in the past 5 years or Unlikely during the next 50 years	May occur in exceptional circumstances, i.e. less than 10% chance of occurring in the identified time period if the risk is not mitigated

Table 5.2(b) – Consequence Criteria (Source: AS5334-2013 Climate change adaptation for settlements and infrastructure)

Consequence	Adaptive Capacity	Infrastructure, Service	Social / Cultural	Governance	Financial	Environmental	Economy
Insignificant	No change.	No infrastructure damage, no change to service.	No adverse human health effects.	No changes to management required.	Little financial loss or increase in operating expenses.	No adverse effects on natural environment.	No effects on the broader economy.
Minor	Minor decrease to the adaptive capacity of the asset. Capacity easily restored.	Localised infrastructure service disruption. No permanent damage. Some minor restoration work required. Early renewal of infrastructure by 10-20%. Need for new/ modified ancillary equipment.	Short-term disruption to employees, customers or neighbours. Slight adverse human health effects or general amenity issues.	General concern raised by regulators, requiring response action.	Additional operational costs Financial loss small, <10%.	Minimal effects on the natural environment.	Minor effect on the broader economy due to disruption of service provided by the asset.
Moderate	Some change in adaptive capacity. Renewal or repair may need new design to improve adaptive capacity.	Limited infrastructure damage and loss of service. Damage recoverable by maintenance and minor repair. Early renewal of infrastructure by 20-50%.	Frequent disruptions to employees, customers or neighbours. Adverse human health effects.	Investigation by regulators Changes to management actions required.	Moderate financial loss 10-50%.	Some damage to the environment, including local ecosystems. Some remedial action may be required.	High impact on the local economy, with some effect on the wider economy.

Consequence	Adaptive Capacity	Infrastructure, Service	Social / Cultural	Governance	Financial	Environmental	Economy
Major	Major loss in adaptive capacity. Renewal or repair would need new design to improve adaptive capacity.	Extensive infrastructure damage requiring major repair. Major loss of infrastructure service. Early renewal of infrastructure by 50-90%.	Permanent physical injuries and fatalities may occur. Severe disruptions to employees, customers or neighbours.	Notices issued by regulators for corrective actions. Changes required in management. Senior management Responsibility questionable.	Major financial loss 50-90%.	Significant effect on the environment and local ecosystems. Remedial action likely to be required.	Serious effect on the local economy spreading to the wider economy
Catastrophic	Capacity destroyed, redesign required when repairing or renewing asset.	Significant permanent damage and/or complete loss of the infrastructure and the infrastructure service. Loss of infrastructure support and translocation of service to other sites. Early renewal of infrastructure by 90%.	Severe adverse human health effects, leading to multiple events of total disability or fatalities. Total disruption to employees, customers or neighbours. Emergency response at a major level.	Major policy shifts. Change to legislative requirements	Extreme financial loss > 90%.	Very significant loss to the environment. May include localised loss of species, habitats or ecosystems. Extensive remedial action essential to prevent further degradation. Restoration likely to be required.	Major effect on the local, regional and state economies.

Table 5.2(c) – Risk Rating Matrix (Source: AS5334-2013 Climate change adaptation for settlements and infrastructure)

Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	Medium	High	Extreme
Moderate	Low	Low	Medium	High	Extreme
Unlikely	Low	Low	Medium	Medium	High
Very Unlikely (Rare)	Low	Low	Low	Medium	Medium

5.2.1 Climate risk workshop

Assessing climate change risks for a project or asset involves a rigorous and comprehensive approach, and consideration and inclusion of important factors such as design life and stakeholder involvement are essential in identifying accurate climate risks and potential mitigation measures.

In alignment with this, a preliminary desktop risk assessment should be undertaken based on a review of project documentation, local hazard mapping and in consideration of future climate projections.

These climate change hazards and climate risks should be presented, refined and agreed for the project/program through a multidisciplinary Climate Risk Workshop attended by a multi-disciplinary internal team representing Transport and Main Roads and the consultant's team.

The workshop shall seek to review the:

- validation of preliminary climate change risks informed by a desktop assessment
- identification of new climate change risks
- allocation of preliminary risk ratings, and
- identification of current adaptation actions and development of potential approaches / actions.

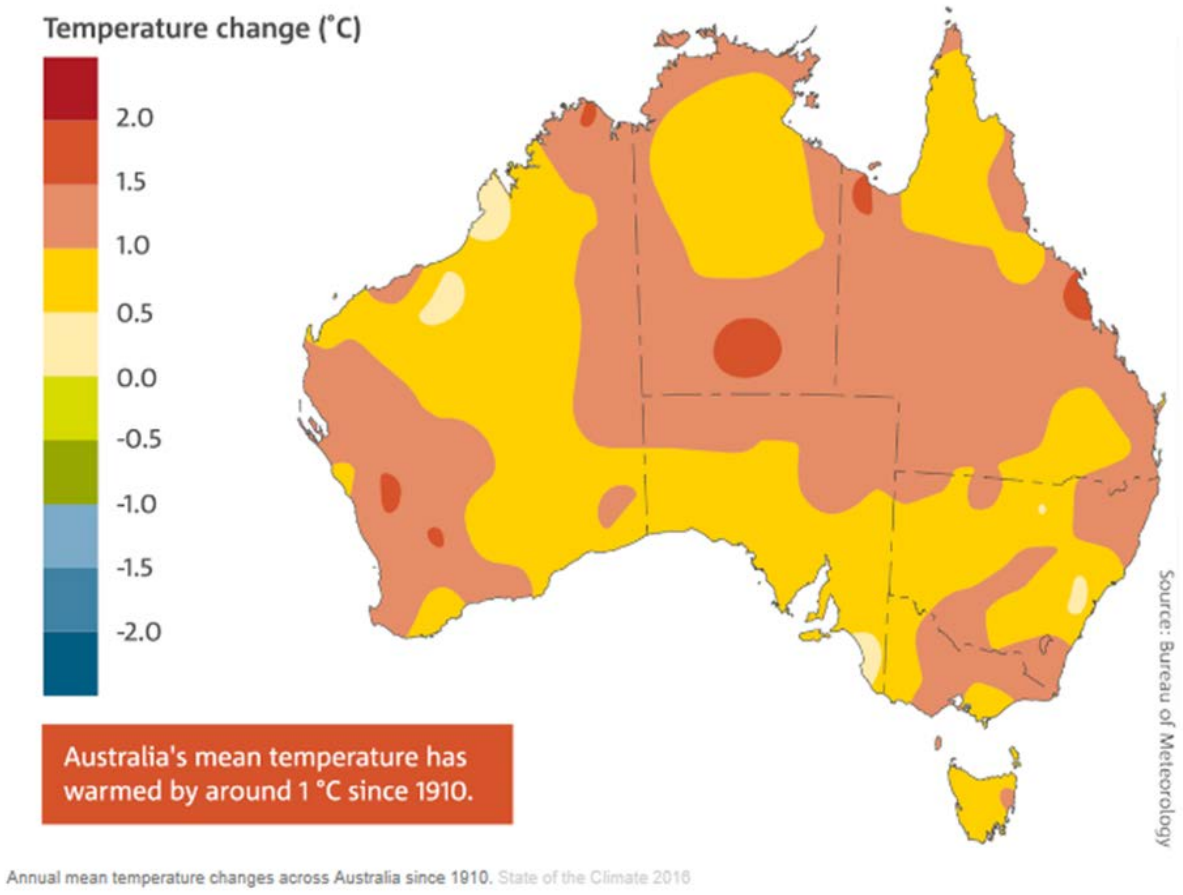
6 Climate change

6.1 Climate change context

Climate change is a global challenge posing significant threats to the natural environment, infrastructure, communities, and the economy. In recent years, Australia has experienced an increase in the duration, intensity and frequency of extreme weather events such as fires, floods and drought, which are likely to increase further in the future. It is essential that adaptation measures and resilience strategies be implemented both within infrastructure developments and within communities, in order to increase resiliency, preparedness and recovery against extreme climate events.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has reported that Australia’s climate has warmed by 1 degree Celsius since national records began in 1910, and that the years 2013 to 2015 are among the top five warmest years on record, with 2019 being Australia's hottest and driest year on record. Figure 6.1 below displays the annual mean temperature changes across Australia since 1910, demonstrating that an increase in annual mean temperature is experienced across the country.

Figure 6.1 – Annual mean temperature changes across Australia since 1910 (Bureau of Meteorology and CSIRO, 2019)



Annual mean temperature changes across Australia since 1910. State of the Climate 2016

In addition to an increase in mean annual temperature, oceans around Australia are warming and acidifying (decreasing in pH) and sea levels are rising. It is also predicted that longer droughts will be experienced in the south and increased flooding in the north, and a long-term increase in extreme fire weather and length of the fire season will progressively be experienced. The national annual accumulated Forest Fire Danger Index – an indication of the severity of fire weather – was the highest on record in 2019. The effects of climate change will not only be felt within Australia, but across the globe. These extreme weather events pose significant threat to the environment, society and the economy, and building self-resilience throughout Australian communities is critical.

