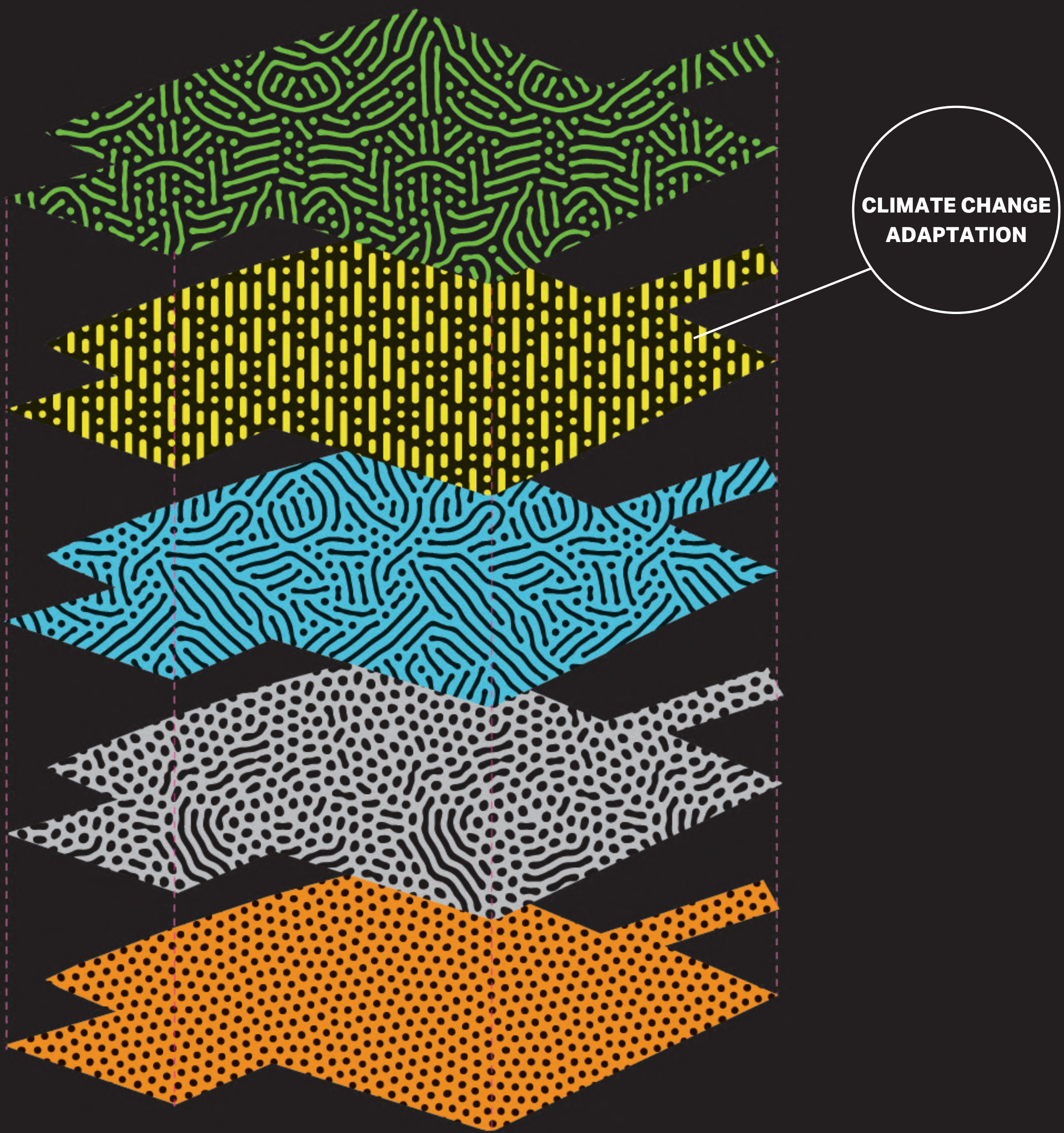
WATERLOO
CLIMATE CHANGE ADAPTATION REPORT



Prepared for

NSW Land and Housing Corporation

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AECOM

Quality information

Prepared by	Checked by	Verified by	Approved by
Harley Lewington	Suzanna Remmerswaal	Adam Davis	Daniel Fettell
Environmental Consultant	Principal Consultant – Sustainability & Resilience	Technical Director – Sustainability and Resilience	Principal Engineer

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Prepared for:

NSW Land and Housing Corporation

Prepared by:

AECOM Australia Pty Ltd
Level 21, 420 George Street
Sydney NSW 2000
PO Box Q410
QVB Post Office, NSW 1230

T: +61 2 8934 0000
F: +61 2 8934 0001
aecom.com

ABN 24 960 729 253

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Executive Summary

This Climate Change Adaptation Report details how the Waterloo South Indicative Concept Proposal addresses the social, environmental and economic effects of climate change on the future community of Waterloo South. The report aligns with the development of the adjoining Waterloo Metro Quarter and provides consistent adaptation actions for the precinct.

The Climate Change Adaptation Report outlines historical and future exposure of the site to climate related shocks; presents the participatory risk assessment process undertaken in preparing this report; outlines adaptation actions that have been integrated into the Indicative Concept Proposal; and provides additional actions that can be considered in future development stages (e.g. detailed design). This Report references certain Study Requirements issued by the NSW Minister for Planning in May 2017. While the project is going through a different planning pathway, the overall SSP Study Requirements are still relevant and require the NSW Land and Housing Corporation 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.*

Risks were identified and included within the *Climate Risk Register* (AECOM, 2018), which can be found in Appendix A. As part of the risk assessment process, a number of key risks were extracted (refer Section 5.1.2) with adaptation actions identified (refer Section 6). Of climate related variables, the site's exposure to the increasing frequency and intensity of heat events, extreme rainfall and flooding, and storms have been identified as priority focus areas for adaptation. The key climate impacts identified through the risk assessment workshop process are outlined below.

Key impacts identified for Waterloo South

Variable	Climate Impact
Heat	• 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 at or beyond capacity. • Increased heat stress events can lead to significant health impacts to residents, particularly vulnerable community members. This leads to increasing requirements for cooling and areas of respite.
Flooding	• Greater intensity of rainfall and runoff has the potential to overwhelm drainage capacity and cause flooding and inundation of roof, ground, and subterranean systems. • Greater intensity of rainfall and runoff has the potential to cause inundation and malfunction of underground utilities such as electricity distribution, fibre cables, pumping stations, other network infrastructure.
Storms	• Rain and moisture penetration during storms and high winds causing damages to buildings and plant.
Drought	• Drought risk affecting water storage systems on site and increasing dependency on mains water supply for non-potable water use.
Bushfires	• Increased bushfire frequency and intensity impacting power supply continuity. • Increased bushfire frequency and intensity causing reduced air quality leading to health impacts to community members.
Combined	• 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.

Variable	Climate Impact
	• 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 heat in areas without air conditioning causing greater demand on shared spaces that are cooled. • Impacts of increased incidence of violent crime during heatwave events on community.

Adaptation actions and responses have been identified and integrated into the Indicative Concept Proposal to address these climate impacts and associated potential social, environmental and economic effects of climate change on future communities:

Response to key climate impacts outlined in the Indicative Concept Proposal

Variable	Indicative Concept Proposal response
Heat	• The Indicative Concept Proposal Metrics target 30% of Waterloo South to be occupied by the tree canopy, which represents an increase of the existing canopy coverage. Canopy coverage over paved surfaces serves as a cost-effective means of mitigating urban heat island effects and additional projected increases in mean temperature and extreme heat events. The tree retention and replacement targets will help to reduce the urban heat for pedestrians and residents (including those most vulnerable; elderly, youth, disabled). An increase in vegetation surrounding an urban site also helps to improve air quality which benefits those with respiratory issues. • The Indicative Concept Proposal features several water sensitive urban design (WSUD) measures which provide a means for cooling the microclimate and reducing urban heat island effects. For example, the integration of water into landscapes assists in cooling urban areas via evaporation, provides activities for children, and provides amenity for the community. If designed appropriately, there are also significant co-benefits for flood mitigation. • The commitment to achieving a 6 Star Green Star Communities rating target strengthens many adaptation actions and provides a platform for integrated planning to be undertaken. Targeting 5-Star Green Star – Design & As Built (Design Review certified) building ratings for individual buildings within Waterloo South also has co-benefits related to adaptation, particularly around creating energy and water efficient buildings that are better able to maintain thermal comfort. • Passive design measures such as delivering dual aspect dwellings provide more effective natural ventilation, avoiding overheating and excessive reliance on air conditioning systems. • Provision of diverse community facilities provide community members with options for respite during extreme heat events. • The de-prioritisation of cars throughout Waterloo South will help alleviate the effects of increasing temperatures and the associated reduction in air quality.
Flooding	• Ensure all residential areas and critical infrastructure are raised above the flood planning level. The flood planning level to be established as the greater of: – Probable Maximum Flood (PMF) levels or; – 100-year average recurrence interval (ARI) plus a minimum 10% increase in rainfall inputs to allow for an increase in rainfall intensity associated with climate change, plus freeboard. • Bio-retention and detention basin provisions to be made within the public parks to better allow Waterloo South to manage flooding. • The provision and consideration of green spaces, green roofs, community gardens, retention of trees, and general prioritisation of delivering urban vegetation helps control the flow of rainwater into the stormwater system and improve the water quality of stormwater prior to discharge into the system.
Storms	• Provision and retention of trees associated with the tree canopy targets provide wind amelioration benefits, given appropriate species selection (refer to Arterra, 2020). • Installation of onsite renewables reduces reliance on grid-supplied electricity, particularly where they are complimented by microgrids and batteries.
Drought	• For landscape maintenance, passive irrigation through water sensitive urban design (WSUD) initiatives are to be designed into new tree planting areas and to alleviate water stress to vegetation in times of drought and reduce potable water use during normal times. • 5-Star Green Star – Design & As Built (Design Review certified) building rating has co-benefits related to adaptation, particularly around creating energy and water efficient buildings that are better able to maintain thermal comfort. • Species selected for tree planting and revegetation should be drought tolerant and suitable for future climate conditions.

It is anticipated that as the proposed development progresses from the master plan planning application to detailed design, further climate risk assessment and mitigation will be 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, additional actions have been identified in this report to pursue and address in subsequent phases of the development of Waterloo South.

1 Introduction

The Greater Sydney Region Plan and Eastern City District Plan seek to align growth with infrastructure, including transport, social and green infrastructure. With the catalyst of Waterloo Metro Station, there is an opportunity to deliver urban renewal to Waterloo Estate that will create great spaces and places for people to live, work and visit.

The proposed rezoning of Waterloo Estate is to be staged over the next 20 years to enable a coordinated renewal approach that minimises disruption for existing tenants and allows for the up-front delivery of key public domain elements such as public open space. Aligned to this staged approach, Waterloo Estate comprises three separate, but adjoining and inter-related stages:

- Waterloo South;
- Waterloo Central; and
- Waterloo North.

Waterloo South has been identified as the first stage for renewal. The lower number and density social housing dwellings spread over a relatively large area, makes Waterloo South ideal as a first sub-precinct, as new housing can be provided with the least disruption for existing tenants and early delivery of key public domain elements, such as public open space.

