Prepared for
Major Projects Canberra
ABN: 66 676 633 401

AECOM

# Climate and Natural Hazards Assessment

## Technical Report

28-Sep-2021
Raising London Circuit

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Technical Report

Client: Major Projects Canberra

ABN: 66 676 633 401

Prepared by

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# List of Acronyms

| Acronym | Definition |
|---|---|
| **ACT** | Australian Capital Territory |
| **AEP** | Annual Exceedance Probability |
| **ANU** | Australian National University |
| **ARI** | Average Recurrence Interval |
| **AS** | Australian Standard |
| **BoM** | Bureau of Meteorology |
| **CNHA** | Climate and Natural Hazards Assessment |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **DEH** | Department of Environment and Heritage |
| **FFDI** | Forest Fire Danger Index |
| **GHG** | Greenhouse Gas |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IS** | Infrastructure Sustainability |
| **ISCA** | Infrastructure Sustainability Council of Australia |
| **ISO** | International Standards Organisation |
| **MPC** | Major Projects Canberra |
| **NARCliM** | NSW and ACT Regional Climate Modelling |
| **NZS** | New Zealand Standard |
| **OEH** | Office of Environment and Heritage |
| **PMF** | Probable Maximum Flood |
| **PPE** | Personal Protective Equipment |
| **RCP** | Representative Concentration Pathway |
| **RLC** | Raising London Circuit |
| **RLs** | Relative Levels |
| **SRES** | Special Report on Emissions Scenarios |
| **WSUD** | Water Sensitive Urban Design |

# Executive summary

### Overview

The purpose of this report is to present the findings of a Climate and Natural Hazards Assessment (CNHA) completed as part of the proposal to raise London Circuit between Edinburgh Avenue and Constitution Avenue to provide a new at-grade, signalised intersection with Commonwealth Avenue (referred to as Raising London Circuit (RLC) ('the Project')).

This report aims to align with relevant National and ACT Government policies, strategies and plans such as the Australian Government's National Climate Resilience and Adaptation Strategy and the ACT Climate Change Strategy 2019-2025. It also aligns with the criteria outlined in the ISCA Rating Scheme v2.0.

This report assesses risks and vulnerability related to climate change relevant to the Project in accordance with current guidelines, utilises relevant climate change projections, and identifies and recommends specific adaptation actions.

In addition to complying with the relevant policies, strategies and plans, this report identifies relevant climate effects and provides an assessment of the potential climate change risks to the Project. It further identifies appropriate risk management and adaptation measures to build the resilience of the Project to changing climate conditions. It is worth noting the scope of this CNHA covers physical climate risks and no consideration to transition climate risks has been given.

### Data sources

In order to assess the risk to the Project posed by climate change, the current climate science and model projections have been investigated for the following parameters based on available data sources. Reflecting the requirements of the relevant National and ACT Government policies, strategies and plans, this CNHA has used two data sources for climate change projections:

- NARCliM developed by the Office of Environment and Heritage (OEH) (OEH, 2015) which provides projections at the 10 kilometre resolution
- CSIRO and BOM Climate Futures (CSIRO, 2015) which supplements the information available from the NARCliM projections for a number of key climate variables.

Projections are presented for emission scenarios or possible pathways, referred to as Representative Concentration Pathways (RCPs), each of which reflects a different concentration of global GHG emissions. While RCPs exist for low emissions (RCP 2.5) and medium emissions (RCP 4.5), the RCP reported here is for high emissions (RCP 8.5). The RCP 8.5 pathway, which arises from limited effort to reduce emissions and represents a failure to prevent warming by 2100, is similar to the highest SRES scenario and is used in this report. The RCP 8.5 pathway is also closest to the current emissions trajectory.

### Construction risks

Risks for construction resulting from a changing climate were not identified as part of the risk assessment process, in the understanding that construction would be complete within the next few years, and that changes in the climate over this period would not be too dissimilar to current conditions. As such, risks to construction were only assessed at the 2030 time horizon (and not 2070) as works are expected to be completed well in advance of 2030.

Due to previous events experienced in and around the Project, including observed trends, risks to construction from climate hazards could occur by way of physical damage, reduced capacity, and potential risks to human health and safety. Based on these past events and trends, risks to the construction process could include:

- Extreme rainfall (including wind and hail) and flooding resulting in delays to construction schedules and cost impacts
- Extreme heat (days over 35°C) resulting in increased incidence of tools down and heat-related stress delays to construction, increasing schedules and cost impacts.
- Bushfire smoke affecting visibility and air quality for construction workers

Mitigation and adaptation measure to reduce the impacts of the identified construction climate risks for the Project have been provided.

**Operational risks**

Based on the CNHA for the Project, the following risks were identified as presenting the highest risk in both the near term (2030) and long term (2070):

- Extreme rainfall and flooding
- Extreme heat
- Drought / mean rainfall changes
- Extreme storms
- Bushfire.

The assessment identified a total of 18 risks, both direct and indirect risks. Of these, five (5) were high or very high risks and no (0) extreme (significant) risks at 2030, increasing to ten (10) high or very high risks and no (0) extreme risk (significant) risks at 2070 for the Project.

The consequences of these risks may include physical damage, increased discharge of water and the accelerated deterioration of assets.

In accordance with best practice and current design standards, operations and maintenance practices, risk management, and adaptation measures, a number of treatment options have been incorporated into the pre-concept and concept designs for the Project. The full list of treatment options is provided in **Appendix F**.

A residual risk assessment (post-application of adaptation measures) for the Project was undertaken. Based on the application of the adaptation measures, no residual 'very high' or 'high' risk ratings remain for the Project.

**Next steps**

The climate risk and adaptation actions identified in this report have been tested and refined through feedback and discussion from team members across a range of disciplines and provide a baseline assessment to inform the design process. There are opportunities to identify and explore additional treatment options to add value and support improved response to climate change. These could include:

- Exploring initiatives such as coordination / opportunities with other stakeholders for downstream augmentation to support better drainage outcomes as well as additional water capture options to improve response to flood risks and extreme rainfall
- Communicating outcomes of Project investigations, such as sensitivity testing and shading constraints, to surrounding stakeholders to develop shared / collaborative responses
- Exploring additional options to improve the response to extreme heat through actions such as additional shading in the footprint, materials selections for Project elements (e.g. pervious pavements) and reviewing key specifications (such as pavement design) to accommodate future increases in temperature

In order to apply these findings and support the requirements set out the relevant National and ACT Government policies, strategies and plans, the following next steps are recommended:

- Risk and adaptation review – the risk assessment and adaptation actions have been identified based on the current design for the Project and are a snapshot at this time in the Project development process. It is noted that the adaptation actions should be re-examined at future milestones or phases to confirm inclusion and suitability as well as for feasibility of construction for the Project. Changes to the adaptation actions may reduce or enhance the ability to respond to the identified risks

# 1.0 Introduction

## 1.1 Project overview

Major Projects Canberra (MPC) proposes to raise London Circuit between Edinburgh Avenue and Constitution Avenue to provide a new at-grade, signalised intersection with Commonwealth Avenue (referred to as Raising London Circuit (RLC) ('the Project')).

The Project is needed as part of coordinated and holistic delivery of a series of major projects in Canberra City and surrounds, to realise the strategic planning and development for the city presented in the National Capital Plan. It would facilitate other major projects, most notably the extension of the Canberra Light Rail network and development of Section 63, and through well-timed delivery would support orderly, economic and efficient development of land within Canberra City. The Project also provides an important opportunity to future proof the city's transport network to accommodate future growth, and to provide high quality urban design and amenity outcomes consistent with the National Capital Plan.

MPC's projects align well with an extensive legislative and policy framework in the ACT, highlighting a commitment for providing climate resilient infrastructure and to delivering on the principles of ecologically sustainable development. MPC have a demonstrated commitment to achieving sustainable and resilient outcomes, as evidenced by their achieving a 'Leading' rating from the Infrastructure Sustainability Council Australia (ISCA) for Stage 1 Light Rail (approximately 12km light rail route connecting the Gungahlin area in the north with Canberra's city centre). MPC have committed to pursue Infrastructure Sustainability (IS) ratings under the new ISCA Rating Scheme V1.2, but are trialling the use of the Resilience category for V2.0 with the aim of providing improved resilience outcomes for the Project. . This will drive a culture of sustainable decision making to benefit the wider Canberra community.

## 1.2 Purpose of this report

Recent events, such as the 2019/2020 bushfires, maximum temperature records set in 2020 and a more recent 2021 extreme rainfall event, have demonstrated the vulnerability of critical infrastructure in and around Canberra. This technical report provides a *Climate and Natural Hazards Assessment* (CNHA) for the Project.

The assessment has been completed to understand and identify the potential effects and risks associated with climate change as well as the identifying treatment options and risk management measures to be incorporated throughout the design, construction and operation phases to build the resilience of the Project to changing climate conditions. It is worth noting the scope of this CNHA covers physical climate risks, while no consideration to transition climate risks has been given.

## 1.3 Approach

Section 1 has provided an overview of the Project and presented the purpose of the CNHA. The remainder of the report is structured as follows:

- **Section 2** provides the Project description.
- **Section 3** highlights and summarises the relevant legislation and strategic context.
- **Section 4** details the methodology including risk assessment guidelines and stakeholder engagement.
- **Section 5** provides an overview of the existing environment including the local climate context and observed climate.
- **Section 6** provides the projected future conditions resulting from a changing climate for the region.
- **Section 7** presents the risks to construction of the project.
- **Section 8** presents the risks to operation of the project.
- **Section 9** concludes the report and provides the next steps.

# 2.0 Project description

Raising London Circuit (the Project) would involve raising London Circuit between Edinburgh Avenue and Constitution Avenue on a gradual filled embankment to meet the current height of Commonwealth Avenue, and provision of a new signalised intersection between London Circuit and Commonwealth Avenue.

The completed Project, including its main features and elements, is shown in Figure 2-1. Key elements of the Project are summarised in Table 2-1. Further details of the Project are provided in Chapter 3.0 of the Environmental Assessment.

**Table 2-1 Key elements of the Project**

| Key element | Description |
|---|---|
| **Main embankment** | A main embankment with associated retaining walls and batters between Edinburgh Avenue in the west and Constitution Avenue in the east, rising in the centre to around the current height of Commonwealth Avenue. The main embankment-would have a slope of up to 3.5 per cent, tapering off to around 2.0 per cent towards the new London Circuit-Commonwealth Avenue intersection |
| **London Circuit West** | A modified and reconstructed London Circuit West between Edinburgh Avenue and Commonwealth Avenue:<br>• London Circuit West would be generally one travel lane in each direction, widening to two lanes between the potential future intersection with the proposed West Road and the new Commonwealth Avenue intersection. |
| **London Circuit East** | A modified and reconstructed London Circuit East between Commonwealth Avenue and Constitution Avenue:<br>• London Circuit East would be two travel lanes in each direction |
| **New and modified intersections** | New and modified intersections would be delivered at Edinburgh Avenue (modified) and Commonwealth Avenue (new), as well as making provision for a future potential intersection to tie into the potential future West Road (which would run south from London Circuit West to the future New Acton Waterfront Precinct, but which does not form part of this project).<br>***Modified London Circuit-Edinburgh Avenue intersection***<br>The modified London Circuit-Edinburgh Avenue intersection would include tie-in works with London Circuit to the west of the intersection. No changes to Edinburgh Avenue outside the intersection are proposed.<br>The intersection would retain three travel lanes in each direction on Edinburgh Avenue and one travel lane in each direction on London Circuit.<br>***New London Circuit-Commonwealth Avenue intersection***<br>The new London Circuit-Commonwealth Avenue intersection would be signalised and would include tie-in works on Commonwealth Avenue to the north and south of the intersection. The intersection would be designed to integrate into the local landscape and to minimise intrusion into the significant vista along the Commonwealth Avenue corridor between City Hill and Capital Hill.<br>On Commonwealth Avenue, the southern approach would provide one left turn lane, two through lanes and a right turn lane into London Circuit East. On London Circuit there would be two travel lanes in each direction on both the eastern and western approaches. This intersection configuration would be integrated through tie-in works to the existing |

| Key element | Description |
|---|---|
| | configuration of Commonwealth Avenue north and south of this intersection.<br>The new intersection would allow full vehicle movements in all directions between London Circuit and Commonwealth Avenue, except for:<br>• No right turn from London Circuit westbound into Commonwealth Avenue northbound<br>• No right turn from Commonwealth Avenue southbound into London Circuit westbound.<br>• No right turn from London Circuit eastbound into Commonwealth Avenue southbound |
| **Modification and removal of existing cloverleaf ramps** | Modification and removal of existing cloverleaf ramp connections between Commonwealth Avenue, London Circuit and Parkes Way:<br>• The cloverleaf ramp connections to the north west and to the south west of the existing London Circuit-Commonwealth Avenue interchange would be removed, with affected land stabilised and rehabilitated.<br>• The cloverleaf ramp connection to the south east of the existing London-Circuit-Commonwealth Avenue interchange would be modified. This would remove the connection from London Circuit (westbound) on to Commonwealth Avenue (southbound), but would retain the connection between Parkes Way (eastbound) and Commonwealth Avenue (southbound). |
| **Bicycle infrastructure** | Provision of bicycle facilities:<br>• Dedicated, separated off-road bicycle paths would be provided on the verge on both sides of London Circuit West and London Circuit East, which would operate as one-way pairs in each direction.<br>• Dedicated, separated off-road bicycle paths bicycle paths would be provided along both sides of the tie-in works on Commonwealth Avenue to the north and to the south of the new London Circuit-Commonwealth Avenue intersection. |
| **Pedestrian infrastructure** | Provision of pedestrian facilities:<br>• Dedicated, separated pedestrian paths would be provided on both sides of London Circuit West and London Circuit East, and along both sides of the tie-in works on Commonwealth Avenue around the new London Circuit-Commonwealth Avenue intersection. |
| **Ancillary infrastructure** | Ancillary infrastructure and works, including utility connections, lighting, street furniture, landscaping and drainage are included in the project. |

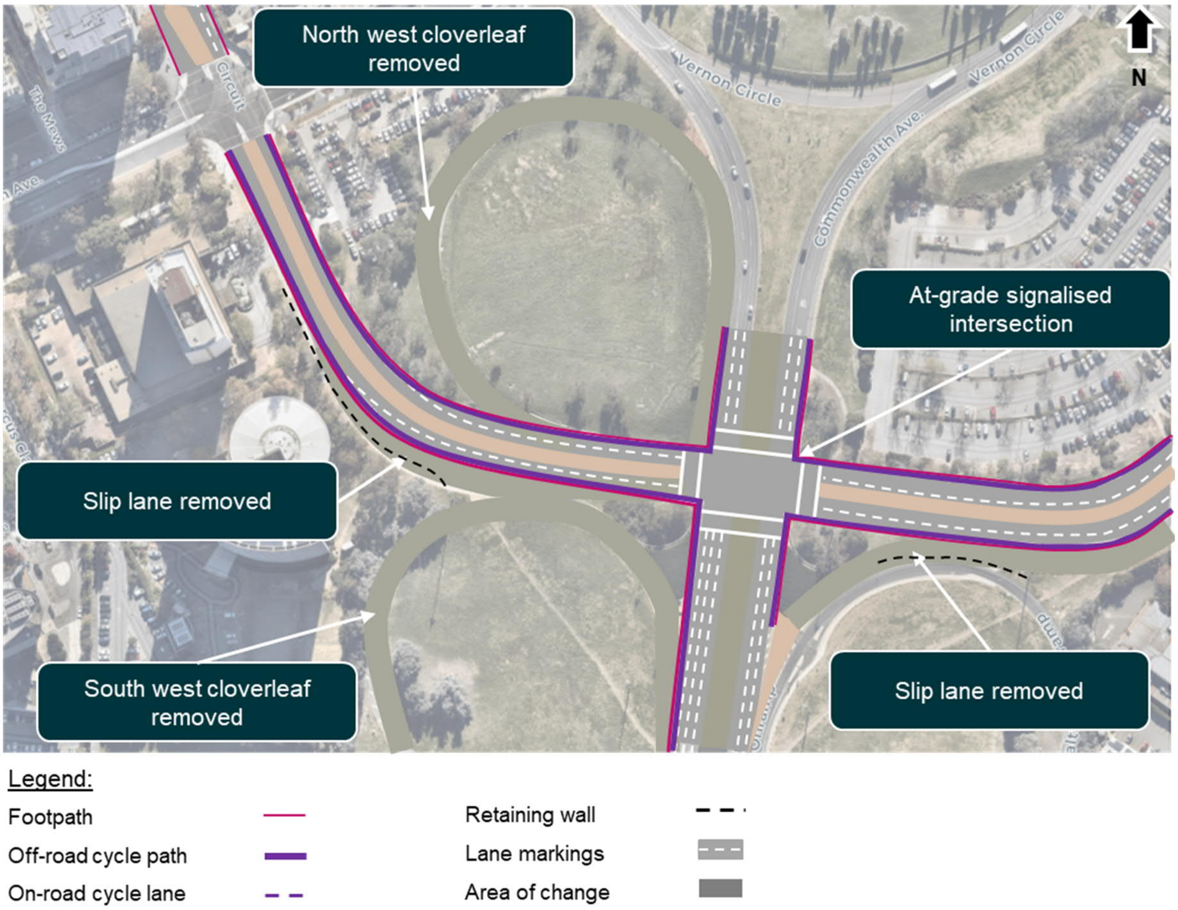


**Figure 2-1 The Project and its main features and elements**

Subject to securing and complying with the conditions of environmental and planning approvals, construction of the Project would commence around April 2022 and would take approximately two years to complete. The construction footprint for the Project, and the areas affected by separate early works are show in Figure 2-2.

