# Climate Change Adaptation Report
## Waterloo - Metro Quarter

UrbanGrowth NSW

Project number: 60548148

September 17, 2018

## Quality information

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## Revision History

| Revision | Revision date | Details | Authorized | Name | Position |
|---|---|---|---|---|---|
| 1 | 25-May-2018 | Draft | | Adam Davis | Technical Director – Sustainability and Resilience |
| 2 | 25-June-2018 | Final | | Adam Davis | Technical Director – Sustainability and Resilience |
| 3 | 6-July-2018 | Revised Final | | Adam Davis | Technical Director – Sustainability and Resilience |
| 4 | 20-August-2018 | Update to address TfNSW comments | | Adam Davis | Technical Director – Sustainability and Resilience |
| 5 | 17-September-2018 | Revised based on DPE review |  | Adam Davis | Technical Director – Sustainability and Resilience |

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# Executive Summary

The Minister for Planning has determined that parts of Waterloo are of State planning significance which should be investigated for rezoning through the State Significant Precinct (SSP) process. Study Requirements for such investigations were issued by the Minister on 19 May 2017.

Investigation of the Precinct is being undertaken by UrbanGrowth NSW Development Corporation (UrbanGrowth NSW), in partnership with the Land and Housing Corporation (LAHC). The outcome of the SSP process will be new planning controls that will enable future development applications for the renewal of the Precinct.

While this report therefore provides comprehensive baseline investigations for the entire Precinct, it only assesses the proposed Planning Framework amendments and Indicative Concept Proposal for the Metro Quarter. This Climate Change Adaptation Report further includes a climate risk assessment and summarises the effects of climate change and the actions taken to address these effects.

Adaptation actions and initiatives have been incorporated and planned for the Metro Quarter. These actions have resulted in a reduction in risk from climate change. It is anticipated that as the proposed development progresses from the master plan planning application to detailed design, further climate risk assessment and mitigation is undertaken to verify integration of adaptation measures in the design and how that has resulted in changes to the risks previously identified. Furthermore, as integrating adaptation measures can occur throughout the life of the project, further actions have been identified in this report to pursue and address in subsequent phases of the Metro Quarter development.

Section 5 of this report summarises the actions and responses that have been undertaken in direct response to the SSPs identified as part of the development application. It is considered that the measures undertaken to date and the future provision of additional measures are sufficient to reduce the risk to vulnerable populations from climate change.

### Study Requirements

A study of the Metro Quarter has been commissioned to inform the new planning framework that will be applied to the Metro Quarter in accordance with the broader Waterloo Precinct and to align with development of the adjoining Waterloo Estate.

As a result, Study Requirements for investigations were issued by the Minister on 19 May 2017, guiding development of various plans, policies and technical reports in support of the State Significant Precinct application. This Climate Change Adaptation Report seeks to address Study Requirement 10: Climate Change Mitigation and Adaptation, which requires UrbanGrowth to:

- *10.2 – Provide a Climate Change Adaptation Report which details how the proposal will address social, environmental and economic effects of climate change on future communities (see NSW and ACT Regional Climate Modelling: NARCLIM), including designing to manage changing temperatures and rainfall patterns through the integration of vegetation (existing and future), permeable and reflective surfaces, and Water Sensitive Urban Design.*
- *10.3 - Assess the potential impacts of climate change on vulnerable groups, including older people, and mechanisms for implementing mitigation strategies.*
- *10.4 - Undertake a sensitivity analysis to address the impact of climate change due to increased temperatures, extreme heat events and changing rainfall patterns integrated with the Water Quality, Flooding and Stormwater Study.*

There are several other additional requirements under Study Requirement 10, including the requirement for a sustainability assessment, demonstrating consideration of the Urban Green Cover in NSW Technical Guidelines and compliance with BASIX. These requirements have been addressed in other supporting documentation including the *ESD Report* (AECOM, 2018).

### Climate Risks

The climate risk assessment was undertaken in accordance with the:

- Green Building Council of Australia (GBCA) Green Star Communities *Gov-6 Adaption and Resilience credits*;
- AS 5334:2013 *Climate change adaptation for settlements and infrastructure*; and,

- Australian Greenhouse Office (AGO), *Climate Change Impact & Risk Management – a Guide for Business and Government*, 2006.

Risks were identified and included as part of the *Climate Risk Register* (AECOM, 2018), which can be found in Appendix A. As part of the development application process, a number of key risks were extracted (refer Section 3.1.2) with adaptation actions identified (refer Section 4) to help reduce risk exposure and improve the resilience of the Metro Quarter.

Based on the location of the Metro Quarter and the scope of works, it was determined that extreme temperature change and extreme rainfall and flooding were the key climatic variables relevant for the project. Specific risks as extracted from the risk register are as follows:

Extreme Heat and Mean Temperature Change

- Extreme heat both increases demand on the energy network because air conditioning units work harder to maintain temperature and reduces energy network capacity, which can cause brownouts and blackouts when the power grid is overwhelmed
- Extreme heat causes reduced energy network capacity and disrupts communication system
- Increased heat stress events causing health impacts to residents
- Extreme events harming health and wellbeing and activation (safety) due to reduced walkability
- Extreme heat increasing requirements for cooling and areas of respite
- Extreme heat impacting health of vulnerable elderly and community members who are especially vulnerable at night
- Extreme heat in areas without air conditioning causing greater demand on cooled shared spaces
- Impacts of increased incidence of violent crime during heatwave events on community

Extreme Rainfall and Flooding

- Greater intensity of rainfall and runoff overwhelming drainage capacity and causing flooding and inundation of roof, ground and subterranean systems
- Greater intensity of rainfall and runoff causing inundation of underground utility issues (electricity distribution, fibre cables, pumping stations, other network infrastructure malfunctions)
- In an evacuation scenario caused by flooding, extreme storms, or bushfires, those who are mentally ill, physically impaired, and those who have limited English proficiency are not evacuated.

**Adaptation Actions**

A number of adaptation actions and responses have been identified and integrated into the Master Plan to address these risks and associated potential social, environmental and economic effects of climate change on future communities. The status of integration of these actions into the Master Plan is summarised as follows:

- The Metro Quarter Urban Forest Strategy provides an estimated canopy coverage which supports current targets set by the City of Sydney and will help to reduce flooding impacts based on increased rainfall and reduce the overall heat island effect through shading and provide a natural solution to those who suffer from a number of health issues. Specifically, the Urban Forest Strategy helps to achieve the implementation of adaptation actions including:
  - Canopy coverage over paved surfaces, serving as a cost-effective means of mitigating urban heat island effects (including additional projected increases in mean temperature and extreme heat events).
  - Street trees helping to provide areas of respite for commuters, pedestrians and local residents (including those most vulnerable; elderly, youth, disabled).
  - An increase in vegetation surrounding an urban site helping to improve air quality (of benefit to those with respiratory issues) and strengthen community ties.

- In addition to the ground level natural areas / open space, the creation of a green roof or community garden on the lower podiums of the Metro Quarter is identified for further development at detailed design. Providing a green roof and/or community garden helps serve several purposes including:
  - Controlling the flow of rainwater into the stormwater system.
  - Helping improve the water quality of stormwater prior to discharge into the system.
  - Providing additional communal space for residents to help encourage healthier lifestyles and strengthen community networks.
  - Reducing the heat load on the building during the warmer months, reducing the energy consumption and subsequently energy bills for residents and tenants.
- The proposed development has also included a number of design considerations to help minimise and reduce the impacts from climate change. These include:
  - Large mature trees along the footpath and above the bus shelter to provide shade, respite and natural air pollution control. Water sensitive urban design also allows the trees to act as natural stormwater management and treatment.
  - Entrances to ground level retail areas have both awnings to prevent rainfall from reaching the main internal areas as well as a ramp for access to help prevent potential flooding within the ground floor.
  - Elevated residential ground floors above the levels of a 100 year ARI with a 10% increase in rainfall intensity due to climate change applied flood event, with the staircase serving as a built flood barrier.
  - The provision of a ‘public domain area’. In addition to the reduction in heat it provides a means to strengthen the social cohesion by allowing residents and other users an opportunity to socialise. Natural settings have also been shown to help mental health.
  - The building floorplan caters for a sufficient void, or ‘space’, to allow for future retrofit of individualised heating/cooling systems. It would be up to the detailed building design to optimise the floorplan to allow both maximum usage of the unit space, while catering for the mechanical / utility considerations.
- As part of the future design, opportunities to incorporate additional green infrastructure are to be pursued. Plantings on podiums, balconies, walls and within the public domain provide a number of benefits (reduction in heat, strengthen community ties, provide natural air pollution mitigation) with the added benefit of not limiting space required for other functions (plant / equipment).
- The proposed development footprint has allowed for climate change. The design allows for 100 year Average Recurrence Interval (ARI) with a 10% increase in rainfall intensity due to climate change applied events. The proposed development (entries, exits, evacuation paths) have considered the extent of these flood events and oriented ingress/egress points accordingly. The design has also catered to ingress/egress concerns of emergency personnel having to access the site during an emergency.

Consideration and response to climate risks can be undertaken at all stages of development. Table 4-1 identifies both actions that have been incorporated in the design and considerations that are subject to detailed design development. Many of these considerations are important to carry forward into the next phase of design. These include:

- **Providing the opportunity for future heating and cooling as retrofit –** considering space for future equipment / plant as part of an internal retrofit for heating and cooling options could serve to avoid the need for reverse-cycle units on the balconies of individual units which would reduce the amount of heat generated into the Metro Quarter and reduce costs to residents.
- **Encourage the implementation of green infrastructure where possible -** identifying opportunities to increase the amount of green infrastructure (e.g. plantings, landscaped areas, trees) across the roofs, balconies, podiums, walls and public domain would serve not only to improve air quality in highly trafficked areas, but reduce heat loads on buildings, allowing HVAC and other systems to operate efficiently and help reduce potential impacts from rainfall events as green infrastructure serves to capture some of the falls.

# 1 Introduction

The Minister for Planning has determined that parts of Waterloo (the Precinct) are of State planning significance which should be investigated for rezoning through the State Significant Precinct (SSP) process. Study Requirements for such investigations were issued by the Minister on 19 May 2017.

Investigation of the Precinct is being undertaken by UrbanGrowth NSW Development Corporation (UrbanGrowth NSW), in partnership with NSW Land and Housing Corporation (LAHC) and Sydney Metro. The outcome of the State Significant Precinct process will be new planning controls that will enable development applications for renewal of the Precinct.

The Precinct includes two separate, but adjoining and inter-related parts:

- The Waterloo Metro Quarter (the Metro Quarter)
- The Waterloo Estate (the Estate)

While the study requirements for the Precinct were provided as separate requirements for the Metro Quarter and for the Estate, comprehensive baseline investigations have been prepared for the entire Precinct. However, lodgement of a separate SSP study for the Metro Quarter in advance of the SSP Study for the Estate is proposed to allow construction of Over Station Development (OSD) within the Metro Quarter to be delivered concurrently with the Metro Station, as an Integrated Station Development (ISD).

While this report therefore provides comprehensive baseline investigations for the entire Precinct, it only assesses the proposed Planning Framework amendments and Indicative Concept Proposal for the Metro Quarter.

## 1.1 Overall precinct objectives

The following are the objectives for renewal of the Precinct:

| Objective |
|---|
| **Housing:** A fully integrated urban village of social, private and affordable housing |
| A place that meets the housing needs of people with different background, ages, incomes, abilities and lifestyles – a place where everyone belongs. New homes for social, affordable and private residents that are not distinguishable and are modern, comfortable, efficient, sustainable and adaptable. |
| **Services and Amenities:** New and improved services, facilities and amenities to support a diverse community |
| A place that provides suitable and essential services and facilities so that all residents have easy access to health, wellbeing, community support, retail and government services. |
| **Culture & Design:** A safe and welcoming place to live and visit |
| A place where there is activity day and night, where people feel safe, at ease and part of a cohesive and proud community. A place that respects the land and Aboriginal people by showcasing and celebrating Waterloo's culture, history and heritage. |
| **Open Space & Environment:** High quality public spaces and a sustainable urban environment |
| A place that promotes a walkable, comfortable and healthy lifestyle with high quality, well designed and sustainable buildings, natural features and safe open spaces for everyone to enjoy, regardless of age, culture or ability. |
| **Transport and Connectivity:** A well connected inner city location |
| Integrate the new metro station and other modes of transport in such a way that anyone who lives, works or visits Waterloo can get around easily, safely and efficiently. |

## 1.2 Waterloo State Significant Precinct

The Precinct is located approximately 3.3km south-south-west of the Sydney CBD in the suburb of Waterloo (refer Figure 1-2). It is located entirely within the City of Sydney local government area (LGA).

It is bordered by Phillip Street to the north, Pitt Street to the east, McEvoy Street to the south and Botany Road to the west. It also includes one block east of Pitt Street bordered by Wellington, Gibson and Kellick Streets. The Precinct has an approximate gross site area of 20.03 hectares (ha) (including road reserves) and comprises two separate but adjoining parts:

- The Waterloo Estate (the Estate); and
- The Waterloo Metro Quarter (the Metro Quarter)

A map of the Precinct and relevant boundaries is at Figure 1-2.

## 1.3 The Metro Quarter

The Metro Quarter comprises land to the west of Cope Street, east of Botany Road, south of Raglan Street and north of Wellington Street. It has an approximate gross site area of 1.91ha and a developable area of 1.28ha. The heritage listed Waterloo Congregational Church located at 103–105 Botany Road is located within the Precinct. However, there are no proposals for physical works or changes to the planning framework applicable to the church.

Formerly privately owned, all land in the Metro Quarter was purchased by the NSW Government to facilitate construction of the Waterloo Metro Station and associated over station development.

## 1.4 Approved Metro rail infrastructure

The Waterloo Metro station will be constructed within the eastern side of the Metro Quarter as part of the Sydney Metro City & Southwest - Chatswood to Sydenham. This section of the Sydney Metro project received planning approval in January 2017 (SSI 15_7400), with construction led by Sydney Metro. While most of the Metro Station will be located beneath finished ground level, two substantial entry/plant structures, with heights equivalent to a 5 storey residential building (up to 20 metres), will protrude above finished ground level; one along the northern end of Cope Street, the other along the southern end of Cope Street.

Demolition of existing buildings has been completed and excavation of the Waterloo Metro Station is underway.