A planning proposal for Waterloo South is being led by NSW Land and Housing Corporation (LAHC). This will set out the strategic justification for the proposal and provide an assessment of the relevant strategic plans, state environmental planning policies, ministerial directions and the environmental, social and economic impacts of the proposed amendment. The outcome of this planning proposal will be a revised planning framework that will enable future development applications for the redevelopment of Waterloo South. The proposed planning framework that is subject of this planning proposal, includes:

- **Amendments to the Sydney Local Environmental Plan 2012** – This will include amendments to the zoning and development standards (i.e. maximum building heights and floor space ratio) applied to Waterloo South. Precinct-specific local provisions may also be included.
- **A Development Control Plan (DCP)** – This will be a new part inserted into 'Section 5: Specific Areas' of the Sydney DCP 2012 and include detailed controls to inform future development of Waterloo South.
- **An infrastructure framework** – in depth needs analysis of the infrastructure required to service the needs of the future community including open space, community facilities and servicing infrastructure.

1.1 Waterloo Estate

Waterloo Estate is located approximately 3.3km south-south-west of the Sydney CBD in the suburb of Waterloo (refer to Figure 1-1). It is located entirely within the City of Sydney local government area (LGA). Waterloo Estate is situated approximately 0.6km from Redfern train station and 0.5km from Australia Technology Park. The precinct adjoins the new Waterloo Metro Station, scheduled to open in 2024. The Waterloo Metro Quarter adjoins Waterloo Estate and includes the station and over station development, and was rezoned in 2019. Waterloo Estate comprises land bounded by Cope, Phillip, Pitt and McEvoy Street, including an additional area bounded by Wellington, Gibson, Kellick and Pitt Streets. It has an approximate gross site area of 18.98 hectares (14.4 hectares excluding roads). Waterloo Estate currently comprises 2,012 social housing dwellings owned by LAHC, 125 private dwellings, a small group of shops and community uses on the corner of Wellington and George Streets, and commercial properties on the south-east corner of Cope and Wellington Streets.

A map of Waterloo Estate and relevant boundaries is illustrated in Figure 1-2.

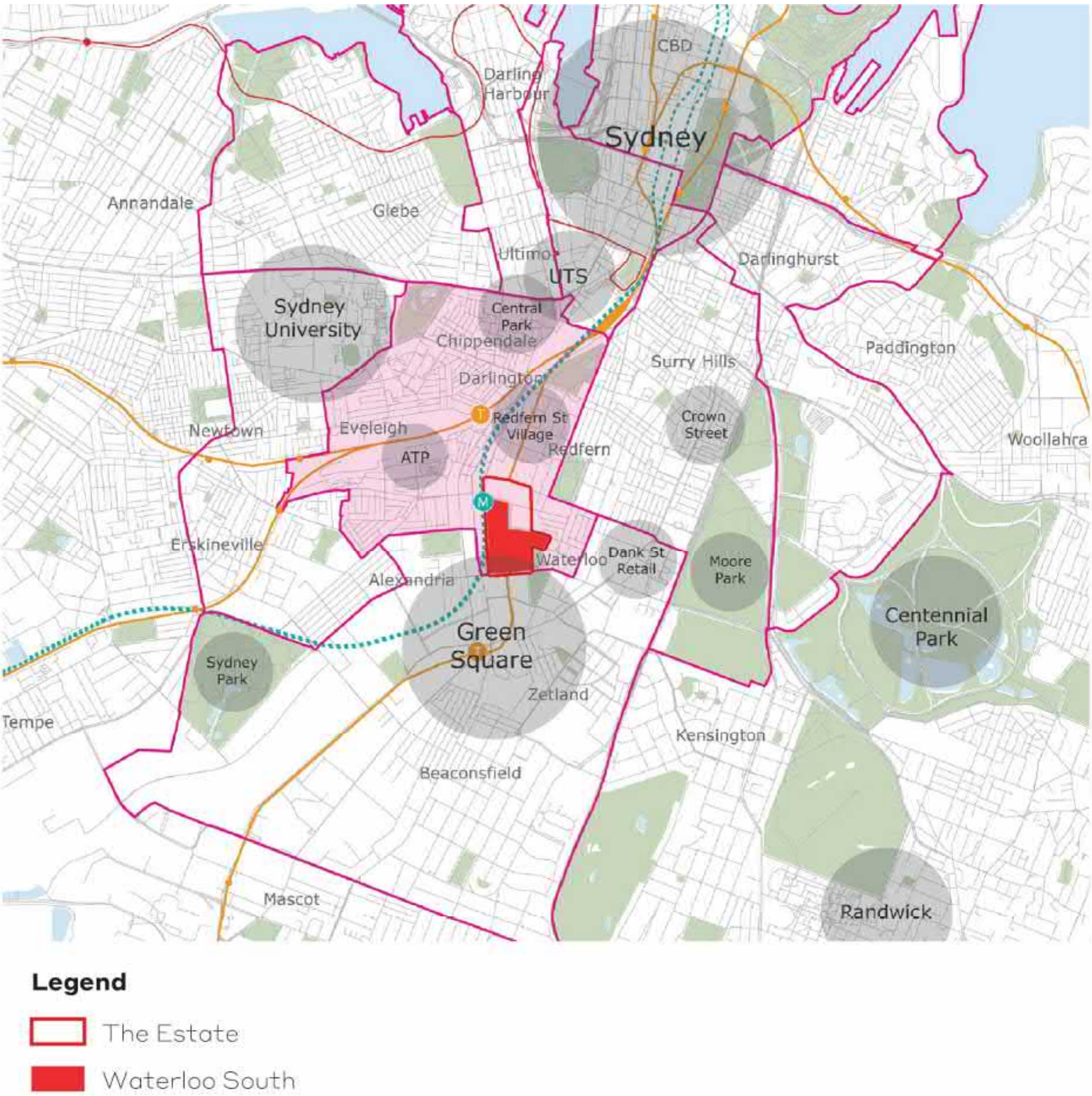

Figure 1-1 Location plan of Waterloo Estate and Waterloo South ***(Source: Turner Studio)***

1.2 Waterloo South

Waterloo South includes land bounded by Cope, Raglan, George, Wellington, Gibson, Kellick, Pitt and McEvoy Streets, and has an approximate gross site area of 12.32 hectares (approximately 65% of the total Estate).

Waterloo South currently comprises 749 social housing dwellings owned by LAHC, 125 private dwellings, and commercial properties on the south-east corner of Cope and Wellington Streets. Existing social housing within Waterloo South is predominantly walk up flat buildings constructed in the 1950s and '60s, and mid-rise residential flat buildings (Drysdale, Dobell & 76 Wellington Street) constructed in the 1980s. Listed Heritage Items within Waterloo South include the Duke of Wellington Hotel, Electricity Substation 174 on the corner of George and McEvoy Streets, the terrace houses at 229-231 Cope Street and the Former Waterloo Pre-School at 225-227 Cope Street. The State Heritage listed 'Potts Hill to Waterloo Pressure Tunnel and Shafts' passes underneath the precinct.

A map of Waterloo South and relevant boundaries is illustrated in Figure 1-2**.**

Figure 1-2 Waterloo Precinct *(Source: Ethos Urban)*

1.3 Redevelopment Vision

The transition of Waterloo Estate will occur over a 20-year timeframe, replacing and providing fit for purpose social (affordable rental) housing as well as private housing to create a new integrated and inclusive mixed-tenure community.

This aligns with Future Directions for Social Housing in NSW – the NSW Government's vision for social housing. It also aligns with LAHC's Communities Plus program, which is tasked with achieving three key objectives:

1. Provide more social housing
2. Provide a better social housing experience
3. Provide more opportunities and support for social housing tenants

The following is LAHC's Redevelopment Vision for Waterloo Estate, which was derived from extensive consultation and technical studies:

Table 1-1 LAHC's Redevelopment Vision for Waterloo Estate (Source: Elton Consulting)

Source: Let's Talk Waterloo: Waterloo Redevelopment (Elton Consulting, 2019)

Culture and Heritage

- Recognise and celebrate the significance of Waterloo's Aboriginal history and heritage across the built and natural environments.
- Make Waterloo an affordable place for more Aboriginal people to live and work.
- Foster connection to culture by supporting authentic storytelling and recognition of artistic, cultural and sporting achievements.

Communal and Open Space

- Create high quality, accessible and safe open spaces that connect people to nature and cater to different needs, purposes and age groups.
- Create open spaces that bring people together and contribute to community cohesion and wellbeing.

Movement and Connectivity

- Make public transport, walking and cycling the preferred choice with accessible, reliable and safe connections and amenities.
- Make Waterloo a desired destination with the new Waterloo Station at the heart of the Precinct's transport network – serving as the gateway to a welcoming, safe and active community.

Character of Waterloo

- Strengthen the diversity, inclusiveness and community spirit of Waterloo.
- Reflect the current character of Waterloo in the new built environment by mixing old and new.

Local Employment Opportunities

- Encourage a broad mix of businesses and social enterprise in the area that provides choice for residents and creates local job opportunities.

Community Services, Including Support for Those Who Are Vulnerable

- Ensure that social and human services support an increased population and meet the diverse needs of the community, including the most vulnerable residents.
- Provide flexible communal spaces to support cultural events, festivals and activities that strengthen community spirit.

Accessible Services

- Deliver improved and affordable services that support the everyday needs of the community, such as health and wellbeing, grocery and retail options.

Design Excellence

- Ensure architectural design excellence so that buildings and surrounds reflect community diversity, are environmentally sustainable & people friendly – contributing to lively, attractive and safe neighbourhoods.
- Recognise and celebrate Waterloo's history and culture in the built environment through artistic and creative expression.
- Create an integrated, inclusive community where existing residents and newcomers feel welcome, through a thoughtfully designed mix of private, social (affordable rental) housing.

1.4 Purpose of this report

This report relates to the Waterloo South planning proposal. While it provides comprehensive baseline investigations for Waterloo Estate, it only assesses the proposed planning framework amendments and Indicative Concept Proposal for Waterloo South.

The key matters addressed as part of this study, include:

- 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.

- SR 10.3 Assess the potential impacts of climate change on vulnerable groups, including older people, and mechanisms for implementing mitigation strategies.
- 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 (AECOM, 2020).

1.5 Waterloo South planning proposal

The planning proposal will establish new land use planning controls for Waterloo South, including zoning and development standards to be included in Sydney LEP 2012, a new section in Part 5 of DCP 2012, and an infrastructure framework. Turner Studio and Turf has prepared an Urban Design and Public Domain Study which establishes an Indicative Concept Proposal presenting an indicative renewal outcome for Waterloo South. The Urban Design and Public Domain Study provides a comprehensive urban design vision and strategy to guide future development of Waterloo South and has informed the proposed planning framework. The Indicative Concept Proposal has also been used as the basis for testing, understanding and communicating the potential development outcomes of the proposed planning framework.

