Climate Change Adaptation Study
600-660 Elizabeth Street, Redfern

NSW Land and Housing Corporation

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COMMERCIAL IN CONFIDENCE

Quality information

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Executive Summary

600-600 Elizabeth Street, Redfern will be transformed into a market leading build-to-rent redevelopment featuring contemporary urban and architectural design and creating a high-quality mixed community of social, affordable and private housing. LAHC has initiated a rezoning investigation and Study Requirements and Planning Proposal Requirements have been developed in collaboration with City of Sydney (CoS) and other government agencies. The Study Requirements outline a range of investigations needed to analyse the potential impact of any planning control changes.

To support the long-term climate resilience of the development it is important that climate change projections are considered from master-planning and rezoning through to detailed design. This Climate Change Adaptation Study details how the planned development will address temperature increases from climate change, extreme heat events and increase of rainfall intensity. This study provides a summary of the local climate, climate projections and identifies priority climate risks for the Development.

An increased frequency and duration of hot days and heatwaves is projected with very high confidence under both medium and high emissions scenarios. As the differences in projections between the scenarios are largely negligible, however, the worst-case high emissions scenario has been assumed for the identification and recommendation of adaptation actions. The high emissions scenario is based on Representative Concentration Pathway (RCP) 8.5 which predicts future levels of greenhouse gas concentrations. Current trends in global greenhouse gas concentrations and observed climate change are tracking in line with RCP 8.5 predictions.

This Study has been developed in line with the guidelines and methodology outlined in Section 3, and considers existing and future climate hazards (Section 4), and undertakes a climate risk assessment (Section 5). The design of the development is still in its master-planning and rezoning stage; however, a broad range of appropriate actions have been identified that will minimise the risks identified and increase the resilience of the future community to climate-related hazards. Sensitivity testing in the form of emissions scenario review has been undertaken for increased temperatures and extreme heat, and modelling of increased rainfall intensity has been undertaken.

This study recommends that the development is designed to account for the flood risks prevalent throughout and surrounding the site including incorporating a potential 10% increase in rainfall to the 1% annual exceedance probability event to account for climate change to 2050.

The Reference Scheme considers climate change adaptation and incorporates a number of the recommended actions, including:

- Communal areas with opportunities for shade and respite.
- Building orientation has considered effective ventilation and solar access.
- The indicative apartment layout achieves cross ventilation above the ADG minimum.
- The landscape plan considers opportunity for water features to assist in cooling.
- Improved street landscaping and front setbacks incorporate water sensitive urban design (WSUD) principles
- All residential areas above the flood planning levels and all building entries are above the Probable Maximum Flood (PMF).
- Improved street landscaping and front setbacks incorporate WSUD principles
- Detailed analysis of building and basement entries has demonstrated the ability to provide steps and ramps above PMF and incorporate accessibility facilities where necessary.

A number of actions can be considered further in the detailed design phase and the following could be incorporated in the design of the site:

- Consider the delivery of green walls and incorporate items of higher reflectivity value (such as light-coloured roofing) to help reduce the site's contributions to the urban heat island effect.
- Ongoing maintenance of vegetation should be considered.

The detailed design of the communal spaces should further consider the ability to assist with water retention and permeability of paved areas. The detailed design of the buildings should ensure entries/exits are located away from the known flood locations areas.

Based on the identified adaptation actions above it is expected that 600-660 Elizabeth Street has both considered a range of climate risks at the development application phase and not precluded the future development of a range of solutions.

1. The Proposal

1.1 Introduction

600-600 Elizabeth Street, Redfern will be transformed into a market leading build-to-rent redevelopment featuring contemporary urban and architectural design and creating a high-quality mixed community of social, affordable and private housing.

The Climate Change Adaptation Study has been prepared on behalf of NSW Land and Housing Corporation (LAHC) to accompany a Planning Proposal to be lodged with the City of Sydney (CoS).

This Planning Proposal relates to land at 600-660 Elizabeth Street, Redfern (the Site). The Planning Proposal seeks to rezone the Site to allow redevelopment for a mix of social, affordable and private housing in an integrated residential community. The aims of the Planning Proposal are to rezone the Site to R1 General Residential.

An indicative reference scheme and urban design report has been prepared by Architectus, Silvester Fuller and Tyrell (the Project Team) to support the Planning Proposal and demonstrates how the Site may be redeveloped. The indicative reference scheme comprises:

- Approximately 327 dwellings, with building heights ranging between 6 and 14 storeys;
- A mixed-use development, with over 1,500m^2 of non-residential floor space for local shops, cafes, community space and other services; and
- Three ground floor communal courtyard spaces.

This report assesses the risks associated with climate change on the development and its community associated with the proposed development.

1.2 Communities Plus Build to Rent

Communities Plus is a key program under NSW Government's *Future Directions for Social Housing in NSW*, delivering integrated social, affordable and private housing by partnering with the private and not for profit sectors including registered Tier 1 or Tier 2 Community Housing Providers (CHPs).

The Redfern project aligns with Future Directions, by providing innovative options for private sector investment in social housing under a long-term lease. The project presents an opportunity to renew and increase social housing in a well-located integrated community with good access to education, training, local employment, and close to community facilities such as shopping, health services and transport.

On 6 July 2018, the NSW Government announced the Site as the pilot for Communities Plus build-to-rent. The Project provides an opportunity for the private sector, in partnership with the not-for-profit sector, to fund, design, develop and manage the buildings as rental accommodation under a long-term lease.

Build-to-rent is a new residential housing delivery framework that is capable of providing access to broader housing choices. Established in overseas markets such as the UK and the USA, locally, build-to-rent has significant scope to provide increased rental housing supply and the opportunity for investment in residential housing in NSW.

2. Background

2.1 Overview of the project

The Site includes government-owned land of state importance for delivering government policies relating to jobs, homes, and the provision of social housing in an inner-city location and close to existing and future public transport. It will be transformed into a market leading build-to-rent redevelopment featuring contemporary urban and architectural design and creating a high-quality integrated community of social, affordable and private housing.

LAHC has initiated a rezoning investigation and Planning Proposal Requirements have been developed in collaboration with CoS and other government agencies. The requirements outline a range of investigations needed to analyse the potential impact of any planning control changes.

The project involves the residential redevelopment of the Site which occupies a discrete block bounded by Kettle Street (north) and Phillip Street (south) each with 70 m frontage, and Walker Street (east) and Elizabeth Street (west) each with 146 m frontage (Figure 1).

Located approximately 3 km south of Sydney CBD in the suburb of Redfern, the precinct is entirely within the CoS local government area (LGA) and has a gross site area of 10,850 sqm. The site is part of the wider social housing estate at Redfern in the vicinity of the Waterloo Estate Precinct.

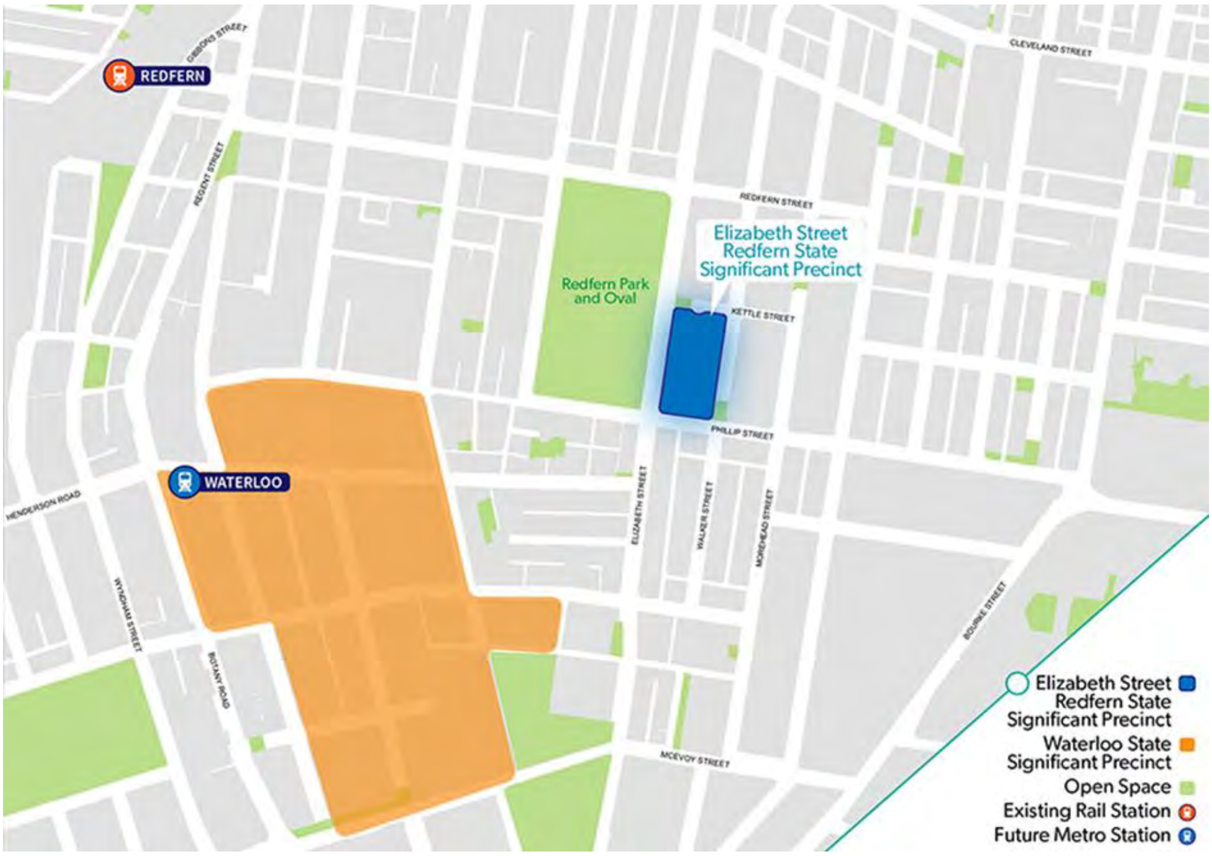


Figure 1: Map of the Elizabeth Street, Redfern Site

2.2 Vision, Reference Scheme, and Planning Framework

The Study has been prepared to formulate and assess a suitable suite of controls to guide the redevelopment of the Site. A design, technical analysis and consultation process was undertaken to prepare a Reference Scheme which indicates how the future public domain, building form and connections could be delivered. The reference scheme (shown at Figure 2) balances the challenges and opportunities of the Site, particularly the desire to deliver high quality urban design while providing new and modern social housing in an integrated mixed tenure environment.

The Reference Scheme was prepared to indicate how the Site could, rather than will, be redeveloped and has been used as a basis to prepare draft amendments to the Sydney Local Environmental Plan 2012 (including zoning, height, floor space ratio (FSR) and car parking controls) and the development of a new site specific Development Control Plan which will guide the detailed design of the Site.