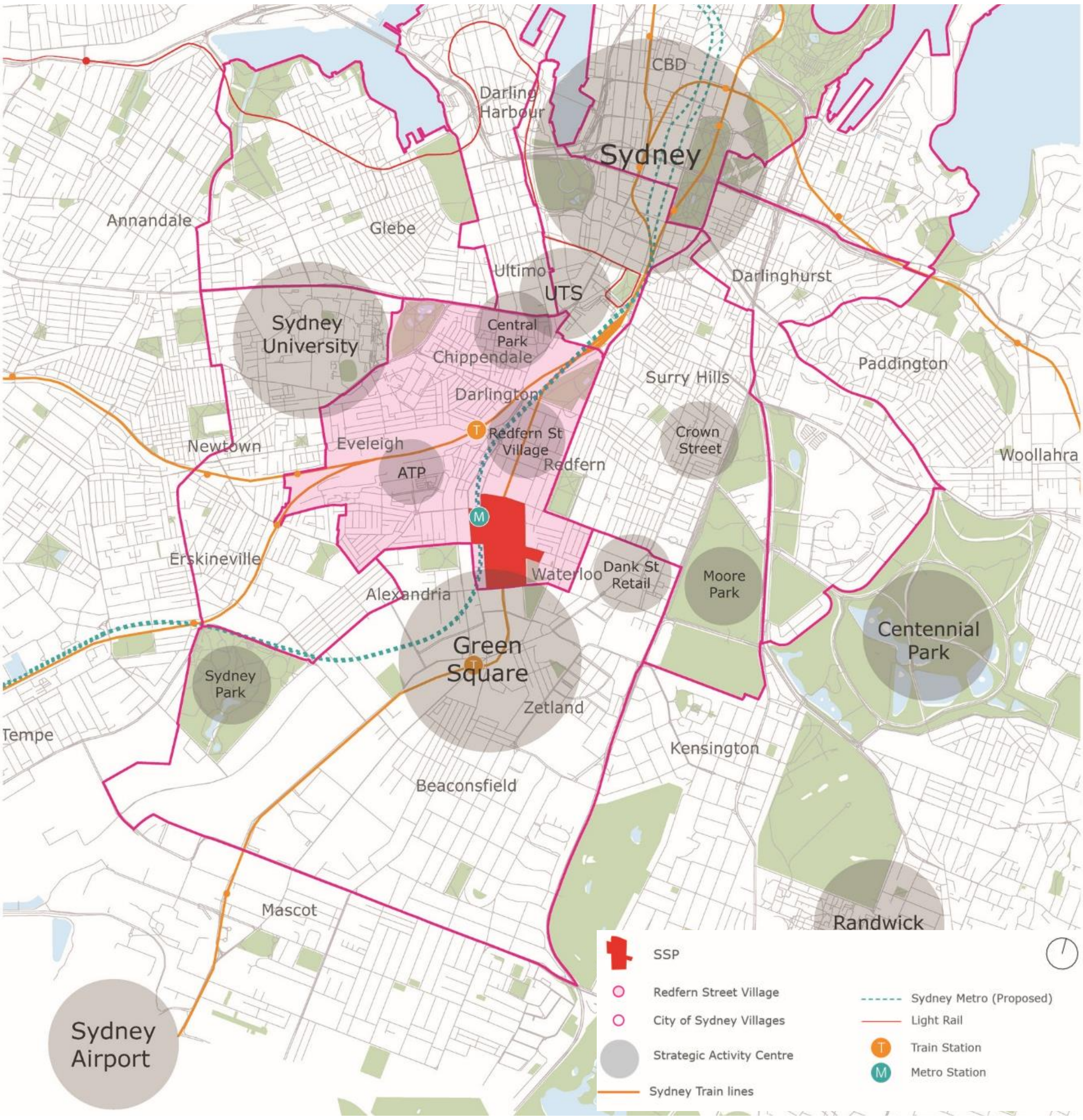



**Figure 1-1 - Location and site plan of the Precinct. Source: Turner Studio**

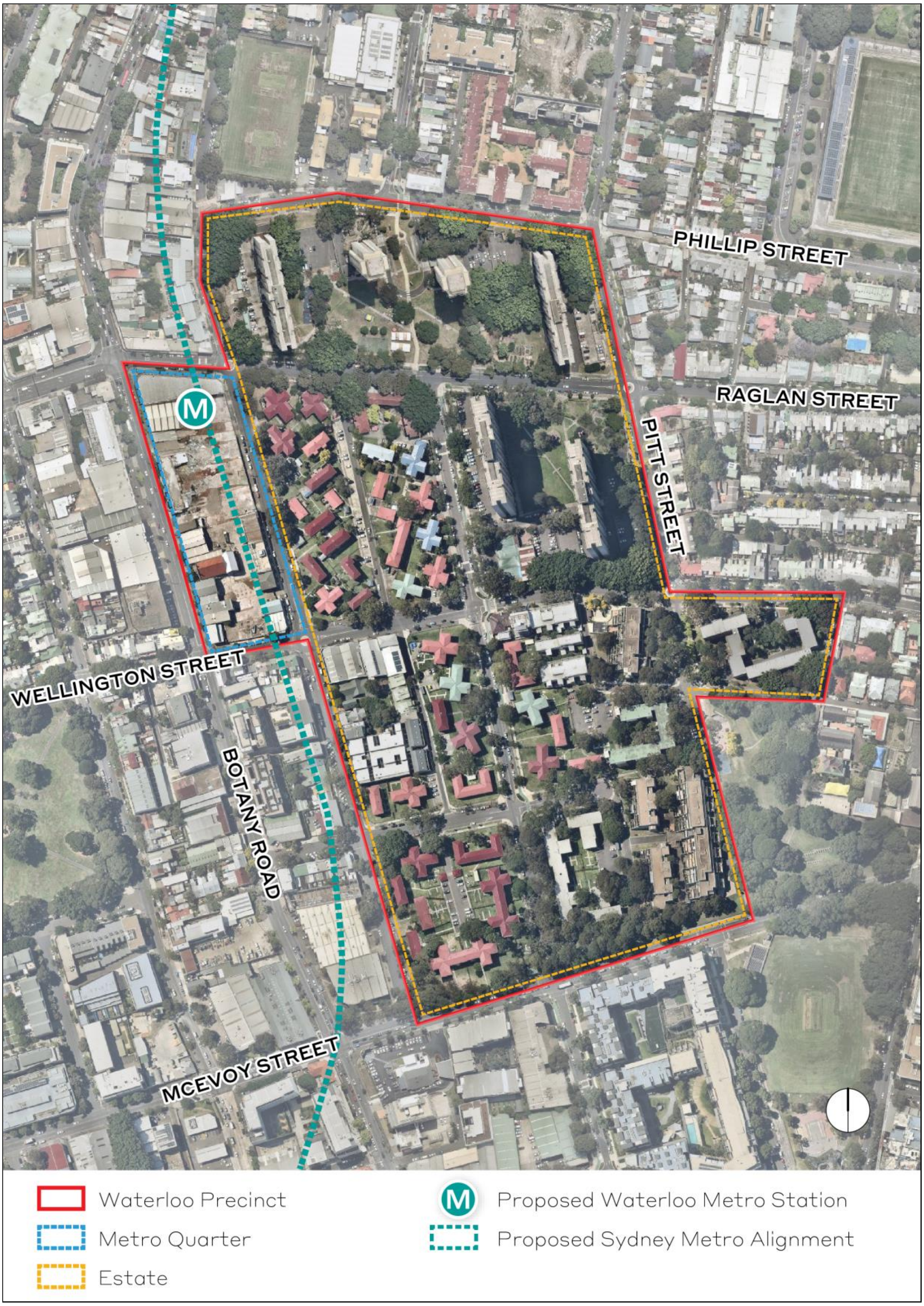



**Figure 1-2 – Aerial photograph. Source: Ethos Urban & Nearmap.**

## 1.5 Purpose

The purpose of this report is to address the relevant Study Requirements detailed below.

## 1.6 Study Requirements

On 19 May 2017 the Minister issued Study Requirements for the nominated Precinct. Of relevance to this study are the following requirements:

- *SR 10.2 – Provide a Climate Change Adaptation Report which details how the proposal will address social, environmental and economic effects of climate change on future communities (see NSW and ACT Regional Climate Modelling: NARCLIM), including designing to manage changing temperatures and rainfall patterns through the integration of vegetation (existing and future), permeable and reflective surfaces, and Water Sensitive Urban Design.* Refer **Section 3** for consideration of changing temperature and rainfall, while **Section 4** provides design considerations such as vegetation and Water Sensitive Urban Design (WSUD). **Section 5.1** summarises the compliance with SR 10.2.
- *SR 10.3 - Assess the potential impacts of climate change on vulnerable groups, including older people, and mechanisms for implementing mitigation strategies.* Refer **Section 3** for potential impacts on vulnerable groups and **Section 4** for mechanisms and mitigation strategies. **Section 5.2** summarises the compliance with SR 10.3.
- *SR 10.4 - Undertake a sensitivity analysis to address the impact of climate change due to increased temperatures, extreme heat events and changing rainfall patterns integrated with the Water Quality, Flooding and Stormwater Study*. **Section 2.1.2.1** details the sensitivity and scenario testing approach used for mean and extreme temperature, **Section 4.1** discusses how this has influence adaptation actions, while **Section 4.1.2** details the sensitivity analysis that was undertaken for changing rainfall patterns. **Section 5.3** summarises compliance with SR 10.4 and addresses sensitivity analysis for changing rainfall patterns, temperature and extreme heat events.

There are several other additional requirements under SR 10, including the requirement for a sustainability assessment, demonstrating consideration of the Urban Green Cover in NSW Technical Guidelines and compliance with BASIX. These requirements have been addressed in other supporting documentation including the *ESD Report* (AECOM, 2018).

The Climate Change Adaptation Report has also been prepared with reference to the NSW Climate Change Policy Framework 2016, which sets a goal to improve the resilience of NSW to a changing climate.

The Climate Change Adaptation report also supports Sustainable Development Goal 13 – Climate Action, specifically:

- *13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.* Refer to **Section 2** for climate change projections and **Section 4** for adaption actions.
- *13.2 Integrate climate change measures into national policies, strategies and planning.* This Climate Change Adaptation Report forms part of the Precinct rezoning planning and assessment process. Climate change adaptation measures are detailed in **Section 4.**
- *13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.* This Climate Change Adaptation Report forms part of the Precinct rezoning planning and assessment process. Climate change adaptation measures are detailed in **Section 4.** Future actions over the development lifecycle of the development are identified in **Section 6.1.**

Addressing these study requirements will help provide a more resilient precinct and better account for future changes related to climate change. Recommendations and adaptation measures identified within this report will further serve to support the implementation of the NSW Climate Change Policy Framework and Sustainable Development Goals.

## 1.7 Proposal

This report relates to:

- An SSP Study to create a new suite of planning controls; and
- an Indicative Concept Proposal.

for the Waterloo Metro Quarter ISD.

### 1.7.1 Proposed Planning Framework

The existing and proposed planning controls for the Metro Quarter are:

| | Existing | Proposed |
|---|---|---|
| **Zoning** | B4 Mixed Use | B4 Mixed Use |
| **Height of Buildings** | Part 12, Part 15 metres | - Part RL 116.9 (AHD) - North<br>- Part RL 104.2 (AHD) - Central<br>- Part RL 96.9 (AHD) - South |
| **Floor Space Ratio** | 1.75:1 | 6.1:1 (including Metro Station) |

### 1.7.2 Indicative Concept Proposal

The Indicative Concept Proposal for the Metro Quarter ISD comprises:

- Approximately 69,000 sqm of gross floor area (GFA), comprising:
  - Approximately 56,500 sqm GFA of residential accommodation, providing for approximately 700 dwellings, including 5 to 10% affordable housing and 70 social housing dwellings;
  - Approximately 4,000 sqm of GFA for retail premises and entertainment facilities.
  - Approximately 8,500 sqm GFA for business and commercial premises and community, health and recreation facilities (indoor).
- Publicly accessible plazas fronting Cope Street (approximately 1,400 sqm) and Raglan Street (580sqm).
- A three storey mixed-use, non-residential podium, including a free standing building within the Cope Street Plaza.
- Three taller residential buildings of 23, 25 and 29 storeys, and four mid-rise buildings of four to ten storeys above the podium and/or the approved metro station infrastructure.
- Parking for approximately 65 cars, 700 residential bicycles and 520 public bicycles.
- Two east-west, through-block pedestrian connections.

Approval has already been separately granted for a Sydney Metro station on the site, which will comprise approximately 8,415 sqm of GFA. The total GFA for the ISD, including the metro station GFA is approximately 77,500 sqm. Transport interchange facilities including bus stops on Botany Road and kiss and ride facilities on Cope Street will be provided under the existing CSSI Approval.

The above figures are deliberately approximate to accommodate detailed design resolution.

While the existing heritage listed Waterloo Congregational Church is within the SSP Study Area, there are no proposals for physical works or changes to the planning framework applicable to the church.

Three dimensional drawings of the Concept Proposal are included on Figure 1-3 and Figure 1-4.