The Indicative Concept Proposal comprises:

- Approximately 2.57 hectares of public open space representing 17.8% of the total Estate (Gross Estate area – existing roads) proposed to be dedicated to the City of Sydney Council, comprising:
  - Village Green – a 2.25-hectare park located next to the Waterloo Metro Station; and
  - Waterloo Common and adjacent – 0.32 hectares located in the heart of the Waterloo South precinct.
  - The 2.57 hectares all fall within the Waterloo South Planning Proposal representing 32.3% of public open space (Gross Waterloo South area – proposed roads)
- Retention of 52% of existing high and moderate value trees (including existing fig trees) and the planting of three trees to replace each high and moderate value tree removed.
- Coverage of 30% of Waterloo South by tree canopy.
- Approximately 257,000 sqm of GFA on the LAHC land, comprising:
  - Approximately 239,100 sqm GFA of residential accommodation, providing for approximately 3,048 dwellings comprising a mix of market and social (affordable rental) housing dwellings;
  - Approximately 11,200 sqm of GFA for commercial premises, including, but not limited to, supermarkets, shops, food & drink premises and health facilities; and
  - Approximately 6,700 sqm of community facilities and early education and child care facilities.

The key features of the Indicative Concept Proposal are:

- It is a design and open space led approach.
- Creation of two large parks of high amenity by ensuring good sunlight access.
- Creation of a pedestrian priority precinct with new open spaces and a network of roads, lanes and pedestrian links.
- Conversion of George Street into a landscaped pedestrian and cycle friendly boulevard and creation of a walkable loop designed to cater to the needs of all ages.
- A new local retail hub located centrally within Waterloo South to serve the needs of the local community.
- A target of 80% of dwellings to have local retail services and open space within 200m of their building entry.

- Achievement of a 6 Star Green Star Communities rating, with minimum 5-star Green Star – Design & As-Built (Design Review certified).
- A range of Water Sensitive Urban Design (WSUD) features.

The proposed land allocation for the Waterloo South precinct is described in Table 1-2 below.

Table 1-2 Breakdown of allocation of land within the Waterloo South

Land allocation	Existing	Proposed
Roads	3.12ha / 25.3%	4.38ha / 35.5%
Developed area (Private sites)	0.86ha / 6.98%	0.86ha / 7%
Developed area (LAHC property)	8.28ha / 67.2%	4.26ha / 34.6%
Public open space (proposed to be dedicated to the City of Sydney)	Nil / 0%	2.57ha / 20.9% (32.3% excluding roads)
Other publicly accessible open space (Including former roads and private/LAHC land)	0.06ha / 0.5%	0.25ha / 2%
Total	**12.32ha**	**12.32ha**

The Indicative Concept Proposal for the Waterloo South is illustrated in Figure 1-3 below.

Figure 1-3 Indicative Concept Proposal ***(Source: Turner Studio)***

2 Study Requirements

On 19 May 2017, the NSW Minister for Planning issued Study Requirements (SR) for the nominated Precinct. While this project is going through a different planning pathway, the overall SSP Study Requirements are still relevant and addressed below.

Table 2-1 – Study requirements addressed by this report

Number	Study Requirement (SR)	Addressed at
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.	• **Section 5** outlines consideration of changing temperature and rainfall, • **Section 6** provides design considerations such as vegetation and Water Sensitive Urban Design (WSUD).
SR 10.3	Assess the potential impacts of climate change on vulnerable groups, including older people, and mechanisms for implementing mitigation strategies.	• **Section 5** outlines potential impacts on vulnerable groups • **Section 6** describes mechanisms and mitigation strategies.
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 (AECOM, 2020)	• **Section 4.2.1** details the sensitivity and scenario testing approach used for mean and extreme temperature. • **Section 6.1** discusses how this has influence adaptation actions. • **Section 4.4** details the sensitivity analysis that was undertaken for changing rainfall patterns.

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 Waterloo South Ecologically Sustainable Development Study (AECOM, 2020).

This Climate Change Adaptation Report has also been prepared with reference to the NSW Climate Change Policy Framework (NSW OEH, 2016). The framework aims to maximise the economic, social and environmental wellbeing of NSW in the context of a changing climate. The framework outlines policy directions for implementing the government’s long-term objectives of achieving net zero emissions by 2050 and improving the resilience of NSW to a changing climate.

As part of the implementation of this framework, two additional draft plans have been released for public consultation:

- *Draft Climate Change Fund Strategic Plan 2017–2022* (NSW OEH, 2016)
- *A Draft Plan to Save NSW Energy and Money* (NSW OEH, 2016).

The *Draft Climate Change Fund Strategic Plan 2017–2022* sets out priority investment areas for funding over the next five years, including the provision of up to $100 million in new funding for actions to prepare NSW for a changing climate. As part of this priority investment area, the draft plan identifies actions for reducing the costs to public and private assets arising from climate change; reducing the impacts of climate change on health and wellbeing, particularly for vulnerable communities; and managing the impacts of climate change on natural resources, natural ecosystems and communities.

The *Draft Plan to Save NSW Energy and Money* is proposed to meet the NSW Government's energy efficiency target of 16,000 gigawatt hours of annual energy savings by 2020 and contribute to achieving net zero emissions by 2050. The draft plan summarises the preferred options for achieving the state's energy savings target, which include opportunities for implementing energy standards for State significant developments and major infrastructure projects. The Policy Framework includes a goal to achieve net-zero carbon emissions by 2050. This goal will drive the future investigation of opportunities for achieving both net zero buildings and a net zero Precinct.

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.

3 Climate change adaptation report

To reduce the risk to vulnerable populations from climate change and minimise the effects of climate change on Waterloo south, a climate change adaptation report has been prepared. This report is structured as follows:

- **Section 3** presents the objectives of this climate change adaptation report.
- **Section 4** provides the climate change projections used as part of the assessment.
- **Section 5** provides a summary of the risk assessment undertaken.
- **Section 6** provides the adaptation actions that have been integrated and considered in the early planning process.
- **Section 6** also identifies future actions for consideration in subsequent planning and design phases.

The objectives of this assessment are to:

- Prepare a report that addresses the relevant climate change mitigation and adaptation Study Requirements;
- Provide a Climate Change Adaptation Report that details how Waterloo South 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.

4 Climate context and 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 Waterloo South as well as how future climate projections may impact Waterloo South. The following sections provide that context as well as describe various scenarios across multiple timeframes to understand how Waterloo South may change with respect to climate change over the life of the project, including impacts to those living and using Waterloo South.

4.1 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).

4.2 Climate change data

To assess the risk to Waterloo South 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.

4.2.1 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 4-1.

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 Section 4.4. A sensitivity assessment has also been undertaken to consider projections under additional emissions scenarios including RCP4.5 and SRES A2 is also discussed in Section 4.4.

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). The NARCliM project downscaled projections based on AR4 data, while Climate Futures utilise models from AR5. 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.

4.2.2 Time scales

Given the expected design life of the infrastructure within Waterloo South (in excess of 50 years), the general timeframe for the proposed construction works (up to around 2040) and the available climate data, the time periods which have been used 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 Waterloo South by around 2040). 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.

4.3 Summary of results

A summary of climate change projections for Waterloo South are presented in Table 4-1.

Table 4-1 – Climate Change Projections 2030 & 2090 (for RCP8.5 – High Emissions)

Climate Variable	Baseline (1981-2010)[1]	2030[2]	2090[2]
Mean annual temperature	22.5°C	Increase of 0.7°C to 1.3°C	Increase of 2.9°C to 4.6°C
Extreme temperature (number of days per year above 35°C)	3.4 days	4.3 more days[1]	11 more days
Mean annual rainfall	1223mm	Decrease of 11% to increase of 6%	Decrease of 20% to increase of 16%
Average annual increase in rainfall intensity	328mm (highest daily rainfall)	Increase of 4.5% (RCP4.5) Increase of 4.9%[3] (RCP8.5)	Increase of 9.1% (RCP4.5) Increase of 18.6% (RCP8.5)
Extreme rainfall (one in 20-year event)	321mm (daily)	Projections not available	Increase by 5% to 40%
Mean annual wind speed	13.9km/h	Decrease of 2.3% to increase of 1.9%	Decrease of 6.9% to increase of 4.2%
Annual bushfire weather	N/A	Increase by 45%	Increase by 130%
Mean sea level rise	N/A	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

A sensitivity assessment has also been undertaken to consider projections under additional emissions scenarios including RCP4.5 and SRES A2. This is discussed in Section 4.4.

4.3.1 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).

[1] Bureau of Meteorology, 2019. Climate statistics for Australian locations – Observatory Hill. Period 1981-2010). Available: http://www.bom.gov.au/jsp/ncc/cdio/cvg/av?p_stn_num=066062&p_prim_element_index=0&p_comp_element_index=0&redraw=null&p_display_type=full_statistics_table&normals_years=1981-2010&tablesizebutt=normal
[2] Dowdy, A. et al. 2015, East Coast Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds.Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia.
[3] AR&R (2016) uses CSIRO data to determine a nominal 5% increase in rainfall intensity per degree of temperature increase.

4.3.2 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 4-6 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 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).

These additional days are not spread throughout the year, with the greatest increases projected during spring and summer, while also extending into autumn. Given the site only currently experiences 3.4 days on average above 35°C (which occur during the summer months), an additional 11 days by 2090 represents a very large increase. There are significant health impacts associated with heatwaves and extreme heat days, particularly for vulnerable members of the community (e.g. children, the elderly, and those experiencing illness).

4.3.3 Urban heat island effect

Urban heat islands occur in an area such as a city or industrial site leading to consistently higher temperatures than surrounding areas because of a greater retention of heat. This is caused by the suns heat being absorbed, and not reflected, by buildings, dark roofs, car parks, paved surfaces and roads. Human activities, such as motorised transport and using air conditioning also increase the waste heat generated (City of Sydney, 2013). Urban heat island effects and the ongoing development of greenfield sites throughout the Sydney region exacerbate stresses of climate change related temperature increases discussed above.

Figure 4-1 and Figure 4-2 demonstrate the way different surfaces in the existing Waterloo Estate retain heat during the day and night, highlighting that highly urbanised areas of Sydney are more prone to urban heat retention than those with a higher proportion of canopy coverage. The existing Waterloo Estate site is moderately affected by urban heat with existing streetscapes indicating average temperatures of 33°C, and the majority of development blocks approximately 30°C (Figure 4-1). The Redfern area in Figure 4-2 is shown to be among the worst performing areas within the City of Sydney.