The proposed planning framework has regard to:

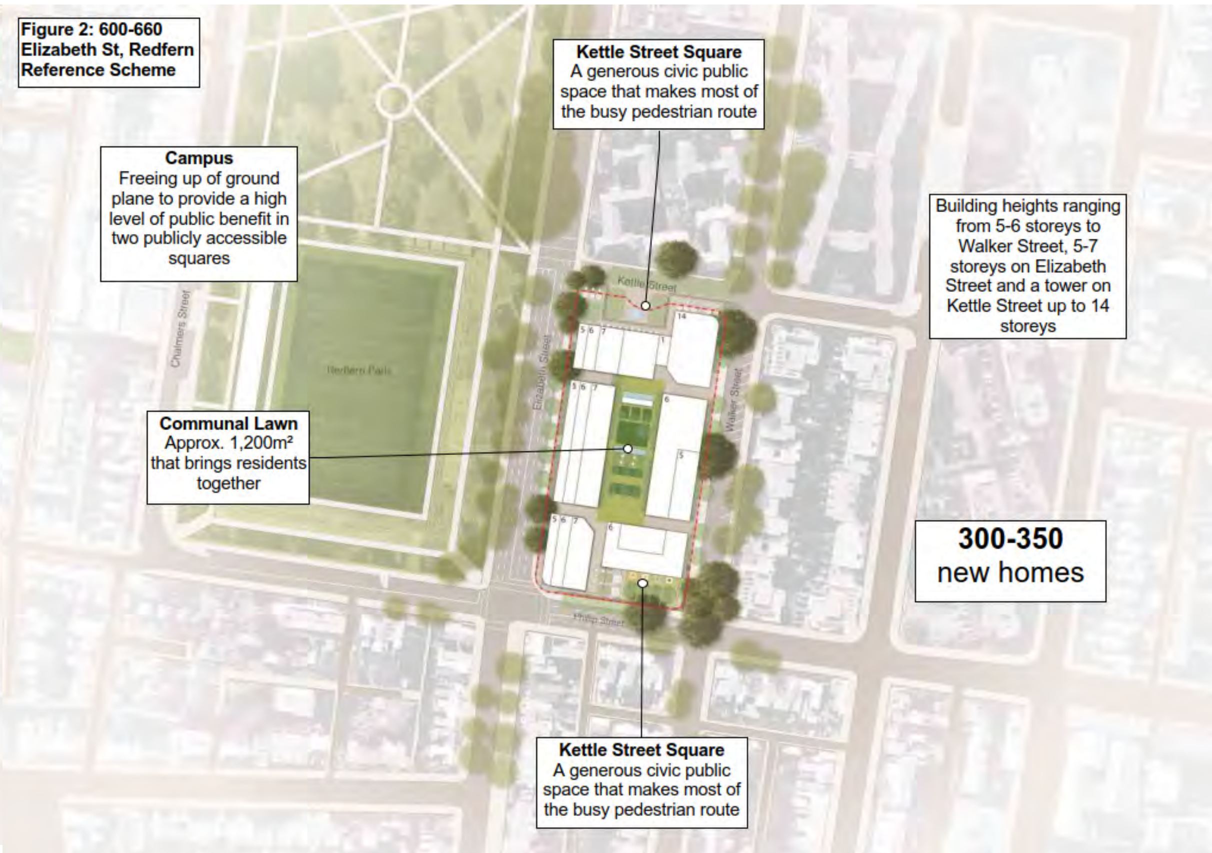
- accessibility and connectivity of the Site to public transport, employment, shops, education and other services,
- the site and local area's rich history and cultural significance,
- the surrounding urban form and context, and
- the environmental and servicing considerations, including flooding, stormwater, traffic, utilities, noise, air quality and wind.

The proposed planning framework will guide future development applications for the Site which are anticipated to achieve the following:

- Approximately 327 dwellings, with a maximum FSR of 2.75
- Buildings with a predominant height of 6-7 storeys with a single taller tower
- Some supporting retail and communal floor space to support the incoming population
- New public spaces on Kettle and Phillip Streets activated by shops, cafes, community space and other services.

It is expected the site will be developed over a period of three years, once the site has been rezoned.

Figure 2: 600-660 Elizabeth St, Redfern Reference Scheme



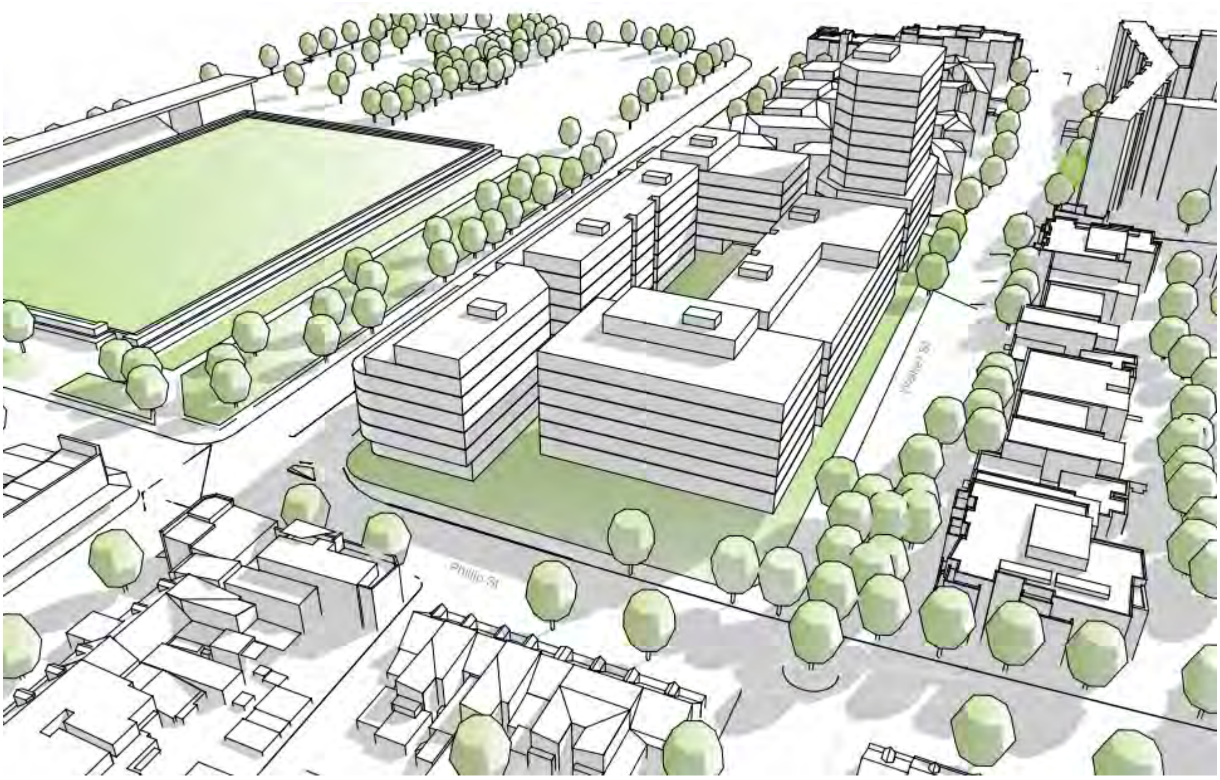


Figure 2: 600-660 Elizabeth St, Redfern Reference Scheme

2.3 Site Context

The precinct is opposite Redfern Park and Oval currently comprising two thirds of vacant land with some mature trees and the remaining third portion, at the southern end, occupied by a building currently leased to the Police Citizens Youth Club (PCYC) and the South Sydney Aboriginal Corporation Resource Centre (refer Figure 3)

Redfern train station is located approximately 900m to the east-north-east of the site, and the future Waterloo Metro station approximately 700m to the east. The site is currently serviced by the 301, 302, 303, 343, 355 and M20 bus routes, with a southbound bus stop on the Elizabeth Street boundary. These routes connect the site with Sydney CBD, North Sydney and Chatswood to the north, with Waterloo, Zetland, Roseberry, Mascot and Botany to the south, with Newtown and Marrickville to the west, and with Moore Park and Bondi Junction to the east.

Figure 3: Aerial photograph of the site

The vacant land was previously occupied by eighteen duplexes, until their demolition in mid 2013 (refer Figure 3). While the site is still in the planning phase it is expected to deliver approximately 327 dwellings, of which up to 35% could be social or affordable housing.

Figure 4: Aerial imagery 600-660 Redfern taken 30/3/2013 (left) and 6/11/13 (right)[1]

2.4 Purpose of this report

The objectives of this assessment are to:

- Prepare a report that addresses relevant climate change risks for the development and its community;
- 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;
- Document and understand the implication of increasing climate effects (including future projections) through sensitivity testing;
- Make recommendations for design elements to be incorporated in detailed design phase.

A complementary document, the Ecologically Sustainable Development (ESD) Report (AECOM, 2020), discusses the relevant Sustainability and Environmentally Sustainable Planning Proposal Requirements. The ESD Report also considers several other aspects that will have interrelationships with this document such as undertaking a sustainability assessment of the proposal, and demonstrating compliance and opportunities for overcompliance with BASIX.

This adaptation plan has been developed in line with the guidelines and methodology outlined in Section 3, and considers existing and future climate hazards (Section 4), and undertakes a climate risk assessment (Section 5). The design of the development is still in its early stages; however, a broad range of appropriate actions have been identified that will minimise the risks identified and increase the resilience of the future community to climate-related hazards. These actions are outlined in Table 7 and Section 6.

[1] Google Earth v7.3.2.5491

3. Approach

This Climate Change Adaptation Report has been developed to demonstrate the commitment of LAHC to addressing climate change risk for the Site.. It is intended that this report and its findings be read in conjunction with the ESD Report (AECOM, 2020) which details broader environmental sustainability and resilience outcomes for the development, including precinct water and energy use, waste, and carbon emissions.

3.1 Standards and guidelines

To support any future certifications of the project may seek, the approach undertaken to assess climate and community resilience aligns with the requirements of Version 1.1 of the Green Buildings Council of Australia's Green Star - Communities Adaptation and Resilience credit. As such, the climate risk assessment methodology adopted by this document aligns with the guidelines and Standards of:

- Green Building Council of Australia's (GBCA) Green Star Communities v1.1 (Governance *4.1 – Climate Adaptation* and *4.2 Community Resilience*)
  - Gov 4.1 awards 2 points where *a project-specific Climate Adaptation Plan (CAP) has been developed in accordance with a recognised standard (refer below); and solutions have been included into the plan for development that specifically address the risk assessment component of the adaptation plan*
  - Gov 4.2 awards 2 points where *prior to the occupation of any habitable building on the project site, a project-specific Community Resilience Plan (CRP) has been developed that addresses preparation, during- and post-disaster communication, safety, and response.*
- Australian Standard 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.

3.2 Methodology

The adopted methodology comprises the following steps in line with recognised climate change risk assessment guidance and standards outlined above:

1. Identification and summary of the site, location and climate characteristics
2. Identification of key climate variables (such as temperature, humidity, rainfall, sea level rise and extreme events) and the climate variability that differentiates regional climate zones.
3. Development of a number of potential climate change scenarios, based on the latest climate science, that broadly identify how each climate variable may change over the design life of the project.
4. Identification of the climate variables which the development is exposed to.
5. Identification of broad climate-based risks that may impact on the development.
6. Completion of a climate risk assessment, with risk ratings evaluated using guidance provided in the Green Building Council of Australia (GBCA) Green Star Communities v1.1 Adaptation and Resilience credit. The risk assessment matrix used for Elizabeth St Redfern is based on the Australian Greenhouse Office (AGO) Climate Change Risks and Impacts: A Guide for Government and Business (2006). The risk assessment criteria to determine the consequence and likelihood of each risk is provided in Appendix A.
7. Validating and socialising identified risks via a multi-stakeholder risk assessment workshop.
8. Identification of measures to mitigate and adapt to climate risks, including next steps and stakeholder consultation.

Risks were identified and included as part of the climate risk register (Table 6). As part of the development application process, a number of key risks were extracted (refer Section 4.3) with adaptation actions identified (refer Section 6) to help reduce risk exposure and improve the resilience of the site.

4. Climate change context

4.1 Historical climate and exposure to climate hazards

The local climate is predominantly temperate, typically resulting in warm, wet summers and mild, dry winters. The precinct's proximity to the coast (which is approx. 3km to the north, and 6km to the east) influences the local climate, with cooler temperatures experienced compared to more western areas of Sydney. Trends indicate variability in the amount of rainfall received from year to year. Storms result in periods of heavy rainfall and strong wind and may lead to flood events. Table 1 provides a summary of the observed climate exposure for the region.