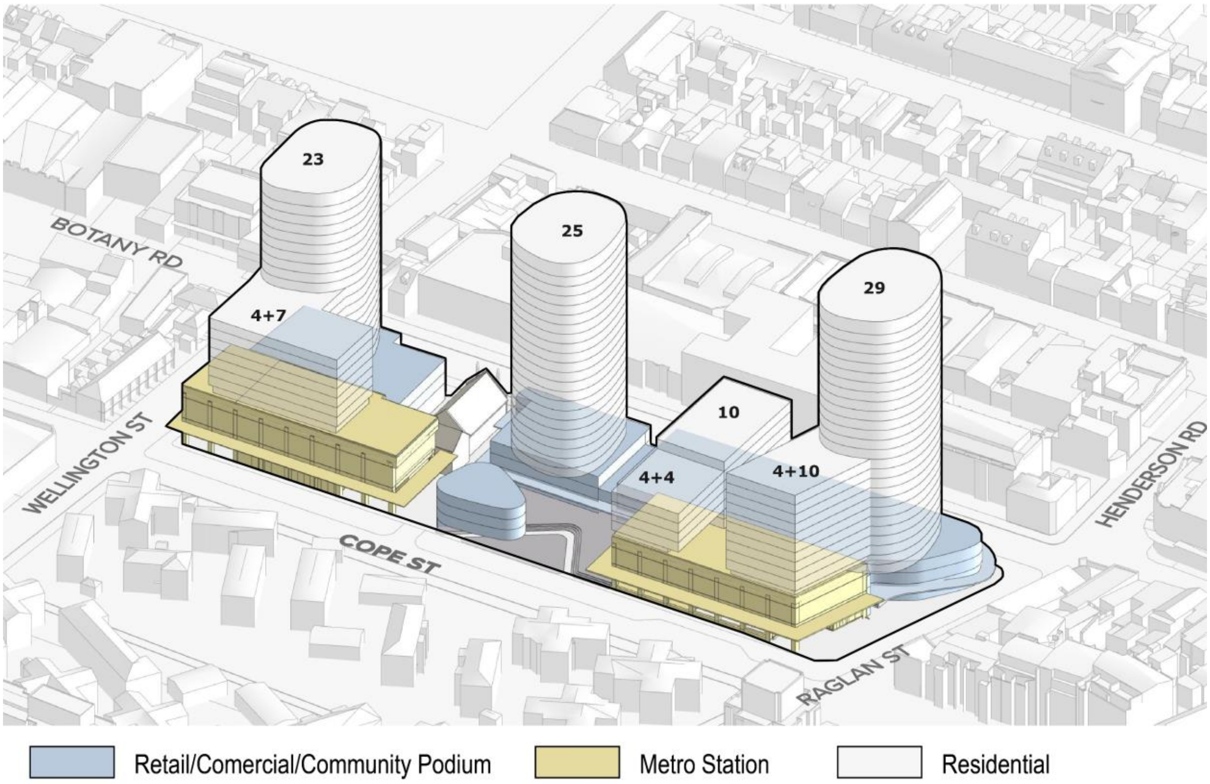



Figure 1-3 – Three-dimensional drawing of the Indicative Concept Proposal, viewed from East

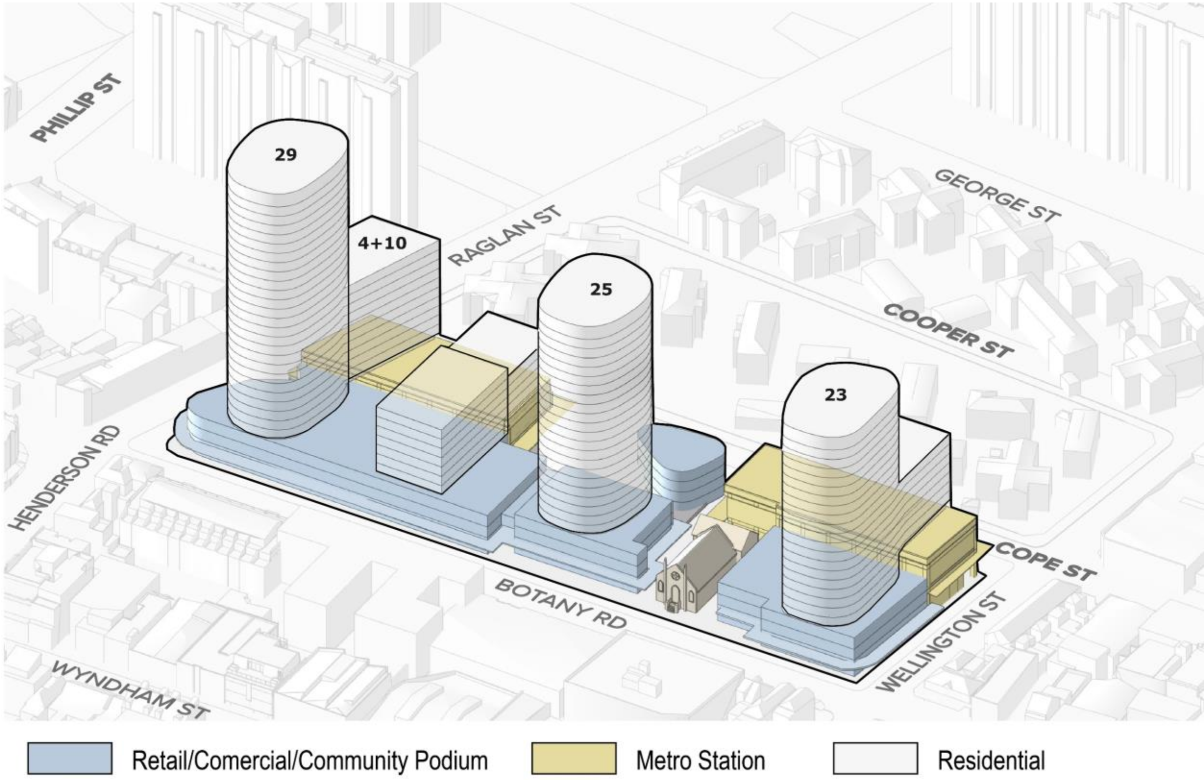



Figure 1-4 – Three-dimensional drawing of the Indicative Concept Proposal, viewed from West

## 1.8 Objectives

The objectives of this assessment are to:

- Prepare a report that addresses the relevant climate change mitigation and adaptation (SR 10) for the SSP application;
- Provide a Climate Change Adaptation Report that details how the Metro Quarter will address social, environmental and economic effects of climate change on future communities;
- Provide an assessment of the potential impacts of climate change on vulnerable communities and recommend / documents adaptation measures to minimise and mitigate these potential impacts; and
- Document and understand the implication of increasing climate effects (including future projections) through sensitivity testing.

# 2 Climate change adaptation report

In order to reduce the risk to vulnerable populations from climate change and minimise the effects of climate change on the Metro Quarter development, a climate change adaptation report has been prepared.

This report is structured as follows:

- **Section 1** presents the objectives of this climate change adaptation report.
- **Section 2** provides the climate change projections used as part of the assessment.
- **Section 3** provides a summary of the risk assessment undertaken.
- **Section 4** provides the adaptation actions that have been integrated and considered in the early planning process.
- **Section 5** identified future actions for consideration in subsequent planning and design phases.

## 2.1 Climate change projections

For the purposes of identifying and evaluating the effects and impacts of climate change it is important to note both the current global and local context and the influence on the Metro Quarter as well as how future climate projections may impact the Quarter. The following sections provide that context as well as describe various scenarios across multiple timeframes to understand how the Metro Quarter may change with respect to climate change over the life of the project, including impacts to those living and using the Metro Quarter.

### 2.1.1 Global and local context

The *State of the Climate 2014* (CSIRO and the Australian Bureau of Meteorology (BOM), 2014) confirms the long-term warming trend over Australia's land and oceans, showing that Australia's climate has warmed by 0.9ºC since 1910. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (IPCC, 2013) states with high confidence that Australia is already experiencing impacts from recent climate change, including a greater frequency and severity of extreme weather events.  Other observed trends include an increase in record hot days, a decrease in record cold days, ocean warming, sea-level rise and increases in global greenhouse gas (GHG) concentrations. Due to long lag times associated with climate processes, even if GHG emissions are mitigated and significantly reduced, the warming trend is expected to continue for centuries (IPCC, 2007).

### 2.1.2 Summary of climate change projections

In order to assess the risk to the proposed works posed by climate change, the current climate science and model projections have been investigated based on available data sources, which for the purposes of this climate change risk assessment have been chosen in accordance with the hierarchy presented in the TfNSW *Climate Risk Assessment Guidelines*, as follows:

- Adapt NSW and NARCliM developed by the NSW Office of Environment and Heritage (OEH, 2014 & 2015).
- CSIRO and Bureau of Meteorology (BOM) Climate Futures (CSIRO & BOM, 2015).

It is important to note the integrity of each climate data set as a whole, as the projections presented by each source represent a range of climate futures based on specific modelling parameters, scenarios and assumptions as described in the following sections. Care has been taken to consider each set of climate projections as a whole, to ensure an 'internally consistent climate future' approach.

#### 2.1.2.1 Emissions scenarios

GHG 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 emissions scenarios used to inform this climate risk assessment are chosen based on the available climate projections from the following sources and include:

NARCliM

- The Special Report on Emissions Scenarios (SRES) A2 scenario represents a high emissions pathway driven by economic growth and is projected to result in warming by approximately 3.4ºC by 2100. The SRES A2 emission scenario was selected for use in the NARCliM climate projections as a review of the global emissions trajectory suggests that we are tracking along the higher end of the A2 scenario (OEH, 2014 & 2015).

Climate Futures

- Projections are presented for two emission scenarios or possible pathways, referred to as 'Representative Concentration Pathways' (RCPs), each of which reflects a different concentration of global greenhouse gas emissions. Two RCPs were evaluated; the intermediate emissions (RCP4.5) and high emissions (RCP8.5) scenarios. The RCP8.5 pathway, which arises from little effort to reduce emissions and represents a failure to prevent warming by 2100, is similar to the highest SRES scenario, while the RCP 4.5 pathway arises from some effort to reduce emissions.
- For the purposes of this assessment, RCP 8.5 data has been provided as global measurements currently suggest this trajectory. Climate change projections for RCP 8.5 are provided in Table 2-1.
  - Comparing the two pathways for key climate variables can also serve as a form of sensitivity testing and scenario planning to understand the impacts based on different projections. Adaptation planning can take into consideration potential changes and how this may influence design actions. A comparison of mean temperature and extreme heat days between RCP 4.5 and RCP 8.5 is provided in Table 2-2.

It is worth noting that NARCLiM and Climate Futures are based on different versions of the International Panel on Climate Change (IPCC) Assessment Reports (AR). NARCLiM downscale projections based on AR4 data, while Climate Futures utilise projections from the AR5 data. While the AR5 data is more recent, the use of AR4 data represents a more conservative approach to adaptation planning and more in line with the current emissions trajectory.

#### 2.1.2.2 Time scales

Given the expected design life of the infrastructure within the Metro Quarter (in excess of 50 years), the general timeframe for the proposed construction works (around 2020) and the available climate data, the time periods which were selected for assessment are 2030 and 2090. Climate change projections for 2030 were identified as appropriate for assessment of short term impacts of climate change on the proposed works (assuming full build out of the Quarter by around 2030). Climate change projections for 2090 are relevant to the longer-term operation and maintenance stages of the proposed works.

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

- Projections for 2030 represent the average for the 20-year period between 2020 - 2039.
- Projections for 2090 represent the average for the 20-year period between 2080 - 2099.

#### 2.1.2.3 Summary of climate change projections

A summary of climate change projections for the Metro Quarter are presented in Table 2-1.

**Table 2-1 - Climate Change Projections 2030 & 2090 (for RCP8.5 – High Emissions)**

| Climate Variable | 2030 | 2090 |
|---|---|---|
| Mean annual temperature | Increase of 0.7ºC to 1.3ºC | Increase of 2.9ºC to 4.6ºC |
| Extreme temperature | 4.3 more days above 35ºC[1] | 11 more days above 35ºC |

| | | |
|---|---|---|
| Mean annual rainfall | Decrease of 11% to increase of 6% | Decrease of 20% to increase of 16% |
| Average annual increase in rainfall intensity | AR&R increase of 4.9% | AR&R indicated increase of 18.9% |
| Extreme rainfall (one in 20 year event) | Not available | Increase by 5% to 40% |
| Mean annual wind speed | Decrease of 2.3% to increase of 1.9% | Decrease of 6.9% to increase of 4.2% |
| Annual bushfire weather | Increase by 45% | Increase by 130% |
| Mean sea level rise | Increase of 0.10 metres to 0.19 metres | Increase of 0.45 metres to 0.88 metres |

[1] data for RCP 4.5 as data for RCP 8.5 not available

**Table 2-2 – Mean Temperature and Extreme Heat Days Comparison (RCP 4.5 vs RCP 8.5)**

| Emissions Scenario | 2030 mean temperature change | 2090 mean temperature change | 2030 extreme heat days | 2090 extreme heat days |
|---|---|---|---|---|
| RCP 4.5 | +0.6$^{O}$C to +1.1$^{O}$C | +1.3$^{O}$C to +2.5$^{O}$C | +4.3 days | +6 days |
| RCP 8.5 | +0.7$^{O}$C to +1.3$^{O}$C | +2.9$^{O}$C to +4.6$^{O}$C | - | +11 days |

The IPCC Fifth Assessment Report (AR5, 2013) states with high confidence, that Australia is already experiencing impacts from recent climate change, including a greater frequency and severity of extreme weather events.

As a result, it is especially important to understand the ‘most likely’ and ‘worst case’ implications of climate change on high-value infrastructure, including works across the Metro Quarter. Consideration and integration of these projections early in the planning will allow the design to manage these changes and incorporate flexible mitigation strategies.

#### 2.1.2.4 Detailed climate projections for the Metro Quarter

The current and historical local climate of the Metropolitan Sydney region provides an indication of the exposure of the proposed works to future climate risks. It is important to note that the local climate of the Metropolitan Sydney region can be broken into three areas; the Blue Mountains, Western Sydney, and coastal Sydney. Where feasible, discussion for the Metro Quarter will report coastal Sydney climate projections.

OEH (2014) describes the complex topography of the region and its coastal setting that result in a variety of climates across the region. Relatively wet conditions exist along the coast, while warmer conditions are present in Western Sydney during the summer.

Specific detail for relevant climate variables for the local climate of the region is included below.

**Mean surface temperature**

Under SRES A2, mean temperatures are projected to rise by 0.7 ºC by 2030 for the Sydney Metropolitan region, with the greatest change projected during spring months. Mean temperatures are projected to rise by 1.9 ºC by 2070.

There is a very high level of confidence in temperature projections as all models show increases in mean temperatures across the Sydney Metropolitan region for both the near future and far future, for a range of emissions scenarios (CSIRO & BOM, 2015).

**Extreme temperature and heatwaves**

The Metropolitan Sydney Region is expected to experience more hot days in both the near future and far future. Currently, areas along the coast in Sydney experience around 10 hot days on average per year. The region, on average, is projected to experience four additional hot days in the near future, increasing to around 11 additional hot days in the far future under SRES A2 (OEH, 2014 & 2015). The greatest increases are projected during spring and summer, while also extending into autumn.

An increased frequency and duration of hot days and heatwaves is projected for the East Coast in general with very high confidence under RCP4.5 and RCP8.5 (CSIRO & BOM, 2015).

**Bushfire weather**

By 2030, severe fire weather (days per year with Forest Fire Danger Index (FFDI) > 50) is projected to increase during summer and spring across the Metropolitan Sydney region under SRES A2 (OEH, 2014 & 2015). The greatest increases are projected during the peak prescribed burning season (spring) and peak fire risk season (summer). Severe fire weather is projected to increase across the region by 2070, with the greatest increases occurring during spring (the peak prescribed burning season).

Modelling shows a high confidence of more severe bushfire weather in future under RCP4.5 and RCP8.5 for the East Coast, however there is a lower confidence in the magnitude of the increase due to uncertainties around projections in rainfall variability (CSIRO & BOM, 2015).

**Mean annual rainfall**

The Metropolitan Sydney region currently experiences considerable rainfall variability from year-to-year and this variability is also reflected in the projections for SRES A2 (OEH, 2014 & 2015). By 2030 the Metropolitan Sydney region is projected to have a slight increase in annual rainfall. Rainfall is projected to increase in autumn while rainfall is projected to decrease in the spring. Seasonal rainfall projections span both drying and wetting scenarios for both the near future and far future.