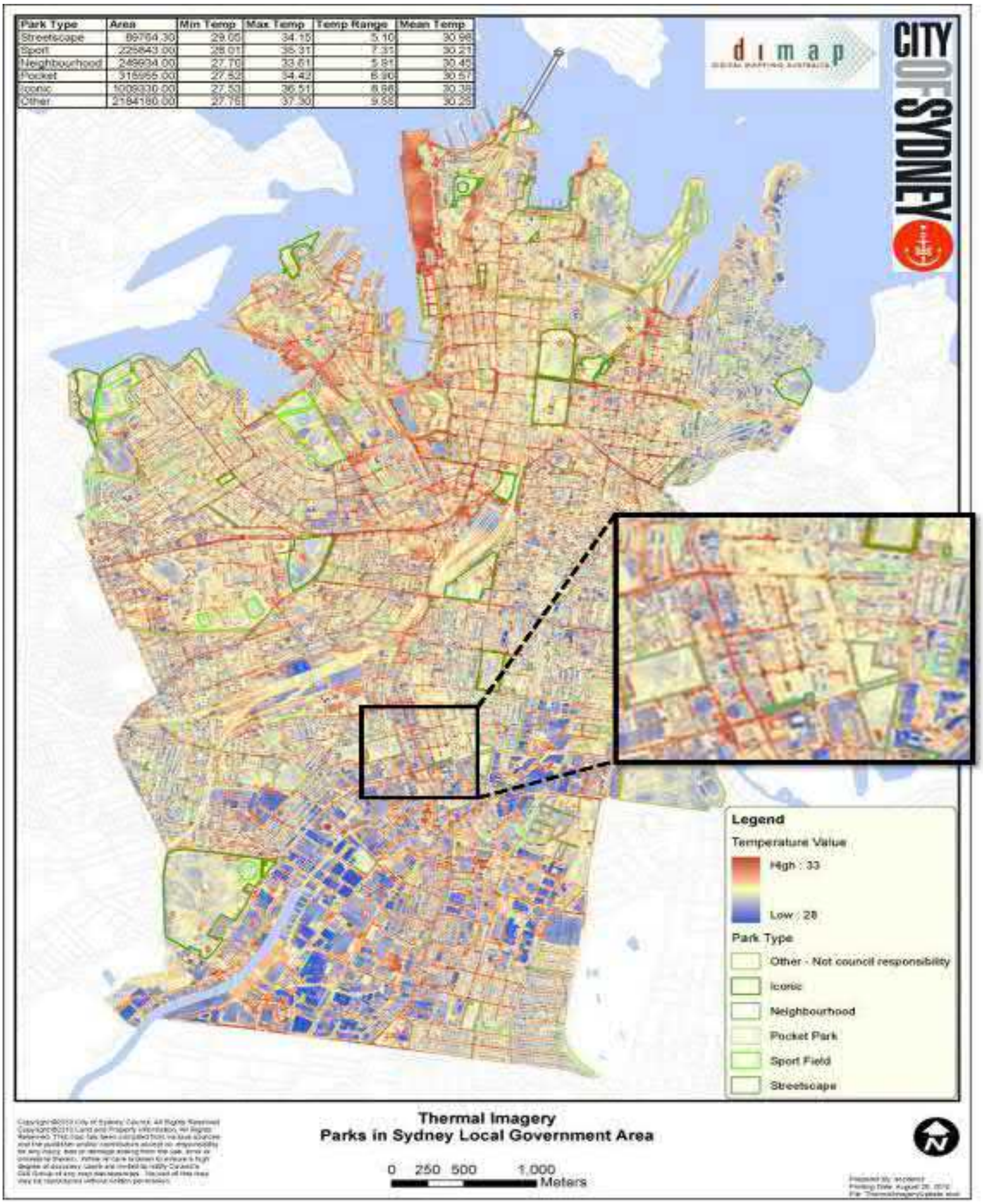

Figure 4-1 – Thermal Imagery (Extreme heat). Subject area shown in black. Source: City of Sydney.

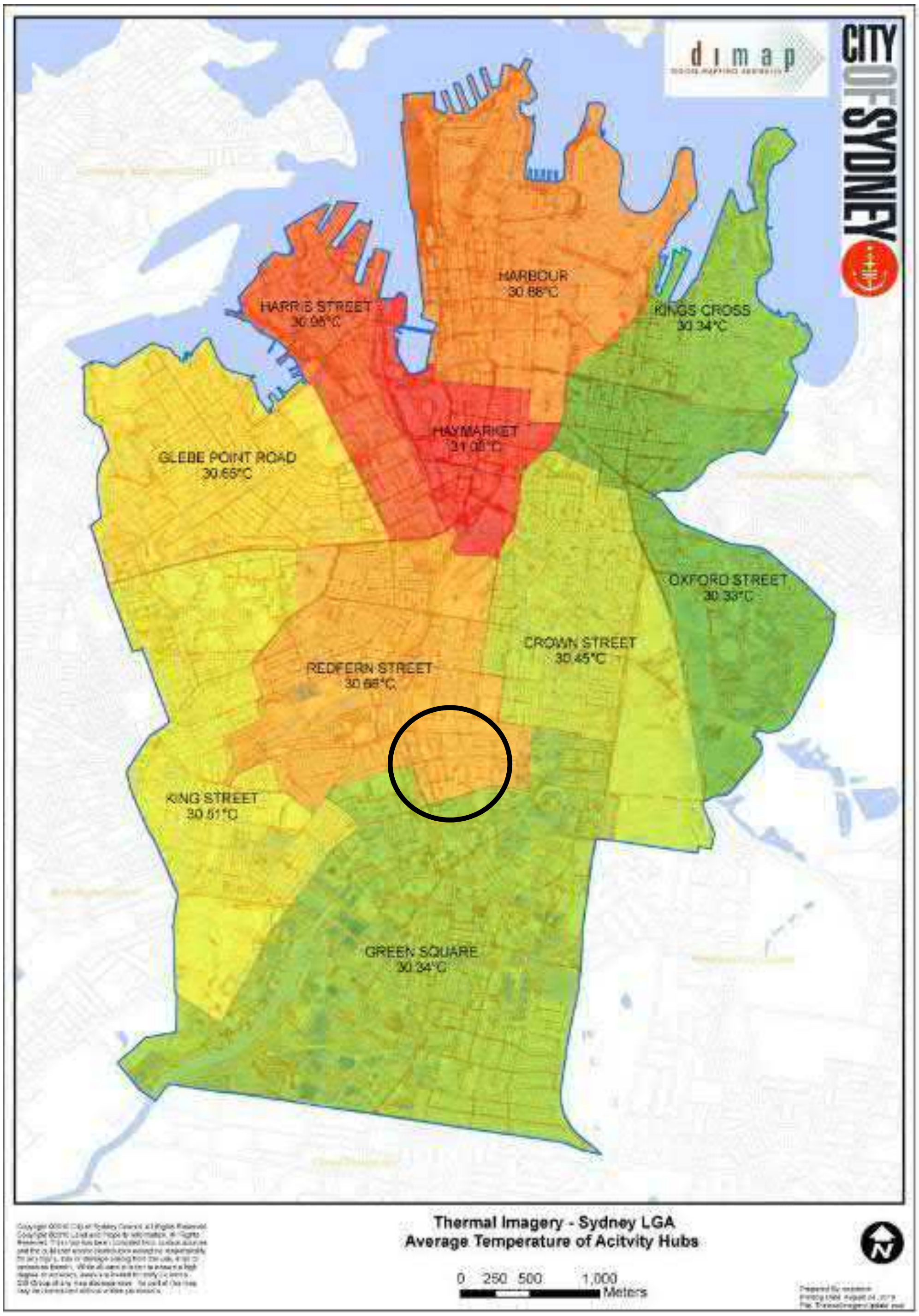

Figure 4-2 – Thermal Imagery (Extreme heat). Subject area shown in black. Source: City of Sydney.

However, the existing site is currently less developed than it will be over the coming decades. Adams (2015) found that suburbs transitioning from medium density to high density are likely to experience a decrease in annual temperatures as effects of overshadowing and localised wind tunnelling effects come into play (Figure 4-3). What this ultimately will mean for the development is uncertain, however there is a clear opportunity for the development to reduce and better manage its own ambient temperature, as well as minimise (and provide a positive contribution to) its cumulative impacts on the surrounding City of Sydney LGA.

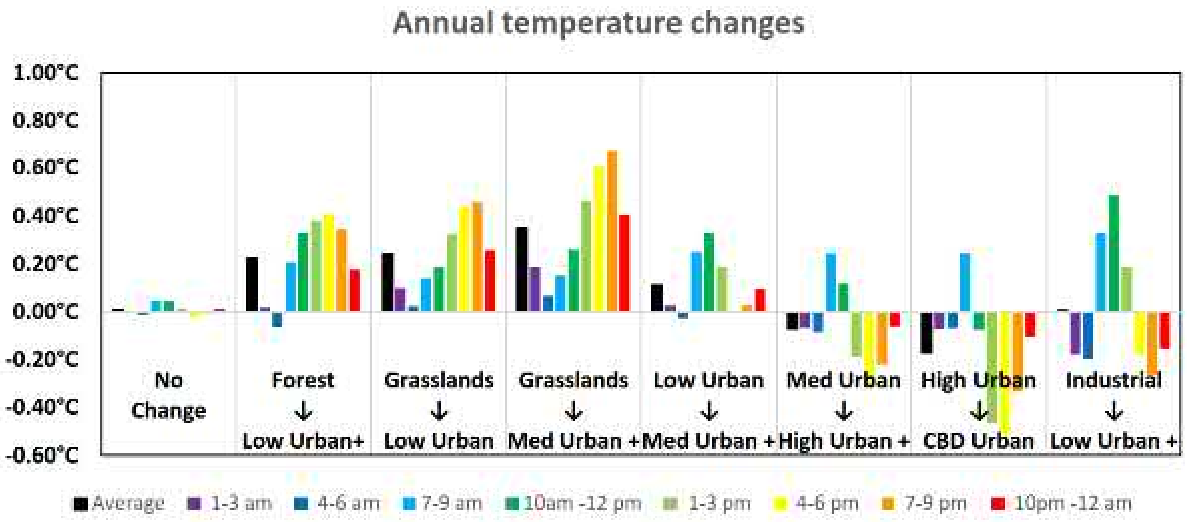

Figure 4-3 – Average 3-hourly annual temperature changes for projected land-use changes (Adams, 2015)

4.3.4 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). Under RCP 4.5 and RCP 8.5, modelling shows a high confidence of more severe bushfire weather in future time periods 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).

While bushfire is unlikely to pose a direct impact to the site given its location within a highly urbanised area, indirect impacts of bushfire occurring in Western Sydney can include significant reduction in air quality (due to smoke) and impacts to infrastructure such as transport and utilities.

4.3.5 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.

4.3.6 Increased intensity in rainfall

Current climate change projections as documented in IPCC AR5 are based on four climate change futures, which are classified based on RCPs discussed in Section 4.2. A 5% increase in rainfall intensity corresponds to 2030 conditions, and a predicted 20% by 2090 predicted under the RCP 8.5 emissions scenario (AR&R 2016). As such, the sensitivity analysis for Waterloo South was undertaken by increasing the rainfall intensity by 10% for the 100-year ARI in flood modelling, in line with AR&R 2016 and OEH Guidelines. This approach is conservative with respect to the projections for 2030 shown in Table 4-11.

Flood modelling results including flood depths and flood impacts for the proposed cases plus a 10% increase to allow for climate change are shown in Figure 4-4 which highlight flood occurrence predominantly along Cope and Buckland Streets, as well as the southern end of George Street. When compared to Figure 4-5 (100-year ARI without climate change allowance), Figure 4-4 (100-year ARI with additional 10% allowance for climate change) shows depths that exceed the current case, particularly around the existing flood risk areas.

