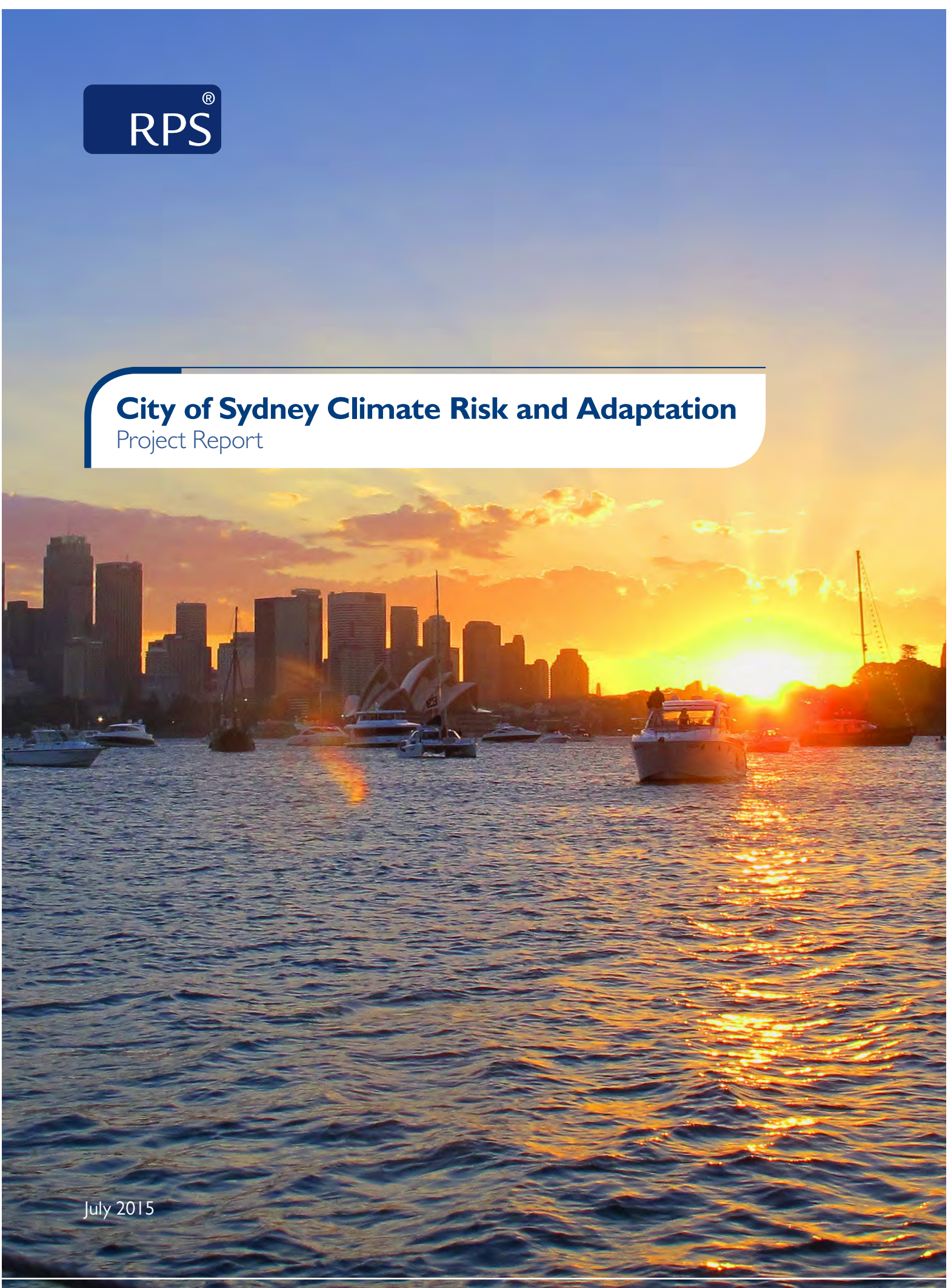
ATTACHMENT D

APPENDIX: CITY OF SYDNEY CLIMATE RISK AND ADAPTATION PROJECT REPORT BY RPS AND KPMG

RPS®

City of Sydney Climate Risk and Adaptation

Project Report



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City of Sydney Climate Risk and Adaptation

Project Report

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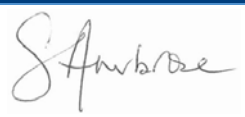
Steve Ambrose		08/07/2015

We have prepared this report for the sole purposes of The City of Sydney ('**Client'**) for the specific purpose of only for which it is supplied ('**Purpose'**). This report is strictly limited to the purpose and the facts and matters stated in it and does not apply directly or indirectly and will not be used for any other application, purpose, use or matter.

This report provides a project summary of the work undertaken by RPS Manidis Roberts Pty Ltd and KPMG to undertake a Climate Risk and Adaptation Assessment for The City of Sydney. This report does not comprise the City's Climate Adaptation Plan; rather it outlines the necessary information and recommendations required for the City to develop its Climate Adaptation Plan.

Contents

Report acronyms summary

Acronym	Translation
ACELG	The Australian Centre of Excellence for Local Government
BoM	Bureau of Meteorology
BASIX	The Building Sustainability Index
CALD	Culturally and Linguistically Diverse
CAP	Climate Adaptation Plan
CoS	City of Sydney
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCC	Australian Government Department of Climate Change
EIANZ	Environment Institute of Australia and New Zealand
GCM	Global Climate Model (sometimes referred to as General Circulation Model)
GEV	Generalised Extreme Value
HAT	Highest Astronomical Tide
ICLEI	International Council for Local Environmental Initiatives
ICT	Information and Communications Technology
IPCC	Intergovernmental Panel on Climate Change
IPWEA	Institute of Public Works Engineering Australasia
IRVA	Integrated Regional Vulnerability Assessment
IVA	Integrated Vulnerability Assessment
LGA	Local Government Area
LGA SA	Local Government Association South Australia
LEMO	Local Emergency Management Officer
MCA	Multi-criteria Analysis
NCCAP	National Climate Change Adaptation Programme
NARCliM	New South Wales and Australian Capital Territory Regional Climate Modelling
OEH	New South Wales Office of Environment and Heritage
PIA	Planning Institute of Australia
RAR	Risk and Adaptation Register
RCP	Representative Concentration Pathways
SCCG	Sydney Coastal Councils Group
SimCLIM	Statistically downscaling climate modelling software package
SRG	Science Reference Group
WSUD	Water Sensitive Urban Design

Executive summary

Suggested vision for Sydney's Climate Adaptation:

By 2030 the City of Sydney (the City) will have delivered effective strategies and solutions to focus its approach to climate risk and resilience. It will have worked in collaboration with key stakeholders to address the relevant impacts to the City from extreme temperature, sea level rise, extreme rainfall as well as the series of combined climate risks arising from these. The actions undertaken will have helped better protect the City's communities, businesses and iconic areas from future changes to the climate, and built its ability to adapt, respond, and thrive in the face of change.

Background

Extreme climate events across Australia, particularly recent flooding, heat wave and bushfire events have demonstrated the vulnerability of local government and their communities to climate extremes. Overall the future climate of the Sydney region is expected to be hotter and drier than it is today and will experience a significant increase in extreme heat events. These changes in climate extremes will have a range of impacts including scarcity of water resources, increase in ozone air pollution, and increase in bushfire frequency and intensity, all of which place vulnerable community members under stress and reduce asset and infrastructure resilience. It will also affect the richness of local biodiversity and the health of vegetation and the local ecosystem.

In order to meaningfully address these and other climate related risks and impacts the City of Sydney commissioned RPS and KPMG to assess the risk of climate hazards to the region and set out a framework to assist in adopting a leading practice approach to embedding adaptation planning at a Council level. The City recognises the role it plays as a global leader and the benefits gained from proactively adapting to climate extremes. It acknowledges its responsibility to taking appropriate steps to increase the resilience of all aspects that make up a liveable community, as well as addressing the impacts of projected climate variability while dealing with uncertainty. As a global city it maintains its assets and services to the highest standards, however these are based upon historical climate data and information (building codes, design standards etc), and as such may not be resilient to future climatic conditions. This project will inform new standards and ways of working to proactively manage the city in a changing climate to ensure better outcomes in the future and improved resilience.

To develop the steps necessary to minimise the potential impacts of a changing climate, it is critical that climate adaptation actions respond to the specific needs of the City's Local Government Area (LGA) and its local vulnerabilities. This report seeks to address this challenge by presenting targeted and specific climate adaptation actions informed by a leading practice approach and methodology.

The climate futures presented in this report are based on publicly available global climate models. The analysis considers three futures based on models representing low, medium and high rates of climate change. These futures assume a scenario in which global emissions of greenhouse gases continue to grow steadily.[1] The report's approach to climate modelling has been supported by the Project's Science Reference Group[2] (SRG). It is recommended the City revisit the climate modelling undertaken for this project as climate science improves and the global emissions trajectory becomes apparent.

[1] *The scenario is RCP8.5 from the IPCC's Fifth Assessment Report.*

[2] *The City's Science Reference Group comprises some of Australia's leading climate science and adaptation experts enlisted to provide scientific rigour and specialist input to the process.*

Overview

The following report provides the relevant data, analysis and recommendations required to enable the City to develop its Climate Adaptation Plan (CAP) to guide Council's future planning and response. As a recently announced member of the Rockefeller Foundation's 100 Resilient Cities initiative, this work supports the City's application to the program and provides a blueprint for action.