Table 1: Climate exposure (Bureau of Meteorology)[2]

Climate variable	Local climate baseline (Observations for the time period of 1981-2010)[3]
Mean maximum daily temperature	22.5°C **Seasonal variations:** The mean maximum temperature (average highest) during summer for the baseline time period is recorded at 26.5°C. The mean maximum temperature (average highest) during winter for the baseline time period is recorded at 17.4°C.
Mean minimum daily temperature	14.5°C **Seasonal variations:** The mean minimum temperature (average lowest) during summer for the baseline time period is recorded at 19.7°C. The mean minimum temperature (average lowest) during winter for the baseline time period is recorded at 8.4°C.
Extreme temperatures above 35°C	3.4 days above 35°C recorded per year
Mean annual rainfall	1,222.7mm average annual rainfall per year (average highest 137mm in Autumn (April) and average lowest 69.2mm in Spring (September)). **Seasonal variations:** The mean highest monthly rainfall (average highest) during autumn for the baseline time period is recorded at 137mm. The mean lowest rainfall during spring for the baseline time period is recorded at 69.2mm.

4.1.1 Flooding

Flooding has historically been considered a significant risk for the site. Local hazard mapping confirms the exposure, identifying the extent of existing flood risk for the site. Figure 5 shows the probable maximum flood (PMF) for the Alexandra Canal Catchment (and highlights the site as 'high' hazard). Figure 6 shows the PMF for the Elizabeth Street site itself and notes it is likely to see the worst impacts in the area with peak flood depth significantly exceeding 1m. This is evidenced by *February 2017 flash flood eve showing Chalmers Street (Left), Intersection of Chalmers and Redfern Street (Right)*

Figure 7 which demonstrates flood impacting nearby Chalmers Street and Redfern Street during a 2017 extreme rainfall event.

[2] Sydney Observatory is the nearest available climate station and is located approximately 4.4km away from Elizabeth St, Redfern. Refer: 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

[3] While the Sydney Observatory weather station has a wider temporal range of data available, the period 1981-2010 has been chosen for best comparison to the climate projections of NARCliM which use a baseline dataset of 1990-2009)

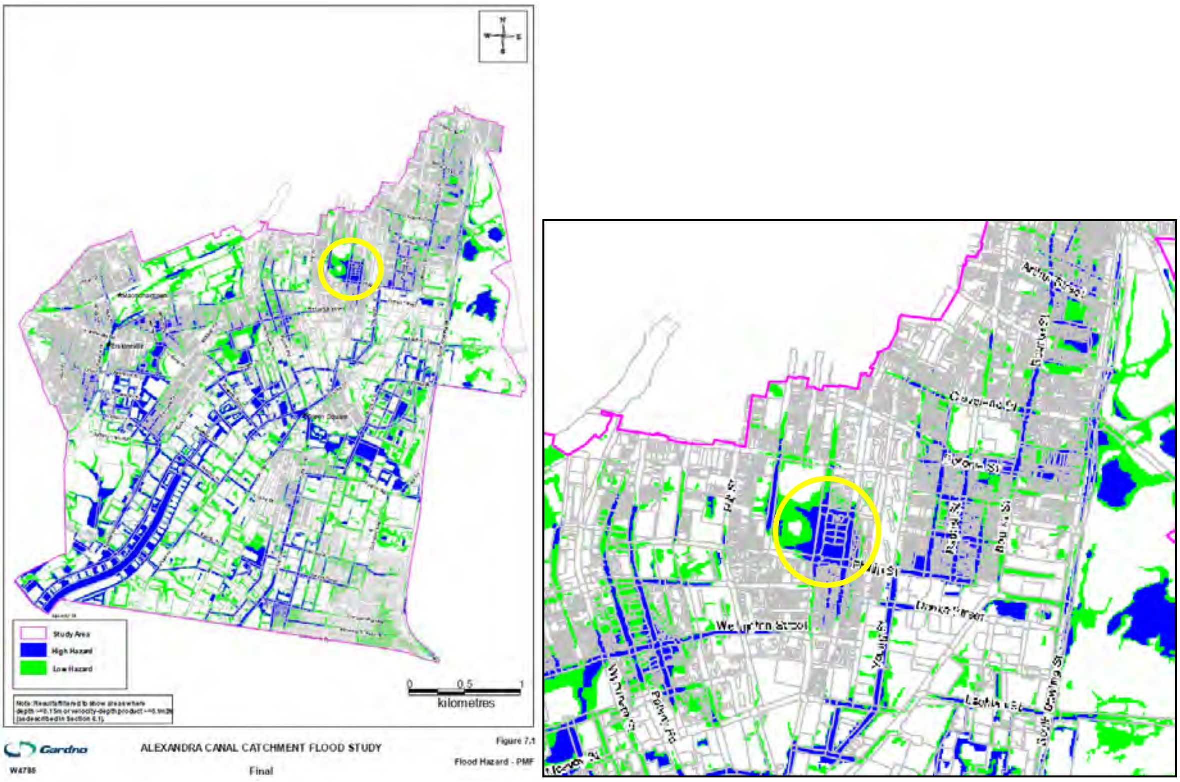


Figure 5: Probable Maximum Flood (site circled in yellow)[4]

[4] Cardno, 2014. Alexandra Canal Catchment Flood Study

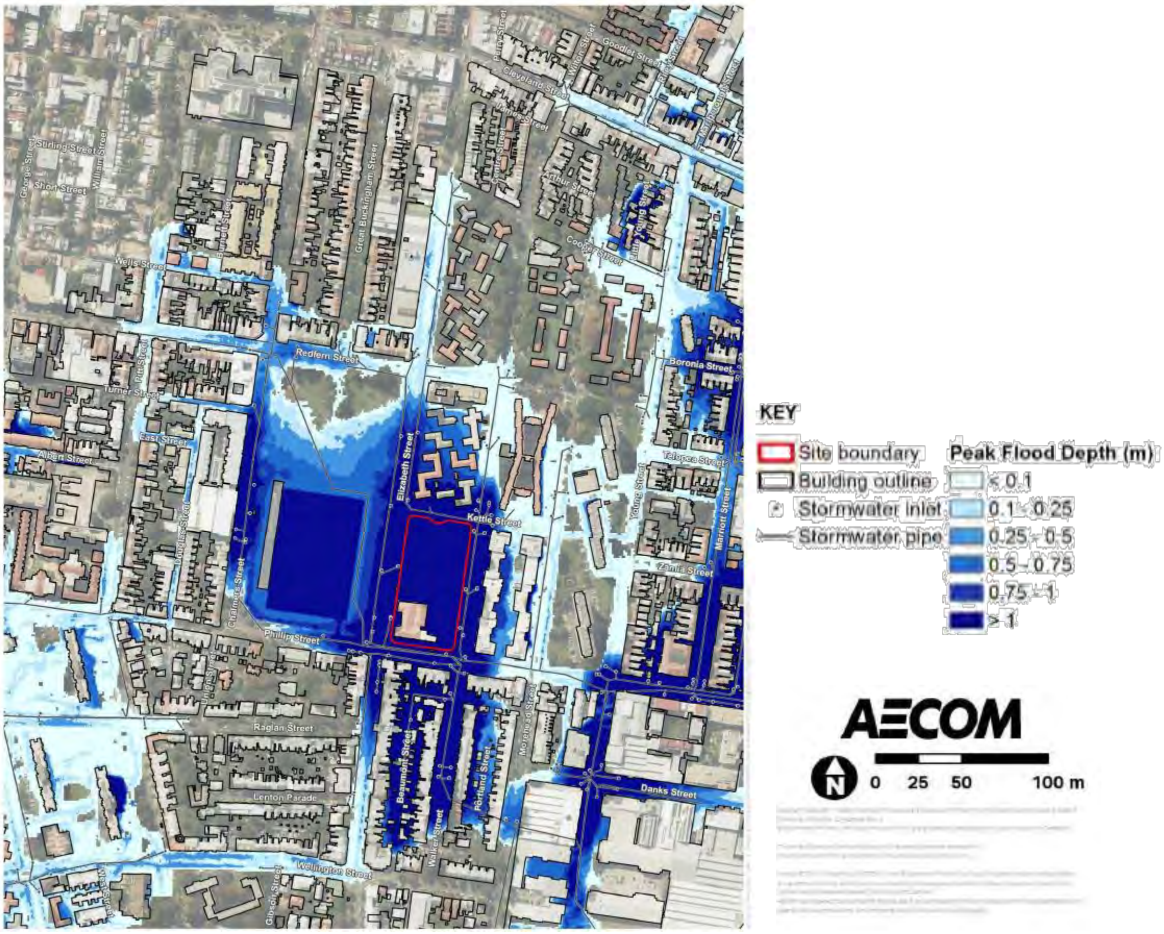


Figure 6: Existing case Probable Maximum Flood peak flood depth

February 2017 flash flood eve showing Chalmers Street (Left), Intersection of Chalmers and Redfern Street (Right)

Figure 7: February 2017 flash flood event[5]

[5] Source: Social Media and The Guardian, February 2017

4.1.2 Urban heat

Urbanisation can modify the heat balance in Sydney resulting in the urban heat island effect (UHI). Metropolitan Sydney has increasing issues with UHI, and developments that result in net loss of green space (such as this development) contribute to the cumulative increase in its effects. Figure 8 and Figure 9 identify the site's current exposure to urban heat, demonstrating relatively moderate overnight heat retention compared to the rest of the city.

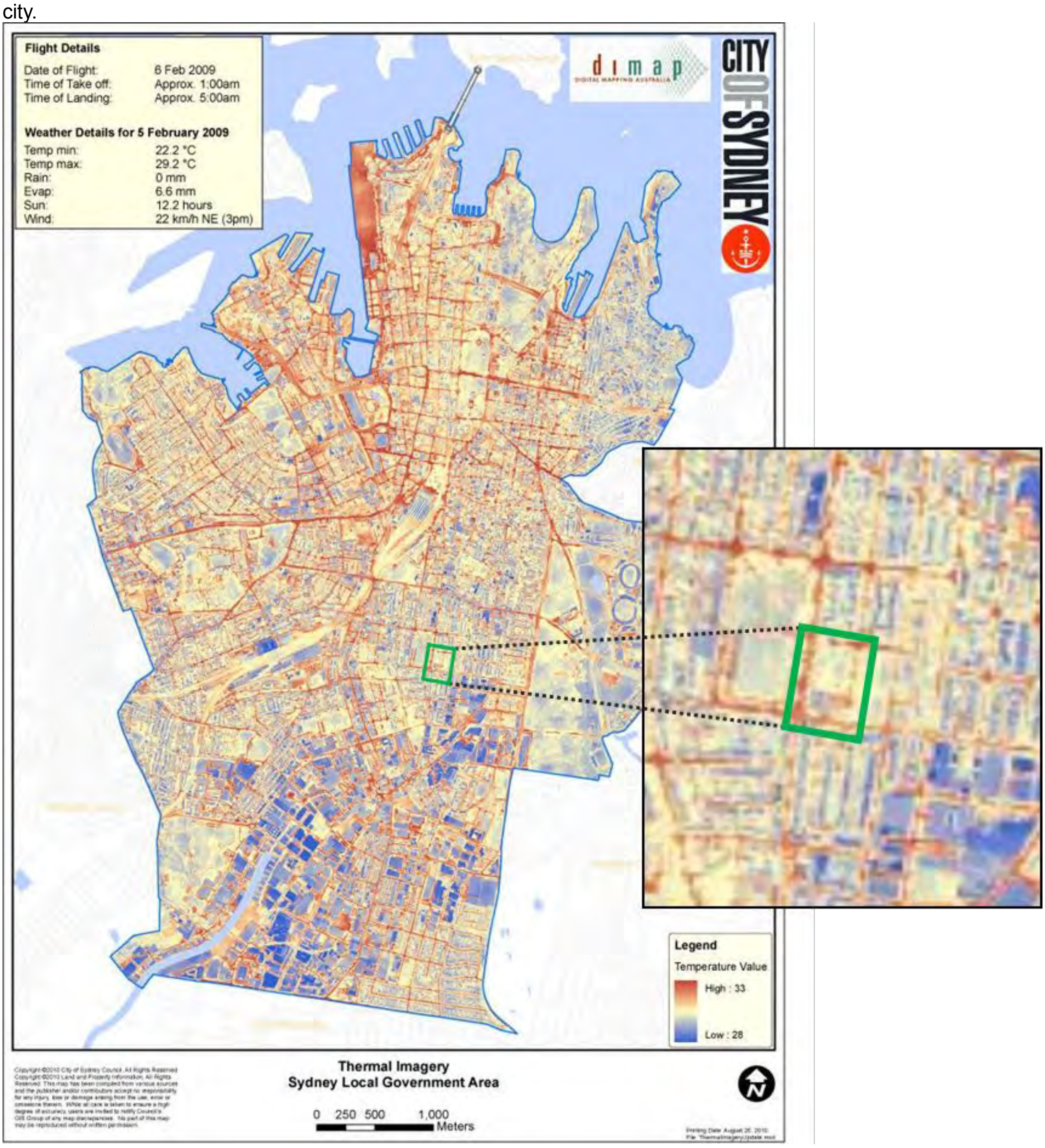


Figure 8: Thermal imagery (overnight) for the City of Sydney and the Elizabeth Street precinct

