CHAPTER 22

Climate change risk

ILLABO TO STOCKINBINGAL ENVIRONMENTAL IMPACT STATEMENT

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22. Climate change risk

22.1 Overview

The ongoing change in global climate presents a diverse range of challenges to modern society with the predicted increase in temperatures, sea level rise, altered climatic patterns, and increase in the occurrence and severity of extreme weather events. Projected climatic changes have the potential to impact the construction and operation of rail infrastructure and, given the long design life of the proposal, this is important to consider these potential impacts.

The *Inland Rail Climate Change Risk Assessment Framework* (ARTC, 2018b) provides a standard approach to climate change risk assessment and mitigation across all Inland Rail projects. It provides a foundation for how each project should undertake a climate change risk assessment and assign adaptation measures. It provides an agreed list of climate hazards, pre-determined list of impact descriptions, and assessment of likelihood and consequence for both 2030 and 2090 adopting an emissions scenario aligned with Representative Concentration Pathway (RCP) 8.5, which global emissions are currently tracking against. It also provides identified adaptation measures and categories of potential additional measures.

A preliminary climate change assessment was undertaken to consider climate change risks, opportunities and adaptations, to inform the design process. The key findings were:

- during construction, extreme rainfall and flooding resulting in delays to the construction schedule and cost impacts present the highest risk
- during operation, extreme rainfall events, flooding and extreme heat will present the highest risk in both the near future (2030) and far future (2090).

Further consideration of the potential for climate change risks would be undertaken to support detailed design. This would include a review of climate adaptation measures identified for the proposal and incorporation into design as far as practicable; conduct of sensitivity testing for increases in rainfall (in accordance with *the Inland Rail Climate Change Risk Assessment Framework);* and consideration of RCP 8.5 in modelling used to inform design of drainage and waterways.

22.2 Scope of chapter

The potential impacts of climate change have been considered for the design and operation of the Inland Rail—Illabo to Stockinbingal project (the proposal) through a climate change risk assessment. The objective of the climate change risk assessment is to identify key climate variables that would pose a risk to the asset and to identify appropriate adaptation measures to create climate resilient infrastructure. The findings of this assessment will inform relevant decision-making processes, ensuring adaptation measures are integrated into the design and operation of the proposal to improve resilience across the life of the asset.

The climate change risk assessment will both serve to address the Secretary's Environmental Assessment Requirements (SEARs) compliance as well as consider the requirements outlined in the Infrastructure Sustainability (IS) Rating Scheme V1.2 for Cli-1 and Cli-2. The IS Rating Scheme V1.2 is coordinated by the Infrastructure Sustainability Council of Australia (ISCA) to drive sustainability outcomes in infrastructure through evidence-based compliance against performance requirements, more information on the IS Rating Scheme V1.2, Cli-1 and Cli-2 is provided in Chapter 23: Sustainability.

22.3 Secretary's Environmental Assessment Requirements

The SEARs relevant to climate change, together with a reference to where they are addressed in the EIS, are provided in Appendix A.

22.4 Legislation, policies, standards and guidelines

This section describes the legislative, policy and management framework relevant to climate change and risk adaption for the proposal.

The following resources contain climate change risk requirements, guidance, manuals and frameworks applicable to the proposal:

- *AS 5334:2013 Climate change adaptation for settlements and infrastructure—A risk-based approach* (Standards Australia, 2013)
- *AS/NZS ISO 31000:2018 Risk management—Guidelines* (Standards Australia, 2018)
- *Biodiversity Conservation Act 2016* (NSW)
- *Environment Protection and Biodiversity Conservation Act 1999* (Cth)
- *National Greenhouse and Energy Reporting Act* 2007 (Cth)
- Checklist for best practice adaptation planning and implementation (OEH, 2013b)

- *Climate Change Impacts and Risk Management—A Guide for Business and Government* ((then) Department of the Environment and Heritage (now Heritage NSW) and Australian Greenhouse Office, 2006)
- Climate Change in Australia: Projections for Australia's NRM Regions - Central Slopes Cluster Report (Ekstrom et al., 2015)
- *State of the Climate 2020 Report* (Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BoM), 2020)
- *The good, the bad and the ugly: Limiting temperature rise to 1.5°C* (International Panel on Climate Change (IPCC), 2018)
- *Guide to Climate Change Risk Assessment for NSW Local Government* (Office of Environment and Heritage (OEH), 2011d)
- *Infrastructure Sustainability Planning Guidelines V1.2* (ISCA, 2016)
- Infrastructure Sustainability Rating Tool Scorecard V1.2 (ISCA, 2018b)
- *National Climate Resilience and Adaptation Strategy* (Department of the Environment, 2015)
- *Climate Risk Assessment Guidelines* (Transport for NSW (TfNSW), 2018e)
- *Technical Guide for Climate Change Adaptation for the State Road Network* (RMS, in draft).

