APPENDIX X

DUNGOWAN DAM AND PIPELINE EIS

Climate Change Adaptation Plan

Report for EMM Consulting

Dungowan Dam and pipeline project Climate Change Adaptation Plan

28 September 2022

DUN-EMM-EN-RPT-0008

EDGE

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Revision	Revision Details	Author	Approved by	Date Approved
1	Issue to WaterNSW	Tim Watson & Julian Marchant	Tim Watson	19th November 2020
2	Revision to WaterNSW	Tim Watson & Julian Marchant	Tim Watson	13th January 2021
3	Revision 2 to WaterNSW	Tim Watson & Julian Marchant	Tim Watson	18th March 2021
4	Revision for updated scope and project details	Tim Watson	Dr James Hooper	8th June 2022
5	Revision for finalisation	Tim Watson	Dr James Hooper	14th July 2022
6	CSSI update (EMM)			28th September 2022

Executive Summary

Anthropogenic climate change is driving important changes in rainfall patterns, temperature, bushfire behaviour, storms and flooding. These impacts pose significant challenges to infrastructure now and into the future. Implementing a climate change focused risk assessment process allows for the identification of climate related risks and the ability to plan for and adapt to future extreme weather events.

This report outlines the climate related risks and adaptation opportunities associated with the Dungowan Dam and pipeline project, located in Dungowan, New South Wales. The project includes a new 22.5 GL dam at Dungowan about 3.5 km downstream of the existing Dungowan Dam and an enlarged delivery pipeline from the new Dungowan Dam outlet to the tie in point to the existing pipeline from Dungowan Showground to the Calala WTP. The Dungowan Dam and pipeline project is within the Peel Valley catchment.

EMM Consulting Services Pty Ltd (EMM) have engaged Edge Environment (Edge) to facilitate the development of a Climate Change Risk Assessment (CCRA) to deliver a Climate Change Adaptation Plan (CCAP) for the concept design stage of the project and supporting the Environmental Impact Statement (EIS) for the project. The CCRA investigates the project's exposure and vulnerability to projected climate change variables, in line with the risk management approach and guidelines articulated in the Australian Standard (AS) 5334-2013 *Climate change adaptation for settlements and infrastructure* (AS 5334-2013).

As part of the Secretary's Environmental Assessment Requirements (SEARs), the project is required to meet several climate risk management requirements as well as the alignment to a certified sustainability rating framework. Therefore, this CCAP has been developed in line with Level 2 requirements of the Infrastructure Sustainability (IS) rating (v1.2) Cli-1 and Cli-2 credits.

Our approach

Following the AS 5334-2013 standard, Edge undertook an in-depth analysis of historic climate and future projections relevant for the project site. A multi-disciplinary climate risk workshop was undertaken to present the climate analysis and assess the potential impact of these projected future climate scenarios on the Dungowan Dam and pipeline project. In the workshop, Edge facilitated the identification of climate risks as well as potential adaptation measures. An additional workshop was undertaken with selected project stakeholders to review the risk profile of the project given the updated scope of the assessment (refer to Section 3.5 for details). The key output of the workshops was a climate risk register that provides a comprehensive list of the project's climate risks and corresponding opportunities for mitigating risks through adaptation initiatives.

Key findings

This CCAP identifies a total of 57 individual risks to the Dungowan Dam and pipeline project, with six high risks for the short term (2030) and 11 high risks identified for the far future (2090) (refer to Figure 1 below). The main source of risk to the project was temperature (28%), followed by the impacts of increased rainfall intensity (23%) and storms (19%).

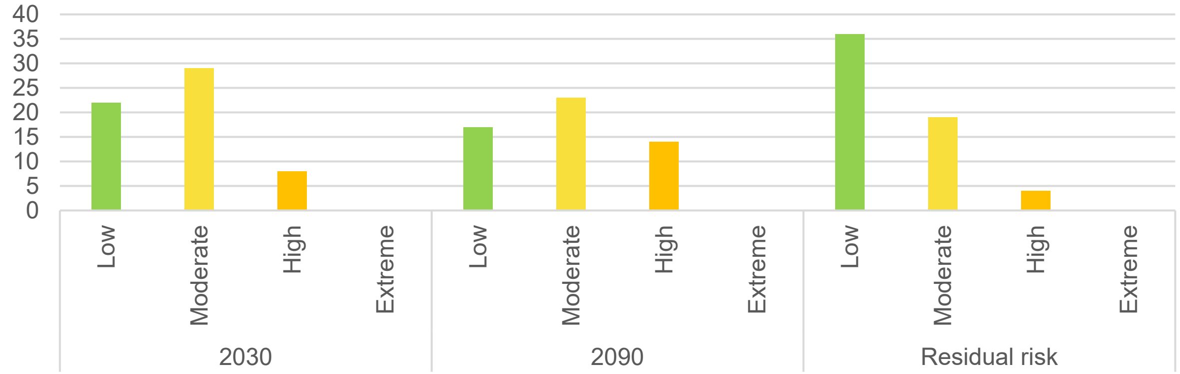


Figure 1 - Proportion of extreme and high risks to the project (L) and sources of risk to the project (R).

The elements of the new Dungowan Dam associated with the highest number of priority risks included water quality, power supply, reservoir, dam operations and embankment.

A breakdown of the number and ratings of risks to specific project elements is provided in Table 1 below.

Table 1 – Summary of climate risks by project element.

	2030				2090				Residual risk			
Component	Low	Mod.	High	Extreme	Low	Mod.	High	Extreme	Low	Mod.	High	Extreme
Embankment	5	0	0	0	3	0	0	0	5	0	0	0
Spillway	2	1	0	0	2	1	0	0	3	0	0	0
Reservoir rim	0	1	0	0	0	1	0	0	1	0	0	0
Reservoir	3	2	0	0	2	2	0	0	4	1	0	0
Operations	4	1	0	0	3	1	0	0	4	1	0	0
Water quality	1	8	4	0	1	7	5	0	4	8	1	0
Power supply	0	5	2	0	0	4	3	0	3	4	0	0
Pipeline	3	2	0	0	2	2	0	0	1	0	0	0
Access road	0	2	0	0	0	2	0	0	0	2	0	0
Existing Dungowan Dam	2	0	0	0	2	0	0	0	2	0	0	0
Water supply	0	3	0	0	0	0	3	0	0	1	2	0
Total risks	17	24	6	0	13	19	11	0	27	17	3	0

A total of 50 direct and six indirect risks were identified to the new Dungowan Dam project. Direct risks included damage to infrastructure elements from floods and storms as well as impacts from bushfires. Indirect risks were mainly associated with damage to the electricity network.

Priority risk areas and adaptation actions

The identified risks have been broken down into three priority risk areas based on their ratings (from high to extreme), focussing on common impacts to the project and/or its operations and the range of sources of these impacts as well as their consequences for project design and operation.

Priority risk areas to be addressed included:

- Maintenance of water quality for downstream users and the environment.
- Operational impacts from climate-related blackouts.
- The impacts of drought and increased water demand on long-term water supply.

Priority risk areas, risk examples and their controls are provided in the table below. In addition, proposed adaptation measures to address these risks have also been provided. Importantly, the project team should investigate and implement (where possible) adaptation actions to address all high and extreme risks identified through the assessment. Adaptation actions outlined in this report were developed in consultation with the workshop stakeholders and are provided as potential solutions. In most cases, the proposed adaptation actions could appropriately manage the risk, however there were some exceptions related to water quality and availability (e.g. Risks A18, A51, A52) where the residual risk remained higher. These are detailed in Appendix C. It is recognised that not all adaptation actions lie within the jurisdiction of Water Infrastructure NSW. Where this is the case, the relevant project owner or other stakeholders should be consulted to encourage and support risk mitigation planning.

Table 2 – Summary of priority risk areas, risk, control examples and proposed adaptation actions.

Priority risk areas	Key risk examples	Risk ref.	Current control examples	Example adaptation actions
1. Maintenance of water quality for downstream users and the environment	• Increased frequency and severity of algal blooms due to both heatwave and drought conditions, with both environmental and human health impacts for downstream users.	A13 A14 A18 A23 A46 A49	• Continuous water quality monitoring programs to identify any change in water quality. • Implementation of a multi-level intake tower in design that allows the user to select the option of water drawn out at specific points. • Operational protocols on how to operate the dam when there is an algal bloom, including the release of water from deeper in the reservoir to avoid surface algae (this control may have implications for cold water release goals)	• Review opportunities to ensure vegetation is monitored over time (e.g. through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed. • Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS. • After fire events, appropriate sediment and erosion controls could be considered in relevant tributaries leading to the dam (subject to relevant jurisdiction and responsibility).
2. Operational impacts from climate-related blackouts	• Increase in bushfire and storm intensity was identified as potentially increasing hazards such as the burning or destruction of power and communications lines, leading to important service delivery impacts for the dam.	A11 A12 A17	• Vegetation clearing from near power lines to reduce direct bushfire damage to power transmission • Operational procedures to guide operators under blackout scenarios • Onsite energy generation capabilities and manual backup of dam if power is lost. • Manual operation of valves to establish control of dam flows without a power source.	• Review opportunities to ensure vegetation is monitored over time (e.g. through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed. • Consider opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS and other relevant stakeholders. • Consider opportunities to include non-flammable pylons and buried power cables to reduce powerline exposure to local bushfire impacts. • Consider the opportunity to develop APZ specification for both design and operation, as required by relevant

Priority risk areas	Key risk examples	Risk ref.	Current control examples	Example adaptation actions
				planning instruments.
3. The impacts of more frequent severe drought and reduced inflows and increased water demand on long-term water supply	• Downstream local environmental impacts due to reduced water availability for the environment • Service disruption due to reduced ability to deliver water under severe drought conditions • Increased water demands from town water supply and irrigation in conjunction with drought conditions was also identified as a key long-term risk	A7 A51 A52	• Enact water restrictions when required to reduce water demand during drought periods. • Consideration of drought scenarios in the planning and design process • Peel Valley water sharing plan (refer to (NSW Office of Water, 2010)) • Pipeline designed to minimise water losses on transference to town • Review and revise current Tamworth drought management plan	• Consider supporting the update of the water sharing plan for the Peel Valley to account for the implications of climate change on drought conditions.

Recommendations

This CCAP provides a summary of the priority climate-related risk areas to the Dungowan Dam and pipeline project's current concept design and future operations. The assessment reveals a range of important impacts that may hinder the successful operation of the project and its long-term resilience to the projected changes in climate in the Tamworth region.

The following steps are recommended to ensure that the Dungowan Dam and pipeline project is designed and operated to be resilient to the effects of a changing climate:

1. During detailed design and the preparation of environmental management plans, the design and construction teams should review the priority risk areas and consider the incorporation of adaptation actions provided in Section 7. Importantly, where incorporated, specific roles and responsibilities within the team should be assigned to each management action to ensure ownership and implementation.
2. Take steps to identify and integrate relevant adaptation actions into operational requirements (where relevant), as well as ensuring the ongoing monitoring and review of the climate adaptation risk register through design, construction and operational phases.
3. Monitor any potential changes in the IPCC's RCP scenarios and localised projections for the Dungowan/Tamworth region to continually update the ratings of identified risks associated with a changing climate.

Contents

Abbreviations

AEP – Annual Exceedance Probability

CCRA – Climate Change Risk Assessment

CCAP – Climate Change Adaptation Plan

CWP – Cold Water Pollution

DCCEEW - Commonwealth Department of Climate Change, Energy, the Environment and Water

DPE – NSW Department of Planning and Environment

EIS – Environmental Impact Statement

FSL – Full supply level

GHG – Greenhouse gases

IPCC – Intergovernmental Panel on Climate Change

RCP – Representative Concentration Pathway

SEARs - Standard Secretary's Environmental Assessment Requirements

WTP – Water Treatment Plant

1 Introduction

1.1 The project

The Peel River, part of the Namoi River catchment, provides water for irrigation as well as being the primary water supply for the city of Tamworth. Prompted by the millennium drought, investigations into the future water supply and demand for bulk water were undertaken for the regional city of Tamworth and the Peel Valley water users. The Dungowan Dam and pipeline project (the project) is a critical project to improving long-term water security for the region. The project includes a new dam at Dungowan (new Dungowan Dam) approximately 3.5 km downstream of the existing Dungowan Dam and a new section of pipeline about 32km long between the proposed Dam outlet and the tie in point to an existing pipeline from Dungowan Showground to the Calala Water Treatment Plant (WTP).

In September 2022, the Minister for Planning and Homes declared the project to be Critical State Significant Infrastructure (CSSI) as it is a development that is essential for the State for economic and social reasons. This requires Schedule 5 of the *State Environmental Planning Policy (Planning Systems) 2021* to be updated to reflect the CSSI status of the project. As CSSI, the project is subject to Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act), which requires the preparation of an environmental impact statement (EIS) and the approval of the NSW Minister for Planning and Homes. This Climate Change Adaptation Plan has been prepared to support the EIS.

In addition to requiring approval from the NSW Minister for Planning and Homes, the project has been deemed a controlled action under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and requires approval from the Commonwealth Minister for the Environment and Water. The Minister for the Environment and Water has accredited the NSW planning process for the assessment of the project. Therefore, a single EIS has been prepared to address the requirements set out by the NSW Department of Planning and Environment (DPE) and the Commonwealth Department of Climate Change, Energy, the Environment and Water.

1.2 Project location

The project is located in the Tamworth Regional local government area (LGA), the New England Tablelands bioregion and part of the New England and North West region of NSW, west of the Great Dividing Range (DPE 2017). The New England and North West region is home to approximately 186,900 people and has a total area of around 99,100 km2 (ABS 2018).

The city of Tamworth is the nearest (and largest) town to the project with over 40,000 residents. Other nearby regional towns include Quirindi (70 km west), Manilla (90 km north-west), Gloucester (90 km south-east), Armidale (100 km north) and Gunnedah (110 km west of the project).

The existing Dungowan Dam is in the Namoi River catchment approximately 50 km south-east of Tamworth in NSW. The Namoi catchment covers 4,700 km2 and borders the Gwydir and Castlereagh catchments and is bounded by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mount Kaputar to the north.

The existing Dungowan Dam is on Dungowan Creek, which is a tributary of the Peel River. Dungowan Creek is confined by the existing Dungowan Dam, while the Peel River system is regulated by Chaffey Dam, located in the upper catchment near the town of Woolomin, approximately 45 km from Tamworth.

The project's regional setting is shown in Figure 2.

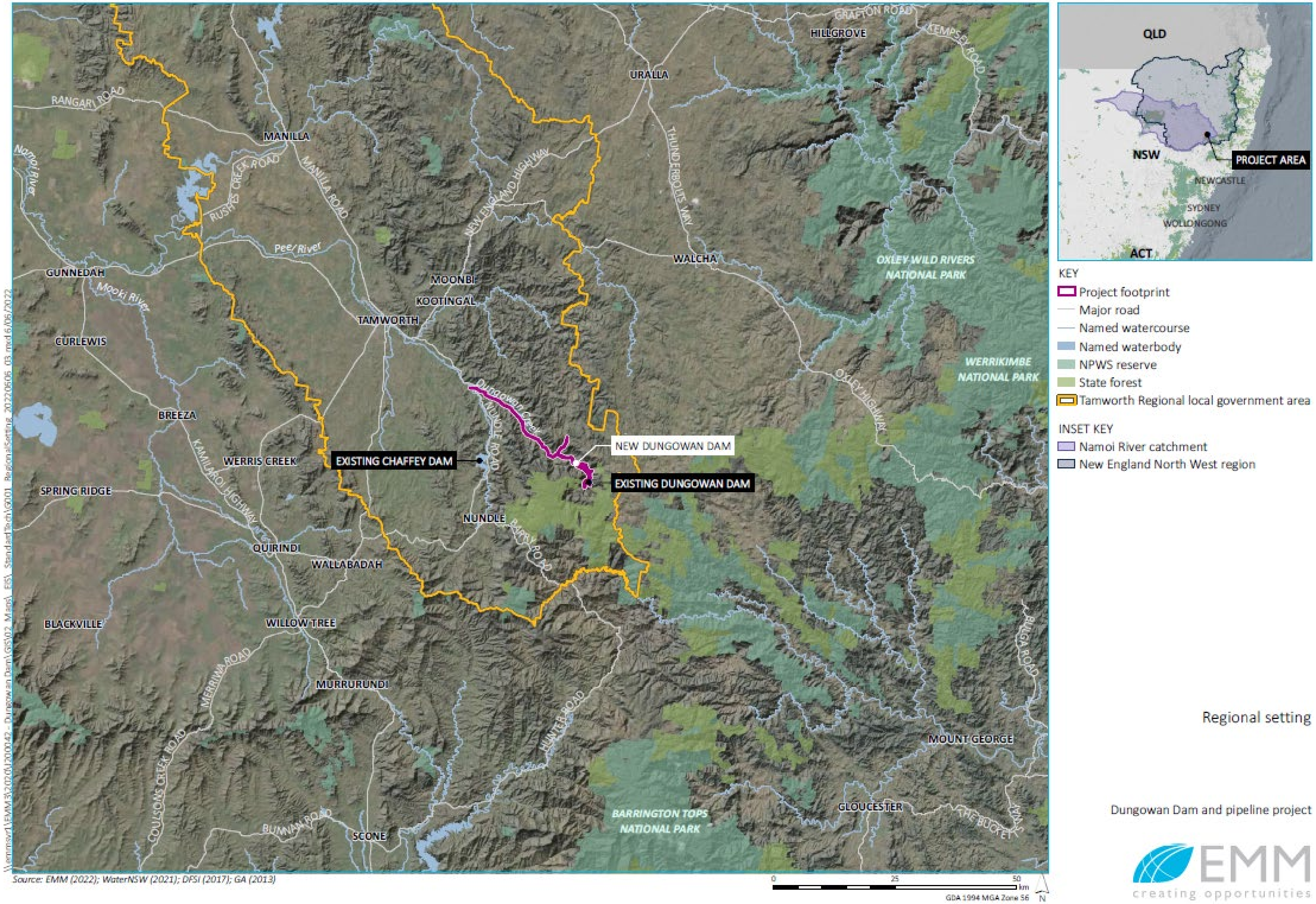


Figure 2 Regional setting.