The Waterloo Water Quality, Flooding, and Stormwater Report's (AECOM, 2019) examination of flood modelling indicates that during the probable maximum flood (PMF), the depth of flooding on the internal roads, outside of the flow paths and low areas, is typically less than 250 mm. However, the velocity depth product in many locations is typically greater than 0.3 m^2/s. For a small car, the maximum advisable depth for vehicle stability is 300 mm, and maximum velocity depth product is 0.3 m^2/s. For children, the maximum advisable velocity depth product is 0.4 m^2/s (Smith, 2013). As such, emergency access to some of the buildings and evacuation may be risk at certain locations. Access to buildings along the flow paths and low areas, such as Raglan Street, Wellington Street and Cope Street, may be difficult as flood depths exceed 1.0 m, and velocity depth product exceeds 0.5 m^2/s. The Waterloo Water Quality, Flooding, and Stormwater Report (AECOM, 2020) models a rainfall intensity increase of 10% for the 100-year ARI, in line with AR&R 2016 and OEH Guidelines. A 10% increase in rainfall intensity corresponds to 2090 conditions predicted under the RCP 4.5 emissions scenario (AR&R 2016).

Figure 4-4 – Developed case 100-year ARI +10%. Source: Waterloo Water Quality, Flooding, and Stormwater Report (AECOM, 20120)

Figure 4-5 – Developed case 100-year ARI. Source: Waterloo Water Quality, Flooding, and Stormwater Report (AECOM, 2020)

4.3.7 Extreme rainfall events and flooding

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

The images shown in Figure 4-6 are noted within the *Water Quality, Flooding and Stormwater Report* (AECOM, 2020) to be of particular relevance to Waterloo South and surrounding areas. These images demonstrate that the area is known for historical flooding issues and creates constraints for any development works in the area.

Figure 4-6 – Flooding on Hunter Street (Left), Botany Road & Buckland Street Intersection (Right)

Photo taken May 2011 by J. Chaytor (left), Photo taken February 2010 by J. Gelbart (right)

4.3.8 Storm events and wind

NARCliM projections for SRES A2 (OEH, 2014 & 2015) are not specifically available storms, east coast lows (ECLs)[4], or extreme wind speed. However, a related project, the Eastern Seaboard Climate Change Initiative (ESCCI), used NARCliM models to project ECLs into the future. It found that there will be increased seasonal variability with a decrease in the number of small to moderate ECLs in the cool season with little change in these storms during the warm season. However extreme ECLs in the warmer months may increase in number. Extreme ECLs in cool seasons may not change. Projected changes in ECLs into the future are smaller than the natural variability we see in ECLs from the historical record. This means that 'planning for the past' in addition to the future will enhance risk management by accounting for the broader range of ECL variability and associated risk. Risk analysis should consider the storminess of the 1600-1900 period (AdaptNSW, 2014).

[4] East coast lows (ECLs) are intense low-pressure systems that occur off the east coast of Australia. They can form at any time of the year and significant ECLs occur on average about 10 times each year. These storms can bring damaging winds and surf and heavy rainfall. They can cause coastal erosion and flooding (AdaptNSW, 2014)

CSIRO and BOM also find that 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 and BOM (2015) also 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.

4.3.9 Sea level rise

The following mapping shows the location of the Site relative to current and future climate impacts. Figure 4-7 shows Waterloo South in relation to areas subject to future sea level rise (of up to +0.74 metres). It is noted that Waterloo South would not be impacted by sea level rise. However indirect impacts may occur given the broader exposure of Sydney's infrastructure to the impacts of sea level rise, including stormwater systems, transport systems, as well as energy and water utilities.

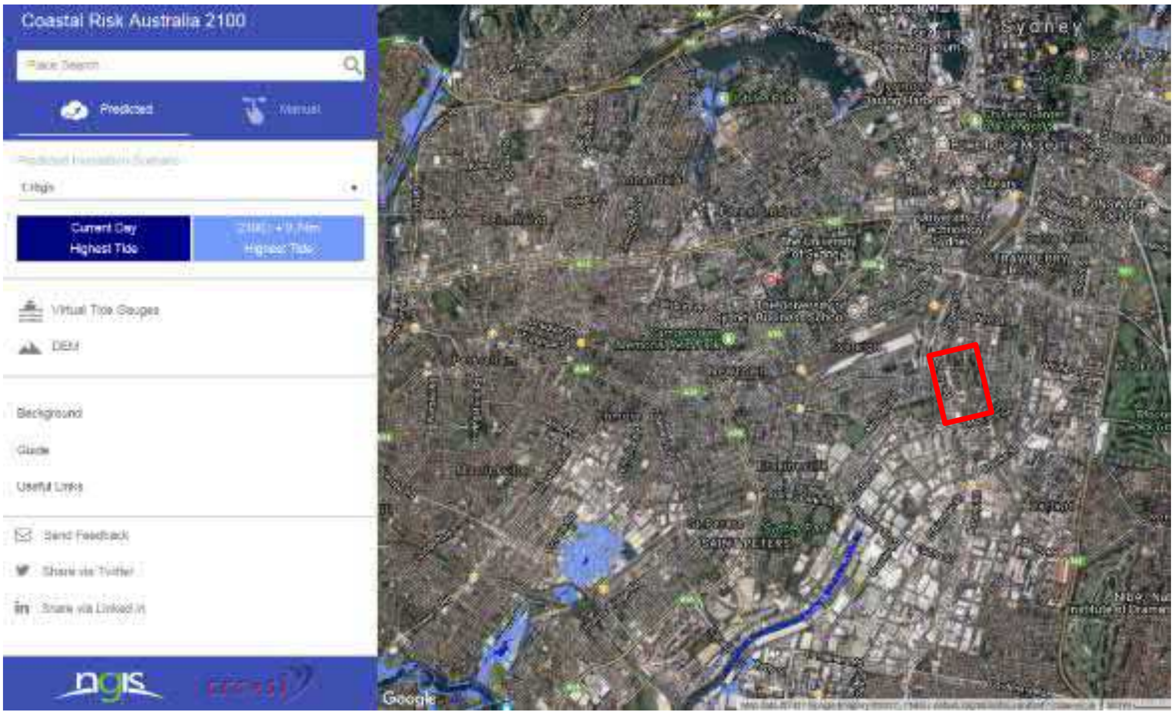

Figure 4-7 – Coastal Risk 2100 High Tide plus Sea Level Rise (Subject area shown in red). Source: Coastal Risk Australia.

4.4 Climate change sensitivity analysis

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 Waterloo South. Consideration and integration of these projections early in the planning will allow the design to manage these changes and incorporate flexible mitigation strategies.

In accordance with SR 10.4, sensitivity analysis has been undertaken as described below:

- *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.*

While heat modelling has not been undertaken to assess the proposed site in response to increasing temperatures and extreme heat events, 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.

4.4.1 Increased temperatures, extreme heat events

The range and relative scale of projections for increased temperatures and extreme heat events mean that sensitivity testing is undertaken at a high level, by comparing NARCliM projections to the latest AR5 representative concentration pathways, RCP 4.5 and 8.5 data have been used as a comparison point for key climate variables to serve as sensitivity testing and scenario planning to understand the impacts based on different projections. A comparison of mean temperature and extreme heat days between SRES A2, RCP 4.5, and RCP 8.5 is provided in Table 4-2.

Table 4-2 – Sensitivity Analysis – 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
SRES A2	+0.7°C	+1.9°C (2070)	+4 days	+11 days
RCP 4.5	+0.6°C to +1.1°C	+1.3°C to +2.5°C	+4.3 days	+6 days
RCP 8.5	+0.7°C to +1.3°C (1)	+2.9°C to +4.6°C (3.75)	-+4.3 days (RCP4.5)	+11 days

It is also important to note that Sydney has a variable topography, and significant local variance is present given that the above projections encompass the city's coast through to the western suburbs. In terms of exposure to heat, Waterloo's proximity to the coast within these regional projections is likely to mean the site is spared from the extreme end of the projections, while the western suburbs of Sydney are expected to experience the most significant increase.

As the projections under RCP 8.5 exceed the projections under SRES A2, RCP 8.5 represents a 'worst case scenario'. Risk assessments and recommended adaptation actions have therefore taken into consideration of this worst-case scenario.

4.4.2 Changing rainfall patterns – Increased rainfall intensity

A sensitivity analysis for changing rainfall patterns due to climate change has been performed for both the existing and proposed development cases. The current climate change guidelines in Australia are based on the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5). The recent draft revision of Australian Rainfall and Runoff (AR&R 2016) provides guidelines for assessing climate change impacts on flood behaviour and is based on IPCC AR5 projections. It recommends a risk-based approach that considers:

- Regional climate change projections
- Service life of asset/planning horizon
- Design standards
- Purpose and nature of the asset
- Consequence of failure of the asset

Current climate change projections as documented in IPCC AR5 are based on four climate change futures, which are classified based on RCPs discussed in Section 4.2. A 5% increase in rainfall intensity corresponds to 2030 conditions and an increase of 20% by 2090 predicted under the RCP 8.5 emissions scenario (AR&R 2016). As such, the sensitivity analysis for Waterloo South was undertaken by increasing the rainfall intensity by 10% for the 100-year ARI, in line with AR&R 2016 and OEH Guidelines. Flood modelling results including flood depths and flood impacts for the developed case with and without climate change are shown in Figure 4-4 and Figure 4-5 respectively.

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, 2020). 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 *Waterloo South Ecologically Sustainable Development Study* (AECOM, 2020).

5 Risk assessment

In order to adequately and appropriately detail how Waterloo South 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 Waterloo South as well as those that are relevant for Waterloo South, 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 5-1 outlines how risks to the assets have been developed from an assessment of climate variables and projected climate change.

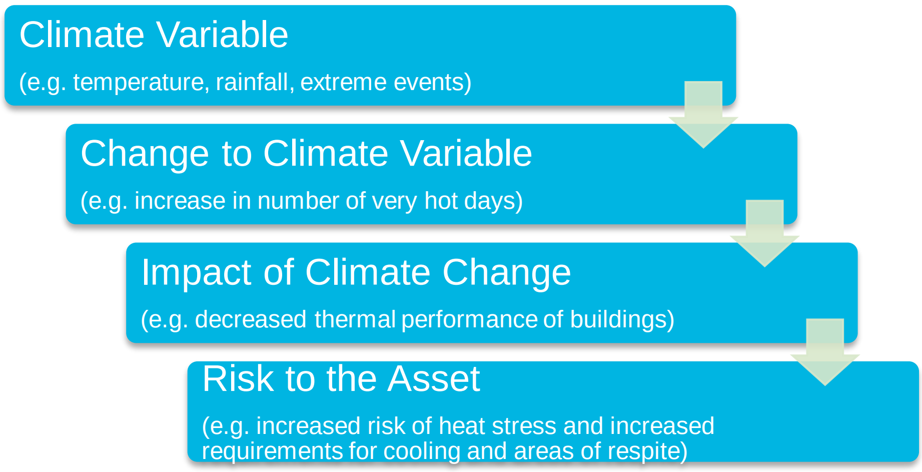

Figure 5-1 – Climate Change Risk Assessment Process (adapted from OEH, 2008)

5.1 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 stakeholders attended 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 and the wider design team for development of the adaptation actions.