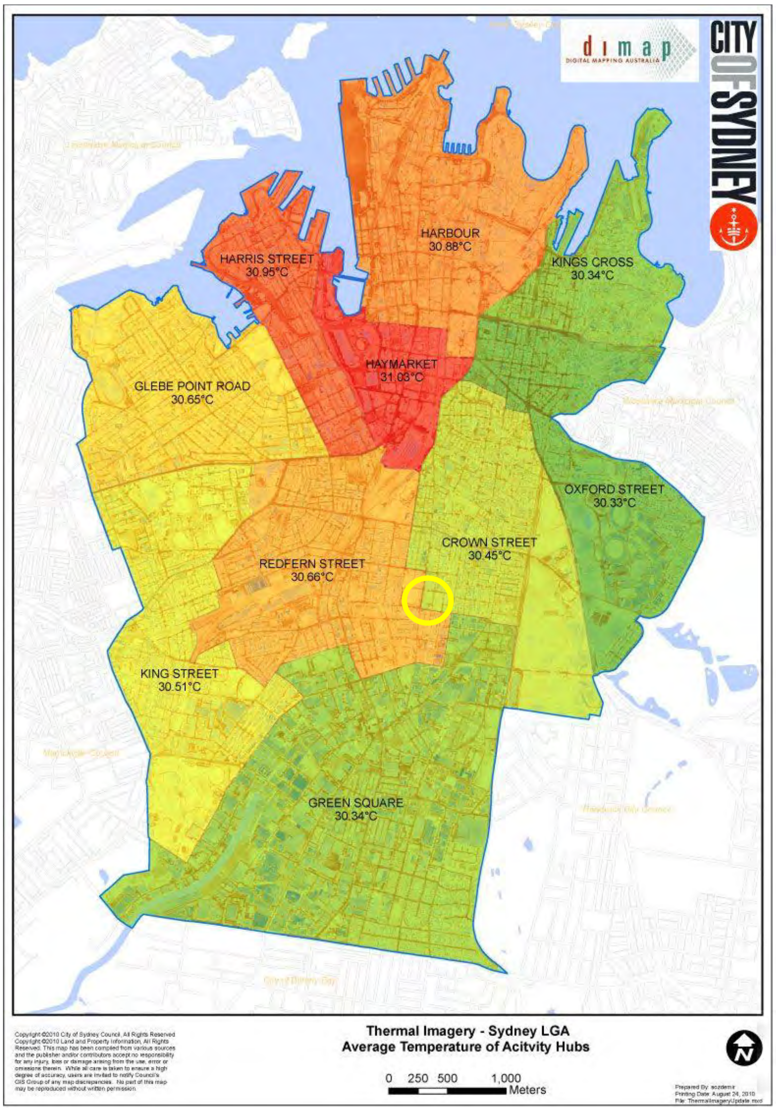


Figure 9: Average temperature of activity hubs within the City of Sydney

4.2 Climate change projections

4.2.1 Introduction

To assess the risk to the proposed development of the site posed by climate change the current climate science and model projections have been investigated based on available data sources. For the purposes of this Climate Change Adaptation Report, these have been chosen in accordance with the hierarchy presented in the Planning Proposal Requirements which request the use of Adapt NSW and the NARCliM project, developed by the NSW Office of Environment and Heritage (OEH, 2014 & 2015).

Risks to the development have been assessed against current climate projections based on the parameters outlined below. These parameters include the Special Report on Emissions Scenarios (SRES) A2 scenario referenced as part of the assessment, in line with the Planning Proposal Requirements to use "*NSW and ACT Regional Climate Modelling: NARCLIM*", the timescale of the projections; and the climate variables specific to the Metropolitan Sydney region. Climate projections sourced from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Bureau of Meteorology (BOM) have also been used where supplementary data is needed and for sensitivity testing purposes. However, 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.

For the purposes of identifying and evaluating the impacts of climate change it is important to note both the current global and local context and the influence on the Elizabeth Street development as well as how future climate projections may impact the site. The following sections provide this context and describe various scenarios across two future timeframes to understand how the site may change with respect to climate change over the life of the project. Climate variables assessed as part of this report are outlined in Table 2, and have been chosen to align with trends experienced by the Sydney metropolitan region, and the Green Building Council of Australia guidance.

Table 2: Primary and Secondary Climate Variables Relevant to Elizabeth St, Redfern

Primary climate variables	Secondary climate variables
Mean surface temperature	Extreme temperatures and heatwaves
Average annual rainfall	Relative humidity (impacts to residents, customers and employees and mechanical systems)
Solar radiation	Sea level rise and coastal inundation
Absolute humidity	Bushfire weather
Wind	Drought conditions
	Extreme rainfall and flooding
	Storm events and extreme wind

4.2.1.1 Emissions scenarios

Greenhouse gas (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 align with that used to undertake the projections modelling for the NARCliM project, SRES A2. The 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).

With regard to the CSIRO and BOM data (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 of observed climate change and GHG emissions currently align to this trajectory.

It is worth noting that NARCliM and Climate Futures are based on different versions of the International Panel on Climate Change (IPCC) Assessment Reports (AR). NARCliM downscales projections based on AR4 data, while Climate Futures utilise projections from the AR5 data.

4.2.1.2 Time scales

Given the expected design life of the development (in excess of 50 years), the general timeframe for the proposed construction works (early 2020s), and the availability of NARCliM-provided climate data, the time periods which were selected for assessment are 2030 and 2070. Climate change projections for 2030 were identified as appropriate for assessment of short term impacts of climate change on the proposed works (assuming full build out of the site by mid 2020s). Climate change projections for 2070 are relevant to the longer-term operation and maintenance stages of the proposed works.

- Projections for 2030 represent the average for the 20-year period between 2020 - 2039.
- Projections for 2070 represent the average for the 20-year period between 2060 - 2079.

4.2.2 Summary

A summary of climate change projections for the site are presented in Table 3 and Figure 10.

Table 3: Climate change projections for Redfern in 2030 & 2070[6]

Climate variable	Baseline average climate for site (1981-2010)	2030	2070
Mean temperature	21.2°C	Increase of 0.7°C	Increase of 1.9°C
Extreme temperature (Number of days where temperatures are greater than 35°C per year)[7]	3.4 days	Increase of 4 days	Increase of 11 days
Cold nights (Number of nights where minimum temperatures are less than 2°C)[7]	0 nights	Cold nights will decrease across Metropolitan Sydney, with 5 cold nights fewer per year	Cold nights will decrease across Metropolitan Sydney, with 12 cold nights fewer per year
Mean annual rainfall [7]	1,223mm	Little change in annual rainfall (+1.7%)	Increase of +8.9% in annual rainfall
Extreme rainfall (one in 20-year event) [RCP8.5]	321mm (daily)	Projections not available	Increase by 5% to 40%
Average annual increase in rainfall intensity	328mm (highest daily rainfall)	Increase of 4.5% (RCP4.5) Increase of 4.9%[8] (RCP8.5)	Increase of 9.1% (RCP4.5) Increase of 18.6% (RCP8.5)
Mean annual wind speed [RCP8.5]	N/A	Decrease of 2.3% to increase of 1.9%	Decrease of 6.9% to increase of 4.2%
Bushfire (Number of days a year Forest Fire Danger Index (FFDI) is greater than 50) [7]	5.5 days	Little change (+0.1 days in summer)	+0.6 days Severe fire weather is projected to increase during summer and spring
Sea level rise	N/A	N/A	N/A

[6] Climate change projections for Redfern in 2030 & 2070 under SRES A2 unless otherwise stated (AdaptNSW, 2014)
[7] Office of Environment and Heritage, 2014. AdaptNSW Interactive Map.
[8] AR&R (2016) uses CSIRO data to determine a nominal 5% increase in rainfall intensity per degree of temperature increase.

Projected **temperature** changes	
Maximum temperatures are projected to increase in the near future by 0.3–1.0°C	Maximum temperatures are projected to increase in the far future by 1.6–2.5°C
Minimum temperatures are projected to increase in the near future by 0.4–0.8°C	Minimum temperatures are projected to increase in the far future by 1.4–2.5°C
The number of hot days will increase	The number of cold nights will decrease
Projected **rainfall** changes	
Rainfall is projected to decrease in spring and winter	Rainfall is projected to increase in summer and autumn
Projected **Forest Fire Danger Index (FFDI)** changes	
Average fire weather is projected to increase in spring by 2070	Severe fire weather days are projected to increase in summer and spring by 2070

Figure 10: Overview of climate projections for Metropolitan Sydney in the near-future (2030) and far future (2070) (OEH, 2014)[9]

4.2.2.1 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.

4.2.2.2 Extreme temperature and heatwaves

The Metropolitan Sydney Region is expected to experience more hot days in both the near future and far future. Currently, Redfern experiences around 3 hot days on average per year. The region, on average, is projected to experience four additional hot days in the near future, increasing to around 11 additional hot days in the far future under SRES A2 (OEH, 2014 & 2015). The greatest increases are projected during spring and summer, while also extending into autumn.

4.2.2.3 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.

4.2.2.4 Extreme rainfall and overland flooding

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

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

[9] Office of Environment and Heritage, 2014. AdaptNSW Metropolitan Sydney Climate Change Snapshot

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

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

The flood study of the Alexandra Canal Catchment, which was commissioned by the Office of Environment and Heritage and the City of Sydney, incorporates sensitivity allowances that account for climate change. Figure 11 shows the current 5 year average recurrence interval, which demonstrates even minor flood events are currently expected to impact the site. Average Recurrence Interval (ARI) refers to the long-term average or expected number of years between occurrences of a flood of a certain size. It is implicit in this definition that the periods between exceedances are generally random. ARI is another way of expressing the likelihood of occurrence of a flood event.

Figure 12 shows the extent of a current 100-year ARI event, also demonstrating severe impacts to the site with depths up to 1 metre. When compared to Figure 13 and Figure 14, which demonstrate the projected inundation of the site during a 100 year ARI event with an additional 30% increase in rainfall intensity as a sensitivity test to consider impacts of climate change, the extent of flooding is significantly increased. The sensitivity analysis is further discussed in Section 4.3.

