Climate Change and Natural Hazards Risk Assessment Guideline

July 2024

Queensland Government

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Glossary

Terms, abbreviations and acronyms	Meaning
BoM	Bureau of Meteorology
CCNHRA	Climate Change and Natural Hazard Risk Assessment
Climate Change Adaptation	The planning, design and construction (including retrofitting) of infrastructure and services in order to avoid failure or impact from the weather.
Climate Change Mitigation	The actions taken to avoid or reduce release of greenhouse gas emissions including reduction of carbon footprint of construction materials.
Climate hazard	The potential occurrence of a [climate-related] natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
Climate variable	A variable that contributes to the characterization of Earth's climate e.g., sea level, temperature, wind, precipitation.
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.
ISC	Infrastructure Sustainability Council
Natural hazard	The potential occurrence of a natural event that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources. Natural hazards include extreme events arising from heatwaves, bushfires, droughts, cyclones, severe storms, flooding, etc.
Physical risk	The physical consequence and outcomes on infrastructure and communities resulting from climate hazards, including direct damage to assets and networks, impacts to livelihoods and wellbeing, or liability due to failure to foresee and mitigate losses from any physical risks.
RCP (Representative Concentration Pathways)	The predicted concentrations of CO_2 in the atmosphere over the 21st century depending on different levels of global action to reduce greenhouse gas emissions.
Resilience	The planning, design, management or construction of infrastructure and/or services to plan for failures to ensure services are not interrupted or are able to be quickly re-established following failure (planning for failure).

Terms, abbreviations and acronyms	Meaning
Shocks	Large-scale high-impact events and catastrophes such as human-made and natural disasters. Examples of shocks include cyber-attack; digital network failure; terrorist attack; war and conflict, collapse of financial systems; natural disasters such as earthquakes and floods; widespread pandemics; and diseases.
SSP (Shared Socioeconomic Pathway)	The SSPs represent pathways of various hypothetical global socio-economic and political futures that result in various outcomes in the physical state of the climate.
Stresses	Often defined as the underlying 'slow burn' issues that have the potential to exacerbate a shock. Examples of stresses in the context of infrastructure may include: social cohesion; housing affordability; access to transport; increased energy costs; and ageing population.
Transition risk	Uncertainties driven by policy, legal, technological or market changes that influence supply and demand, customer expectations and reputation, as global and local systems transition to a low carbon economy.
Treatment options	Treatment measures associated with climate and natural hazard risks can include: • Structural measures, such as physical changes to the infrastructure to achieve or facilitate adaptation. • 'Non-structural' measures, such as changes to maintenance contracts or the implementation of an emergency management plan. Treatment can be undertaken immediately, or at timescales when the risk occurs.

1 Introduction

1.1 Purpose

The purpose of this *Climate Change and Natural Hazards Risk Assessment Guideline* is to outline the methodology for undertaking a risk assessment, including process, specific elements to outline (in line with *IS Technical Manual v2.1* Res-1 credit), likelihood and consequence descriptors, risk matrix and link to risk register template.

This guideline is designed to be integrated into Transport and Main Roads' Risk Management Framework, Risk Assessment and Ratings Matrix and Risk Context Profiles.

This guideline guides and operationalises the risk assessment process. While this guideline does not provide specific advice on climate change and natural hazards treatment methodologies, indicative treatment options are included in the *Climate Change and Natural Hazards Risk Assessment template* and the guideline is supported by the EP170 *Climate Change and Natural Hazards Risk Assessment*.

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 Technical Manual v2.1* Res-1 credit, and must be provided by the project team in support of the ISC credit verification process.

1.2 Background

In recent years, there has been a recognition and commitment across both government and industry that a response to climate change is required. Refer to EP170 *Climate Change and Natural Hazards Risk Assessment* for information regarding policy background and context.

2 Infrastructure sustainability ratings

For major projects applying the Infrastructure Sustainability Council Infrastructure Sustainability Rating Scheme, the Res-1 credit requires identification, assessment and treatment of climate change and natural hazard risks. This guideline will aid projects in addressing these requirements.

Use of the baseline CCNHRA provided in this guideline 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. Res-1 Level 2 is a stretch target as per relevant Transport and Main Roads Functional Specification Sustainability Addenda.