6.2 Observed Queensland climate exposure

In accordance with the Transport and Main Roads EP170 *Climate Change Risk Assessment Methodology*, the projected changes in local climate hazards should be identified and considered over a variety of timeframes.

The Queensland summaries are based on global climate models (GCMs):

- Queensland (https://www.qld.gov.au/environment/assets/documents/climate/queensland-climate-change-impact-summary.pdf)
- Cape York (https://www.qld.gov.au/environment/assets/documents/climate/cape-york-climate-change-impact-summary.pdf)

- Central Queensland (https://www.qld.gov.au/environment/assets/documents/climate/central-qld-climate-change-impact-summary.pdf)
- Central West Queensland (https://www.qld.gov.au/environment/assets/documents/climate/central-west-qld-climate-change-impact-summary.pdf)
- Eastern Downs (https://www.qld.gov.au/environment/assets/documents/climate/eastern-downs-climate-change-impact-summary.pdf)
- Far North Queensland (https://www.qld.gov.au/environment/assets/documents/climate/far-north-qld-climate-change-impact-summary.pdf)
- Gulf Region (https://www.qld.gov.au/environment/assets/documents/climate/gulf-region-climate-change-impact-summary.pdf)
- Maranoa and District (https://www.qld.gov.au/environment/assets/documents/climate/maranoa-climate-change-impact-summary.pdf)
- North Queensland (https://www.qld.gov.au/environment/assets/documents/climate/north-qld-climate-change-impact-summary.pdf)
- North West Queensland (https://www.qld.gov.au/environment/assets/documents/climate/north-west-qld-climate-change-impact-summary.pdf)
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- South West Queensland (https://www.qld.gov.au/environment/assets/documents/climate/south-west-qld-climate-change-impact-summary.pdf)
- Whitsunday, Hinterland and Mackay (https://www.qld.gov.au/environment/assets/documents/climate/mackay-whitsunday-climate-change-impact-summary.pdf)
- Wide Bay-Burnett (https://www.qld.gov.au/environment/assets/documents/climate/wide-bay-burnett-climate-change-impact-summary.pdf)

Local Governments have also undertaken a variety of climate change risk assessments and produced hazard mapping for their respective jurisdictions.

Local hazard mapping commonly relates to sea level inundation and riverine flooding.

6.2.1 Climate hazards

In accordance with the EP170 *Climate Change Risk Assessment Methodology*, the hazards that should be considered are listed below in Table 6.2.1.

Table 6.2.1 The minimum climate change hazards that should be considered as part of Transport and Main Roads' risk assessment.

Direct Impacts	Indirect Impacts
• Sea level rise and coastal inundation • Precipitation and rainfall intensity • Cyclones and storms • Flooding • Wind and hail • Air Temperature and humidity • Solar radiation • Heatwaves and droughts • Bushfire weather	• Water shortages • Disruptions to electricity supply • Inundation of coastal areas

6.3 Climate modelling

The climate of Queensland, as with global climate trends, is naturally variable. Climate change however, will lead to shifts beyond this natural variability.

Risk assessment based on climate change requires an understanding of the current climate using historical data for comparison with future climate scenarios.

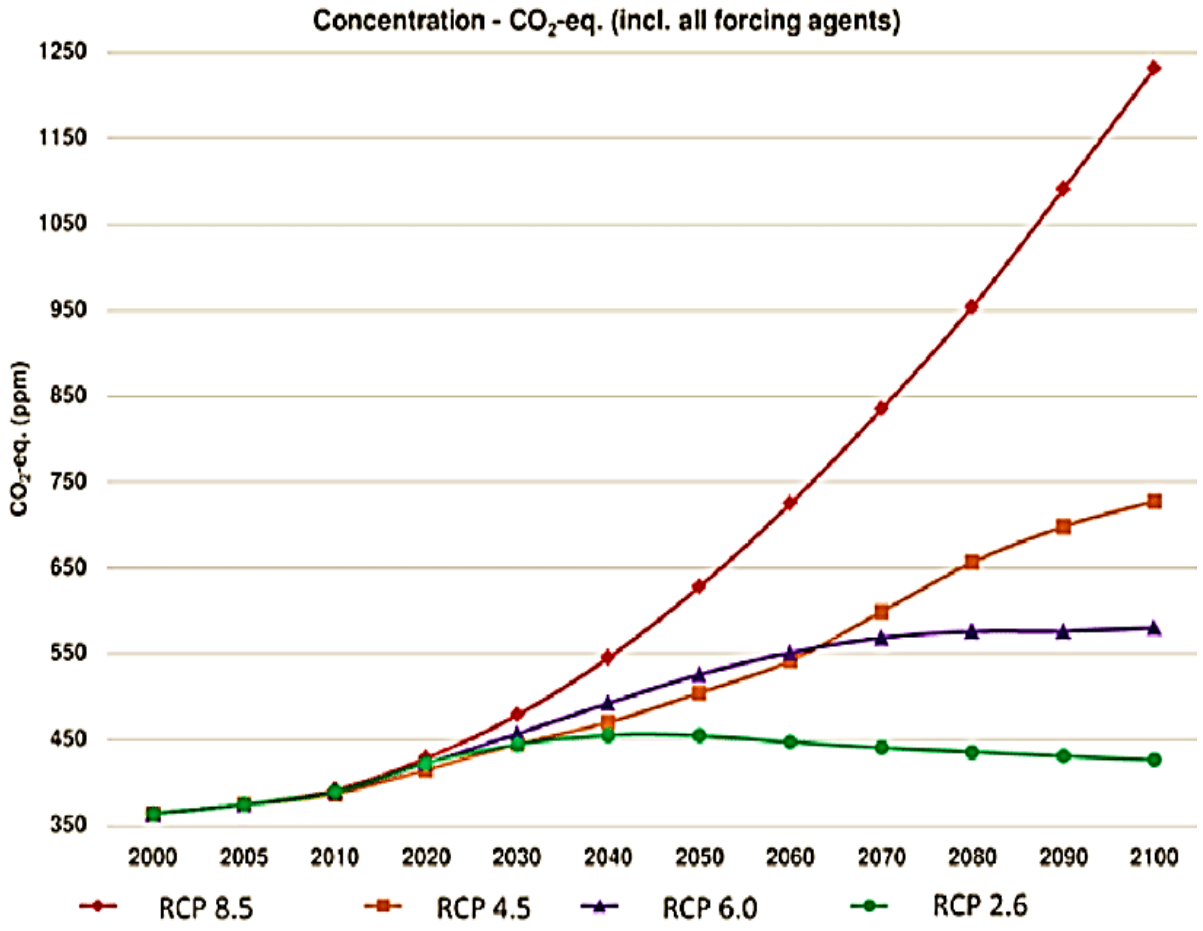
Future climate scenarios are generated and prepared using data from Global Climate Models (GCM). GCMs are tools used for understanding how the climate will respond to changes in greenhouse gas (GHG) emission levels.

6.3.1 Representative concentration pathways

The Intergovernmental Panel on Climate Change (IPCC) is an intergovernmental organisation of the United Nations whose primary objective is to conduct research and assessments in relation to climate change science in order to inform adaptation and mitigation measures. The IPCC has defined four greenhouse gas concentration trajectories (outlined in Figure 6.3.1 below) known as Representation Concentration Pathways (RCPs) for use in climate modelling and research.

Projections are presented for an emission scenario or possible pathways, referred to as 'representative concentration pathway' (RCP), each of which reflects a different concentration of global greenhouse gas emissions. RCPs have been modelled for low emissions (RCP 2.5), medium emissions (RCP 4.5) and high emissions (RCP 8.5). The RCP 8.5 pathway, which arises from little effort to reduce emissions and represents a failure to prevent warming by 2100, is similar to the highest Special Report on Emissions Scenarios (SRES) scenario and is used in this report. The RCP 8.5 pathway is also closest to the current emissions trajectory.

Figure 6.3.1 – CO_2 Concentrations from global observations



6.3.2 Timescales

Roadway infrastructure has a varied expected design life depending on the component or system (e.g. pavement versus electrical). Minimum design lives outlined in Table 6.3.2 are indicative for the purposes of the climate change assessment and may be subject to change through project design development.

It may be appropriate to re-consider minimum design lives on a project by project, component basis where delayed climate change risk may be able to be better accounted for through delayed adaptation.