The policies and guidelines relevant to the proposal with respect climate change risk are presented in Table 22.1.

TABLE 22.1 SUMMARY OF POLICIES, STRATEGIES OR GUIDELINES

Policy, strategy or guideline	Relevance to the proposal
International	
Paris Agreement under the United Nations Framework Convention on Climate Change	In 2015, the Australian Government announced its commitment to a target of reducing greenhouse gas (GHG) emissions by 26 to 28 per cent below 2005 levels by 2030, building on its previous target of 5 per cent below 2000 emission levels by 2020, irrespective of what other countries do. The Australian 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. 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 5 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 - financial, technological and capacity building support to help developing countries implement the Agreement.
Commonwealth	
Commonwealth Government's Direct Action Plan	The 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.
Commonwealth Government's National Climate Resilience and Adaptation Strategy	The 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.
State (NSW)	
Climate Change Policy Framework for NSW	The policy aims to maximise the economic, social and environmental wellbeing of NSW in the context of a changing climate. The framework considers current and emerging policy settings both nationally and internationally. The framework sets out two aspirational long-term objectives; achieve net-zero emission by 2050 and make NSW more resilient to a changing climate. In making NSW more resilient to a changing climate, the NSW Government role includes: - implementing policies to plan for climate change risks and provide targeted support - assessing and effectively managing climate change risk to government assets and services - advocating for action to support effective adaptation.
Technical Guide for Climate Change Adaptation for the State Road Network (draft)	The draft provides guidance for State Road network projects that require climate change adaptation in response to changes in climate processes. While the Technical Guide has been developed considering existing Roads and Maritime processes, it aligns with the broader NSW Government initiatives and programs responding to climate change impacts, and as a result been referenced within the SEARs for the proposal.

22.5 Impact assessment methodology

22.5.1 Climate change risk assessment

A climate change risk assessment has been undertaken for the proposal in accordance with the climate change risk assessment process developed by ARTC for the entire Inland Rail Program. A project-specific assessment for the proposal was undertaken in line with the program-wide assessment, with specific risks and adaptation measures proposed, where appropriate.

The climate change impact assessment has followed the following approach:

- review of existing environment, climate change data and projections based on the data available from the Australian Bureau of Meteorology (BOM) (adopting RCP 8.5), the NSW and ACT Regional Climate Modelling (NARCliM)
- assessment of the proposal in response to the risk identified for a RCP8.5 against near future (2030) and far future (2090) time frames to identify project-specific impacts
- identification of adaptation measures based on the potential risks and impacts identified within the risk assessment
- reassessment to determine residual risk and ongoing management strategies.

The assessment of climate change risk and vulnerability was undertaken in accordance with relevant legislation and guidelines, including with AS 5334:2013 *Climate change adaptation for settlements and infrastructure—a risk-based approach and satisfy climate risk,* IS0 31000: 2018 *Risk management—principles and guidelines*, the climate adaptation requirements of the Infrastructure Sustainability (IS) rating tool and ARTC's *Inland Rail Project Risk Management Framework*. It has also taken into consideration state-specific guidance documents, such as *Climate Risk Assessment Guidelines* (TfNSW, 2018e).

The assessment considered climate projections at a 10-kilometre (km) resolution (NARCliM) with specific adaptation measures incorporated within the proposal as measures to mitigate the impact of the associated climate change risk.

22.5.1.1 Limitations

While the proposal includes an assessment of the impacts of rail operations, including rollingstock, the ability for ARTC to influence the climate change aspects of the rollingstock is limited as rollingstock is owned and operated by third-party operators. As such, the proposal will focus on the climate change resilience of the permanent infrastructure of the proposal, e.g. track and signaling climate resilience. Additionally, where impacts to rollingstock would have an impact on operation or maintenance of the proposal (indirect impacts), consideration has been given in the risk assessment and through the identification of adaptation responses.

22.6 Existing and future climate

The Paris Climate Change Agreement (effective 4 November 2016) seeks to limit climate change to under 2°C with a target of 1.5°C (United Nations Framework Convention on Climate Change, 2022). Seeking to achieve these targets presents a significant challenge, and even at 1°C, the earth's climate and weather systems are experiencing considerable changes. The Intergovernmental Panel on Climate Change (IPCC Special Report) launched on 8 October 2018, outlines the impacts of global warming of 1.5°C above pre-industrial levels and explores global GHG pollution reduction pathways consistent with meeting the 1.5°C Paris target. The IPCC Special Report states that Australia is one of the most vulnerable developed countries in the world to the impacts of climate change.