The report also draws on and references a number of actions already underway by the City. These include (but are not limited to) measures to:

- Drought proof its parks.
- Increase canopy cover to help address the impacts of the urban heat island effect.
- Ongoing monitoring of the City's urban heat.
- Undertake flood modelling.
- Implement energy efficiency and energy management.
- Implement event management procedures that respond to the impacts associated with extreme heat.

The City of Sydney is located in Australia within the state of New South Wales, Sydney is the state capital, and occupies the unique position of being Australia's leading global city.

The City's Local Government Area (LGA) comprises 26 square kilometres (km^2) and 33 suburbs. It is home to 183,000 residents with an additional worker population of close to 450,000. On any given day, once figures for the City's tourist population are included, the LGA plays host to 1 million people.

The City represents a thriving economic hub for both the state and for the country, responsible for 25% of NSW's economy and 8% of Australia's total economy. It is also the heart of Australia's tourist economy, home to icons such as the Sydney Opera House, and Sydney Harbour Bridge, with over 4.5 million hotel stays recorded per annum (City of Sydney Annual Report, 2013).

Approach

Consultation and engagement has proved a defining feature of the project and has contributed to the leading practice approach undertaken by the City. Specifically the findings of this report have been shaped by the contribution of:

- The **consultant project team**, RPS have been responsible for developing and providing each of the inputs presented in this report, with KPMG managing the climate risk and interdependencies assessment.
- The **City of Sydney Project Control Group and Executive** who have provided the strategic direction and focus necessary to guide the project's delivery and outcomes.
- Relevant **stakeholders from within the City** including representatives from key Divisions and Business Units to provide valuable insight and feedback to the process undertaken to develop the proposed climate adaptation actions.
- Relevant **external stakeholders for the City** comprising a group of over 50 representatives offering a diverse representation of those organisations whose support, collaboration and partnership are essential for implementing many of the actions presented in this plan. They include (but are not limited to) businesses and agencies responsible for health, transport, emergency services; development; finance and commercial development.

- A **Science Reference Group** comprising a panel of climate science and adaptation experts established to provide oversight project to the process and approach and provide scientific rigour and specialist input into the process.
- A **Citizen's Panel** comprising 23 citizen representatives from across the LGA selected to participate in a 2.5 day community engagement event, following a deliberative democracy approach designed to draw out and test the project approach and findings.

The City of Sydney's Climate Risk and Exposure

Central to this project has been developing a clear understanding of the City's level of climate risk and exposure.

In particular the following changes to climate are expected to have the most significant impact on the City of Sydney:

- Increase in average temperatures.
- Increase in extreme heat days.
- Increase in ozone air pollutants.
- Decrease in annual rainfall.
- Increase in extreme precipitation events.
- Increase in bushfire conditions.
- Increase in drought conditions.
- Increase in sea levels and extent of coastal inundation.

In addition, while the frequency and intensity of storms and extreme wind are likely to be affected by climate change and therefore have an impact on the City, current certainty regarding the direction and magnitude of this is poorly understood at present. Models show a possible increase or decrease in both intensity and/or frequency. Given the level of impact storms and extreme wind can have however, it has been considered in the process of identifying the City's climate risks.

Based on these climate variables, a comprehensive risk assessment, accompanied by a leading practice approach to interdependencies assessment, has been undertaken. A total of 32 risks have been identified for the City and are listed in full in Section 9.1 of this report. Of these 32, 14 have been identified as being of highest risk. These are listed in the following table:

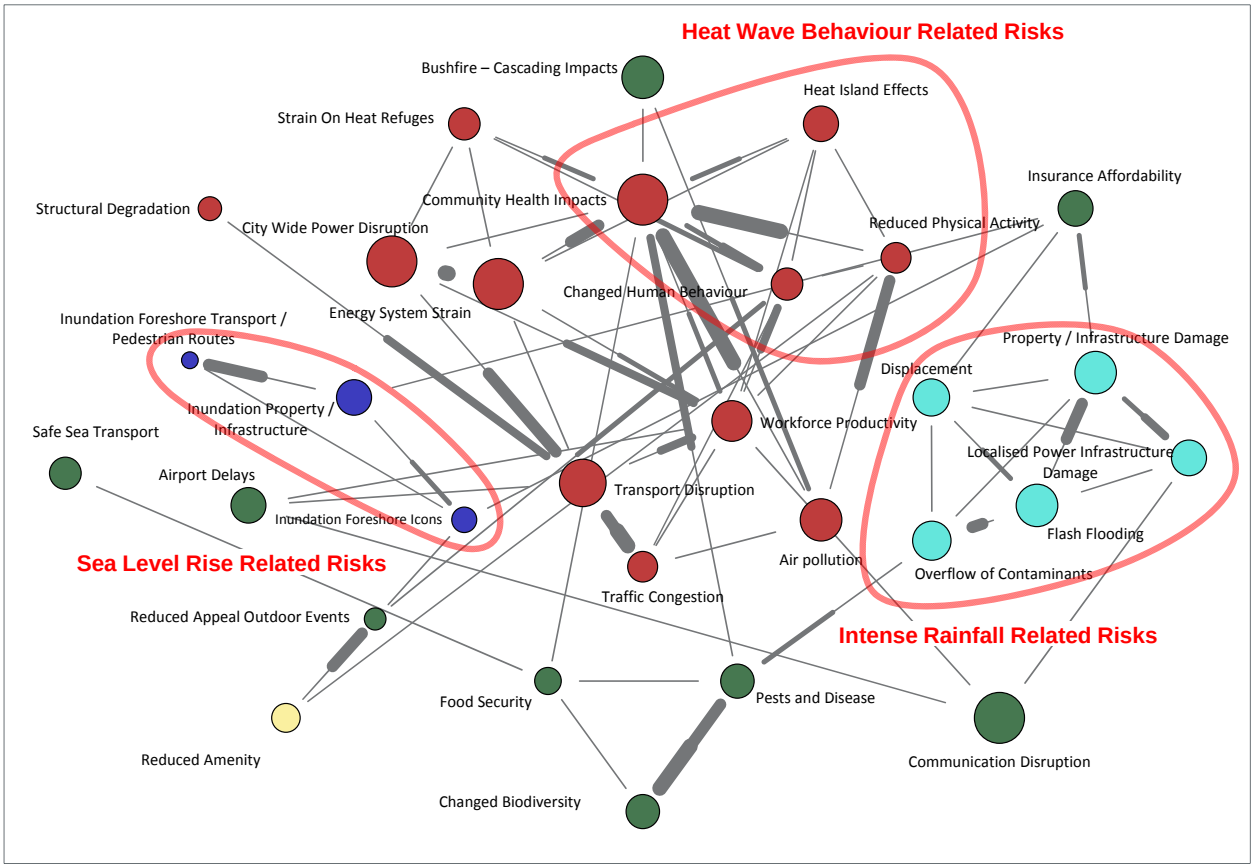
Highest climate risks for the City of Sydney	
Climate variable	**Highest risk areas**
Temperature	▪ T1: Energy system strain ▪ T2: Workforce productivity ▪ T3: Community health impacts ▪ T5: City-wide power disruption ▪ T8: Transport disruption ▪ T9: Air pollution
Sea level rise	▪ S1: Inundation to property/infrastructure

Highest climate risks for the City of Sydney	
Climate variable	**Highest risk areas**
Precipitation	▪ P2: Property/infrastructure damage ▪ P3: Flash flooding
Combined risks	▪ C3: Bushfire – cascading impacts ▪ C5: Insurance affordability for the City ▪ C9: Communication disruption ▪ C10: Financial viability of council ▪ C11: Increased storms causing disruption

Risk interdependencies

An essential element of the project analysis was to understand the interdependencies and interconnectivity between the identified climate risks. The diagram illustrated overleaf has drawn on the survey responses generated through the risk engagement process to graphically present the relationship between the risks and perception of severity for current state 2014 and 2030. The graph is also able to demonstrate those risks that are central to causing other risks, and those that are most affected by other risks. The relative inter-connectedness and relative severity of risks has been determined. Portraying information in this format offers a straightforward way to identify clustered risks as shown in the diagram. Risk clusters are groups of risks identified as being particularly strongly connected. These risks should be considered together for risk management purposes.

Clustering is determined by analysing a number of factors, including the strength and number of connections between a small group of risks. For example, the temperature cluster illustrated acknowledges the knock-on effect of heat-waves on urban heat island, reduced physical activity and changed human behaviour and the interconnected nature this impact has on a cluster of risks. As acknowledged by the City's SRG the identification of these interconnectivities align with a leading approach to climate risk assessment and enables the development of targeted actions that are able to respond to (and cut across) multiple risk areas. These clustered risks should be considered and actioned together.



How to interpret the connections

A thin line shows risks that are related. A thick line indicates a risk that makes the originating risk worse. For example, respondents indicated Air Pollution is the most pertinent risk to make Reduced Physical Activity (middle right) more likely or potentially worse.

The diagram is able to demonstrate those risks that are pivotal to the risk network in terms of causing other risks (cause), and being impacted by other risks (effect).

Climate Adaptation Actions for the City of Sydney

A detailed and involved process has been undertaken to develop the climate adaptation actions proposed in this report and within the *supporting materials* documentation that has been provided independently to the City.

Over 230 actions have been identified to correspond with each of the 32 identified risk statements. Of these, 120 relate directly to the City's 14 highest climate risks. The majority of actions identified (over 55%) cut across multiple risk areas and provide the City with a clear focus point from which to start implementation. Focussing implementation based on addressing cross cutting actions will enable the City to address multiple risks simultaneously thereby delivering maximum value.