By 2070 annual rainfall is projected to increase for the Metropolitan Sydney region. The largest increase occurs along the coast and seasonally during autumn. Seasonal rainfall projections span both drying and wetting scenarios.

CSIRO & BOM (2015) project less confidence in rainfall modelling for the East Coast of NSW under RCP4.5 and RCP8.5 as natural climate variability is considered to remain the key driver for rainfall. Models suggest a decrease in winter rainfall, but other changes are unclear. The range of results demonstrates the need to consider a range of climate futures and assess potential risks of both drier and wetter conditions.

**Extreme rainfall**

NARCliM projections for SRES A2 (OEH, 2014 & 2015) are not yet available for extreme rainfall.

In a warming climate, extreme rainfall events are expected to increase in magnitude mainly due to a warmer atmosphere being able to hold more moisture (Sherwood et al., 2010). Using an understanding of the physical processes that cause extreme rainfall, coupled with modelled projections for RCP4.5 and RCP8.5, CSIRO & BOM (2015) indicate with high confidence a future increase in the intensity of extreme rainfall events across the East Coast. However, given the natural variability of rainfall the frequency and magnitude of increases in extreme rainfall cannot be confidently projected.

According to the CSIRO and BoM (CSIRO 2015), detection of changes in heavy rainfall in Australia tends to be sensitive to the indices and thresholds chosen to monitor change over time. The period 2010 through to 2013 has also seen widespread, individual very-heavy rainfall events, particularly through the warmer months of the year. Based on the linear relationship between Southern Oscillation Index (SOI) values and Australian rainfall, the El Niño Southern Oscillation (ENSO) remains the dominant driver of changes in rainfall extremes in Australia.

Attribution studies have also found that the warming trend in sea surface temperatures (SSTs) to the north of Australia may have contributed to the magnitude of recent heavy rainfall in 2010-11 in eastern Australia — contributing around 10 to 20 percent of the heavy rainfall anomalies. Another study found that the warm SSTs increased the chances of above average rainfall in eastern Australia in March 2012 by 5-15 %.

### Storm events

NARCliM projections for SRES A2 (OEH, 2014 & 2015) are not yet available for wind speed.

Global and regional studies suggest that extreme storms are projected to become less frequent but increases in the proportion of the most intense storms are anticipated with medium confidence for the East Coast region. While uncertainty exists with the prediction of east coast lows, scientific literature suggests a decline in the number of east coast lows in the future (CSIRO & BOM, 2015).

CSIRO & BOM (2015) project little change in mean surface wind speed under all RCPs with high confidence, particularly by 2030, and with medium confidence by 2070 for the East Coast. However, under RCP8.5 in East Coast South, winter decreases in mean wind speed (associated with southward shift of storms) are projected with medium confidence. Decreases are also suggested for extreme wind speeds, particularly for the rarer extremes under both RCP4.5 and 8.5 with medium confidence.

### Sea level rise

As the proposed works are located inland, sea level rise projections are not relevant to the proposed works.

## 2.2 Climate change mapping

The following mapping shows the location of the Site relative to current and future climate impacts. Figure 2-1 shows the Metro Quarter in relation to areas subject to future sea level rise (of up to +0.74 metres). It is noted that the Site would not be impacted by sea level rise. Figure 2-2 provides heat mapping for the Sydney CBD and in particular showing the urban heat island effect of the surrounding areas. Figure 2-3 shows the Probable Maximum Flood (PMF) event for the areas surrounding the Metro Quarter. The PMF forms part of the baseline on which the sensitivity testing is based upon.

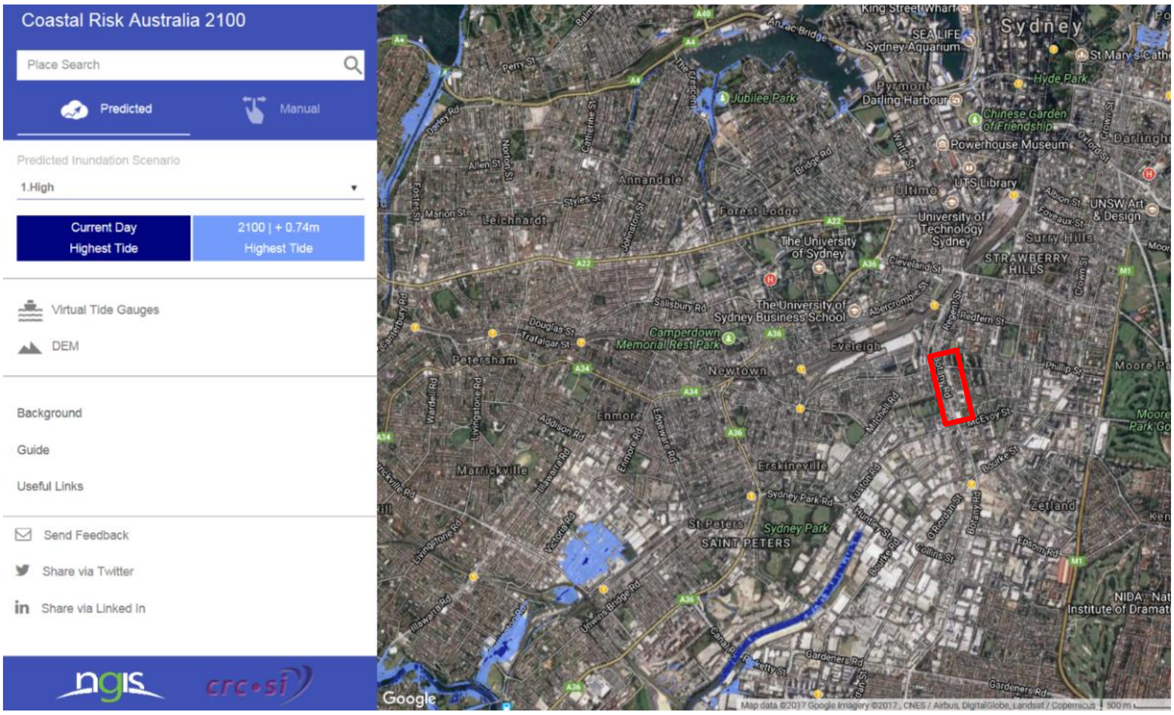



Figure 2-1 - Coastal Risk 2100 High Tide plus Sea Level Rise (Subject area shown in red). Source: Coastal Risk Australia.

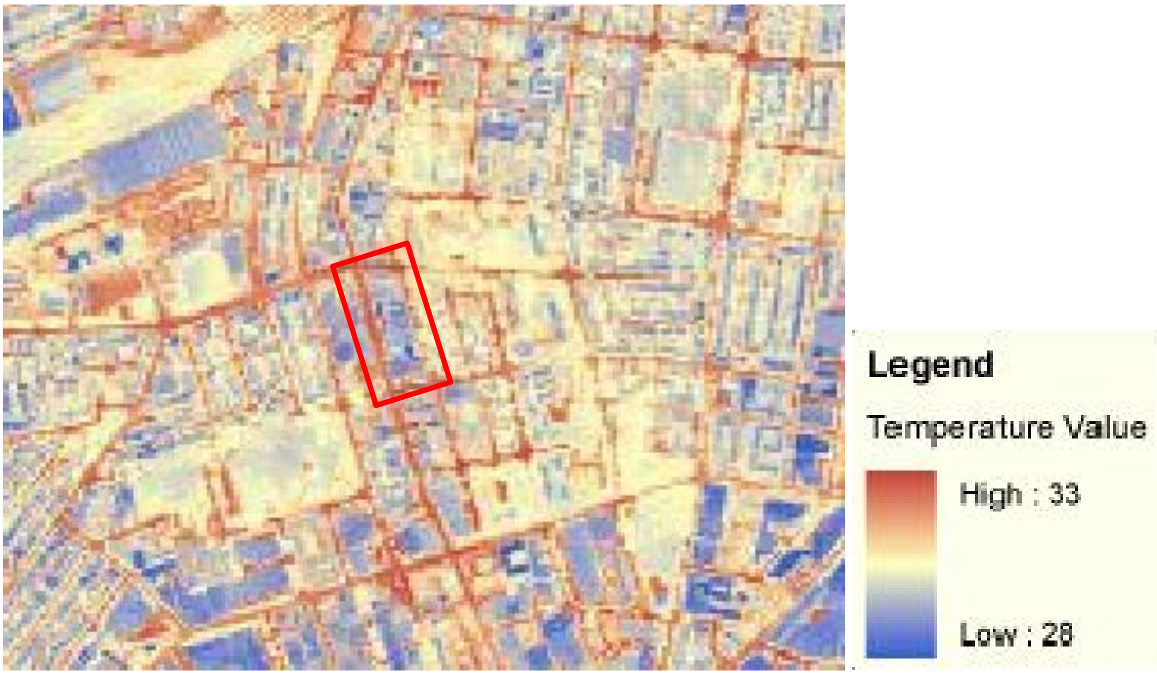
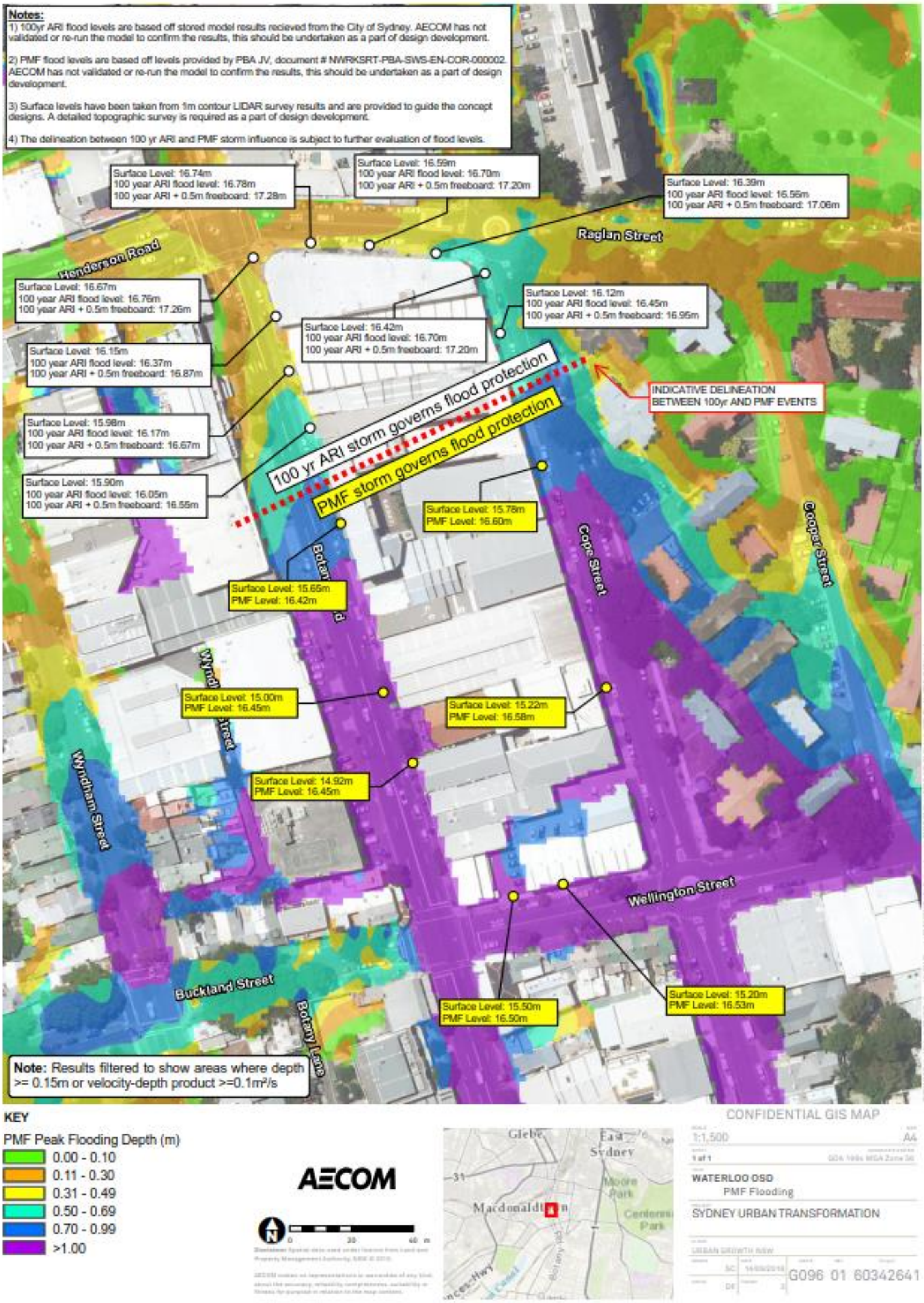



Figure 2-2 - Thermal Imagery (Extreme heat). Subject area shown in red. Source: City of Sydney.




## Figure 2-3 – Probable Maximum Flood Event

# 3 Risk assessment

In order to adequately and appropriately detail how the Metro Quarter will address the social, environmental and economic effects of climate change including potential impacts on vulnerable groups, it is necessary to understand the risks. The following section details the risks that were identified for the Metro Estate as well as those that are relevant for the Metro Quarter, provides those that are most important to address and detail the existing and proposed adaption options and mitigation strategies to help reduce the risks.

The climate risk assessment that was undertaken as part of the Precinct study requirements was done in accordance with the:

- Green Building Council of Australia (GBCA) Green Star Communities *Gov-6 Adaption and Resilience credits*;
- AS 5334:2013 *Climate change adaptation for settlements and infrastructure*; and,
- Australian Greenhouse Office (AGO), *Climate Change Impact & Risk Management – a Guide for Business and Government*, 2006.

Appendix B contains definitions of each of the consequence and likelihood criteria used to determine risk ratings and the overall matrix to determine the risk rating for each risk.

Figure 3-1 identifies how risks to the assets have been developed from an assessment of climate variables and projected climate change.