Table 6.3.2 – Program / project design lives

Asset	Minimum Design Life
Abutment protection either not subject or subject to scour	100 years
Bridge drainage systems	50 years
Difficult to maintain drainage elements, which must include: a) any culvert (existing or new) within the Upgrade road formation; b) culvert end walls that are difficult to access.	100 years
Expansion Joints and Rubbers in expansion joints; Drainage systems (replaceable elements only); Steel bridge traffic barrier, safety screens and fencing; Light poles (including outreach arms) and signs on side of bridge; Gantries and cantilever structures over any portion of the roadway; Bridge bearings; and Median slabs.	Refer clause 3.7.1 “Design Life – New Bridges” of the Transport and Main Roads Manual: Design Criteria for Bridges and Other Structures.
Sign faces	10 years
Fences, including fence posts, fauna fences (excluding fencing on bridges and noise fences)	20 years
ITS components	Refer to respective Transport and Main Roads' standard specifications
Lighting (including luminaries) and electrical equipment excluding light poles, outreach arms, and foundations	20 years
Outreach arms, Light Poles, and foundations for light poles	40 years
Retaining walls, including reinforced soil structure walls	100 years
Noise-attenuating structures	Refer MRTS15 "Noise Fences"
Batter treatments	100 years (Austroads *Guide to Road Design Part 2: Design considerations*)
Mechanical and electrical equipment	20 years
Traffic management and control systems	20 years
Buildings	50 years
Pavements	30 years
Timber furniture for environmental works	40 years
Temporary Works, excluding pavements	2 years

Typically for major projects, based on these design lives, construction of the proposal being likely in the next several years and the latest available climate data, the time periods selected for assessment are 2030 and 2070. The year 2030 was considered appropriate for short-term impacts of the proposal including consideration for the first round of component renewal. Climate change projections for 2070 are considered relevant to longer term operation and maintenance as well as a majority of the infrastructure given the expected design life.

Climate projections for the selected time scales represent averages over a 20-year period:

- projections for 2030 represent the average for the 20-year period between 2020 to 2039
- projections for 2050 represent the average for the 20-year period between 2040 and 2059, and
- projections for 2070 represent the average for the 20-year period between 2060 to 2079.

As a means of comparison and to consider the full range of the design life of the program (e.g. 100 years), projections for 2050 or 2090 could alternatively be considered. It depends on the type of infrastructure. At present, 2090 represents the furthest time horizon for understanding projections and future changes to the climate. It is worth noting that the level of confidence in global models decreases with further time horizons however adaptation actions taken to reduce risk in 2070 are likely to have benefit to the 2090 scenario, including treatments identified currently that protect the longer design life elements (e.g. drainage and bridge piles). It is recommended that when new projections and other information become available (and have greater confidence), climate risks to the project should be reviewed and reassessed using this new information.

6.4 Climate Change Projections

CSIRO and Bureau of Meteorology (BoM) have published climate change projections for Australia based on published data sets and emissions scenarios specific to relevant locations defined as ‘clusters’ across the country. Projections for a full range of variables are only provided for the 2030-time and 2090-time horizons for the Cluster reports. The 2090-time horizon, as noted in Section 6.3.2, serves as a comparison to understand how the climate may change for some of the longer life design elements.

The Queensland Climate Futures Dashboard provides an interactive tool that can be used to identify the varying changes to climate across geographical areas, timeframes and climate change projection. The Queensland Government Future Climate Scenarios are presented in the Long Paddock Website and are subdivided into 14 regions. Recognising that the majority of the design elements have a less than 50-year design life, 2030 and 2070 were selected for the detailed climate change projections for this example. Table 6.4 below provides an example of the climate change projects for South East Queensland.

Table 6.4 – Example of detailed climate change projections – South East Queensland example

Climate Variable	2030[1]	2030[2]	2070[3]	2090[4]
Mean Temperature (°C)(Annual)	0.9 (0.6 to 1.3)	1 (0.6 to 1.3)	2.8 (2.0 to 3.7)	3.7 (2.5 to 4.7)
Maximum Temperature (°C)(Annual)	1.0 (0.6 to 1.6)	1 (0.5 to 1.4)	3.1 (2.1 to 4.1)	3.6 (2.9 to 4.7)
Minimum Temperature (°C)(Annual)	0.9 (0.6 to 1.2)	1 (0.7 to 1.4)	2.8 (2.1 to 3.7)	3.7 (2.6 to 4.7)
Days above 40°C	0.2 (0 to 0.5)	+1.2 (1.1 to 1.6)	+1 (0 to 2)	+6.0 (2.9 to 11)
Hot Days (days above 35°C)	+4 (1 to 9)	+18 (15 to 22)	+22 (9 to 41)	+55 (37 to 80)
Bushfire (Days)	N/A	0.9	N/A	1.3
Precipitation (%)	0.3 (-10 to 12)	-6 (-17 to 8)	-1 (-37 to 12)	-16 (-32 to 17)
Surface Wind (%)	-1 (-4 to 0.8)	0.8 (-0.5 to 3.6)	2.1 (-4.6 to -0.2)	2.2 (-1.2 to 6.5)
Solar Radiation (%)	1.1 (-0.6 to 5.1)	0.7 (-0.9 to 1.8)	2.1 (-1.1 to 5)	0.8 (-2.1 to 3.1)
Duration of Drought (change in months)	-0.6 (-4 to 5)	Unclear around frequency and duration of drought	+2.5 months (-3 to 18)	Greater time spent in duration of drought
Duration of floods (change in months)	0.5 (-2 to 3)	N/A	0 (-5 to 4)	N/A
Sea level rise (metres)	N/A	0.14 (0.09-0.18)	N/A	0.65 (0.45-0.87)
Thunderstorms (days per year)	High confidence heavy rainfalls will increase, but magnitude cannot be reliably projected			

1 & 3 – Future Climate Dashboard (Southeast Queensland Region):
https://app.longpaddock.qld.gov.au/dashboard

2 & 4 – CSIRO and BOM Climate Futures Tool*: East Coast Cluster Report – North*

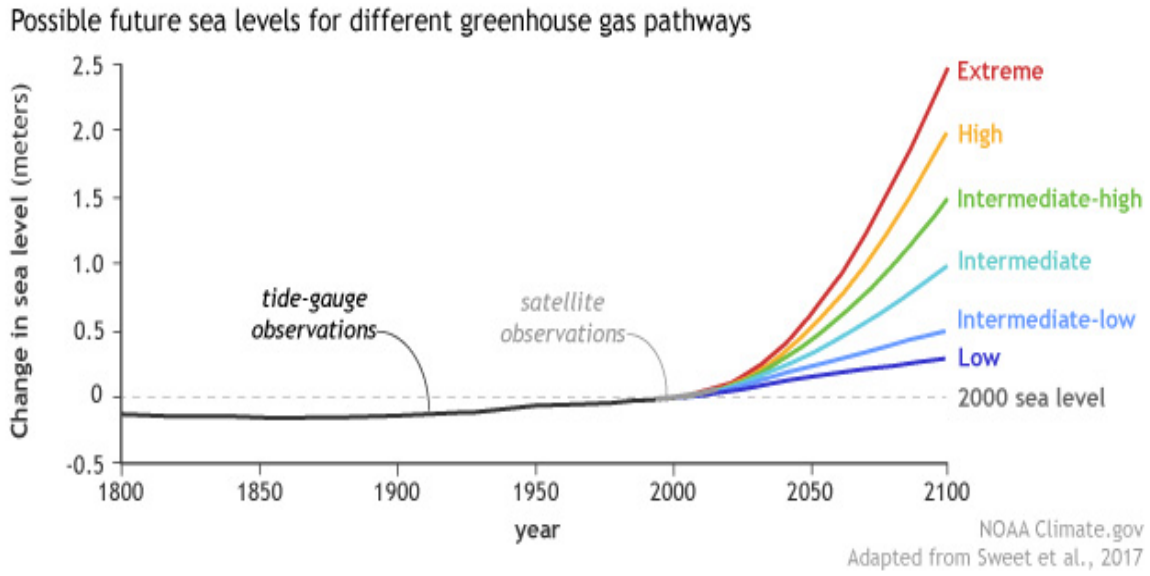
7 Potential climate change consequences

7.1 Sea level rise and coastal inundation

The Queensland Government has adopted a projected sea-level rise of 0.8 m by the year 2100. This is based on the climate modelling for probable scenarios presented at the *Intergovernmental Panel on Climate Change Fifth Assessment Report 2014.*

There are some concerns that this may be a low estimate. With a high emissions projection (RCP 8.5), modelling potential seal level rise is 2 m by 2100 as shown by the National Oceanic and Atmospheric Administration (NOAA) of the United States of America.

Figure 7.1 – Projected sea level rise



7.2 Mean temperature

There is strong agreement on the direction and magnitude of temperature changes among GCMs and downscaling results and as a result, there is very high confidence in substantial warming for the annual and seasonal projections for daily mean, maximum and minimum surface air temperature for a range of emissions scenarios.