The State of the Climate 2020 (BOM and CSIRO, 2020) confirms the long-term warming trend over Australia's land and oceans, showing that Australia's climate has warmed by 1.44 ± 0.24°C since national records began in 1910, leading to an increase in the frequency of extreme heat events. The heatwaves have already become longer, hotter, dangerous bushfire weather is increasing, cool season rainfall is dropping off and creating challenges for the agriculture industry.

22.6.1 Observed local climate

The proposal is generally located within the Murray Murrumbidgee region. Lying to the lower west of the Great Dividing Range, the landscape is dominated by large floodplains and unconfined river valleys.

According to the AdaptNSW Murray Murrumbidgee Climate Change snapshot (OEH, 2014a), the region experiences a very distinct seasonal variation in temperature. Average maximum temperatures during summer range from 34°C on the plains north of Hay to 14°C in the Snowy Mountains. In winter, the average minimum temperature ranges from –6°C in the Snowy Mountains to 6°C in the west of the region.

The number of cold nights per year (minimum temperatures below 2°C) varies considerably across the region. Western parts of the region experience the lowest number of cold nights (fewer than 30 per year). The number of cold nights increases, moving to the east and into the mountains. Wagga Wagga sees around 50 cold nights per year and there are over 200 cold nights per year in the peaks of the Snowy Mountains.

Rainfall varies considerably across the region with average annual rainfall ranging from 1600–2400 millimetres (mm) in the Snowy Mountains to 200–400 mm in the semiarid plains in the west of the region. The South West Slopes receive an average annual rainfall in the range of 400–800 mm, with lower rainfall in the west and higher rainfall in the east towards the mountains. Rainfall is relatively uniform throughout the year across much of the region, with marginally higher rainfall during winter and spring. The region has experienced considerable rainfall variability in the past, with periods of both wetter and drier conditions. During much of the first half of the 20th century the region experienced drier conditions. The first decade of the 21st century saw a long period of below average rainfall during the Millennium Drought. This dry period ended with two of the wettest years on record for Australia (2010–2011), with 2010 being the third wettest year on record for NSW. Extreme fire weather conditions occur on average one day per year at Hay and five days per year at Wagga Wagga and are more likely to occur in summer and spring months.

The closest BoM weather station to the proposal is the Cootamundra Airport station. This station is located about 60 km from the proposal and the data collected at this station is considered to be representative of the proposal site. Based on this data it is evident that on average the highest mean rainfall occurs in June and majority of the average rainfall falls in the last six months of the year, with a mean annual rainfall of 583 mm. Mean maximum temperatures during summer range from 26.4°C and 32°C and during winter range from 13°C and 14.6°C. Three extreme storm events have been reported at the site, with one storm cell causing significant damage to a building in January 2018, and wind events causing disruptions and State Emergency Services (SES) assistance in January 2018.

Historic climate data for the Cootamundra Airport station from 1995 to 2018 is shown in Figure 22.1.