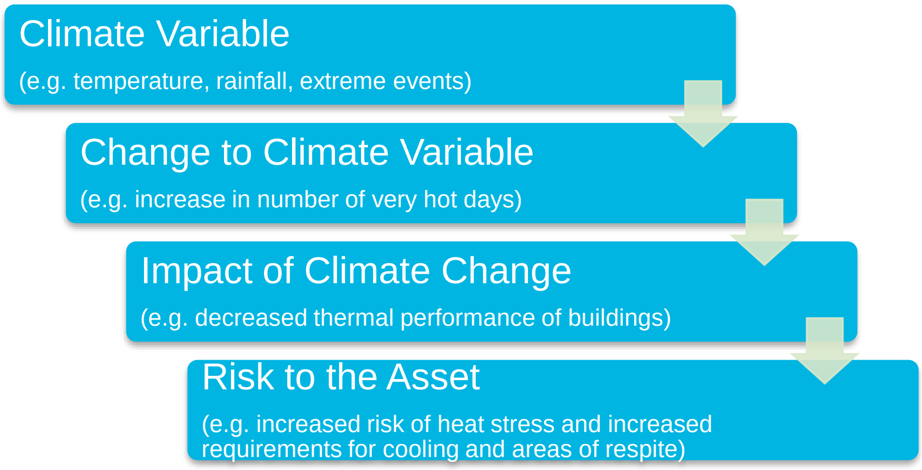



**Figure 3-1 – Climate Change Risk Assessment Process (adapted from OEH, 2008)**

## 3.1 Climate Change Risk Assessment workshop

On 6 September 2017, AECOM hosted a multidisciplinary risk assessment workshop in which stakeholders reviewed and prioritised preliminary climate risk assessments and identified additional risks facing the precinct. Adaptation options to respond to priority risks were identified.

The following were in attendance at the workshop:

- Joshua Atkinson, AECOM - Flooding
- Jack Blackwell, AECOM – Services and Sustainability
- Martin Boran, AECOM – Civil and Drainage
- Ian Cady, UrbanGrowth NSW – Design and Development
- Adam Davis, AECOM – Resilience and Sustainability
- Lauren Harding, GHD, - Social Sustainability
- Cecilia Huang, Turner Studio – Architecture and Urban Design
- Suzanna Remmerswaal, AECOM - Resilience and Sustainability.

Direct coordination has been undertaken with the attendees for development of the adaptation plan. Coordination has also been undertaken with: UrbanGrowth; Robert Smart, Arterra – Urban Forest; Meike Tabel, Turner – Architecture & Urban Design; AECOM – Daniel Fettell – Flooding, civil and drainage design, Roger Swinbourne – Sustainability.

### 3.1.1 Risk Identification

In all, the preliminary assessment and workshop identified and rated 41 key climate risks based on their likelihood and consequences for a 2030 and 2090 time horizon (as part of the *Climate Risk Register* (AECOM, 2017), which can be found in Appendix A. As part of the risk register, detailed risk analysis, risk ratings (both 2030 and 2090), preliminary proposed actions and responsibilities were identified. It is worth noting that risks were assessed prior to treatment actions being identified and residual risk ratings will be undertaken prior to construction.

The risks relate to indirect and direct harm to people and the services and infrastructure that support them as caused by climate hazards. A summary of the 41 risk ratings for the 2030 time horizon are as follows:

**Table 3-1 – Climate Risk Register Summary (2030)**

| Risk Rating | Number | Description |
|---|---|---|
| Extreme Risk | 0 | Generally intolerable |
| High Risk | 13 | Undesirable |
| Medium Risk | 17 | Tolerable |
| Low Risk | 11 | Broadly Acceptable |
| **Total** | **41** | |

During the course of design development and following further coordination with the team, key risks were extracted (refer Section 3.1.2) as part of the climate risk assessment process with adaptation actions identified (refer Section 4) to help reduce risk exposure and improve the resilience of the Metro Quarter.

### 3.1.2 Focus areas

Based on the location of the Metro Quarter and the scope of works, it was determined that extreme heat and mean temperature change and extreme rainfall and flooding were the key climatic variables relevant for the project. Given these key climatic variables and the undesirable nature of high risks, all 13 'high risks' were extracted from the risk register for consideration. These are detailed in Table 3-2.

**Table 3-2 – Climate Risk Register Extract – High Risks**

| Risk ID | Variable & Associated Risk | Risk Consequence (C) | Risk Likelihood (L) | Risk Rating |
|---|---|---|---|---|
| W-9 | In an extreme event where power is lost (outages from storms, bushfires, or from excess demand on the power grid), the interdependencies between healthcare systems and electrical and communications could fail and cause loss of life and injury | **C2** | **L3** | High |
| W-10 | In an evacuation scenario caused by flooding, extreme storms, or bushfires, those who are mentally ill, physically impaired, and those who have limited English proficiency are not evacuated | **C3** | **L2** | High |
| F-3 | Greater intensity of rainfall and runoff overwhelming drainage capacity and causing flooding and inundation of roof, ground and subterranean | **C3** | **L2** | High |

| Risk ID | Variable & Associated Risk | Risk Consequence (C) | Risk Likelihood (L) | Risk Rating |
|---|---|---|---|---|
| | systems | | | |
| F-4 | Greater intensity of rainfall and runoff causing inundation of underground utility issues (electricity distribution, fibre cables, pumping stations, other network infrastructure malfunctions) | **C3** | **L2** | High |
| H-2 | Extreme heat both increases demand on the energy network because air conditioning units work harder to maintain temperature and reduces energy network capacity, which can cause brownouts and blackouts when the power grid is overwhelmed | **C2** | **L2** | High |
| H-3 | Extreme heat causes reduced energy network capacity and disrupts communication system | **C2** | **L2** | High |
| H-4 | Increased heat stress events causing health impacts to residents | **C3** | **L2** | High |
| H-5 | Extreme heat increasing requirements for cooling and areas of respite | **C3** | **L2** | High |
| W-2 | Climate extremes across the region increasing operational energy costs and living costs | **C3** | **L1** | High |
| W-7 | Extreme events harming health and wellbeing and activation (safety) due to reduced walkability | **C3** | **L2** | High |
| W-8 | Extreme heat impacting health of vulnerable elderly and community members who are especially at night | **C3** | **L2** | High |
| W-12 | Extreme heat in areas without air conditioning causing greater demand on shared spaces that are cooled | **C3** | **L1** | High |
| W-13 | Impacts of increased incidence of violent crime during heatwave events on community | **C3** | **L2** | High |

## 3.2 Risk evaluation

It is generally recognised that vulnerable members of the population (youth, elderly, socio-economically disadvantaged and those with physical or mental health conditions) also face additional risks that are further exacerbated by climate change and are more likely to occupy social and affordable housing included in the development of the Metro Quarter. As noted below, many of the key risks for the Metro Quarter involve vulnerable populations that would be living in or around and using the Metro Quarter. Adaptation actions and responses identified and ultimately implemented by UrbanGrowth NSW seek to reduce the risk exposure of these vulnerable populations and ensure a thriving and resilient Quarter. Specific adaptation actions and mitigation measures have been identified for vulnerable populations (refer Table 4-1); all responses would serve to improve the resilience of vulnerable populations both visiting and residing in the Quarter.

# 4 Adaptation actions

Adaptation actions and responses have been identified for the risks identified above and have been integrated into the Master Plan (Table 4-1). The integration of these actions into the Master Plan is documented in Section 4.1.

### Table 4-1 - Adaptation actions based on climate risk

| | Climate Risk | | |
|---|---|---|---|
| | **Heat** | **Rainfall** | **Flooding** |
| **Built Response** | Architecture / Urban Design –<br>• Provision of shaded communal spaces including utilising solar PV as shade.<br>• Passive building design includes orientation, western shading, natural ventilation and minimal glazing.<br>• At least 75% of the total project site area, in plan view, comprises building or landscaping elements that reduce the impact of heat island effect (in line with Green Star Communities Urban Heat Island Credit). This includes a higher reflectivity value for built elements (street pavement, roofs, etc.)<br>Services –<br>• Design apartments for potential retrofit of an in-unit fan system to avoid the use of individual systems on balconies which would increase heat load within the Quarter. | Architecture –<br>• Provision of awnings around entrances / exits for residential, commercial and retail spaces including connectivity across the corridor.<br>Flooding / Urban Design –<br>• Flood modelling accounts for a 10% increase in rainfall intensities. | Flooding –<br>• Onsite detention (OSD) situated above the 100 year Average Recurrence Interval (ARI)[1] +10% flood event levels<br>• OSD sized with consideration for bypass areas in extreme events.<br>• Trunk drainage designed to account for 100 year ARI + 10%.<br>Flooding / Architecture / Urban Design –<br>• All residential areas raised above the flood planning level (greater of Probable Maximum Flood (PMF)[2] levels or 100 year ARI plus 0.5m to allow for an increase in rainfall intensity of 10%).<br>• All critical infrastructure levels designed above the 100 year ARI +10%. |
| **Vegetation Response** | Architecture / Landscape –<br>• Provision of green roofs, increased planting areas and other green infrastructure where possible to reduce surrounding temperatures.<br>Landscape –<br>• Urban Forest Strategy to maximise retained trees and provision of trees with adequate coverage for heat reduction. | Landscape / Urban Design –<br>• Rain gardens, green roofs, increased planting areas and other green infrastructure to capture and/or dissipate intensity of rainfall prior to reaching ground level. | Landscape / Urban Design –<br>• Management of water quality through the incorporation of Water Sensitive Urban Design (WSUD) techniques. |

[1] Average Recurrence Interval (ARI) – the long-term average number of years between occurrences of a flood of a certain size. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
[2] Probable Maximum Flood (PMF) - The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum rainfall, coupled with the worst flood producing catchment conditions.

| | Climate Risk | | |
|---|---|---|---|
| | **Heat** | **Rainfall** | **Flooding** |
| **Vulnerable Communities Response** | Architecture –<br>• Dual aspect dwellings provide more effective natural ventilation, avoiding overheating and excessive reliance on air conditioning systems.<br>Architecture / Urban Design –<br>• Areas of respite provided (both built and vegetative).<br>• Evaluate connectivity of respite areas, pedestrian pathways and active transport network to ensure continuity of shaded coverage.<br>Architecture / Services / Sustainability –<br>• Reduce occupancy energy costs through rooftop solar PV and/or battery storage.<br>Services –<br>• Provision of uninterruptable power supply for emergency support services (‘call button’).<br>• Design apartments for potential retrofit of an in-unit fan system with condenser unit plant room within the building to avoid the use of individual split systems on balconies which would increase heat load on balconies and limit natural ventilation. | Landscape / Urban Design –<br>• Permeable pavement in areas of high pedestrian traffic with bio-retention to reduce risks. | Flooding / Architecture / Urban Design –<br>• Installation of threshold ramps / steps at flood breach locations.<br>• Entries and exits oriented away from known flooding locations, especially accessible routes. |

## 4.1 Implementation of adaptation actions

The master planning process has considered climate risk and implemented adaptation actions within its scope to benefit the life of the proposed development. The following section describes, in detail, a number of these actions and how they:

- address the social, environmental and economic effects of climate change (SR 10.2);
- provide mitigation for vulnerable groups (in addition to the general residents and users of the Quarter) (SR 10.3); and,
- show the results of an increased sensitivity analysis (SR 10.4).

Further information regarding the sensitivity testing including base line conditions, assumptions and additional detail can be found within the *Water Quality, Flooding and Stormwater Report* (AECOM, 2018). Additionally, a number of initiatives, design considerations and adaptation actions that would both directly and indirectly support climate change adaptation have been included in the *ESD Report* (AECOM, 2018).

While heat modelling has not been undertaken to assess the proposed site in response to increasing temperatures, sensitivity testing has been undertaken through a review of the CSIRO & BOM Climate Futures emissions scenarios (RCP 4.5 versus RCP 8.5) to determine the relative impact on the proposed site and resulting decisions to select adaptation actions to account for the worst-case scenario (RCP 8.5). The Climate Risk Register and recommended adaptation actions have taken into consideration of the worst case scenario.

### 4.1.1 Adaptation for heat

Table 4-2 provides the estimated canopy coverage that would be provided through the *Metro Quarter Urban Forest Strategy* (Arterra, 2018), which supports current targets set by the City of Sydney (increase to 23.25% by 2030 and 27.13% by 2050). Providing such dense urban vegetation helps to reduce the overall heat island effect through the shading and provides a natural solution to those who suffer from a number of physical and mental health issues.

As part of the Urban Forest Strategy, the planting strategy for trees identified opportunity to cover approximately 34% of the site to address a number of aspects related to climate change. Tree species have been identified that both have high evapotranspiration rates to help cool the surrounds and effectively mitigate heat as well as those that are tolerant of high temperatures and potential periods of limited water. Specifically, it is recognised that:

- Canopy coverage over paved surfaces serves as a cost-effective means of mitigating urban heat island effects.
- Street trees (mainly large mature trees) help provide areas of respite for commuters, pedestrians and local residents (including those most vulnerable; elderly, youth, disabled) as well as natural air pollution control. These have been sited along the footpaths in and around the Quarter and around bus shelters.
- An increase in vegetation surrounding an urban site helps improve air quality (of benefit to those with respiratory issues) and strengthen community ties. Natural settings have also been shown to help mental health.

**Table 4-2 - Canopy Coverage**

| Canopy Type | Total Area | Canopy Coverage[1] | % of Total Area | % of Relative Area |
|---|---|---|---|---|
| Private | 13,683 $m^2$ | 2,182 $m^2$ | 9% | 16% |
| Street | 9,854 $m^2$ | 5,896 $m^2$ | 25% | 60% |
| **Total** | | **8,340 $m^2$** | **34%** | **-** |

1: Canopy calculations are based on conservative estimates of ultimate mature canopy spreads for species of tree expected to be used.

Figure 4-1 shows that in addition to the ground level natural areas / open space, opportunity to create a green roof or community garden on the lower podiums of the Quarter is being explored. Providing a green roof and/or community garden helps to reduce the heat load on the building during the warmer months, reducing the energy consumption and subsequently energy bills for residents and tenants.

As the building envelope design progresses, opportunities for expanding on this provision of green space, such as the implementation of additional green infrastructure should be explored. Green infrastructure (such as vertical plantings / balcony plantings) provide a number of benefits (reduction in heat, strengthen community ties, provide natural air pollution mitigation) with the added benefit of not requiring as much space that would typically be occupied by building footprints, communal areas and other service / utility requirements. Where reasonable and feasible, detailed design should encourage and incorporate green infrastructure.