Changes in mean temperature that can affect road infrastructure occur at the extremes, for instance increasing the duration of bushfire seasons and impacting heatwaves and days over 35ºC. While mean temperature can influence most elements of the roadway, it is the extremes that could result in the greatest impact to the project, both from a construction and operational perspective, including prolonged bushfire seasons impacting roadside infrastructure, motorists, cyclists, pedestrians and operations personnel. Prolonged heat exposure can also impact on the materials and infrastructure as well as personnel working along the corridor.

7.3 Extreme temperature and heatwaves

Heat related extremes are projected to increase at the same rate as projected mean temperature with a substantial increase in the number of warm spell days. An increased frequency and duration of hot days and heatwaves is projected for the proposed works area in general with very high confidence under both RCP 4.5 and RCP 8.5 scenarios (CSIRO and BOM, 2015).

As noted above, extreme temperatures and heatwaves have the potential to reduce the efficiency of electrical infrastructure and impact on operations and maintenance activities (both personnel and rate of infrastructure renewal).

7.4 Mean rainfall and drought

Projected changes in rainfall tend to be location specific. Generally speaking, all projects suggest an increase in the variability of rainfall. Projected changes to meteorological drought share much of the uncertainty of mean rainfall change, and there is no clear indication on changes to drought conditions.

Changes in precipitation and increased duration of drought can impact on the longer-life elements of the proposed works including drainage infrastructure, road base and bridges. Soil cracking and subsidence based on these changes in patterns can lead to instability and more frequent maintenance over the life of the project.

7.5 Extreme rainfall and flooding

In a warming climate, heavy rainfall events are expected to increase in magnitude mainly due to a warmer atmosphere being able to hold more moisture (Sherwood et al., 2010).

The CSIRO and BOM (2015) indicate with high confidence a future increase in the intensity of extreme rainfall events across the proposed works area. However, given the natural variability of rainfall the frequency and magnitude of increases in extreme rainfall cannot be confidently projected.

Extreme rainfall can result in severe flooding which can directly impact the road, including inundation of drainage infrastructure, damage/malfunctioning of electrical infrastructure and sheet flows resulting in aquaplaning. In addition, flooding can impact the surrounding local road network, potentially restricting emergency access and/or driving additional users onto the road.

7.6 Bushfire weather

Studies suggest that climate change will have a significant impact on future fire weather (e.g. Williams et al, 2009; Clarke et al, 2011; Grose et al, 2014). Suitable weather conditions (hot, dry and windy) must generally exist for fires to spread. Given the combination of factors required for increased bushfire conditions, the potential increase in the future will rely heavily on projected changes in the weather.

There is high confidence that climate change will result in harsher fire weather in the future. This is seen in the mean changes and when examining individual models and scenarios. However, there is low confidence in the magnitude of the change, as this is strongly dependent on the rainfall projection. It is also recognised that the actual variability of fire weather across Queensland may be underestimated as the baseline fire climate is poorly sampled due to the small number of stations.

Increased incidence of bushfire weather and the number of severe fire weather days could result in damage to electrical equipment and other roadside infrastructure (e.g. noise walls) as well as increased smoke impacting on the visibility for motorists and health of cyclists and pedestrians using the active transport network.

7.7 Extreme storms (including wind, lightening and hail)

Projections indicate a decrease in the formation of tropical cyclones, however it is anticipated that the proportion of the most intense cyclones will increase over the century while the intensity of associated rainfall may increase further.

Thunderstorms can also be hazardous, bringing accompanying winds hail, tornados, flash flooding and lightening. While uncertainty exists with the projected changes in terms of number of additional thunderstorms, global models agree that the intensity of storms is predicted to increase.

As the intensity of cyclones and thunderstorms increase, potential impacts to transport infrastructure include damage to electrical infrastructure from high winds and hail as well as from debris blowing onto the corridor and adversely impacting vehicle safety.

7.8 Solar radiation

For both 2030 and 2070, models simulate little change in radiation (about –1 to +3%) for both RCP 4.5 and RCP 8.5 with the higher changes projected for winter given decreases in cloudiness associated with reduced rainfall. Globally however, several models appear to underestimate the observed trends in some regions due to underestimation of influence caused by aerosol emissions (Allen et al, 2013). Taking this into account, we have high confidence in little change for 2030. For 2070, there is medium confidence in increased winter radiation, and low confidence for the small changes projected for the other seasons.

Increased solar exposure could potentially result in the accelerated degradation of materials, particularly the less hardened materials (e.g. signalling and cabling). Given the low relative change in the future, solar radiation isn't considered likely to impact on the project.

7.9 Water shortages

Related to mean rainfall and drought trends, water shortages may be a more common indirect consequence to QTRIP in future. This could present particular challenges for network operations and maintenance, particularly on gravel roads.

7.10 Electricity supply disruptions

Increase in the frequency and intensity of extreme weather events may also have an indirect impact to the road network through disruption to electricity supply. Again, this primarily has potential consequences for future network operations and impacts the level of service for the network.

8 Potential likelihood

The likelihood of particular climate hazards impacting on an asset are largely dependent on:

- location of the asset, and
- local climate projections.

9 Summary of Transport and Main Roads Infrastructure climate change risks

Summary of Climate Change Risks identified for Transport and Main Roads assets are listed in Table 9 below. The project / asset specific likelihood and consequence of each risks must be considered on a project by project or asset by asset basis.

Table 9 – Typical Transport and Main Roads Asset Risks and a template for a TMR Project Climate Change Risk Assessment

NOTE: The projected timeframes, risk likelihood and consequence need to be assessed on a project/asset specific basis.

				2030			2070		
Risk ID	**Climate change variable**	**Risk statement**	**Direct / Indirect**	Likelihood	Consequence	Risk Rating	Likelihood	Consequence	Risk Rating
BF-1	Increased risk of bushfire events and weather resulting in:	Damage to electrical infrastructure as a result of ash accumulation (ramp metering, signals and variable speed limit signs), resulting in impacts to operation of the road	Direct						
BF-2		Damage to infrastructure (e.g. noise walls, pavement) resulting in increased maintenance and decrease in operational safety	Direct						
BF-3		Potential smoke inhalation and health concerns for maintenance workers	Direct						
BF-4		Potential smoke inhalation and health concerns for pedestrian / cyclist / vehicle users	Direct						
BF-5		Visibility concerns for motorists	Direct						
BF-6		Delays to maintenance and operational requirements impacting scheduled activities	Direct						
BF-7		Damage to substations and associated infrastructure resulting in disruption of electricity supply with potential power outages and communications network failure	Indirect						
BF-8		Loss of access resulting in user delays, emergency vehicle access or additional traffic on surrounding road network	Direct						
BF-9		Electrical infrastructure sparking bushfires and subsequent damage (and impact) to surrounding areas	Indirect						

				2030			2070		
Risk ID	**Climate change variable**	**Risk statement**	**Direct / Indirect**	Likelihood	Consequence	Risk Rating	Likelihood	Consequence	Risk Rating
BF-10	Increased risk of bushfire events and weather resulting in:	A loss of access to the surrounding road network, resulting in increased traffic and subsequent safety concerns for motorists along the road	Indirect						
BF-11		Fauna and residents using the infrastructure as egress to escape bushfire	Indirect						
BF-12		Increased risk of bushfire ignition within roadside vegetation	Indirect						
SE-1	Increased incidence and severity of storm events (e.g. wind, lightning) resulting in:	Damage to electrical infrastructure from lightning, wind or hail (e.g. ramp metering, lighting, signals and variable speed limit signage) resulting in disruption of road operation	Direct						
SE-2		Structural stability concerns and/or impacts for bridge / noise structures - potential for collapse	Direct						
SE-3		An increase in the scale and quantity of debris blown onto the road (as well as impacts to vehicles on the road) causing damage/impact to supporting infrastructure and impacting user safety (motorists, cyclists and pedestrians)	Direct						
SE-4		An increase to maintenance and operational costs to support routine repair and replacement works	Direct						
SE-5		Power outages (black outs) as a result of damage to energy substations and associated energy/electrical infrastructure	Indirect						
SE-6		Damage to the surrounding road network, resulting in increased vehicle usage of the motorway and potential decrease in safety due to the increase in usage	Indirect						

				2030			2070		
Risk ID	**Climate change variable**	**Risk statement**	**Direct / Indirect**	Likelihood	Consequence	Risk Rating	Likelihood	Consequence	Risk Rating
ERF-1	Increased incidence of extreme rainfall events and subsequent flooding resulting in:	The capacity of existing drainage infrastructure being exceeded (due to either blockage from debris or volume of water) leading to inundation of surrounding infrastructure (e.g. properties, road, bus stations, kiss and ride, interchanges)	Direct						
ERF-2		Exacerbated local flooding risks impacting motorists	Direct						
ERF-3		Increased rainfall intensity along the road resulting in increased road incidents (e.g. aquaplaning) and safety risks to motorists	Direct						
ERF-4		An increased safety risk and disruption to the users of the cycle / pedestrian network due to inundation of infrastructure	Direct						
ERF-5		Water damage to electrical infrastructure (ramp metering, signals and variable speed limit signs) resulting in disruption of road operation	Direct						
ERF-6		Erosion of infrastructure foundations resulting in the exposure of concrete (e.g. road base, drainage infrastructure, pier supports), particularly along river and creek crossings	Direct						
ERF-7		Increased risk of landslip (e.g. weakened verges and decreased slope stability) in surrounding areas resulting in damage to infrastructure	Direct						
ERF-8		Accelerated degradation of assets from increased rainfall intensities and prolonged flooding resulting in increased maintenance and operational costs and repairs	Direct						