5.1.1 Risk Identification

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. 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 given detailed design is not yet complete. 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 5-1 – 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 5.1.2) as part of the climate risk assessment process with adaptation actions identified (refer Section 6) to help reduce risk exposure and improve the resilience of Waterloo South.

5.1.2 Focus areas

Based on the location of Waterloo South 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 below in Table 5-2.The likelihood and consequence coding is outlined in Table 5-3, and the full risk assessment criteria outlined in Appendix B.

Table 5-2 – 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 systems	**C3**	**L2**	High
F-4	Greater intensity of rainfall and runoff causing inundation of underground utility issues (electricity	**C3**	**L2**	High

Risk ID	Variable & Associated Risk	Risk Consequence (C)	Risk Likelihood (L)	Risk Rating
	distribution, fibre cables, pumping stations, other network infrastructure malfunctions)			
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, especially during overnight extremes	**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

Table 5-3 – Likelihood and consequence coding

Consequence		Likelihood	
C1	Catastrophic	L1	Almost Certain
C2	Major	L2	Likely
C3	Moderate	L3	Possible
C4	Minor	L4	Unlikely
C5	Insignificant	L5	Rare

6 Adaptation actions

Overall, extreme rainfall and flooding, extreme heat, and extreme storm events are hazards considered to have the most potential impact on the development and its community. Extreme rainfall can damage properties through flooding, increase costs associated with flood protection and insurance, limit safe access and egress from a site, and cause structural damage to buildings. Given the site is historically extremely affected by overland flooding (refer Section 4.3.6) and can reasonably be expected to become more severe under all climate change scenarios, flood risks have been identified as the most relevant to the site.

Extreme heat can cause heat stress to residents and increase the incidence of illness, increase the cost of keeping buildings cool because more energy is needed, and increase the risk of critical energy infrastructure failing. In particular, there are significant health impacts associated with heatwaves and extreme heat days, particularly for vulnerable members of Waterloo South (e.g. children, the elderly, and those experiencing illness). Adaptation actions regarding the management of heat and its impacts primarily relate to ensuring the health of safety of community members and understanding the implications for infrastructure continuity and building performance.

Adaptation actions related to flood mitigation are primarily targeted to reducing safety hazards to residents and the community, minimising damage, reducing runoff, managing water on site, providing shelter for the wider community, and educating residents on flood safety. Similarly, the primary risks associated with storms include hazards related to wind and hail damage to buildings and outdoor areas, as well as damage and interruption to supporting critical infrastructure such as power and water supplies.

Adaptation actions and responses identified seek to reduce the risk exposure of the whole community, including Waterloo South, and private and social housing residents to ensure a thriving and resilient community. Specific adaptation actions and mitigation measures have been identified and all responses serve to improve the resilience of the community visiting and residing in Waterloo South. Actions have been prioritised based on their cross-cutting benefits, where gains in resilience also lead to gains in resource efficiency, human health, and community cohesion. The integration of these actions into the Indicative Concept Proposal is documented in Sections 6.1 and 6.2.

6.1 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 Waterloo South) (SR 10.3); and,
- Show the results of an increased sensitivity analysis (SR 10.4).

6.2 Adaptation actions integrated into the Indicative Concept Proposal

Based on a review of site drawings, and technical prepared reports to date, a number of design features have been identified that directly or indirectly increase Waterloo South's resilience to climate hazards. These are summarised below. To support the resilience of Waterloo South, these features should be retained throughout the master planning and development process and enhanced through detailed design.

The current design proposal is not yet at a stage that is detailed enough to demonstrate additional adaptation actions that have been identified. These actions to increase the climate and community resilience of Waterloo South are appropriate for later stages of planning (such as detailed design). As such, they have been outlined separately in Section 6.3.

Table 6-1 – Adaptation actions integrated within the Indicative Concept Proposal

Variable	Category	Action
Increasing mean temperatures, number of hot days, and urban heat	Urban greening	The Indicative Concept Proposal Metrics targets 30% of Waterloo South to be occupied by the tree canopy. The preliminary draft Waterloo South Urban Forest Study (Arterra, 2020) outlines how trees have a great deal of influence over the environmental performance of an urban area. Good canopy cover, particularly over streets and fronting buildings can help mitigate urban heat island effects, lower ambient temperatures by several degrees during heat waves and reduce the demands for air conditioning. The sensible use of deciduous species in key locations also allows solar access for sunlight and warmth during cooler months. However, street and other trees that will be planted should be suited to future climate conditions, such as being drought tolerant. Arterra (2018) outlines suitable species for use in further detail.
		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 Waterloo South and around bus shelters (Arterra, 2020).
		An increase in vegetation surrounding an urban site assists in the improvement of air quality (of benefit to those with respiratory issues) and helps strengthen community ties through providing social areas and amenity.
		In addition to the ground level green open space, the creation of urban greenery helps mitigate urban heat island effects and provides benefits to buildings in terms of energy efficiency, thermal comfort, and air quality. Proposed green roofs and community gardens helps provide additional communal space for residents to help encourage healthier lifestyles and strengthen community networks. Providing a green roof and/or community garden also 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.
	Water sensitive urban design	WSUD measures provide a means for cooling the microclimate and reducing urban heat island effects. The Indicative Concept Proposal features a number of WSUD initiatives, and an indicative layout plan of the WSUD strategy is presented in the Water Quality, Flooding, and Stormwater Report (AECOM, 2020).
		The integration of water into landscapes assists in cooling urban areas via evaporation, provides activities for children, and provides amenity for the community. If designed appropriately, there are also significant co-benefits for flood mitigation (discussed below).
		Deprioritising the use of cars throughout Waterloo South will help alleviate the effects of increasing temperatures and decreases in air quality.
	Building and urban design	Targeting 5-Star Green Star – Design & As-Built (Design Review certified) ratings has co-benefits related to adaptation, particularly around creating energy and water efficient buildings. Buildings that consume fewer resources are less reliant on the stability of wider utility networks that may become increasingly prone to failure during extreme events.
		Adoption of a 6 Star Green Star Communities target for the development strengthens a number of adaptation actions and provides a platform for holistic planning to be undertaken. Specifically, the adoption of credit 31. Heat Island Effect which requires "*at least 50% of the total project site area, in plan view, comprises of buildings or landscaping elements that reduce the impact of heat island effect*" is recommended.
		Dual aspect dwellings provide more effective natural ventilation, avoiding overheating and excessive reliance on air conditioning systems.

Variable	Category	Action
		Areas of respite provided (both built and vegetative) though community, retail, and cultural facilities, as well as parks and water play areas, offer alternative areas for community members during extreme heat events, particularly if they do not have adequate cooling at home.
		Installation of onsite renewables reduces reliance on grid-supplied electricity, particularly where they are complimented by microgrids and batteries (further discussed below).
		Design is to maximise on-site sourcing of renewable energy through PV cells or similar technology which will reduce energy costs for vulnerable groups.
		Evaluate connectivity of respite areas, pedestrian pathways and active transport network to ensure continuity of shaded coverage.
Extreme rainfall and flooding	Flood mitigation	Provision for bio-retention and on-site detention which is able to cope with increased rainfall and droughts from climate change
		Trunk drainage designed to account for 100-year ARI + 10%.
	Water sensitive urban design	In addition to the heat-related adaptation benefits noted above, the proposed green roofs, community gardens, open green areas, retention of trees, and general prioritisation of delivering green space helps control the flow of rainwater into the stormwater system and improve the water quality of stormwater prior to discharge into the system. The Indicative Concept Proposal features a number of WSUD features, and an indicative layout plan of the WSUD strategy is presented in the Water Quality, Flooding, and Stormwater Report (AECOM, 2019).
	Flood planning levels	Design all residential areas and critical infrastructure to be raised above the flood planning level (greater of Probable Maximum Flood (PMF) levels or 100-year ARI (plus a minimum 10% increase in rainfall inputs to allow for an increase in rainfall intensity associated with climate change) plus freeboard. A 10% increase in rainfall intensity corresponds to 2090 conditions predicted under the RCP 4.5 emissions scenario, while a 20% increase corresponds to the 2090 conditions predicted under the RCP 8.5 emissions scenario (ARR, 2016). Proposed ground levels (for residential) and orientation of access for both residents and underground services (e.g. car park) should be raised to ensure there are no floodwater breeches from significant storm events particularly at residential building entrances and community facilities. Further information regarding the sensitivity testing including base line conditions, assumptions and additional detail is be found within the *Water Quality, Flooding and Stormwater Study* (AECOM, 2020).
	Emergency Management	Evacuation from the buildings in this Estate or emergency vehicle access is a possibility; however, as the buildings will be above the PMF level, a shelter in place strategy is preferable to avoid unnecessary vehicle or pedestrian movement during extreme storm events. Sufficient warning time can be provided for the occupied areas including retail levels where the occupants will need to move to the stepped-up shelter in place zone within their property.
	Building and urban design	Installation of threshold ramps / steps at flood breach locations.
		Entries and exits oriented away from known flooding locations, especially accessible routes.
	Community facilities	Opportunity to utilise community facility spaces as emergency shelters during and after extreme events.
Drought	Water sensitive urban design	Passive irrigation through WSUD initiatives will be designed into many of the new tree planting areas and will assist with additional water being available to trees in times of drought and during normal times (Arterra, 2020).
		Adoption of 5-Star Green Star – Design & As-Built (Design Review certified) targets for all buildings, and specifically credits such as Wat-1 Potable Water Efficiency to reduce water demand for Waterloo South.

Variable	Category	Action
		WSUD measures provide a means for cooling the microclimate and reducing urban heat island effects. At-source biofiltration provides a means for passively irrigating the landscape and providing a dual stormwater and landscape function to green infrastructure. Biofiltration street trees should provide significantly shady canopies without damaging surrounding pavements or causing trip hazards for pedestrians
	Demand reduction	Adoption of 5-Star Green Star – Design & As-Built (Design Review certified) targets for all buildings, and specifically credits such as *Wat-1 Potable Water Efficiency* to reduce water demand for Waterloo South.
Storm events	Urban greening	Given the appropriate species selection, the provision and maintenance of trees provide wind amelioration benefits.
	Building and urban design	Installation of onsite renewables reduces reliance on grid-supplied electricity, particularly where they are complimented by microgrids and batteries (further discussed below).
	Community facilities	The development of community facilities is an opportunity to provide shelter for community members that are unable to travel or return home during extreme events.
Community health, safety, and cohesion	Connectivity and transport	Provision of active transport infrastructure through prioritising pedestrians by minimising car use including: • The conversion of George St to a pedestrian boulevard, • Designating 82% of vehicular streets as 'slow streets' which are narrowed to 6m in width, • Increasing in the amount of connecting laneways and intersections (by 108%) to facilitate pedestrian access • Targeting a Walk Score of 90-100 • Implementing a new cycle link that connects to all site boundaries and regional cycling routes (George St to the north, Wellington St to the East, McEvoy St to the south, and Buckland St to the west). • Proximity to the Sydney Metro Waterloo Station • Providing 72 car share spaces
	Community facilities and open green space	Maximising sun access for amenity – 50% of the total area is to receive sunlight for 4 hours during winter
		Providing amenity through the Urban Forest Strategy, tree retention, and the 3:1 tree replacement program.
		Provision of retail and community areas which provide key services provide opportunities for community members to connect
		Diversity in housing types and typologies that will encourage a diverse community of families and small households that increases the resilience of the community as a whole. The Indicative Concept Proposal has allowances for: • A variety in the provision of 1, 2 and 3 bedroom houses to facilitate a diversity in resident demographics • Full replacement of existing social housing within Waterloo South

6.3 Additional adaptation opportunities

Further options to improve the resilience of Waterloo South with regards to climate change have been identified. These are to be considered and further refined in subsequent stages of design. These actions have been identified for further development and integration into Waterloo South's design, socialising with key stakeholders, and inclusion in detailed design, planning controls, and management measures.