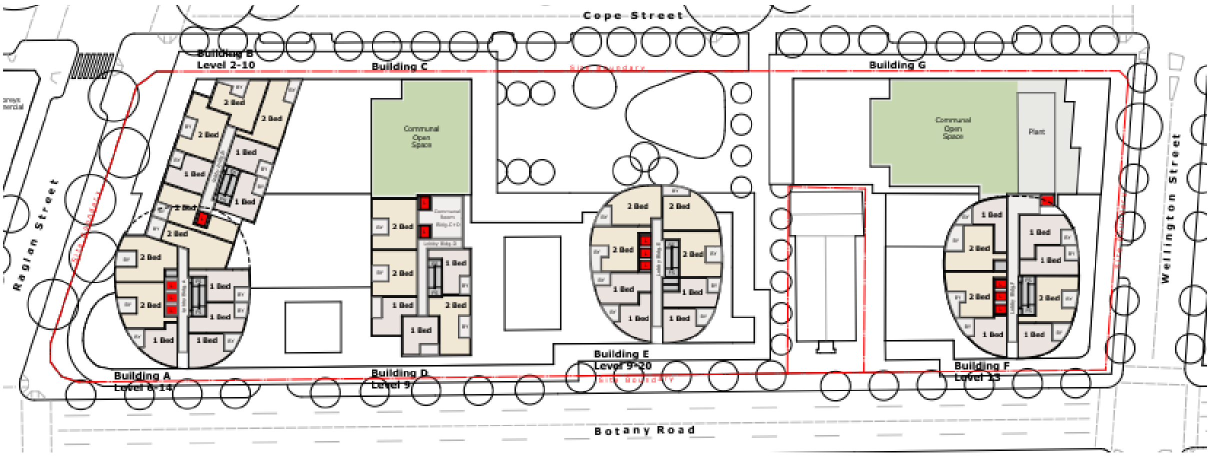



**Figure 4-1 - Green Roof (Heat Reduction & Rainwater Capture)**

While not specifically identified in the design drawings, the apartment design has included a sufficient void, or 'space', to allow for the future retrofit of individualised mechanical heating/cooling systems (e.g. indoor direct expansion fan cooling units with pipe reticulation). It would be up to the detailed building design to optimise the floorplan to allow both maximum usage of the unit space, while catering for the mechanical / utility considerations.

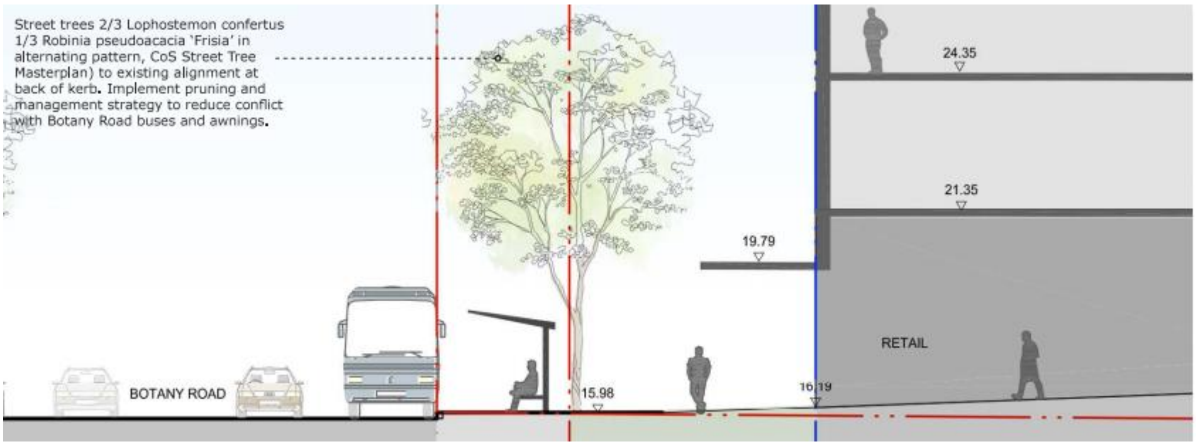
## 4.1.2 Adaptation for rainfall and flooding

A green roof or community garden on the lower podiums of the Quarter would also help in:

- Controlling the flow of rainwater into the stormwater system.
- Improving the water quality of stormwater prior to discharge into the system.
- Providing additional communal space for residents to help encourage healthier lifestyles and strengthen community networks.

Figure 4-2 shows a typical cross section of the proposed development along Botany Street with a number of design considerations to help minimise and reduce the impacts from rainfall and flooding. These include:

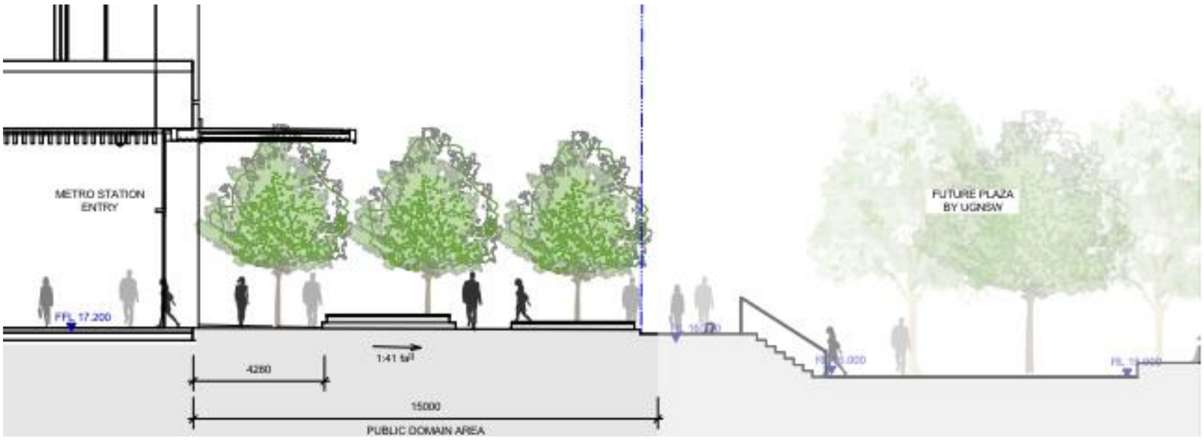
- Water sensitive urban design allows the trees to act as natural stormwater management and treatment.
- Entrances to ground level retail areas have both awnings to prevent rainfall from reaching the main internal areas as well as a ramp for access to help prevent potential flooding within the ground floor.




## Figure 4-2 - Botany Street cross section

Figure 4-3 shows a similar cross section of the Metro Quarter which notes some of the similar design considerations as above, but also further considering:

- Elevated residential ground floors above the levels of a 100 year ARI with a 10% increase in rainfall intensity due to climate change applied flood event (flood planning level), with the staircase serving as a built flood barrier.
- Commercial floors have been designed to allow for extreme flood events (e.g. provision of multiple exit / entry points), with minimal disruption to business continuity. It is recognised that tenants will need to develop internal measures based on potential disruption (e.g. locating stock off the ground).
- The provision of a 'public domain area'. In addition to the reduction in heat lead it further provides a means to capture stormwater and dissipate the intensity of extreme rainfall events.




## Figure 4-3 - Flood Protection Measure

Figure 4-4 shows the proposed development footprint in relation to the identified 100 year ARI with a 10% increase in rainfall intensity due to climate change applied events. The proposed development (entries, exits, evacuation paths) have considered the extent of these flood events and oriented these ingress/egress points accordingly. While flood modelling does show that flood events would subside in a short period, these design considerations have reduced the potential impact on residents, tenants and other users during an emergency events. The design has also catered to ingress/egress concerns of emergency personnel having to access the site during an emergency.

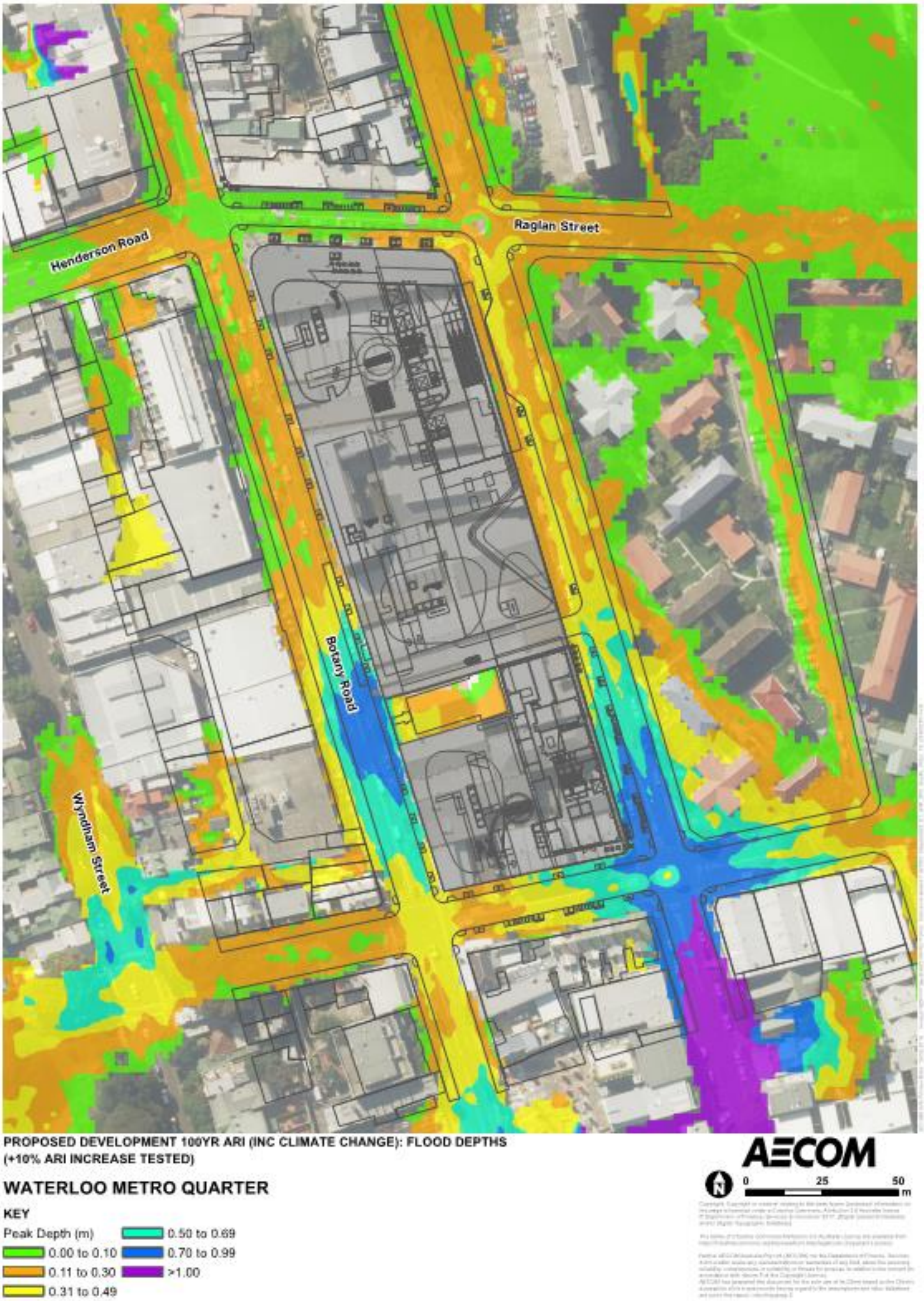



**Figure 4-4 - Entry Flood Protection**

# 5 Study Requirement compliance

Based on the identified adaptation actions above it is expected that the Metro Quarter has both appropriately considered a range of climate risks at the master planning phase and not precluded the future development of a range of solutions. Furthermore, the incorporated and identified adaptation actions and design considerations are considered sufficient to address the SSP requirements.

In specific response to the SSP requirements:

## 5.1 SSP 10.2 – Provide a Climate Change Adaptation Report

*Detail how the proposal will address social, environmental and economic effects of climate change on future communities, including designing to manage changing temperatures and rainfall patterns through the integration of vegetation (existing and future), permeable and reflective surfaces, and Water Sensitive Urban Design.*

**Master Plan Response:**

As identified throughout this Climate Change Adaptation Report, the proposal has incorporated a number of actions and considerations to address the potential changes in the climate with respect to the social, environmental and economic effects.

The following table provides a summary of the responses.

| Effect | Adaption Report Response |
|---|---|
| Social | • Provision of natural shade (trees) and community gardens will encourage stronger social networks and improved health amongst residents.<br>• Provision of water sensitive urban design (including pervious pavement and OSD) will help minimise flood risks during an extreme event, including decreasing the risk of an incident during an evacuation. |
| Environmental | • Provision of vegetation across the quarter would help reduce the urban heat island effect, improve stormwater quality discharge and provide habitat for urban-dwelling species. |
| Economic | • Provision of green roofs, orientation of units (based on solar and wind exposure) and solar PV would allow for increased efficiencies with heating/cooling and watering, resulting in decreased utility costs for residents and tenants.<br>• Providing opportunity for heating/cooling retrofit internal to the building would reduce the need for residents to have a single split system on balconies and give residents control over whether to install a system. |

## 5.2 SSP 10.3 - Vulnerable population impacts resulting from climate change

*Assess the potential impacts of climate change on vulnerable groups, including older people, and mechanisms for implementing mitigation strategies.*

**Master Plan Response:**

As mentioned previously, climate change may result in exacerbated impacts for vulnerable members of the population. Through the risk identification process, potential risks to these vulnerable groups were identified with a relative risk rating assigned. Those risks that were highest ranked were extracted and included in Section 3.1.2 for further consideration and identification of adaptation options and mitigation strategies.

<u>Extreme Heat</u>

It is well understood that extreme heat events result in impacts to vulnerable groups primarily through increased utility costs and heat stress events. As evidenced throughout this report, a number of design elements and site considerations have been incorporated to address this increased concern. These have included:

- The provision of a well-connected network of street trees would provide areas of respite and shading around the Metro Quarter. This in turn helps reduce the surrounding temperatures which would serve to reduce the potential for heat stress events of residents and other users within the Metro Quarter. Cooler surrounding temperatures would also have the effect of improving sleeping conditions during hot nights, which has been shown to improve mental health and stress levels of individuals.
- The consideration of internal heating / cooling retrofit opportunities would allow residents the flexibility of installing a system, or doing without. The use of green roofs and other natural cooling strategies (natural ventilation) would help reduce the operating costs for individuals who may use things like air conditioning on hot days or portable heaters on cold days. Opportunities for offset power generation (through solar PV or otherwise) should be investigated to help reduce the overall burden on residents.

Rainfall

Flood modelling has shown that the surrounding catchment is already constrained by development and there is little or no ability for any adverse flood impacts resulting from future development in the Metro Quarter to be absorbed. These flood events could potentially impact on residents and commuters travelling to, from and within the Metro Quarter. Each building will therefore contain an OSD tank, to both capture incoming flow and reduce the peak outflow from the study area. This will in turn not only help reduce risks to those within the Metro Quarter, but also will also assist in offsetting any potential adverse impacts downstream.

In addition, design features such as pervious pavement and the orientation of walking areas to divert water away from critical areas have been included to reduce the risks of residents and other users of the Metro Quarter.

Flooding

Potential emergency response measures have been considered to assist in reducing the consequences of flood risks. For the Waterloo precinct, this will primarily rely on adopting an appropriate FPL, and ensuring that developments are sufficiently raised to enable a shelter in place strategy to be effective. In the case of the Metro Quarter, this has required that access to the Waterloo Station box be elevated above the PMF level. Residential areas are expected to be raised to this level also.