Construction of the Project would be preceded by a series of early works required to allow construction works to commence around April 2022. These early works are subject to separate assessment and approvals, and would include:

- Relocation of utilities currently located within the Project construction footprint
- Translocation of Golden Sun Moth (*Synemon plana*) larvae from areas affected by utility relocations
- Traffic management works at the London Circuit-Edinburgh Avenue intersection to allow closure of London Circuit during construction of the Project
- Traffic management works at the Commonwealth Avenue-Vernon Circle intersection, including signalisation, and at the London Circuit-Constitution Avenue intersection to allow closure of London Circuit and traffic management along Commonwealth Avenue during construction of the Project.

Further details of early works are provided in Chapter 4.0 of the Environmental Assessment.

Key construction activities for the Project are summarised in Table 2-2. Further details of the construction of the Project are provided in Chapter 4.0 of the Environmental Assessment.

**Table 2-2 Key construction activities**

| Key construction activity | Description |
|---|---|
| **Site establishment and preparation** | Site establishment and preparatory works would involve:<br>• Mobilisation and establishment of construction compound sites. Construction compounds approved for use as part of the utility relocation early works would continue to be used for construction of the Project (refer to Figure 2-2)<br>• Translocation of Golden Sun Moth (*Synemon plana*) larvae from within the Project construction footprint<br>• Implementation of temporary surface water and drainage management infrastructure, including temporary grass swales, along around areas of London Circuit to be filled and raised with bulk earthworks<br>• Decommissioning and removal of utilities from within the Project construction footprint. Some decommissioning and removal works may also be carried out as part of construction works along London Circuit and around the new London Circuit-Commonwealth Avenue intersection<br>• Implementation of traffic management measures, including reliance on early works carried out at the London Circuit-Edinburgh Avenue, Commonwealth Avenue-Vernon Circle and London Circuit-Constitution Avenue intersections, and closure of London Circuit to traffic between Edinburgh Avenue and Constitution Avenue. |
| **Closure and raising of London Circuit** | Closure and raising of London Circuit would involve:<br>• Removal of existing street furniture, road pavement and vegetation along London Circuit and within the Project construction footprint<br>• Removal of existing street furniture and road pavement along the north west and south west cloverleaf ramp connections between Commonwealth Avenue, London Circuit and Parkes Way, and stabilisation and rehabilitation of land in those areas<br>• Removal of existing street furniture and road pavement for the connection between London Circuit East and the south east clover leaf ramp connection between London Circuit, Commonwealth Avenue and Parkes Way. Only the connection with London Circuit would be affected, with the remainder of the ramp connection retained with potential minor modification to accommodate the embankment batter for London Circuit East. Land affected by removal of the London Circuit connection would be stabilised and rehabilitated<br>• Construction of retaining walls and batters, and staged filling of the London Circuit road corridor between Edinburgh Avenue and Constitution Avenue. The infilling along London Avenue would continue concurrently and in coordination with demolition and infilling beneath the Commonwealth Avenue northbound and southbound bridges (refer below) |
| **Demolition and infilling of Commonwealth Avenue bridges** | Demolition and infilling of the Commonwealth Avenue bridges would be carried out in stages to allow continued passage of traffic during the works. Indicative staging would be as follows:<br>• A temporary sidetrack would be constructed to the east of the existing Commonwealth Avenue southbound bridge and associated temporary pavement of the existing Commonwealth Avenue median to allow traffic diversion around the Commonwealth Avenue bridges during demolition works. The sidetrack would provide two traffic lanes as shown in Figure 2-3 |

| Key construction activity | Description |
|---|---|
| | • Implementation of traffic management measures, including reliance on early works carried out at the Commonwealth Avenue-Vernon Circle intersection, to divert traffic on Commonwealth Avenue so that:<br>  - Southbound traffic travels via the temporary sidetrack<br>  - Northbound traffic crosses onto the existing southbound carriageway<br>  - The Commonwealth Avenue northbound bridge is free of traffic<br>• Demolition of the Commonwealth Avenue northbound bridge<br>• Infilling and stabilisation of the area beneath the demolished Commonwealth Avenue northbound bridge as part of the staged program to infill along London Circuit<br>• Construction of the western part of the new London Circuit-Commonwealth Avenue intersection, including a new northbound carriageway<br>• Implementation of traffic management measures following completion of the demolition and infilling of the Commonwealth Avenue northbound bridge so that:<br>  - Southbound traffic continues to travel via the temporary sidetrack<br>  - Northbound traffic travels via the new northbound traffic lanes and western part of the London Circuit-Commonwealth Avenue intersection<br>  - The Commonwealth Avenue southbound bridge is free of traffic<br>• Demolition of the Commonwealth Avenue southbound bridge<br>• Infilling and stabilisation of the area beneath the demolished Commonwealth Avenue southbound bridge as part of the staged program to infill along London Circuit<br>• Construction of the eastern part of the new London Circuit-Commonwealth Avenue intersection, including a new southbound carriageway<br>• Implementation of traffic management measures to return southbound traffic on Commonwealth Avenue to the new southbound traffic lanes and eastern part of the London Circuit-Commonwealth Avenue intersection<br>• Demolition of the temporary sidetrack and infilling the area beneath it as part of the staged program to infill along London Circuit. |
| **Permanent road works** | Permanent road pavement, median works and kerb and guttering would be constructed in coordination with the completion of infilling London Circuit to provide the permanent reconstructed London Circuit. Road works would include intersection works at Edinburgh Avenue and Commonwealth Avenue, and tie-in works at Constitution Avenue and around the modified and new intersections with Edinburgh and Commonwealth Avenues. |
| **Ancillary infrastructure and finishing works** | Ancillary infrastructure and finishing works would be completed prior to commissioning and opening London Circuit to traffic, including:<br>• Construction of active transport infrastructure, permanent drainage and utilities works<br>• Installation of lighting and street furniture, and road line marking<br>• Landscaping<br>• Demobilisation, and stabilisation and rehabilitation of disturbed areas, including construction compound sites. |


**Figure 2-2 The Project construction footprint and early works areas**


**Figure 2-3 Temporary Commonwealth Avenue sidetrack configuration**

# 3.0 Legislation and strategic context

## 3.1 National policy

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

While the Project is not specifically mentioned as part of this strategy, the preparation of this CNHA will support the effective implementation of adaptation and help further build the resilience of not only the Project, but also the broader Canberra region. This includes the use of the best available scientific data, support for vulnerable communities, a multi-disciplinary / stakeholder approach to design as well as learnings from previous infrastructure projects to improve on performance outcomes.

Furthermore, the Australian Government's *Direct Action Plan* sets out how the 2030 emissions reduction target will be achieved. As part of the *Direct Action Plan*, a range of policies, programs and aims were identified to reduce Australia's GHG emissions by creating positive incentives to adopt better technologies and practices to reduce emissions. The Australian Government has considered the 2030 target policy framework in detail in 2017-2018 and is confident in achieving the identified reduction targets through the implementation of the Renewable Energy Target, Minimum Energy Performance Standards and the 20 Million Trees Program. No additional national policies or plans have been prepared since 2018. While the *Direct Action Plan* is largely aimed at climate mitigation, policies and program, if applied at the local level, can support adaptation to physical risks. In addition, establishing low energy / energy efficient standards for the Project will reduce power requirements serving to both reduce the risk of power outages / faults as well as reducing the power loads / demand on fossil fuel generated sources.

## 3.2 Territory policy

### 3.2.1 ACT Climate Change Strategy 2019-2025 (ACT Government, 2019)

As part of Canberra's commitment to achieving net zero emissions by 2045, the ACT has outlined a series of 5 year interim targets to support emissions reductions. The 2019-2025 Strategy outlines this next stage of the ACT Government's response to climate change and identifies the necessary steps to meet both interim targets and set up longer-term aspirations to achieve the end goal of net zero. Actions have been developed in concert with both the community and a range of stakeholders and are focused on a number of climate adaptation and mitigation options, most notably, building resilience to physical climate change impacts.

The Strategy has a particular focus on transport, the largest sources of emissions (generally accounting for more than 60% of total emissions) and specifically, outlines several key priorities, several of which the Project helps support, as described in **Table 3-1**.

**Table 3-1 Project compliance with ACT Climate Change Strategy 2019-2025**

| Priority | Description | Project support of the priority |
|---|---|---|
| ACT Government Leadership | Consider climate change adaptation outcomes in all policies, budget decisions and capital works decisions | Treatment options identified in this report are intended to achieve climate change adaptation outcomes |
| ACT Government Leadership | Monitor climate change projections and ensure infrastructure and services are resilient to climate change impacts | This report provides the latest climate change projections. These projections were utilised to identify potential impacts to the project |
| Transport | Supporting higher uptake of public transport by continuing to improve services to meet community travel needs | Treatment options identified in this report provide opportunity to improve climate response of the Project and encourage community travel through active transport and connections to existing public transport services, including light rail services |

This Strategy replaces the *Climate Change Strategy and Action Plan 2* (2012) and the 2016 *Climate Change Adaptation Strategy*. It is supported by the *Living Infrastructure Plan: Cooling the City* and has been developed in alignment with the *ACT Planning Strategy 2018*, *ACT Housing Strategy 2018* and the draft *Moving Canberra: Integrated Transport Strategy*.

Key other actions where the Project can support the aims and the 2025 target goals are highlighted in Table 3-2 below.

**Table 3-2 Project response to aims and target goals**

| Action | Project Response |
|---|---|
| *Action 1.5 – Work with the ACT Climate Change Council to encourage community participation in climate change initiatives* | Community engagement activities are being encouraged to facilitate the opportunity to comment on the climate risk assessment and work to identify potential responses to climate change. |
| *Action 3.4 – Prioritise improving public transport services and supporting infrastructure, including buses, light rail stage two and connecting services* | The Project would help facilitate the eventual extension of the light rail stage two to areas to the south including Woden. |
| *Action 3.9 - Prioritise walking and cycling and enhance active travel infrastructure to improve safety and connectivity of the active travel network.* | The Project would include upgrades to the existing active transport in and around London Circuit. These upgrades aim of provide safer and improved active transport connections. |
| *Action 3.18 - Investigate options for dedicating a greater proportion of road space and public realm space to sustainable transport modes.* | A key Project objective is to "provide Canberrans with an attractive, convenient, efficient and reliable integrated public transport system that facilitates choice, increases public transport patronage and reduces car dependency." Road space has been taken and property boundaries reduced to provide the active verges along London Cct and facilitate future light rail. |
| *Action 4.22 - Implement Canberra's Living Infrastructure Plan to work towards 30% urban* | The Project has included as part of its design a range of green infrastructure including the planting of mature |

| Action | Project Response |
|---|---|
| *canopy cover and 30% surface permeability, account for the value of living infrastructure and assess local needs for managing heat* | canopy trees to provide shade, landscaping across the footprint to reduce the need for hardstand as well as the use of pervious pavement where possible to help improve response to heat and flooding. |
| *Action 5.5 - Ensure the social cost of carbon and climate change adaptation outcomes are considered in all ACT Government policies, budget decisions, capital works projects and procurements.* | Climate change adaptation outcomes identified in this report have been considered in the design development of the Project and incorporated into the scope. |
| *Action 5.6 - Ensure all new Government capital works with a budget of more than $10 million either seek or are consistent with an independent sustainability rating such as an Infrastructure Sustainability rating from the Infrastructure Sustainability Council of Australia (ISCA), or a Greenstar rating from the Green Building Council of Australia or equivalent, and review ratings at least every five years.* | The Project is seeking a 'Leading' rating under v2.0 of the ISCA Rating Scheme. As part of the rating scheme, two credits will be pursued that respond to community resilience as well as climate change and natural hazards (the subject of this report). |

### Canberra's Living Infrastructure Plan: Cooling the City

The *Living Infrastructure Plan* (EPSDD, 2019) details the ACT Government's strategic direction and commitment, through action, to maintain and improve living infrastructure across Canberra. This includes the understanding that urban areas generally contribute to the urban heat island effect – raising temperatures across urban areas both during the day and retaining heat during the night (up to 10$^{o}$C warmer than other parts of Canberra). Living infrastructure supports efforts to make cities 'climate-wise' by enhancing capacity to respond to climate change and extreme weather events – through retention of water in the landscape, using rainfall better, increasing access to shade, improving water penetration and facilitating recharge and improving access to and amenity of nature in urban areas.

The Plan in particular seeks to increase the canopy coverage of the city from a current 21% coverage to 30% by 2045 through the use of trees, or tree canopy equivalent (e.g. green roofs, shrub beds, rain gardens, etc.) as well as a 30% commitment to permeable surfaces. The Plan further recognised the need to respond to climate change, particularly considering the criticality of living infrastructure and potential impacts resulting from longer periods of drought, higher temperatures, and increased duration of heatwaves.

Key actions resulting from the Plan of relevance to the Project are highlighted in Table 3-3. Specific treatment option and design features that support each action can be found in the treatment options register in **Appendix F**.