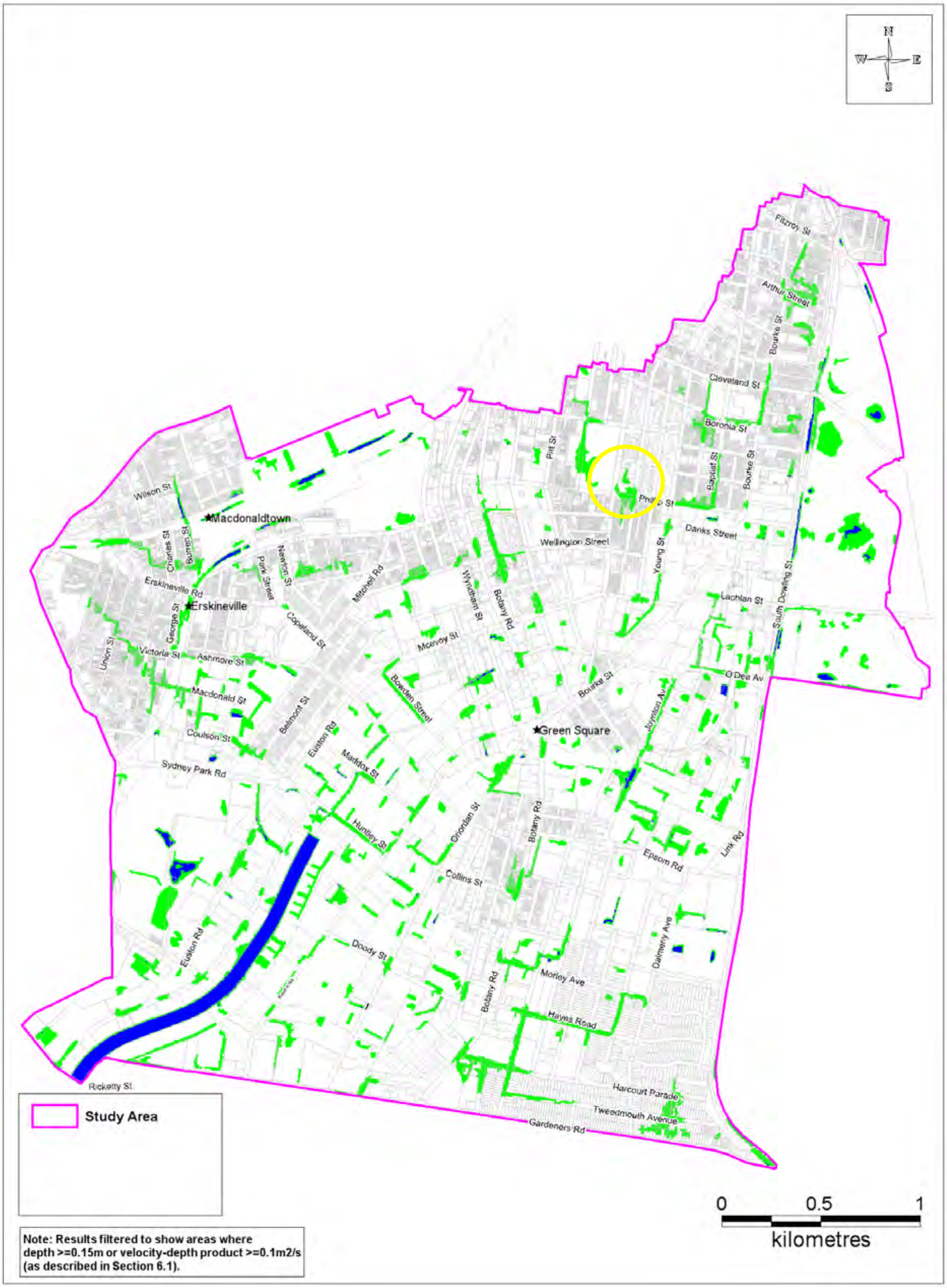


Figure 11: Current 5-year ARI event (site identified by yellow circle)

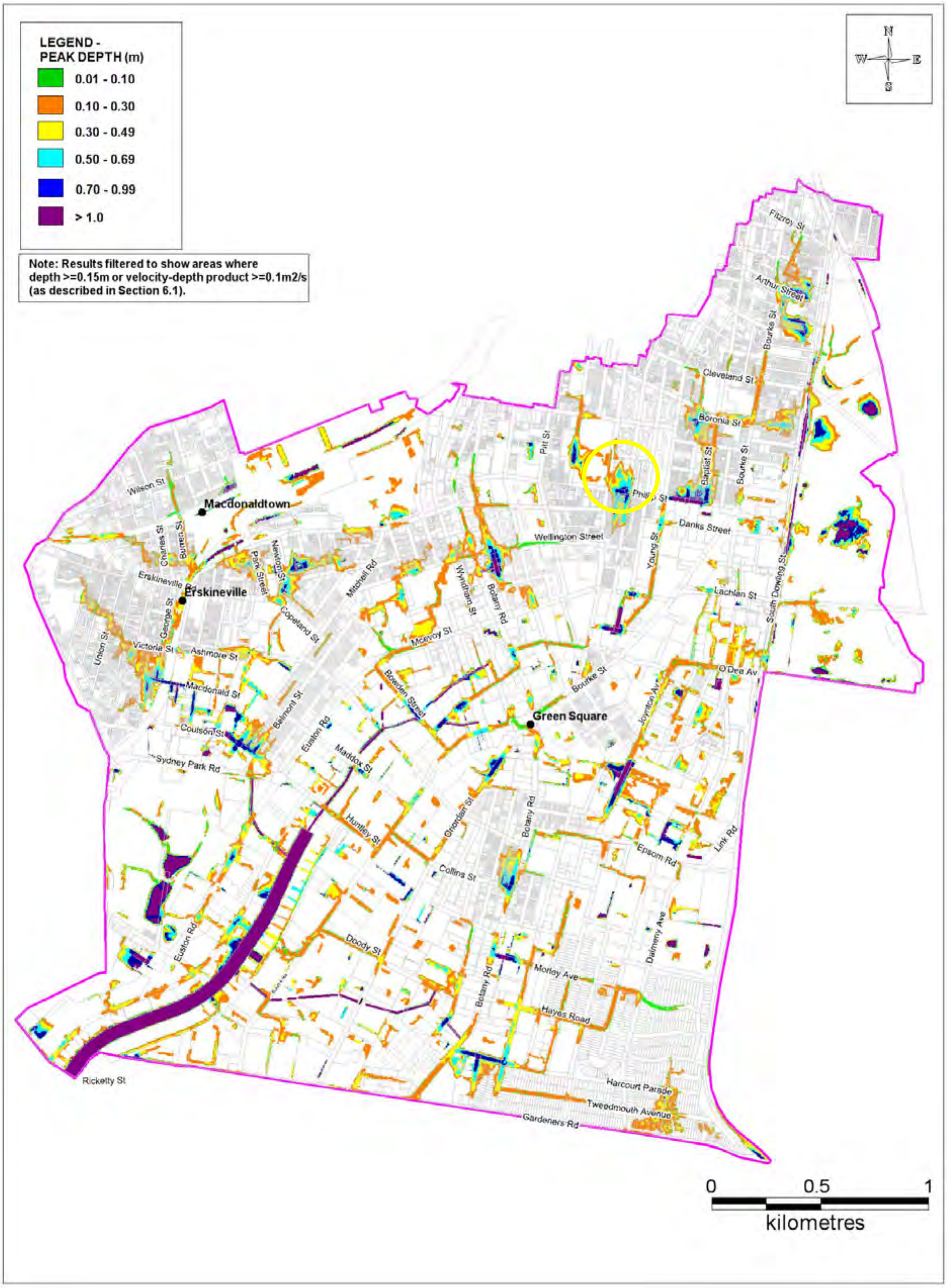


Figure 12: Current 100-year ARI event (site identified by yellow circle)

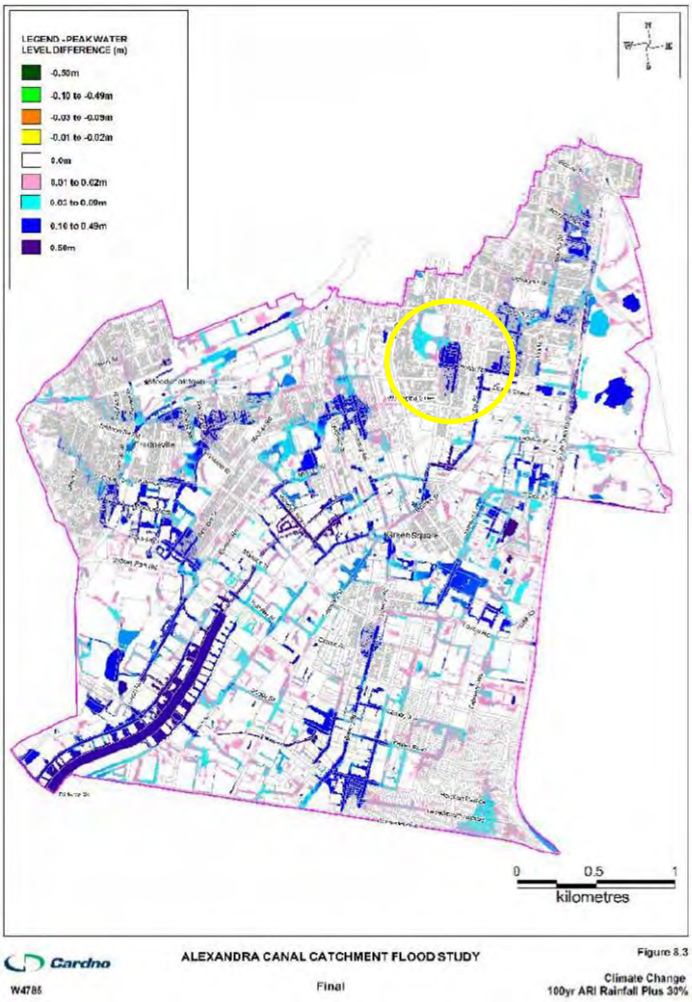


Figure 13: 100yr ARI +30% increase in rainfall intensity to allow for climate change – peak water level difference[4]

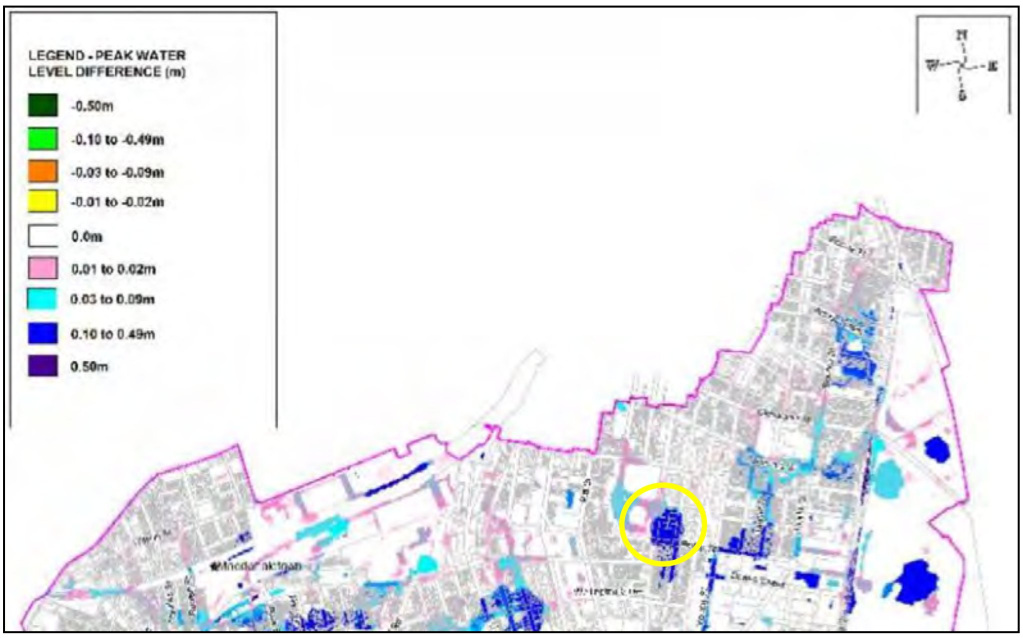


Figure 14: 100yr ARI +30% increase in rainfall intensity to allow for climate change – peak water level difference[4]

4.2.2.5 Storm and extreme wind events

NARCliM projections for SRES A2 (OEH, 2014 & 2015) are not specifically available for storms, east coast lows (ECLs)[10], or extreme wind speed. However, a related project, the Eastern Seaboard Climate Change Initiative (ESCCI), used NARCliM models to project east coast lows into the future.