				2030			2070		
Risk ID	**Climate change variable**	**Risk statement**	**Direct / Indirect**	Likelihood	Consequence	Risk Rating	Likelihood	Consequence	Risk Rating
ERF-9	Increased incidence of extreme rainfall events and subsequent flooding resulting in:	Increased risk of additional scour and erosional impacts on surrounding waterways and the associated environmental impacts (e.g. water quality, ecological implications for species)	Direct						
ERF-10		Increased stormwater flow from surrounding developed areas contributing to additional water volumes in drainage lines and other stormwater infrastructure (e.g. culverts) resulting in additional localised flooding impacts	Indirect						
ERF-11		Localised ponding leading to an increased attraction for animals resulting in increased hazards for fauna / automobile accidents.	Indirect						
ERF-12		Power outages at substations disrupting supply to electrical and communications systems impacting operation of the road	Indirect						
ERF-13		Surrounding areas being inundated, resulting in an increase of motorists using the road as an escape route and potential decrease in safety along the road due to increased traffic in a hazard event	Indirect						
MRD-1	Changes in mean rainfall levels and increased incidence of drought conditions resulting in:	Soil cracking resulting in damage to infrastructure (e.g. culverts, foundations, road base, embankments)	Direct						
MRD-2		Adverse impacts to proposed landscaping areas (including those reinstated) including lack of available water for irrigation	Direct						
MRD-3		Wildlife migration to watercourses	Indirect						
MRD-4		Increased fuel for bushfire	Indirect						

				2030			2070		
Risk ID	**Climate change variable**	**Risk statement**	**Direct / Indirect**	Likelihood	Consequence	Risk Rating	Likelihood	Consequence	Risk Rating
MRD-5	Changes in mean rainfall levels and increased incidence of drought conditions resulting in:	Dust impacts from quarry – skid resistance, visibility and erosion leading to poor water quality	Indirect						
MRD-6		Water shortage during prolonged construction phase and operational phase	Indirect						
SLR-1	Increasing sea levels resulting in:	Inundation of road formation resulting in disruption to operation	Direct						
SLR-2		Permanent inundation of drainage infrastructure reducing the flood immunity of structures	Direct						
SLR-3		Exacerbated local flooding risks	Direct						
SLR-4		Ingress of saltwater intrusion into embankment and lower pavement layers causing reduced performance life	Direct						
SLR-5		Increased incidence of coastal erosion, exposing footings and other buried structures, resulting in damage or potential collapse	Direct						
SLR-6		Increased incidence of saltwater intrusion, accelerating corrosion of concrete and steel structures	Direct						

				2030			2070		
Risk ID	**Climate change variable**	**Risk statement**	**Direct / Indirect**	Likelihood	Consequence	Risk Rating	Likelihood	Consequence	Risk Rating
EH-1	Increased incidence and duration of extreme heat events and solar radiation resulting in:	Damage to electrical system components (e.g. cabling, sensor loops, housings) resulting in disruption smart motorway operation, CCTV and emergency response	Direct						
EH-2		The accelerated degradation and malfunctioning of electrical equipment, requiring replacement more often, increasing maintenance and operational costs	Direct						
EH-3		The accelerated deterioration of concrete / asphalt infrastructure, resulting in decreased safety for motorists (e.g. potholes)	Direct						
EH-4		The accelerated deterioration of concrete / asphalt / steel infrastructure, resulting in increased maintenance and operational costs (e.g. resurfacing)	Direct						
EH-5		Steel structures (e.g. expansion joints, guardrails, bridge components) buckling or warping and impacting safety of users	Direct						
EH-6		An increased risk of heat stress for cyclists and pedestrians) using the new facilities	Direct						
EH-7		An increase in the number of vehicle breakdowns along the road (due to vehicle overheating) resulting in safety concerns and increased requirements for road management	Direct						
EH-8		Adverse impacts to proposed landscaping areas (including those reinstated) including loss of planted species due to ongoing heat exposure	Indirect						

				2030			2070		
Risk ID	**Climate change variable**	**Risk statement**	**Direct / Indirect**	Likelihood	Consequence	Risk Rating	Likelihood	Consequence	Risk Rating
EH-9	Increased incidence and duration of extreme heat events and solar radiation resulting in:	Increased power demand and/or faults in the network resulting in power supply interruptions and/or outages for electrical infrastructure, including CCTV	Indirect						
EH-10		An increased risk to workers during operation from heat stroke, heat stress or heat exhaustion resulting in reduced productivity	Direct						
EH-11		Increased sag on overhead cables - decreased clearance	Indirect						
EH-12		Equipment heat ratings insufficient to meet increased heat	Indirect						
EH-13		Reduced safety for travelling public due to ITS outages, debris on road, potential damage to assets	Indirect						

10 Adaptation options

The following section outlines the adaptation options identified as common risk treatments that could be applied. Both current (i.e. planned) and future (i.e. potential) controls and actions are identified, including designation of which variable the control applies to and the responsibility for implementation.

The adaptation actions presented in this section provide an overarching response to the risks outlined in the baseline assessment (refer Table 10 below) and should be reviewed and tested for applicability at the project level. In addition, adaptation planning should consider the following four adaptation treatment types in accordance with Transport and Main Roads guidance provided in the Engineering Policy, as detailed in Table 10.

Table 10 – Adaptation Planning

Adaptation Treatment	Description	Expected Financial Implication	Example
Build for end of design life scenario	Build to maintain standards and level of service for the climate change scenario expected at end of life	Generally higher upfront costs, although lower addition costs through design life for adaptation. Provides a higher level of service for entire design life. Risk that actual climate change will exceed prediction	Bridge is designed and constructed with capacity for climate change.
Planned adaptation	Plan an upgrade program to progressively adapt the infrastructure as climate change occurs. Initial design considers predicted climate changes and provides functionality to adapt the infrastructure at another time. Consultation with program and asset managers required to secure investment program.	Moderate Upfront Costs expected, although further investment is required during infrastructure life cycle. Provides some increase in level of service.	Culvert is designed and constructed for mid-life span climate change conditions, but considerations made in current design for an upgrade in capacity i.e. second culvert can be installed in parallel.
Progressive modification (existing asset)	Redesign and reconstruct as required and as possible in response to verified climate change as part of existing maintenance regime or project upgrades. Future verified climate changes will be captured in investigatory criteria of audits.	Moderate upfront costs expected. Further climate changes will force re-design. Higher costs to adapt asset in long term. Maintains level of service.	Culvert is constructed according to current climatic conditions (assume standards may not be current). Culvert will be upgraded if needed in future.
No Adaptation / Redundancy	No adaptation or making the overall asset redundant as there are suitable alternatives, or the asset is not required	No extra investment required.	Culvert is not constructed at all or not replaced when it fails.

10.1 Current Actions

Table 10.1 presents adaptation actions that can be considered during the design of the projects. Additional controls, as identified by the project team, will need to be considered to further treat supplementary project-specific risks.

Table 10.1 – Current Transport and Main Roads Climate Risk Treatments

Adaptation Action	Climate Variable	Responsibility
Utilise a consolidated flood model based on Local Government Hazard Mapping, and includes storm surge, sea level rise and increased rainfall intensity of in accordance with Australian Rainfall and Runoff 2018.	Rainfall, storm events, sea level rise	Design Consultant
Undertake sensitivity checks against modelling utilising climate change projections for storm surge, sea level rise and increased rainfall intensity (Local Government Hazard Mapping)	Rainfall, storm events, sea level rise	Design Consultant
Locate critical infrastructure outside of known low areas and/or flood risk areas	Rainfall and flooding	Design Consultant
Incorporate Transport and Main Roads Design Criteria for Bridges and Other Structures (2018) which accounts for climate change	Rainfall and flooding	Design Consultant and TMR
Design new bridges and drainage to minimise and mitigate scour	Rainfall and flooding	Design Consultant
Review plant selection and irrigation requirements for planted species (e.g. review similar climates through tools such as the Climate Analogues Explorer)	Extreme heat / drought	TMR
Incorporate fauna fencing and underpasses (crossing points) into the design	Mean rainfall / drought	Design Consultant
Locate intelligent transportation system cabinets in locations outside of bushfire prone areas and away from combustible vegetation	Bushfire	Design Consultant
Review and if required, revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for climate extremes, including provisions for road closures and/or diversions and emergency bays for vehicle breakdowns and/or emergency access	All	TMR
Investigate the inclusion of backup power or redundant supply (e.g. uninterruptable power supply) for electrical systems as part of design	All	Design Consultants and TMR
Use the Emergency Variable Message Signs (VMS) Alert Request and Social Media request forms for warnings and to convey weather hazard information	All	TMR
Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g. static signs, backup power)	All	Design Consultants and TMR
Incorporate lightening protection into the gantries and VMS	Extreme storms	Design Consultants and TMR

10.2 Potential controls

To further mitigate and respond to climate risks, a number of proposed/potential adaptation actions have been identified as applicable for consideration and inclusion across projects. These are provided in Table 10.2. In accordance with requirements for Cli-2, evidence of these actions (e.g. design drawings, specifications, policies) must be provided with the credit documentation to demonstrate action in reducing the risk ratings.