1.2.1 Project impact areas

In outlining the project, a project footprint has been defined to facilitate the assessment of direct impacts from the project:

- Project footprint: all areas where direct impacts may be experienced during construction and/or operation.

The project footprint has an area of 315 ha and is comprised of the construction and operational footprints, of which there is some overlap:

- Construction footprint: areas where vegetation clearing and/or ground disturbance is required for construction of the dam, pipeline and ancillary facilities, including the area needed to decommission and rehabilitate the existing dam.
- Operational footprint: areas where there will be permanent operational elements or easements, including infrastructure needed to operate the new Dungowan Dam and pipeline. The operation footprint includes the inundation area, being the area defined by the proposed full supply level (FSL) for the project.

Additional areas outside the project footprint have also been considered where relevant to the assessment of project impacts and include:

- Upstream flood extent: An area above the FSL to the level of a probable maximum flood (PMF) event that would be inundated for relatively short periods during operation associated with extreme rainfall events.
- Project area: A 10 km buffer around the project footprint defined to allow for assessment of potential indirect impacts.
- Downstream impact area: the area where hydrological changes may occur due to the project. This area is discussed in detail in the Surface Water Assessment (EMM 2022) as well as other technical reports subject to changed flow regimes as a result of the new Dungowan Dam operation. The downstream impact area includes Dungowan Creek and also the Peel River downstream of Chaffey Dam.

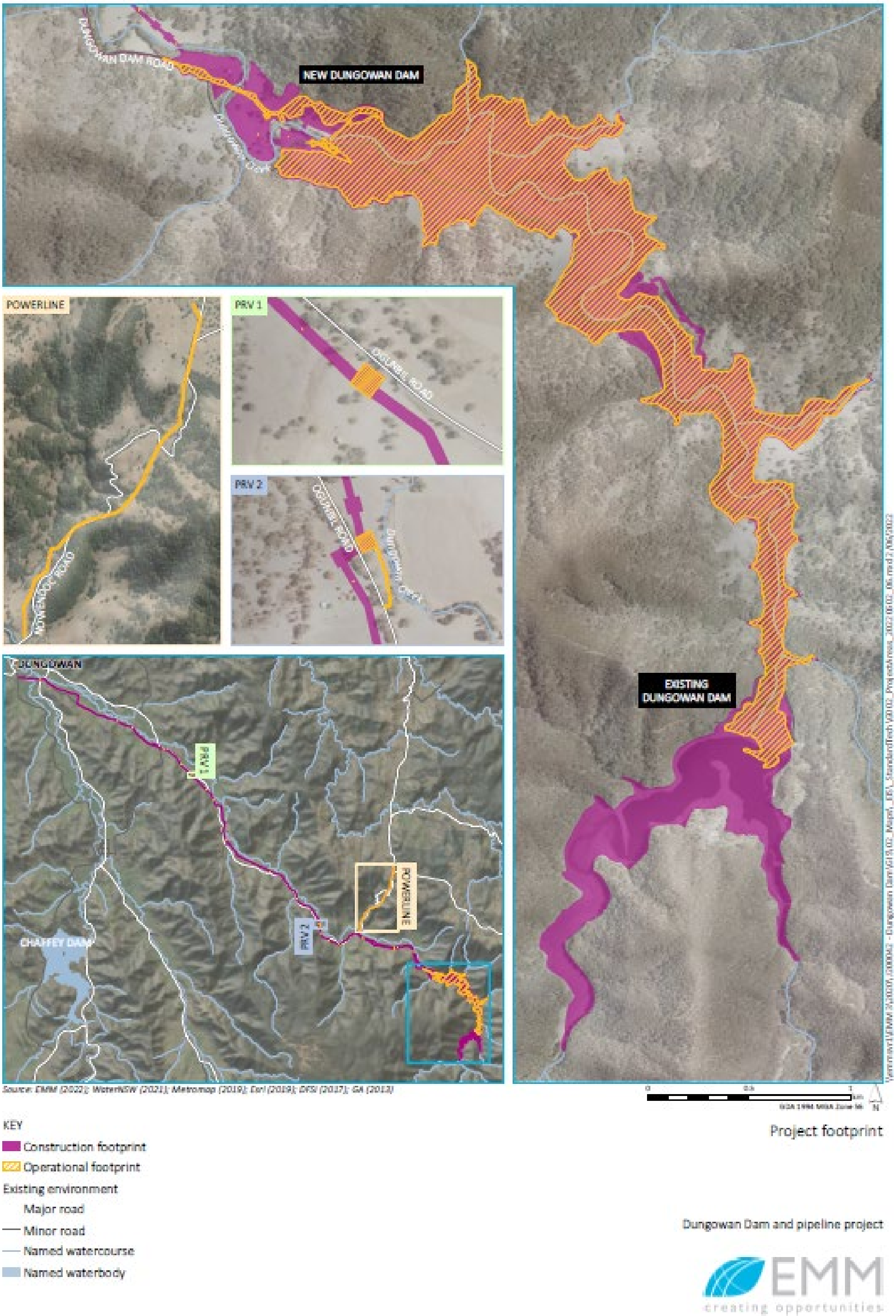


Figure 3 Project footprint

1.3 Climate risk assessment

Climate change poses significant long-term risks to infrastructure through changes in temperature, rainfall and the increased occurrence or intensity of extreme weather events. Implementing a climate change-focused risk assessment process is a responsible course of action for long-term civil infrastructure assets. The relevant Australian Standard (AS 5334:2013) states:

"It is clear that taking a pre-emptive approach to adapting to our changing circumstances is preferable to dealing with the increasingly severe consequences of our inaction in the future."

EMM Consulting (EMM) have commissioned Edge Environment (Edge) to facilitate the development of a Climate Change Adaptation Plan (CCAP) for the new Dungowan Dam and pipeline (the project) at the concept design / Environmental Impact Statement (EIS) phase. The Dungowan dam and pipeline project seeks to provide more reliable water availability to the Tamworth region and is a key project of Water Infrastructure NSW (the Proponent).

The CCAP details the methodology and findings of the Climate Change Risk Assessment (CCRA) process, as well specific actions for reducing the climate-related exposure of the project. It aims to inform design and operational guidelines to proactively mitigate and manage climate-related risks over the construction and operational lifetime of the project.

1.4 Purpose of the report

The broad objectives of this CCAP are to understand how direct and indirect impacts of climate change could affect the new Dungowan Dam project, and to explore current and future adaptation actions to mitigate the high risks. This CCAP supports the EIS for the new Dungowan Dam project. The EIS documents the CCAP methods and results, key risk findings as well as opportunities to mitigate risks through adaptation actions.

This report and associated deliverables include:

- A description of the CCRA process and project methodology;
- An overview of current climate for the project location in Dungowan, NSW;
- An overview of best available climate change projections, sourced from the Intergovernmental Panel on Climate Change (IPCC) endorsed Global Circulation Models (GCMs), for the relevant location in Australia;
- A risk assessment summary of climate change exposure and vulnerability based on available projections and key stakeholder input; and
- A comprehensive, project-specific risk register and adaptation plan providing potential risk treatment measures for consideration.

1.5 Assessment guidelines and requirements

This Climate Change Adaptation Plan has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for the Dungowan Dam and pipeline project as well as relevant government assessment requirements, guidelines and policies, and in consultation with the responsible government agencies.

The SEARs must be addressed in the EIS. Table 3 lists the matters relevant to this assessment and where they are addressed in this report.

Table 3 - Relevant matters raised in SEARs

Requirement	Relevant section
70. Assessment of the risk and vulnerability of the project to climate change in accordance with the current guidelines, including any Regional Water Strategy and associated climate change modelling as relevant to the project.	Sections 3 and 5 (Water modelling with future climate predictions is detailed in the Surface Water Assessment – Appendix to the EIS)

71. Quantified specific climate change risks with reference to the NSW Government's climate projections and incorporate specific adaptation actions in the design.	Sections 6 and 7
72. An assessment of potential future climate variability impacts on the operation and management of the existing and proposed dam, proposed pipeline, and associated delivery works (such as water deliver by way of river operations), having regard to research on groundwater recharge and surface run-off and the NSW Climate Impact Profile.	Sections 5.2, 5.4, 6 and 7 (Water modelling with future climate predictions is detailed in the Surface Water Assessment – Appendix to the EIS)

The climate change data employed in this assessment was sourced from CSIRO's Climate Change In Australia (CCIA) online resources. These reputable Australian government sources, which provide summaries of modelled climate change data, informed the development of the climate change context for the new Dungowan Dam site. While ground and surface water risks were considered in this assessment, detailed studies of groundwater & surface run-off impacts were out of the scope of this assessment and have been undertaken subsequently in the following reports:

- Groundwater Impact Assessment (EMM (a), 2022)– Appended to the EIS; and
- Surface Water Assessment (EMM (b), 2022)– Appended to the EIS.

To inform preparation of the SEARs, DPE invited relevant government agencies to advise on matters to be addressed in the EIS. These matters were taken into account by the Secretary for DPE when preparing the SEARs.

1.6 IS Rating

The Water Infrastructure NSW project team aims to develop a robust, relevant and up to date CCAP during design. This includes the identification of new design initiatives to manage risks associated with future climate change related impacts.

This CCAP has been developed to align with the Level 2 requirements of the Cli-1 credit and Level 1 for Cli-2 credit from version 1.2 of the Infrastructure Sustainability Council of Australia (ISCA) Infrastructure Sustainability (IS) Rating Tool. Table 4 and Table 5 (as well as Appendix B) provide an overview of the Cli-1 and Cli-2 requirements and where they are addressed in this CCAP.

Table 4 - Cli-1 IS Requirements and alignment.

Cli-1 Climate Change Risk Assessment			
Level	**ISCA requirement**	**How requirements have been addressed in the CCAP**	**Page number or section of CCAP**
1	***Direct climate change risks to the asset over the forecast useful life are identified and assessed.***	Direct risks were identified and assessed according to AS 5334:2013.	Section 6.3
2	***The requirements of Level 1 are achieved.***	See above	
	The climate change risk assessment also considered indirect climate change risks to the asset.	Indirect risks are defined as risks impacting the project's *external* context. Indirect risks were identified and assessed according to AS 5334:2013.	Section 6.3
	A multi-disciplinary team participated in identifying climate change risks and issues.	Stakeholder consultation was undertaken during preparation.	Appendix A
3	***The requirements of Level 2 are achieved.***	See above	
	Modelling is undertaken to characterise the likely impacts of the projected climate change for all High and Extreme priority climate change risks.	NA	NA
	A comprehensive set of affected external stakeholders participated in identifying climate change risks and issues.	NA	NA

Table 5 - Cli-2 IS Requirements and alignment

Cli-2 Adaptation Measures			
Level	**ISCA requirement**	**How requirements have been addressed in the CCAP**	**Page number or section of CCAP**
1	***Adaptation options to treat all extreme and high priority climate change risks are identified, assessed and appropriate measures implemented.***	Adaptation actions proposed for all high and extreme risks	Section 7
	After treatment there are no extreme priority residual climate change risks.	There were no extreme risks after treatment	Section 7
2	***Adaptation options to treat 25-50% of all medium priority climate change risks are identified, assessed and appropriate measures implemented.***	To be evidenced at "As- Built" stage	N/A
3	***The optimal scale and timing of options is addressed (which may be triggered by when a specific climate threshold is likely to be achieved).***	To be evidenced at "As- Built" stage	N/A
	Adaptation options to treat at least 50% of all medium priority climate change risks are identified, assessed and appropriate measures implemented.	To be evidenced at "As- Built" stage	N/A
	After treatment there are no high priority residual climate change risks.	To be evidenced at "As- Built" stage	N/A

1.7 Other relevant reports

This CCAP has been prepared with reference to other technical reports that were compiled as part of the EIS. The other relevant reports referenced in this report are listed below.

- Bushfire Risk Assessment (BlackAsh, 2022)– Appended to the EIS;
- Groundwater Impact Assessment (EMM (a), 2022)– Appended to the EIS; and
- Surface Water Assessment ((EMM (b), 2022)– Appended to the EIS.

2 Description of the project

This chapter provides a summary of the Dungowan Dam and pipeline project. It outlines the permanent infrastructure required to operate the project, as well as the key construction elements and activities required to construct the project. A comprehensive and detailed description of the project is provided as Appendix B1 of the EIS, which has been relied upon for the basis of this technical assessment.

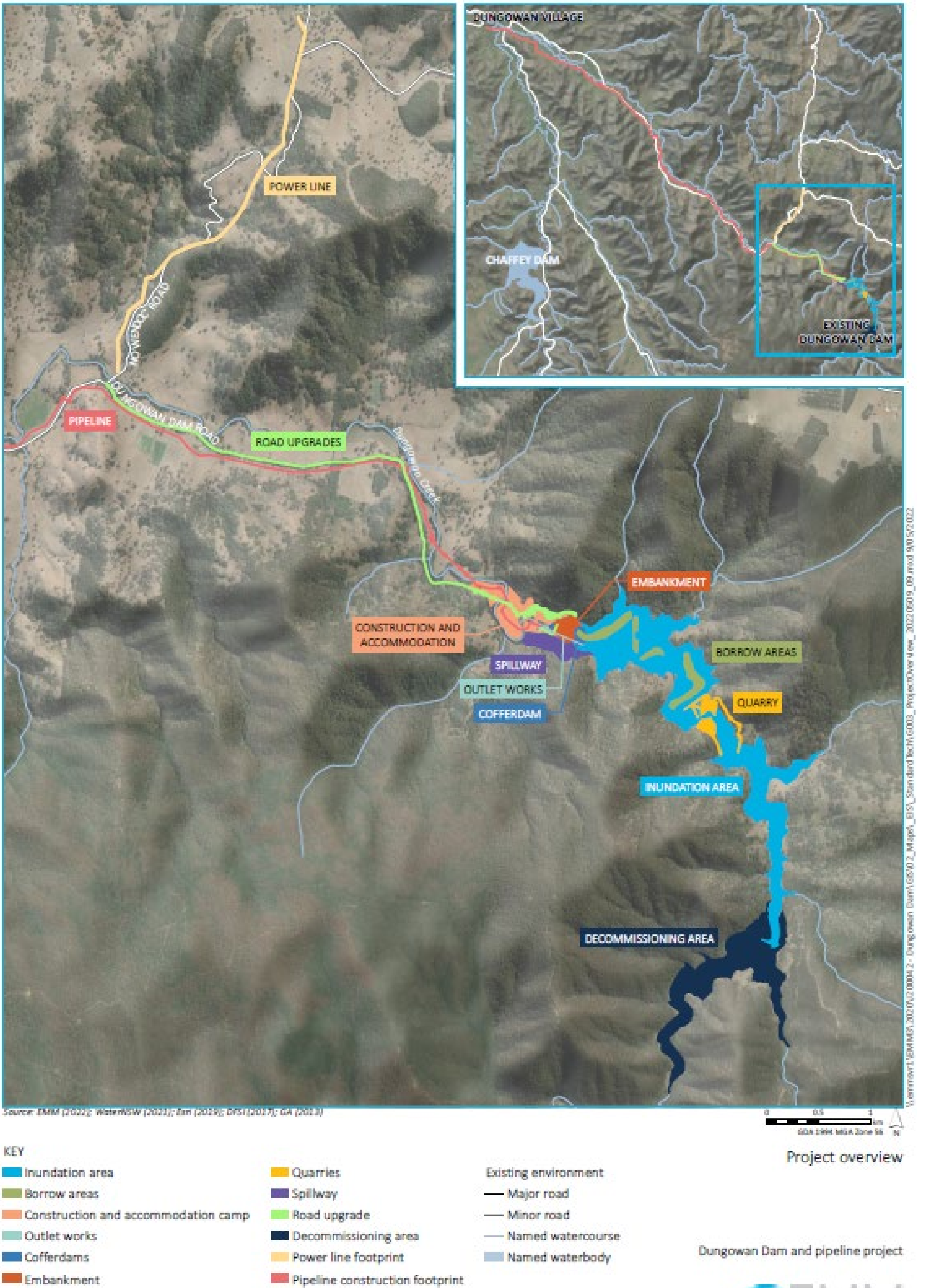
2.1 Project overview

Water Infrastructure NSW proposes to build a new dam at Dungowan (new Dungowan Dam) about 3.5 km downstream of the existing Dungowan Dam and an enlarged delivery pipeline from the new Dungowan Dam outlet to the tie in point to the existing pipeline from Dungowan Showground to the Calala WTP. The existing pipeline from Dungowan Showground to the Calala WTP is not part of the Dungowan Dam and pipeline project. A summary of project elements is provided in Table 6. An overview of the project is provided in Figure 4.