Access to and from the buildings during a flood event, including for the purposes of evacuation should also be considered. The majority of the Waterloo Precinct east of Cooper Street is expected to be subject to shallow depth overland flows which are managed with appropriate drainage. Evacuation from the buildings in this precinct, or emergency vehicle access, is still likely to be possible. However, as the buildings will be above the PMF level, a shelter in place strategy is likely preferable to avoid unnecessary vehicle or pedestrian movements during an extreme storm event. In the instance of commercial spaces where flooding may impact on the ground level, each space will have a secondary entry / exit point to a location within the Quarter that is located above the PMF level.

There may be difficulty accessing the Metro Quarter, as well as some of the Buildings along Cooper Street or Wellington Street as flood depths approach 1.5m. It may be possible for large vehicles to access the Metro Quarter from Raglan Street; however, this will be dependent on the flood conditions in the surrounding streets, as well as the judgment of the vehicle operator.

The expected duration of flooding is expected to be relatively short, with the flooding along Cope Street and Botany Road responding quickly to local rainfall. As a consequence, flood levels will recede relatively quickly (approximately 1 hour following storm commencement) which will allow vehicle access to the Metro Quarter following the rainfall event. Isolated ponding areas may remain throughout the catchment that take longer to recede, and these may contribute to greater traffic issues.

## 5.3 SSP 10.4 – Sensitivity testing to address climate change

*Undertake a sensitivity analysis to address the impact of climate change due to increased temperatures, extreme heat events and changing rainfall patterns integrated with the Water Quality, Flooding and Stormwater Study.*

**Master Plan Response:**

The proposed site has been designed to account for the flood risks prevalent throughout and surrounding the site including incorporating a potential 10% increase in the ARI to account for climate change (refer Section 4.1). Proposed ground levels (for residential) and orientation of access for both residents and underground services (e.g. car park) will be raised to ensure there are no floodwater breeches from significant storm events particularly at Metro and building entrances. This sensitivity testing for climate change with regard to flooding would be further refined during detailed design, with specific electrical and other critical systems being sited appropriately in response to the results of these tests. Further information regarding the sensitivity testing including base line conditions, assumptions and additional detail can be found within the *Water Quality, Flooding and Stormwater Report* (AECOM, 2018).

As noted in Section 4.1, while modelling for temperature has not been specifically undertaken, sensitivity testing in the form of emissions scenario review has been undertaken for increased temperatures and extreme heat. As projected by the CSIRO & BOM, an increased frequency and duration of hot days and heatwaves is projected for the East Coast in general with very high confidence under both RCP 4.5 and RCP 8.5 emissions scenarios. As the differences in projections between the scenarios are largely negligible however (refer Table 2-2), the worst-case scenario (RCP 8.5) has been assumed for the identification and recommendation of adaptation actions.

Of benefit for the proposed site, utilising data prepared by the City of Sydney, the area around the Metro Quarter currently experiences lower temperatures when compared with the whole of the City of Sydney, affording the site a relatively lower temperature baseline when compared to other parts of Sydney. As part of the *Metro Quarter Urban Forest Strategy* (Arterra, 2018), the Metro Quarter will not only support, but exceed the targets for tree coverage further contributing towards mitigating potential changes in mean and extreme temperature (including the urban heat island effect) resulting from climate change.

# 6 Conclusion

As part of the broader State Significant Precinct process, a Climate Risk Assessment was undertaken with a number of risks identified. While no 'extreme' risks were identified, 14 'high' risks were identified. Section 4 of this report has detailed the adaptation actions and initiatives that have been incorporated and planned for the Metro Quarter to address these risks. While a formal residual risk assessment has not been undertaken, these actions will result in a reduction in risk from climate change. It is anticipated that as the proposed development progresses from the master plan planning application to detailed design, the climate risk assessment would be revisited with a residual risk assessment undertaken to verify integration of adaptation measures and how that has resulted in changes to the risks previously identified.

Section 5 of this report summarises the actions and responses that have been undertaken in direct response to the study requirements for the SSP study. It is considered that the measures undertaken to date and the future provision of additional measures are sufficient to reduce the risk to vulnerable populations from climate change and minimise the effects of climate change through social, environmental and economic considerations.

## 6.1 Future actions

Consideration and response to climate risks can be undertaken at all stages of development. Table 4-1 identified both actions that have been incorporated design and considerations that are subject to detailed design development. Many of these adaptation actions are important to carry forward into the next phase of design. These include:

- **Providing the opportunity for future heating and cooling as retrofit –** it is recognised that while passive, natural ventilation has been provided at the master planning stage, considering space for future equipment / plant (e.g. indoor direct expansion fans, pipe reticulation) as part of an internal retrofit could serve to avoid the use of reverse-cycle units on the balconies of individual units. This would serve two purposes including reducing the amount of heat generated into the Metro Quarter (further reducing the effects of the urban heat island) and reduce costs to residents (passive natural ventilation will largely eliminate the need for HVAC systems, while the provision of retrofit capacity will allow residents to make their own decision).
- **Encourage the implementation of green infrastructure where possible -** it is understood that in planning for the Metro Quarter, a number of competing interests have to be considered (community gardens, locating of equipment / plant, potential inclusion of Solar PV). Identifying opportunities to increase the amount of green infrastructure (e.g. plantings, landscaped areas, trees) across the roofs, balconies, podiums, walls and public domain would serve not only to improve air quality in highly trafficked areas, but reduce heat loads on buildings, allowing HVAC and other systems to operate efficiently and help reduce potential impacts from rainfall events as green infrastructure serves to capture some of the falls.

Additional measures need to be addressed in future phases (detailed design, tender requirements, construction). As the planning and design for the Metro Quarter is an ongoing process, actions to be addressed in future phases have been included in Table 6-1.

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**Table 6-1 - Adaptation action plan**

| Climate Risk | Importance | Adaptation Response |
|---|---|---|
| Extreme heat | It has been demonstrated above that extreme heat is a high risk, particularly in Sydney. While site planning goes a long way in reducing ambient heat levels, further actions are required to help reduce risk to individual residents and/or tenants. The following responses should be incorporated / investigated further during detailed design to determine the feasibility, and where feasible, incorporated into contracting requirements or construction. | Material selection for buildings should provide insulation for heat as well as reflectivity against solar exposure. |
| | | HVAC systems and other critical plant to adopt projected 2030 temperatures as ambient design conditions. |
| | | Provision of external shade devices / fixed shading (louvres) to reduce heat loads on buildings. |
| | | Prepare an Urban Heat Strategy that provides actions to help achieve a net reduction in heat island effect (temperature). |
| Rainfall / Extreme Flooding | Rainfall and associated flooding have been identified as being some of the most important climate risks facing the Metro Quarter. Flash flooding currently impacts the area surrounding the Metro Quarter and will likely worsen with projected changes to the climate. Consideration of these worsening events would further provide safer conditions for residents and help make the Quarter more resilient to these extreme events. | Sensitivity testing should consider 20% and 30% increases in rainfall volume. |
| | | Consider the increased use of pervious pavement where possible. |
| | | Consider providing flexibility in the stormwater design to account for future increases in flow or volume (e.g. allow for expansion in capacity) without the need for future costly upgrades. |
| Bushfire | While not as high of a concern for the Sydney CBD, an increase in canopy coverage and landscaping is likely to result in an increased risk of bushfire. Furthermore, it is recognised that bushfire smoke from the surrounding region can often bring smoke into the city, while physical damage to power infrastructure can impact supply to the city. | Consider materials that have a higher fire risk rating, particularly around critical equipment. |
| | | Consider the provision of a back-up power supply on-site for critical systems in the event of a supply disruption. |

# Appendix A Climate Risk Register

**Table 6-2 - Climate Risk Register**

| Risk ID | Variable & Associated Risk | Climate Variable | Pre-Mitigation 2030 Risk Rating Consequence (C), Likelihood (L) | | | Priority Yes (Y) | Pre-Mitigation 2090 Risk Rating Consequence (C), Likelihood (L) | | | Stage at which risk will be addressed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | L | Rating | Y | C | L | Rating | Planned measures to further reduce risk | Phase |
| W-5 | Sea level rise changing groundwater levels causing from subsidence that potentially impacts utility lines | Sea Level Rise | C2 | L4 | M | | C2 | L3 | H | 1) Engage with UrbanGrowth to understand groundwater issues around site<br>2) Include groundwater considerations within design<br>3) Include groundwater consideration within construction planning e.g. review construction methods for likelihood to cause subsidence to existing or heritage buildings<br>4) Consider projected future groundwater levels and relocate at risk utilities<br>5) 2090 sea level rise projections adopted for all drainage and stormwater design | Design |
| W-6 | Groundwater level changes causing subsidence in wider area (especially heritage items and existing buildings) | Sea Level Rise | C2 | L4 | M | | C2 | L5 | L | 1) Engage with UrbanGrowth to understand groundwater issues around site<br>2) Include groundwater considerations within design<br>3) Include groundwater consideration within construction planning e.g. Review construction methods for likelihood to cause subsidence to existing or heritage buildings<br>4) 2090 sea level rise projections adopted for all drainage and stormwater design | Design |
| W-9 | In an extreme event where power is lost (outages from storms, bushfires, or from excess demand on the power grid), the interdependencies between healthcare systems and electrical and communications could fail and cause loss of life and injury | Extreme Storms, Bushfires, Extreme Heat and Mean Temperature | C2 | L3 | H | Y | C2 | L2 | H | 1) Consider providing a continuous power supply with backup generators for critical uses in all areas of the development<br>2) Ensure number of users who will need critical supply connections is planned for across life of development<br>3) Ensure energy supply backups provided to facilities caring for the elderly or infirm | Design |
| W-10 | In an evacuation scenario caused by flooding, extreme storms, or bushfires, those who are mentally ill, physically impaired, and those who have limited English proficiency are not evacuated | Extreme Rainfall and Flooding, Extreme Storms, Bushfires, Extreme Heat and Mean Temperature | C3 | L2 | H | Y | C3 | L1 | H | 1) Community emergency planning to include information on mobility impaired or those needing additional care in the event of an evacuation<br>2) Educational materials for disaster preparation should be translated and distributed through culturally appropriate channels<br>3) Number of community members who are likely to be vulnerable to this issue to be reviewed<br>4) In areas where there are a high number of people who may be affected by this issue, operations and maintenance plans to include requirement for staff to visit home to assist in evacuation<br>5) Trial evacuations may be rehearsed with first responders | O&M |
| F-1 | Inundation of buildings, roads, footpaths and other site infrastructure by water limiting access and egress and potentially leading to isolation | Extreme Rainfall and Flooding | C3 | L3 | M | | C3 | L2 | H | 1) Emergency and flood planning for buildings should include site access considerations<br>2) 2030 rainfall intensity projections adopted as the base case design for drainage and stormwater design | Design |
| F-2 | Increase in safety issues to personnel, residents and transport customers around stormwater runoff and flood waters | Extreme Rainfall and Flooding | C3 | L3 | M | | C3 | L3 | M | 1) 2030 rainfall intensity projections adopted as the base case design for drainage and stormwater design<br>2) Educate personnel, residents and transport customers around dangers of flood water and runoff<br>3) Prepare and communicate clear evacuation plan for community prior to hazard event | Design<br>O&M |
| F-3 | Greater intensity of rainfall and runoff overwhelming drainage capacity and causing flooding and inundation of roof, ground and subterranean systems | Extreme Rainfall and Flooding | C3 | L2 | H | | C3 | L2 | H | 2030 rainfall intensity projections adopted as the base case design for drainage and stormwater design<br><br>Water sensitive urban design measures incorporated as part of site planning to accommodate an increase in rainfall.<br>Design to minimize impervious surfaces to reduce runoff | Design |
| F-4 | Greater intensity of rainfall and runoff causing inundation of underground utility issues (electricity distribution, fibre cables, pumping stations, other network | Extreme Rainfall and Flooding | C3 | L2 | H | | C3 | L2 | H | 2030 rainfall intensity projections adopted as the base case design for design levels for critical infrastructure, drainage and stormwater design<br><br>Locate utilities above ground where possible | Design |

| Risk ID | Variable & Associated Risk | Climate Variable | Pre-Mitigation 2030 Risk Rating Consequence (C), Likelihood (L) | | | Priority Yes (Y) | Pre-Mitigation 2090 Risk Rating Consequence (C), Likelihood (L) | | | Stage at which risk will be addressed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | L | Rating | Y | C | L | Rating | Planned measures to further reduce risk | Phase |
| | infrastructure malfunctions) | | | | | | | | | | |
| F-5 | Extreme rainfall can cause inundation of car parks, tunnels and other below-ground infrastructure resulting in transport network disruption | Extreme Rainfall and Flooding | **C4** | **L3** | M | | **C4** | **L2** | M | 2030 rainfall intensity projections adopted as the base case design for design levels for critical infrastructure, drainage and stormwater design<br><br>Prepare operation and maintenance plans to minimize service interruption | Design<br><br>O&M |
| F-6 | Extreme rainfall can impact potable water supply due to overflow of water catchment and supply systems | Extreme Rainfall and Flooding | **C2** | **L5** | L | | **C2** | **L4** | M | 1) Manage risks to water supply from extreme rainfall by diversifying water supply, including expanding desalination<br>2) Manage water demand in crisis situation | External Stakeholders |
| H-1 | Extreme heat impacting the human body's ability to function, which will lead to reduced work capacity of workers and a risk to their health and safety | Extreme Heat and Mean Temperature Change | **C3** | **L3** | M | | **C3** | **L2** | H | Allow for frequent breaks and hydration of staff; consider adjustment of working hours to avoid the hottest period of the day. | O&M |
| H-2 | Extreme heat both increases demand on the energy network because air conditioning units work harder to maintain temperature and reduces energy network capacity, which can cause brownouts and blackouts when the power grid is overwhelmed | Extreme Heat and Mean Temperature Change | **C2** | **L2** | H | | **C2** | **L2** | H | 1) Design electrical infrastructure to minimise peak energy demand<br>2) Consider use of water cooled air conditioning systems as they are more energy efficient at higher temperatures<br>3) Develop O&M and emergency plans for heat waves when energy demands are high, including shutting down key power users to prevent black outs and public outreach to promote turning off non-essential electric devices | Design<br><br>O&M |
| H-3 | Extreme heat causes reduced energy network capacity and disrupts communication system | Extreme Heat and Mean Temperature Change | **C2** | **L2** | H | | **C2** | **L2** | H | 1) Connect critical communications systems to energy supplies with back up generation<br>2) Understand interdependencies between critical communication systems and electrical energy supply<br>3) Develop O&M and emergency plans for heat waves to keep essential communications systems intact<br>4) Utility providers to manage demand, including shutting down key power users to prevent black outs and public outreach to promote turning off non-essential electric devices | Design<br><br>O&M<br><br>O&M, External Stakeholders |
| H-4 | Increased heat stress events causing health impacts to residents | Extreme Heat and Mean Temperature Change | **C3** | **L2** | H | | **C3** | **L2** | H | 1) Develop an urban heat island management plan during design to reduce urban heat island effect<br>2) Provide shaded areas, drinking fountains, water features, solar reflective materials in public domain areas<br>3) Maximise passive cooling features in design e.g. glazing, shading, orientation<br>4) Building design to be flexible for potential future retrofit for air conditioning | Design |
| H-5 | Extreme heat increasing requirements for cooling and areas of respite | Extreme Heat and Mean Temperature Change | **C3** | **L2** | H | | **C3** | **L1** | H | Adopt 2030 climate projections to ambient design temperature for Heating Ventilation Air Conditioning (HVAC) design | Design |