The following presents the synthesised list of cross-cutting actions responding to the 14 highest priority risks for the City. They have been developed by evaluating all of the cross-cutting actions identified across the highest climate risk areas within the Resilience and Adaptation Register (RAR) developed for the City, with a view to consolidating like actions and themes to streamline delivery against multiple risk areas.

It is noted that of the 28 prioritised actions presented here, the majority require the City to work in a collaborative or advocacy approach with relevant stakeholders (refer Section 11.3.3 for further information).

Based on the review to identify those actions that cut across the largest number of multiple climate risks, **the most important action necessary for the City is to develop a Heat Wave Response Plan aligned with the NSW State Heatwave Sub Plan 2011**. This action alone responds to eight (8) different risk statements (refer Table 33, Section 11.3.3). Further, as the impacts of heat have been identified as the primary climate risk facing the City a targeted approach to managing these impacts is critical for the City.

Priority climate adaptation actions for the City of Sydney

1. **Develop Heat Wave Response Plan** aligned with the NSW State Heatwave Sub Plan 2011, (include transport and behaviour aspects in the Plan as well as impacts to vulnerable communities – consult with community).
2. Work with agencies and stakeholders, especially energy companies, to assess the **potential extent of vulnerability of the City's power supply** to increased severity, frequency and duration of extreme events to help build resilience across the City's network.
3. Consider impacts for more frequent and more intense flooding on Council's **insurance cover**, its long-term financial plan and overall viability.
4. Review all relevant **biodiversity and vegetation plans** and operations to increase climate resilient planting and species selection.
5. Continue to roll out **energy efficiency measures**, renewable energy technologies or other suitable efficient power systems (including co/tri-generation facilities and manage demand for energy and water across City's assets, equipment and services).
6. Require development to **design for energy and water efficient buildings** and infrastructure (including review of BASIX and WSUD).
7. Review land use planning to **ensure sensible precautions and contingencies for proposed future developments** are made to consider Sea Level Rise and flooding.
8. Explore opportunities **to design/redesign the City's buildings and public realm for passive cooling** (including vegetative cover) to inform the City's asset management and renewal planning. Relevant opportunities should then be fed into the City's asset management and renewal planning.
9. Raise **staff awareness**, including provision of training on what to do in a heat wave, air pollution, bushfire and other climate events, (including review of Design Safety Risk Assessment).
10. Amend **Business Continuity Plan** 2013/2014 to consider impacts of extreme events on essential services.
11. Consider further revision to **event protocols** to enable safe, successful events in hot and extreme conditions (including research on feasibility of a public steward program and event safety plans).
12. Work in partnership with relevant stakeholders to develop a communications campaign to **inform the community** about climate extremes.
13. Review City of Sydney **Decentralised Water Master Plan** 2014 and Decentralised Energy Master Plan 2012 for reference to climate resilience.
14. Work with stakeholders/ agencies to **support community-based self-help responses** to extreme events (including heat waves).
15. Identify and develop additional (larger) **refuges**, facilities and amenities for use in extreme events

16. Advocate for transport agencies to review **resilience of transport services** in the City to extreme events (including review of passenger comfort and provision of back-up power and forming a strategic alliance with transport agencies).
17. Revisit the research undertaken regarding **Heat Island Effect** impacts for consistency with the projections modelled as part of the City's Climate Risk Assessment. Following this research, investigate its contribution towards extreme heat and negative changes in behaviour.
18. In partnership with other agencies develop a **Heat Wave and Extreme Event Alert System**, incorporating transportation system status information.
19. Undertake an assessment of building, construction, and other **materials** to determine their **durability** to projected climatic conditions to inform Council's asset maintenance program.
20. Advocate to ensure **access to the web** and websites (and emergency notices relating to transport delays) are operable from a back-up server and have built-in resilience.
21. Advocate for increased **police and security presence** in extreme events especially in transport hubs or areas of traffic congestion to manage the impact from distressed, aggravated and or displaced travellers.
22. Improve **drainage system** for roads and around at risk buildings and primary transport assets.
23. Work with and actively engage on the development of rapid response and **emergency evacuation procedures** in extreme events including development of the City's Community Resilience Plan, (working with emergency services, government agencies and community groups (including arts, heritage and indigenous groups)).
24. Advocate to relevant agencies on the need to **consider revisions to engineering/building standards and codes** for exposed buildings and infrastructure (including Standards Australia).
25. Advocate to Sydney Water Corporation with regard to completing **ongoing and periodic reviews of the sewerage system strategies** to better handle extreme events.
26. Prepare for **rapid deployment of emergency pumps** and sand bags either located in, or rapidly deployed to, high risk areas to reduce flooding impacts.
27. Establish a cross sector **Climate Resilience Taskforce** to regularly assess and jointly plan for future climate extremes.
28. Develop procedures to ensure that climate resilience is incorporated into all future **key Council decision-making** (projects, plans, strategies etc.).

Key decisions for the City

From the outset this project has adopted a decision-centred approach, one that requires the City to think upfront about the major decisions it will need to be make for the future to better protect against future changes in the climate. These decision areas have been developed and refined throughout the project. As part of the process to develop a top 10 list of decision-making considerations, a cross check against leading climate vulnerability mapping undertaken by Sydney Coastal Councils Group in 2008 and the NSW Government's Integrated Vulnerability Assessment was completed. This process reaffirmed the findings of this project and established that the fundamental priorities facing the City with regard to climate risk remain applicable.

A decision-centred approach offers an alternate method for communicating priorities by structuring responses based on critical issues, or, key decision-making points. At its core, adopting this approach would require the City to consider the critical decisions it needs to make to *proactively manage the City in a*

changing climate (see overleaf) in order to filter the climate variables and modelling it requires, its adaptation actions and priorities. For example, in developing its Climate Adaptation Plan the City could use the decision-centred approach to inform which of the top 28 prioritised actions best align and respond to the key decisions it needs to make. Following this first review, the same approach can be applied to provide an organised and systematic manner of selecting and prioritising the remaining adaptation actions.

Once the City has confirmed those actions that best respond to the decisions it needs to make, it can then plan and plot their delivery through an adaptation pathway (as illustrated in Section 11.3.5). Adaptation Pathways offer a useful tool for adaptation planning as they allow for flexibility and recognise and address the long-term and uncertain nature of climate change, enabling identified actions and strategies to be subsequently adjusted to reflect new information and changing circumstances.


Key decisions for the City of Sydney
How can we proactively manage the City in a changing climate?
T1
T5
ENERGY
How do we build resilience in the City's energy supply?
T2
WORKFORCE – HEAT
How do we improve the resilience of the City's workforce and businesses to interruption from extreme events?
T3
T9
PEOPLE – HEAT
How do we protect residents, visitors and businesses from extreme heat (including ozone pollution)?
Which areas/communities have the greatest vulnerability?
T8
TRANSPORT
How do we manage transport disruptions from extreme events (storms, heat, hail)?
S1
HARBOURSIDE DEVELOPMENT AND INFRASTRUCTURE
How do we manage existing and new low lying developments and assets?
Which land/property, assets are vulnerable to sea level rise?
P3
PEOPLE – FLASH FLOODING
How do we minimise the impacts of flash flooding for residents, workers and visitors?
P2
C11
INFRASTRUCTURE AND PROPERTY – FLASH FLOODING AND STORM
How do we ensure business continuity and upgrade of the drainage system to manage flooding and storm impacts?
How does infrastructure respond to significant urban stormwater run off – which areas are the most vulnerable?
C3
PRODUCTIVITY – BUSHFIRE
How do we manage the effects of bushfires in the greater metropolitan area affecting the City?
How will bushfires impact the City?
C5
C10
FINANCIAL VIABILITY OF COUNCIL
How do we ensure ongoing financial viability and insurability for the City and its assets?
Which areas/assets are least resilient to climate change?
C9
ICT
How do we ensure availability of information and communications technology during extreme events?
KEY
Vulnerability to City identified in SCCG vulnerability assessment 2008
CoS climate risk dentification number

Recommendations

The following provides a series of insights and recommendations compiled across the project. Specifically, six priority tasks have been identified for the City to progress, these are summarised as follows.

1. Develop an adaptation implementation plan (CAP) to address all actions that respond to multiple risk areas.
2. Work in partnership with identified stakeholders to progress development of a Heatwave Response Plan that includes as a community engagement campaign as part of this.
3. Assign risks and actions (starting with the highest ranked risks) to relevant functional areas within the City to progress development of triggers/thresholds etc with a view to completing adaptation pathways.
4. Undertake highest priority, cross-cutting studies/plans to inform completion adaptation pathways.
5. Undertake internal capacity building activities to support staff action implementation.
6. Consider establishing cross sector Climate Adaptation Taskforce for the City to continue to capitalise on momentum and collaboration.