**Table 3-3 Project response to key actions from Canberra's Living Infrastructure Plan**

| Action | Project Response |
|---|---|
| *Action 2: Living Infrastructure Targets* - achieve 30% tree canopy cover (or equivalent) and 30% permeable surfaces in Canberra's urban footprint by 2045 | The Project has included as part of its design a range of green infrastructure including the planting of mature canopy trees to provide shade, landscaping across the footprint to reduce the need for hardstand as well as the use of pervious pavement where possible to help improve response to heat and flooding. |
| *Action 5*: *Climate-wise Landscape Guide* – prepare a guide for use by the community and built environment professionals to support effective landscape plans, and increase the opportunity for healthy, climate resilient and biodiverse gardens and public lands | The landscaping plan for the Project is incorporating elements from the climate-wise landscape guide to improve outcomes and response to extreme heat, drought, bushfire and changes to rainfall patterns (e.g. less frequency, higher volume). |

| Action | Project Response |
|---|---|
| *Action 10*: *City Cooling Program* – trial city cooling initiatives in high priority locations | The Project will include a high proportion of green infrastructure to help reduce the urban heat island effect along the footprint and improve response to heat challenges within the city centre. |
| *Action 14*: *Water Sensitive Urban Design* – support trials and demonstration projects to retrofit infrastructure to allow hydration of open spaces using stormwater. | The design of the Project includes WSUD features (such as bioswales) where feasible to capture stormwater, minimise flood risks and allow for the hydration of open spaces. |

In addition, the Plan recognises that living infrastructure provides a range of other benefits including improved social (e.g. higher liveability and connections) and health (e.g. mental health) outcomes from being closer to nature.

## 3.3 Infrastructure Sustainability Council requirements

The CNHA report is an assessment that aligns to the requirements for climate and natural hazard risks outlined in v2.0 of the ISC IS Rating Scheme for Res-2. In particular, this report highlights the consideration of direct and indirect risks in the context of past and observed climate as well as projected future changes. The report further validates and identifies risks and treatment options to respond to those high-priority and extreme rated risks.

# 4.0 Methodology

## 4.1 Risk assessment guidelines

The CNHA provided in this report has been undertaken in line with the following relevant standards and guidelines:

- The climate change projections used in this assessment have been collated and informed by both the AdaptNSW NARCliM data and CSIRO Climate Futures data in accordance with AS 5334:2013 *Climate change adaptation for settlements and infrastructure*
- The climate change risks have been assessed in line with the methods recommended in *Climate Change Impacts and Risk Management: A Guide for Business and Government* (Department of Environment and Heritage (DEH), 2006)
- The *ISCA Resilience Credit Guidelines* (Infrastructure Sustainability Council of Australia, 2018) have been reviewed and used to guide, confirm and validate measures to mitigate and adapt to climate risks and natural hazards
- The project-specific Risk Management approach, in accordance with Australian Standard (AS) / New Zealand Standard (NZS) ISO 31000:2018 *Risk Management – Principles and guidelines* (note the Likelihood and Consequence descriptors and Risk Matrix can be found in **Appendix B**).

## 4.2 Risk assessment methodology

The following key steps were undertaken to complete the climate change risk assessment (DEH, 2006 and AS 5334:2013):

1. Identification of key climate variables (such as temperature, rainfall, and extreme events) and the climate variability that differentiates regional climate zones.
2. Development of potential climate change scenarios, based on the latest climate science, that broadly identify how each climate variable may change over the design life of the proposed works.
3. Identification of broad climate-based risks that may impact on the proposed works.
4. Completion of a high-level climate change risk assessment, with risk ratings evaluated using the project-specific Risk Management framework criteria and further refined through stakeholder consultation to evaluate and socialise the consequence and likelihood of each risk.
5. Identification of treatment options to mitigate and respond to climate risks.

Figure 4-1 identifies how risks to the Project have been developed from an assessment of climate variables and projected changes in climate.

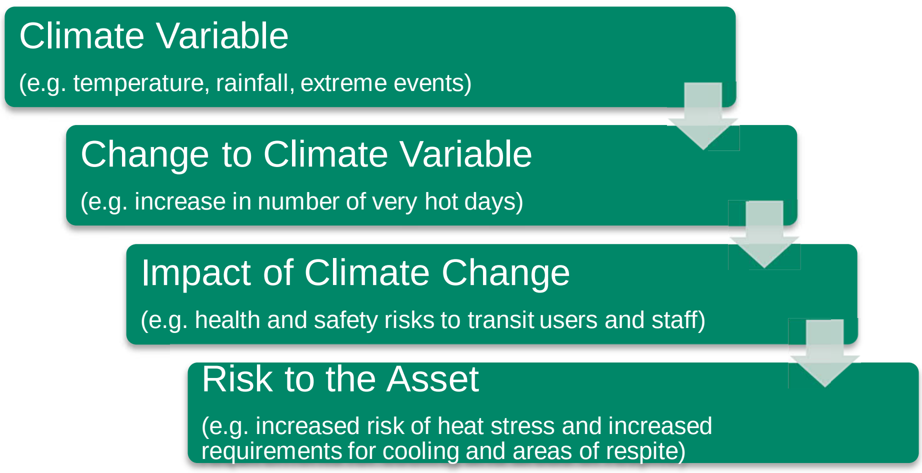


**Figure 4-1 - Climate Change Risk Assessment Process (adapted from DEH, 2006)**

## 4.3 Stakeholder consultation

To review, evaluate and validate climate risks to the Project, a workshop was undertaken with key stakeholders on the 8 June 2021. In addition to the session facilitator, the workshop was attended by 31 key internal and external stakeholders (both in person and virtually) from:

- Major Projects Canberra
- Canberra Metro Operations
- Infrastructure Australia
- Cox Architecture
- Layer 2 Intelligence (Rail Network Integration), and
- AECOM (Design, and Sustainability and Resilience)
- Transport Canberra and City Services
- Environment, Planning and Sustainable Development Directorate.

These stakeholders contributed to the validation and further identification of climate risks, as well as undertaking a sensitivity test of the risk ratings attributed to each risk and efforts to prioritise risks for future action. Key risks areas identified during the stakeholder workshop included:

- The potential impacts due to extreme rainfall impacting on drainage infrastructure and surrounding areas resulting in nuisance flooding
- The exacerbation of extreme heat impacts due to the highly urbanised nature of the Project footprint including safety risks to transport users from lack of shading as well as implications for electrical equipment
- The consideration of drought and changes to rainfall impacting on landscaping, particularly in relation to the green infrastructure and ongoing maintenance.

Furthermore, discussion during the workshop included the identification of a range of opportunities for design elements and other responses to be incorporated to enhance the climate resilience of the Project through the implementation of treatment options.

Refer to **Appendix C** for a summary of workshop participants and a copy of the workshop materials. Workshop participants were consulted in the refinement and development of climate risks, risk ratings and treatment options for the Project. This includes better considering climate change through sensitivity testing for flooding and rainfall, the use of additional shade and cooling materials to reduce heat impacts and climate-wise considerations for landscaping along the footprint to better account for heat, drought and changes in rainfall.

# 5.0 Existing environment

## 5.1 Overview

The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC, 2021) states with high confidence that Australia is already experiencing impacts from recent climate change, including a greater frequency and severity of extreme weather events, an increase in record hot days, a decrease in record cold days and increases in global GHG concentrations.

As highlighted in the *State of The Climate* (CSIRO and BoM, 2020) report, it is noted that Australia's climate has warmed on average by 1.44°C (+/- 0.24°C) since 1910. It is noted that the Paris Climate Change Accord (effective 4 November 2016) seeks to limit climate change to under 2°C with a target of 1.5°C.

Other key points of note from *State of The Climate 2020* include:

- There has been an increase in extreme fire weather, and in the length of the fire season, across large parts of the country since the 1950s, especially in southern Australia
- In the southeast of Australia there has been a decline of around 12 per cent in April to October rainfall since the late 1990s
- There has been a decrease in streamflow at the majority of streamflow gauges across southern Australia since 1975.

## 5.2 Climate variables

Climate variables fall into two categories: primary and secondary effects.

- **Primary effects** are those climate variables that are directly influenced or changed as a result of climate change. These include things such as air temperature, precipitation, wind and solar exposure.
- **Secondary effects** are those derived from primary effects, but still influenced by climate change. These include things such as bushfire weather and drought.

Selection of climate variables are based on the following factors:

- The location of the Project in an area subject to overland flooding
- The location of the Project being surrounded by areas subject to increased bushfire risk (resulting in smoke impacts)
- The location of the Project within an urbanised area, contributing to higher ambient temperatures and greater durations of heatwaves, and
- A growing trend of increased drought conditions, influencing water availability in the region.

The relevant climate variables applicable to the Project are listed below. It is noted that due to the inland location the Project, sea level rise was not considered.

- Mean ambient temperature, extreme heat days and heatwaves
- Solar exposure / radiation
- Average annual and extreme rainfall
- Bushfire weather
- Flooding and flash floods
- Drought / evapotranspiration
- Storm events.

## 5.3 Local climate context

The local climate surrounding the Project (being the broader region – not simply the urban area of the Canberra central business district) varies widely owing to the range of topographical conditions over a relatively small area. Areas to the north of Canberra are characterised by relatively dry and warm conditions, based on its lower altitudes and flatter land, while areas to the south experience colder temperatures, being higher in elevation.

The average annual temperature for the region is 16°C with an average summer temperature range of 20-22°C and average winter temperature range of 12-14°C. Long term temperature measurements have shown an increase in annual temperatures from around 1950 to present, with an acceleration in the rate of increase over the past 20 years. Furthermore, the area experiences fewer than 10 days over 35°C per year. It is worth noting however, that the three hottest days on record (across the months of December, January and February) have occurred since December 2019 – highlighting the increasing trend of hotter days and more frequent heatwaves (BoM, 2021).

Rainfall throughout the area is largely consistent across the seasons with limited variability, with an average of 100-300 mm per season, bringing an average annual total of approximately 800-1200 mm. The first decade of the 21st century however was characterised by lower than average rainfall (associated with the Millennium Drought) (ACT Government, 2019).

Bushfires are highly dependent on four criteria –available fuel, dry fuel loads, favourable weather conditions (e.g. high winds) and an ignition source. In NSW and the ACT, the Forest Fire Danger Index (FFDI) is the mechanism for measuring fire weather. FFDI combines the observed climate variables of temperature, humidity and wind speed. Long term FFDI estimates for Canberra show daily average FFDI of 7 (indicating low to moderate fire weather), while observations note that Canberra has on average, 1.1 severe fire weather days each year.

## 5.4 Observed climate

The past five years saw a range of extreme weather events affect the area in which the Project would be located, but also the broader surrounds of Canberra.

**Table 5-1 Summary of recent climate events**

| Climate Events | Date | Impacts |
|---|---|---|
| Extreme rainfall | December 2017 | Canberra Airport recorded 55mm of rain over an 8 hour period resulting in wide-spread flooding events (Sibthorpe & Evans, 2017) |
| Extreme rainfall | February 2018 | More rain fell in 6 hours than a typical month of February which resulted in the backflow of stormwater drainage across the city, disrupting services and flooding of residential areas resulting in damage (Australian Institute for Disaster Resilience, 2018) |
| Extreme storm | January 2019 | Damaging hail and uprooted trees resulted in numerous callouts to emergency services across Canberra including for accidents, power outages and other disruptions (Lindell & Dingwall, 2019) |
| Bushfire | Summer 19/20 | Bushfires (both flames and smoke) resulted in a backlog of emergency callouts, heavy smoke across the city (including several days where air quality was the worst in the world) and requirements for residential evacuation (and in some cases, 'too late to leave warnings') (Brown & Bungard, 2019), (Australian Associated Press, 2019) - refer Figure 5-1 |
| Extreme heat | January 2020 | Highest ever temperature was recorded in Canberra (44°C) resulting in increased heat stress and disruptions across the city (Brown, 2020) as well as leading to drought conditions bordering on a 'worst-case scenario' as defined by Icon Water[1] (Lievre, 2020) |
| Extreme storm | January 2020 | Hailstones damaged numerous buildings and vehicles as well as lightning which resulted in injuries to multiple persons (Guardian |

[1] https://www.canberratimes.com.au/story/6586098/canberras-drought-close-to-worst-case-scenario/

| Climate Events | Date | Impacts |
|---|---|---|
| | | staff and Australian Associated Press, 2020), (Kanapathippillai & Lewis, 2020) - refer Figure 5-2 |
| Extreme rainfall | March 2021 | 60mm of rain was recorded in an hour, resulting in the wide-spread closure of roads, inundation of buildings and further disruption around the city (Mannheim, 2020), (Healy, 2021) |

**Figure 5-1 Bushfire impacts - existing Canberra Light Rail Stage 1. Source: Getty Images, 2020.**

**Figure 5-2 CBD flooding. Source: Canberra Times, 2020.**

## 5.5 Hazard mapping

To better understand the local climate and exposure of the Project, local hazard mapping was sourced to help identify risks. In particular, data was gathered for bushfire, flooding and urban heat. Additional mapping around flood hazards, erosion and heat is provided in **Appendix D**.

### 5.5.1 Bushfire

Figure 5-3 shows that while direct bushfire risk (from flames) is limited due to the urban nature of the area in which the Project is located, significant areas surrounding the footprint have high exposure, highlighting the potential impacts from smoke. Smoke risk can manifest as human health and safety concerns, potential disruption to electrical systems and increased maintenance requirements such as cleaning drains blocked with ash or debris.

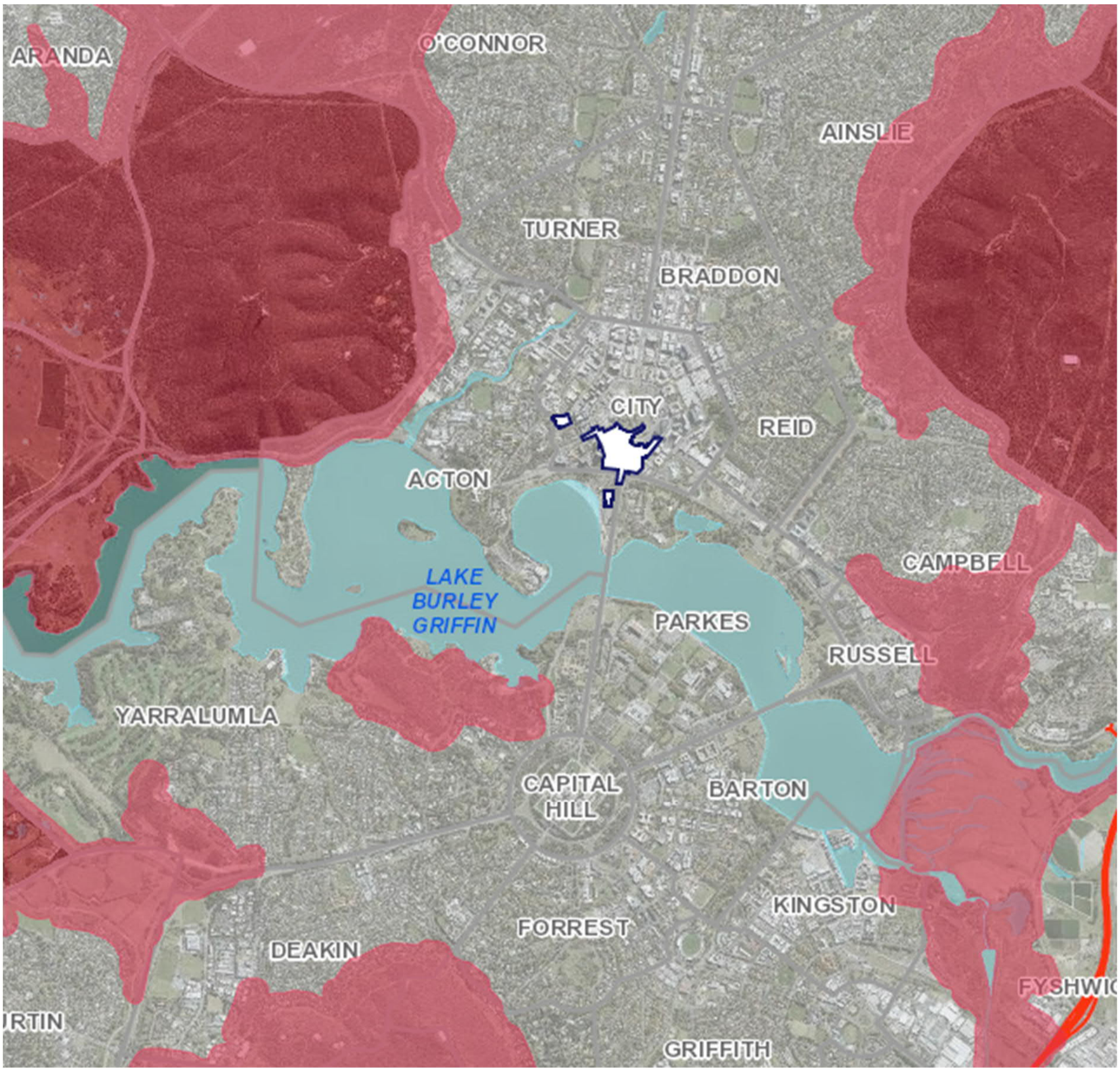


**Figure 5-3 Bushfire Prone Areas. Source: ACTmapi, 2021 (ACT Government, 2021).**

### 5.5.2 Flooding

A Flooding and Water Quality Assessment has been prepared for the Project. The existing flood extents, levels and depths for the 5% annual exceedance probability (AEP) flood are presented on Figure 5-4 and for the 1% AEP flood on Figure 5-5. The AEP percentage signifies the probability that a flood event will occur in any year.