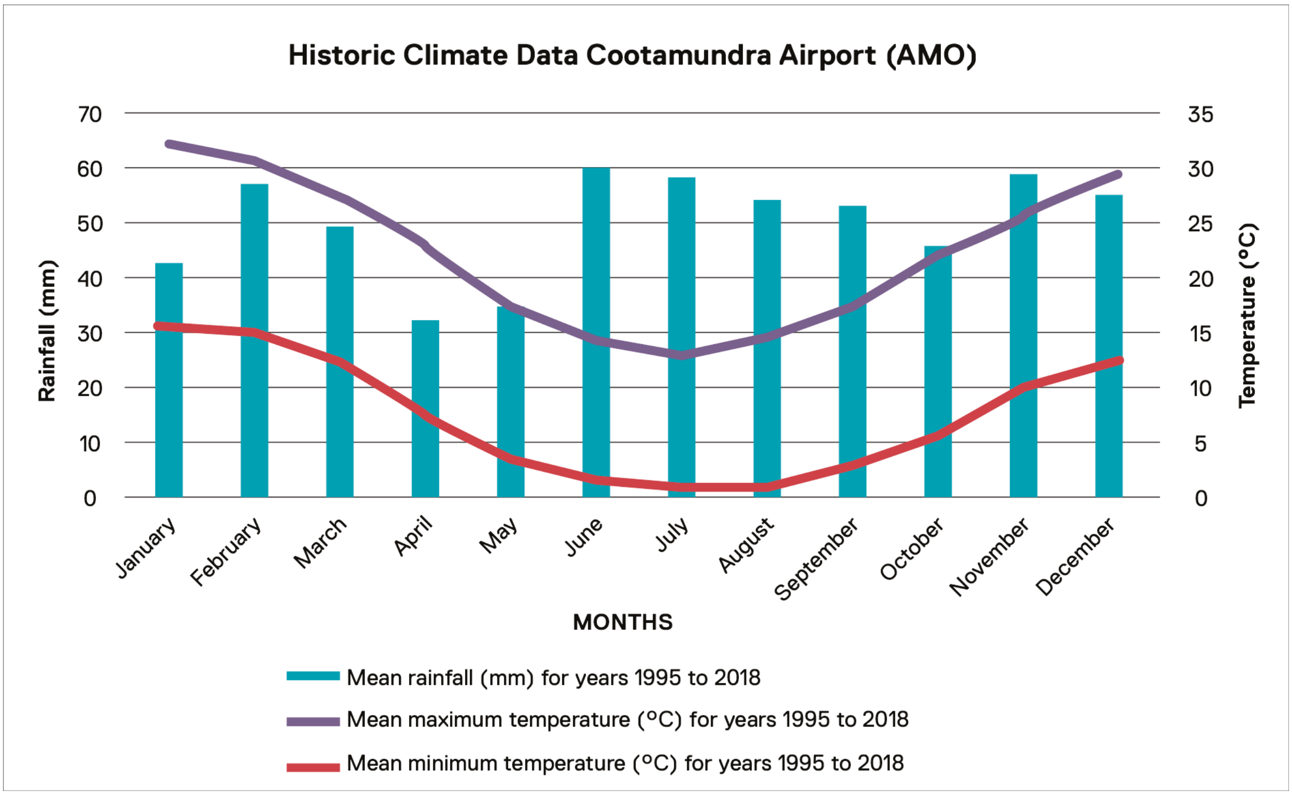

FIGURE 22.1 **HISTORIC CLIMATE DATA FOR COOTAMUNDRA AIRPORT**

22.6.1.1 Climate variables

Selecting relevant climate change variables is critical input to the climate change risk assessment process. Selection of these is based on the following factors related to the broader context and nature of the proposal:

- the location of the proposal in an area is projected for increased temperature and solar radiation
- the location of the proposal in an area subject to decreased annual rainfall resulting prolonged periods of drought
- the location of the proposal in an area projected for an increase in extreme rainfall with subsequent flooding of local waterways.

As a result, the climate variables relevant to the proposal are listed in Table 22.2.

TABLE 22.2 PRIMARY AND SECONDARY CLIMATE EFFECTS

Primary climate effect[1]	Secondary climate effect[2]
Mean surface temperature	Extreme temperature and heatwaves
Average annual rainfall	Bushfire weather
Solar radiation	Flood and flash flood events
Extreme rainfall	Drought
Increased CO_2	Storm events and wind speed

(1) Primary effects: are those climate variables that are directly influenced or changed as a result of global warming or climate change. These include things such as air and sea surface temperature, precipitation, wind and solar radiation.

(2) Secondary effects: are those variables that are derived from primary effects which are still influenced by a changing climate. These include things such as increased risk of bush fire weather and drought.

22.6.1.2 Climate projection scenarios

In order to assess the level of climate change risks to the proposal, the current climate science and model projections have been investigated for the identified climate variables relevant to the proposal based on available data sources. Reflecting ARTC's commitment to future-proofing Inland Rail, and the requirements of the climate change credits (Cli-1, Cli-2) in the IS rating scheme, this climate change risk assessment has used two data sources for climate change projections:

- *AdaptNSW* and NARCliM developed by the OEH (2014a; 2015), which provides projections at the 10 km resolution
- *Commonwealth Scientific and Industrial Research Organisation* and *Bureau of Meteorology Climate Futures* (CSIRO and BoM, 2015), which (having adopted a 'worst case' emission scenario of RCP 8.5) supplements the information available from the NARCliM projections for a number of key climate variables.

The CSIRO and BoM present climate data through the Climate Futures tool in the form of Cluster Reports, which are regional downscaled climate projects across eight regions in Australia. Based on the location of the proposal, the Central Slopes Cluster Report has been used to inform this assessment.

22.6.1.3 Time scales

Rail infrastructure has a varied expected design life depending on the component. For the purposes of this assessment, it has been assumed that the following design lives would be applied to rail components:

- electrical, signalling and communications components—20 years
- earthworks—50 years
- concrete infrastructure (e.g. bridges, culverts, sleepers) and railway tracks—100 years.