For Res-1 this is demonstrated by the following:

- The CCNHRA 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, 2050 and 2070).
- The climate change projections used in the risk assessment have been expanded to provide a level of sensitivity analysis.
- The CCNHRA identified a range of direct and indirect risks and undertook an assessment of those identified risks.

- A comprehensive set of affected stakeholders participated in identifying climate and natural hazard direct and indirect risks and treatment options.
- Treatment options for direct and indirect risks have been identified and implemented and after treatment all extreme and high priority direct or indirect risks have been reduced to an acceptable level.

3 Climate change risk assessment methodology

This guideline and the associated EP170 *Climate Change and Natural Hazards Risk Assessment* have been developed in accordance with Australian Standard AS 5334 *Climate change adaptation for settlements and infrastructure – A risk-based approach*.

The process has also been developed to be consistent with Transport and Main Roads' Risk Management Framework.

The overarching process follows:

1. Identification of key climate variables (temperature, rainfall, extreme events), natural hazards and the climate variability that differentiates regional climate zones.
2. Development of potential climate change scenarios, based on the latest climate science, which describe how each variable may change over the design life of the proposed works.
3. Identification of broad climate and natural hazard risks that may impact on the proposed works.
4. Completion of a climate and natural hazard risk assessment as part of the overall risk assessment process, with risk ratings evaluated using AS 5334 *Risk Management Framework*, including likelihood and consequence criteria.
5. Consequence ratings have been selected based on the highest rating for the risk categories. This risk assessment should also identify the likely timing of particular risks and opportunities.
6. Identification of measures to mitigate, adapt or build resilience to the identified high and extreme climate and natural hazard risks.
7. Assessment of residual risks to the project, considering adaptation measures to treat all high and extreme risks.

This overarching methodology for integration of climate and natural hazard risk assessment and management into the existing *Transport and Main Roads Risk Management Framework* is prescribed in more detail in the steps below:

1. The person or team undertaking the risk assessment should review the forecasted climate impacts and natural hazard risks for the applicable region based on:
   a) the climate change projection
   b) published natural hazard data and historic natural hazards for the asset's region, and
   c) the appropriate timeframe for the design life of the asset.

This information is available through a number of sources. It is recommended that for consistency Transport and Main Roads utilise:

a) Queensland Future Climate Scenarios from the Long Paddock website

b) CSIRO climate data available through the Climate Change in Australia website, and

c) Respective Local Government hazard mapping.

2. Describe the climate model and projection data that applies for the relevant time horizons (at least 2050 and 2090 where data is available).

3. Describe the design life and design standard of key infrastructure components (i.e., pavement, bridges, culverts, electrical / ITS, roadside and drainage).

4. Generate a list of **direct** climate change and natural hazards for the applicable area at the relevant time horizons (at least 2050 and 2090 where data is available).

   For more information on selecting relevant time horizons, refer to EP170 *Climate Change and Natural Hazards Risk Assessment*. It is important to identify hazards at shorter timeframe and longer timeframes as this could present opportunities for delayed risk treatment.

   NOTE: For risk context profiling, the impacts from climate change and natural hazards on the branch / district, project should be considered as part of the weather risk category.

5. Consider the **indirect** impacts from climate change and natural hazards on the organisation, project or design. Consider how the direct and indirect climate change and natural hazard impacts may influence other risks identified (for example, increased rainfall intensity may increase the consequence of flash flooding events).

   Impacts should be considered in relation to:

   a) impact on the asset

   b) impact on the level of service

   c) impact to the public utilising the asset

   d) impact to the network operations and maintenance activities, and

   e) impact to the workforce.

6. Consider the influence on identified risks associated with interrelated infrastructure and the impacts on and from interrelated services failing (for example, if a road embankment is submerged more frequently due to sea level rise, if local government roads are also inundated the consequence of failure may be more significant).

7. Address climate change and natural hazard risks though Transport and Main Roads' standard risk management practices.

8. Consider risk treatment options as per Section 4.9 of this guideline. Adaptation treatments should be considered in association with the Climate Change and Natural Hazards Risk Assessment template.

9. Undertake a multi-disciplinary review (such as via a workshop) of the draft risk assessment outcomes to consider and validate the hazard likelihood, consequence and potential treatment options.