Table 6-2 – Additional adaptation opportunities

Variable	Category	Action
Increasing mean temperatures, number of hot days, and urban heat	Urban forest	In addition to the Indicative Concept Proposal's target for the site to have canopy coverage of 30%.
		Consider trees as a multi-tasking asset that provide shade, traffic calming, wind amelioration, environmental services, fauna connectivity and aesthetic benefits. They make the streets more inviting and contribute to people wanting to use them for activities like socialising, walking and cycling.
		Prioritise the retention and planting of medium to large trees provide the greatest ecological and community benefits, in comparison to small trees. They create more canopy spread and shading benefits, absorption of more gaseous pollutants, stormwater interception, lower levels of tree vandalism, and achieve higher canopy clearances (Arterra, 2020).
		An increase in vegetation surrounding Waterloo South to improve air quality decreases (of benefit to those with respiratory issues) associated with climate change and strengthen community ties. Natural settings have also been shown to help mental health.
		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.
		New planting selection should consider suitability to changing conditions (i.e. noting higher temperatures, increasing frequency and intensity of droughts, etc.) as per Arterra (2020).
		Design of outdoor spaces to be universally usable and comfortable for those "under 8 and over 80".
		Apartment design should include 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). Optimisation of floorplans to allow both maximum usage of the unit space, while catering for the mechanical / utility considerations to occur during detailed design.
	Building and urban design	Consider building design features such as passive cooling, cross ventilation, onsite renewable energy generation, and maximising energy efficiency to reduce reliance on grid sources electricity.
		Consider providing air conditioning (AC), particularly for vulnerable residents. AC use is the strongest protective predictor against heat related hospitalisation – residents are 35 times less likely to be hospitalised[5]. As an example, 0% of heatwave deaths in NYC in the 11-year period 2001-2012 had an air conditioner[6]. However, the cost of providing AC from an energy and carbon perspective is significant and should be considered in tandem with the Waterloo South Ecologically Sustainable Development Study (AECOM, 2020). Consider additional indoor recreation areas to provide communal airconditioned areas of respite.
		Area of total paved surfaces should be reduced as much as possible to reduce thermal mass (and thus urban heat island effects) and prioritise permeable and low albedo surfaces in line with Green Star Communities Urban Heat Island Credit. The credit states

[5] Kaiser, R., Rubin, C. H., Henderson, A. K., Wolfe, M. I., Kieszak, S., Parrott, C. L., & Adcock, M. (2001). Heat-related death and mental illness during the 1999 Cincinnati heat wave. The American journal of forensic medicine and pathology, 22(3), 303-307.
[6] Wheeler, K., Lane, K., Walters, S., & Matte, T. (2013). Heat illness and deaths—New York city, 2000–2011. MMWR. Morbidity and mortality weekly report, 62(31), 617.

Variable	Category	Action
		that "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 This includes a higher reflectivity value for built elements (street pavement, roofs, etc.)".
		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.
		Design process to explore potential of an Estate wide microgrid and opportunities to provide back up generation and reduce reliance on the grid, using technologies such as back up generators, cogeneration, and / or solar power.
		Explore additional provision of shaded communal spaces including utilising solar panels as shade.
		Provision of uninterruptable power supply for emergency support services ('call button').
		Adopt 2030 climate projections to ambient design temperature for Heating Ventilation Air Conditioning (HVAC) and other building plant design.
		Undertake cost modelling during design process to include projections for adjusted energy costs due to climate change.
		Ensure that building and maintenance schedules are regularly revised and comprehensive in order to maintain efficiency of assets.
	Operation and management	Educational campaign to help families understand special care needed for very young children in hot temperatures.
Extreme rainfall and flooding	Building and urban design	Rain gardens may also be incorporated within some open space areas, providing treatment to runoff from adjacent pavements able to be drained overland or via shallow pipes and grated drains to the raingarden surface. Green roofs, community gardens, retention of trees, and general prioritisation of delivering green space in Waterloo South 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.
		Explore opportunities to leverage green open spaces as multipurpose areas that function as recreation areas during good weather, and flood detention areas during extreme rainfall events. Integrate WSUD principles such as integrating detention basins with rain gardens as part of streetscapes.
		In detailed design phases, the area of total paved surfaces should be reduced as much as possible, prioritising permeable surfaces.
		To prevent rainfall from reaching main internal areas of buildings, consider design interventions such as the provision of awnings.
		Emergency and flood planning for buildings should include site access considerations.
		2030 rainfall intensity projections adopted as the base case design for drainage and stormwater design.
		Commercial floors should be 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).
	Emergency management	Install threshold ramps / steps at flood breach locations, and ensure all exits are accessible for less mobile persons.
		Entries and exits should be oriented away from known flooding locations, especially accessible routes, and ensure the development of comprehensive emergency evacuation plans which are cognisant of vulnerable community members.

Variable	Category	Action
		Development of comprehensive emergency evacuation plans which are cognisant of vulnerable community members.
		Identification of vulnerable community members (e.g. elderly, ill, children, etc) and their places of residence throughout Waterloo South for prioritised management before, during, and after an extreme event. Ensure number of users who will need critical supply connections is planned for across life of development.
		Community emergency planning to include information on mobility impaired or those needing additional care in the event of an evacuation. Trial evacuations should be rehearsed with first responders.
	Operations	Develop operations and maintenance 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.
		Understand interdependencies between critical communication systems and electrical energy supply.
		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.
Drought	Water sensitive urban design	Adoption of 5-Star Green Star – Design & As-Built (Design Review certified) targets for all buildings, and specifically credits such as *Wat-1 Potable Water Efficiency* to reduce water demand for the precinct.
Storms	Buildings and urban design	Actively consider the storm resistance of building materials to wind, debris, driving rain such as roofing, guttering, windows, eaves, building ventilation, etc.
		Ensure critical infrastructure not exposed to potential damage by wind, flying debris, or driving rain (e.g. roof mounted plant and equipment).
		Reduce amount of and reinforce external façade fittings.
		Ensure roof structural stability of roof design and construction accounts for increased uplift wind forces. E.g. consider adopting cyclone standards.
		Consider vulnerabilities of external infrastructure networks (energy, telecommunications, water, transport, etc) and where possible reduce the reliance on these networks (onsite power generation, demand reduction initiatives).
	Emergency management	Development of comprehensive emergency evacuation plans which are cognisant of vulnerable community members.
		Identification of vulnerable community members (e.g. elderly, ill, children, etc) and their places of residence throughout Waterloo South for prioritised management before, during, and after an extreme event.
Sea Level Rise	Utilities and infrastructure	Consider implication of sea level rise on groundwater, adopting 2090 sea level rise projections for all drainage and stormwater design.
Community health, safety, and cohesion	Buildings and urban design	Ensure social and affordable housing design is held to achieving high thermal performance standards, as residents occupying this segment are likely to have a higher proportion of community members vulnerable to extreme and prolonged heat events.
	Emergency management	Development of comprehensive emergency evacuation plans which are cognisant of vulnerable community members.
		Encourage commercial operators within Waterloo South (during construction and operation) to allow for frequent breaks and hydration of staff; consider adjustment of working hours to avoid the hottest period of the day.
		Identification of vulnerable community members (e.g. elderly, ill, children, etc) and their places of residence throughout Waterloo South for prioritised management before, during, and after an extreme event.

7 Conclusion

A climate risk assessment was undertaken with a number of risks identified for Waterloo South. While no 'extreme' risks were identified, 14 'high' risks were identified. Risks were included as part of the *Climate Risk Register* (AECOM, 2018), which can be found in Appendix A. As part of the risk assessment process, a number of key risks were extracted (refer Section 5.1.2) with adaptation actions identified (refer Section 6). Of climate related variables, the site's exposure to increasing frequency and intensity of heat events, extreme rainfall and flooding, and storms have been identified as priority focus areas for adaptation. The key risks identified through the risk assessment workshop process are outlined in Table 7-1.

Table 7-1 – Key impacts identified for Waterloo South

Variable	Climate Impact
Heat	• 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 at or beyond capacity. Increased heat stress events can lead to significant health impacts to residents, particularly vulnerable community members. This leads to increasing requirements for cooling and areas of respite.
Flooding	• Greater intensity of rainfall and runoff has the potential to overwhelm drainage capacity and cause flooding and inundation of roof, ground, and subterranean systems. • Greater intensity of rainfall and runoff has the potential to cause inundation and malfunction of underground utilities such as electricity distribution, fibre cables, pumping stations, other network infrastructure.
Storms	• Rain and moisture penetration during storms and high winds causing damages to buildings and plant.
Drought	• Drought risk affecting water storage systems on site and increasing dependency on mains water supply for non-potable water use.
Bushfires	• Increased bushfire frequency and intensity impacting power supply continuity. • Increased bushfire frequency and intensity causing reduced air quality leading to health impacts to community members.
Combined	• 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. • 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 heat in areas without air conditioning causing greater demand on shared spaces that are cooled. • Impacts of increased incidence of violent crime during heatwave events on community.

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. Key responses incorporated into the Indicative Concept Proposal are listed in Table 7-2.

Table 7-2 – Response to key impacts outlined in the Indicative Concept Proposal

Variable	Indicative Concept Proposal response
Heat	• The Indicative Concept Proposal Metrics target 30% of Waterloo South to be occupied by the tree canopy, which represents an increase of the existing canopy coverage. Canopy coverage over paved surfaces serves as a cost-effective means of mitigating urban heat island effects and additional projected increases in mean temperature and extreme heat events. The tree retention and replacement targets will help to reduce the urban heat for pedestrians and residents (including those most vulnerable; elderly, youth, disabled). An increase in vegetation surrounding an urban site also helps to improve air quality which benefits those with respiratory issues.