Detailed recommendations

- The City has already made significant progress to forward climate mitigation initiatives. In undertaking this next step – climate adaptation, appropriate communication and messaging needs to be developed that makes clear that in developing the City's CAP they are taking the next step in building the City's resilience to a changing climate. One that goes significantly beyond the principles of mitigation.
- To ensure the carriage of climate adaptation is distributed across the City and does not lie solely with the Sustainability Strategy Unit, a necessary step will be allocating appropriate actions to relevant Divisions and Business Units within Council and establishing ownership and responsibility within these teams.
- The implementation of a Heatwave Response Plan will address multiple risks associated with the highest impact climate variable for the City (extreme heat), and draw together a focussed approach to build resilience across the community. The Plan will need to include measures that consider vulnerable members of the community and include engagement with relevant stakeholders and external agencies (such as transport, emergency services, energy networks etc) will be needed to inform both development and implementation. A specific recommendation of the Citizens' Panel was for the City to identify groups that are particularly vulnerable to climate change.
- It is recommended the City use the 28 cross-cutting and prioritised adaptation actions listed in Table 34 of the report to drive development of the CAP. These actions have been identified as addressing (cutting across) the most number of the City's highest priority risks and therefore offer significant value.
- The City's continued collaboration and input to the State Government's Office of Environment and Heritage (OEH) current *Towards a Resilient Sydney* program will provide important information to address existing gaps related with understanding areas of vulnerability and adaptive capacity within the LGA.

  (While the development of an Integrated Vulnerability Assessment (IVA) has not been the focus of this project, it also important to acknowledge that given the small geographic scale of the City, it is also not the best place for one. Leading approaches to IVA are undertaken across numerous political and geographical boundaries in order to establish an accurate picture of areas of vulnerability and interdependency).

- The identification of appropriate barriers, triggers and thresholds should be continued through internal dialogue and investigation into these areas. The starting point for this will be reviewing the provided adaptation action time horizons to enable these to be more fully completed and for adaptation pathways to be mapped in a similar format to the ones presented in this report (refer Figure 68 to Figure 71).
- Climate modelling and projections will need to be reviewed at periodic intervals following the guidance provided by the SRG in Section 5.3.2 to inform detailed decision-making.
- The majority of actions identified through the Project can be categorised as leading and best practice (as is appropriate for the stage the City is at in terms of building its climate adaptation response). It is important to socialise the identified actions further with a view to asking participants to think beyond the now, to consider what would be required to generate the transformational action and change needed to address the more extreme future impacts.
- Once the City's CAP has been completed the Health Check survey (refer Section 4) should be re-issued to assess whether the engagement afforded through its development has impacted responses to the assessment categories.

Key insights

- The most notable of climate impacts is temperature. While a projected change of 1°C or 2°C may not, in isolation, be considered as having a significant impact, the knock-on effect this rise in temperature will have on extremes is important. It will mean hotter seasons and more warm months in the year. In particular increased temperature is likely to result in a longer bushfire season as temperatures remain higher (and drier) for longer periods of time. It is also likely to have an impact on the intensity, frequency and duration of heatwaves. Both of these pose a significant risk to wellbeing and liveability within the City and there are as yet unanswered question with regard to its ability to respond and adapt.
- The level of external stakeholder participation undertaken for the Project is to be commended. While community consultation is often undertaken following the release of a draft Climate Adaptation Plan, the process the City has taken to engage with external stakeholders during the actual preparation of the plan reflects a leading approach to both engagement and adaptation planning. Of note is the fact that the Citizens' Panel engaged in the project (for the most part) affirmed the risks and actions identified in the overall process. Communication of these risks and actions to the community was their number one concern.
- An important observation drawn from the Health Check analysis is that the barriers and enablers to action and implementation are closely related to more general barriers associated with implementing organisational change management approaches in general. They are not necessarily specific to addressing climate change.
- In many instances barriers to climate adaptation action within local government stems from a lack of understanding and awareness of the issue; a failure to prioritise action and or a lack of leadership and political/cultural support. An anecdotal finding of this project has been the engagement challenge within the City appears to stem, not from a lack of valuing or prioritising the need to respond to the impacts of a changing climate, but rather because they think that they, or another part of Council, are already doing it and therefore it is not a high priority.
- Subsequent engagement, and in particular the one-to-one interviews provided evidence of the considerable work the City has progressed so far with regard to stormwater management; urban heat island effects; event management, and energy efficiency. It also highlighted opportunities for future action and response across a range of issues including (but not limited to):
    - Identifying and engaging with stakeholders.

  - Working with identified stakeholders to change/update and progress design standards.
  - Considering the full range of potential climate futures including the most extreme conditions, and
  - Undertaking associated studies and investigations to better understand the baseline for future adaptation response.

- Actions attributed to the Capital Works and Land Use Planning areas of operation across the City currently have the least number of identified actions. This is to be expected as the City's initial need will be to focus on relevant investigations to increase understanding of the exact scope and nature of the challenge. Undertaking these studies will assist Council in thinking about the adaptation needs over the longer timeframes ie post 2030 and when climate conditions are more severe. For these longer timeframes the actions will need to be of a more transformational in nature and not based upon business as usual or leading practice. For example, the evidence suggests that Australian Design Standards and building codes should be based on improved data of expected weather events rather than historical trends. Following completion of these studies the City will be able to identify and commit to direct actions in the form of changes to the planning scheme or building protective structures, often referred to in other City adaptation plans as hardening actions.
- The work undertaken by KPMG to cluster risks based on areas of interdependency provides the City with a leading approach to adaptation planning that will also help deliver resource efficiencies. Drawing on the cross-cutting actions that relate to the most number of risks (and clustered risks) will provide significant value for the City and help support tasks related to action prioritisation.
- Following completion of the necessary preparatory reviews, investigations and studies identified in the proposed actions, the City will need to evolve its actions into the next stages of implementation. This evolution is likely to carry with it increasing investment requirements as actions move from planning studies through to the delivery/redesign of infrastructure and assets.
- The task of allocating pathways akin to those provided in Section 11 is useful for breaking up what can appear to be a seemingly endless list of actions into 'bite-size' pieces of work that are specific, time bound, measurable and therefore achievable.
- At its core, true climate adaptation planning across an organisation needs to be supported through a change management approach that seeks to embed climate resilience across all areas of the City. This document and the actions herein provide a starting point for this engagement in particular by identifying those functional areas across the City that will be responsible for delivering the recommended adaptation actions.

1 Introduction

Globally 207 cities are taking the lead on climate adaptation. Protecting 394,360,000 people and $4 trillion of asset value (by 2030) from the effects of climate change and creating resilient places to do business. Of these 207 cities, 757 adaptation activities have been reported and 102 cities have developed climate adaptation plans[1]. Further to this, the Local Governments for Sustainability (ICLEI) reported that 422 cities and local governments representing 12% of the world's urban population are reporting on their climate data including climate adaptation actions.[2]

[1] *CDP 2014 Protecting our Capital – How climate adaptation in cities creates a resilient place for business.*
[2] *ICLEI 2014 Carbon Cities Climate Registry 2013 Annual Report*

1.1 Background

Extreme climate events across Australia, particularly recent flooding, heat wave and bushfire events have demonstrated the vulnerability of local government and their communities to climate extremes. Overall the future climate of the Sydney region is expected to be hotter and drier than it is today and will experience a significant increase in extreme heat events. These changes in climate extremes will have a range of impacts including scarcity of water resources, increase in ozone air pollution, and increase in bushfire frequency and intensity, all of which place vulnerable community members under stress and reduce asset and infrastructure resilience. It will also affect the richness of local biodiversity and the health of vegetation and the local ecosystem.

In order to meaningfully address these and other climate related risks and impacts the City of Sydney (the City) commissioned RPS and KPMG to assess the risk of climate hazards to the region and set out a framework to assist in adopting a leading practice approach to embedding adaptation planning at a Council level. The City recognises the role it plays as a global leader and the benefits gained from proactively adapting to climate extremes. It acknowledges its responsibility to taking appropriate steps to increase the resilience of all aspects that make up a liveable community, as well as addressing the impacts of projected climate variability while dealing with uncertainty. As a global City it maintains its assets and services to the highest standards, however these are based upon historical climate data and information (building codes, design standards etc), and as such may not be resilient to future climatic conditions. This project will inform new standards and ways of working to proactively manage the city in a changing climate to ensure better outcomes in the future and improved resilience.

To develop the steps necessary to minimise the potential impacts of a changing climate, it is critical that climate adaptation actions respond to the specific needs of the City's Local Government Area (LGA) and its local vulnerabilities. This report seeks to address this challenge by presenting targeted and specific climate adaptation actions informed by a leading practice approach and methodology.

The climate futures presented in this report are based on publicly available global climate models. The analysis considers three futures based on models representing low, medium and high rates of climate change. These futures assume a scenario in which global emissions of greenhouse gases continue to grow steadily[3]. The report's approach to climate modelling has been supported by the Project's Science Reference Group[4] (SRG). It is recommended the City revisit the climate modelling undertaken for this project as climate science improves and the global emissions trajectory becomes apparent.

[3] *The scenario is RCP8.5 from the IPCC's Fifth Assessment Report.*

[4] *The City's Science Reference Group comprises some of Australia's leading climate science and adaptation experts enlisted to provide scientific rigour and specialist input to the process.*

1.1.1 Overview

This Climate Risk and Adaptation report provides the necessary data, analysis and recommendations required to enable the City to develop its Climate Adaptation Plan (CAP) to guide Council's future planning and response. As a recently announced member of the Rockefeller Foundation's 100 Resilient Cities initiative this work supports the City's application to the program and provides a blueprint for action.