Table 6 - Overview of the project

Project element	Summary of the project
New Dungowan Dam infrastructure	Earth and rockfill embankment dam with height of ~58 m and a dam crest length of ~270 m.
	Storage capacity of 22.5 GL at full supply level (FSL) of RL 660.2 m AHD.
	The new Dungowan Dam on Dungowan Creek has a catchment size of 175 km^2 and is part of the Peel Valley and Namoi River catchment.
	Inundation extent (to FSL) of 130 ha (1.3 km^2)
	Spillway to the south of the dam wall including an approach channel, uncontrolled concrete ogee crest, chute and stilling basin. Free standing multiple-level intake tower connected with a bridge to the embankment, diversion tunnel with outlet conduit, valve house and associated pipework and valves.
	A permanent access road over the Dam crest to the valve house for operation and maintenance.
	Water diversion works including a diversion tunnel and temporary pipeline and upstream and downstream cofferdams to facilitate construction of the dam wall embankment.
Pipeline infrastructure	31.6 km of buried high-density polyethylene (HDPE) pipe between 710 mm to 900 mm nominal diameter.
	Maximum 71 ML/day from the proposed dam to the junction with the pipeline from Chaffey Dam to the Calala Water Treatment Plant, to replace the existing 22 ML/day pipeline. The pipeline would connect to the valve house on the left abutment of the embankment. Valve infrastructure would include control valves installed in two above ground buildings along the pipeline.
	10 m wide easement for the 31.6 km length of the pipeline. The replacement pipeline extends from the new Dungowan Dam to a connection point with the existing pipeline between Dungowan Showground and Calala WTP.
Ancillary infrastructure and works	Road works to improve existing roads to provide construction access, temporary establishment and use of a construction compound, an accommodation camp, two upstream quarries and four borrow areas within the inundation area.
	A new 4.2 km long 11 kV overhead powerline (including a new easement and access track) connecting to an existing overhead line approximately 6 km north west of the dam. The existing overhead line that extends approximately 13.2 km to the Niangala area would also require minor upgrades, including re-stringing of new overhead wiring and replacement of some poles.
Decommissioning of existing Dungowan Dam	Dewatering of existing dam, removal of existing Dungowan Dam infrastructure and full height breach of the existing Dungowan Dam wall. Rehabilitation of inundation area of the existing Dungowan Dam.
Disturbance	Areas of disturbance have been identified based on the direct impacts of the project. There is some overlap in the areas disturbed during construction and operation, with a resulting total disturbance area proposed for the project of 315 ha (project footprint). Disturbance would occur in a staged manner, with construction requiring disturbance of

	approximately 315 ha (construction footprint). Following construction and once rehabilitation is completed, there would be a permanent disturbance of approximately 158 ha comprising the inundation area and permanent infrastructure (operational footprint).
Construction	Construction duration of approximately 6 years.
	Construction workforce of approximately 125 workers at construction peak.
Operation	WaterNSW will be responsible for management, operation and general maintenance of the new dam. Tamworth Regional Council will be responsible for the management, operation and general maintenance of the pipeline. Public use and access to the dam would not be permitted and there would be no public facilities available during operation.
	One to two new full time workers plus part time work for existing WaterNSW operations team. Due to the new Dungowan Dam being prioritised over Chaffey Dam for Tamworth's future water supply, the water reserved for town water in Chaffey Dam would increase from 14.3 GL to 30 GL to ensure that water is set aside to meet Tamworth's town water supply water demand in years when rainfall is low.
Design life	100 years for zoned earthen embankment, structural concrete elements of the dam and the pipeline. 15 to 50 years for other non-structural project elements and pavements.
Assessment period (operational)	The assessment end point is when the water system performance reaches a level when an additional water supply option or change to the Water Sharing Plan is required. This has been estimated to be when the mean average annual water demand from Tamworth increases to 11 GL/year.



EMM creating opportunities

Figure 4 Project overview

3 Methodology

As per the IS requirements, this CCAP aligns with the following standards for applying climate change risk analysis to infrastructure assets:

- ISO 31000:2018 Risk Management – Principles and Guidelines; and
- AS 5334:2013 – Climate Change Adaptation for Settlements and Infrastructure – A Risk Based Approach (AS 5334, 2013) (Figure 5).

The risk management framework employed in these standards is illustrated in Figure 5 below, highlighting the three key tasks of the risk assessment process. These are summarised in detail in the sections below.

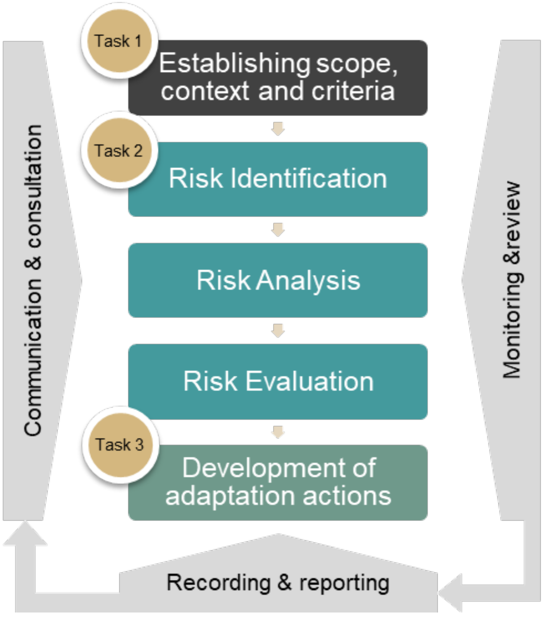


Figure 5 - The collaborative climate change risk analysis process as described by the ISO 31000:2018 and AS 5334:2013 climate risk assessment approach.

3.1 Establishing the context

Defining the context of the risk assessment supports the effective evaluation of both direct and indirect risks to the target asset. The context around climate change and the asset is defined in Table 7 below.

Table 7 - Internal, external and climate change context definition and relevance.

Context	AS 5334:2013 definition	Relevance for this CCAP
Internal context	The internal context characterises pertinent features of the internal environment in which the organisation seeks to achieve its objectives.	The internal context defines the project's direct aims and therefore the CCAP's direct risks.
External context	The external context characterises pertinent features of the external environment in which the organisation seeks to achieve its objectives, including its climate change and adaptation objectives.	The external context defines the project's indirect aims and therefore the CCAP's indirect risks.
Climate change context	Defining how climate is likely to change in the future	This includes analysing data to establish an understanding of the historic and future climate.

3.1.1 Internal and external context

To determine the project's internal and external context, the Dungowan Final Concept Design for 22.5 GL Storage report (SMEC, 2020) was reviewed according to the respective definitions and guidance within AS5334:2013.

A list of the key elements of the project's external and internal context was presented at the climate change risk workshop (see Section 4.1). Participants incorporated their understanding of the project's external and internal context into the risk statements in the form of 'consequences' of direct and indirect risks.

3.1.2 Climate change context

Establishing how the climate is likely to change in the future involves examining both the historic and projected future climate for the project's location. The sections below summarise the approach and data sources used to define the future climate context of the project. This information was presented to a multi-disciplinary group of stakeholders at the CCRA Workshop, held on September 29th, 2020 (Appendix A for attendance register).

Historic climate

The historic climate analysis covered the primary effects of temperature, precipitation and sea-level rise, and the secondary effects of relative humidity, drought/flood, wind, cyclones, bushfire and heatwaves. Due to their potential for significant impacts on water infrastructure assets, the following climatic variables were of key interest:

- Temperature.
- Precipitation.
- Extreme climate events (drought, flood, heatwave and bushfires).

Historic climate information was gathered from the Bureau of Meteorology database (BOM, 2019), CSIRO (Ekstrom, et al., 2015) and localised flood studies. The weather station at Tamworth Airport (located 48 km north-west of the proposed Dungowan Dam site) has been used as the source for historic rainfall, temperature and climate data. The Tamworth Airport weather station has been recording temperature data since 1907 and rainfall data since 1876 and has collected consistent long-term data for a range of climate variables. In 1992 Tamworth Airport weather station ceased recording data and Tamworth Airport AWS started recording data. Tamworth AWS site is located 1.7 kilometres from the now non-operational Tamworth Airport weather station. This and the station's proximity to Dungowan Dam made it the most appropriate weather station to use. Further information on the station and its location in relation to the project site is shown in Table 8 and Figure 6.

Table 8 - BOM weather station selected for this study.

BOM ID	Name	Nearest suburb	Latitude	Longitude	Distance from project site	Operational time period
055054	Tamworth Airport	Westdale	31.09ºS	150.85ºE	48 km	Closed 31st December 1992
055325	Tamworth Airport AWS	Westdale	31.07ºS	150.84ºE	48km	Opened 1st January 1993

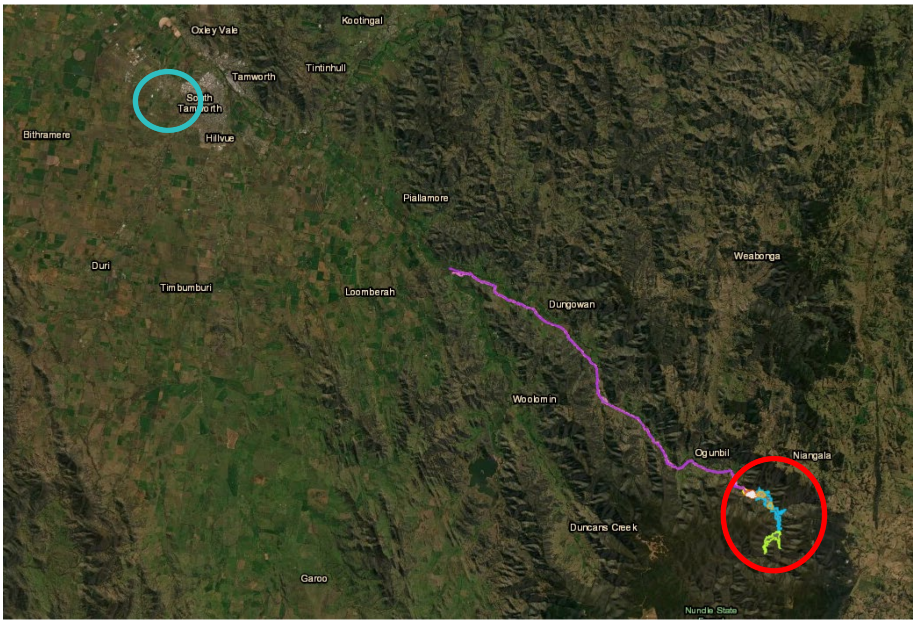


Figure 6 - The location of Tamworth Airport BoM station (circled in Blue) in relation to the Dungowan Dam project (circled in red) (ESRI, 2020).

Future climate

Current understanding of climate change is based on the climate system, its historical trends, and the output from climate models (Masson-Delmotte, 2019). Climate models are mathematical simulations of the complex interactions between climate drivers, including land mass, ice, oceans and the atmosphere, and the impacts of greenhouse gas (GHG) concentrations and ozone dynamics in the atmosphere (Masson-Delmotte, 2019). Climate models can be used to make continental-scale predictions about changes to the climate resulting from several anthropogenic GHG emissions scenarios (Masson-Delmotte, 2019). Climate models are routinely calibrated and evaluated by comparison to historical climate information (Masson-Delmotte, 2019).

Making use of dynamically downscaled climate projections, it is possible to understand regionally specific climate change impacts that vary due to local climate systems and topography. These projections can then be used to perform climate risk analyses and impact studies on the built environment. AS 5334:2013 does not stipulate or endorse specific climate models and states *"It will be up to individuals and organisations to locate and use the best available data."* (AS 5334-2013)

This CCAP adopted CSIRO projections for this study to build an understanding of the future climate context of the project's region, summarising the primary effects of temperature, precipitation and sea-level rise, and the secondary effects of relative humidity, drought/flood, wind, cyclone, bushfire and heatwave (Ekstrom, et al., 2015).

CSIRO Projections

Downscaled CSIRO climate projections offer insight into regional changes to the climate system in NSW and locates the Dungowan Dam area on the border of the East Coast and Central Slopes clusters[1].(Figure 7) These projections are based on the Representative Concentration Pathways (RCP) emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) in the Fifth Assessment Report (IPCC, 2014).

[1] The East Coast Cluster is a geographic area defined by the CSIRO for the purposes of region-specific climate modelling. The East Coast Cluster stretches from Rockhampton in QLD to Sydney in NSW. The Central Slopes cluster extends from Central Queensland (north of Roma) to south of Orange, NSW, bounded to the east by the East Coast Cluster.

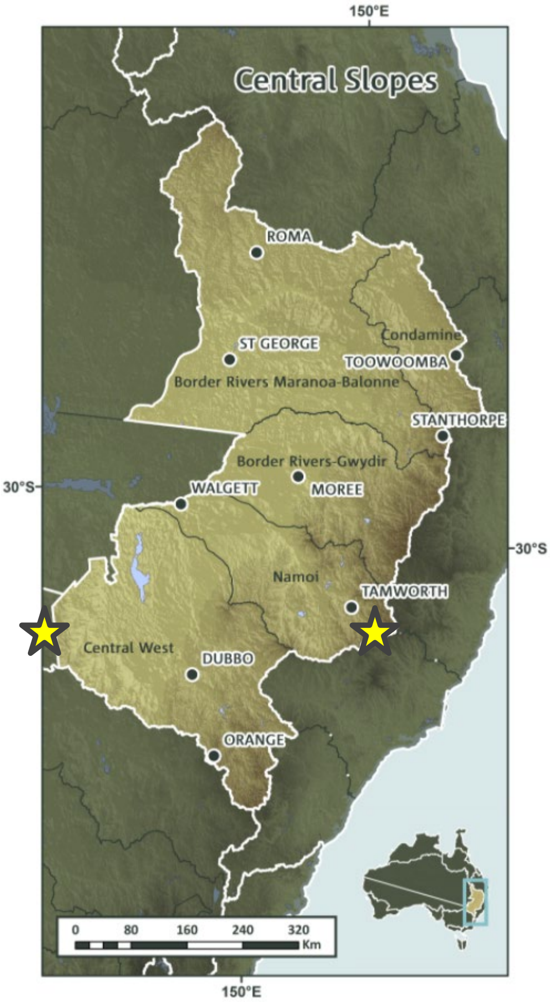


Figure 7 - The Central Slopes Natural Resource Management (NRM) region. The Yellow star represents the approximate location of the Dungowan Dam in relation to Tamworth.

This analysis uses the RCP 8.5 scenario that aligns with the following IS Rating Tool (v1.2) requirements for considering indirect climate risks of the project:

- Projections based on Representative Concentration Pathways (RCP) 8.5 must be used.
- Analyses, projections and RCPs from CSIRO/BOM Climate Future Framework may be used.

The RCP 8.5 scenario is characterised by rapid increases in emissions through the early-mid 2000s. Under this scenario, atmospheric CO_2 levels reach 950 ppm by 2100 (compared with approximately 414 ppm in early 2020). This scenario represents the worst-case, high emissions and rapid global development scenario.

Employing RCP 8.5 for the near (2030) and far future (2090) in the Central Slopes Cluster provides climate change projections for the project's region towards the end of its forecast useful life (100 years) for consideration by the project team. Projections for 2090 include the period from 2080 to 2099 and are the furthest projections available for the Dungowan region at the time of this study. Further justification for this selection is provided in Table 9.

Table 9 - Summary of emissions scenario characteristics and justification

Scenario	Characteristics	Time periods employed	Justification for employment
RCP 8.5	• Rapid increases in emissions • Atmospheric CO_2 levels reach 950 ppm by 2100 • Worst-case, high emissions and rapid global development scenario.	• 2030 (2020-2039) • 2090 (2080-2099)	Worst-case scenario employed to describe the projected climate given a business-as-usual approach to managing climate change. Emissions are currently tracking in line with the RCP 8.5 scenario.

Limitations and uncertainty

It is important to note that although the climate models adopted for this report are based on rigorous research, there is inherent uncertainty associated with using statistical models. Uncertainty arises due to:

- Local and regional variations in the climate system.
- The actual trajectory of anthropogenic GHG emissions.
- Uncertainty around broader climate responses to changes in GHG concentrations in the atmosphere (often referred to as tipping points).

The uncertainty surrounding climate projections reveals important limitations to the projections used in this study. Future changes to climate may thus be *more* or *less* extreme than described in this report. The uncertainty surrounding climate projections highlights the need for climate risk analyses to consider a range of future climate scenarios and to undergo ongoing review to include updated projection data when it becomes available.

3.2 DPE's Climate change assessment for water infrastructure proposals

This CCAP was undertaken in alignment with the methodology outlined and prescribed by *AS5335:2013 Climate change adaptation for settlements and infrastructure – a risk-based approach*. This recommends the use of best available climate change projection data, the application of which for this study is summarised in Section 3.1.2. More recently, the New South Wales Department of Planning and Environment (DPE), in consultation with Water Analytics, has developed a draft methodology within the Fact Sheet entitled Climate change assessment for water infrastructure proposals (DPE, 2022). This document details the use of climate risk datasets developed for Regional Water Strategies to assess climate change impacts relating to water infrastructure projects, which Edge understands referenced against rainfall projection data from CSIRO to determine reference periods in a 10,000-year stochastic rainfall record that reflect the average reduction in rainfall in the projection data.

The approach outlined in DPE Factsheet (DPE, 2022) goes beyond the scope of analysis undertaken in this CCAP. Priority risks associated with drought-related impacts on Dungowan Dam's long term water supply capability (and service delivery impacts) are identified in this assessment however, these risks were identified employing readily available climate change projection data and no modelling activities were undertaken as part of this assessment (refer to Section 5.4.2 for more detail on drought projections employed in this study).

Hydrological modelling has been undertaken for the project and is presented in the Surface Water Assessment (EMM (b), 2022), which is appended to the EIS. This includes modelled results that apply NARCLiM climate projection data. The results presented in the Surface Water Assessment (EMM (b), 2022) predict impacts to water supply and streamflow under modelled climate change conditions. Given that these modelled outcomes presented in the Surface Water Assessment (EMM (b), 2022) align to several risks identified in this assessment, it is suggested that Water Infrastructure NSW undertake further investigation into, and consideration of, the potential implications of prolonged drought conditions as a result of anthropogenic climate change on the operational objectives of the Dungowan Dam and pipeline project.

3.3 Risk Assessment

3.3.1 Risk identification

The CCRA aimed to identify key climate change related risks to Dungowan Dam and pipeline and to evaluate these risks based on their likelihood and potential impacts. Both direct and indirect climate risks were considered, highlighting the broad impacts of a changing climate on water infrastructure assets. Risk identification was carried out in consultation with WaterNSW (the original project proponent and future Dam owner/operator), EMM Consulting and SMEC initially in 2020 and then Water Infrastructure NSW and EMM Consulting in 2022. (It is noted that Water Infrastructure NSW assumed responsibility for the project development in mid-2021).

The attendees that participated in the workshop are listed in Appendix A.

By setting the future climate context and bringing together key project stakeholders, the workshop process resulted in the identification of a wide range of potential risks that were subsequently rated using the risk analysis framework outlined.