Table 10.2 – Potential Transport and Main Roads Climate Risk Treatments

Adaptation Action	Climate Variable	Responsibility
Update maintenance plan to increase the frequency and review of maintenance activities	All	TMR
Evaluate design levels for electrical systems for resilience against flooding and rainfall risks	Rainfall and flooding	Design Consultant and TMR
Review design standards / inclusions and determine if additional protection (e.g. covers for electrical systems or resistant coatings) is required for critical infrastructure	Rainfall and flooding	Design Consultant and TMR
Provide strengthening to existing bridge structures	All	Design Consultant, TMR and Construction Contractor
Consider sensitivity testing for flood models (e.g. RCP 8.5 or greater than 10% increase)	Rainfall, storm surge and flooding	Design Consultant
Design and construct larger culverts, without impacting upstream flows, to account for additional surface flow	Rainfall, storm surge and flooding	Design Consultant
Review and where relevant, change road geometry (such as the gradient, removal of sag curves or vertical elevation in critical areas) to shorten flow paths and reduce risk of motorway inundation	Rainfall, storm surge and flooding	Design Consultant
Design bridge piles to a Q2000 event	Rainfall, storm surge and flooding	Design Consultant
Prepare an emergency management plan to restrict access to critical areas (e.g. shared paths) and outline emergency service provisions (e.g. access, notification, etc.)	All	TMR and Construction Contractor
Design infrastructure to account for higher temperatures (e.g. increased heat ratings of surfaces / equipment, minimum standards for wire sag)	Extreme heat	Design Consultant
Incorporate weather projections and procedures (e.g. wet weather plan) into works scheduling	Rainfall, storm surge and flooding	TMR
Update maintenance and operations plans to provide for consideration and changes in pavement design (e.g. alternative materials)	Extreme heat	TMR
Prepare and implement maintenance regimes for clearing	Bushfire	TMR and

Adaptation Action	Climate Variable	Responsibility
potential fuel load around electrical infrastructure where present within the corridor		Construction Contractor
Design noise walls to reduce the probability of damage from bushfire risk	Bushfire	Design Consultant, TMR and Construction Contractor
Provide additional pedestrian / cyclist features such as shade shelters (e.g. shade sails, bench shelters, canopy coverage, etc.), bubblers and CCTV to minimise heat related illness	Extreme heat	TMR
Investigate options for providing relief to cyclists / pedestrians from extreme heat days (e.g. underpass as opposed to bridge, roof structures on bridge)	Extreme heat	Design Consultant and TMR
Optimise the design of barriers to be multi-purpose (e.g. withstand bushfire and control fauna)	Bushfire, mean rainfall, drought	Design Consultant, TMR and Construction Contractor
Investigate mobile phone reception along corridor to support full coverage as manner of emergency response	All	TMR
Revise the Transport and Main Roads Communication Plan / improve notifications and information provided to motorists using the variable message signs (VMS)	All	TMR
Plan for alternative routes in the event of road closure due to extreme event or bushfire	Extreme weather event, bushfire	TMR
Improved coverage of fire-fighting equipment	Bushfire	TMR
Enhanced cooling and ventilation of electrical equipment	Temperature	Design Consultant
Enclosing abutments to protect from flood water (impermeable linings)	Rainfall intensity	Design consultant
Raising road level to adjust for local flooding risk	Rainfall intensity and sea level rise	Design consultant
Installation of fire breaks between asset and vegetated areas	Bushfire	Design consultant
Reduce batter slopes to reduce scouring/erosion/embankment failure	Rainfall intensity	Design consultant
Use foamed bitumen pavement for regularly inundated roads	Rainfall intensity and sea level rise	Design consultant
For critical assets consider ancillary power supply for critical signalling to maintain level of service	Extreme weather events	Design Consultant
Consider line marking options to maximise visibility during intense rainfall events	Rainfall intensity and extreme weather events	Design consultant

11 Residual risk assessment

The final step in completing the baseline assessment outlined within this framework is understanding the level of residual climate risk relative to the programs once the adaptation actions identified have been applied.

In support of this, the proposed and identified adaptation measures, should be prepared on a project-by-project basis through review and feedback from a multi-disciplinary workshop. Certain generic adaptation actions (e.g. update emergency response plans) can be modified within the residual risk assessment to better clarify the intent and provide examples specific to the climate variable.

The following template (Table 11) provides a methodology and template for mapping adaptation treatment and residual risk assessment to understand the ability for the relevant adaptation options to treat and respond to specific risks. Some adaptation measures will treat and reduce multiple risks while others are specific to a single risk.

In line with achieving both the Cli-1 and Cli-2 requirements, projects should aim to target all very high and high risks as a minimum. Where feasible the project may also consider adaptation risk treatments for medium risks.

Risk statements that have been rated as low are not required to have treatment options identified and have not been considered further in the residual risk assessment.

Table 11 – Typical Transport and Main Roads Climate Risks, Adaptation Treatments and Template for Capturing Residual Risk Ratings

NOTE: Each project should consider most suitable timelines, likelihood and consequence on a case-by-case basis. Also identify other potential hazards and adaptation actions that may apply.

Risk ID	Risk statement	2030 Risk Rating	2070 Risk Rating	Adaptation Actions	2030			2070		
					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
Bushfire Weather										
BF-1	Damage to electrical infrastructure as a result of ash accumulation (ramp metering, signals and variable speed limit signs), resulting in impacts to operation of the motorway			Construct housing for electrical components to protect from weather and atmospheric deposition.						
BF-2	Damage to infrastructure (e.g. noise walls, pavement) resulting in increased maintenance and decrease in operational safety			Review and if required, revise the Transport and Main Roads Traffic Operations Business Continuity Plan in response to bushfire events to account for climate extremes (increased severity, increased frequency) including provisions for road closures and/or diversions and emergency bays for vehicle breakdowns and/or emergency access. Update maintenance plan to increase the frequency and review of maintenance activities such as pavement repair. Design noise walls to reduce the probability of damage from bushfire risk. Optimise the design of barriers to be multi-purpose (e.g. withstand bushfire and control fauna). Consider pavement susceptibility to extreme heat. Consider bridge and culvert materials for suitability to bushfire risk.						
BF-3	Potential smoke inhalation and health concerns for maintenance workers			Revise Standard Operation Procedures (e.g. providing correct PPE (respirators)) and Protocols (rescheduling non-essential works) to account for smoke. Incorporate weather projections and procedures (e.g. dry, windy days) into works scheduling.						

Risk ID	Risk statement	2030 Risk Rating	2070 Risk Rating	Adaptation Actions	2030			2070		
					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
BF-4	Potential smoke inhalation and health concerns for pedestrian / cyclist / vehicle users			Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for climate extremes including selective closure of transports corridor during periods of high smoke and response plans for user emergencies (e.g. health-related incident). Investigate mobile phone reception along corridor to support full coverage as manner of emergency response Revise the Transport and Main Roads Communication Plan / improve notifications and information provided to motorists using the variable message signs.						
BF-5	Visibility concerns for motorists			Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information to motorists. Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for bushfire risk including road closures and/or diversions when visibility becomes limited and emergency bays for vehicle breakdowns. Revise the Transport and Main Roads Communication Plan / improve notifications and information provided to motorists using the variable message signs.						
BF-6	Delays to maintenance and operational requirements impacting scheduled activities			Update maintenance and operations plans to provide for rescheduling of impacted activities.						