Based on these design lives, construction of the proposal occurring between mid-2024 and mid-2026, and the latest available climate projections data, the time periods selected for assessment are 2030 (near future) and 2090 (far future). 2030 was considered appropriate for short-term impacts on construction of the proposal (assuming construction would be finished in mid-2026 with initial operation occurring soon after). Climate change projections for 2090 are considered relevant to longer term operation and maintenance of the proposal given the expected design life. Projections, where available, for 2070 were included as a means of confirming long-term trends.

22.6.1.4 Detailed projections

A summary of the current climate science available for the Murray Basin Cluster Report (Ekström et al., 2015) using the RCP 8.5 data and the Murray Murrumbidgee Climate Change Snapshot (OEH, 2014a) using the *Special Report on Emissions Scenarios* (SRES) A2 data are provided in Table 22.3.

The RCP 8.5 data and SRES A2 data were used a worst-case scenario to help guide risk assessment and adaptation planning.

TABLE 22.3 DETAILED CLIMATE CHANGE PROJECTIONS

		NARCliM AdaptNSW (OEH)		Climate Futures CSIRO and BoM	
		2030	2070	2030	2090
Climate variable	Baseline data[2]	SRES A2[3] (high emissions)	SRES A2 (high emissions)	RCP 8.5[4] (high emissions)	RCP 8.5 (high emissions)
Average daily annual temperature	–	+0.62°C (0.41–0.81)	+1.94°C (1.44–2.34)	0.9°C	3.8°C
Average maximum temperature	––	+0.65°C (0.40–0.97)	+1.99°C (1.62–2.47)	1.1°C	4.1°C
Average minimum temperature	–	+0.60°C (0.44–0.76)	+1.93°C (1.28–2.38)	0.9°C	3.5°C
Extreme heat days (above 35°C)	7.1 days	+8 days	+22.9 days	+12	+29
Average annual rainfall	–	-0.9% (-9%–13%)	+2.5% (-7.6%–16.1%)	-1%	-5%
Extreme rainfall (>125mm in 24 hours)	N/A	Extreme rainfall events to increase in intensity and severity			
Fire weather (number of days/year FFDI[5] > 50)	3.6 days/year	+0.6 (-0.4–1.7)	+2.0 (-0.37–4.3)	+4.6	+7.6
Drought[6]	N/A	Both time spent in drought and occurrence of drought are anticipated to increase in intensity and severity.			

(1) Quantitative results presented as model median (50th percentile) value, with 10 to 90 percentile range in brackets.
(1) NARCliM changes relative to 1990 to 2009 baseline, CSIRO and BoM changes relative to 1986 to 2005 baseline.
(2) The SRES A2 is the high emissions trajectory resulting from IPCC Fourth Assessment Report.
(3) The RCP 8.5 is the high emissions scenario resulting from the IPCC Fifth Assessment Report
(4) The Forest Fire Daily Index (FFDI) combines observations of temperature, humidity and wind speed. Fire weather is classified as severe when the FFDI is above 50.
(5) As drought conditions are directly linked to corresponding rainfall projections, there is uncertainty regarding these projections. Rainfall is dependent on local climate drivers including topography with most models showing contrasting patterns and trajectories.

22.7 Potential impacts

There were 43 climate change risks identified as part of the climate change risk assessment process for the proposal. It is important to note that the climate change risk assessment process detailed in this chapter is subject to a different process to, and sits outside of, the project wide risk assessment in Appendix G.

Risks have been grouped by the following climate variables:

- extreme rainfall/flood events
- extreme heat
- bushfire events
- storm events and wind
- mean rainfall reduction/drought.

22.7.1 Construction

Due to previous events experienced in and around the rail corridor, and observed and projected trends, risks to rail infrastructure, by way of physical damage, delays in schedule and potential risks to human health and safety are likely. The increased frequency and intensity of extreme weather events, increased rainfall, bushfires and rising temperatures are already causing strain on existing rail networks and associated infrastructure. More extreme weather events are likely to damage rail infrastructure and, by 2030, design criteria for extreme events are very likely to be exceeded more frequently (Thom et al., 2010).

Table 22.4 presents the climate change risks during construction, as well as their risk rating.

TABLE 22.4 CLIMATE CHANGE RISKS TO PROPOSAL CONSTRUCTION (2030) PRIOR TO MITIGATION

Risk ID	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
CCR 20	Extreme rainfall and flooding resulting in delays to construction schedule and cost impacts.	Possible	Major	High	Direct

22.7.2 Operation

Based on the climate change risk assessment for the proposal, extreme rainfall events, flooding and extreme heat will present the highest risk in both the near future and far future. Risks associated with these events involve:

- more frequent flooding, resulting in inundation of track and trackside infrastructure (signalling/communications equipment and drainage basins)
- increased incidents of extreme events (heat, rainfall and bushfire) and more severe impacts of extreme events on power supply and demand (both internal and external to the rail corridor), and network (communications) interruption
- increased heat events leading to track buckling and subsequent disruption of service.