In order to add value to the risk assessment process and to address the IS Cli-1 requirement to engage stakeholders in climate risk identification, the following organisations were involved in providing input into workshop outcomes:

- WaterNSW (original project proponent, new Dungowan Dam owner and operator)
- Water Infrastructure (project proponent)
- EMM Consulting (Planning and Environmental Consultants).
- SMEC (Engineering and Development Consultants).

3.3.2 Risk analysis

The consulted representatives of each organisation detailed above offered in-depth knowledge into the likelihood and consequence of the identified risks. To analyse risks systematically, likelihood and consequences scales were used to determine how likely a risk was to occur given current controls. Existing risk controls were documented in the risk register provided in Appendix C.

Likelihood ratings employed are described both qualitatively and quantitatively in Table 10 & Table 11 below. The project life is defined as 100 years.

Table 10 - Likelihood scales (Source: Water NSW a (2020))

Score	Likelihood	Probability or chance	Qualitative assessment
5	Almost certain	80% + likely	Almost certain to occur during the project/ contract life
4	Likely	60-80% likely	Considered likely to occur during the project/ contract life
3	Possible	40-60% likely	Considered a possible occurrence during the project/ contract life
2	Unlikely	20-40% likely	Considered unlikely to occur during the project/ contract life
1	Rare	< 20% likely	Considered a rare occurrence to happen during the project/ contract life

Consequence is an assessment of the severity of a risk's impacts, should it occur. Consequence assessment included use of the Water NSW risk management guidelines (Refer to Table below), providing quantified impact across a range of categories.

Table 11 - Corporate consequence scales (Water NSW, 2020).

Consequence scales					
	Severe	**Major**	**Moderate**	**Minor**	**Negligible**
Safety (People)	A fatality or life-threatening injuries or illness. Public or staff exposed to a severe, adverse long-term health impact or life-threatening hazard.	Permanent disability of a person attributable to Water NSW. Public or staff exposed to a hazard that results in major surgery or permanent disablement. Serious health impact on multiple members of the public. Reportable LTI.	Serious health impact on one or more people (workforce or public) attributable to Water NSW. Public or staff exposed to a hazard that could cause injuries or moderate adverse health effects. Medical treatment injury	Injuries or illness requiring medical attention by a recognised medical practitioner with no long-term effects. Exposure of public and staff to a hazard that could cause minor injuries or minor adverse health effects. Local treatment by a first aid officer.	Minor injury or ailment that does NOT require medical treatment or first aid.

Consequence scales					
	Severe	**Major**	**Moderate**	**Minor**	**Negligible**
Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Failure of physical assets sufficient to severely impact Water NSW. All critical capabilities cease and Water NSW is unable to conduct core activities or there is a major unacceptable delay in delivery of capability. Significant loss of supply (or water quality where water is supplied for drinking) for an extended period (failure to deliver service to a valley for a whole season). A strategically important operation cannot occur due to asset failure(s). Widespread public illness attributed to raw water is supplied for drinking in Greater Sydney. Significant, long-term social and economic impacts on the NSW community.	Failure of physical assets causing significant impact on WaterNSW's outcomes. A strategically important operational capability is partially functional due to asset failures) - i.e. requires significant workarounds that limit the performance. Some critical capabilities are curtailed and Water NSW is either required to relocate particular functions or conduct them in a significantly degraded state. Major service delivery failure or asset condition problem resulting in significant loss of supply (or water quality impact where water is supplied for drinking) for a short period or moderate loss of supply for an extended period. (exceeding maximum acceptable outage). Serious health impacts on multiple members of the public attributed to the Greater Sydney raw water supply. Interruption to several key business processes or breakdown of several management systems. Significant social and economic impacts on the NSW community.	Failure of physical assets impacting on delivery of WaterNSW's outcomes A strategically important operational capability requires enduring workarounds due to asset failure(s), which impacts the performance of some key critical processes. Some capabilities are curtailed. Activities conducted in a substandard or limited state. One or more requirements would not be met. Moderate impact on ability of Water NSW to provide services to customers. Interruption to a key business process or breakdown of a management system. Serious health impact to one member of the public attributed to the Greater Sydney raw water supply. Moderate degradation of system or asset operation, resulting in moderate loss of supply for a short period. Some social and economic impacts on localised areas.	Failure of physical assets resulting in manageable delays in achieving organisational objectives Capability is supported by the asset for all desired tasks, but there would be some qualification to the level it would perform non-critical elements. Activities can be conducted with minor degradation to requirements or minor delays or minor performance degradation of system/asset operation with minor impact on supply. Minor impact on ability of Water NSW to provide services to customers. Some non-critical processes not achieved. Interruption to business processes/management systems. Minor, short-term social/economic impacts on a local community.	Failure of physical asset/s resulting in inconvenience but no impact on organisational objectives. Minimal activities curtailed with negligible performance impact. Activities can be conducted using the asset with minor degradation in requirements. Insignificant impact on the ability of Water NSW to provide services to customers. Some non-critical processes not able to be achieved

Consequence scales					
	Severe	**Major**	**Moderate**	**Minor**	**Negligible**
Environment	Widespread long term environmental impacts which are irreversible.	Environmental impacts that take up to 25 years to reverse	Moderate impacts to the environment or heritage listed area that will recover within 25 years with intervention	Environmental impacts limited and localised in effect and immediately contained. Self recovery of impacts by flora, fauna, populations, habitats or ecosystems in <2 years with minor intervention	Localised impacts. Damage contained on-site and fully recoverable with no permanent effect on the environment or the asset, < 6 months for recovery
Compliance	Loss of Operating Licence. Serious compliance breach with potential prosecution with maximum penalty imposed. Multiple compliance breaches that together result in potential prosecution with maximum penalty imposed. Failure to achieve critical legislated/regulator/licence or governance requirements.	Major compliance breach with potential exposure to large damages or awards. Prosecution or multiple compliance breaches with >50% to maximum penalty imposed. Significant failure to achieve industry minimum standards. High profile legal challenge/prosecution with heavy fine. Possible imprisonment. Class action or substantial number or size of claims for compensation	Compliance breach with investigation with prosecution and/or possible fine. Some legal constraints imposed that affect Water NSW, minimal fine. Partial achievement of critical legislated/regulatory/licence or governance requirements. Some failure to achieve industry minimum standards. Technical legal challenge/ prosecution for minor infringement. Small number of civil actions seeking significant compensation.	Minor technical non-compliances and breaches of regulations or law with potential for minor damages or monetary penalty.	Minor technical breach but no damages. No monetary penalty

Consequence scales					
	Severe	**Major**	**Moderate**	**Minor**	**Negligible**
Financial (Fiscal responsibility/ viability/resource procurement)	Insufficient operating funds to continue operations over a sustained period. Revenue or opportunity loss or operating cost increase of >$50M in one year.	Significant difficulty maintaining sufficient operating funds to continue operations. Revenue or opportunity loss or cost increase of >–10 - 50 M.	Some difficulty maintaining sufficient operating funds to continue operations. Revenue or opportunity loss or cost increase of –1M - 10 M	Some short-term impact on operating funds. Revenue or opportunity loss or cost increase of $0.1 – 1M.	Short-term impact on operating funds. Financial loss less than $100,000
Reputation (Staff/customers/public confidence	Complete loss of government /regulator/shareholder/community support. Serious public and media outcry leading to Federal and State Government intervention. Large-scale critical staff walkout - unable to be replaced for a substantial time resulting in significant disruption and loss of core capabilities.	Major loss of government/regulator/community support. (3 to 10 years). Significant adverse State media or public attention. Federal government scrutiny. State intervention. Subject to parliamentary inquiry. Serious adverse findings by investigatory bodies. Substantial damage to key relationships. Service failure provokes community outrage. Numbers of senior managers/experienced staff leave. Water NSW perceived as an unattractive employer.	Limited detrimental national or state media attention and moderate impact on the reputation of Water NSW. Adverse public attention. Federal government scrutiny. State government scrutiny. Impact on the reputation and reduced confidence for a period of time (<3 years). Widespread customer discontent, community complaints, moderate rectification measures required. Poor reputation as an employer.	High profile detrimental local media attention and minimal impact on the reputation of Water NSW. Media attention and heightened concern by local community. State Government scrutiny. (Local member/ community) Reduced public confidence for a short period. Low employee morale and attitude problems.	Low profile local media attention. No impact on the reputation of Water NSW. Minor adverse local public or media attention or complaints Occasional complaint from the community. Localised low morale and attitude problems.

Risk likelihood and consequence were combined using the risk assessment matrix in Table 12, which resulted in the systematic development of a risk rating to prioritise management and adaptation strategies.

Table 12 - Risk assessment matrix (Water NSW, 2020).

Risk rating Red - Extreme Orange - High Yellow - Moderate Green - Low		Consequence				
		1-Negligible	2-Minor	3-Moderate	4-Major	5-Severe
Likelihood	5-Almost Certain	5	10	15	20	25
	4-Likely	4	8	12	16	20
	3-Possible	3	6	9	12	15
	2-Unlikely	2	4	6	8	10
	1-Rare	1	2	3	4	5

3.3.3 Risk evaluation

The objective of risk evaluation is to ensure that risk ratings are consistent and are reflective of the stakeholder group's opinions. The evaluation process occurred during and after the workshop, where the risk statements and ratings developed during the workshop were reviewed and consolidated. The outcome of this stage was the development of a single set of prioritised climate risks for the project.

To do this, the risk ratings defined above were used to prioritise risks that are of increased significance for the project. Minor risks were screened out at this stage to focus on addressing the issues associated with high and extreme risks.

3.4 Risk Treatment

The risk treatment stage involved identifying the best management options for each risk, based on workshop participant input. Treatment options were documented in the risk register, with the aim of integrating these into future design and operational documents to mitigate climate-related risks and ensure the long-term resilience of the asset to the physical effects of climate change.

3.5 Modified scope risk review

In May 2022, following design development for the project, the climate change risk assessment was revisited and updated for a number of modified scope components, including:

- **Existing dam decommissioning** to include a full height breach rather than partial height breach, so no water will sit behind the existing dam after construction.
- **Pipeline route modification**, so that the pipeline, instead of only running predominantly along the south bank of the Dungowan Creek, now traverses Dungowan Creek eight times. The pipe is to be buried in a trench; however creek excavation and rebuilding is required through the construction process.
- **Construction duration**, where the construction period is increasing from a four to a six year duration.

To understand the implications of the modified scope on the overall project climate risk profile, an additional workshop was undertaken on the 26th May 2022, with selected EMM and Water Infrastructure NSW stakeholders (refer to session minutes in Appendix D). The findings of this assessment are included in this report.

4 Project context

While this CCAP is limited to informing the EIS for the new Dungowan Dam project, this includes the design, construction and operation phases, which have been considered in the assessment. A summary of the project context (in alignment with the AS5334:2013 standard) is provided below, including both internal and external parameters to be taken into account when risks were identified.

4.1 Internal context

The internal context refers to the direct objectives of the project's design and operations. The details of the project components are provided in Section 2. The CCRA considered these aims in the context of a changing climate to identify climate related risks to the new Dungowan Dam and pipeline, as well as adaptation actions to address them.

Dungowan Dam's construction and operational elements are summarised in Table 13 below.

Table 13 - New Dungowan Dam construction and operational elements.

Project element	Summary of the project
New Dungowan Dam infrastructure	Earth and rockfill embankment dam with height of ~58 m and a dam crest length of ~270 m.
	Storage capacity of 22.5 GL at full supply level (FSL) of RL 660.2 m AHD.
	The new Dungowan Dam on Dungowan Creek has a catchment size of 175 km^2 and is part of the Peel Valley and Namoi River catchment.
	Inundation extent (to FSL) of 130 ha (1.3 km^2)
	Spillway to the south of the dam wall including an approach channel, uncontrolled concrete ogee crest, chute and stilling basin. Free standing multiple-level intake tower connected with a bridge to the embankment, diversion tunnel with outlet conduit, valve house and associated pipework and valves.
	A permanent access road over the Dam crest to the valve house for operation and maintenance.
	Water diversion works including a diversion tunnel and temporary pipeline and upstream and downstream cofferdams to facilitate construction of the dam wall embankment.
Pipeline infrastructure	31.6 km of buried high-density polyethylene (HDPE) pipe between 710 mm to 900 mm nominal diameter.
	Maximum 71 ML/day from the proposed dam to the junction with the pipeline from Chaffey Dam to the Calala Water Treatment Plant, to replace the existing 22 ML/day pipeline. The pipeline would connect to the valve house on the left abutment of the embankment. Valve infrastructure would include control valves installed in two above ground buildings along the pipeline.
	10 m wide easement for the 31.6 km length of the pipeline. The replacement pipeline extends from the new Dungowan Dam to a connection point with the existing pipeline between Dungowan Showground and Calala WTP.
Ancillary infrastructure and works	Road works to improve existing roads to provide construction access, temporary establishment and use of a construction compound, an accommodation camp, two upstream quarries and four borrow areas within the inundation area.
	A new 4.2 km long 11 kV overhead powerline (including a new easement and access track) connecting to an existing overhead line approximately 6 km north west of the dam. The existing overhead line that extends approximately 13.2 km to the Niangala area would also require minor upgrades, including re-stringing of new overhead wiring and replacement of some poles.
Decommissioning of existing Dungowan Dam	Dewatering of existing dam, removal of existing Dungowan Dam infrastructure and full height breach of the existing Dungowan Dam wall. Rehabilitation of inundation area of the existing Dungowan Dam.
Disturbance	Areas of disturbance have been identified based on the direct impacts of the project. There

	is some overlap in the areas disturbed during construction and operation, with a resulting total disturbance area proposed for the project of 315 ha (project footprint). Disturbance would occur in a staged manner, with construction requiring disturbance of approximately 315 ha (construction footprint). Following construction and once rehabilitation is completed, there would be a permanent disturbance of approximately 158 ha comprising the inundation area and permanent infrastructure (operational footprint).
Construction	Construction duration of approximately 6 years.
	Construction workforce of approximately 125 workers at construction peak.
Operation	WaterNSW will be responsible for management, operation and general maintenance of the new dam. Tamworth Regional Council will be responsible for the management, operation and general maintenance of the pipeline. Public use and access to the dam would not be permitted and there would be no public facilities available during operation.
	One to two new full time workers plus part time work for existing WaterNSW operations team. Due to the new Dungowan Dam being prioritised over Chaffey Dam for Tamworth's future water supply, the water reserved for town water in Chaffey Dam would increase from 14.3 GL to 30 GL to ensure that water is set aside to meet Tamworth's town water supply water demand in years when rainfall is low.
Design life	100 years for zoned earthen embankment, structural concrete elements of the dam and the pipeline. 15 to 50 years for other non-structural project elements and pavements.
Assessment period (operational)	The assessment end point is when the water system performance reaches a level when an additional water supply option or change to the Water Sharing Plan is required. This has been estimated to be when the mean average annual water demand from Tamworth increases to 11 GL/year.

Dungowan Dam's key design and operational aims include:

- Building a new embankment dam with an expected capacity of 22.5 gigalitres, to replace the current dam located 3.5 kilometres upstream from the proposed project site.
- Incorporating a spillway to provide controlled release of water.
- Provision of a multi-level offtake tower to mitigate downstream water quality impacts from planned water releases.
- Decommissioning (or partial decommissioning) the existing dam and rehabilitating the storage area of the dam, while retaining/repurposing infrastructure where possible.
- Constructing a new augmented delivery pipeline (nominally 71 megalitres per day capacity) to Tamworth.

4.2 External context

The external context refers to the external environment in which the project seeks to achieve its objectives. These include the regulatory context within which it operates as well as the needs and expectations of external stakeholders. Importantly, stakeholders require the following objectives to be met:

- Ensure long-term water supply for Tamworth and surrounding areas.
- Help to buffer the region from the effects of drought through increasing the amount of water captured by the Dungowan Dam.

5 Climate context

The climate context summarised in this section informed the risk assessment workshop, which reviewed the new Dungowan Dam's design and operational considerations in conjunction with the historic and future climate change projections for the Dungowan region.

5.1 Temperature

5.1.1 Historic climate

The climate of the Tamworth Region is classified as temperate with cool and mild winters experiencing moderate rainfall and hot summers. The mean maximum temperature in the Tamworth area peaks in January at 33.0˚C, with mean minimum temperature dipping to 16.5˚C in July (Bureau of Meteorology, 2022). According to data collected from 1992 – 2022, the highest temperature of 45.9˚C was recorded on the 12th February 2017 (Bureau of Meteorology, 2022).

According to data collected from 1992-2022, Tamworth Airport experiences an average of 2.2 days over 40˚C, 26.1 days over 35˚C and 91.6 days over 30˚C. (Bureau of Meteorology, 2022). This has increased since the recording period of 1957 – 1992. During this time, a mean number of 0.5 days over 30˚C, 14.1 days over 35˚C, and 0.5 days over 40˚C were recorded (Bureau of Meteorology, 2022).