Figure 1 City of Sydney Climate Risk and Adaptation Project Stages

Delivery of the project and development of this report has been informed by the stages highlighted in Figure 1 and, specifically this report (representing Stage 5 in the process) seeks to present the outcomes of the following investigations:

- A survey undertaken to determine the level of climate adaptation awareness and action amongst the City's workforce, divisions and business units (City of Sydney Health Check).
- An overview of the City's climate exposure, sensitivity and vulnerability to projected changes in climate, including uncertainties regarding the latest climate science focussing on climate extremes.
- The findings of a comprehensive risk assessment process which includes the identification of 32 risk identification statements.
- The outcomes of adaptation planning engagement activities including an overview of the process and findings from the following:
  - one-to-one interviews with Council staff
  - adaptation planning workshop with the City and feedback session with external stakeholders
  - Climate Change Adaptation Planning Citizen's Panel
  - Science Reference Group Meetings and feedback, and
  - Climate Adaptation Actions and Adaptation Pathways development.

The project has involved the contribution of many including:

- Consultant project team.
  - RPS – lead consultant, climate risk and resilience team.
  - KPMG – climate risk and actuaries team.
- The City of Sydney Project Control Group and Executive.
- Relevant internal stakeholders from within the City.
- Relevant external stakeholders for the City.
- A Science Reference Group.
- A Citizens' Panel.

The City has taken an exemplary approach to engagement throughout the project, involving scientists, businesses, government agencies and the community in interactive sessions.

The specific deliverables undertaken as part of the process are highlighted in Table 1 below.

Table 1 City of Sydney Climate Risk and Adaptation Deliverables

No.	Deliverable	Overview	Report section
1	**Detailed climate modelling**	Detailed climate modelling to understand the City of Sydney's level of climate exposure. This modelling has been communicated to project stakeholders and participants through the provision of comprehensive climate modelling slide packs.	Section 5
2	**City of Sydney Health Check Survey**	Survey of relevant internal stakeholders to understand the City's 'state-of-play' with regard to climate adaptation and resilience. Preparation of a dashboard infographic.	Section 4
3	**Risk Assessment, Register, Statements and Interdependencies**	Pre-populated Risk Register that has been tested and refined through internal and external stakeholder engagement. ▪ Development and refinement of associated risk statements. ▪ Interdependencies survey to enable risk interdependencies to be plotted.	Section 9
4	**Multi-Criteria Analysis (MCA) Database**	Pre-population of database of over 700 climate adaptation actions that were refined through an MCA process, before further testing and refinement with 25 stakeholders from across the City during 10 x 2 hour interviews. The MCA database comprises adaptation actions for each of the 32 risk statements and prioritises actions based on MCA results.	Section 11
5	**Risk and Adaptation Register (RAR)**	Based on the MCA a comprehensive RAR has been produced for the City's use. The RAR blends the Risk Register with the findings of the MCA and enables the City to filter actions based on type/sphere of influence/functional area/level of risk.	Section 11
6	**Adaptation Pathways**	Illustrative approach to guide the development of the City's Adaptation Plan and shape how the City should think about implementation. The approach was informed by a 2 hour workshop with key representatives from within Council to identify delivery timeframes and parameters. The approach has been reviewed and supported by the Science Reference Group. In addition, a 2 hour feedback session has been held with a selection of the City's external stakeholders to present the findings of the Risk and Adaptation Approach.	Section 11
7	**Science Reference Group**	A panel of climate science and adaptation experts have provided oversight to the project process and approach to provide scientific rigour and specialist input into the process.	Section 8
8	**Citizens' Panel**	Undertaken by the University of Sydney, a 2.5 day community engagement event, using a deliberative democracy approach was held to draw out and test the project approach and findings.	Section 10
9	**Project Evaluation Report**	Project Report detailing the findings and outcomes of the deliverables listed in this table to enable the City of Sydney to write its Climate Adaptation and Resilience Plan.	The full report
10	**Supporting Materials**	A suite of supporting information and materials has been assembled to support the outcomes and findings presented in this report. These have been packaged separately and will be provided to the City on completion of the project.	Not included – to be provided separately

In addition to the above, we have developed an infographic (Figure 2) to detail the specific components involved in taking a decision centred approach to adaptation planning. This approach is aligned with leading

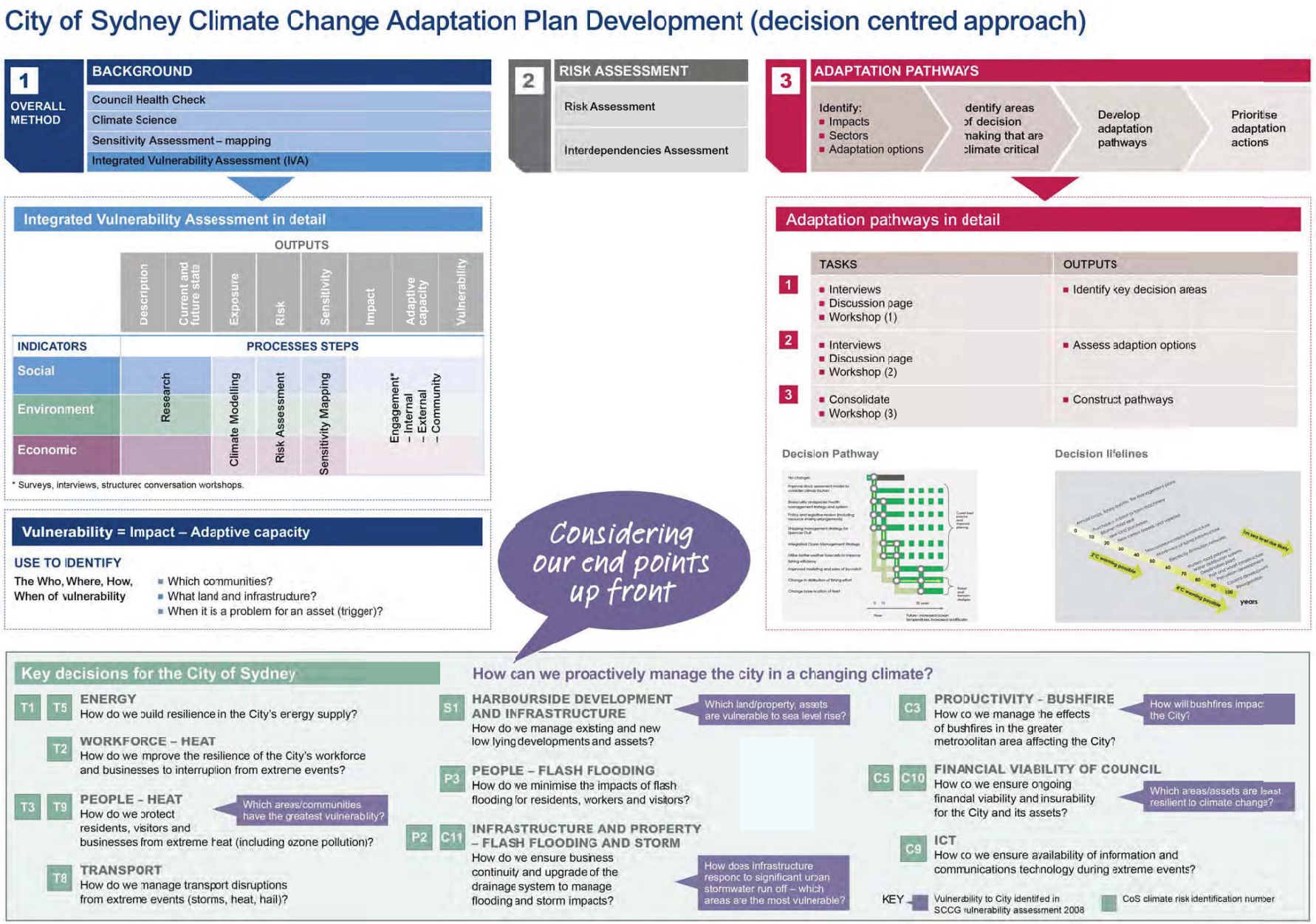
practice adaptation work underway across the country and is particularly informed by the best practice adaptation pathways work being progressed by Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Local Government Association of South Australia.

The approach presented in Figure 2 centres on the need to consider future events at the start of the adaptation planning process – decision centred adaptation. The first two components of the work applied a whole of City-wide approach to the assessment whilst the final (third) component related to adaptation planning has focused specifically on the Council and its local government area only. In this way it was possible to frame the risks in a holistic and comprehensive manner, including interdependencies, whilst focusing the adaptation actions to those where the Council has the most control. This will assist in the implementation of the adaptation actions.

To support a robust approach, a cross-check of those issues identified for the project through the risk assessment process has been performed against those identified through a historical assessment undertaken in 2008 by the Sydney Coastal Councils Group (*Mapping Climate Change Vulnerability in the SSCG*, 2008). The lower portion of the diagram overleaf) illustrates this comparison with the blue text boxes highlighting areas of similarity between these two projects. In particular, commonalities have been established regarding the following issues in both pieces of work:

- **People and Heat:**
  - SCCG 2008 work: Which areas/communities have the greatest vulnerability?
  - CoS current work: How do we protect residents, visitors and businesses from extreme heat (including ozone pollution)?
- **Harbourside Development and Infrastructure:**
  - SCCG 2008 work: Which land/property, assets are vulnerable to sea level rise?
  - CoS current work: How do we minimise the impacts of flash flooding for residents, workers and visitors?
- **Infrastructure and Property: Flash flooding and storm:**
  - SCCG 2008 work: How does infrastructure respond to significant urban stormwater run off – which areas are the most vulnerable?
  - CoS current work: How do we ensure business continuity and upgrade of the drainage system to manage flooding and storm impacts?
- **Productivity and Bushfire:**
  - SCCG 2008 work: How will bushfires impact the City?
  - CoS current work: How do we manage the effects of bushfires in the greater metropolitan area affecting the City?
- **Financial Viability of Council:**
  - SCCG 2008 work: Which areas/assets are least resilient to climate change?
  - CoS current work: How do we ensure ongoing financial viability and insurability for the City and its assets.