| Risk ID | Variable & Associated Risk | Climate Variable | Pre-Mitigation 2030 Risk Rating Consequence (C), Likelihood (L) | | | Priority Yes (Y) | Pre-Mitigation 2090 Risk Rating Consequence (C), Likelihood (L) | | | Stage at which risk will be addressed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | L | Rating | Y | C | L | Rating | Planned measures to further reduce risk | Phase |
| H-6 | Extreme heat causing an increase in operation and maintenance costs (HVAC performance, failure of infrastructure, repair / replacement) | Extreme Heat and Mean Temperature Change | **C3** | **L3** | M | | **C3** | **L2** | H | 1) Adopt 2030 climate projections to ambient design temperature for HVAC design.<br>2) Include passive cooling features on buildings to reduce load on HVAC system e.g. glazing, shading, orientation | Design |
| H-7 | Extreme heat causing buildings to overheat / impact on thermal performance – increased requirement for cooling | Extreme Heat and Mean Temperature Change | **C4** | **L4** | L | | **C4** | **L3** | M | 1) Adopt 2030 climate projections to ambient design temperature for HVAC design.<br>2) Life cycle analysis, with projected impacts of climate change, to understand true cost of heating and cooling system, building orientation, and insulation materials choices in building construction<br>3) Design electrical infrastructure to minimise peak energy demand<br>4) Use water cooled air conditioning systems as they are more energy efficient at higher temperatures | Design |
| H-8 | Extreme heat causing the public to stay inside of air conditioned areas, which reduces the use of outdoor public recreational space | Extreme Heat and Mean Temperature Change | **C4** | **L2** | M | | **C4** | **L1** | M | 1) Construction of Shade Structures and inclusion of water features and/or misters in outdoor public recreational space<br>2) Creation of air conditioned, interior public recreation space | Design |
| H-9 | Extreme heat causing people to use more air conditioning and fans, increasing energy demand. It also leads people to drink more water and use more water to maintain landscaping | Extreme Heat and Mean Temperature Change | **C4** | **L2** | M | | **C4** | **L1** | M | Onsite water harvesting and reuse and energy generation to, reduce vulnerability by creating redundancy and backup supply | Design |
| H-10 | Extreme heat causing health risks among vulnerable populations in social housing who are without access to air conditioning within their units. | Extreme Heat and Mean Temperature Change | **C4** | **L2** | M | | **C4** | **L1** | M | 1) Availability of air conditioning for social housing – Identify climate scenarios where increased ambient design temperatures or extreme heat triggers need to provide air conditioning in social housing<br>2) Increased landscape irrigation requirements during establishment and O&M | Policy<br><br>O&M |
| H-11 | Extreme heat causing deterioration of external surfaces/cladding on buildings costing building operators maintenance money and can also pose a safety risk if cladding begins to fail | Extreme Heat and Mean Temperature Change; Extreme Storm (High Winds) | **C4** | **L4** | L | | **C4** | **L3** | M | Life cycle analysis, with projected impacts of climate change, to understand true cost of materials choices in original building construction | Design |
| H-12 | Extreme heat causing deterioration of external surfaces/cladding on buildings costing building operators maintenance money and can also pose a safety risk if cladding begins to fail | Extreme Heat and Mean Temperature Change; Extreme Storm (High Winds) | **C4** | **L4** | L | | **C4** | **L3** | M | 1) Regular maintenance and repair<br>2) Storm preparation | O&M |
| H-13 | Extreme heat causing accelerated degradation of concrete structures / reduced building life costing building operators money and posing safety risk in load-bearing areas | Extreme Heat and Mean Temperature Change | **C4** | **L4** | L | | **C4** | **L3** | M | Building modelling during design process to include projections for accelerated degradation due to climate change and possible mitigation to keep concrete from degradation | Design |

| Risk ID | Variable & Associated Risk | Climate Variable | Pre-Mitigation 2030 Risk Rating Consequence (C), Likelihood (L) | | | Priority Yes (Y) | Pre-Mitigation 2090 Risk Rating Consequence (C), Likelihood (L) | | | Stage at which risk will be addressed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | C | L | Rating | Y | C | L | Rating | Planned measures to further reduce risk | Phase |
| H-14 | Heat wave temperature leading to increased softening pavements causes road disruptions and higher maintenance costs | Extreme Heat and Mean Temperature Change | C4 | L4 | L | | C4 | L3 | M | Regular inspection of pavements with maintenance activities undertaken as necessary | O&M |
| W-1 | Increased number of shelter in place occasions during extreme events creating increased behavioural stresses | Extreme Heat and Mean Temperature Change | C4 | L3 | M | | C4 | L2 | M | 1) Integration of Psychological and Mental Health into Public Health Planning, Design and Implement Psychological First Aid Training<br>2) Prepare Materials for Media and Public Education, especially in schools, essential components of community preparedness, response, and recovery | External Stakeholder |
| W-2 | Climate extremes across the region increasing operational energy costs and living costs | Extreme Heat and Mean Temperature Change | C3 | L1 | H | Y | C3 | L1 | H | Cost modelling during design process to include projections for adjusted energy costs due to climate change | Design |
| W-7 | Extreme events harming health and wellbeing and activation (safety) due to reduced walkability | Extreme Heat and Mean Temperature Change | C3 | L2 | H | Y | C3 | L2 | H | Promote indoor physical activities to maintain health and well-being during a shock event. See H4 or further adaptation measure | O&M |
| W-8 | Extreme heat impacting health of vulnerable elderly and community members who are especially at night | Extreme Heat and Mean Temperature Change | C3 | L2 | H | Y | C3 | L1 | H | Design of outdoor spaces to be universally usable and comfortable for those "under 8 and over 80"<br><br>Educational campaign to help families understand special care needed for very young children in hot temperatures | Design |
| W-12 | Extreme heat in areas without air conditioning causing greater demand on shared spaces that are cooled | Extreme Heat and Mean Temperature Change | C3 | L1 | H | Y | C3 | L1 | H | Prepare shared spaces for additional use during extreme heat events, including adding additional seating and/or creating an overflow area to meet the increased demand | O&M |
| W-13 | Impacts of increased incidence of violent crime during heatwave events on community | Extreme Heat and Mean Temperature Change | C3 | L2 | H | Y | C3 | L1 | H | 1) Increase security presence during heat waves<br>2) Provide increased access to indoor and outdoor shared cool spaces | O&M |
| B-1 | Bushfires impacting power supply continuity | Bushfire | C3 | L3 | M | | C3 | L2 | H | Design process to explore potential of installing generator, design process to explore possibility of precinct cogeneration, design process to explore possibility of installation of solar power for redundant supply, design process to explore possibility of a waterloo precinct microgrid | Design |
| B-2 | Smoke from bushfires and back burning lowers air quality and can impact respiratory and human health of personnel and residents, especially outdoor workers and children playing outdoors | Bushfire | C4 | L3 | M | Y | C4 | L2 | M | 1) Citizen education on how to protect their respiratory systems during a bushfire, including using recycled air with the HVAC system, avoiding outdoor activities, and information on when air quality poses a risk<br>2) Routine checks of building air filters to control interior air quality<br>3) Labour policy to include exemption for outdoor workers when air quality reaches hazardous levels or mandatory respiratory filters for outdoor workers | O&M |
| B-3 | Smoke penetrating into buildings through unsealed areas and reduced efficiency of equipment (e.g. HVAC units) can cause damage to the building and health issues | Bushfire | C4 | L4 | L | | C4 | L3 | M | Building operators to help tenants prevent, evaluate, and mitigate smoke damage | O&M |

| Risk ID | Variable & Associated Risk | Climate Variable | Pre-Mitigation 2030 Risk Rating Consequence (C), Likelihood (L) | | | Priority Yes (Y) | Pre-Mitigation 2090 Risk Rating Consequence (C), Likelihood (L) | | | Stage at which risk will be addressed | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **C** | **L** | **Rating** | **Y** | **C** | **L** | **Rating** | **Planned measures to further reduce risk** | **Phase** |
| D-1 | Drought conditions demand increased maintenance for landscaping of parks, open space and street trees | Drought | **C5** | **L3** | L | | **C5** | **L2** | L | 1) Inclusion of drought tolerant species in site design<br>2) Gradual replacement of existing plants and trees at end of life cycle with drought tolerant plant and tree species in parks and open spaces<br>3) Citizen education campaign for helping to water trees | Design<br>O&M |
| D-2 | Drought conditions can cause soil subsidence, movement and cracking as a result of increased variability of periods of wetting and drying causing reduced integrity of building foundations and potential structural failure | Drought | **C4** | **L4** | L | | **C4** | **L3** | M | Building operational practices to include an inspection cycle | O&M |
| W-11 | Drought risk affecting water storage systems on site and increasing dependency on an already stressed mains water supply | Drought | **C3** | **L3** | M | | **C3** | **L2** | H | 1) Design to consider additional water storage to maintain independent supply in times of drought<br>2) Program to reduce water demand in times of drought (ban on yard water usage) | Design, Policy |
| S-1 | Extreme storms causing damage to external surfaces (e.g. loss of building materials) and exposed plant / equipment (e.g. HVAC units) from hail damage and debris from high winds | Extreme Storms (e.g. East Coast Low) and High Winds | **C3** | **L3** | M | | **C3** | **L3** | M | 1) Detailed design to consider sensitivity to extreme wind cases in materials selection, with an understanding of life cycle cost<br>2) Building operators will plan for extreme wind events (pedestrian areas susceptible to flying debris closed off, for example) | Design |
| S-2 | Rain and moisture penetration during storms and high winds (e.g. damaged roofing, window frames) | Extreme Storms (e.g. East Coast Low) and High Winds | **C3** | **L3** | M | | **C3** | **L2** | H | Regular maintenance checks to windows as part of normal building operations, use of draining windows (instead of barrier) to allow for drainage/dry out of any water penetration, education for residents about mould growth prevention | O&M |
| W-3 | Extreme hail events causing blockages of drainage pits and box gutters resulting in inundation and localised flooding | Extreme Storms (e.g. East Coast Low) and High Winds | **C3** | **L3** | M | | **C3** | **L3** | M | Roof drain design requirements adjusted in building code to prevent blockage and allow for additional rainfall capacity | Design |
| W-4 | Extreme wind and rainfall causing increased penetration of water into facades and windows | Extreme Storms (e.g. East Coast Low) and High Winds | **C4** | **L4** | L | | **C4** | **L3** | M | Refer to S-2 for adaptation options | |
| S-3 | Increased ambient temperatures and changing seasonal rainfall causing increased reservoir bacteria levels impacting ability to treat water quality enough to meet public demand | Extreme Heat and Mean Temperature Change Extreme Storms (e.g. East Coast Low) and High Winds | **C4** | **L4** | L | | **C4** | **L3** | M | Water provider to expand treatment capacity and research ways to prevent bacteria growth | External Stakeholder |

# Appendix B Consequence, Likelihood and Risk Matrices

### Table 6-3 - Consequence and Success Criteria (Source: GBCA)

| Consequence and Success Criteria | Community and Lifestyle | Environment and Sustainability | Service Quality | Development Delivery | Community Confidence |
|---|---|---|---|---|---|
| **Catastrophic** | The region would be seen as very unattractive, moribund and unable to support its community. | Major widespread loss of environmental amenity and progressive irrecoverable environmental damage. | Services would fall well below acceptable standards and this would be clear to all. | Development potential would be restricted, delivered late or not at all in a large number of cases. | There would be widespread concern about the capacity to serve the community. |
| **Major** | Severe and widespread decline in services, accessibility and quality of life within the community. | Severe loss of environmental amenity and a danger of continuing environmental damage. | The general public would regard the development's services as unsatisfactory. | There would be isolated instances of development being restricted, delayed or not delivered at all. | There would be serious expressions of concern about the capacity to serve the community. |
| **Moderate** | General appreciable decline in services and accessibility. | Isolated but significant instances of environmental damage that might be reversed with intensive efforts. | Services would be regarded as barely satisfactory by the general public and the development's project team. | There would be isolated but important instances of development being restricted or delayed. | There would be isolated expressions of concern about the capacity to serve the community. |
| **Minor** | Isolated but noticeable examples of decline in services and accessibility. | Minor instances of environmental damage that could be reversed. | Services would be regarded as satisfactory by the general public but the development's project team would be aware of deficiencies. | There would be isolated instances of development delivery failing to meet acceptable standards to a limited extent. | There would be some concern about the capacity to serve the community but it would not be considered serious. |
| **Insignificant** | There would be minor areas in which the region was unable to maintain its current services. | No environmental damage. | Minor deficiencies in principle that would pass without comment. | Minor technical shortcomings in service delivery would attract no attention. | There would be minor concerns but they would attract no attention. |

## Table 6-4 - Likelihood Criteria

| Rating | Recurrent risks | Single events |
|---|---|---|
| Almost certain | Could occur several times per year | More likely than not – Probability greater than 50%. |
| Likely | May arise about once per year | As likely as not – 50/50 chance. |
| Possible | May arise once in ten years | Less likely than not but still appreciable – Probability less than 50% but still quite high. |
| Unlikely | May arise once in ten years to 25 years | Unlikely but not negligible – Probability low but noticeably greater than zero. |
| Rare | Unlikely during the next 25 years | Negligible – Probability very small, close to zero. |

## Table 6-5 - Risk Matrix

| | Consequences | | | | |
|---|---|---|---|---|---|
| Likelihood | Insignificant | Minor | Moderate | Major | Catastrophic |
| Almost certain | Medium | Medium | High | Extreme | Extreme |
| Likely | Low | Medium | High | High | Extreme |
| Possible | Low | Medium | Medium | High | High |
| Unlikely | Low | Low | Medium | Medium | Medium |
| Rare | Low | Low | Low | Low | Medium |