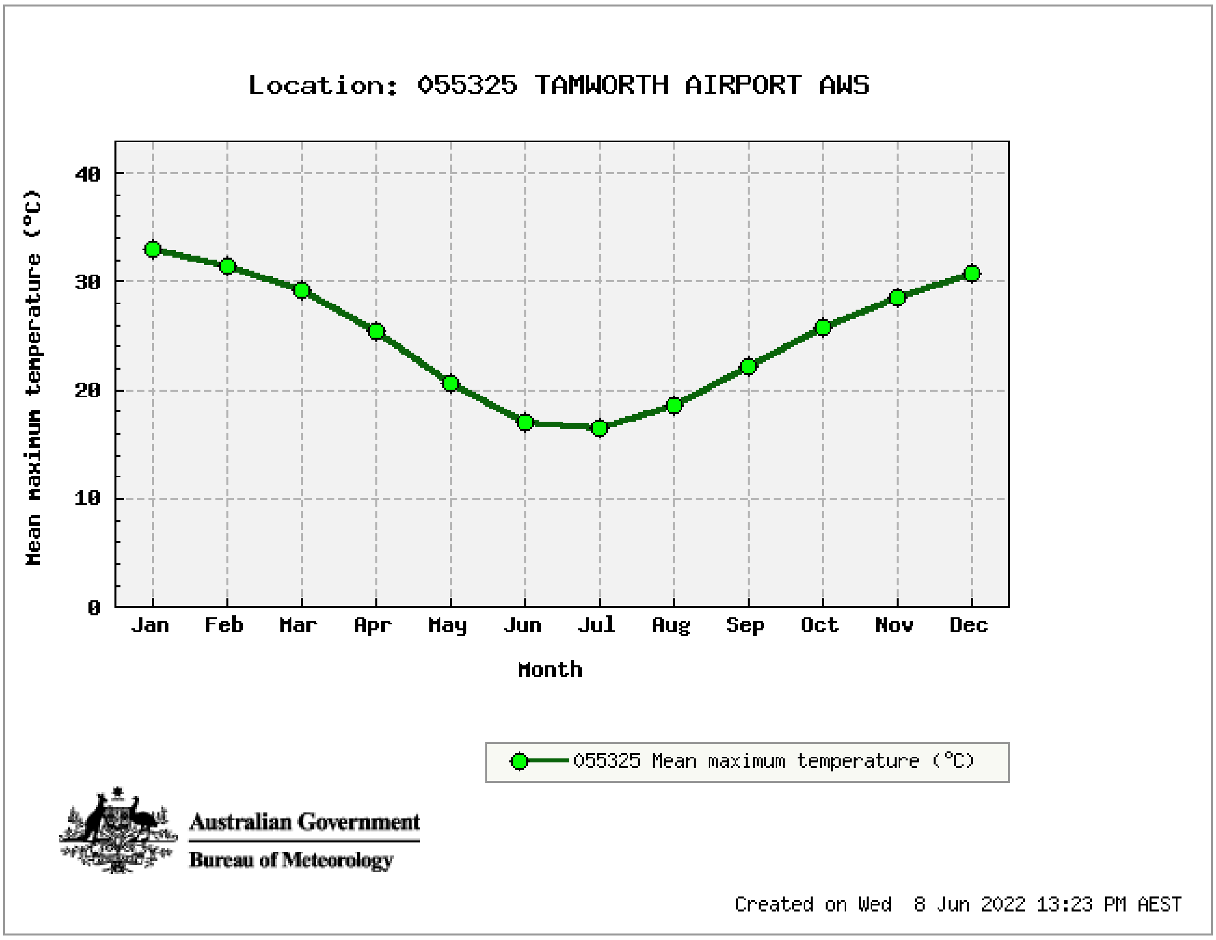


Figure 8 - The highest temperature for each month recorded between 1992 and 2022 at Tamworth Airport AWS (Bureau of Meteorology, 2022).

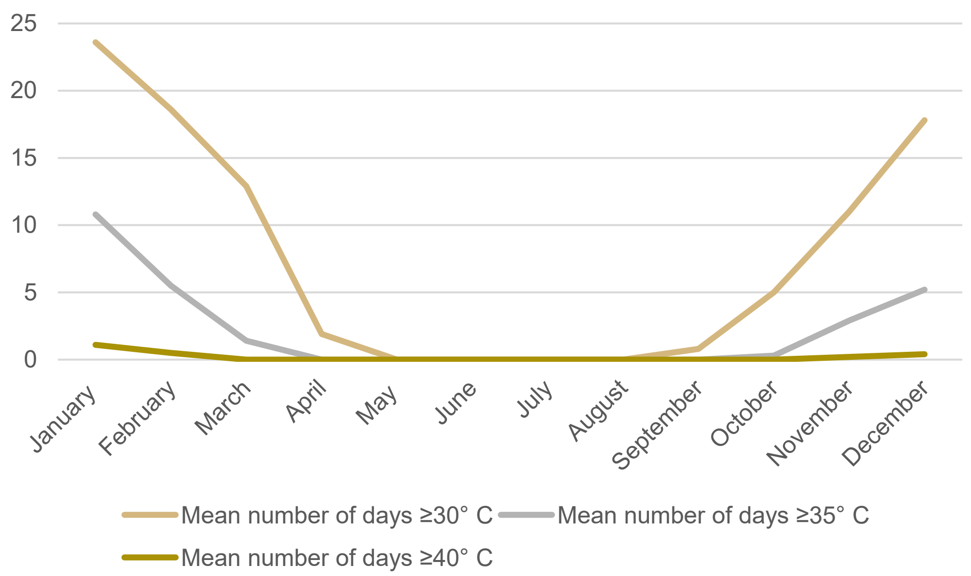


Figure 9 - The mean number of days over 30 ° C, 35 ° C and 40 ° C for each month, recorded between 1992 and 2022 at Tamworth Airport AWS (Bureau of Meteorology, 2022).

5.1.2 Future climate

Average annual temperatures for the Central Slopes NRM Cluster are projected to increase with high confidence in all seasons (CSIRO, 2016). Under an RCP 8.5 emissions scenario Tamworth can expect an average annual increase in temperature of 1˚C for the 2030 time period (CSIRO, 2016). By 2030 Tamworth is projected to experience a mean of 93.22 days of maximum temperatures above 30˚C, 22.75 days above 35 ˚C and 1.33 days above 40˚C. By 2090 average annual temperatures are expected to increase by 3.0˚C C – 5.4˚C (CSIRO, 2016). By 2090 the mean number of days is projected to increase to 154.19 days above 30˚C, 62.04 days above 35 ˚C and 9.41 days above 40 ˚C (CSIRO, 2016). Importantly, extreme temperatures are projected to increase at a similar rate to mean temperature (CSIRO, 2016).

Rising average temperature will also lead to fewer days with frost, projected with a high degree of confidence for the long term (2090).

There is very high confidence in the projection of an increase in the frequency of hot days, the temperature reached on hot days and the duration of warm spells, meaning that extreme temperatures are projected to extend in frequency, intensity and duration across the region.

5.2 Precipitation

5.2.1 Historic climate

From 1876 – 1992, Tamworth Airport AWS received annual mean rainfall of 673.6 mm (Bureau of Meteorology, 2022). From 1993 – 2022 the average annual rainfall reduced to 638.5 mm (Bureau of Meteorology, 2022). Mean 1993 – 2020 rainfall peaks in November (82.3 mm), with April receiving the lowest mean rainfall (25.3 mm) (Figure 10). Figure 10 displays the highest daily rainfall recorded in the 1993-2022 period. Significant rainfall events of over 100mm were recorded on the 17th January 2004, 2nd February 2012 and 29th November 2008. The highest mean rainfall occurs in the warmer month months from November to February. The NSW Climate Impact Profile describes surface water runoff across the New England region as following a similar pattern to precipitation (DECCW, 2010).

An increase in winter extreme rainfall proportion indices and a decrease in spring extreme proportion indices was observed for the southern section of the Central Slopes Cluster from 1910 – 2005 (Ekstrom, et al., 2015). These patterns highlight the variability of rainfall across the region, with topography and the El Nino Southern Oscillation influencing climate patterns (Adapt NSW, 2014). As such, the rainfall received in the Dungowan Dam catchment is likely to vary from rainfall recorded at Tamworth Airport AWS.

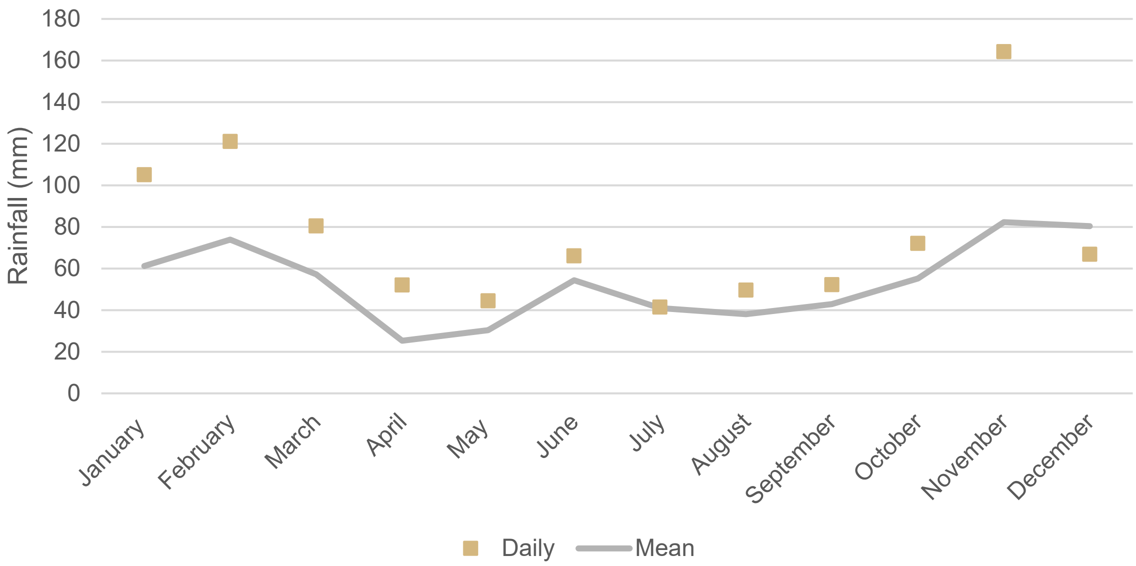


Figure 10 - Highest daily rainfall and mean rainfall for each month, recorded between 1993 and 2022 at Tamworth Airport AWS (Bureau of Meteorology, 2022)

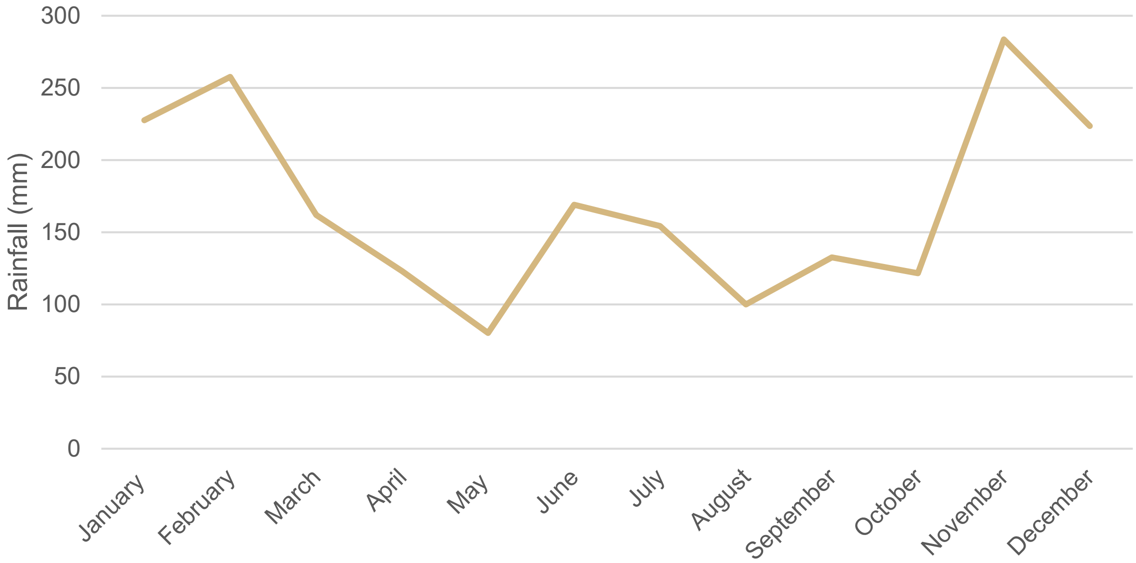


Figure 11 - Highest rainfall recorded over a calendar month at Tamworth Airport AWS BOM site (Bureau of Meteorology, 2022)

5.2.2 Future climate

Average annual rainfall in the Tamworth region is expected to decrease by 1% by 2030 and by 17% by 2090 (CSIRO, 2016). Although it must be noted that rainfall is highly variable and as such models range from a drying to a wetting trend for the 2030, 2070 and 2090 time period (Ekstrom, et al., 2015). This is highlighted by a decline in winter rainfall (high confidence) and spring rainfall (medium confidence) (Ekstrom, et al., 2015). The NSW Climate Impact Profile describes the projected future water balance as similar to current conditions, although with increases in summer runoff and decreases projected for both winter and spring given projected changes in precipitation (DECCW, 2010).

Although there is a general drying trend for the region, under an RCP 8.5 scenario, extreme rainfall intensity is projected to increase (CSIRO, 2016). This change is due to a warmer atmosphere, meaning heavy rainfall events are expected to increase in magnitude (Ekstrom, et al., 2015). However, the magnitude of such increases cannot be confidently projected (CSIRO, 2016).

5.3 Flooding

5.3.1 Historic climate

Flooding has been recorded several times over the past 150 years in Tamworth and the Peel Valley catchment (Cashman, 2019). Significant floods were recorded in 1864, 1908, 1910 and 1955, prior to flood mitigation infrastructure being introduced to the area to manage these impacts (Cashman, 2019). Flood levels on headwaters of the rivers and creeks in the area depend on peak flows and warning times are generally short. Tamworth local government manages flood levees across the region (DECCW, 2010).

5.3.2 Future climate

Flooding in the area is difficult to project due to the complexities associated with accurately projecting future rainfall events (as described in Section 5.3.1 above) (Ekstrom, et al., 2015). However, rainfall intensity is projected to increase, and with it, associated flooding. Future rainfall projections vary from a drying trend to a wetting trend across all seasons for both the 2030 and 2090 time periods.

5.4 Drought and reduced surface water run-off

5.4.1 Historic climate

Historically Australia has experienced drought on a semi-regular basis, with important considerations for water infrastructure that relies on surface water flows. Many parts of NSW were considered in drought up until late 2020, and have been since 2017 (Department of Primary Industries, 2020). The Tamworth area has been affected by drought multiple times in recorded European history (1895-1903, 1937-1945, 2001-2010) (Department of Primary Industries, 2020). In addition to these multi-year droughts, the Tamworth area has also been affected by shorter term drought (1914-1915, 1965-67, 1982-83) (Department of Primary Industries, 2020). Since 2020, the NSW Department of Primary Industries classifies the parish of Dungowan as recovering from drought (NSW Department of Primary Industries, 2020) and Monthly Drought Reports are no longer being developed for the region (WaterNSW, 2022).

5.4.2 Future climate

Time spent in drought is projected to increase with medium confidence (CSIRO, 2016). Evaporation is projected to increase in all seasons as warming continues with high confidence (CSIRO, 2016). Increased temperature combined with lower rainfall results in a higher drought factor (Ekstrom, et al., 2015). The NSW Climate Impact Profile suggests that prolonged future drought conditions are anticipated for the New England and North West Region of NSW (DECCW, 2010).

There is low confidence in projecting the frequency and duration of extreme drought (Ekstrom, et al., 2015). However, there is medium confidence that the time spent in drought will increase (Ekstrom, et al., 2015).

5.5 Bushfire

5.5.1 Historic climate

Bushfires regularly occur through areas located near the site of the project. As recently as the 25th December 2019, the Northern Daily Leader reported potential water quality issues for the existing Dungowan Dam (located 3 kilometres from the proposed dam site) after fire was followed by significant rainfall, leading to concerns of soil and ash being washed into the dam (McArthur, 2019). In October 2019, Tasmanian Firefighters were brought in to assist NSW firefighters to combat a fire in Nundle State Forest, less than 10 kilometres from the new Dungowan Dam site (Chillingworth, 2019). The 2019-2020 Australian bushfires had a monumental impact on heavily wooded areas, such as national parks and state forest, which reflect the land that surrounds the project site (Paliament of Australia, 2020). Over the most recent bushfire period (2019-20), 55 parks or reserves across NSW had more than 99% of their area affected by fire, 70 parks or reserves had 75 – 99% of their area affected by fire and 29 parks or reserves had 50-74% of their area affected by fire (Paliament of Australia, 2020).

5.5.2 Future climate

Due to the relationship between rainfall and fire weather, there is high confidence that a general drying trend will result in a harsher fire weather climate (CSIRO, 2016). However, as with precipitation, the magnitude of this change can only be projected with low confidence (CSIRO, 2016). This is coupled with a decline in relative humidity over winter and spring (high confidence) and summer and autumn (medium confidence), which further exacerbate fire conditions (CSIRO, 2016).

Broadly speaking, the general fire weather risk is expected to increase from 9% to 15% by 2030 and by 40% by 2090. The number of days with a severe fire danger rating increases by 35% – 70% by 2030 and to 220% by 2090 (Ekstrom, et al., 2015). It must also be noted that modelling of future fire weather scenarios does not consider the surrounding fuel load of locations. As such, heavily wooded areas, such as Terrible Billy State Forest and Nundle State Forest, located adjacent to the project site may be at even higher risk of bush fire in the future.

5.6 Storms

5.6.1 Historic climate

Storms and high winds have been recorded on an infrequent basis in the Tamworth region. Wind gusts of up to 85 km/h and hail stones that broke windows and damaged vehicles were recorded in October 2013 (Clifford, 2013). Summer surface winds are traditionally dominated by easterly to north-easterly winds (Ekstrom, et al., 2015).

5.6.2 Future climate

Projected changes to seasonal surface winds are minimal (less than 5%) for the Central Slopes cluster for the 2030 period (Ekstrom, et al., 2015). The 2090 time period indicates a high confidence projection for an increase in spring wind speeds (Ekstrom, et al., 2015). There is a low confidence model for changes to wind across winter, autumn and summer for 2090 (Ekstrom, et al., 2015).

Projections for extreme wind for the 2090 time period suggest that both an increase and decrease in extreme winds are possible, reflecting high uncertainty surrounding this projection (Ekstrom, et al., 2015).