The project found that climate change projections may cause the following changes to east coast lows:

- Greater seasonal variability with a decrease in the number of small to moderate east coast lows in the cool season with little change in these storms during the warm season.
- Extreme east coast lows in the warmer months may increase in number but extreme east coast lows in cool seasons may not change.
- Projected changes into the future are smaller than the natural variability we already see in east coast lows 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 east coast low variability and associated risk. Risk analysis should consider the storminess of the 1600-1900 period (AdaptNSW, 2014).

CSIRO and BOM 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.

4.2.2.6 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).

4.2.2.7 Sea Level Rise

As the proposed works are located inland, sea level rise projections are unlikely to have direct impacts on the site, with mapping suggesting the nearest impacted areas are approximately 2.2km to the south-east of the site in Alexandria. 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, and energy and water utilities. Climate change, including an impact of sea level rise and rainfall intensity increases, has been assessed (Figure 14) demonstrating the likely increase in peak water levels observed. The analysis found that the model is generally more sensitive to pit and culvert blockages than to climate change.

[10] East coast lows are intense low-pressure systems that occur off the east coast of Australia. They can form at any time of the year and significant east coast lows 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)

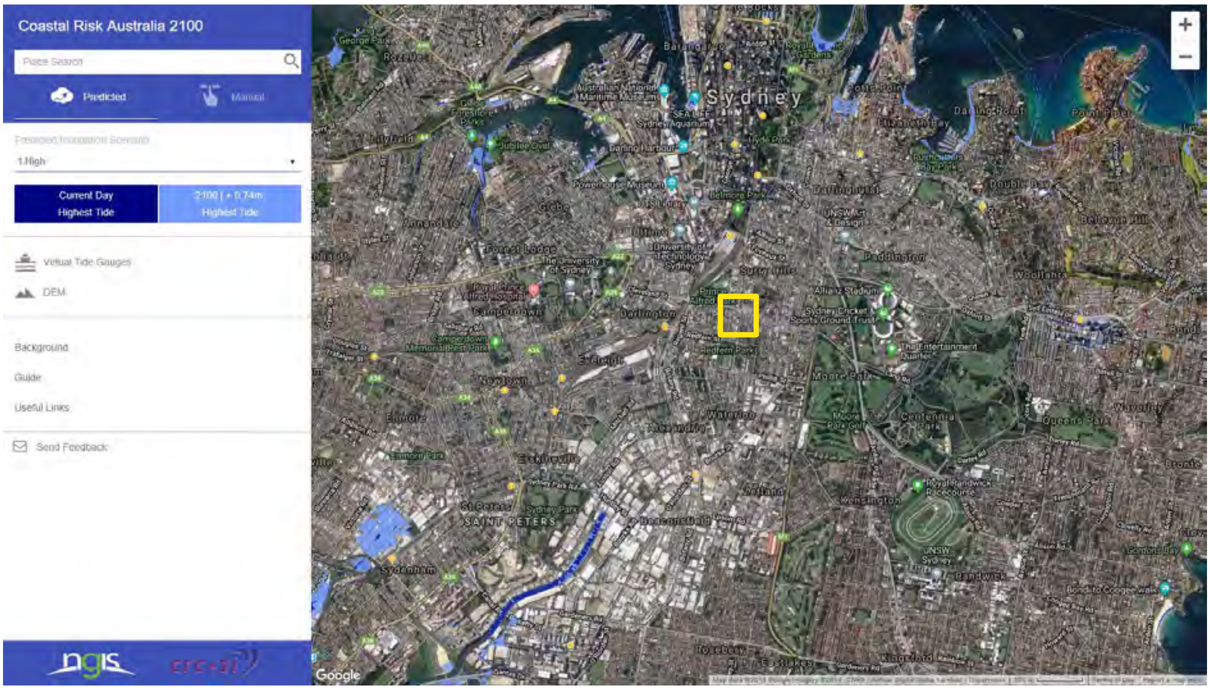


Figure 15: Sea level rise mapping for Sydney in 2100 (Coastal Risk Australia)

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

4.3.1 Increased temperatures, extreme heat events:

Sensitivity testing has been undertaken through reviewing the projections generated by the NARCliM project, which uses selected AR4 models, as well as 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).

A comparison of mean temperature and extreme heat days between RCP 4.5 and RCP 8.5 is provided in Table 4. The Climate Risk Register and recommended adaptation actions have taken into consideration of the worst-case scenario. This sensitivity analysis considers projections for 2090 under the CSIRO & BOM Climate Futures emissions scenarios as a worst-case scenario, compared to the projections for 2070 summarised in Section 4.2.2.

Table 4: Sensitivity analysis - Mean Temperature and Extreme Heat Days: comparison between emissions scenarios

Emissions Scenarios	Mean temperature change		Extreme heat days	
	2030	2090[11]	2030	2090
SRES A2 (NARCliM)	+0.7°C	+1.9°C[12]	+4 days	+11 days
RCP 4.5 (CSIRO & BOM)	+0.85 °C (+0.6°C to +1.1°C)	+1.9 °C (+1.3°C to +2.5°C)	+4.3 days	+6 days
RCP 8.5 (CSIRO & BOM)	+1.0 °C (+0.7°C to +1.3°C)	+3.75 °C (+2.9°C to +4.6°C)	+4.3 days[13]	+11 days

As the projections under RCP 8.5 exceed the projections under SRES A2, the Climate Risk Register and recommended adaptation actions have taken into consideration the RCP 8.5 projections as the worst-case scenario.

4.3.2 Increase of rainfall intensity:

Sensitivity testing of rainfall intensity has been undertaken by reviewing the recent draft revision of Australian Rainfall and Runoff (AR&R) Guidelines (2016). The AR&R Guidelines provide guidance on assessing climate change impacts on flood behaviour and is based on IPCC AR5 projections (rather than the NARCliM 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

[11] This sensitivity analysis considers projections for 2090 under the CSIRO & BOM Climate Futures emissions scenarios as a worst case scenario, compared to the projections for 2070 summarised in Section 4.2.2.
[12] SRES A2 does not provide projections for 2090, so the projection for 2070 has been used.
[13] RCP 8.5 does not provide projections for 2090, so the projection for RCP 4.5 has been used.

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 Elizabeth St was undertaken by increasing the rainfall intensity by 10% for the 100-year ARI, in line with AR&R 2016 and OEH Guidelines. 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, 2019).

This sensitivity testing has driven the adaptation actions developed, in particular supporting the adoption of an allowance for an increased rainfall intensity consideration due to climate change. 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 *Ecologically Sustainable Development Study* (AECOM, 2019).

5. Climate risk assessment

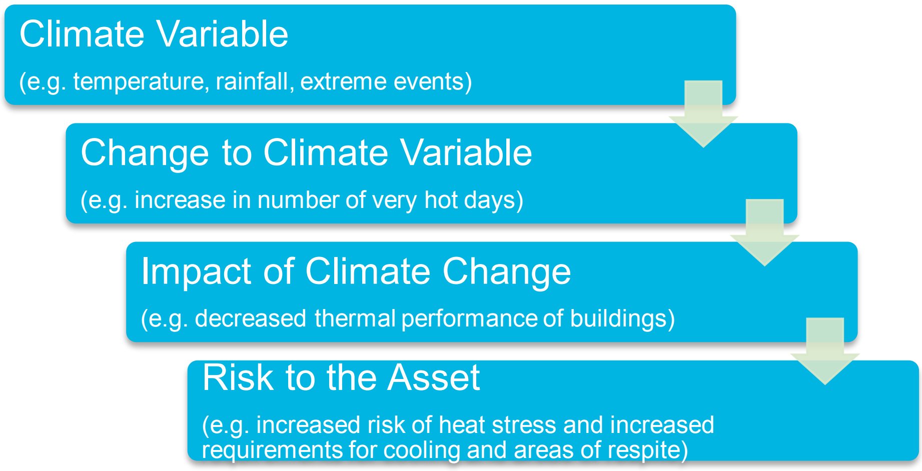
In order to adequately and appropriately detail how the site will address the social, environmental and economic effects of climate change including potential impacts on vulnerable groups, it is necessary to understand the risks. The following section details the risks that were identified and details the existing and proposed adaption options to help reduce the risks.

The climate risk assessment that was undertaken is 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 A Risk Assessment Criteria 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 16 outlines how risks have been developed from an assessment of climate variables and projected climate change.

Figure 16: Climate Change Risk Assessment Process (adapted from OEH, 2008)



5.1 Consultation with stakeholders

A climate risk assessment workshop was held in AECOM offices in Sydney on the 3rd October 2018 to socialise the climate risks identified through a preliminary climate risk assessment informed by desktop research. Workshop participants comprised multidisciplinary members of the project team including:

- Lindsey Noble, LAHC – Design and Development
- Katrina Burley, Architectus - Architecture and Urban Design
- Ivan Ip, Architectus – Architecture and Urban Design
- Stephen Read, Jacobs – Traffic Management
- Dan Sharp, Tyrell Studio – Landscape Design
- Roger Swinbourne, AECOM - Sustainability
- Stacey Atkinson, AECOM – Climate Resilience
- James Herbert, AECOM - Sustainability
- Ulises Demeneghi, AECOM - Sustainability
- Joshua Atkinson, AECOM – Water and Flooding
- Harley Lewington, AECOM – Climate Resilience

Direct coordination has been concurrently undertaken between teams to ensure any climate adaptation options identified align with the sustainability targets proposed in the *Ecologically Sustainable Development Report* to ensure optimal outcomes are achieved within the project.

5.2 Key climate risks for the project

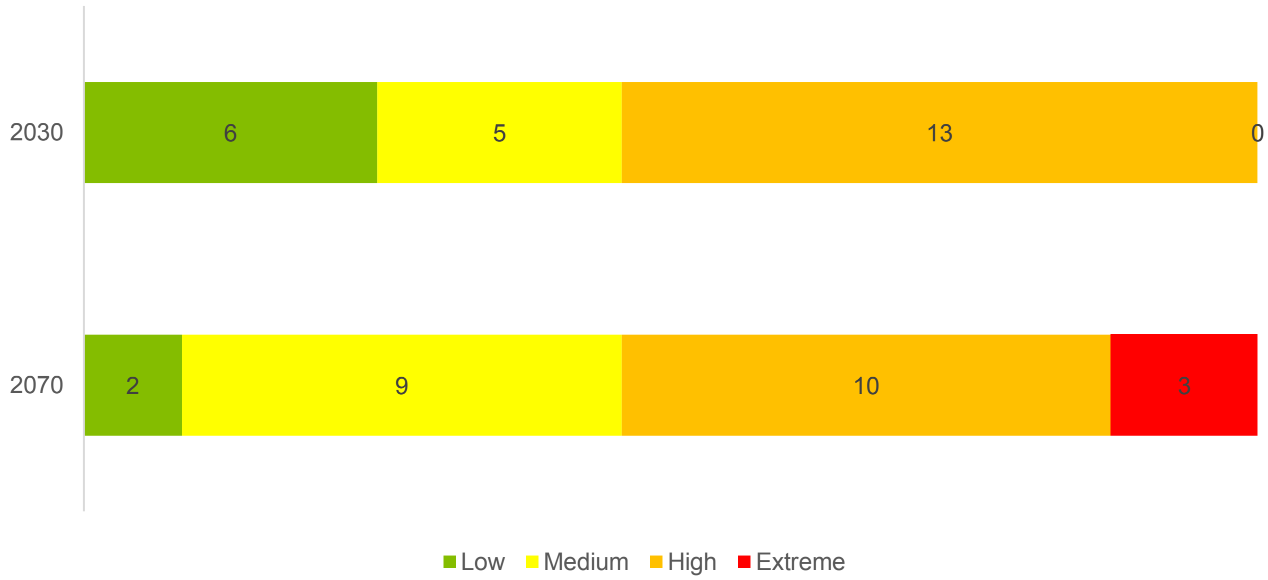
The preliminary assessment and workshop identified and rated 24 key climate risks based on their likelihood and consequences for a 2030 and 2070-time horizon to consider the planned building life-cycle of approximately 50 years. As part of the risk register, detailed risk analysis, risk ratings (both 2030 and 2070), preliminary proposed actions and responsibilities were identified. It is worth noting that risks were assessed based on preliminary concept designs only, and prior to treatment actions being identified or implemented. Assessment of residual risk ratings should be undertaken prior to construction.