10. Formalise the list of climate and natural hazard related risk treatments by incorporating them into the overall project / program / district risk and opportunity register.
11. Obtain endorsement by the Program or Project Customer.

4 Guidance

4.1 Natural hazards

Undertaking a climate and natural hazard risk assessment should involve the consideration of whether the asset's location has been previously impacted by natural hazards or disasters. During early planning, considering the performance of any similar infrastructure assets located nearby may also be useful. Data sources to review include national and/or state-based and/or local government agency databases, media reports and news alerts for the area and warnings provided by local state government or community agencies.

4.2 Queensland Future Climate Dashboard and Regional Climate Summaries

The Queensland Future Climate Dashboard within the Long Paddock website provides an interactive tool that can be used to identify the varying changes to climate across geographical areas, timeframes and climate projections. The dashboard allows users to explore, visualise and download the latest high-resolution climate modelling data for specific regions, catchments, disaster areas, local government areas and grid squares.

The Regional Climate Summaries are based on Global Climate Models (GCMs) and are available on the Department of Energy and Climate website. They show climate change projections for the years 2030 and 2070 at a state-wide scale for Queensland and for 13 Queensland regions. Summaries are available for the following regions:

- Queensland
- Cape York
- Central Queensland
- Central West Queensland
- Eastern Downs
- Far North Queensland
- Gulf Region
- Maranoa and District
- North Queensland
- North West Queensland
- South East Queensland
- South West Queensland
- Whitsunday, Hinterland and Mackay
- Wide Bay-Burnett

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.

4.3 Climate change projections

The predicted release of global greenhouse gas and aerosol emissions are modelled using four possible Representative Concentration Pathways (RCPs), initiated by the Intergovernmental Panel on Climate Change (IPCC). The IPCC's AR6 Report included the release of another set of climate change models referred to as Shared Socioeconomic Pathways (SSPs). More information on SSPs is available in EP170 *Climate Change and Natural Hazards Risk Assessment*.

The RCP number refers to the amount of extra radiative forcing (i.e., warming) on the climate system by the end of the century. The different RCP pathways are based on different assumptions on global greenhouse gas emissions:

- RCP 8.5 (high) – little global action taken to reduce greenhouse gas emissions.
- RCP 4.5 (medium) – strong global action taken to reduce emissions towards end of century.
- RCP 2.6 (low) – ambitious global action.

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 serves as a comparison to understand how the climate may change for some of the longer life design elements.

Table 4.3 below provides an example of climate change projections for South East Queensland.

Table 4.3 – Example of detailed climate change projections – South East Queensland

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)

Climate Variable	2030[1]	2030[2]	2070[3]	2090[4]
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)

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

Guidance: It is recommended that Transport and Main Roads projects consider assessment under at least two RCP scenarios including RCP 4.5 and RCP 8.5 to develop a complete understanding of potential climate risks. The RCP 8.5 projection should be applied as a minimum for climate change risk assessment for critical infrastructure. The Res-1 credit under the *IS Technical Manual v2.1* requires the use of projections based on RCP 8.5, and one other RCP to achieve a Level 2 rating. Furthermore, when undertaking a CCNHRA, it is recommended that the department be aware of the latest climate modelling.

4.4 Climate projection timeframe

Generally, climate projections are considered over time frames of 2030, 2050, 2070 and 2090. The projection timeframe selected for a risk assessment should be based on the design life of the asset, project or corporate planning timeframe.

However, the impacts of climate change will be different across the different timeframes. In fact, the impacts could be considerably different trends (positive change versus negative impact) that may need to be considered for the asset.

If the forecast useful life for the asset is over 20 years, at least two time-horizons must be selected with at least one being the final expected operating year of the asset or beyond. For example, if the asset life is 70 years, then 2050 and 2100 may be selected for assessment. If projections do not exist beyond the end of life of the asset (e.g., for an asset with a 100-year design life) then the longest projections available must be used (e.g., 2090, which is currently the limit available on Long Paddock as of 2024).