	• The Indicative Concept Proposal features several water sensitive urban design (WSUD) measures which provide a means for cooling the microclimate and reducing urban heat island effects. For example, the integration of water into landscapes assists in cooling urban areas via evaporation, provides activities for children, and provides amenity for the community. If designed appropriately, there are also significant co-benefits for flood mitigation. • The commitment to achieving a 6 Star Green Star Communities rating target strengthens many adaptation actions and provides a platform for integrated planning to be undertaken. Targeting 5-Star Green Star – Design & As-Built (Design Review certified) building ratings for individual buildings within Waterloo South also has co-benefits related to adaptation, particularly around creating energy and water efficient buildings that are better able to maintain thermal comfort. • Passive design measures such as delivering dual aspect dwellings provide more effective natural ventilation, avoiding overheating and excessive reliance on air conditioning systems. • Provision of diverse community facilities provide community members with options for respite during extreme heat events. • The de-prioritisation of cars throughout Waterloo South will help alleviate the effects of increasing temperatures and the associated reduction in air quality.
Flooding	• Ensure all residential areas and critical infrastructure are raised above the flood planning level. The flood planning level to be established as the greater of: – Probable Maximum Flood (PMF) levels or; – 100-year average recurrence interval (ARI) plus a minimum 10% increase in rainfall inputs to allow for an increase in rainfall intensity associated with climate change, plus freeboard. • Bio-retention and detention basin provisions to be made within the public parks to better allow Waterloo South to manage flooding. • The provision and consideration of green spaces, green roofs, community gardens, retention of trees, and general prioritisation of delivering urban vegetation helps control the flow of rainwater into the stormwater system and improve the water quality of stormwater prior to discharge into the system.
Storms	• Provision and retention of trees associated with the tree canopy targets provide wind amelioration benefits, given appropriate species selection (refer to Arterra, 2020). • Installation of onsite renewables reduces reliance on grid-supplied electricity, particularly where they are complimented by microgrids and batteries.
Drought	• For landscape maintenance, passive irrigation through water sensitive urban design (WSUD) initiatives are to be designed into new tree planting areas and to alleviate water stress to vegetation in times of drought and reduce potable water use during normal times. • 5-Star Green Star – Design & As-Built (Design Review certified) ratings have co-benefits related to adaptation, particularly around creating energy and water efficient buildings that are better able to maintain thermal comfort. • Species selected for tree planting and revegetation should be drought tolerant and suitable for future climate conditions.

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.

Appendix A Climate Risk Register

Table 7-3 – 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) Include groundwater considerations within design 2) Include groundwater consideration within construction planning e.g. review construction methods for likelihood to cause subsidence to existing or heritage buildings 3) Consider projected future groundwater levels and relocate at risk utilities 4) 2090 sea level rise projections adopted for all drainage and stormwater design	Detailed 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) Include groundwater considerations within design 2) Include groundwater consideration within construction planning e.g. Review construction methods for likelihood to cause subsidence to existing or heritage buildings 3) 2090 sea level rise projections adopted for all drainage and stormwater design	Detailed 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 2) Ensure number of users who will need critical supply connections is planned for across life of development 3) Ensure energy supply backups provided to facilities caring for the elderly or infirm	Detailed 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 2) Educational materials for disaster preparation should be translated and distributed through culturally appropriate channels 3) Number of community members who are likely to be vulnerable to this issue to be reviewed 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 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 2) 2030 rainfall intensity projections adopted as the base case design for drainage and stormwater design	Detailed 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 2) Educate personnel, residents and transport customers around dangers of flood water and runoff 3) Prepare and communicate clear evacuation plan for community prior to hazard event	Detailed design 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	1) 2030 rainfall intensity projections adopted as the base case design for drainage and stormwater design 2) Water sensitive urban design measures incorporated as part of site planning to accommodate an increase in rainfall. 3) Design to minimize impervious surfaces to reduce runoff	Detailed design
F-4	Greater intensity of rainfall and runoff causing inundation of underground utility issues (electricity distribution, fibre cables, pumping stations, other network infrastructure malfunctions)	Extreme Rainfall and Flooding	C3	L2	H		C3	L2	H	1) 2030 rainfall intensity projections adopted as the base case design for design levels for critical infrastructure, drainage and stormwater design 2) Locate utilities above ground where possible	Detailed design
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	1) 2030 rainfall intensity projections adopted as the base case design for design levels for critical infrastructure, drainage and stormwater design 2) Prepare operation and maintenance plans to minimise service interruption	Detailed design 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
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 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.	Construction 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 2) 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	Detailed design 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 2) Understand interdependencies between critical communication systems and electrical energy supply 3) Develop O&M and emergency plans for heat waves to keep essential communications systems intact 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	Detailed Design O&M 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 2) Provide shaded areas, drinking fountains, water features, solar reflective materials in public domain areas 3) Maximise passive cooling features in design e.g. glazing, shading, orientation 4) Building design to be flexible for potential future retrofit for air conditioning 5) 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 Waterloo South and around bus shelters (Arterra, 2020).	Detailed 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	1) Adopt 2030 climate projections to ambient design temperature for Heating Ventilation Air Conditioning (HVAC) design 2) In addition to the ground level green open space, the creation and retention of urban vegetation (as per Arterra, 2020) helps mitigate urban heat island effects and provides benefits to buildings in terms of energy efficiency, thermal comfort, and air quality. Proposed green roofs and community gardens helps provide additional communal space for residents to help encourage healthier lifestyles and strengthen community networks.	Detailed Design
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. 2) Include passive cooling features on buildings to reduce load on HVAC system e.g. glazing, shading, orientation	Detailed 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) Targeting 5-Star Green Star – Design & As-Built (Design Review certified) ratings has co-benefits related to adaptation, particularly around creating energy and water efficient buildings. Buildings that consume fewer resources are less reliant on the stability of wider utility networks that may become increasingly prone to failure during extreme events. 2) Adopt 2030 climate projections to ambient design temperature for HVAC design.	Detailed 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
										3) 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 4) Design electrical infrastructure to minimise peak energy demand	
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 2) Creation of air conditioned, interior public recreation space	Detailed 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	Detailed 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 2) Increased landscape irrigation requirements during establishment and O&M 3) Dual aspect dwellings provide more effective natural ventilation, avoiding overheating and excessive reliance on air conditioning systems. 4) Areas of respite provided (both built and vegetative) though community, retail, and cultural facilities, as well as parks and water play areas, offer alternative areas for community members during extreme heat events, particularly if they do not have adequate cooling at home.	Policy 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	Detailed 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) Adoption of a 6 Star Green Star Communities target for the development strengthens a number of adaptation actions and provides a platform for holistic planning to be undertaken. Specifically, the adoption of credit 31. Heat Island Effect which requires "at least 50% of the total project site area, in plan view, comprises of buildings or landscaping elements that reduce the impact of heat island effect" is recommended. 2) Regular maintenance and repair 3) 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	Detailed Design
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 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	Detailed 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	1) Develop an urban heat island management plan during design to reduce urban heat island effect	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
										2) Provide shaded areas, drinking fountains, water features, solar reflective materials in public domain areas 3) Promote indoor physical activities to maintain health and well-being during a shock event. 4) Maximise passive cooling features in design e.g. glazing, shading, orientation 5) Building design to be flexible for potential future retrofit for air conditioning 6) 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 Waterloo South and around bus shelters (Arterra, 2020).	
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" Educational campaign to help families understand special care needed for very young children in hot temperatures	Detailed 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 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 Estate cogeneration, design process to explore possibility of installation of solar power for redundant supply, design process to explore possibility of a Estate microgrid	Detailed 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 2) Routine checks of building air filters to control interior air quality 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
D-1	Drought conditions demand increased maintenance for landscaping of parks, open space and street trees	Drought	C5	L3	L		C5	L2	L	1) Passive irrigation through WSUD initiatives will be designed into many of the new tree planting areas and will assist with additional water being available to trees in times of drought and during normal times (Arterra, 2020). 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 3) Citizen education campaign for helping to water trees	Detailed Design 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 2) Program to reduce water demand in times of drought (ban on yard water usage) 3) WSUD measures provide a means for cooling the microclimate and reducing urban heat island effects. At-source biofiltration provides a means for passively irrigating the landscape and providing a dual stormwater and landscape function to green infrastructure. Biofiltration street trees should provide	Detailed Design, Policy

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
										significantly shady canopies without damaging surrounding pavements or causing trip hazards for pedestrians. 4) Adoption of 5-Star Green Star – Design & As-Built (Design Review certified) targets for all buildings, and specifically credits such as Wat-1 Potable Water Efficiency to reduce water demand for Waterloo South.	
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 2) Building operators will plan for extreme wind events (pedestrian areas susceptible to flying debris closed off, for example)	Detailed 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	1) Provision and maintenance of trees provide wind amelioration benefits given the right selection through understanding the most desirable forms, sizes and densities of tree canopy in given locations. 2) Actively consider the storm resistance (to wind, debris, driving rain) of building materials such as roofing, guttering, windows, eaves, building ventilation, etc. 3) Reduce amount of and reinforce external façade fittings 4) Ensure roof structural stability of roof design and construction accounts for increased uplift wind forces. E.g. consider adopting cyclone standards. 5) 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	Detailed 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	1) Provision and maintenance of trees provide wind amelioration benefits given the right selection through understanding the most desirable forms, sizes and densities of tree canopy in given locations. 2) Actively consider the storm resistance (to wind, debris, driving rain) of building materials such as roofing, guttering, windows, eaves, building ventilation, etc. 3) Reduce amount of and reinforce external façade fittings 4) Ensure roof structural stability of roof design and construction accounts for increased uplift wind forces. E.g. consider adopting cyclone standards. 5) 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	
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 7-4 – Consequence and Success Criteria (Source: GBCA)

Code	Consequence and success criteria	Community and Lifestyle	Environment and Sustainability	Service Quality	Development Delivery	Community Confidence
C1	**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 word be restricted delivered late, or not at all in a large number of cases.	There would be widespread concern about our capacity to serve the community.
C2	**Major**	Severe widespread decline in services, accessibility, and quality of life within the community.	Severe loss of environmental amenity and 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, delivered late, or not at all in a large number of cases.	There would be serious expressions of concern about our capacity to serve the community.
C3	**Moderate**	General appreciable decline in services and accessibility.	Isolated significant instances of environmental damage that might be reversed with intensive efforts.	Services old be regarded barely satisfactory by the general public and the developments project team.	There would be isolated but important cases of development being restricted or delayed.	There would be isolated expressions of concern about our capacity to serve the community.
C4	**Minor**	Isolates 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 developments project team would be aware of the deficiencies.	There would be isolated instances of development delivery failing to meet acceptable standards to a limited extent.	There would be some concern about our capacity to serve the community but it would not be considered serious.
C5	**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 7-5 – Likelihood Criteria

Code	Rating	Recurrent Risks	Single events
L1	**Almost Certain**	Could occur several times per year	More likely than not – Probability greater than 50%.
L2	**Likely**	May arise about once per year	As likely as not – 50/50 chance.
L3	**Possible**	May arise once in ten years	Less likely than not but still appreciable – Probability less than 50% but still quite high.
L4	**Unlikely**	May arise once in ten years to 25 years	Unlikely but not negligible – Probability low but noticeably greater than zero.
L5	**Rare**	Unlikely during the next 25 years	Negligible – Probability very small, close to zero.

Table 7-6 – Risk Matrix

		Consequence				
		Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Likelihood	**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

CONTACT DETAILS

DANIEL FETTELL

PRINCIPAL ENGINEER

D +61 2 8934 0905 M +61 422 623 253

DANIEL.FETTELL@AECOM.COM