These figures below show that for the 5% AEP event, flood depths within the Project footprint range from 10 mm to 700 mm in isolated pockets at the southern extent of the existing cloverleaf arrangement. Similarly, they range from 10 mm to 740 mm for the 1% AEP event. During the 1% AEP event, flooding may be experienced at the southern extent of the existing clover leaf arrangement as well as on London Circuit adjacent to the QT Hotel, and adjacent to London Circuit, at the section 116 carpark.

These depths and extents of possible floods events indicate that the existing stormwater drainage network generally has sufficient capacity to convey the 5% AEP flood waters. For the 1% AEP, more areas are flood affected.

While the Project would be minimally affected by the 5% AEP and 1% AEP flood event, it is noted that flood events may result in a backflow of drainage infrastructure, resulting in potential impacts such as nuisance flooding and inundation of the footprint resulting in disruption to traffic movements.

It is also noted that the areas subject to inundation within these maps to not account for any potential future increases due to rainfall, overland flow or construction of additional infrastructure.

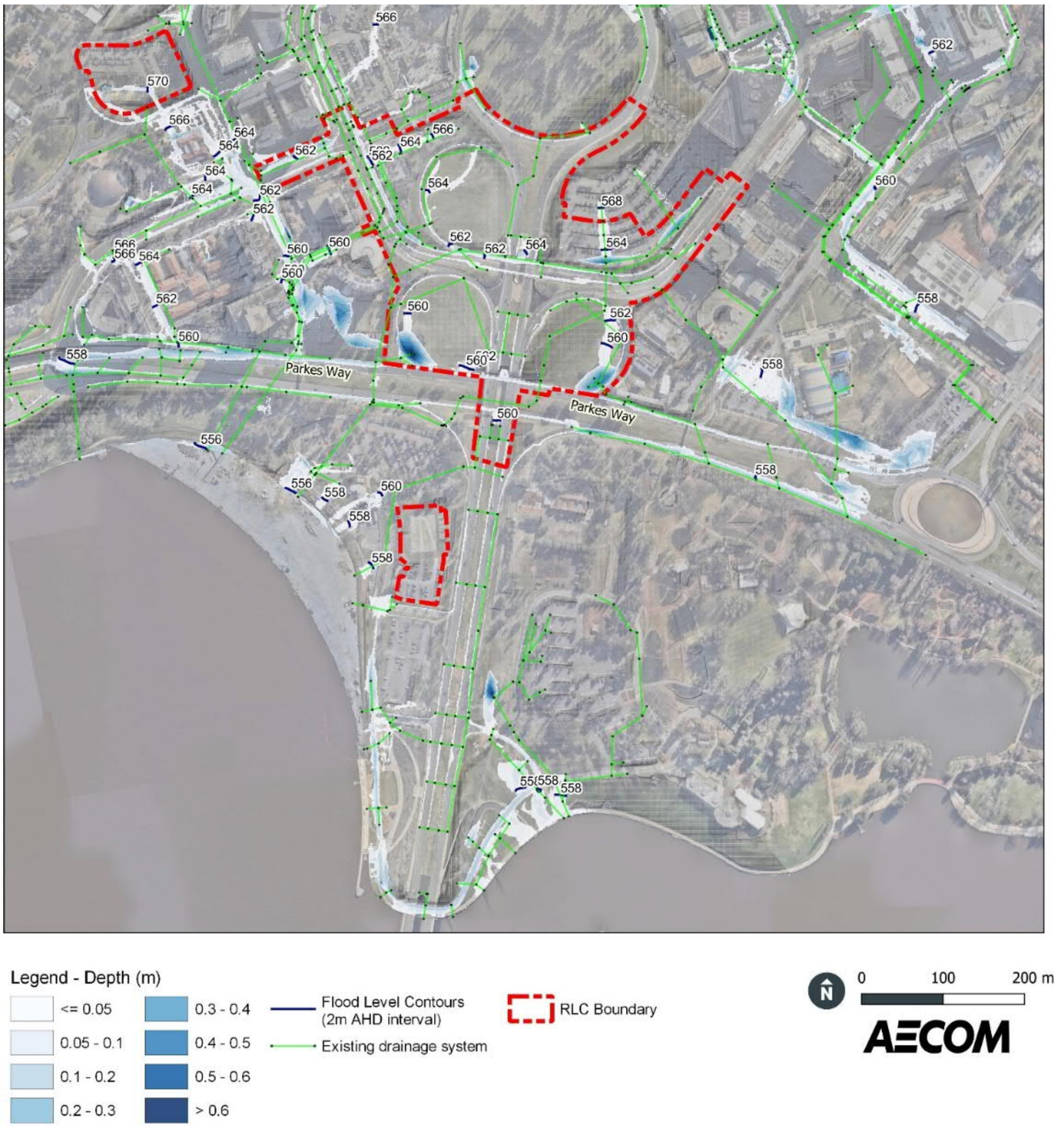


**Figure 5-4 Existing conditions 5% AEP flood extents, levels and depths**

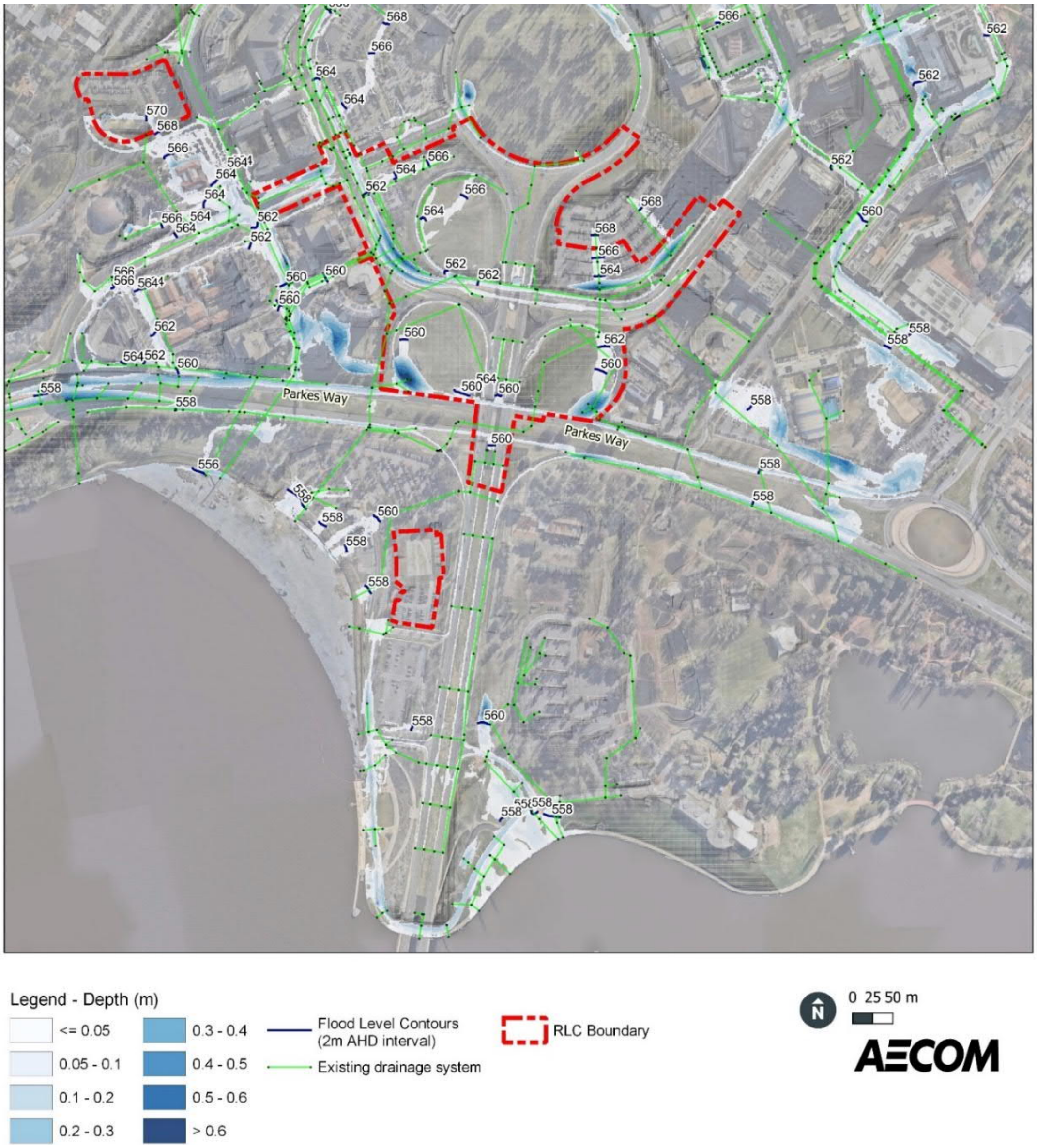


**Figure 5-5 Existing conditions 1% AEP flood extents, levels and depths.**

### 5.5.3 Urban Heat

Figure 5-6 shows the relative heat distribution across the ACT region, in particular the maximum temperatures experienced during the day, minimum temperatures at night and the relative difference in day and night temperatures over a summer period. While the Project is generally located within areas of lower maximum temperature (Plate (a)), due to the urban nature of the surrounds, it experiences a higher average night-time temperature (Plate (b)). The smaller range between maximum and minimum across the Project highlights how components (e.g. pavements), active transport users and other Project elements (e.g. landscaping) are subject to higher ongoing temperatures and do not experience the night-time reprieve when compared to the surrounds. This can result in difficulties as electrical equipment operates at higher temperatures for longer periods (higher risk of failure) and materials (such as pavements) degrade quicker due to heat exposure.

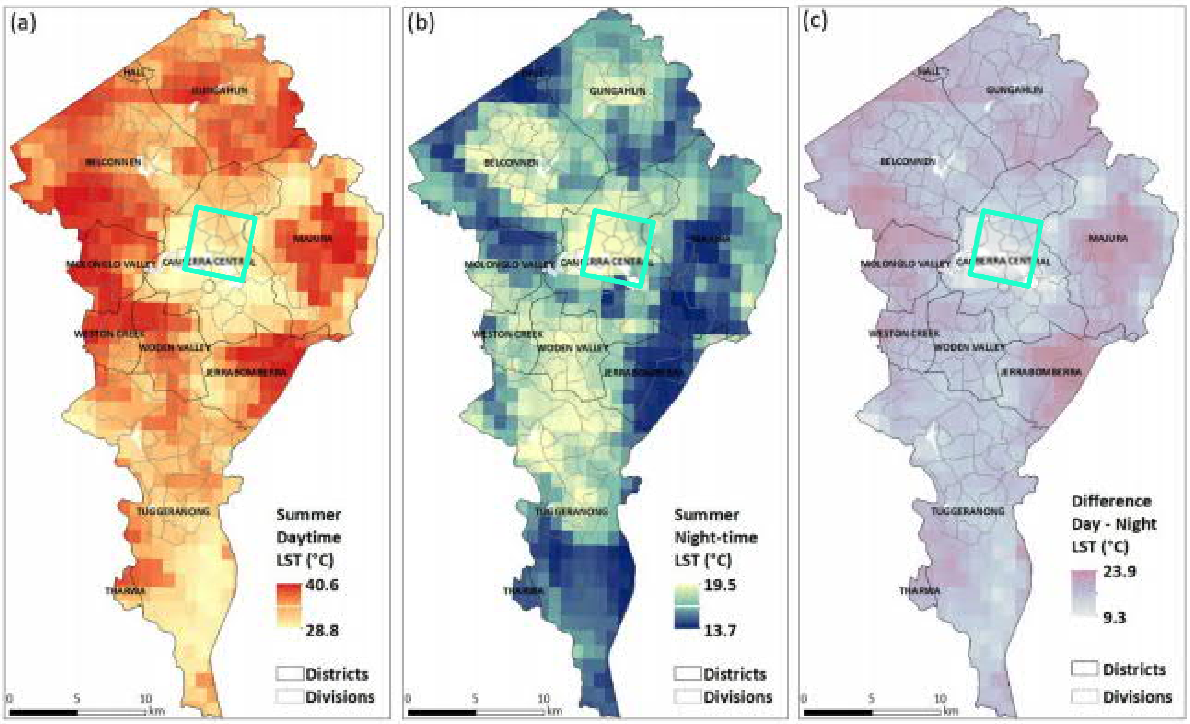


**Figure 5-6 Land Surface Temperatures. (Government, 2017). Approximate Project area shown in teal.**

# 6.0 Projected future conditions

The climate of Canberra, as is the case with global climate trends, is naturally variable; however, it is expected that climate change will lead to shifts beyond this natural variability. An assessment of the risk of climate change requires an understanding of the current climate using historical data for comparison with future climate scenarios.

Future climate scenarios are typically prepared using data from a Global Climate Models. Climate change model projections, generated by Global Climate Models, are tools used for understanding how the climate will respond to changes in greenhouse gas (GHG) emission levels.

Data projections for future climate scenarios were obtained from two data sources, NARCliM data, and CSIRO data. This allows for the comparison of data, which provides a better understanding of predicted future climate and can help assist in the identification of risks to the Project. Understanding the range of future climate scenarios and associated risk can also help inform the appetite for various treatment options and mitigation undertaken for the project.

NARCliM data presents regional downscaled climate projections for 12 regions within NSW and the ACT – the most appliable being the Australian Capital Territory Climate Change Snapshot (OEH and ACT Government, 2014).

The Murray Basin Cluster Report (CSIRO, 2015) provides the best approximation of future climate projection conditions for Canberra. These two reports have been used to inform this assessment with preference being given to the NARCliM data, while the CSIRO data was used as a basis of scenario comparison to understand potential differences in future impacts.

## 6.1 Time horizons

It is important to choose several time horizons for climate projections to understand how a changing climate may impact on various design elements, understanding that different assets and elements of the Project have varying design lives.