Given the site's historical incidence of flooding, and the likely high proportion of vulnerable residents the most relevant hazards identified for the development are associated with flooding and extreme heat. The workshop process also identified storms as a significant hazard given the sites future population.

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 24 risk ratings for the 2030 and 2070 time horizons are as follows:

Table 5: Summary of climate risk assessment

Risk rating	2030	2070
Low	6	2
Medium	5	9
High	13	10
Extreme	0	3
Total	**24**	**24**



5.3 Climate risk assessment

The climate risk assessment identified a total of 24 climate risks to the project (both direct and indirect risks). Table 5 summarises the risks identified for the project for future climate conditions in 2030 and 2070. Table 6 presents the climate risk assessment for the project, with risk ratings evaluated in consultation with project team members (refer Section 5.1), and using the consequence and likelihood criteria outlined in *Climate Change Impacts and Risk Management: A Guide for Business and Government* (DEH, 2006), provided in *Appendix A Risk Assessment Criteria.*

Table 6: Climate risk assessment

Climate impact	Code	Risk to the project	2030 Likelihood	2030 Consequence	2030 Risk rating	2070 Likelihood	2070 Consequence	2070 Risk rating
Extreme heat (days over 35°C) leading to…								
	H1	Increased pressure on cooling and air conditioning causing decreased thermal comfort and health impacts	Likely	Moderate	**High**	Likely	Moderate	**High**
	H2	Increased energy and water demand causing increased energy costs	Likely	Moderate	**High**	Likely	Moderate	**High**
	H3	Reduced energy network capacity causing brownouts and/or blackouts disrupting health systems	Likely	Major	**High**	Likely	Major	**High**
	H4	Increased heat stress events among residents	Likely	Major	**High**	Almost Certain	Major	**Extreme**
	H5	Increased demand for areas of respite	Likely	Moderate	**High**	Likely	Moderate	**High**
	H6	Reduced working capacity of contractors/staff (including in outdoor areas)	Likely	Moderate	**High**	Likely	Moderate	**High**
Extreme rainfall and flood events leading to…								
	F1	Increased local flood events, limiting access and egress	Likely	Major	**High**	Almost Certain	Major	**Extreme**
	F2	Greater intensity of rainfall, runoff and drainage capacity issues (roof and ground level) causing property damage	Likely	Moderate	**High**	Almost Certain	Moderate	**High**
	F3	Flooding resulting in inundation of roads, carparks, and buildings causing property and equipment damage	Likely	Major	**High**	Almost Certain	Major	**Extreme**
	F4	Increase in safety issues for residents around flooding	Possible	Major	**High**	Likely	Major	**High**

Climate impact	Code	Risk to the project	2030 Likelihood	2030 Consequence	2030 Risk rating	2070 Likelihood	2070 Consequence	2070 Risk rating
Storm events, wind and hail leading to…								
	S1	Increased storm and hail damage to structure (roofing, guttering and windows)	Likely	Moderate	**High**	Likely	Moderate	**High**
	S2	Increased storm and hail damage to utilities and services	Likely	Moderate	**High**	Likely	Moderate	**High**
	S3	Rain/moisture penetration following storm/hail/wind damage	Possible	Moderate	**Medium**	Possible	Moderate	**Medium**
	S4	Increase in safety issues for residents, and operations and maintenance staff	Possible	Major	**Medium**	Possible	Major	**Medium**
Mean rainfall change leading to…								
	R1	Decrease in available potable water (water restrictions) leading to health impacts for residents	Possible	Moderate	**Medium**	Possible	Moderate	**Medium**
Drought leading to…								
	D1	Decrease in soil moisture leading to degradation of foundations and/or other structural damage	Unlikely	Minor	**Low**	Possible	Moderate	**Medium**
Bushfire leading to…								
	B1	Smoke and embers entrained into ventilation and air conditioning systems causing damage	Rare	Moderate	**Low**	Rare	Moderate	**Low**
	B2	Smoke damage from penetration into building through unsealed areas leading to health impacts of residents	Rare	Moderate	**Low**	Possible	Moderate	**Medium**
	B3	Accumulation of ash in roof drainage leading to blocked drains and structural impacts	Rare	Moderate	**Low**	Rare	Moderate	**Low**
	B4	Bushfire impacts on air quality in open air areas leading to health impacts of residents	Possible	Moderate	**Medium**	Possible	Moderate	**Medium**
Relative humidity leading to…								
	RH1	Decreased thermal performance of building causing health impacts to residents	Likely	Moderate	**High**	Likely	Moderate	**High**

Climate impact	Code	Risk to the project	2030 Likelihood	2030 Consequence	2030 Risk rating	2070 Likelihood	2070 Consequence	2070 Risk rating
	RH2	Accelerated carbonation of concrete structures and structural damage	Unlikely	Minor	**Low**	Unlikely	Moderate	**Medium**
	RH3	Changes to environment suitable for water borne diseases and pest species distribution	Unlikely	Moderate	**Medium**	Unlikely	Moderate	**Medium**
Sea level rise leading to…								
	SL1	Potential to exacerbate extreme rainfall and flood events, leading to greater inundation and localised flooding	Rare	Moderate	**Low**	Possible	Moderate	**Medium**

6. Climate adaptation plan

6.1 Climate change considerations in design

Given that extreme heat, extreme rainfall and flooding, and storms/extreme wind have been identified as the hazards most likely to impact the development and its community, the following actions have been identified for potential integration by the design team into the final masterplan and rezoning proposal. Adaptation actions and responses identified seek to reduce the risk exposure of the whole precinct, including private, affordable and social housing residents to ensure a thriving and resilient community. Many actions will also be valued for their cross-cutting benefits, where gains in resilience also lead to gains in resource efficiency, human health, and community cohesion.

Adaptation actions are summarised by highest risk hazards in Sections 6.1.1, 6.1.2, and 6.1.3. Section 6.2 identifies detailed actions to mitigate the High and Extreme risks outlined in the climate risk register (Section 5).

The Reference Scheme considers climate change adaptation and incorporates a number of the recommended actions, including:

- Three at-grade communal areas with opportunities for shade and respite (approx. 2,900m2 of the site)
- A number of green roofs providing additional communal open space
- Achieving tree canopy of 25% of the site
- Building orientation has considered effective ventilation and solar access
- The indicative apartment layout achieves 62% cross ventilation (above the ADG minimum)
- The landscape plan considers opportunity for water features to assist in cooling

A number of actions can be considered further in the detailed design phase and the following could be incorporated in the design of the site:

- Consider the delivery of green walls and incorporate items of higher reflectivity value (such as light-coloured roofing) to help reduce the site's contributions to the urban heat island effect.
- Ongoing maintenance of vegetation should be considered.

The Reference Scheme considers a number of the above actions by incorporating the following:

- The large area of at-grade communal space (approximately 2,900m2 of the site), 15% deep soil and green roofs will help control the flow of rainwater into the stormwater system
- All residential areas above the flood planning levels and all building entries are above PMF
- Improved street landscaping and front setbacks incorporate WSUD principles
- Detailed analysis of building and basement entries has demonstrated the ability to provide steps and ramps above PMF and incorporate accessibility facilities where necessary.

The detailed design of the communal spaces should further consider the ability to assist with water retention and permeability of paved areas. The detailed design of the buildings should ensure entries/exits are located away from the known flood locations areas.

Based on the identified adaptation actions it is expected that 600-660 Elizabeth Street has both considered a range of climate risks at the development application phase and not precluded the future development of a range of solutions. Furthermore, the incorporated and identified adaptation actions and design considerations are considered sufficient to address the Planning Proposal Requirements.

6.1.1 Adaptation actions for temperature increases and extreme heat

Adaptation actions related to heat mitigation are primarily targeted to maintaining thermal comfort of buildings, ensuring the health and safety of residents and the community are maintained, and providing areas of respite when extreme heat days do occur. Through the participatory workshop with urban designers, architects and the developer, the following actions are recommended for adoption in future iterations of the design.

The Reference Scheme considers climate change adaptation and incorporates a number of the recommended actions, including:

- Three at-grade communal areas with opportunities for shade and respite (approx. 2,900m2 of the site)
- A number of green roofs providing additional communal open space
- Achieving tree canopy of 25% of the site
- Building orientation has considered effective ventilation and solar access
- The indicative apartment layout achieves 62% cross ventilation (above the ADG minimum)
- The landscape plan considers opportunity for water features to assist in cooling

A number of actions can be considered further in the detailed design phase and the following could be incorporated in future DCP controls for the site:

- Consider the delivery of green walls
- Materials should incorporate items of higher reflectivity value
- Ongoing maintenance of vegetation should be considered

Figure 17 Adaptation actions responding to temperature increases and extreme heat

Type	Adaptation actions
Temperature increases and extreme heat	
Architectural and urban design	Consider maximising ground level green open space. Communal areas that are well shaded provide areas of respite during heat events and assist in mitigating urban heat island effects.
	Consider the creation of green vertical buildings which feature vegetated facades. This also helps mitigate urban heat island effects and provides benefits to buildings in terms of energy efficiency, thermal comfort, and air quality. The green roofs featured help provide additional communal space for residents to help encourage healthier lifestyles and strengthen community networks.
	Design apartments to achieve the highest level of energy and water efficiency as practicable, e.g. adopting passive cooling through cross ventilation, insulation, and performance glazing. Dwellings that consume fewer resources are less dependent on wider networks in times of outages (such as blackouts), lead to better health outcomes for residents during extreme heat events, and are cheaper to operate due to lower consumption.
	Maximise the proportion of the total project site area that comprises building or landscaping elements that reduce the impact of heat island effect (in line with Green Star Communities Urban Heat Island Credit). This includes a higher reflectivity value for built elements (street pavement, roofs, etc.)
	Maximise opportunities to create cool buildings through effective orientation, ventilation, shading, and cooling systems. Targeting high performance buildings (such as a 6 Star NABERS and 6 Star Green Star rating) also 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.
Vegetation	Tree canopy coverage over paved surfaces serves as a cost-effective means of mitigating urban heat island effects (including additional projected increases in mean temperature and extreme heat events). Any program that encourages tree retention and replacement 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 (of benefit to those with respiratory issues).
	Given the upcoming density of the site and the resultant heavy use of parks and outdoor recreation facilities, ongoing maintenance of vegetation must be considered. For example, plant and tree species should be chosen for suitability in future climate scenarios (i.e. noting higher temperatures, increasing frequency and intensity of droughts, etc.)

Type	Adaptation actions
Water sensitive urban design	The integration of water features 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 as flood mitigation (discussed below).

6.1.2 Adaptation actions for increased rainfall intensity and flooding

Adaptation actions related to flood mitigation are primarily targeted to reducing safety hazards to residents and the community, minimising damages, reducing runoff and managing water on site, and providing shelter for the wider community, and educating residents on flood safety.

The Reference Scheme considers a number of the above actions by incorporating the following:

- The large area of at-grade communal space (approximately 2,900m2 of the site), 15% deep soil and green roofs will help control the flow of rainwater into the stormwater system
- All residential areas above the flood planning levels and all building entries are above PMF
- Improved street landscaping and front setbacks incorporate WSUD principles
- Detailed analysis of building and basement entries has demonstrated the ability to provide steps and ramps above PMF and incorporate accessibility facilities where necessary.

The detailed design of the communal spaces should further consider the ability to assist with water retention and permeability of paved areas. The detailed design of the buildings should ensure entries/exits are located away from the known flood locations areas.