Figure 2 Decision Centred Approach for the City of Sydney



2 Understanding the context

The City recognises the importance of an enduring, balanced approach which takes into account the City's economy, ecology, society and culture. We are addressing each with bold ideas and good governance. The results mean better outcomes now and in the future, for everyone. The Sustainable Sydney 2030 plan is for a Green, Global and Connected City.

Sydney 2030, Community Strategic Plan (2013)

2.1 City of Sydney Local Government Area

The City of Sydney is located in Australia within the state of New South Wales, Sydney is the state capital, and occupies the unique position of being Australia's leading global city. As represented in Figure 3, the City of Sydney Local Government Area (LGA) comprises 26 square kilometres (km^2) and 33 suburbs. It is home to 183,000 residents with an additional worker population of close to 450,000. On any given day, once figures for the City's tourist population are included, the LGA plays host to 1 million people.

The City represents a thriving economic hub for both the state and for the country, responsible for 25% of NSW's economy and 8% of Australia's total economy. It is also the heart of Australia's tourist economy, home to icons such as the Sydney Opera House, and Sydney Harbour Bridge, with over 4.5 million hotel stays recorded per annum (City of Sydney Annual Report, 2013).

Each year the City plays host to an impressive catalogue of events from New Years Eve and Chinese New Year through to Vivid and the Sydney Festival. Additionally the City is recognised as Australia's premier shopping, dining and cultural centre, home to a plethora of shops, arcades, museums, galleries and restaurants.

The City of Sydney Council plays a vital role in supporting many of the features that make the city great including the management of more than 400 parks and playgrounds (854 green spaces to maintain in total), plus hundreds of kilometres of roads, footpaths and cycle paths in the local area. It does not operate alone however, and within the LGA boundaries the City collaborates with a number of stakeholders including but not limited to:

- The Sydney Harbour Foreshore Authority (SHFA).
- Transport for NSW (TfNSW) including Roads and Maritime Service, Sydney Rail etc.
- Utilities including Ausgrid and Sydney Water Corporation.
- Sydney Ports Corporation.
- The Centennial and Moore Park Trust.
- The Royal Botanic Garden and Domain Trust.
- Commonwealth Department of Defence.
- Redfern-Waterloo Authority.
- Urban Growth NSW, and
- Barangaroo Development Authority.

In commissioning the work associated with this project, Council has recognised the role it has in building the resilience of the City to the impacts of a changing climate. It has already started work to address issues associated with extreme heat and stormwater management as evidenced through a number of the City's current plans and strategies including its:

- Urban Forest Strategy.
- Energy Efficiency Master Plan.
- City Access Plan.
- Floodplain Risk Management Plan.
- Decentralised Energy Master Plan.
- Decentralised Water Master Plan.

The findings and recommendations outlined in this report provide the road map by which the City can develop its CAP and build resilience to the climate impacts most likely to affect Sydney.

Figure 3 City of Sydney Local Government Area

Source: Sustainable Sydney 2030, Community Strategy Plan (2013)

3 Vision for the future

As part of the project scope RPS was charged with proposing a vision for the City that seeks to provide focus to the development of its CAP and the actions required to build resilience to 2030.

Of the seven climate adaptation plans reviewed as part of this task, only one (the Gold Coast Climate Change Strategy) articulated a specific and dedicated vision for climate adaptation with accompanying objectives. Both the London and New York plans provide overarching statements and directives that could be considered to represent a vision and objectives, although they are not labelled as such in the documents. The benefit of identifying a vision and objectives is they provide aspirational direction and means for measuring delivery that can be further supported through the development of targets and actions. It also reaffirms the city's leading practice approach for addressing climate adaptation.

Table 2 Climate Adaptation Plans – Vision Benchmarking

List of reviewed plans
1. City of Melbourne Climate Change Adaptation Strategy
2. Regional Climate Change Adaptation Plan for the Eyre Peninsula
3. Resilient South: Strengthening the Southern Region for Changes in our Climate, Regional Climate Adaptation Plan
4. Gold Coast City Council Climate Change Strategy 2009 – 2014: Enabling Action Today
5. PlaNYC – A stronger more resilient New York
6. Copenhagen Climate Adaptation Plan
7. Managing Risks and Increasing Resilience, the Mayor's climate change adaptation strategy – London

Based on guidance received by the City's Project Control Group (PCG), the following considerations have been factored into the development of the proposed vision:

- What will they City look like in 2030 with regard to climate action, resilience and response?
- What will the City be building resilience to?

The PCG also noted that while it was important that the vision aligns with the Sustainable Sydney 2030 Community Strategic Plan it does not need to follow the 'Green Global Connected' themes directly, rather work to support the ultimate delivery of these commitments. As such, the following vision statement is proposed to guide development of CAP:

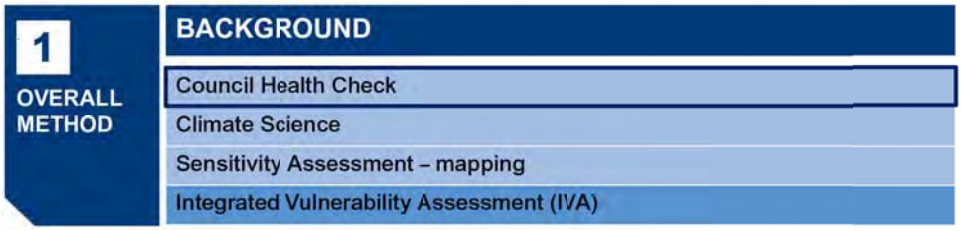
By 2030 the City of Sydney will have delivered effective strategies and solutions to focus its approach to climate risk and resilience. It will have worked in collaboration with key stakeholders to address the relevant impacts to the City from extreme temperature, sea level rise, extreme rainfall as well as the series of combined climate risks arising from these. The actions undertaken will have helped better protect the City's communities, businesses and iconic areas from future changes to the climate, and built its ability to adapt, respond and thrive in the face of change.

Supporting delivery of this vision and reflecting the importance of the community's input, the following principles developed by the City of Sydney Citizens' Panel on climate adaptation and resilience are suggested for use to guide development of the CAP.

- A resilient, long term plan – politically sustainable, economically efficient and socially inclusive.
- A flexible and dynamic plan, able to evolve and respond to unexpected trends and consequences.
- A plan that is based on the most up-to-date data.
- A plan that is delivered via a comprehensive and effective communication strategy.

It is anticipated that these principles can be used to provide a metric for how the City may develop the CAP, and could (with further work) be translated into a set of objectives. These will help guide the delivery of the CAP and help the City in finalising its adaptation roadmap to achieve the proposed vision.

4 Climate Adaptation Health Check



4.1 Overview

From the 8th to 18th July 2014 the City ran a survey to check the health of Council to gain insight into how staff perceive and experience the City's preparation, planning and response to the impacts of a changing climate. The survey was issued to close to 100 identified participants across Council. Initial results indicated a total of 50 participants provided response, however of these, 14 responses had to be removed/discredited due to incomplete submissions, as such a total of 36 responses were completed during the two-week survey period, representing an approximate sample size of 36% of participants targeted for input.

The survey was developed by the consultant project team (refer *Supporting Materials* documentation for survey) and facilitated through City's 'Survey Monkey' account. The decision to use Survey Monkey was informed by its familiarity in the market/data analysis sector (many surveys are collected this way and therefore many of the would be participants are familiar with how to use it); its simple and intuitive user interface, and the fact that City already had an account which means it will be able to access and analyse the unfiltered data should it require.

The Health Check results provided a benchmark at the beginning of the project of the City's internal capability and capacity in climate risk and resilience. In the long term, the framework used can be used as a monitoring and evaluation framework for the Council's climate adaptation efforts. If repeated at periodic intervals into the future it will provide a progress report on how the Council and its staff are developing their understanding, skills and expertise as well as how they are translating this into action.

The following provides an overview of the approach taken to develop the survey and presents the main findings from the subsequent data analysis process.

4.2 Approach

The 30 survey questions comprised a range of multiple choice and free text response options designed to gain an understanding of how staff view the City's current approach to addressing climate change adaptation initiatives and managing climate risk.

The survey was structured to establish the City's performance across core categories related to Engaging, Understanding, Planning, Responding and Monitoring to enable a dashboard (refer Figure 4) to be produced summarising the City's current, collective level of climate resilience. The definition of each of these categories is provided in Table 3, with analysis of performance under the corresponding categories provided in Section 4.3.1.