Table 22.5 and Table 22.6 present the very high, high and medium risks (excluding low risks) identified to proposal operation prior to mitigation for the period of 2030 and 2090, respectively. Low risks have been excluded as they do not require the same level of consideration as the very high, high and medium risks.

TABLE 22.5 CLIMATE CHANGE RISKS TO PROPOSAL OPERATION (2030) PRIOR TO MITIGATION

Risk ID	Climate variable	Climate change risk impact description	Likelihood	Consequence	Risk rating	Risk type
CCR 2	Temperature increase—More hot days and warm spells	Risk to business continuity as a result of heat event (e.g. increased incidence of delayed services).	Likely	Minor	Medium	Direct
CCR 11	Increased intensity of extreme rainfall events	More intense rainfall (and increased runoff volume from catchment) could lead to flooding of tracks and assets, inundation of drainage infrastructure and damage due to scour	Possible	Moderate	Medium	Direct
CCR 12	Increased intensity of extreme rainfall events	More intense rainfall could lead to flooding of tracks and assets, inundation of drainage infrastructure reducing the safety of running conditions with resulting service disruption.	Possible	Moderate	Medium	Direct
CCR 13	Increased intensity of extreme rainfall events	Increase in intense rainfall could result in overtopping leading to damaged infrastructure	Possible	Moderate	Medium	Direct
CCR 25	Increased intensity of extreme rainfall events	Increased intense rainfall and flooding resulting in scour damage to adjacent properties	Possible	Moderate	Medium	Direct

Risk ID	Climate variable	Climate change risk impact description	Likelihood	Consequence	Risk rating	Risk type
CCR 41	Harsher fire-weather conditions	Bushfire event along the corridor resulting in stoppage of freight along the rail and subsequent severing of community evacuation and CFA access/egress points	Unlikely	Major	Medium	Direct

TABLE 22.6 CLIMATE CHANGE RISKS TO PROPOSAL OPERATION (2090) PRIOR TO MITIGATION

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
CCR 2	Temperature increase—More hot days and warm spells	Risk to business continuity as a result of heat event (e.g. increased incidence of delayed services).	Almost certain	Minor	Medium	Direct
CCR 3	Temperature increase— More hot days and warm spells	Increase in hot days resulting in track twisting (buckling), which could lead to derailment of trains along the rail line	Possible	Moderate	Medium	Direct
CCR 6	Temperature increase— More hot days and warm spells	Extreme heat, leading to increased power demand and/or failure of power infrastructure (i.e. substations, LV/HV switchboards) resulting in interruptions to power mains supply with increased frequency and duration of power outages	Likely	Minor	Medium	Indirect
CCR 7	Temperature increase—More hot days and warm spells	Increased incidence of extreme heat limiting the ability for ARTC to attract workers due to undesirable conditions	Likely	Minor	Medium	Indirect
CCR 8	Temperature increase—More hot days and warm spells	Rollingstock or hot works igniting fire due to hot, dry and windy conditions	Likely	Minor	Medium	Direct
CCR 10	Increased intensity of extreme rainfall events	Risk to health and safety of staff (e.g. conductor, emergency crews) working along the rail corridor due to velocity and flow of flooding (e.g. flash flooding events)	Likely	Minor	Medium	Direct
CCR 11	Increased intensity of extreme rainfall events	More intense rainfall (and increased runoff volume from catchment) could lead to flooding of tracks and assets, inundation of drainage infrastructure and damage due to scour	Likely	Moderate	High	Direct
CCR 12	Increased intensity of extreme rainfall events	More intense rainfall could lead to flooding of tracks and assets, inundation of drainage infrastructure reducing the safety of running conditions with resulting service disruption.	Likely	Moderate	High	Direct
CCR 13	Increased intensity of extreme rainfall events	Increase in intense rainfall could result in overtopping leading to damaged infrastructure	Likely	Major	Very high	Direct
CCR 14	Increased intensity of extreme rainfall events	Longitudinal scour through water running along embankment, impacting on embankment.	Likely	Moderate	High	Direct
CCR 15	Increased intensity of extreme rainfall events	Inundation of adjacent road network and signalling equipment causing potential isolation of assets due to flooding	Likely	Minor	Medium	Direct