As the design lives for various components of the Project range from approximately:

- 10-20 years (e.g. pavements, electrical equipment)
- 50 years (e.g. drainage structures, tanks and inaccessible pipe systems)
- 100 years (e.g. culverts and concrete pits).

As a result, the time periods selected for the assessment are 2030 and 2070. Climate projections for these time scales represent averages over a 20 year period, being:

- Projections for 2030 represent the 20 year period between 2020-2039 (*near future*, as defined by AdaptNSW); and
- Projections for 2070 represent the 20 year period between 2060-2079 (*far future*, as defined by AdaptNSW).

In addition, projections for 2030 were identified as appropriate to account for potential impacts during construction as well as early years of the roadway operations, while projections for 2070 are relevant for the longer, on-going operation and maintenance requirements. Climate projections have been provided for 2090 to provide an understanding of the longer-term potential changes due to climate change for the longer lived elements such as drainage infrastructure. These are provided in **Appendix E**.

## 6.2 Emission scenarios

Greenhouse gas emission scenarios estimate the quantity of GHG that may be released into the atmosphere in the future, based on a range of possible future economic, business, social and environmental pathways.

The GHG emission scenario used to inform this CNHA was based on the Special Report on Emissions Scenarios (SRES) (IPCC, 2000) A2 scenario, representing a high emissions pathway driven by economic growth, which is projected to result in a global warming of approximately 3.4°C by

2100. The SRES A2 scenario was used as a review of current global emissions trajectory suggest we are tracking along the higher end of the A2 scenario.

The Climate Futures data used in this CNHA were for the representative concentration pathway (RCP) 8.5, which most closely corresponds to the SRES A2 data, given current trajectory. The RCP 8.5 pathway arises from little effort to reduce emissions and is most closely aligned with how global emissions are tracking (CSIRO, 2015).

## 6.3 Climate change projections

The most recent IPCC Assessment Report – AR 5 (AR5, 2013) states with high confidence, that Australia is currently experiencing impacts from climate change, including the greater frequency and intensity of extreme weather events. As noted in *State of The Climate 2020*, Australia is likely to experience a range of ongoing changes into the future including:

- Continued increases in air temperatures, more heat extremes and fewer cold extremes
- Continued decrease in cool season rainfall across many regions of southern and eastern Australia, likely leading to more time in drought, yet more intense, short duration heavy rainfall events
- A consequential increase in the number of dangerous fire weather days and a longer fire season for southern and eastern Australia.

A summary of the current climate science available based on AR5 for the Australian Capital Territory (OEH, 2014) is provided in Table 6-1. Detailed quantitative climate projections (including for the Murray Basin Cluster Report) are provided in **Appendix E** for reference. The Murray Basin Cluster Report is also based on AR 5 projections.

**Table 6-1 Climate projections**

| Climate variable | Baseline | 2030 | 2070 | Summary |
|---|---|---|---|---|
| **Mean temperature (ºC)** | 20 to 22ºC (Summer)<br>6 to 8ºC (Winter) | +0.7ºC<br>(0.50 to 0.81ºC) | +2.0ºC<br>(1.56 to 2.34ºC) | Changes in temperature often occur at the extremes, for instance increasing the duration of drought, extending bushfire seasons and resulting in heat waves that last longer and are more intense.<br>There is a high level of confidence across all models showing an increase in temperature for both the 2030 and 2070 timeframes across all temperature variables (average, maximum and minimum). The greatest change in temperature for the region is projected for the spring months. |
| **Average maximum temperature change (ºC)** | 26-28ºC (Summer) | +0.7ºC<br>(0.58 to 0.95ºC) | +2.0ºC<br>(1.82 to 2.48ºC) | |
| **Average minimum temperature change (ºC)** | 2-4ºC (Winter) | +0.6ºC<br>(0.40 to 0.74ºC) | +2.0ºC<br>(1.38 to 2.33ºC) | |
| **Extreme heat (days above 35ºC) for Canberra** | <10 days per year | +1 to 5 days | +10 to 20 days | While Canberra currently only experiences around 10 days per year where temperatures are higher than 35ºC, it is expected to experience more hot days in the future. The greatest increase is expected around the Canberra area for the far future.<br>Equipment, plant and individuals are sensitive to extreme temperature, with days over 35ºC having the potential to adversely impact on both infrastructure and people (such as active transport users).<br>Figure 6-1 shows the projected increase of days above 35ºC by 2070. |
| **Bushfire weather days (FFDI > 50)** | 1.1 days per year | +0.1 days<br>(-0.13 to 0.36 days) | +0.3 days<br>(-0.04 to +0.78 days) | Severe fire weather days (FFDI > 50) (FFDI – Forest Fire Danger Index: The FFDI combines observations of temperature, humidity and wind speed. Fire weather is classified as severe when the FFDI is above 50) are projected to increase, particularly during summer (peak fire risk) and spring (peak prescribed burning season) months across the region for both the 2030 and 2070 timeframes.<br>As shown previously in Figure 5-3, there is a low direct bushfire risk to the Project, however areas surrounding that are bushfire prone highlight a range of indirect risks (e.g. smoke inhalation for active transport users or potential power supply interruption with transmission lines disrupting Project lighting). |
| **Mean annual rainfall change (%)** | 400 to 800 mm per year | -2.8%<br>-11% to +8% | -0.4%<br>-9% to 13% | Mean annual rainfall varies considerably from year to year and this variability is reflected in global models. While overall rainfall is expected to remain much the same through 2030, seasonal falls are likely to change, with an increased forecast for autumn, while spring will likely see decreases in rainfall totals.<br>By 2070, annual rainfall is projected to increase, however seasonal projections span both drying and wetting scenarios, highlighting the need for appropriate consideration during Project planning.<br>Changes to rainfall can correspond to drought conditions, which in turn may impact the Project through increased risk of erosion / soil cracking and / or loss of landscaping / green infrastructure. |
| **Extreme rainfall - flooding** | N/A | Extreme rainfall events to increase in intensity and severity. | | While projections for extreme rainfall (NARCliM) are not yet available, in a warming climate, extreme rainfall events are expected to increase in intensity due to a warmer atmosphere being able to hold more moisture.<br>According to the CSIRO and BoM (CSIRO 2015), the period from 2010 to present has seen widespread, individual very-heavy rainfall events, particularly during the warmer months.<br>In 2017, an event where the 24 hour rainfall total exceeded the $99^{th}$ percentile resulted in wide-spread flash flooding across the city. |
| **Drought** | N/A | Time spent in drought conditions to increase | | Global models suggest a similar uncertainty for drought as it does mean rainfall change. The models do strongly indicate however, that there will be an increase in the proportion of time spent in drought. Variability in mean rainfall and the occurrence of storms will largely drive time spent in drought across the Central Slopes.<br>As ground conditions become further subjected to drought, there is an increased risk of infrastructure movement as a result of soil cracking. |

## 6.4 Projected future mapping

### 6.4.1 Bushfire

As highlighted above, the FFDI is based on a range of factors that sum to a numerical value. The value indicates the relative severity of fire conditions – being low to moderate, high, very high, severe, extreme and catastrophic. When FFDI values exceed 50, it is likely that total fire bans will be put in place to limit the potential for a bushfire.

The ACT is projected to experience an increase in both average and severe FFDI, both into the near future and far future – highlighting the increase potential for both indirect and direct bushfire risks to the project. Changes are projected to be higher in summer and spring (including a lengthening of the traditional 'bushfire season'), while autumn is projected to have a slightly lower occurrence of high FFDI days. This is largely related to the projected increase in rainfall for autumn.

### 6.4.2 Mean temperature, heatwaves and extreme heat days

According to projections provided by NARCliM, all temperature variables (minimum, average and maximum) are expected to increase across the ACT. By 2030, temperatures are projected to increase by 0.7ºC and 2ºC by 2070. It is noted that spring will experience the greatest rise in temperatures across the year – highlighting the growing risk to human health.

As shown below in Figure 6-1, the change in number of projected days above 35ºC is anticipated to be the highest for the Canberra region and surrounds (approximately 10-20 additional days per year), when compared to the rest of the ACT. As noted above, this is likely to be further exacerbated by the urban heat island effect, placing additional pressure onto electrical systems, pavements and landscaping.

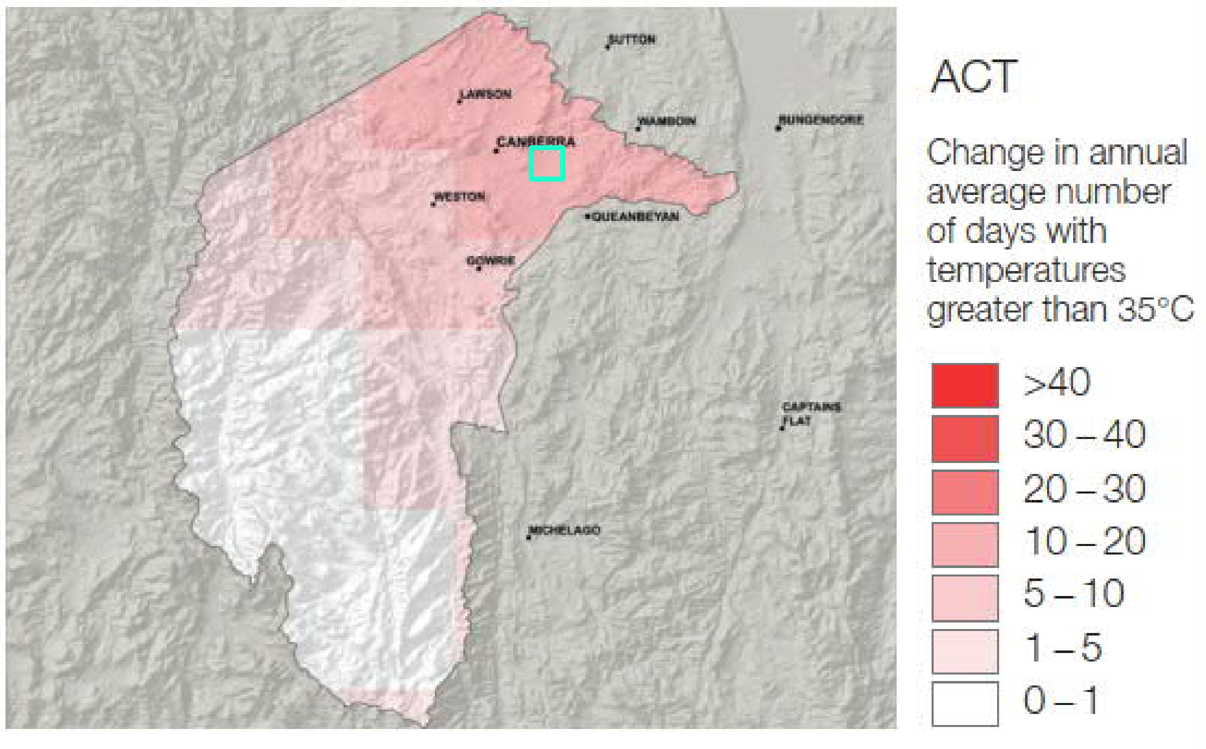


**Figure 6-1 Future changes in days per year above 35ºC. Source: AdaptNSW. Approximate location of the Project highlighted in teal.**

### 6.4.3 Mean rainfall, drought and extreme rainfall

Changes to mean rainfall are projected to remain highly variable into both the near future and far future. Changes in rainfall have the ability to exacerbate extreme events resulting in severe drought or more frequent flood events – both of which result in secondary impacts such as challenges for water quality and soil erosion. It is noted that rainfall in winter and spring is projected to decrease, while increases are projected for autumn.

As highlighted below in Figure 6-2 and Figure 6-3, changes in rainfall are projected to be highly variable into the future, with an anticipated decrease in rainfall by 2030, but increase in rainfall for Canberra by 2070. It is further projected that year on year changes will remain highly variable as well, highlighting the need to consider both drying (e.g. drought) and wetting (e.g. floods) scenarios.

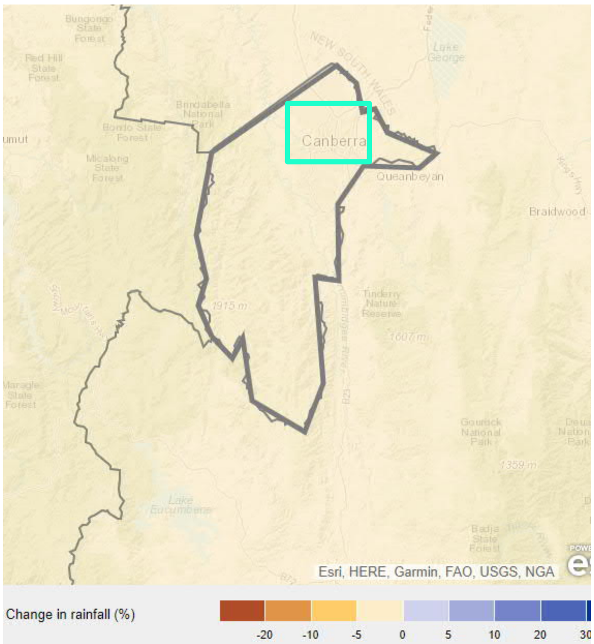


**Figure 6-2 Future changes in rainfall (percentage change) - 2030. Source: AdaptNSW. Approximate footprint highlighted in teal.**

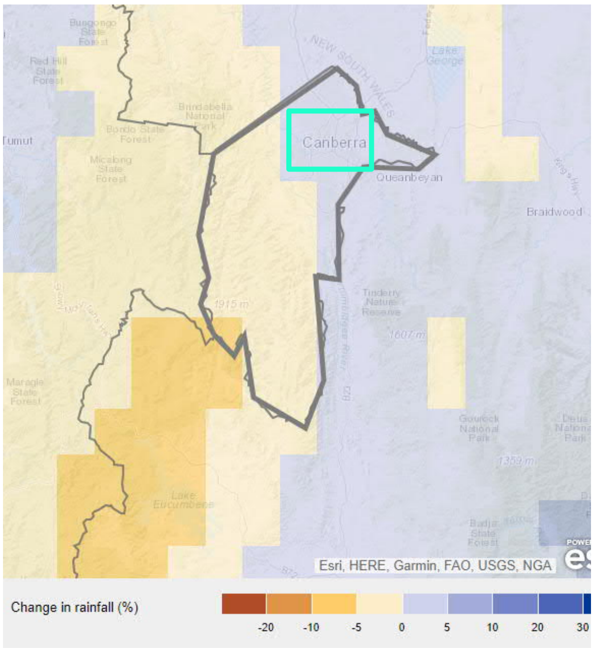


**Figure 6-3 Future changes in rainfall (percentage change) - 2070. Source: AdaptNSW. Approximate footprint highlighted in teal.**

# 7.0 Construction

## 7.1 Assessment of potential impacts

Risks to the Project as a result of climate events by way of delays in construction schedule and potential risks to human health and safety are likely, based on observed events and projected trends. The increased frequency and intensity of extreme weather events, increased rainfall, bushfires and rising temperatures are already causing strain on existing construction schedules and the availability of both workers and supplies.

The climate risk assessment identified a total of two (2) climate change risk statements relating to construction of the Project. Based on the rating of risk statements, there would be one (1) high or very high risk and no (0) extreme risks at 2030. It is noted that risks to construction were only assessed at the 2030 time horizon (and not 2070) as works are expected to be completed well in advance of 2030.