Guidance: The timeframe for projecting climate impacts should correlate with the design life or the timeframe context of the risk assessment. It is also important to consider shorter term climate impacts as these may differ from the longer-term impacts and the asset may be exposed to both. The Res-1 credit under the *IS Technical Manual v2.1* requires the completion of a sensitivity assessment for relevant climate variables under both RCPs for both time horizons to achieve a Level 2 rating.

4.5 Climate and natural hazards to be considered

Climate Change and Natural Hazards Risk Assessments completed on departmental networks and/or assets shall consider as a minimum, direct and indirect climate and natural hazards.

In addition, the risk assessment shall consider the variations in likelihood and consequence of those hazards depending on the projected climate changes.

The risk assessment should consider hazards across the lifecycle of the asset. This may include hazards to the asset, asset users, properties around the asset, essential services provided by the asset.

To respond to the Res-1 credit, the hazards listed in Table 4.5 must be considered at a minimum as part of a risk assessment, as well as:

- existing natural hazard and climate change management plans in the Local Government area
- published natural hazard data and climate change projections for the asset's region, and
- government data associated with historic natural hazards such as volcanic and seismic (earthquake and tsunami) activity as well as details on landslides that is publicly available.

Table 4.5 – The minimum climate and natural hazards that should be considered as part of the department's risk assessment (in accordance with Res-1 credit)

Primary variables (stresses)	Secondary variables (shocks)
• Air temperature • Humidity • Sea surface temperature • Precipitation • Sea level rise • Wind and hail • Coastal inundation • Drought • Frost	• Precipitation • Wind and hail • Bushfire • Coastal inundation • Cyclones/storms • Flooding • Heatwave • Earthquake • Tsunami

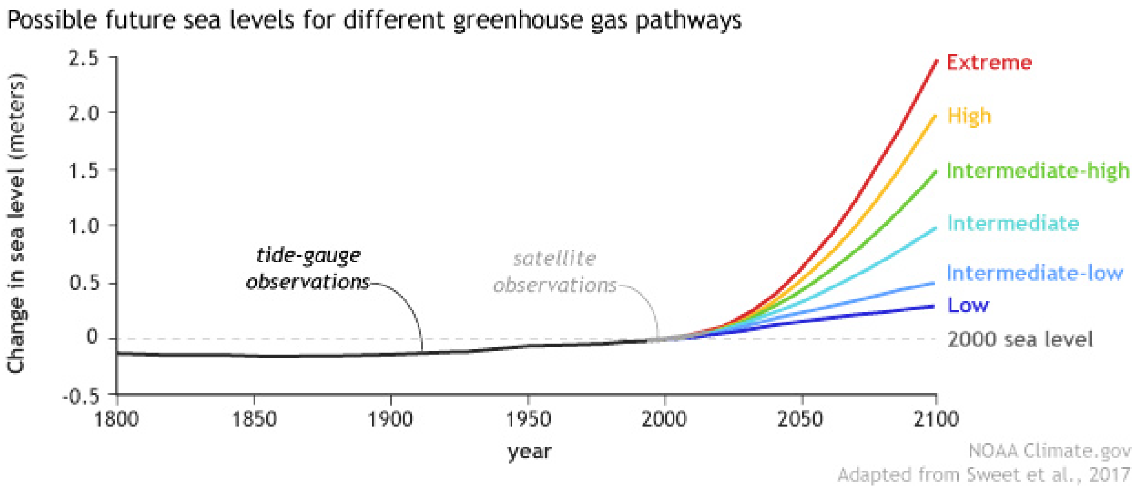
4.6 Potential climate change and natural hazard consequences

4.6.1 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 2m by 2100 as shown by the National Oceanic and Atmospheric Administration (NOAA) of the United States of America in Figure 4.6.1.

Figure 4.6.1 Projected sea level rise (NOAA, 2017)



4.6.2 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.

4.6.3 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).

4.6.4 Mean rainfall and drought

Projected changes in rainfall tend to be location specific. Generally speaking, all sources 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.

4.6.5 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.

4.6.6 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.

4.6.7 Extreme storms (including wind, lightning 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 lightning. 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.

4.6.8 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.