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
CCR 16	Increased intensity of extreme rainfall events	More intense rainfall could lead to flooding of tracks and assets, inundation of drainage infrastructure, increasing maintenance and insurance premiums costs.	Almost certain	Minor	Medium	Direct
CCR 17	Increased intensity of extreme rainfall events	Inundation of adjacent road network impacting on ability of emergency response to reach the corridor	Likely	Minor	Medium	Direct
CCR 22	Increased intensity of extreme rainfall events	Extreme rainfall and flooding causing damage to non-rail structures potentially impacting operations	Possible	Moderate	Medium	Direct
CCR 24	Increased intensity of extreme rainfall events	The projected periodic extreme dry and wet periods may increase the potential for erosion of substrate and ballast materials, causing increase washout. This could cause infrastructure instability, train derailment and disruption in the event of collapse.	Possible	Moderate	Medium	Direct
CCR 25	Increased intensity of extreme rainfall events	Increased intense rainfall and flooding resulting in scour damage to adjacent properties	Likely	Moderate	High	Direct
CCR 26	Increased intensity of extreme rainfall events	Potential blockages of drainage infrastructure caused by the movement of debris during flood.	Likely	Minor	Medium	Direct
CCR 28	Increased intensity of extreme rainfall events	Increased rainfall intensities leading to greater discharges, which leads to increased hydraulic impacts (e.g. afflux) on adjacent properties	Likely	Moderate	High	Direct
CCR 29	Decrease in average rainfall	Structural deterioration, soil subsidence, erosion, movement and cracking as a result of increased variability of periods of wetting and drying, reducing integrity of tracks, bridges, embankments and signalling infrastructure with potential structural failure	Unlikely	Major	Medium	Direct
CCR 30	Decrease in average rainfall	Structural deterioration, soil subsidence, erosion, movement and cracking as a result of increased variability of periods of wetting and drying causing increases in monitoring and maintenance programs	Likely	Minor	Medium	Direct
CCR 31	Increase in extreme weather events and storms	Damage to tracks/siding, electrical, communications infrastructure and other structures due to higher wind speeds and falling debris requiring repair and/or replacement and an increase in capital costs	Possible	Moderate	Medium	Direct
CCR 32	Increase in extreme weather events and storms	Storm events resulting in closure of rail line (due to damage to communications equipment, for safety purposes or loss of power supply/increased frequency and duration of power outages) with subsequent delays	Possible	Moderate	Medium	Direct/Indirect

Risk ID	Climate variable	Climate change risk	Likelihood	Consequence	Risk rating	Risk type
CCR 33	Increase in extreme weather events and storms	Storm events and subsequent higher winds resulting in derailment (loss of freight, rolling stock, cessation of operation) including damage to infrastructure	Possible	Moderate	Medium	Direct/Indirect
CCR 36	Harsher fire-weather conditions	Bushfire damaging rail infrastructure including trackside infrastructure (e.g. signals, communications equipment requiring increased operational costs)	Possible	Moderate	Medium	Direct
CCR 38	Harsher fire-weather conditions	Bushfire events leading to damage to power supply infrastructure or a need to cut supply resulting in interruptions to power supply (particularly signalling and communications equipment) with increased frequency and duration of power outages	Possible	Moderate	Medium	Indirect
CCR 41	Harsher fire-weather conditions	Bushfire event along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent severing of community evacuation and CFA access/egress points	Possible	Major	High	Indirect
CCR 42	Harsher fire-weather conditions	Bushfire event along the Inland Rail corridor resulting in stoppage of freight along the rail and subsequent impacts on customers good not being delivered	Possible	Minor	Medium	Indirect

* Storm events encompass a range of impacts in a single event, e.g. extreme winds, risk of debris, rainfall, poor visibility in one 'storm event' as identified and recorded by BoM.

22.8 Adaptation measures

22.8.1 Climate adaptation measures

Table 22.7 outlines associated adaptation measures to reduce the impact of climate change risks to the proposal, with those noted as being 'current' as existing practises within the design, construction and operation of railway assets, and those 'planned' being options for future consideration and application that are not currently existing practices. It is noted that, in some instances, a changing climate can result in beneficial outcomes. For the most part, however, identified measures include a combined approach that addresses the avoidance of risk, designing out risk where possible and practicable, as well as procedures for the management of risks that may be unavoidable.

The adaptation options identified in Table 22.7 have been either integrated into the proposal and current procedures or are scheduled to be addressed in further design development; these adaptation options align with the program-wide adaptation options for Inland Rail works. It is noted that recommended future actions ('potential actions') have been identified and will be investigated in the course of detailed design and project delivery, as per the climate change risk assessment process outlined in the *Inland Rail Climate Change Risk Assessment Framework*.