Figure 4 City of Sydney Health Check Results

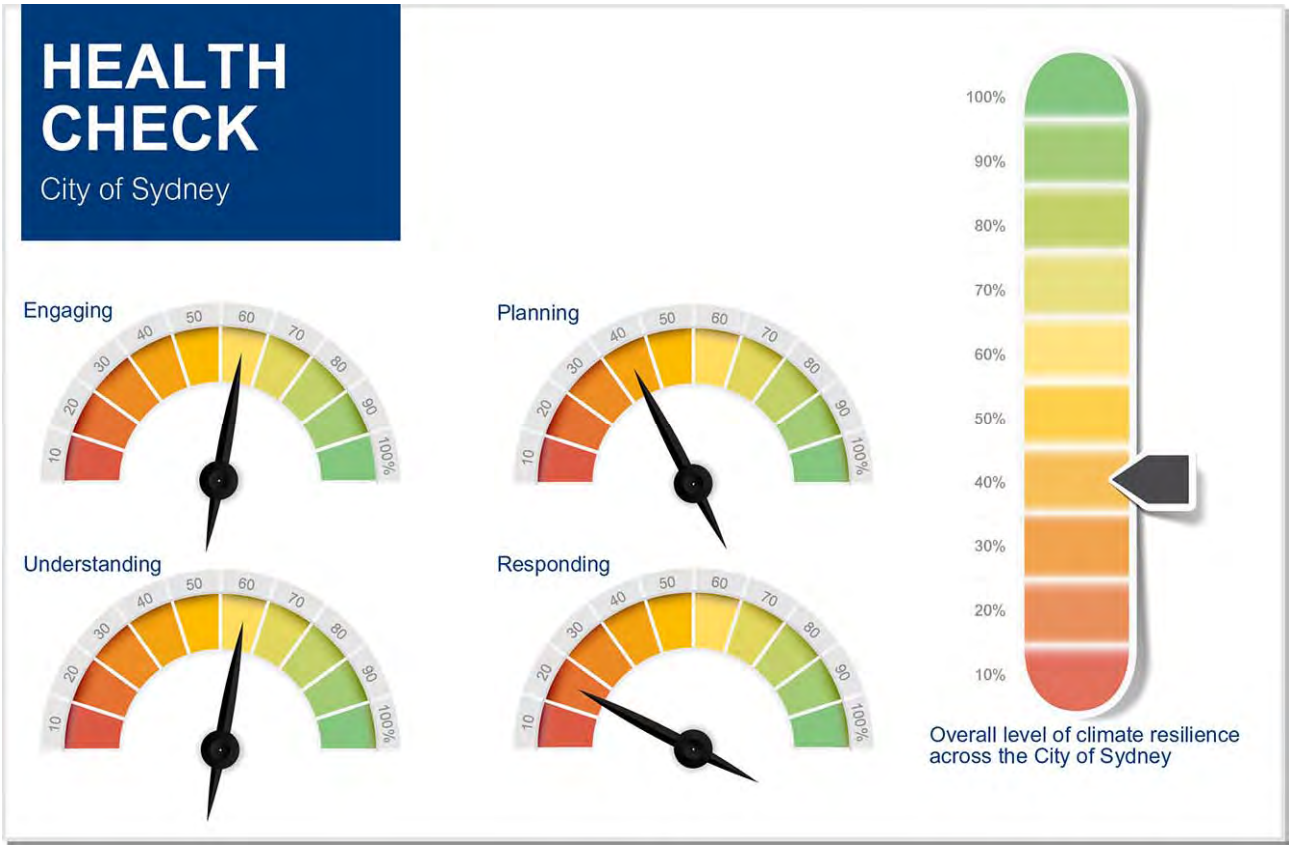


Table 3 City of Sydney Climate Health Check Categories

Category	Justification/Definition
Engaging	Engaging considers Council's governance framework and participatory processes in relation to extreme climate events and their impacts. This includes the documentation and communication of a chain of command, the integration of climate risk considerations throughout the organisation (eg planning instruments) and the extent of climate risk and resilience related roles and responsibilities. In relation to participatory processes, it considers the engagement and empowering of identified stakeholders including barriers and enablers to change.
Understanding	Understanding considers Council's internal awareness, knowledge and understanding of the risks posed by a changing climate. It seeks to establish a baseline of awareness relating to understanding the roles, Divisions, and individuals in particular play within Council to help manage and respond to climate risk.
Planning	Planning represents the level of responsiveness the City has in preparing for and responding to the challenges of a changing climate, it considers initiatives that have been undertaken thus far to plan for extreme climate events and how these were incorporated.
Responding	Responding considers how often climate risk and resilience is considered in the review of any strategic and operational documents (eg emergency management plans, fire management plans, risk registers, master plans etc). It also includes how prepared Council is for any disruptions due to extreme weather events. At a higher level this includes how well Council demonstrates balance across initiatives.

Category	Justification/Definition
Monitoring	Monitoring involves measuring, monitoring and review of initiatives. This demonstrates to what extent Council remains relevant, up to date and reflective of current initiatives and considers the comprehensiveness of Councils' activities in terms of procedures, activities and responsiveness.

To produce the dashboard diagram (Figure 4) the responses for all 30 questions from each of the 36 respondents were reviewed with a weighting applied to those questions that corresponded directly to the categories listed in Table 4. The weighting was based on a 1-5 ranking with 1 denoting the minimum level of compliance/action possible, and 5 denoting where actions were considered to be extremely responsive or important. This weighting then allowed a performance percentage to be applied based on the total average across each of the categories. For example the aggregated scores for *Engaging* were 3, equalling 60%; conversely the aggregated scores for performance for *Responding* were 1 equalling 20%.

Based on the aggregated performance within Council across each of the weighted categories, Council's total resilience and adaptation capacity was scored a 2 that equals 40%. This ranking is considered to offer a fair assessment of progress and performance based on subsequent conversations and engagement with the City throughout the project. It confirms that there is some good work underway and that some strong progress has been made but, there is much room for improvement and future development – as identified through climate risk assessment and adaptation pathways findings that are detailed in later sections of this report.

Note: *Monitoring* was not included for the purpose of this analysis due to the relative newness of this work and there being limited progress to monitor.

4.3 Findings

A valuable aspect of the survey is its ability for re-issue and use to benchmark future implementation and support monitoring and evaluation. Ideally the survey would be issued every 18 months or so to provide an understanding of how progress has shifted and (hopefully) evolved. This would enable the dashboard in Figure 4 to be updated to provide a visual output of change over time. The findings of this first survey can be used as a benchmark to test and compare future results.

4.3.1 Category performance across the City's divisions

Figure 5 categorises survey responses based on performance across four of the five identified categories across the following City of Sydney Divisions:

- Chief Operations Office.
- Workforce and Information Services.
- City Project and Property.
- City Operations.
- Legal and Governance.
- City Life.
- City Planning, Development and Transport.
- Chief Finance Office.

As this is the first time the survey has been run, assessment on the effectiveness of monitoring and evaluation is not assessed. It has been included as a category however, should the survey be run again at a later stage (as recommended), the City will be able to gain insights on the monitoring and evaluation of climate risks and adaptation initiatives.

While the survey results are useful in providing an overview of the City's current climate risk and adaptation action they need to be reviewed in context. The numbers of participants across each of the responding divisions are not equal. Table 4 highlights the number of responses per Division and this needs to be considered in the context of viewing the analysis.

Table 4 Breakdown of survey responses by Division

Participating City of Sydney division	Number of respondents per division
Chief Operations Office	15
Workforce and Information Services	1
City Projects and Property	5
City Operations	5
Legal and Governance	2
City Life	3
City Planning, Development & Transport	4
Chief Finance Office	1
Total responses received	**36**

Over 30% of survey respondents were from the Chief Operations Office, with City Projects and Property and City Operations both contributing 14% of respondents respectively.

As per Figure 5, based on the responses received, the City's Legal and Governance Division is leading in terms of actions underway to address the *Engaging* category, this is followed by City Life, with the Chief Operations Office (COO); Workforce and Information Services; City Operations; City Planning, Development and Transport tying for third place.

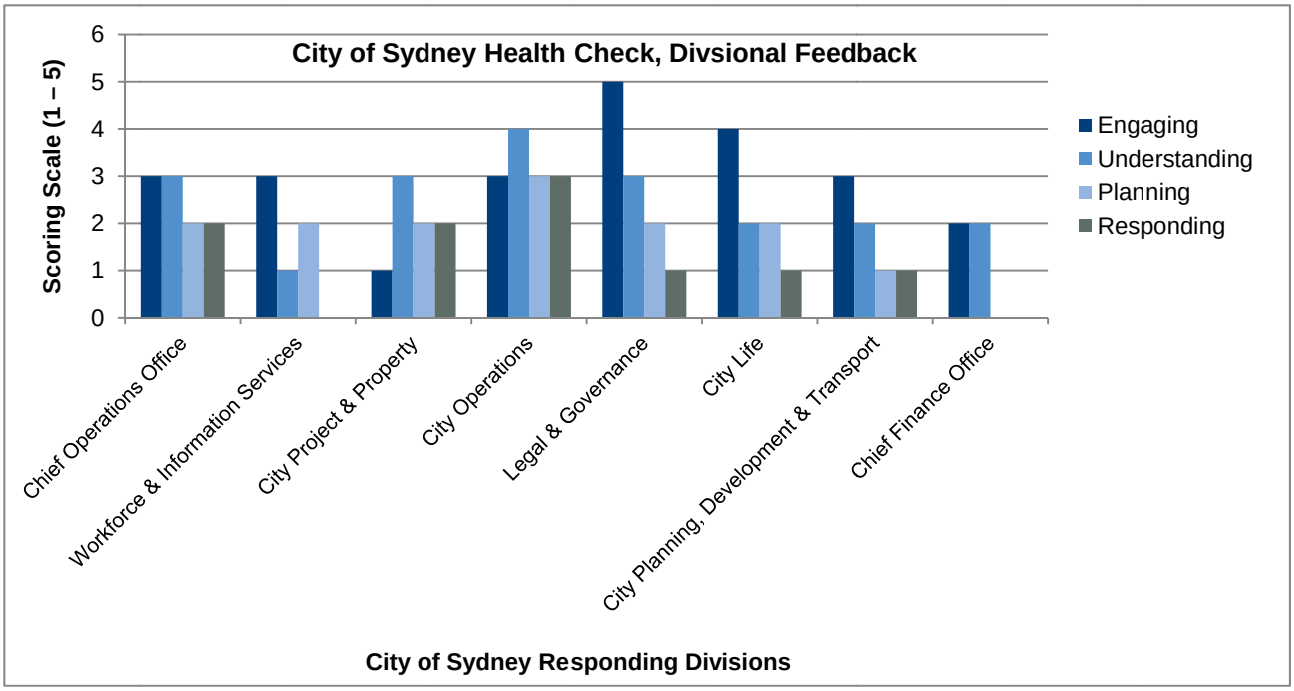
City Operations are leading in terms of *Understanding* climate risk and adaptation options, followed by COO; City Project and Property; and, Legal and Governance who tie for second and City Life; City Planning, Development and Transport; Chief Finance Office tying for third place in terms of how they view performance against questions in this category.