4.6.9 Natural hazard consequences

Natural hazards such as landslides, earthquakes and tsunamis can be disastrous and cause structural damages to transport infrastructure. Landslides are generally caused when heavy rain saturates soil on a hillside, and can result in damage to land, vehicles, roads or highways. Earthquakes have potential to severely disrupt transportation networks and infrastructure, causing structural damage, casualties and injuries in the past. Following an earthquake, for example, some vulnerable transportation infrastructures such as bridges can be severely damaged, resulting in extensive repairs that may take months or years to finish. In the event of a tsunami, coastal highways and road networks can be badly damaged and unpaved roads are easily washed away.

4.6.10 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.

4.7 Climate change transitional risks and opportunities

The identification of transition risks is not a requirement for individual projects, but the potential risks and opportunities related to climate change transitional risks should also be considered by organisational units, districts, programs and projects. These transitional risks commonly have greatest consequence on transport trends and demands in future.

This would generally be best considered as part of strategic planning, service requirement identification and transport demand modelling.

4.8 Hazard likelihood and consequence

The likelihood and consequence climate hazards should be considered in accordance with AS 5334 Climate change adaptation for settlements and infrastructure – A risk-based approach. (see Risk matrices in Appendix A).

4.9 Risk treatment – Climate change and natural hazard risk mitigation, treatment and resilience

Consistent with the ISO 31000 *Risk management standard*, once climate change and natural hazard related risks are identified and quantified as part of the risk assessment process, consideration of risk treatment options shall be considered.

It is recommended that for climate change and natural hazard related risks, the following approach is applied:

1. Determine climate and natural hazard factors that influence project design and that are susceptible to climate change.
2. Assess the risk that these climate and natural hazard factors present for design life of the asset and the required level of service into the future.
3. Consider the design life of the design component impacted by the climate factor and likely impact during the lifespan of the component. (for example, pavement design life is up to 20 years and thus climate change influences beyond a 20 year horizon are not applicable). Refer to Table 4.9(a) for program and project design lives. These are indicative for the purposes of the CCNHRA and may be subject to change through project design development.

4. Consider treatment options for project design, described in more detail in Table 4.9(b):
   a) build for end of design life scenarios
   b) planned adaptation
   c) progressive modification
   d) no adaptation or redundancy.
5. Secure funding for treatment options where this will require investment beyond the previously approved funding limit.

This guideline is not intended to limit the potential treatment options 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.

Table 4.9(a) – 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: • any culvert (existing or new) within the upgrade road formation, and • 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

Asset	Minimum Design Life
Pavements	30 years
Timber furniture for environmental works	40 years
Temporary Works, excluding pavements	2 years

Table 4.9(b) – Description of adaptation treatment options for project designs

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.

(Source: Western Australia Main Roads, Climate change risk assessment guideline).

4.9.1 Current treatment options

Table 4.9.1 presents current treatment options that can be considered during the design of the projects. Additional options, as identified by the project team, will need to be considered to further treat supplementary project-specific risks.

Table 4.9.1 Current Transport and Main Roads Climate Risk Treatments

Treatment	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 which accounts for climate change	Rainfall and flooding	Design Consultant and Transport and Main Roads
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	Transport and Main Roads
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	Transport and Main Roads
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 Transport and Main Roads
Use the Emergency Variable Message Signs (VMS) Alert Request and Social Media request forms for warnings and to convey weather hazard information	All	Transport and Main Roads
Design to include additional redundancy in intelligent transportation system infrastructure and smart motorways (e.g., static signs, backup power)	All	Design Consultants and Transport and Main Roads
Incorporate lightning protection into the gantries and VMS	Extreme storms	Design Consultants and Transport and Main Roads

4.9.2 Potential treatment options

To further respond to climate risks, a number of proposed / potential treatment options have been identified as applicable for consideration and inclusion across projects. These are provided in Table 4.9.2. In accordance with requirements for Res-1, 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 4.9.2 Potential Transport and Main Roads Climate Risk Treatments

Treatment option	Climate Variable	Responsibility
Review and ensure suitability of maintenance treatments for defects	All	Transport and Main Roads
Evaluate design levels for electrical systems for resilience against flooding and rainfall risks	Rainfall and flooding	Design Consultant and Transport and Main Roads
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 Transport and Main Roads
Provide strengthening to existing bridge structures	All	Design Consultant, Transport and Main Roads 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	Transport and Main Roads 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	Transport and Main Roads
Update maintenance and operations plans to provide for consideration and changes in pavement design (e.g., alternative materials)	Extreme heat	Transport and Main Roads