Figure 18 Adaptation actions responding to increased rainfall intensity and flooding

Type	Adaptation actions
Increased rainfall intensity and flooding	
Drainage, stormwater, and flood management design	The proposed development should be designed to account for the flood risks prevalent throughout and surrounding the site including adopting the flood hazard mapping that incorporates a 10% increase in the ARI to account for climate change at a minimum. 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)[14]. Given the design life of the development to be approximately 50 years, a minimum of a 10% increase in rainfall intensity is recommended to be adopted during detailed design of drainage, stormwater, and flood management devices. Further information regarding the sensitivity testing including base line conditions, assumptions and additional detail is be found within the Stormwater Strategy (AECOM, 2020).
Architectural and urban design	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. Ensure all residential areas and critical infrastructure are raised above the flood planning level (greater of Probable Maximum Flood (PMF)[15] levels or 100-year ARI plus freeboard to allow for an increase in rainfall intensity of 10%).
	It is recommended that the area of total paved surfaces be reduced as much as possible, prioritising permeable surfaces.
	There are further 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.
	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.

[14] RCP 4.5 projections for 2090 have been adopted as a worst case scenario in accordance with the sensitivity testing (refer Section 4.3).

[15] Probable Maximum Flood (PMF) - The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum rainfall, coupled with the worst flood producing catchment conditions.

Type	Adaptation actions
Electrical and critical services design	Specific electrical and other critical systems should be sited appropriately in response to flood risks.
Vegetation	Consider rain gardens, green roofs, increased planting areas and other green infrastructure to capture and/or dissipate intensity of rainfall prior to reaching ground level.
Water sensitive urban design	Green roofs, 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.
	There is opportunity to use water sensitive urban design (WSUD) principles such as integrating detention basins with vegetation island as part of streetscapes
	Permeable pavement in areas of high pedestrian traffic with bio-retention to reduce risks.

6.1.3 Adaptation actions for storm events

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.

Figure 19 Adaptation actions responding to storm events

Type	Adaptation actions
Storm events	
Architectural and urban design	Actively consider the storm resistance (to wind, debris, driving rain) of building materials such as roofing, guttering, windows, eaves, building ventilation, etc.
	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.
Electrical and critical services design	Ensure critical infrastructure is not exposed to potential damage by wind, flying debris, or driving rain (e.g. roof mounted plant and equipment)
	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).
Vegetation	Consider use of vegetation as windbreaks

6.2 Summary of adaptation actions

In alignment with the methodology outlined by the Green Building Council of Australia's Green Star credit related to resilience (Green Star Communities v1.2 Gov-4 Adaptation and Resilience Credits), actions have been identified to specifically address all risks rated High and Extreme.

Overall, extreme rainfall and flooding, extreme heat, and extreme storm events are hazards considered to have 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) 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. The economic and psychological impact of major flooding on residents in these suburbs would therefore also be severe given their existing hardships, and the recovery from major flooding, as well as extreme storms, is likely to be difficult and prolonged. Similarly, 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.

The Reference Scheme addresses the risks and adaptation actions identified through this report, where suitable for the master-planning stage.

As a result of the preliminary risk assessment and stakeholder workshop process, adaptation actions have been identified for the risks above (refer Section 4.3) for integration into future concept designs, and ultimately the preferred option. Adaptation actions have been identified by participants in the stakeholder workshop for risks rated High and Extreme. These risks and actions are outlined in Table 7.

Table 7: Climate risk adaptation options identified by stakeholders

Climate risk statement		2030 Risk rating	2070 Risk rating	Adaptation actions	Typical timings	Considered at current stage (master-planning / rezoning)
Extreme heat (days over 35 °C)						
H1	Decreased thermal comfort and increased pressure on cooling and air conditioning	**High**	**High**	• Maximise ground level green open space. Communal areas that are well shaded provide areas of respite during heat events and assist in mitigating urban heat island effects.	• Development application options identify spatial layout and open space provisions. • Shading structures to be defined at detailed design.	
				• High performance façade design (including insulation, glazing ratios) such as reflective/insulated surfaces and windows	• Detailed design	
				• Consider the creation of green vertical buildings which feature vegetated facades. Installation of louvres and awnings for external shading, particularly on western facades.	• Concept design (DA stage)	
				• Orientate buildings to reduce western facing aspects and maximise northern facing aspects.	• Planning stage	Yes
				• Maximise opportunities for passive cooling and natural ventilation for residential and communal areas	• Concept design (DA stage)	
				• Use of high albedo materials where non-permeable surfaces must be used	• Detailed design	
				• Appropriately size HVAC to consider future climate, such as leaving additional space in plant rooms for future upgrade opportunities and designing risers for future retrofitting and upgrade of cooling systems	• Concept design (DA stage)	
				• Investigate high efficiency material selection in terms of wall and roof insulation	• Detailed design and construction	
				• Provide communal spaces and community facilities that are air conditioned to provide respite to residents without air conditioning	• Detailed design	

Climate risk statement		2030 Risk rating	2070 Risk rating	Adaptation actions	Typical timings	Considered at current stage (master-planning / rezoning)
				• Consider spatial requirements for additional energy network provision, such as providing onsite renewables	• Planning stage	Yes – site too small
				• Consider a precinct-wide energy strategy and installation of embedded network or battery storage and associated spatial requirements to provide energy redundancy	• Planning stage	Yes – site too small
H2	Increased energy and water demand	**High**	**High**	• Building management of power centralised cooling to reduce high levels of demand	• Detailed design	
				• Limit minimum temperature of cooling systems to reduce peak demand	• Construction and operation	
				• Consider actions under H1 that aim to efficiently maximise passive thermal performance of buildings	• Refer H1	
H3	Reduced energy network capacity (brownouts/blackouts)	**High**	**High**	• Efficiency measures and alternative supplies are being investigated – refer to the ESD report	• Planning stage	Yes
				• Consider additional energy network provision, such as providing onsite renewables	• Planning stage	Yes – site too small
				• Consider a precinct-wide energy strategy and installation of embedded network to provide energy redundancy	• Concept design (DA stage)	
				• Consider actions under H1 that aim to efficiently maximise passive thermal performance of buildings	• Refer H1	
H4	Increased heat stress events among stakeholders	**High**	**Extreme**	• Increase management controls for extreme heat events such as doorknocking, particularly for single occupant dwellings and vulnerable residents	• Construction and operation	
				• Rooftop gardens and tree canopies to provide respite and cool buildings	• Concept design (DA stage)	
				• Consider actions under H1 that aim to efficiently maximise passive thermal performance of buildings	• Refer H1	
H5	Increased requirements for cooling and areas of respite	**High**	**High**	• All options include a series of communal spaces for external respite from heat	• Planning stage	Yes
				• Opportunity to provide awnings for respite along the street frontage	• Concept design (DA stage)	

Climate risk statement		2030 Risk rating	2070 Risk rating	Adaptation actions	Typical timings	Considered at current stage (master-planning / rezoning)
				• Provision of respite against areas where no active cooling is provided	• Concept design (DA stage)	
				• Adhere (or over comply) to City of Sydney's green canopy requirements to reduce urban heat	• Concept design (DA stage)	
				• Provision of communal green space on both rooftops and at ground level	• Concept design (DA stage)	Yes
				• Consider actions under H1 that aim to efficiently maximise passive thermal performance of buildings and provide areas of respite for residents and community members.	• Refer H1	
H6	Reduced working capacity of staff (including in outdoor areas)	**High**	**High**	• Communal spaces will provide access to vegetation and shade for respite of staff	• Concept design (DA stage)	
				• Consider actions under H5 that aim to provide respite	• Refer H5	
Extreme rainfall and flood events						
F1	Increased local flood events, limiting access and egress	**High**	**Extreme**	• Design communal open spaces on the ground level that incorporate water sensitive urban design (WSUD) principles, and can accommodate flooding and stormwater detention	• Concept design (DA stage)	Yes
				• Future flood levels incorporated to reduce impact on property and life	• Concept design (DA stage)	Yes
				• Consider building access points in relation to flood risk	• Concept design (DA stage)	Yes
				• Flood emergency response plan/strategy, and SES contingency planning	• Construction and operation	
				• Ensure all critical infrastructure is raised above PMF levels	• Concept design (DA stage)	Yes
F2	Greater intensity of runoff and drainage capacity issues (roof and ground level)	**High**	**High**	• Consider F1 actions	• Refer F1	
				• Creation of breaks in built structures to allow water to drain through north-south corridor	• Concept design (DA stage)	

Climate risk statement		2030 Risk rating	2070 Risk rating	Adaptation actions	Typical timings	Considered at current stage (master-planning / rezoning)
				• Design green rooftop spaces to assist with runoff reduction	• Concept design (DA stage)	
				• Reduce impervious areas to reduce run off and assist water detention	• Concept design (DA stage)	
F3	Riverine and flash flooding resulting in inundation of roads and buildings	**High**	**Extreme**	• Rising floor levels above 100yr ARI + 10% climate change provision or PMF	• Concept design (DA stage)	Yes
				• Raise critical infrastructure above 100yr ARI + 10% climate change provision or PMF	• Concept design (DA stage)	Yes
				• Incorporation of flood detention areas	• Planning stage	
				• Potential for buildings to be raised/partly raised above ground level to allow site to flood and apartments to be above flood	• Concept design (DA stage)	Yes
				• Safe points designed to public spaces and flood levels	• Construction and operation	
F4	Increase in safety issues around stormwater detention basins and channels (areas at risk of localised flooding)	**High**	**High**	• Consider F1 actions	• Refer F1	
Storm events, wind and hail						
S1	Increased storm and hail damage to structure (roofing, guttering and windows)	**High**	**High**	• Actively consider the storm resistance (to wind, debris, driving rain) of building materials such as roofing, guttering, windows, eaves, building ventilation, etc.	• Detailed design	
				• Ensure critical infrastructure not exposed to potential damage by wind, flying debris, or driving rain (e.g. roof mounted plant and equipment)	• Concept design (DA stage)	
				• Reduce amount of and reinforce external façade fittings	• Detailed design	
				• Consider use of vegetation as windbreaks	• Concept design (DA stage)	

Climate risk statement		2030 Risk rating	2070 Risk rating	Adaptation actions	Typical timings	Considered at current stage (master-planning / rezoning)
				• Ensure roof structural stability of roof design and construction accounts for increased uplift wind forces. E.g. consider adopting cyclone standards.	• Detailed design	
S2	Increased storm and hail damage to utilities and services	**High**	**High**	• Consider vulnerabilities of external infrastructure networks (energy, telecommunications, water, transport, etc) and where possible reduce the reliance on these networks (e.g. H1 actions such as onsite power generation, demand reduction initiatives).	• Concept design (DA stage)	
Relative humidity						
RH1	Decreased thermal performance of building	**High**	**High**	• Consider H1 actions.	• Refer H1	

7. Conclusion and next steps

This report presents a Climate Adaptation Study for LAHC's Elizabeth Street, Redfern development and is a snapshot of the development at the master-planning and rezoning stage, reflecting the information available at the time of assessment. It is recommended this report is reviewed and revised as needed at the development application stage when the design is developed.

For the 2070 time period 3 'extreme' risks were identified, and 10 'high' risks were identified. Section 6 of this report has detailed the adaptation actions and initiatives that are recommended to be incorporated into further designs to address these risks. While a formal residual risk assessment has not been undertaken, these actions will result in a reduction in risk from climate change. It is anticipated that as the proposed development progresses from the development application stage and rezoning to detailed design, the climate risk assessment would be revisited with a residual risk assessment undertaken to verify integration of adaptation measures and how that has resulted in changes to the risks previously identified.

Section 6.2 of this report summarises the actions and responses that have been undertaken in direct response to the Planning Proposal Requirements. 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.

The Reference Scheme incorporates a series of measures that address the risks and actions in this report.

Appendix A Risk Assessment Criteria

Figure 20: Consequence and Success Criteria[16]

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.

[16] Source: Green Building Council of Australia (GBCA) Green Star Communities v1.1 Adaptation and Resilience credit. This matrix is based on the Australian Greenhouse Office (AGO) Climate Change Risks and Impacts: A Guide for Government and Business (2006)

Figure 21: 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.

Figure 22: 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