The number of winter storm systems are projected to decrease due to a simulated southward shift in winter storm tracks (Ekstrom, et al., 2015). This can to some extent explain the projected reduction in winter rainfall (Ekstrom, et al., 2015)

5.7 Cyclones

5.7.1 Historic climate

The Central Slopes cluster is not regularly affected by cyclone activity (Ekstrom, et al., 2015). One occurrence was recorded in December 1995, when Cyclone Gertie travelled though the interior of Australia (Ekstrom, et al., 2015). However, the influence of cyclones extends beyond their geographical location due to the impact of cyclones on regional circulation (Ekstrom, et al., 2015).

Cyclones often result in heavy rainfall to the south of their location, with associated intense summer rainfall regularly attributed to weather systems affecting northern Australia. As such, cyclones have indirectly affected rainfall and storms in the Tamworth region.

5.7.2 Future climate

Results of modelling indicate a decrease in the formation of tropical cyclones and a low confidence of storms and rainfall associated with tropical cyclones over areas south of 25° S (Ekstrom, et al., 2015). Tropical cyclones are projected with medium confidence to become less frequent, however the proportion of intense storms are projected to increase (Ekstrom, et al., 2015).

5.8 Projections summary

The table below summarises the climate projection information above and direction of change and confidence for all future climate data projections pertinent to the Dungowan Dam project (CSIRO, 2016).

Table 14 - Summary of climate projections for the project area.

Event	Tendency	Confidence
Temperature and heatwaves	Average temperature will increase as well as number of hot days and heat waves	Very high confidence
Extreme rainfall	Increase in the intensity of extreme rainfall	High confidence
Winter rainfall	Decreasing winter rainfall	High confidence
Spring rainfall	Decreasing spring rainfall	Medium confidence
Drought	Time spent in drought will increase	Medium confidence
Flooding and rainfall intensity	Intensity of rainfall will increase with scale of changes unknown.	High confidence
Relative humidity	A decline in winter and spring relative humidity	High confidence
Bushfire	A harsher fire weather regime is projected	High confidence
Cyclones	Decrease in the formation of tropical cyclones	Medium confidence

6 Risk assessment

6.1 Key findings

This section summarises the key climate change risks to the Dungowan Dam and pipeline and associated infrastructure, as identified through the CCRA workshop (described above in Section 3.2). The full risk register, including all risks, ratings and current controls can be found in Appendix C. Risk identification was carried out with respect to the climate variables outlined in Section 5 and the internal and external context summarised in Section 3.1.1. The register of climate risks was developed based on the workshop outcomes and further input and comments from stakeholders identified in Appendix A.

This section summarises the key climate-related risks to the project and priority risk areas that should be addressed to ensure the project is resilient to the projected future changes in climate in the Dungowan region.

6.2 Overall risk findings

At the time of writing, the climate change risk assessment process identified and assessed 52 climate-related risks to the project and associated infrastructure. Risks were evaluated across the life of the dam and its associated infrastructure. Over the long term, 11 risks were high and 24 were rated moderate (refer to Figure 12 below). Importantly, all high priority risks should be addressed with specific actions to satisfy the requirements of the Cli-2 IS credits.

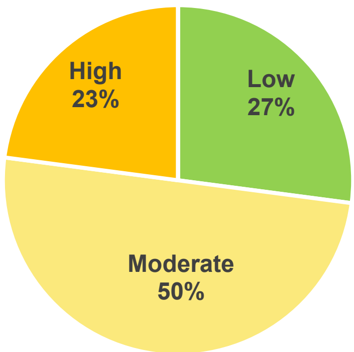


Figure 12 - Dungowan Dam climate risk ratings 2030.

The risks identified were associated with a range of climate variables, including changes in temperature, rainfall intensity, bushfires, droughts and storms. Temperature and the impacts of storms collectively presented the greatest number of risks to the project, representing 68% of all risks identified (refer to Figure 13).

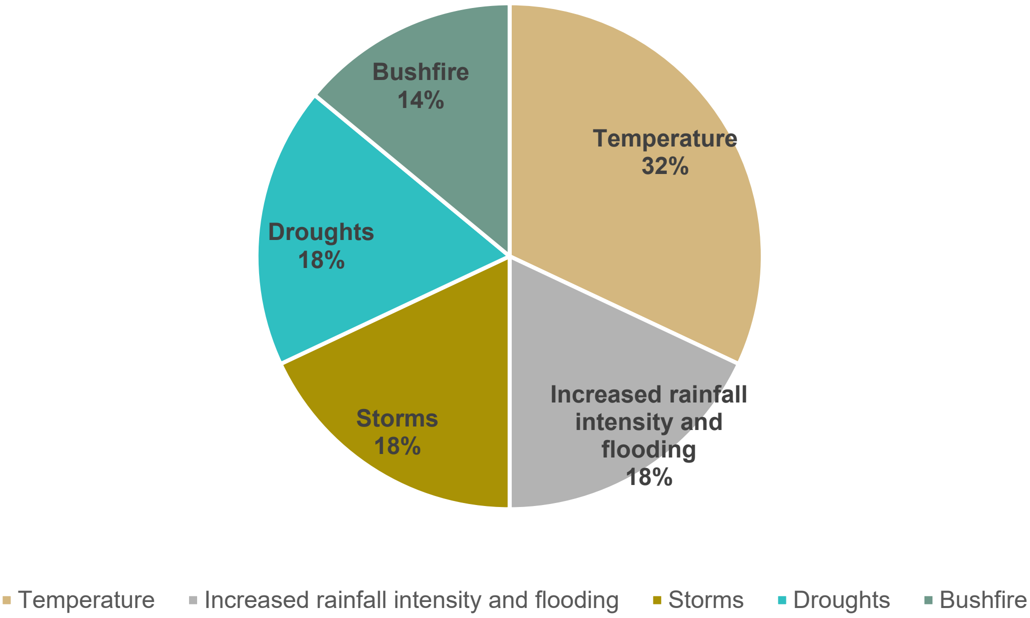


Figure 13 – Summary of sources of climate risk to the Dungowan Dam and associated infrastructure.

A detailed breakdown of the number of risks across each timescale and their ratings is provided in Figure 14 below. There were increased numbers of high risks in the far future compared to the short term, likely associated with the increased magnitude of change and the elevated uncertainty of long-term climate projections. After potential adaptation actions were considered, five high risks remained (Risk treatment discussed in further detail in Section 7).

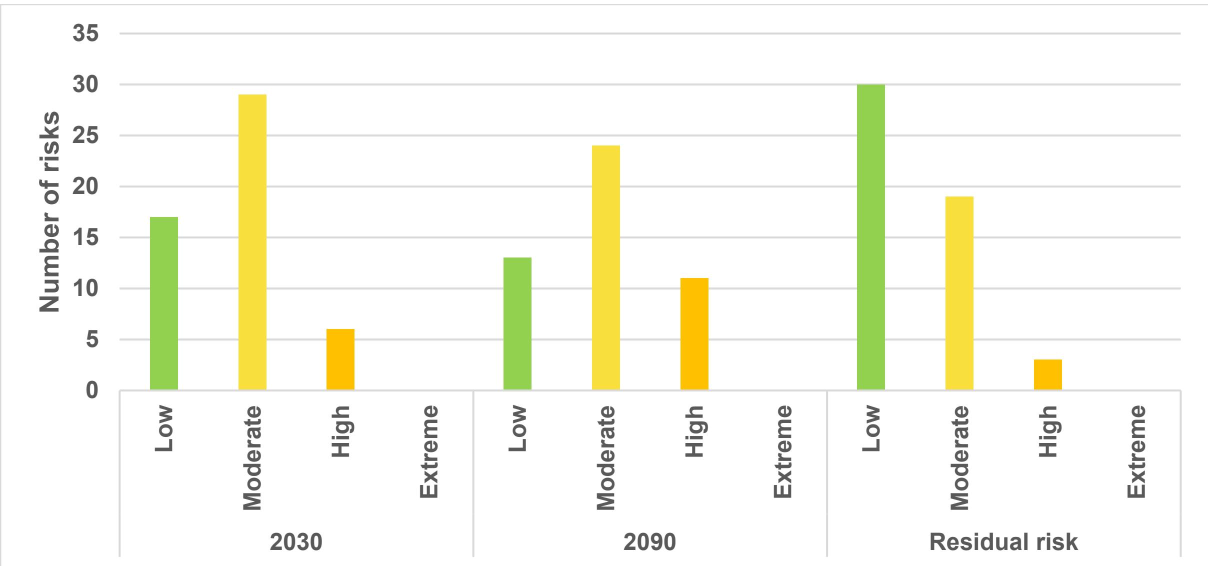


Figure 14 – Number of climate-related risks to the Dungowan Dam by timescale and rating.

Many of the risks identified were associated with the design of the project, with 27 residual risks in total, while 22 residual risks were associated with climate impacts affecting the operations of the project. Three residual risks were associated with climate-related impacts during the construction period. Table 15 summarises the spread of risks across different ratings, time periods and project phases. This illustrates that all construction risks were evaluated as low.

Table 15 - Risks by project phase

	2030				2090				Residual risk			
Project phase	**Low**	**Mod.**	**High**	**Extreme**	**Low**	**Mod.**	**High**	**Extreme**	**Low**	**Mod.**	**High**	**Extreme**
Design	7	20	0	0	7	17	3	0	16	11	0	0
Construction	4	0	0	0	0	0	0	0	3	0	0	0
Operation	9	10	6	0	6	7	8	0	11	8	3	0

The risks identified were associated with many elements of the project. Key focus areas identified in the assessment include the embankment, provision of water quality and power supply. The table below summarises the number of risks associated with each project element as identified with extensive consultation through the workshop and review process.

Table 16 - Risks by project element.

	2030				2090				Residual risk			
Component	**Low**	**Mod.**	**High**	**Extreme**	**Low**	**Mod.**	**High**	**Extreme**	**Low**	**Mod.**	**High**	**Extreme**
Embankment	5	0	0	0	3	0	0	0	5	0	0	0
Spillway	2	1	0	0	2	1	0	0	3	0	0	0
Reservoir rim	0	1	0	0	0	1	0	0	1	0	0	0
Reservoir	3	2	0	0	2	2	0	0	4	1	0	0
Operations	4	1	0	0	3	1	0	0	4	1	0	0
Water quality	1	8	4	0	1	7	5	0	4	8	1	0
Power supply	0	5	2	0	0	4	3	0	3	4	0	0
Pipeline	0	1	0	0	0	1	0	0	1	0	0	0
Access road	0	2	0	0	0	2	0	0	0	2	0	0
Existing Dungowan Dam	2	0	0	0	2	0	0	0	2	0	0	0
Water supply	0	3	0	0	0	0	3	0	0	1	2	0
Total risks	17	24	6	0	13	19	11	0	27	17	3	0

6.3 Priority risk areas

There were six high risks for the short term (2030) and eleven for the long term (2090). Risks were predominantly direct risks; however, six indirect risks were also identified. As mentioned, priority risks should be addressed through the design and operational plans for the project to ensure the project meets IS Cli-1 and Cli-2 requirements and that the asset is resilient to the physical impacts of climate change.

The identified risks have been broken down into a series of priority risk areas (see following sections), which should be addressed during detailed design and preparation of construction and operational environmental management plans. The priority areas focus on common impacts to the project and/or its operations and the range of sources of these impacts as well as their consequences for project design and operation.

The following sections summarise these priority risk areas and their respective impacts on the project across its lifecycle.

6.3.1 Maintenance of water quality for downstream users and the environment

A key high-risk area identified was related to the ability of the project to maintain delivery of high-quality water to user and environmental compliance requirements in the face of a range of climate change impacts. Key climate-related sources of direct risk to the quality of water in the dam included:

- Increased frequency and severity of algal blooms due to both heatwave and drought conditions, with both environmental and human health impacts for downstream users (refer to risks A18 and A49).
- Increased frequency and intensity of bushfires in the dam catchment leading to reduced catchment vegetation cover and influxes of ash and soil into the reservoir, reducing water quality through physical and chemical pollution (refer to risk A13 and A14).

Given the operational goal of the new Dungowan Dam is to provide water for urban use, agriculture and the downstream environment, water quality was identified as a key concern by participants in the stakeholder workshop. The controls in place through both design and operation to manage water quality risks included:

- Continuous water quality monitoring programs to identify any change in water quality.
- The potential to include Downstream chlorine dosing (provided by Tamworth Regional Council) in the new Dungowan dam pipe to remove pathogens in water.
- Implementation of a multi-level intake tower in design that allows the user to select the option of water drawn out at specific points that match the temperature and quality requirements in line with NSW Cold Water Pollution guidelines.
- Protocols on how to operate the Dam when there is an algal bloom and approaches to manage the impacts of this event.

Although effective in mitigating some water quality impacts, these were not considered adequate to manage a range of risks identified (refer to risks A9, A13, A14, A18, A23, A46, A49, in Appendix C). Adaptation actions to address these risks to an appropriate level (where possible) are discussed further in Section 7.1.

6.3.2 Operational impacts from climate-related blackouts

Climate-related electricity network failures were identified as being a significant source of indirect risk to the successful operation of the project. The projected increase in bushfire and storm intensity was identified as potentially increasing hazards such as burning or destruction of power and communications lines, leading to important service delivery impacts for the new Dungowan Dam including;

- Loss of communications systems (Refer to risk A17)
- Loss of power supply (refer to risks A11, A12)

The following controls were identified to manage the risk of blackouts to the project:

- Vegetation clearing from near power lines to reduce direct bushfire damage to power transmission.
- Operational procedures to guide operators under blackout scenarios.
- Onsite energy generation capabilities and manual backup of dam if mains power is lost.
- Manual control of valves to establish control of dam flows without a power source.

These controls were deemed appropriate to keep risks related to storm-related blackouts at a medium priority level but were not sufficient to manage long-term bushfire related damage to power lines (refer to risks A11, A12 and A17). Adaptation actions to manage these risks are discussed further in Section 7.

6.3.3 The impacts of drought and increased water demand on long-term water supply

The ability for the new Dungowan Dam to deliver a secure source of water to both its intended users and for the environment is a key operational goal of the Dungowan Dam. Three high priority long-term risks were identified in relation to this goal, linked to both the impacts of projected increases in drought duration and severity on surface water runoff and reservoir yield, as well as concurrent regional population and industrial growth leading to increased demands for water from the dam. Importantly, the impacts of drought on groundwater were not identified as a material risk given the limited interaction of the reservoir with groundwater stores. The risks identified had the following consequences:

- Downstream local environmental impacts due to reduced water availability for the environment (Risk A51).
- Service disruption due to reduced ability to deliver water under severe drought conditions (Risk A52).

Several controls for these risks were identified, including the:

- Consideration of drought scenarios in the planning and design process, although these were not considered adequate to manage the risks to an appropriate level for the long-term (refer to risk A51 and A52).
- Increased water demands from town water supply and irrigation in conjunction with drought conditions was also identified as a key long term risk (refer to risk A7), which was considered to be controlled in the short term (2030) by existing water sharing and demand management plans, optimised design to match dam yield with catchment, as well as pipeline design that minimises water losses on transference of water to Tamworth. These controls were not considered adequate for the far future given the uncertainty of town and irrigation demand and the magnitude of change in precipitation in the region.

Proposed adaptation measures to address these risks are discussed in further detail in Section 7.

7 Risk treatment and adaptation

This section of the report summarises the proposed adaptation actions developed in the stakeholder workshops that aimed to address the key risk areas described in Section 6.3 above. In alignment with Cli-2, adaptation options to treat all high and extreme climate change risks should be identified, assessed and appropriate measures implemented. The proponent will consider these adaptation measures and their implementation to reduce the severity of the risks to the project.

7.1 Maintenance of water quality for downstream users and the environment

Maintaining water quality is a key operational goal of the project. The various risks associated with reduced water quality may be addressed through the implementation of a range of adaptation actions across the site and through operations. These are summarised in Table 17.

Table 17 – Adaptation initiatives to address water quality impacts.

Water quality impact	Adaptation actions	Responsibility
Bushfire impacts	Review opportunities to ensure vegetation is monitored over time (e.g. through fire surveys, lidar and aerial imagery etc) to ensure fire risk is understood and managed. Conduct fuel reduction burns in collaboration with the SES and NSW Fire for parts of the catchment that become vulnerable to bushfire impacts.	Operator
	After fire events, consider installation of appropriate sediment and erosion controls in tributaries leading to the dam and conduct autumnal post fire planting for soil stabilisation. Also investigate spray options for grass seed to reduce fuel loads in summer.	Operator
	Select intake from which to draw water to avoid floating debris being drawn into water supply. Monitor reservoir debris regularly.	Operator
Algal blooms	Conduct regular maintenance. Implement best practice approaches to reduce the likelihood and remedy algal blooms through reducing organics from entering the reservoir through fuel reduction burns and ample understorey to filter water entering the reservoir. If raw water quality deteriorates due to hotter future conditions to an extent it would affect the permitted uses of raw water customers, further water quality improvement options would be investigated.	Operator

These initiatives were considered appropriate to reduce the risk ratings for a range of risks (refer to Table 18 below). Importantly, risk A18 was not adequately addressed by the adaptation actions provided.

Table 18 – Summary of risks and adaptation actions associated with water quality impacts.

Risk ref.	Risk statement	2030	2090	Proposed adaptation actions	Residual rating
A13	Direct fire impacts on reservoir catchment vegetation leading to reduced water quality as ash and	16	16	Review opportunities to vegetation is monitored over time (e.g. through fire surveys, lidar and aerial imagery) to ensure fire risk is	8

Risk ref.	Risk statement	2030	2090	Proposed adaptation actions	Residual rating
	soil are blown by wind or fire draughts into the reservoir			understood and managed. Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS Select intake from which to draw water to avoid floating debris being drawn in	
A14	Bushfire in catchment leads to loss of vegetation. Post fire rains wash ash and soils into the reservoir resulting in a reduction in water quality	12	12	Post fire, in consultation with relevant stakeholders, consider installation of appropriate sediment and erosion controls in tributaries leading to the dam. Consider autumnal post fire planting for soil stabilisation and investigate spray options for grass seed.	8
A18	Increased frequency of heatwaves leading to increased algal blooms and reduced water quality	16	16	Conduct regular maintenance. Implement best practice approaches to reduce the likelihood and remedy algal blooms through reducing organics from entering the reservoir through fuel reduction burns and ample understorey to filter water entering the reservoir. Where relevant, invest in treatments currently used in hotter climates i.e. Hydrogen peroxide and consider destratification mixer or air curtains to maintain more constant thermal gradient.	12
A23	Deterioration to water quality downstream of the dam for 3rd party access on the bulk water pipeline	9	12	While raw water is not provided for drinking, if raw water quality deteriorates to an extent it would affect the permitted uses, further water quality improvement options would be investigated,	9
A49	Algal Blooms leading to health impacts on downstream water users	16	16	Refer to A18 above	8

7.2 Operational impacts from climate-related blackouts

The three high priority risks associated with climate-related blackouts were related to the impacts of bushfires on the project's powerlines. To manage this impact, a range of adaptation actions have been proposed. These are summarised in the table below.