Treatment option	Climate Variable	Responsibility
Prepare and implement maintenance regimes for clearing potential fuel load around electrical infrastructure where present within the corridor	Bushfire	Transport and Main Roads and Construction Contractor
Design noise walls to reduce the probability of damage from bushfire risk	Bushfire	Design Consultant, Transport and Main Roads 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	Transport and Main Roads
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 Transport and Main Roads
Optimise the design of barriers to be multi-purpose (e.g., withstand bushfire and control fauna)	Bushfire, mean rainfall, drought	Design Consultant, Transport and Main Roads and Construction Contractor
Investigate mobile phone reception along corridor to support full coverage as manner of emergency response	All	Transport and Main Roads
Revise the Transport and Main Roads Communication Plan / improve notifications and information provided to motorists using the variable message signs (VMS)	All	Transport and Main Roads
Plan for alternative routes in the event of road closure due to extreme event or bushfire	Extreme weather event, bushfire	Transport and Main Roads
Improved coverage of fire-fighting equipment	Bushfire	Transport and Main Roads
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

4.10 Stakeholder engagement and consultation

Assessing climate change and natural hazard 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 and natural hazards and risks should be presented, refined and agreed for the project / program through review or a form of engagement contributed to by a multi-disciplinary internal team representing Transport and Main Roads and the consultant's team.

The consultation process shall seek to review the:

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

To support the achievement of Res-1 credit, the consultation process should also engage a comprehensive set of affected stakeholders to assist in identifying climate and natural hazard direct and indirect risks and treatment options.

4.11 Sensitivity analysis

A level of sensitivity analysis is considered best practice when completing climate and natural hazard risk assessment as projects can often see large differences in the numbers (e.g., for flooding and rainfall) under RCP 8.5 vs RCP 4.5. Assessing the risk under both scenarios can better inform decision making and the risk profile the asset owner and stakeholders are prepared to tolerate. Sensitivity analysis responds to the inherent uncertainty associated with far future projections (say 2070 and beyond) so that unnecessary costs are not incurred or alternatively under-design is avoided.

Further guidance on RCPs is available in Section 4.3 of this guideline.

4.12 Direct and indirect risks

A direct risk refers to the chance of an impact (attributable to natural hazards, including climate change) on an infrastructure system or asset causing damage, extra maintenance or replacement costs, accelerated deterioration or disruption of services provided. An example is increased storm or flood damage to an asset.

An indirect risk refers to the possibility that an impact on another system or asset will disrupt the operational capacity of the asset or network (e.g., the disruption of supply of goods or services). Indirect risks include consideration of interdependent and cumulative impacts of different risks and their sources (e.g., power supply interruptions caused by excessive power demand during periods of extreme temperature; or storm damage or disruption at a nearby port, delaying the delivery of urgently-needed equipment so that the infrastructure has to be closed or its services curtailed.) This type of risk focuses on the consequence or impact to the asset itself (inwards focused).

4.13 Residual risk assessment

The final step in completing the baseline assessment 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 *Climate Change and Natural Hazards Risk Assessmenet Matrix Template* 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 the Res-1 requirements, projects should aim to target all high and extreme risks as a minimum.

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

5 Key references

Table 5 – Key References

Reference	URL
AS 5334 *Climate Change adaptation for settlements and infrastructure – a risk-based approach*	https://store.standards.org.au/product/as-5334-2013
Queensland Government – *LongPaddock*	https://www.longpaddock.qld.gov.au/ https://www.longpaddock.qld.gov.au/qld-future-climate/
Queensland Government *Climate Futures Dashboard*	https://www.longpaddock.qld.gov.au/qld-future-climate/dashboard/
Queensland Government *Interactive Map on Climate Change Risks and Impacts*	http://qgsp.maps.arcgis.com/apps/MapJournal/index.html?appid=1f3c05235c6a44dcb1a6faebad4683fc#
CSIRO and BOM *Climate Futures*	https://www.climatechangeinaustralia.gov.au/en/

Appendix A – AS 5334 *Risk Matrices*

Table A1 – 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 A2 – 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 A3 – Risk Rating Matrix (Source: AS 5334:2013 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