**Table 7-1 Climate Change Risks to Construction**

| Risk ID | Risk Statement | 2030 | | |
|---|---|---|---|---|
| | | Likelihood | Consequence | Risk Rating (Refer to Appendix A) |
| CR1 | Extreme rainfall (including wind and hail) and flooding resulting in delays to construction schedules and cost impacts. | Possible | Moderate | Medium |
| CR2 | Extreme heat (days over 35ºC) resulting in increased incidence of tools down and heat-related stress delays to construction, increasing schedules and cost impacts. | Likely | Moderate | High |
| CR3 | Bushfire smoke affecting visibility and air quality for construction workers | Possible | Moderate | Medium |

## 7.2 Management and mitigation measures

The following Table 7-2 outlines the associated mitigation and adaptation measure to reduce the impacts of the identified construction climate risks for the Project. Identified measures include a combined approach that addresses the avoidance of risk where possible, designing out risk where practicable, as well as management / operational procedure changes for risks that may be unavoidable.

The table also outlines identified adaptation measures that have already been considered as part of the design process, are currently underway, or will be undertaken prior to operation (planned). The identification of these adaptation measures has resulted from discussions with design leads and technical specialists, review of design information (including drawings and flooding reports) and documentation of existing operating practices.

**Table 7-2 Management and Mitigation Measures**

| Reference | Mitigation Measure | Timing |
|---|---|---|
| CC-1 | Health and safety plans will include measures for extreme events e.g. heat response (e.g. staffing plans, tools down, etc.) and heat-specific PPE for construction staff, and air quality response. | Prior to construction |
| CC-2 | Emergency response plans for construction staff will be prepared as part of Construction Environmental Management Plans to account for extreme events including extreme storms and rainfall. This includes | Prior to construction |

| Reference | Mitigation Measure | Timing |
|---|---|---|
| | coordination with emergency responders, training and evacuation procedures. | |
| CC-3 | Contingency to be built into the construction schedule to account for delays and disruptions due to extreme events. | Prior to construction |
| CC-4 | Temporary grass swales will be provided along the proposed earthworks within the cloverleaf areas to collect runoff approaching new earthworks batters and direct to the proposed drainage system. | During construction |

## 7.3 Residual impacts

The final step in completing the assessment outlined within this technical report is understanding the level of residual climate risk relative to the Project once the adaptation actions (management and mitigation measures) identified have been applied. In accordance with v.2.0 of the ISCA IS Rating Scheme Res-2 criteria, treatment options for all extreme and high-priority risks have been identified with appropriate measures implemented.

A residual risk assessment for the proposal was undertaken to apply the relevant adaptation measures identified in the above section for all 'high' and 'very high' risks as shown in Table 7-3.

In addition, adaptation actions have been identified to treat all 'medium' risks. Based on the application of the adaptation measures, no residual 'very high' or 'high' risk ratings remain for the Project. It is anticipated that as the Project develops, this register would continue to be incorporated into ongoing monitoring and evaluation documentation for the Project, and used to track compliance and progress against the adaptation measures to assist in reducing the risk exposure of the Project.

**Table 7-3 Residual Risk Table**

| Risk ID | Risk statement | Original Risk Rating | | Adaptation Actions | 2030 Revised | | |
|---|---|---|---|---|---|---|---|
| | | 2030 Rating | 2070 Rating | | Likelihood | Consequence | Risk Rating |
| Increased intensity of extreme rainfall & flash flooding events leading to: | | | | | | | |
| Direct risks | | | | | | | |
| CR-1 | Extreme rainfall (including wind and hail) and flooding resulting in delays to construction schedules and cost impacts. | Medium (Possible / Moderate) | *N/A* | • Emergency response plans for construction staff will be prepared as part of Construction Environmental Management Plans to account for extreme events including extreme storms and rainfall. This includes coordination with emergency responders, training and evacuation procedures.<br>• Temporary grass swales proposed will be provided along the proposed earthworks within the cloverleaf areas to collect runoff approaching new earthworks batters and direct to the proposed drainage system.<br>• Contingency to be built into the construction schedule to account for delays and disruptions due to extreme events. | Possible | Minor | Low |
| CR-2 | Extreme heat (days over 35°C) resulting in increased incidence of tools down and heat-related stress delays to construction, increasing schedules and cost impacts | High (Likely / Moderate) | *N/A* | • Contingency to be built into the construction schedule to account for delays and disruptions due to extreme events.<br>• Health and safety plans will include extreme heat response measures including:<br>- Consideration of temperature thresholds for tools down<br>- Heat-specific PPE for construction staff<br>- Split shifts to avoid hotter parts of the day.<br>- Rest areas and first aid points | Possible | Moderate | Medium |

| Risk ID | Risk statement | Original Risk Rating | | Adaptation Actions | 2030 Revised | | |
|---|---|---|---|---|---|---|---|
| | | 2030 Rating | 2070 Rating | | Likelihood | Consequence | Risk Rating |
| CR 3 | Bushfire smoke affecting visibility and air quality for construction workers | Medium | *N/A* | • Contingency to be built into the construction schedule to account for delays and disruptions due to extreme events.<br>• Health and safety plans will include extreme air quality response measures | Possible | Minor | Low |

# 8.0 Operation

## 8.1 Assessment of potential impacts

Using previous observed events and projected trends, risks to the Project associated infrastructure and human health and safety concerns are likely to occur. The consequences of this risk may include physical damage, increased discharge of water and the accelerated deterioration of assets. The increased frequency of extreme events including rainfall, heatwaves and bushfires are already impacting on infrastructure. Recent events both in and around Canberra have highlighted the susceptibility of infrastructure to these extreme events.

The climate risk assessment identified a total of 18 climate change risk statements relating to operation and maintenance of the Project, both direct and indirect risks. In the context of climate change impacts, direct risk comprise climate hazards (direct impacts of rainfall extremes such as exceeding infrastructure drainage capacity), while indirect climate-related impacts are secondary to the direct risk (roadways becoming inundated due to the failure of drainage infrastructure).

Based on the rating of risk statements, there would be two (2) high or very high risks and no (0) extreme (significant) risks at 2030, increasing to ten (10) high or very high risks and no (0) extreme risk (significant) risks at 2070, Table 8-1 provides a summary of the operational risk assessment, while Table 8-2 details the risk statements and risk ratings.

Risks have been grouped by the following climate variables:

- Extreme rainfall and flooding – 9 risks
- Extreme heat – 3 risks
- Drought / mean rainfall changes – 3 risks
- Extreme storms – 2 risks
- Bushfire – 1 risk.

**Table 8-1 Summary of Operational Risk Assessment**

| Risk Rating | 2030 | 2070 |
|---|---|---|
| Very Low & Low | 6 | 1 |
| Medium | 10 | 7 |
| Very High & High | 2 | 10 |
| Significant (Extreme) | 0 | 0 |
| **Total** | **18** | **18** |

**Table 8-2 Climate Change Risks to Operation (2030 and 2070)**

| Risk ID | Risk statement | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| | | Likelihood | Consequence | Risk rating | Likelihood | Consequence | Risk rating |
| Increased intensity of extreme rainfall & flash flooding events leading to: | | | | | | | |
| Direct risks | | | | | | | |
| R1 | Exceeding the capacity of drainage infrastructure due to blockage from debris such as mulch leading to inundation and nuisance flooding of the roadway | Almost Certain | Minor | High | Almost Certain | Minor | High |
| R2 | Exceeding the capacity of drainage infrastructure due to high volumes of water leading to inundation of the roadway | Possible | Moderate | Medium | Likely | Moderate | High |
| R3 | Scour of key infrastructure (e.g. embankments, cuttings, drainage inlets / outlets) and subsequent maintenance, repairs and service disruptions | Unlikely | Moderate | Low | Unlikely | Moderate | Low |
| R4 | Increased load on stormwater treatment and erosion and sediment control devices (e.g. WSUD) affecting water quality treatment levels | Likely | Minor | Medium | Almost Certain | Minor | High |
| R5 | Increased load on stormwater treatment and erosion and sediment control devices (e.g. WSUD) mobilising pollutant load impacts on operations | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| R6 | An increase in volume of runoff from catchment areas, increasing loads for Project drainage | Likely | Moderate | High | Likely | Moderate | High |
| R7 | An increased water table, resulting in increased loading on structures (e.g. underground pits, retaining walls) | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| Indirect risks | | | | | | | |
| R8 | Exceeding the capacity of network drainage infrastructure (due to either blockage from debris such as mulch or volume of water) leading to inundation of surrounding roads or buildings | Possible | Moderate | Medium | Likely | Moderate | High |
| R9 | Inundation of the surrounding road and rail network (e.g. Stage 1) resulting in reduced access to the roadway (e.g. emergency services, maintenance workers) | Possible | Moderate | Medium | Likely | Moderate | High |
| Increased intensity of extreme storm (including lightning) and wind events resulting in: | | | | | | | |
| Direct risks | | | | | | | |
| R10 | Damage to bridges and other connections (e.g. cycleway, pedestrian, road) resulting in service delay, limited access to stations and potential safety impacts (e.g. active transport users and maintenance workers) | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| Indirect risks | | | | | | | |
| R11 | Damage to the surrounding road and rail network due to debris, fallen branches, etc. resulting in reduced access to the roadway | Possible | Moderate | Medium | Likely | Moderate | High |

| Risk ID | Risk statement | 2030 | | | 2070 | | |
|---|---|---|---|---|---|---|---|
| | | Likelihood | Consequence | Risk rating | Likelihood | Consequence | Risk rating |
| Increased intensity and duration of extreme heat events and increased average temperatures resulting in: | | | | | | | |
| Direct risks | | | | | | | |
| R12 | Adverse impacts to plant species (e.g. wilting of plants), resulting in increased landscaping costs and exacerbate erosional issues | Likely | Minor | Medium | Almost Certain | Minor | High |
| R13 | Increased damage and accelerated degradation of materials and equipment (e.g. concrete, electrical equipment and paved areas) requiring increased maintenance or costs to replace | Likely | Minor | Medium | Almost Certain | Minor | High |
| R14 | Increased expansion movement within key infrastructure joints / sealants resulting in failure, early replacement and increased maintenance and operational costs | Possible | Minor | Low | Likely | Minor | Medium |
| Changes to average annual rainfall and increased duration and intensity of drought resulting in: | | | | | | | |
| Direct risks | | | | | | | |
| R15 | Soil subsidence, movement and cracking as a result of increased variability of soil wetting/drying. This may reduce the integrity of foundations and bridge piles potentially resulting in structural failure over the long-term | Unlikely | Major | Medium | Unlikely | Major | Medium |
| R16 | Decreased availability of water during periods of drought negatively impacting on landscaped areas (particularly green infrastructure) | Likely | Minor | Moderate | Almost Certain | Minor | High |
| R17 | Increased incidents of animal strikes as animals are drawn from surrounding areas to irrigated areas and other water sources along the Project footprint | Possible | Minor | Low | Likely | Minor | Medium |
| Increased frequency and intensity of bushfire and dust events resulting in: | | | | | | | |
| Indirect risks | | | | | | | |
| R18 | Closure of the surrounding road network, impacting emergency access or rescue as well as maintenance needs | Possible | Moderate | Medium | Possible | Moderate | Medium |

## 8.2 Management and mitigation measures

Table 8-3 outlines the planned management and mitigation measures to reduce the impacts of the identified operational climate risks for the Project. Identified measures include a combined approach that addresses the avoidance of risk where possible, designing out risk where practicable, as well as management / operational procedure changes for risks that may be unavoidable.

It is noted that for the purpose of the risk assessment, there are a range of actions / treatment options that have been identified as already having been integrated into the design or part of the planning process. These actions have not been included in the following table, but have been used to inform the residual risk assessment (identified as 'current actions') and are provided in the full list of treatment options in **Appendix F**.

The identification of these adaptation measures has resulted from discussions with design leads and technical specialists, review of design information (including drawings and flooding reports) and documentation of existing operating practices.

**Table 8-3 Management and Mitigation Measures**

| Reference | Mitigation Measure | Timing |
|---|---|---|
| CC-5 | Permeable surfaces will be used in the public realm and verged areas through the use of pavements, green infrastructure and other mechanisms. | Detailed design |
| CC-6 | Flood protection will be provided through consideration of flood levels where identified in the flood study (including climate change) when deciding RLs across alignment. | Detailed design |
| CC-7 | Materials (e.g. electrical box coverings, lighting) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure. | Detailed design / procurement / construction |

## 8.3 Residual impacts

The final step in completing the assessment outlined within this technical report is understanding the level of residual climate risk relative to the Project once the adaptation actions (management and mitigation measures) identified have been applied. Treatment options for all extreme and high-priority risks have been identified with appropriate measures implemented.

A residual risk assessment for the proposal was undertaken to apply the relevant adaptation measures identified in the above section for all 'very high' and 'high' risks and shown in Table 8-4. As a result of the application of treatment options, for the 2030 time period, of the seven (7) medium risks and five (5) high and very high risks, the residual risk rating has resulted in a downgrading to eight (8) low or very low risks, four (4) medium risks. It is noted that additional actions are currently being pursued to respond to the remaining high risk and that subject to inclusion, it is anticipated that this risk will be adequately treated.

In addition, adaptation actions identified contributed towards treating all 'medium' risks, resulting in a number of those 'medium' risks having their corresponding residual risks revised to 'low'. Based on the application of the adaptation measures, no residual 'very high' or 'high' risk ratings remain for the Project,. As part of the residual risk assessment, individual, specific adaptation measures have been applied to multiple risks to help reduce the potential risks to the Project. It is anticipated that as the Project develops, this register will continue to be used to track compliance and progress against the adaptation measures to assist in reducing the risk exposure of the proposal.