Table 19 – Adaptation initiatives to address climate-related blackouts.

Power supply impacts	Adaptation actions	Responsibility
Bushfires	Review opportunities to ensure vegetation is monitored over time (e.g. through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed.	Operator
	Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW Rural Fire Service	Operator
	During detailed design, consider the need for fire resistant pylons and buried power cables to reduce powerline exposure to local bushfire impacts.	Design team

The adaptation initiatives provided were considered appropriate to reduce the risk ratings for the risks summarised in the table below to a moderate level.

Table 20 – Summary of risks related to blackouts.

<table>
<tr><th>Risk Ref.</th><th>Risk statement</th><th>2030</th><th>2090</th><th>Proposed adaptation actions</th><th>Residual rating</th></tr>
<tr><td>A11</td><td>Direct fire impacts resulting in burning and/or melting of power infrastructure resulting in the loss of power to dam operations and reduced service delivery</td><td>9</td><td>12</td><td rowspan="3">Regular maintenance of land clearing around power easement
Review opportunities to ensure vegetation is monitored over time (e.g. through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed.
Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS.
During detailed design, consider fire resistant pylons and buried cables to reduce risk.
Develop APZ specification for both design and operation.</td><td>6</td></tr>
<tr><td>A12</td><td>Direct fire impacts results in burning of power lines and loss of power to the valve house</td><td>16</td><td>16</td><td>8</td></tr>
<tr><td>A17</td><td>Fire burns through power infrastructure resulting in loss of communications</td><td>16</td><td>16</td><td>8</td></tr>
</table>

7.3 The impacts of drought and increased water demand on long-term water supply

The impacts of drought and increased water demand were the source of three priority risks to the Dungowan Dam project. Although the project team suggested it was appropriate to accept the risk related to catchment-wide droughts, Table 21 summarises both design and operational initiatives to address these risks to build project resilience.

Table 21 – Adaptation initiatives to address climate-related impacts on the water supply.

Power supply impacts	Adaptation actions	Responsibility
Droughts and increased temperatures	Enact water restrictions in accordance with Tamworth Regional Council drought management plans to reduce water demand during drought periods.	Tamworth Regional Council
	Update the water sharing plan for the Peel Valley to consider the implications of climate change on drought conditions (refer to (NSW Office of Water, 2010))	DPE Water
	Consider implementation (with relevant stakeholders) of water restrictions that take effect in times of drought and extended low rainfall. Review and update the Tamworth Regional Council Drought Management Plan to consider revised arrangements for the implementation of water restrictions.	Tamworth Regional Council

The adaptation initiatives were considered appropriate to reduce the risk ratings for the risks summarised in Table 22 below.

Table 22 – Summary of risks related to water supply.

<table>
<tr><th>Risk Ref</th><th>Risk statement</th><th>2030</th><th>2090</th><th>Proposed adaptation actions</th><th>Residual rating</th></tr>
<tr><td>A7</td><td>Increased demands for water from town water supply and irrigation leading to reduced water availability and service delivery impacts</td><td>8</td><td>16</td><td>Update the water sharing plan for the Peel Valley (refer to (NSW Office of Water, 2010) Recommend water restrictions over extended dry periods</td><td>9</td></tr>
<tr><td>A51</td><td>Catchment delivers less water than was planned leading to local environmental impacts</td><td>9</td><td>12</td><td rowspan="2">Consider implementation (with relevant stakeholders) of water restrictions that take effect in times of drought and extended low rainfall. Review and update the Tamworth Regional Council Drought Management Plan to consider revised arrangements for the implementation of water restrictions.</td><td>12</td></tr>
<tr><td>A52</td><td>Catchment delivers less water than was planned leading to service level disruptions</td><td>9</td><td>12</td><td>12</td></tr>
</table>

8 Recommendations

This CCAP provides a summary of the priority climate-related risk areas to the Dungowan Dam and pipeline project's current concept design and future operations. The assessment reveals a range of important impacts that may hinder the successful operation of the project and its long-term resilience to the projected changes in climate in the Tamworth region.

Given that modelled outcomes presented in the Surface Water Assessment (EMM 2022) align to several risks identified in this assessment, the consideration of the implications of prolonged drought conditions as a result of anthropogenic climate change on the operational objectives of the Dungowan Dam and pipeline project will be important.

The following actions are recommended to ensure that the Dungowan Dam and pipeline project is designed and operated to be resilient to the effects of a changing climate:

- During detailed design and the preparation of environmental management plans, the design and construction teams should review the priority risk areas and consider the incorporation of adaptation actions provided in Section 7. Importantly, where incorporated, specific roles and responsibilities within the team should be assigned to each management action to ensure ownership and implementation.
- Take steps to identify and integrate relevant adaptation actions into operational requirements (where relevant), as well as ensuring the ongoing monitoring and review of the climate adaptation risk register through design, construction and operational phases.
- Monitor any potential changes in the IPCC's RCP scenarios and localised projections for the Dungowan/Tamworth region to continually update the ratings of identified risks associated with a changing climate.

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Appendix A – Workshop Attendance Register

Group	Name	Role	Organisation
Group 1 – Flooding, storms and extreme rainfall	Tim Watson	Facilitator: Senior Sustainability Consultant	Edge
	Robert Cawley	Planning & Approvals Advisor	WaterNSW
	Alex Frolich	Associate Environmental Scientist	EMM
	Marius Jonker	Dams Engineer	WaterNSW
	Craig Wiltshire	Principal Engineer - Dams	SMEC
	Lara Hess	Planning & Approvals Manager	WaterNSW
Group 2 – Drought and bushfire	Julian Marchant	Facilitator; Sustainability Consultant	Edge
	Maria McElvenny	Environment and Sustainability Officer	WaterNSW
	John Hart	Project Director	WaterNSW
	Tim Rhodes	Technical Principal - Water Resources	SMEC
	Chris Ho	Maintenance Engineer North	WaterNSW
	Clive Saunders	Dams Engineer	WaterNSW
Group 3 – Temperature change	Charlotte Wang	Facilitator; Senior Sustainability Consultant	Edge
	Jonathon Reid	Technical Principal - Dams & Hydro	SMEC
	Katherine Marshall	Project Development Manager	WaterNSW
	Ian Rowbottom	Associate Director, Water Resources	EMM
	Mark Trudgett	Associate Environmental Scientist	EMM

Appendix B – Cli-1 and Cli-2 credit alignment

Cli-1 Climate Change Risk Assessment			
Level	**ISCA requirement**	**How requirements have been addressed in the CCAP**	**Page number or section of CCAP**
1	***Direct climate change risks to the asset over the forecast useful life are identified and assessed.***	Direct risks were identified and asset according to AS 5334:2013.	Section 6.3
2	***The requirements of Level 1 are achieved.***	See above	
	The climate change risk assessment also considered indirect climate change risks to the asset.	Indirect risks are defined as risks impacting the project’s *external* context. Indirect risks were identified and asset according to AS 5334:2013.	Section 6.3
	A multi-disciplinary team participated in identifying climate change risks and issues.	Stakeholder consultation was undertaken during preparation.	Appendix A
3	***The requirements of Level 2 are achieved.***	See above	
	Modelling is undertaken to characterise the likely impacts of the projected climate change for all High and Extreme priority climate change risks.	NA	NA
	A comprehensive set of affected external stakeholders participated in identifying climate change risks and issues.	NA	NA

Cli-2 Adaptation Measures			
Level	**ISCA requirement**	**How requirements have been addressed in the CCAP**	**Page number or section of CCAP**
1	***Adaptation options to treat all extreme and high priority climate change risks are identified, assessed and appropriate measures implemented.***	Adaptation actions proposed for all high and extreme risks	Section 7
	After treatment there are no extreme priority residual climate change risks.	There were no extreme risks after treatment	Section 7
2	***Adaptation options to treat 25-50% of all medium priority climate change risks are identified, assessed and appropriate measures implemented.***	To be evidenced at "As- Built" stage	NA
3	***The optimal scale and timing of options is addressed (which may be triggered by when a specific climate threshold is likely to be achieved).***	To be evidenced at "As- Built" stage	NA
	Adaptation options to treat at least 50% of all medium priority climate change risks are identified, assessed and appropriate measures implemented.	To be evidenced at "As- Built" stage	NA
	After treatment there are no high priority residual climate change risks.	To be evidenced at "As- Built" stage	NA

Appendix C – Dungowan Dam Climate Risk Register

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A1	Increase in frequency of very hot days (very high confidence)	Increased drying and shrinkage leading to cracking impacts on embankment	Environment	Filter protection to the dam crest and road surfacing included in design to mitigate risk. The design includes a surfaced road on the crest of the embankment, and this will reduce the desiccation and potential shrinkage of the core material.	Unlikely	Negligible	2	Unlikely	Minor	4	A maximum value for the shrinkage limit could be applied to the specification of the Zone 1A material.	Unlikely	Negligible	2	Design	Direct
A2	Increase in frequency of very hot days (very high confidence)	Hot days leading to heat impacts on electrical equipment and switchboards in which we have to rely on allow manual backup, with failures leading to reduced service delivery	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Manual operating gear supplied for all equipment to use in if required in emergency. Reliability rating of equipment.	Possible	Minor	6	Likely	Minor	8	Locate wiring in shaded environments, install air conditioning units amongst heat sensitive electrical equipment cases, bury wiring where possible and appropriate, invest in heat tolerant infrastructure. Consider natural ventilation of the buildings and intake tower and suitable insulation to the walls.	Possible	Minor	6	Design	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	**Climate change impact**	**Risk statement**	**Consequence area**	**Current Controls**	**Likelihood**	**Consequence**	Rating	Likelihood	**Consequence**	**Rating**	**Proposed Adaptation actions**	**Likelihood**	**Consequence**	**Rating**	**Resp**	**Risk type**
A3	Increase in frequency of very hot days (very high confidence)	Heat related damage to reservoir vegetation, resulting in loss of slope protection and erosion of the downstream batter face in heavy rainfall events.	Environment	Berms placed at 15m intervals to slow erosion	Possible	Minor	**6**	Possible	Minor	**6**	Heat tolerant vegetation species Vegetation maintenance protocols / inspections Rock armouring of slope if required	Unlikely	Minor	**4**	**Design**	**Direct**
A4	Increase in frequency of very hot days (very high confidence)	Extreme heat impacts on dam workers leading to safety impacts	Safety (People)	Policy dictates outdoor activities, timing and duration of hours spent outdoors	Possible	Minor	**6**	Possible	Minor	**6**	Alter policy as required over time to reflect changing conditions; - Provide adequate lighting so that outdoor activities can be carried out that night when it is cooler. - Ensure the provision of appropriate site facilities for staff - Ensure that SWMS adequately address treatment methods for dehydration	Possible	Minor	**6**	**Operator**	**Direct**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A5	Increase in frequency of very hot days (very high confidence)	Increased stress on lifting gear and hydraulics leading to need to replace and repair elements more frequently	Financial (Fiscal responsibility/ viability/resource procurement)	Regular maintenance, inspection of hydraulics	Unlikely	Minor	4				Increased inspection and maintenance of hydraulics - WaterNSW to have an adequate O&M plan for the new projects	Unlikely	Minor	4	Construction	Direct
A6	Increase in frequency of very hot days (very high confidence)	Impact of increased water temperature on aquatic life leading to reduce environmental value	Environment	Design multi-level outlet to accommodate with appropriate monitoring instrumentation Water drawn from correct level of multi-level outlet to reduce decreased temperatures in outflow	Unlikely	Moderate	6	Possible	Moderate	9	Install destratification mixer or air curtains to maintain more constant thermal gradient. Incorporate with multi-level off-take. (LH) Consider mixers or aeration to prevent water quality impacts associated with stratification	Unlikely	Minor	4	Operator	Direct
A7	Increase in frequency of very hot days (very high confidence)	Increased demands for water from town water supply and irrigation leading to reduced water availability and service delivery impacts	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Existing Water Sharing Plans Design optimises to yield for the current catchment area Pipeline designed to minimise water losses on transference to town Currently operating the existing Dungowan Dam for water supply Recommend water restrictions over extended dry periods	Unlikely	Major	8	Likely	Major	16	Future proofing 22.5 GL dam allowing increase in dam storage (increase capacity of new dam upgrade). Update the water sharing plan for the Peel Valley	Possible	Moderate	9	Operator	Indirect