Risk ID	Risk statement	2030 Risk Rating	2070 Risk Rating	Adaptation Actions	2030			2070		
					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
BF-7	Damage to substations and associated infrastructure resulting in disruption of electricity supply with potential power outages and communications network failure			Investigate the inclusion of backup power or redundant supply (e.g. uninterruptable power supply) for electrical systems as part of design.						
BF-8	Loss of access (both at interchanges, kiss and ride and along the motorway) resulting in user delays, emergency vehicle access or additional traffic on surrounding road network			Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for known areas of bushfire risk and vegetation including timing for road closures and/or diversions and provision of emergency bays for vehicle breakdowns and/or emergency access. Review the Transport and Main Roads Continuity Network Response Plan to restrict access to critical areas (e.g. shared paths or interchanges) during bushfire events and outline emergency service provisions (e.g. access, notification, traffic management, etc.).						
BF-9	Electrical infrastructure sparking bushfires and subsequent damage (and impact) to surrounding areas			Locate intelligent transportation system cabinets and other critical infrastructure in locations outside of bushfire prone areas and away from combustible vegetation. Prepare and implement maintenance regimes for clearing potential fuel load around electrical infrastructure where present within the corridor. Prepare an emergency management plan to restrict access to critical areas (e.g. shared paths) in the event of a bushfire along the corridor and outline emergency service provisions (e.g. access, notification, traffic management, etc.).						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
BF-10	A loss of access to the surrounding road network, resulting in increased traffic and subsequent safety concerns for motorists along the motorway			Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for known areas of bushfire risk and vegetation including timing for road closures and/or diversions and provision of emergency bays for vehicle breakdowns and/or emergency access. Review the Transport and Main Roads Continuity Network Response Plan to restrict access to critical areas (e.g. shared paths) in the event of a bushfire along the corridor and outline emergency service provisions (e.g. access, notification, traffic management, etc.).						
BF-11	Fauna and residents using the infrastructure as egress to escape bushfire			Incorporating fauna fencing and underpasses (crossing points) into the design Optimise the design of barriers to be multi-purpose (e.g. withstand bushfire and control fauna).						
Extreme Storm Event										
SE-1	Damage to electrical infrastructure from lightning, wind or hail (e.g. ramp metering, lighting, signals and variable speed limit signage) resulting in disruption of motorway operation			Undertake sensitivity checks against modelling utilising RCP 6.0 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model Locate critical electrical / communications infrastructure outside of known low areas and/or flood risk areas as identified in relevant local modelling. Incorporate lightning protection into the gantries and variable message signs (VMS). Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g. static signs, backup power). Evaluate design levels for electrical systems for resilience against flooding and rainfall risks Provide additional coverage (e.g. covers for electrical systems) / protection (e.g. resistant coatings) of critical electrical infrastructure.						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
SE-2	Structural stability concerns and/or impacts for bridge / noise structures - potential for collapse			Locate critical infrastructure outside of known low areas and/or flood risk areas identified in relevant local modelling (e.g. local government). Design new bridges and drainage to minimise and mitigate scour. Incorporation of Transport and Main Roads Design Criteria for Bridges and Other Structures (2018) which accounts for climate change Design bridge piles to a Q2000 event. Provide strengthening to existing bridge structures.						
SE-3	An increase in the scale and quantity of debris blown onto the motorway (as well as impacts to vehicles on the motorway) causing damage/impact to supporting infrastructure and impacting user safety (motorists, cyclists and pedestrians)			Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information. Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for extreme storms including road closures during storm events and/or diversions when damage / substantial debris has been identified and provision of emergency bays for vehicle breakdowns and/or emergency access. Revise the Transport and Main Roads Communication Plan / improve notifications and information provided to motorists using the variable message signs. Review the Transport and Main Roads Continuity Network Response Plan for provisions such as restricting access to critical areas during storm events (e.g. shared paths) and outline emergency service provisions and response (e.g. access, notification, traffic management, etc.).						
SE-4	An increase to maintenance and operational costs to support routine repair and replacement works			Update Standard Operating Procedures and maintenance plans to increase the frequency and review of maintenance activities and account for an increase in the intensity of storms and associated expected impacts.						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
SE-5	Power outages (black outs) as a result of damage to energy substations and associated energy/electrical infrastructure			Locate critical infrastructure including any power supply infrastructure outside of known low areas and/or flood risk areas identified in relevant local modelling (e.g. local government). Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g. static signs, backup power). Investigate the inclusion of backup power or redundant supply (e.g. uninterruptable power supply) for electrical systems as part of design.						
SE-6	Damage to the surrounding road network, resulting in increased vehicle usage of the motorway and potential decrease in safety due to the increase in usage			Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information including road closures and detour routes. Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for extreme storms including road closures during storm events and/or diversions when damage / substantial debris has been identified and provision of emergency bays for vehicle breakdowns and/or emergency access. Revise the Transport and Main Roads Continuity Network Response Plan to restrict access to critical areas during storm events (e.g. shared paths) and outline emergency service provisions and response (e.g. access, notification, traffic management, etc.).						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
Extreme rainfall and flooding										
ERF-1	The capacity of existing drainage infrastructure being exceeded (due to either blockage from debris or volume of water) leading to inundation of surrounding infrastructure (e.g. properties, motorway, bus stations, kiss and ride, interchanges)			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity of 11.4% (RCP 6.0). Undertake sensitivity checks against modelling utilising RCP 6.0 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Review and where relevant, change road geometry (such as the gradient, removal of sag curves or vertical elevation in critical areas) to shorten flow paths and reduce risk of motorway inundation. Design and construct larger culverts, without impacting upstream flows, to account for additional surface flow.						
ERF-2	Exacerbated local flooding risks at specific locations			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Review and where relevant, change road geometry (such as the gradient, removal of sag curves or vertical elevation in critical areas) to shorten flow paths and reduce risk of motorway inundation Design and construct larger culverts, without impacting upstream flows, to account for additional surface flow. Revise the Transport and Main Roads Continuity Network Response Plan to restrict access to interchanges subject to inundation during flood events and outline emergency service provisions (e.g. access, notification, traffic management, etc.).						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
ERF-3	Increased rainfall intensity along the motorway resulting in increased road incidents (e.g. aquaplaning) and safety risks to motorists			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model). Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information. Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for extreme rainfall intensities including provisions for road closures and/or diversions and emergency bays for vehicle breakdowns and/or emergency access. Review and where relevant, change road geometry (such as the gradient, removal of sag curves or vertical elevation in critical areas) to shorten flow paths and reduce risk of motorway inundation. Revise the Transport and Main Roads Continuity Network Response Plan to restrict access to interchanges subject to inundation during flood events and outline emergency service provisions (e.g. access, notification, traffic management, etc.).						
ERF-4	An increased safety risk and disruption to the users of the cycle / pedestrian network due to inundation of infrastructure			Locate pedestrian / cycle paths outside of known low areas and/or flood risk areas. Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information. Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for extreme rainfall including selective closure of transports corridor during extreme storms and response plans for user emergencies (e.g. debris incident or injury). Investigate mobile phone reception along corridor to support full coverage as manner of emergency response.						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
ERF-5	Water damage to electrical infrastructure (ramp metering, signals and variable speed limit signs) resulting in disruption of motorway operation			Locate critical infrastructure outside of known low areas and/or flood risk areas. Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g. static signs, backup power). Evaluate design levels for electrical systems for resilience against flooding and rainfall risks Provide additional coverage (e.g. covers for electrical systems).						
ERF-6	Erosion of infrastructure foundations resulting in the exposure of concrete (e.g. road base, drainage infrastructure, pier supports), particularly along river and creek crossings			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Design new bridges and drainage to minimise and mitigate scour. Incorporation of Transport and Main Roads Design Criteria for Bridges and Other Structures (2018) which accounts for climate change Provide strengthening to existing bridge structures. Provide additional protection (e.g. resistant coatings) of critical structures (e.g. steel or otherwise).						
ERF-7	Increased risk of landslip (e.g. weakened verges and decreased slope stability) in surrounding areas resulting in damage to infrastructure			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Locate critical infrastructure outside of known low areas and/or flood risk areas. Update maintenance plan to increase the frequency and review of maintenance activities. Design new bridges and drainage to minimise and mitigate scour.						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
				Design bridge piles to a Q2000 event. Provide strengthening to existing bridge structures.						
ERF-8	Accelerated degradation of assets from increased rainfall intensities and prolonged flooding resulting in increased maintenance and operational costs and repairs			Design new bridges and drainage to minimise and mitigate scour. Revise Standard Operating Procedures to account for climate extremes including increased intensities of rainfall and more frequent inundation of assets. Update maintenance plan to increase the frequency and review of maintenance activities. Provide additional coverage (e.g. covers for electrical systems) / protection (e.g. resistant coatings) of critical structures (e.g. steel or otherwise).						
ERF-9	Increased risk of additional scour and erosional impacts on surrounding waterways and the associated environmental impacts (e.g. water quality, ecological implications for species)			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Design new bridges and drainage to minimise and mitigate scour. Update maintenance plan to increase the frequency and review of maintenance activities. Design and construct larger culverts, without impacting upstream flows, to account for additional surface flow.						