**Table 8-4 Residual Risk**

| Risk ID | Risk statement | Original Risk Rating | | Adaptation Actions | 2030 Revised | | | 2070 Revised | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2030 Rating | 2070 Rating | | Likelihood | Consequence | Risk Rating | Likelihood | Consequence | Risk Rating |
| Increased intensity of extreme rainfall & flash flooding events leading to: | | | | | | | | | | |
| Direct risks | | | | | | | | | | |
| R1 | Exceeding the capacity of drainage infrastructure due to blockage from debris such as mulch leading to inundation and nuisance flooding of the roadway | High (Almost Certain / Minor) | High (Almost Certain / Minor) | Current Actions<br>Where feasible and where the Project design is not constrained by existing infrastructure the following would be provided:<br>• All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities<br>• Curb levels have been set higher than bed levels to reduce the potential of mulch escaping and blocking drains<br>• Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials blocking the drainage<br>• Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Likely | Minor | Medium | Likely | Minor | Medium |
| R2 | Exceeding the capacity of drainage infrastructure due to high volumes of water leading to inundation of the roadway | Medium (Possible / Moderate) | High (Likely / Moderate) | Current Actions<br>Where feasible and where the Project design is not constrained by existing infrastructure the following would be provided:<br>• Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br>• All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities<br>• Water Sensitive Urban Design –such as bio-retention tree pits to collect and clean stormwater<br>• Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials blocking the drainage<br>• Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Possible | Moderate | Medium | Possible | Moderate | Medium |
| R4 | Increased load on stormwater treatment and erosion and sediment control devices (e.g. WSUD) affecting water quality treatment levels | Medium (Likely / Minor) | High (Almost Certain / Minor) | Current Actions<br>Where feasible and where the Project design is not constrained by existing infrastructure the following would be provided:<br>• Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 20% increase in peak rainfall and stormwater)<br>• All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities<br>• Water Sensitive Urban Design – bio swales / bio-retention tree pits to collect and clean stormwater<br>• Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Possible | Minor | Low | Likely | Minor | Medium |
| R6 | An increase in volume of runoff from catchment areas, increasing loads for Project drainage | High (Likely / Moderate) | High (Likely / Moderate) | Current Actions<br>Where feasible and where the Project design is not constrained by existing infrastructure the following would be provided:<br>• Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br>• All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities<br>• Water Sensitive Urban Design – bio swales / bio-retention tree pits to collect and clean stormwater<br>• Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Likely | Minor | Medium | Likely | Minor | Medium |

| Risk ID | Risk statement | Original Risk Rating | | Adaptation Actions | 2030 Revised | | | 2070 Revised | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2030 Rating | 2070 Rating | | Likelihood | Consequence | Risk Rating | Likelihood | Consequence | Risk Rating |
| R8 | Exceeding the capacity of network drainage infrastructure (due to either blockage from debris such as mulch or volume of water) leading to inundation of surrounding property (outside of project construction footprint) | Medium (Possible / Moderate) | High (Likely / Moderate) | Current Actions<br>Where feasible and where the Project design is not constrained by existing infrastructure the following would be provided:<br>• Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater)<br>• All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities<br>• Water Sensitive Urban Design – bio swales / bio-retention tree pits to collect and clean stormwater<br>• Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials blocking the drainage<br>• Incorporate and model 100% permeable surfaces into the public realm through the use of pavements, green infrastructure and other mechanisms<br>• Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Unlikely | Moderate | Low | Possible | Moderate | Medium |
| Indirect risks | | | | | | | | | | |
| R9 | Inundation of the surrounding road and rail network (e.g. Stage 1) resulting in reduced access to the roadway (e.g. emergency services, maintenance workers) | Medium (Possible / Moderate) | High (Likely / Moderate) | Current Actions<br>Where feasible and where the Project design is not constrained by existing infrastructure the following would be provided:<br>• All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities<br>• Emergency response plans for active transport users have been prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | Possible | Minor | Low | Likely | Minor | Medium |
| Increased intensity of extreme storm (including lightning) and wind events resulting in: | | | | | | | | | | |
| Indirect risks | | | | | | | | | | |
| R11 | Damage to the surrounding road network due to debris, fallen branches, etc. resulting in reduced access to the roadway | Medium (Possible / Moderate) | High (Likely / Moderate) | Current Actions<br>• Emergency response plans for active transport users have been prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | Possible | Minor | Low | Likely | Minor | Medium |
| Increased intensity and duration of extreme heat events and increased average temperatures resulting in: | | | | | | | | | | |
| Direct risks | | | | | | | | | | |
| R12 | Adverse impacts to plant species (e.g. wilting of plants), resulting in increased landscaping costs and exacerbate erosional issues | Medium (Likely / Minor) | High (Almost Certain / Minor) | Current Actions<br>• Landscape features and plantings have been selected (including the use of natives) to resist drought and hotter conditions in accordance with the ANU Urban Forest Tree Species Research program. This includes the use of mulch in planting areas to encourage infiltration and reduce evaporation.<br>• Asset management plans have been developed to account for both seasonal variation and in response to climate variables (e.g. frequency of inspection / maintenance)<br>• Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including planting schedules | Possible | Minor | Low | Likely | Minor | Medium |
| R13 | Increased damage and accelerated degradation of materials and equipment (e.g. concrete, electrical equipment and paved areas) requiring increased maintenance or costs to replace | Medium (Likely / Minor) | High (Almost Certain / Minor) | Current Actions<br>• Materials (e.g. electrical box coverings) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy<br>• The gauge of the proposed stainless steel sheet cladding, location and provision of ventilation (e.g. double-skinned) in the integrated services cabinets is sufficient to prevent oil-canning in extreme temperatures<br>• Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including electrical equipment | Possible | Minor | Low | Likely | Minor | Medium |

| Risk ID | Risk statement | Original Risk Rating | | Adaptation Actions | 2030 Revised | | | 2070 Revised | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2030 Rating | 2070 Rating | | Likelihood | Consequence | Risk Rating | Likelihood | Consequence | Risk Rating |
| Changes to average annual rainfall and increased duration and intensity of drought resulting in: | | | | | | | | | | |
| Direct risks | | | | | | | | | | |
| R15 | Soil subsidence, movement and cracking as a result of increased variability of soil wetting/drying. This may reduce the integrity of foundations and bridge piles potentially resulting in structural failure over the long-term | Medium (Unlikely / Major) | Medium (Unlikely / Major) | Current Actions<br>• Landscape features and plantings have been selected (including the use of natives) to resist drought and hotter conditions in accordance with the ANU Urban Forest Tree Species Research program. This includes the use of mulch in planting areas to encourage infiltration and reduce evaporation | Unlikely | Major | Medium | Unlikely | Major | Medium |
| R16 | Decreased availability of water during periods of drought negatively impacting on landscaped areas (particularly green infrastructure) | Medium (Likely / Minor) | High (Almost Certain / Minor) | Current Actions<br>• Landscape features and plantings have been selected (including the use of natives) to resist drought and hotter conditions in accordance with the ANU Urban Forest Tree Species Research program. This includes the use of mulch in planting areas to encourage infiltration and reduce evaporation | Possible | Minor | Low | Likely | Minor | Medium |
| Increased frequency and intensity of bushfire and dust events resulting in: | | | | | | | | | | |
| Indirect risks | | | | | | | | | | |
| R18 | Closure of the surrounding road network, impacting emergency access or rescue as well as maintenance needs | Medium (Possible / Moderate) | Medium (Possible / Moderate) | Current Actions<br>• Coordinate with operators of connecting transport prior to, and during bushfire events<br>• Emergency response plans for transit staff and transit users have been prepared to account for extreme events including heatwaves, bushfire events and extreme storms. This includes coordination with emergency responders, training and evacuation procedures as well as clearly sign-posted emergency warnings and evacuation routes | Possible | Minor | Low | Possible | Minor | Low |

# 9.0 Conclusion

As this CNHA has confirmed, extreme rainfall, flooding and extreme heat are expected to pose the greatest risk to the Project in both the near future and far future. Risks associated with these events include:

- The potential impacts due to extreme rainfall impacting on drainage infrastructure and surrounding areas resulting in nuisance flooding
- Reduced access to the Project and surrounding areas impacting on emergency response during extreme events (e.g. storms, bushfire), and
- The consideration of drought, extreme heat and changes to rainfall impacting on landscaping, particularly in relation to green infrastructure and ongoing maintenance.

The findings of this assessment have confirmed that as a result of the application of treatment options, for the 2030 time period, of the seven (7) medium risks and five (5) high and very high risks, the residual risk rating has resulted in a downgrading to eight (8) low or very low risks, four (4) medium risks. It is noted that additional actions are currently being pursued to respond to the remaining high risk and that subject to inclusion, it is anticipated that this risk will be adequately treated.

It is recognised that while there is uncertainty regarding the extent to which the climate will change beyond 2030, the adaptation actions identified within this assessment will result in the lowering of residual risks across a range of future scenarios (both emissions pathways and future time frames).

## 9.1 Next steps

As noted above, the climate risk and adaptation actions identified in this report have been tested and refined through feedback and discussion from team members across a range of disciplines and provide a baseline assessment to inform the design process. There are opportunities to identify and explore additional treatment options to add value and support improved response to climate change. These could include:

- Exploring initiatives such as coordination / opportunities with other stakeholders for downstream augmentation to support better drainage outcomes as well as additional water capture options to improve response to flood risks and extreme rainfall
- Communicating outcomes of Project investigations, such as sensitivity testing and shading constraints, to surrounding stakeholders to develop shared / collaborative responses
- Exploring additional options to improve to response to extreme heat through actions such as additional shading along the footprint, materials selections for Project elements (e.g. pervious pavements) and reviewing key specifications (such as pavement design) to ensure they can accommodate future increases in temperature

In order to apply these findings and support the requirements set out the policies and strategies discussed in Section 3.0, the following next steps are recommended:

- **Risk and adaptation review –** the risk assessment and adaptation actions have been identified based on the current design for the Project and are a snapshot at this time in the Project development process. It is noted that the adaptation actions should be re-examined at future design milestones or phases to confirm inclusion and suitability as well as for feasibility of construction for the Project. Changes to the adaptation actions may reduce the ability to respond to the identified risks.

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# Appendix A

## IS Rating Tool v2.0 Res-2: Planning summary criteria table

# Appendix A IS Rating Tool v2.0 Res-2: Planning summary criteria table

| | Benchmark / Criteria | Where addressed in the report |
|---|---|---|
| Level 1 | PL1.1 – Review and identify any inherent levels of tolerance to climate and natural hazards afforded by each Project option | An evaluation of three strategic Project alternatives was undertaken at an early stage of the Project design. This options evaluation took into consideration the goals presented in the National Capital Plan for Canberra City and its surrounds and the Project vision and objectives (described in Section 2.1.2 of the EA). As an outcome of this evaluation, a single preferred option was selected (the Project). As such, this report provides an assessment of the Project only. |
| | PL1.2 – Undertake a high-level review of past and observed climate and natural hazard events for the site and specify how the future asset design will avoid or mitigate the associated risks. | A review of past climate events and an overview of the current climate and natural hazard risks are provided in **Section 5.0**. |
| | PL1.3 – A review of climate and natural hazard risks is completed using readily available and current natural hazard data and climate change projections for all <u>direct risks</u> to the asset. | Readily available (and the most up-to-date) natural hazard data and climate change projections are provided in **Section 5.0**, **Section 6.0** and **Appendix D**.<br>Direct risks to the asset are provided in both **Section 7.0**and **Section 8.0**. |
| | PL1.4 – Treatment options for <u>direct risks</u> are identified and implemented and after treatment there are no residual extreme and high-priority <u>direct risks</u>. | A full list of treatment options is provided in **Appendix E**.<br>The residual risk assessment showing application of treatment options (and no residual extreme or high-priority risks) for direct risks is provided in **Section 7.0** and **Section 8.3**. |
| | PL1.5 – A multidisciplinary internal team participated in the identification and assessment of climate and natural hazard <u>direct risks</u>, including selection of treatment options. | The methodology and outcomes of stakeholder engagement are provided in **Section 4.3**, with a copy of the workshop materials and activities (used to identify and assess direct risks and treatment options) provided in **Appendix B**. |
| Level 2 | PL2.1 – The climate and natural hazard risk assessment also considers <u>indirect risks</u> to the asset. | Indirect risks to the asset are provided in **Section 8.0**. |
| | PL2.2 – Treatment options for <u>indirect risks</u> are identified and implemented and after treatment there | The residual risk assessment showing application of treatment options (and no residual extreme or high-priority risks) for both direct and indirect risks is provided in **Section 7.0** and **Section 8.3**. |

| | Benchmark / Criteria | Where addressed in the report |
|---|---|---|
| (The requirements of Level 1 are met, and) | are no residual extreme and high-priority direct or indirect risks. | |
| | PL2.3 – Government representatives participated in the identification of climate and natural hazard direct and indirect risks, including the selection of treatment options. | A summary of engagement with government representatives is provided in **Section 4.3**, with a copy of the workshop materials and activities (used to identify and assess direct risks and treatment options) provided in **Appendix B**. A sign in sheet for the workshop highlights the relevant representative's organisation. |

# Appendix B

# Risk Descriptors

# Appendix B Risk Descriptors

**Table 10-1 Quantitative likelihood descriptors**

| Item | Likelihood | Description |
|---|---|---|
| 1 | Remote | Extremely rare / unprecedented |
| 2 | Unlikely | Not expected to occur in most circumstances |
| 3 | Possible | Could occur |
| 4 | Likely | Probably would occur |
| 5 | Almost Certain | Expected to occur |

**Table 10-2 Consequence descriptors**

| Descriptor | Environment | Economic | Social |
|---|---|---|---|
| Insignificant | No environmental damage. | Minimal losses. | No noticeable change experienced by people in the locality |
| Minor | Minor instances of environmental damage that could be reversed. | Several thousand dollars lost revenue or remediation costs. | Mild deterioration, for a reasonably short time, for a small number of people who are generally adaptable and not vulnerable |
| Moderate | Isolated but significant instances of environmental damage that might be reversed with intense efforts. | Half million dollars lost revenue or remediation costs. | Noticeable deterioration to something that people value highly, either lasting for an extensive time, or affecting a group of people |
| Major | Severe loss of environmental amenities and a danger of continuing. | One million dollars lost revenue or remediation costs. | Substantial deterioration to something that people value highly, either lasting for an indefinite time, or affecting many people in a widespread area |
| Catastrophic | Major widespread loss of environmental amenity and progressive irrecoverable environmental damage. | Several million dollars in lost revenue or remediation costs. | Substantial change experienced in community wellbeing, livelihood, amenity, infrastructure, services, health, and/or heritage values; permanent displacement or addition of at least 20% of a community |

**Table 10-3 Risk matrix**

| Likelihood | Consequence | | | | |
|---|---|---|---|---|---|
| | Insignificant | Minor | Moderate | Major | Catastrophic |
| Almost Certain | **Medium** | **High** | **Very High** | **Significant** | **Significant** |
| Likely | **Low** | **Medium** | **High** | **Very High** | **Significant** |
| Possible | **Very Low** | **Low** | **Medium** | **High** | **Very High** |
| Unlikely | **Negligible** | **Very Low** | **Low** | **Medium** | **High** |
| Rare | **Negligible** | **Negligible** | **Very Low** | **Low** | **Medium** |