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A8	Increase in frequency of very hot days (very high confidence)	Increase / lack of water required during construction, need to truck more water in leading to increased project costs	Financial (Fiscal responsibility/ viability/resource procurement)	None	Unlikely	Minor	2				Short term concern. Not relevant to 2090 scenario	Rare	Negligible	2	Construction	Direct
A9	Increase in frequency of very hot days (very high confidence)	Increased risk of stratification and potential cold-water pollution impacts	Environment	Multi-level intake tower allows the user to select the option of water drawn out	Likely	Minor	8	Likely	Minor	8	Install destratification mixer or air curtains to maintain more constant thermal gradient.	Likely	Negligible	4	Design team	Direct
A10	Increase in frequency of very hot days (very high confidence)	Increased loss of water from evaporation leading to reduced water for service delivery	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	None	Possible	Minor	6	Possible	Moderate	9	Solar farm on reservoir surface Invest in dam covers, such as aqua caps	Possible	Minor	9	Design team	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A11	Increased bushfire weather (FFDI increase) (high confidence)	Direct fire impacts resulting in burning of power lines and loss of power to dam operations and reduced service delivery	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Vegetation is cleared from close proximity to power lines. Dam has manual backup if power is lost. Generator can power the site.	Possible	Moderate	9	Likely	Moderate	12	Regular maintenance of land clearing around power easement Review opportunities to ensure vegetation is monitored over time (e.g. Through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed. Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS [Consider opportunities to design non-flammable pylons and buried cables Develop APZ specification for both design and operation	Unlikely	Moderate	6	**Operator**	**Direct**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A12	Increased bushfire weather (FFDI increase) (high confidence)	Direct fire impacts results in burning of power lines and loss of power to the valve house	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Vegetation is cleared from close proximity to the valve house	Likely	Major	16	Likely	Major	16	Review opportunities to ensure vegetation is monitored over time (e.g. through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed. Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS Remove vegetation from suitable distance around the valve house and conduct regular maintenance	Unlikely	Major	8	Operator	Direct
A13	Increased bushfire weather (FFDI increase) (high confidence)	Direct fire impacts on reservoir catchment vegetation leading to reduced water quality as ash and soil are blown by wind or fire draughts into the reservoir	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	None	Likely	Major	16	Likely	Major	16	Review opportunities to ensure vegetation is monitored over time (e.g. Through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed. Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS Select intake from which to draw water to avoid floating debris being drawn in	Unlikely	Major	8	Operator	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A14	Increased bushfire weather (FFDI increase) (high confidence)	Bushfire in catchment leads to loss of vegetation. Post fire rains wash ash and soils into the reservoir resulting in a reduction in water quality	Compliance	None	Possible	Major	12	Possible	Major	12	Review opportunities to ensure vegetation is monitored over time (e.g. Through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed. Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS Post fire, consider installation of appropriate sediment and erosion controls in selected tributaries leading to the dam. Conduct autumnal post fire planting for soil stabilisation. Investigate spray options for grass seed.	Unlikely	Major	8	**Operator**	**Indirect**
A15	Increased bushfire weather (FFDI increase) (high confidence)	Increased bushfire impacts results in alteration of the vegetation structure leading to increased delivery of water into the reservoir	Environment	Regular modelling and recording of catchment flows	Possible	Negligible	3	Possible	Negligible	3	Monitor vegetation structure over time, conduct planting/clearance/fuel reduction burns where necessary	Possible	Negligible	3	**Design**	**Indirect**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A16	Increased bushfire weather (FFDI increase) (high confidence)	Direct fire impact results in restricted access to site / inaccessibility resulting in prevention of manual backup operation of dam	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Access tracks leading from the dam operations sites to public roads are cleared of vegetation. Policy regarding type of work conducted at dam site is restricted on fire prone days. In the event of fire, policy dictates operations and staff movement. Helipad provided to airlift staff to the dam site if needed and safe to do so.	possible	Minor	8	Likely	Minor	8	Ensure vegetation is regularly cleared from access tracks and dam site entry points. Develop policy that dictates staff movement through unsafe fire precincts on days of high fire danger. Monitor weather and communicate requirements to all on site staff. Ensure vegetation fuel loads are reduced, as per recommendations by NSW Fire Investigate alternative (secondary) access route to the dam	Possible	Minor	9	**Operator**	**Direct**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A17	Increased bushfire weather (FFDI increase) (high confidence)	Fire burns through power lines resulting in loss of communications	Safety (People)	Vegetation is cleared from close proximity to power lines.	Likely	Major	16	Likely	Major	16	Review opportunities to ensure vegetation is monitored over time (e.g. Through fire surveys, lidar and aerial imagery) to ensure fire risk is understood and managed. Review opportunities to conduct fuel reduction burns in collaboration with the SES and NSW RFS. Remove vegetation from suitable distance around the valve house and conduct regular maintenance. Invest in communications systems that are not reliant on mains supply power i.e. battery operated radio systems, satellite phones etc.	Unlikely	Major	8	Operator	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A18	Increased duration of heatwaves (very high confidence)	Increased frequency of heatwaves leading to increased algal blooms and reduced water quality	Environment	Operational protocols on how to operate existing Dam when there is an algal bloom Design multi-level outlet to accommodate with appropriate monitoring instrumentation Water drawn from correct level of multi-level outlet Downstream chlorine dosing (provided by Tamworth Regional Council) in the new Dungowan dam pipe to remove pathogens in water.	Likely	Major	16	Likely	Major	16	Conduct regular maintenance. Implement best practice approaches to reduce the likelihood and remedy algal blooms through reducing organics from entering the reservoir through fuel reduction burns and ample understorey to filter water entering the reservoir. Invest in treatments currently used in hotter climates i.e. Hydrogen peroxide. Install destratification mixer or air curtains to maintain more constant thermal gradient.	Possible	Major	12	Operator	Direct
A19	Increased duration of heatwaves (very high confidence)	Increased water temperatures leading to reduced water quality	Environment	Design multi-level outlet to accommodate with appropriate monitoring instrumentation Water drawn from correct level of multi-level outlet	Unlikely	Moderate	6	Unlikely	Moderate	6	Install destratification mixer or air curtains to maintain more constant thermal gradient.	Unlikely	Moderate	6	Operator	Direct
A20	Increased duration of heatwaves (very high confidence)	Bitumen melts on access road requiring extra maintenance	Financial (Fiscal responsibility/ viability/resource procurement)	Increased maintenance regime for dam operator	Possible	Minor	6	Possible	Minor	6	Invest in heat resistant bitumen mix, invest in solar reflective/high albedo road surfaces	Unlikely	Minor	4	Design team	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A21	Increased duration of heatwaves (very high confidence)	Heat impact on electrical equipment and switchboard in which we must rely on manual backup	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Regular inspection, maintenance and repair	Possible	Minor	6	Likely	Minor	8	Invest in upgraded technology, design for heat tolerance through shading, insulation, air-conditioning units	Unlikely	Minor	4	Design team	Direct
A22	Increased duration of heatwaves (very high confidence)	Power failure if there is a surge in power demand.	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Regular inspection, maintenance and repair. Back-up generator on site.	Likely	Minor	8	Likely	Minor	8	Design for use of surge protectors, inspect and maintain wiring and electrical units. Need a reliable back-up supply to ensure operation	Possible	Minor	6	Design team	Indirect
A23	Increased duration of heatwaves (very high confidence)	Deterioration to water quality downstream of the dam for 3rd party access on the bulk water pipeline	Compliance	None	Possible	Moderate	9	Likely	Moderate	12	Include downstream chlorine dosing (provided by Tamworth Regional Council) in the new Dungowan dam pipe	Possible	Moderate	9	Operator	Direct
A24	Increased extreme rainfall intensity and resultant flooding (high confidence)	Flood event leading to loss of access to dam (access road is vulnerable to flooding impacts) and resultant loss of service delivery	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Road is resilience to 1 in 20-year flood events. Flood management is covered in the dam safety plans	Likely	Minor	8	Likely	Minor	8	Form agreement with emergency services to manage this event.	Possible	minor	8	Design team / operator	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A25	Increased extreme rainfall intensity and resultant flooding (high confidence)	Existing Dungowan Dam damage due to heavy flood events, leading to reduced function of system and reduced environmental benefit	Environment	None	Rare	Moderate	3	Rare	Moderate	3	Accept risk	Rare	Moderate	3	Design team	Direct
A26	Increased extreme rainfall intensity and resultant flooding (high confidence)	Heavy rainfall and flooding leading to accumulation of debris in spillway and increased maintenance and repair costs	Financial (Fiscal responsibility/ viability/resource procurement)	Uncontrolled overflow crest, no equipment to be damaged. Access for vehicles to spillway to clear debris in approach channel	Possible	Minor	6	Possible	Minor	6	Log boom in reservoir to keep large trees from entering spillway. Clear debris from log boom after storm events as part of maintenance schedule.	Rare	Minor	2	Dam owner and operators	Direct
A27	Increased extreme rainfall intensity and resultant flooding (high confidence)	Runoff / flood related landslide leading to collapse of dam rim and subsequent wave creation and damage to dam wall	Financial (Fiscal responsibility/ viability/resource procurement)	Flood management plans for operations. Rim stability currently being assessed to evaluate this risk	Rare	Severe	5	Rare	Severe	5	Evaluate and confirm rim stability for these situations and ensure design is adequate to manage	Rare	Major	4	Design team / Dam owner	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	**Climate change impact**	**Risk statement**	**Consequence area**	**Current Controls**	**Likelihood**	**Consequence**	Rating	Likelihood	**Consequence**	**Rating**	**Proposed Adaptation actions**	**Likelihood**	**Consequence**	**Rating**	**Resp**	**Risk type**
A28	Increased extreme rainfall intensity and resultant flooding (high confidence)	Increased frequency of severe floods leading to overwhelmed spillway and local flood impacts on downstream property and infrastructure	Reputation (Staff/customers /public confidence)	Designed to current PMF conditions	Rare	Major	4	Rare	Major	4	Set up communications plan for spillway flows to ensure downstream stakeholders are aware of severity Design could accommodate future design changes to suit increased outflows (e.g. parapet walls, raise chute walls, etc...)	Rare	Moderate	3	**Design team**	**Direct**
A29	Increased extreme rainfall intensity and resultant flooding (high confidence)	Increased velocity of spillway water results in gully erosion downstream of the spillway and associated environmental impacts	Environment	Lightly vegetated downstream riparian zone	Rare	Minor	2	Unlikely	Minor	4	Effective design of stilling basin/ plunge pool to minimise outflow velocities.	Rare	Negligible	1	**Design team**	**Indirect**
A30	Increased extreme rainfall intensity and resultant flooding (high confidence)	Existing Dungowan Dam damage due to heavy flood events, leading to reduced function of system and increased maintenance and rehabilitation costs	Financial (Fiscal responsibility/ viability/resource procurement)		Rare	Moderate	3	Rare	Moderate	3	Accept risk High flood event diversion.	Rare	Moderate	3	**Design team**	**Direct**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A31	Increased extreme rainfall intensity and resultant flooding (high confidence)	Flood-related damage during construction leading to delays in construction	Reputation (Staff/customers /public confidence)	Appropriate diversion to be placed to protect works	Unlikely	Minor	2				Accept risk	Rare	Minor	2	Construction	Direct
A32	Increased extreme rainfall intensity and resultant flooding (high confidence)	Flood-related damage during construction leading to costly impacts on site	Financial (Fiscal responsibility/ viability/resource procurement)	Appropriate diversion to be placed to protect works	Unlikely	Minor	2				Accept risk	Rare	Minor	2	Construction	Direct
A33	Increased intensity of extreme winds (high confidence)	Storm-related contamination (wind-related) of reservoir leading to water quality impacts	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Communicating quality issues to downstream treatment plant Water quality monitoring system in place (including telemetry)	Likely	Minor	8	Likely	Minor	8	Water column mixing such that reservoir Is pre-mixed and therefor wind has no impact on quality	Rare	Minor	2	Design team / operator	
A34	Increased intensity of extreme winds (high confidence)	Strong winds could lead to wave runup / erosion on embankment (riprap...) and resultant financial implications	Financial (Fiscal responsibility/ viability/resource procurement)	Embankment protected by rip rap designed for winds with 1 in 10,000 AEP and sufficient thickness	Rare	Negligible	1	Rare	Negligible	1	Accept risk	Rare	Negligible	1	Design team	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A35	Increased intensity of storm events and lightning	Increased intensity of storms results in increased lightning strikes and risk of direct lightning damage to infrastructure	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Ensure vulnerable electrical assets are earthed	Rare	Minor	2	Rare	Minor	2	Accept risk.	Rare	Minor	2	Design team	Direct
A36	Increased intensity of storm events and lightning	Increased intensity of storms results in increased lightning strikes and risk of staff and contractor safety	Safety (People)	Safe work protocols in place for storm events. All asset elements are earthed for lightning protection.	Rare	Minor	2	Rare	Minor	2	Include storm-related workplace procedures in operations manual.	Rare	Negligible	1	Operator	Direct
A37	Increased intensity of storm events and lightning	Storm events and resultant landslides leading to damage to pipeline, leading to leaks / loss of pipeline use and resultant stoppage in service provision	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Pipeline buried, so no direct impacts Pipeline now crosses creek and will be buried below creek and protection will be in place to allow creek to flow over pipe trench.	Unlikely	Major	8	Unlikely	Severe	10	Increasing design standard for pipeline to provide better resilience against landslide risks. Check for damage to pipeline during operations following extreme flood events. Increase storm resistance spec. (increase resilience at exposed sites (remove break tanks?)	Rare	Major	4	Design team	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A38	Increased intensity of storm events and lightning	Storm-related damage to power supply leading to blackouts and reduced ability to provide services	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Power outage procedures Multiple backup power supply lines included in scope to cope with blackout scenario.	Possible	Moderate	9	Possible	Moderate	9	Backup power suppliers should be routinely maintained to ensure they can provide power to site in storm event	Possible	Negligible	3	**Operator**	**Indirect**
A39	Increased intensity of storm events and lightning	Storm-related blackouts leading to use and failure of generators in storm events leading to loss of water supply to Tamworth (valve would need to be opened again with people onsite	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	All valves can be opened without power source	Possible	Moderate	9	Possible	Moderate	9	Accept risk	Possible	Negligible	3	**Operator**	**Direct**
A40	Increased intensity of storm events and lightning	Storm-related impact on maintenance regime / ability for maintenance during strong wind events / storm frequency leading to reduced service delivery	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Safe work protocols will be in place for dam operations	Unlikely	Minor	4	Unlikely	Minor	4	Accept risk	Unlikely	Minor	4	**Operator**	**Direct**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A41	Increased intensity of storm events and lightning	Butterfly valve (in tunnel) closing automatically due to power outage, shutting off water supply (needs power to stay open)	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	All valves can be opened without power source. Natural tendency is for valve to open	Unlikely	Moderate	6	Unlikely	Moderate	6	Accept risk	Rare	Moderate	3	Design team	Direct
A42	Increased intensity of storm events and lightning	Storm-related damage to ancillary infrastructure (roads, outbuildings, etc..) leading to increased repair and maintenance costs	Financial (Fiscal responsibility/ viability/resource procurement)	Roads designed to 20-year ARI flood event	Possible	Minor	6	Possible	Minor	6	Increase resilience of ancillary infrastructure elements to storms and flood events	Unlikely	Minor	4	Design team	Direct
A43	Increased intensity of storm events and lightning	Extreme storm impacts on embankment leading to direct damage to asset elements and resultant financial impacts	Financial (Fiscal responsibility/ viability/resource procurement)		Rare	Major	4	Rare	Major	4	Accept risk	Rare	Major	4	Design team	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A44	More frequent/ severe droughts (low confidence)	Extended drought period followed by intense rainfall leading to damage to reservoir structure	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Dead storage allowed for collection of silt run-off. Multiple intakes so can operate storage above silt levels or remove if necessary.	Rare	Minor	2	Unlikely	Minor	4	Consider opportunities to monitor vegetation structure (e.g. through aerial imagery, lidar and vegetation surveys). Where necessary, consider working with NSW Fire and the SES to conduct fuel reduction burns/clearing of vegetation or conversely plant more species if required	Unlikely	Minor	4	Operator	Direct
A45	More frequent/ severe droughts (low confidence)	Extended drought period followed by intense rainfall leads to intrusion of vegetation, negatively affecting water quality	Compliance	Manual removal and management of vegetation as per maintenance regime	Possible	Negligible	3	Possible	Negligible	3	Consider opportunities to monitor vegetation structure (e.g. Through aerial imagery, lidar and vegetation surveys). Where necessary work with NSW Fire and the SES to conduct fuel reduction burns/clearing of vegetation or conversely plant more species if required	Possible	Negligible	3	Operator	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A46	More frequent/ severe droughts (low confidence)	Extended drought period followed by intense rainfall leading to a change in soil structure, increased erosion and poor water quality	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Water quality monitoring program	Almost Certain	Minor	10	Almost Certain	Minor	10	Consider opportunities to install silt booms, monitor vegetation structure (e.g. Through aerial imagery, lidar and vegetation surveys). Where necessary work with NSW Fire and the SES to conduct fuel reduction burns/clearing of vegetation or conversely plant more species if required	Likely	Minor	8	Design team	Direct
A47	More frequent/ severe droughts (low confidence)	Reduced capacity due to build-up of silt (over time) leading to reduced service delivery	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Dead storage allowed for collection of silt run-off. Multiple intakes so can operate storage above silt levels or remove if necessary.	Possible	Minor	6	Likely	Minor	8	Continually monitor water Install silt booms seek solutions from research and development, accept short-term risk	Likely	Minor	8	Operator	Direct
A48	More frequent/ severe droughts (low confidence)	Damage to assets not designed for exposure to UV	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)		Unlikely	Moderate	6	Possible	Moderate	9	Monitor assets prone to UV disintegration, conduct regular maintenance and replacement of parts that are UV stabilised. Factor increased costs into the price of water	Possible	Minor	6	Design	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A49	More frequent/ severe droughts (low confidence)	Algal Blooms leading to health impacts on downstream water users	Safety (People)	Water quality monitoring program	Likely	Major	16	Likely	Major	16	Conduct regular maintenance. Implement best practice approaches to reduce the likelihood and remedy algal blooms through reducing organics from entering the reservoir through fuel reduction burns and ample understorey to filter water entering the reservoir. Invest in treatments currently used in hotter climates i.e. Hydrogen peroxide. Ensure fertilisers are not used in NSW managed catchment land. Install gross pollutant trap and monitor regularly	Unlikely	Major	8	**Operator**	**Direct**
A50	More frequent/ severe droughts (low confidence)	Stratification / cold water pollution	Environment	Design multi-level outlet to accommodate with appropriate monitoring instrumentation Water drawn from correct level of multi-level outlet	Likely	Minor	12	Likely	Minor	8	Install destratification mixer or air curtains to maintain more constant thermal gradient.	Likely	Negligible	4	**Design**	**Direct**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A51	More frequent/ severe droughts (low confidence)	Catchment delivers less water than was planned leading to local environmental impacts	Environment	Enact water restrictions when required Assess potential yield and impact during planning/design, water balance modelling and EIS (i.e. considers drought scenarios)	Possible	Moderate	9	Likely	Moderate	12	Allow for future raising in design. Consider implementation (with relevant stakeholders) of water restrictions that take effect in times of drought and extended low rainfall. Review and update the Tamworth Regional Council Drought Management Plan to consider revised arrangements for the implementation of water restrictions.	Likely	Moderate	12	Operator	Direct
A52	More frequent/ severe droughts (low confidence)	Catchment delivers less water than was planned leading to service level disruptions	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Enact water restrictions when required assess potential yield and impact during planning/design, water balance modelling and EIS (i.e. considers drought scenarios)	Possible	Moderate	9	Likely	Moderate	12	Accept risk. Allow for future raising in design	Likely	Moderate	12	Operator	Direct
A53	More frequent/ severe droughts (low confidence)	Drought related reductions in groundwater recharge leading to reduced water yield	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Minor groundwater interaction with Dungowan Dam means changes in groundwater will have very limited impact on dam yield	Rare	Negligible	1	Rare	Negligible	1	Groundwater study being undertaken to identify impacts from climate change on dam operation	Rare	Negligible	1	Design team	Direct

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A54	Increased extreme rainfall intensity and resultant flooding (high confidence)	Heavy rainfall leading to catchment flooding and direct impacts on pipeline trench and scour impacts adjacent to creek with associated environmental impacts	Environment	subject to localised impacts on creek bank and trench. 'Design of crossings and installation as per required standards	Rare	Minor	2	Rare	Minor	2	Monitoring key risk areas during operations.	Rare	Minor	2	**Operator**	**Direct**
A55	Increased extreme rainfall intensity and resultant flooding (high confidence)	Catchment flooding leading to direct impacts on pipeline trench and damage, leading to temporary inability to supply water to users	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Design of crossings and installation as per required standards	Rare	Minor	2	Rare	Minor	2	Monitoring key risk areas during operations.	Rare	Minor	2	**Operator**	**Direct**
A56	Increased extreme rainfall intensity and resultant flooding (high confidence)	Very heavy rainfall and flood events during the construction period of pipe crossings, leading to construction delays and associated project delivery impacts	Capability / Service Delivery (Assets/ICT/drinking water quality/water quantity/customers)	Timeline managed to accommodate weather. Creek crossing installation targeting short term dry forecasts	Unlikely	Minor	4				Construction risk – accept risk.	Unlikely	Minor	4	**Construction**	**Direct**

Risk information					2030			2090			Risk treatment					
Risk Ref	Climate change impact	Risk statement	Consequence area	Current Controls	Likelihood	Consequence	Rating	Likelihood	Consequence	Rating	Proposed Adaptation actions	Likelihood	Consequence	Rating	Resp	Risk type
A57	Increased extreme rainfall intensity and resultant flooding (high confidence)	Catchment flooding leading to scour impacts on pipeline trench and adjacent to creek banks, leading to associated community / compliance impacts to operator	Compliance	Design of crossings and installation as per required standards	Unlikely	Moderate	6	Unlikely	Moderate	6	Monitoring key risk areas during operations.	Unlikely	Moderate	6	Operator	Direct

Appendix D – Variation Review Workshop Attendance Register

Name	Role	Organisation
Tim Watson	Facilitator: Senior Sustainability Consultant	Edge
Mark Trudgett	Associate Environmental Scientist	EMM
Todd Robinson	Environmental Planning Manager Dungowan Dam and Pipeline	Water Infrastructure NSW

Meeting Summary	
Total Number of Participants	3
Meeting Title	Dungowan Risk Review
Meeting Start Time	5/26/2022, 2:01:29 PM
Meeting End Time	5/26/2022, 3:02:54 PM
Meeting Id	1344d7af-1a6a-497e-98b3-b1ea7dcbd12b