TABLE 22.7 CURRENT AND PLANNED ADAPTATION MEASURES

Adaptation measures	Timing
Maintenance program to be developed/operational policy updated to avoid outdoor works during hotter times (where practicable).	Planned
Implement high temperature stop-work threshold if not already considered within existing ARTC operational framework.	Current
Reduce train speeds during days where trackside temperature exceeds 35°C.	Current
Ensure that design and procurement of trackside equipment (e.g. signals, communication relay points) account for an increase in ambient temperatures and extreme heat days.	Planned

Adaptation measures	Timing
Consider the use of elastic fasteners and/or heavier sleepers to account for potential track buckle.	Current
Provide shade for trackside equipment (double ventilated signal boxes and/or double skinned enclosures) and/or specify material and colour selection to reduce heat load.	Planned
Consider the use of lighter coloured ballast or painted rails to reduce trackside temperature.	Current, infrequently applied
Locate electrical equipment and supporting infrastructure outside of bushfire-prone areas, where reasonable and feasible, to reduce risk of damage from bushfire.	Current
Undertake sensitivity testing in line with climate change scenario planning for RCP 8.5 by reviewing implications of 20 per cent increases in rainfall (in accordance with the *Australian Rainfall and Runoff Guidelines* (Ball et al., 2019), particularly around track-side storage detention basins/stormwater infrastructure.	Current
Implement flood mitigation measures along the rail corridor, including the locating of critical electrical systems (signalling, communications huts, etc.) above potential flood zones and increasing the design height of bunds.	Current
Design site grading to direct flooding into onsite detention and other stormwater channels/drainage infrastructure.	Current
Design culverts and drainage to be concrete-lined to reduce potential for damage.	Current
Incorporate additional drainage network features and flood-protection measures (e.g. larger drainage network, additional pits, larger pipe diameters, larger sumps etc.) to mitigate a potential increase in flood risks.	Current
Investigate the inclusion and development of an early flood warning system (e.g. flood gauges, trackside monitors) to alert ARTC to impending flooding.	Planned
Develop or update emergency response procedures to respond to extreme weather events.	Planned
Establish vegetation clearance zones across the corridor to minimise vegetation (debris and bushfire risk).	Current
Backup power supply and/or built-in system redundancy (in case of substation failure) provided as standard to ensure continuous operation of electrical systems, including signalling and communications equipment along the corridor.	Current
Incorporate solar PV and battery storage as built-in redundancy to ensure ongoing operation of signalling and communications equipment in the event of power failure.	Current
Engage with local emergency services to discuss and coordinate emergency response procedures.	Planned

22.8.2 Recommended mitigation measures

The measures outlined in Table 22.8 will be implemented to reduce the impact of climate change risks to the proposal.

TABLE 22.8 SUMMARY OF CLIMATE CHANGE RISK MITIGATION MEASURES

Impact	Mitigation measure	Timing
Climate change risk management	The climate adaptation measures identified for the proposal would be reviewed, and the final measures would be incorporated in design and implemented during construction and operation, as far as practicable.	Detailed design/ pre-construction
Climate change risk management	Sensitivity testing would be undertaken in line with climate change scenario planning for Representative Concentration Pathway (RCP) 8.5 by reviewing implications for increases in rainfall (in accordance with *the Inland Rail Climate Change Risk Assessment Framework).*	Construction
Climate change risk management	The design would consider Climate Change (RCP 8.5) in modelling used to inform design of drainage and waterways, including: ▸ application of the latest *Inland Rail Climate Change Risk Assessment Framework* (ARTC, 2021c) ▸ application of the latest *Australian Rainfall and Runoff Interim Climate Change Guidelines* (Engineers Australia, 2014)) ▸ assessment of impacts associated with the 1% Annual Exceedance Probability (AEP) to determine the sensitivity of the design to potential changes in the rainfall intensity	Construction

Impact	Mitigation measure	Timing
	‣ where enhancement or upgrading to existing track is to be undertaken, no worsening of the existing track flood immunity would occur.	
Climate change risk management	Operational management and maintenance procedures would address potential climate change risks and adaptation measures.	Operation

22.8.3 Residual risk assessment

A residual risk assessment for the proposal will be undertaken during the detailed design phase to apply the relevant adaptation measures identified in the above section (see Table 22.7) for all 'very high' and 'high' risks. In addition, adaptation measures identified as contributing towards treating all 'medium' risks, resulting in a number of those 'medium' risks having their corresponding residual risks revised to 'low'.

Adaptation measures have been specifically identified and incorporated in the proposal to address specific climate change risks, which satisfies the SEARs, and any residual risk that remains for the proposal will be addressed during the detailed design phase of the proposal, in accordance with ARTC's climate change approach.

While uncertainty regarding future climate projections exists, particularly to 2090, the adaptation measures identified as part of this climate change risk assessment would result in a lowering of residual risks to the rail corridor across future scenarios.