# Appendix C

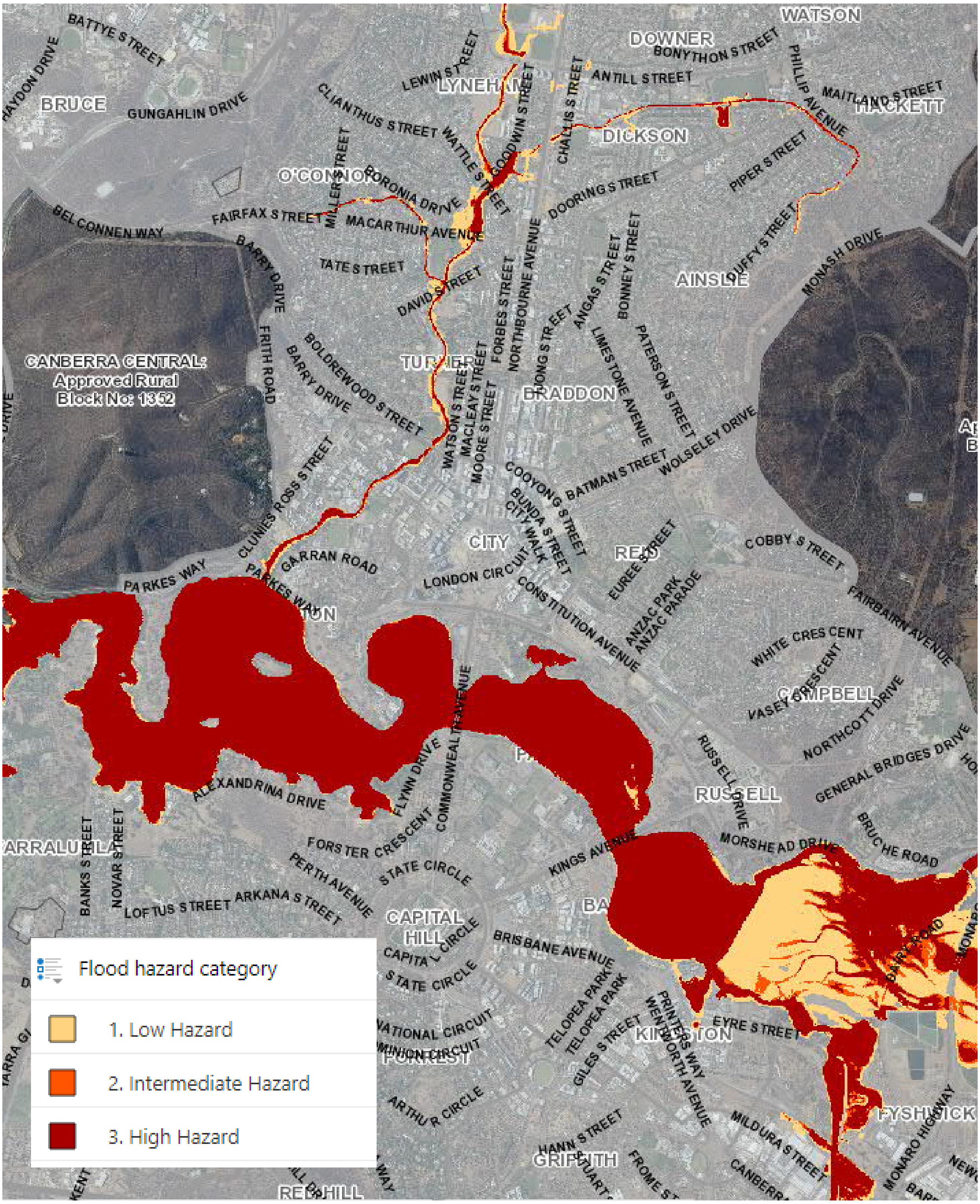
# Workshop Summary and Attendees

# Appendix C Workshop Summary and Attendees

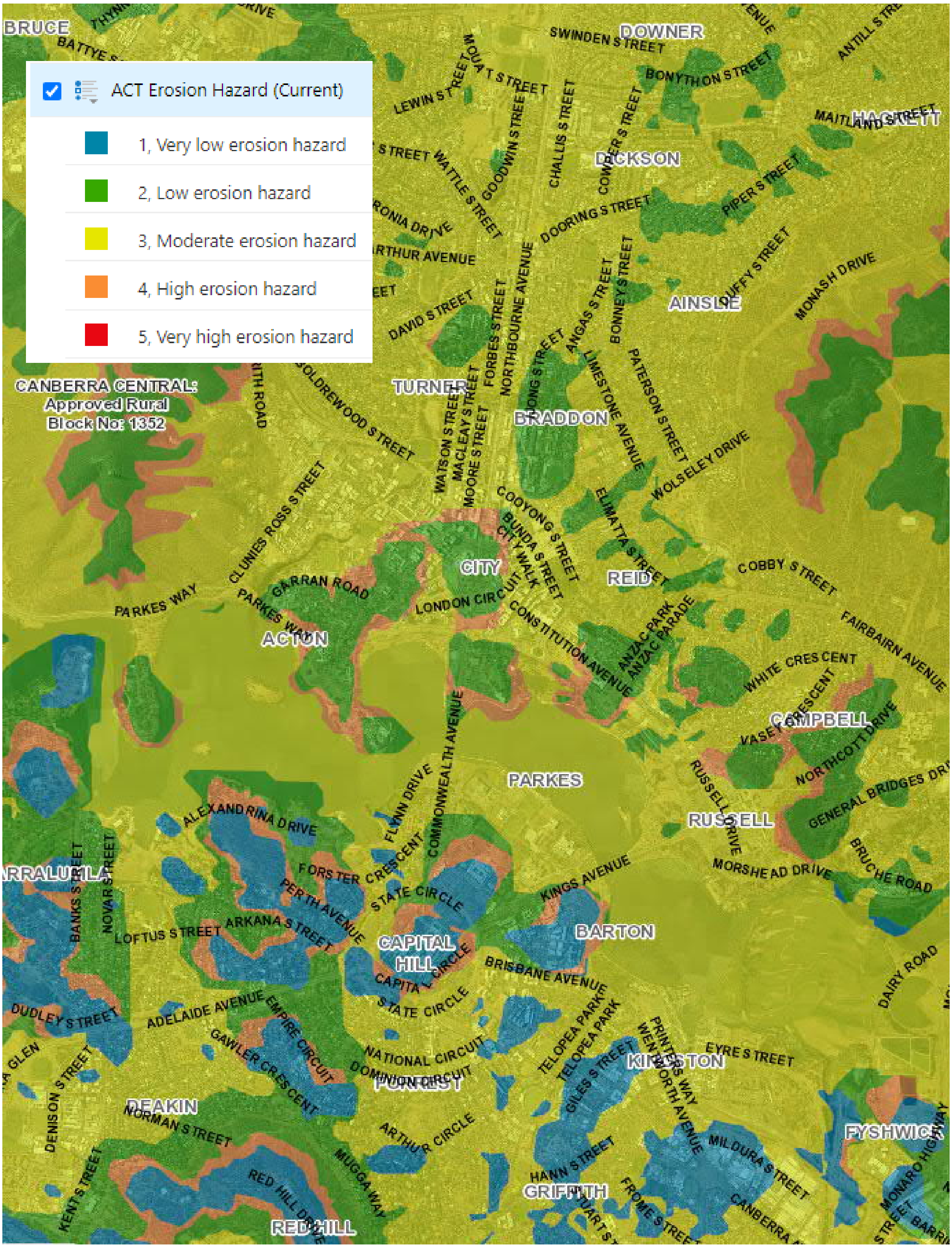
This information has been redacted for the purposes of public exhibition.

# Appendix D

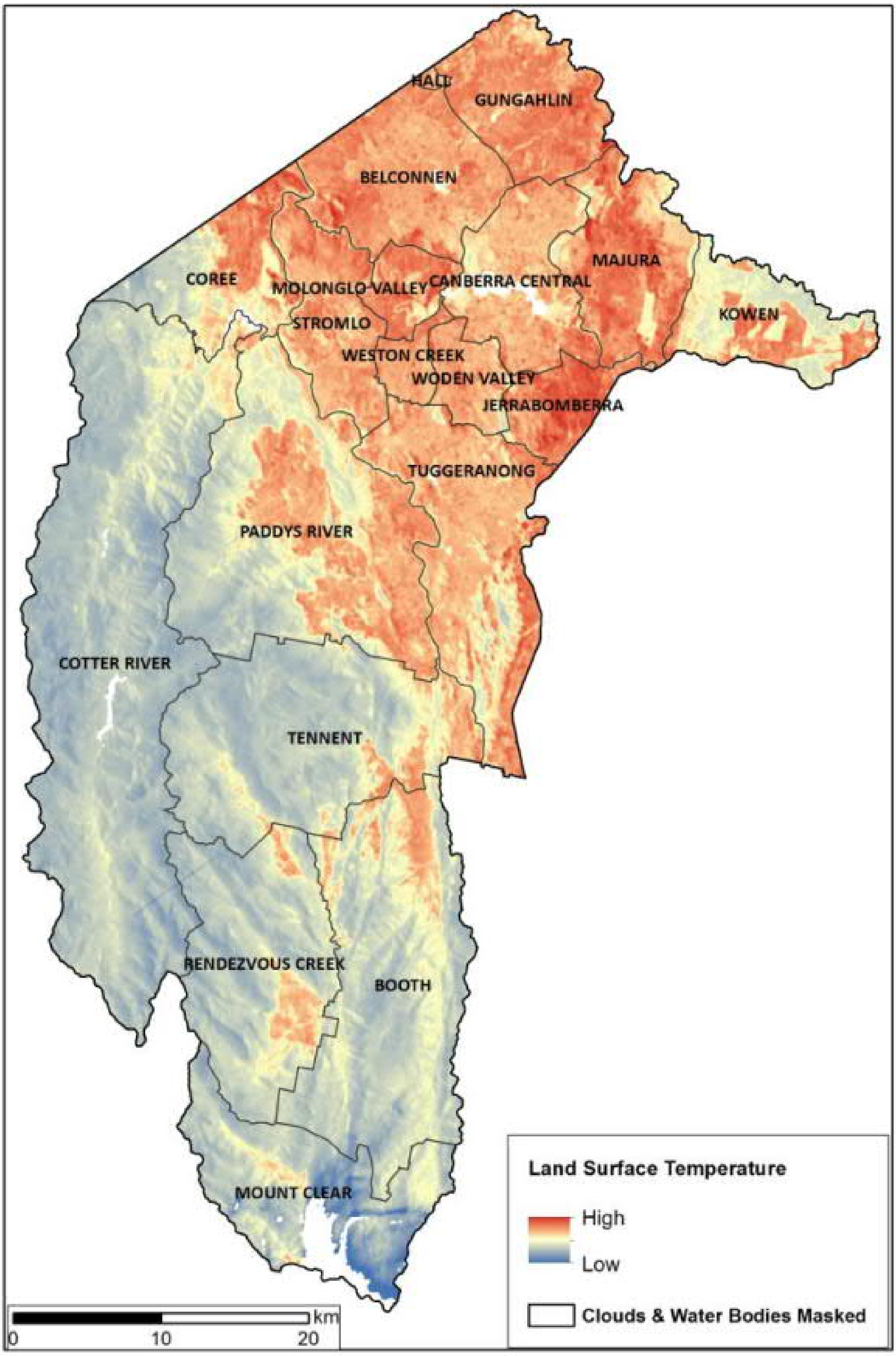
## Climate Mapping




## Flood Hazard Category (ACT Government, 2021)




Current Erosion Hazard (ACT Government, 2021)




Urban Heat Island Mapping (ACT Government, 2017)

# Appendix E

## Climate Projections

# Appendix E Climate Projections

## Murray Basin Cluster Report - Climate Future[1]

| Climate Variable | Baseline | 2030[2] | 2090[3] |
|---|---|---|---|
| Mean temperature change (°C) | Average 20-22°C | +0.9°C<br>(0.7 to 1.3°C) | +3.8°C<br>(2.7 to 4.5°C) |
| Average daily maximum temperature | 33 to 36°C (January) | +1.4°C<br>(0.8 to 1.4°C) | +5.0°C<br>(2.9 to 5°C) |
| Average daily minimum temperature | 0 to 3°C (July) | +1.2°C<br>(0.7 to 1.2°C) | +4.2°C<br>(2.8 to 4.2°C) |
| Extreme heat (days above 35°C) – for Canberra | 7.1 days per year | +12 days<br>(9.4 to 11 days) | +29 days<br>(22 to 39 days) |
| Very extreme heat (days above 40°C) – for Canberra | 0.3 days per year | +1.4 days<br>(0.7 to 3.1 days) | +4.8 days<br>(2.3 to 7.5 days) |
| Bushfire weather days (FFDI[4] > 50) – for Canberra | 1.4 days per year | +0.5 days | +2.9 days |
| Mean annual rainfall change (%) | 400 to 600 mm per year | -1%<br>-11% to +5% | -5%<br>-27% to +9% |
| Extreme rainfall - flooding | Extreme rainfall events to increase in intensity and severity. | | |
| Drought | Time spent in drought conditions to increase | | |
| Evapotranspiration (%) | N/A | +3.1%<br>(+1.9% to 5.1%) | +12%<br>(+7.6% to 18.1%) |
| Solar radiation (%) | N/A | +1%<br>(-0.4% to 2%) | +2.2%<br>(0% to 4.9%) |
| Wind speed (%) | N/A | +0.1%<br>(-2.6% to 2.4%) | -0.6%<br>(-5% to 2.6%) |

1 – RCP8.5 represents a high emissions pathway, with global carbon dioxide concentrations reaching around 940 ppm by the end of the 21st century.

2 – Climate change projections represent the average for the 20 year period between 2020-2039

3 – Climate change projections represent the average for the 20 year period between 2080-2099

4 – The FFDI combines observation of temperature humidity and wind speed. Fire weather is classified as severe when the PPDI is above 50.

# Appendix F

## Treatment Options

# Appendix F Treatment Options

| Related Risk ID / Climate Variable | Adaptation Action | Timing (Current / Planned / Potential) | Trigger Point |
|---|---|---|---|
| Extreme Rainfall & Flooding | Bridges, culverts, WSUD infrastructure and drainage infrastructure designed to accommodate increased runoff that could be caused by changes in rainfall, including increased short duration runoff events (i.e. design drainage structures to accommodate a 10% increase in peak rainfall and stormwater). | Current | Review of flooding and hydrology assessments |
| Extreme Rainfall & Flooding | All new pits and pipes within the Project area to be sized to allow for the 20% increase in rainfall intensities. | Current | Detailed design review |
| Extreme Rainfall & Flooding | Water Sensitive Urban Design – bio swales / bio-retention tree pits to collect and clean stormwater. | Current | *N/A* |
| Extreme Rainfall & Flooding | Blockage factors of drainage have been included in the design for the 1% AEP event that range from 10% to 50% to reduce the risk of debris and other materials blocking the drainage. | Current | Detailed design review |
| Extreme Rainfall & Flooding | Sensitivity testing of a 20% increase in rainfall volume has been undertaken to better understand potential impacts to stormwater load, drainage and performance of WSUD devices as a result of climate change | Current | Detailed design review |
| Extreme Rainfall & Flooding | Maximise the use of permeable surfaces into the public realm or verge areas through the use of pavements, green infrastructure and other mechanisms. | Planned | Detailed design – refer Technical Note TN.00022 Permeable Surfaces. |
| Extreme Rainfall & Flooding | Provide protection from future flooding through consideration of flood levels where identified in the flood study (including climate change) when deciding RLs across alignment (e.g. design for PMF/ minimum 1/100yr ARI+ 10%). | Planned | PSP |
| Extreme Rainfall & Flooding / Extreme Heat | Design pavements and base layers to accommodate impacts caused by variability in rainfall (e.g. wetting and drying) and increases in temperature. | Current | *N/A* |
| Drought / Extreme Heat | Landscape features and plantings have been selected (including the use of natives) to resist drought and hotter conditions in accordance with the ANU Urban Forest Tree Species Research program. This includes the use of mulch in planting areas to encourage infiltration and reduce evaporation. | Current | Review of planting schedules and landscaping plans |
| Extreme Heat | Materials (e.g. electrical box coverings, lighting) will be selected that can withstand / be more resistant to increased extreme and prolonged temperature events to slow / prevent accelerated degradation of infrastructure – in accordance with the ACT Climate Change Adaptation Strategy. | Planned | Procurement |
| Extreme Heat | The gauge of the proposed stainless steel sheet cladding, location and provision of ventilation (e.g. double-skinned) in the integrated services cabinets is sufficient to prevent oil-canning in extreme temperatures. | Current | *N/A* |
| Extreme Heat | Health and safety plans have included extreme heat response (e.g. staffing plans, tools down, etc.) and PPE for transit staff. | Current | *N/A* |
| Bushfire | Inspection of infrastructure after bushfire events to be undertaken to determine damage and appropriate maintenance or repair requirements. | Current | Post-event |
| Bushfire | Maintain landscaped areas to minimise potential bushfire origin point and fuel loads. | Current | Regular maintenance intervals |
| General | Spare capacity has been provided in the combined services route to facilitate future system upgrades (e.g. with more robust components or cabling as needed). | Current | PSP |
| General | Asset management plans have been developed to account for both seasonal variation and in response to climate variables (e.g. inspection after a bushfire or storm event, regular maintenance – dry limb removal). | Current | *N/A* |
| General | Relevant specifications have been checked against climate change factors (e.g. projected increases / decreases in climate variables) including:<br>- Planting schedules<br>- Wind loading for key built elements | Current | Design and specifications review |