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ERF-10	Increased stormwater flow from surrounding developed areas contributing to additional water volumes in drainage lines and other stormwater infrastructure (e.g. culverts) resulting in additional localised flooding impacts			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Design and construct larger culverts, without impacting upstream flows, to account for additional surface flow.						
ERF-11	Localised ponding leading to an increased attraction for animals resulting in increased hazards for fauna / automobile accidents			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model) Incorporating fauna fencing and underpasses (crossing points) into the design.						
ERF-12	Power outages at substations disrupting supply to electrical and communications systems impacting operation of the motorway			Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g. static signs, backup power). Investigate the inclusion of backup power or redundant supply (e.g. uninterruptable power supply) for electrical systems as part of design.						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
ERF-13	Surrounding areas being inundated, resulting in an increase of motorists using the motorway as an escape route and potential decrease in safety along the motorway due to increased traffic in a hazard event			Utilise a consolidated flood model based on local government hazard mapping and modelling, which includes storm surge, sea level rise and increased rainfall intensity. Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information. Revise the Transport and Main Roads Continuity Network Response Plan to restrict access to critical areas during flooding events (e.g. shared paths) and outline emergency service provisions and response (e.g. access, notification, traffic management, etc.).						
Mean rainfall and drought										
MRD-1	Soil cracking resulting in damage to infrastructure (e.g. culverts, foundations, road base, embankments)			Update maintenance plan to increase the frequency and review of maintenance activities.						
MRD-2	Adverse impacts to proposed landscaping areas (including those reinstated) including lack of available water for irrigation			Select drought tolerant plants that will be able to cope with reduced water availability but that withstand short intense rainfall events. Consider vegetation fuel load during landscape planning.						
MRD-3	Wildlife migration to watercourses			Incorporating fauna fencing and underpasses (crossing points) into the design. Optimise the design of barriers to be multi-purpose (e.g. withstand bushfire and control fauna).						
MRD-4	Increased fuel for bushfire			Review plant selection and irrigation requirements for planted species (e.g. review similar climates through tools such as the Climate Analogues Explorer).						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
MRD-5	Dust impacts from quarry - skid resistance, visibility and erosion leading to poor water quality									
MRD-6	Water shortage during prolonged construction phase and operational phase			Implement the Transport and Main Roads Water Security and Sustainability Policy. Undertake water balance assessment of future water requirements for infrastructure links. Where water shortages are possible develop water security plant.						
Sea Level Rise and coastal Inundation										
SLR-1	Inundation of motorway and interchanges (during high tide) resulting in disruption to operation			Revise the Transport and Main Roads Continuity Network Response Plan to restrict access to critical areas during high tide events and periods of inundation (e.g. shared paths and interchanges) and outline emergency service provisions and response (e.g. access, notification, traffic management, etc.).						
SLR-2	Permanent inundation of drainage infrastructure			Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Locate critical infrastructure outside of known low areas and/or flood risk areas.						
SLR-3	Exacerbated local flooding risks			Revise the Transport and Main Roads Continuity Network Response Plan to restrict access to critical areas (e.g. shared paths) and outline emergency service provisions (e.g. access, notification, etc.). Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model. Revise the Transport and Main Roads Continuity Network Response Plan to restrict access to critical areas (e.g. interchange) and outline emergency service provisions (e.g. access, notification, traffic management, etc.).						

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SLR-4	Ingress of saltwater intrusion into embankment and lower pavement layers causing reduced performance life			Raising pavement above projected sea level rise to avoid inundation.						
SLR-5	Increased incidence of coastal erosion, exposing footings and other buried structures, resulting in damage or potential collapse			Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model Design bridge piles to a Q2000 event. Provide strengthening to existing bridge structures.						
SLR-6	Increased incidence of saltwater intrusion, accelerating corrosion of concrete and steel structures			Undertake sensitivity checks against modelling utilising RCP 8.5 projections for storm surge, sea level rise and increased rainfall intensity (e.g. Local Government flood model). Provide strengthening to existing bridge structures. Provide additional coverage (e.g. saline resistant covers for electrical systems) / protection (e.g. resistant coatings) of critical structures (e.g. steel or otherwise).						
Extreme Heat										
EH-1	Damage to electrical system components (e.g. cabling, sensor loops, housings) resulting in disruption smart motorway operation, CCTV and emergency response			Investigate the inclusion of backup power or redundant supply (e.g. uninterruptable power supply) for electrical systems as part of design. Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g. static signs, backup power). Design infrastructure to account for higher temperatures (e.g. increased heat ratings of surfaces / equipment, minimum standards for wire sag).						

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EH-2	The accelerated degradation and malfunctioning of electrical equipment, requiring replacement more often, increasing maintenance and operational costs			Update maintenance plan to increase the frequency and review of maintenance activities. Design infrastructure to account for higher temperatures (e.g. increased heat ratings of surfaces / equipment, minimum standards for wire sag). Provide additional coverage (e.g. covers for electrical systems) / protection (e.g. resistant coatings) of critical structures (e.g. steel or otherwise).						
EH-3	The accelerated deterioration of concrete / asphalt infrastructure, resulting in decreased safety for motorists (e.g. potholes)			Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information Update maintenance and operations plans to provide for consideration and changes in pavement design (e.g. alternative materials).						
EH-4	The accelerated deterioration of concrete / asphalt / steel infrastructure, resulting in increased maintenance and operational costs (e.g. resurfacing)			Update maintenance plan to increase the frequency and review of maintenance activities. Design infrastructure to account for higher temperatures (e.g. increased heat ratings of surfaces / equipment, minimum standards for wire sag). Update maintenance and operations plans to provide for consideration and changes in pavement design (e.g. alternative materials). Provide additional coverage (e.g. covers for electrical systems) / protection (e.g. resistant coatings) of critical structures (e.g. steel or otherwise).						

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EH-5	Steel structures (e.g. expansion joints, guardrails, bridge components) buckling or warping and impacting safety of users			Review design standards / inclusions and determine if additional protection (e.g. alternative materials) is required for critical infrastructure Design infrastructure to account for higher temperatures (e.g. increased heat ratings of surfaces)						
EH-6	An increased risk of heat stress for cyclists and pedestrians) using the new facilities			Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information. Revise Standard Operating Procedures to account for extreme heat including provisions for closures of facilities during heatwaves and/or diversions. Investigate mobile phone reception along corridor to support full coverage as manner of emergency response. Provide additional pedestrian / cyclist features such as shade shelters (e.g. shade sails, bench shelters, canopy coverages, etc.) and CCTV to minimise heat related illness. Investigate options for providing relief to cyclists / pedestrians from extreme heat days (e.g. underpass as opposed to bridge, roof structures on bridge).						
EH-7	An increase in the number of vehicle breakdowns along the motorway (due to vehicle overheating) resulting in safety concerns and increased requirements for motorway management			Use the Emergency VMS Alert Request and Social Media request forms for warnings and to convey weather hazard information. Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for heatwave and extreme heat days including provisions for emergency bays for vehicle breakdowns and/or emergency access / response. Investigate mobile phone reception along corridor to support full coverage as manner of emergency response. Revise / improve notifications and information provided to motorists using the variable message signs. Revise the Transport and Main Roads Continuity Network Response Plan to respond to vehicle breakdowns and outline emergency service provisions (e.g. access, notification, traffic management, etc.).						

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					Revised Likelihood	Revised Consequence	Revised Risk Rating	Revised Likelihood	Revised Consequence	Revised Risk Rating
EH-8	Adverse impacts to proposed landscaping areas (including those reinstated) including loss of planted species due to ongoing heat exposure			Review plant selection and irrigation requirements for planted species (e.g. review similar climates through tools such as the Climate Analogues Explorer).						
EH-9	Increased power demand and/or faults in the network resulting in power supply interruptions and/or outages for electrical infrastructure, including CCTV			Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g. static signs, backup power). Investigate the inclusion of backup power or redundant supply (e.g. uninterruptable power supply) for electrical systems as part of design.						
EH-10	An increased risk to workers during operation from heat stroke, heat stress or heat exhaustion resulting in reduced productivity			Revise the Transport and Main Roads Traffic Operations Business Continuity Plan to account for heatwave and extreme heat days including provisions for emergency bays for vehicle breakdowns and/or emergency access / response. Incorporate weather projections and procedures (e.g. wet weather plan) into works scheduling.						
EH-11	Increased sag on overhead cables - decreased clearance			Design infrastructure to account for higher temperatures (e.g. increased heat ratings of surfaces / equipment, minimum standards for wire sag). Update maintenance plan to increase the frequency and review of maintenance activities. Revise the Transport and Main Roads Communication Plan / improve notifications and information provided to motorists using the variable message signs.						

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EH-12	Equipment heat ratings insufficient to meet increased heat			Design infrastructure to account for higher temperatures (e.g. increased heat ratings of surfaces / equipment, minimum standards for wire sag). Update maintenance plan to increase the frequency and review of maintenance activities.						
EH-13	Reduced safety for travelling public due to ITS outages, debris on road, potential damage to assets			Consider ancillary power supply for critical infrastructure to maintain level of service during ITS outages.						