City Operations led performance based on responses against the *Planning* category; tying for second place were the Chief Operations Office; Workforce and Information Services; City Project and Property; Legal and Governance; and, City Life, with City Planning, Development and Transport in third place.

City Operations led performance based on responses against the *Responding* category, with the Chief Operations Office; City Project and Property in second place and, Workforce and Information Services; Legal and Governance; City Life; and, City Planning, Development and Transport in third.

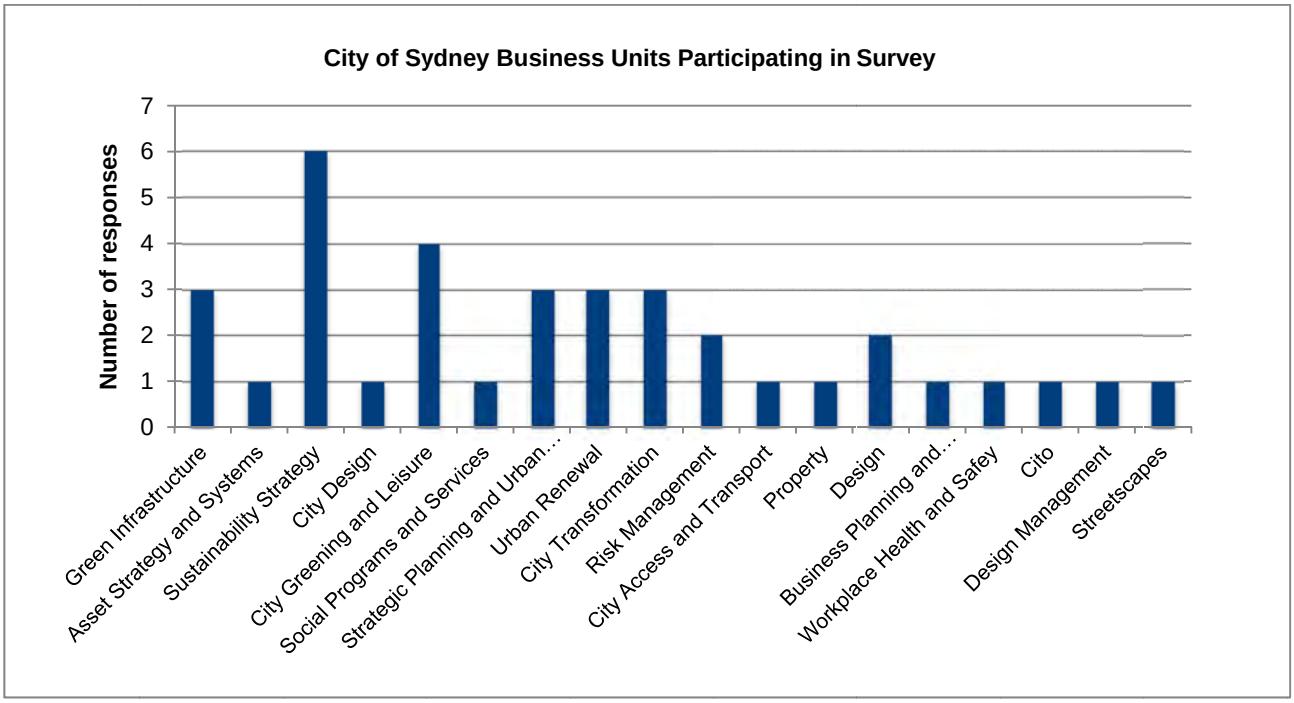
As identified, **these results offer an indicative view only given the skewing of participant numbers from the relevant Divisions**. Further, as the majority of questions were multiple choice it is difficult to interrogate the findings recorded by the various divisions.

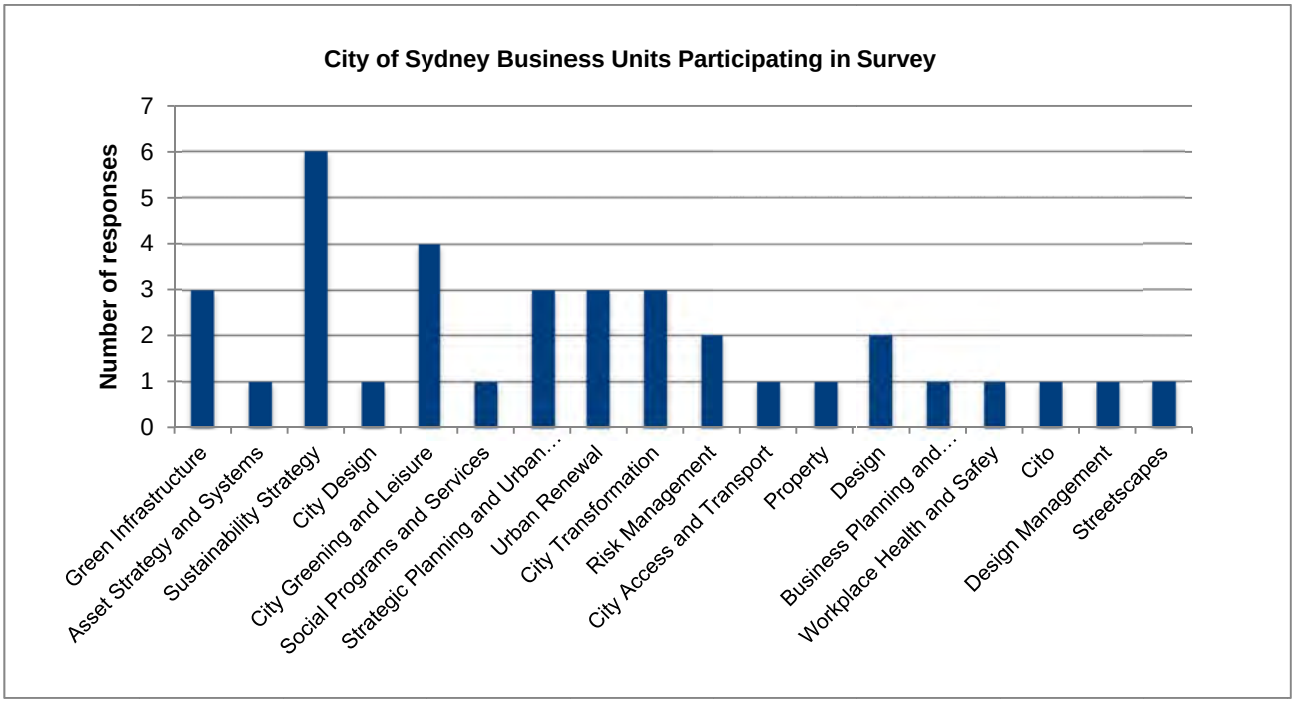
Figure 5 Breakdown of performance across participating divisions



For reference and context, a further breakdown of those divisions that participated in the survey is provided in Figure 6 that identifies those Business Units that participated in the survey. It is unsurprising that the highest participation area was from Sustainability and Strategy and City Greening and Leisure, as these are traditionally the areas which would be leading climate risk and resilience work, although it should be noted that climate change will impact most business units.

Figure 6 Summary of Business Units that participated in health check survey





Barriers and enablers

An important component of the survey was the chance to provide a high-level opportunity to identify barriers and enablers to climate adaptation action and response across Council. The purpose of this is to assist the City in identifying where they may consider focussing internal action in the future.

The task of exploring barriers and enablers in detail and at depth is complex and often multi-layered (and was not the focus of this survey). In many instances areas that might be considered to be a 'primary' barrier actually turn out to be 'secondary', with other barriers coming to the fore as being more pertinent to blocking/inhibiting action. For example, the highest cited barrier to climate adaptation as identified by survey participants was *a lack of understanding as to how to translate the impacts* (Figure 7) further exploration of this issue may in fact reveal that the reason there is a lack of understanding as to how to translate impacts of climate change is due to *a lack of information and knowledge* and/or an *inadequate understanding of the problem*. This was borne out in later stages of the project as the identification of trigger points and thresholds related to the impact of future climate conditions (on asset and service performance) proved challenging. It is recommended further work is undertaken to assist with identifying the point at which the functioning of the City's assets and services could be materially compromised. Adaptation actions have been identified (refer Section 11) which include many additional studies that are aimed at bridging this gap in understanding on how to translate the climate data into action. It is clear Council staff in many areas will need specific support in this.

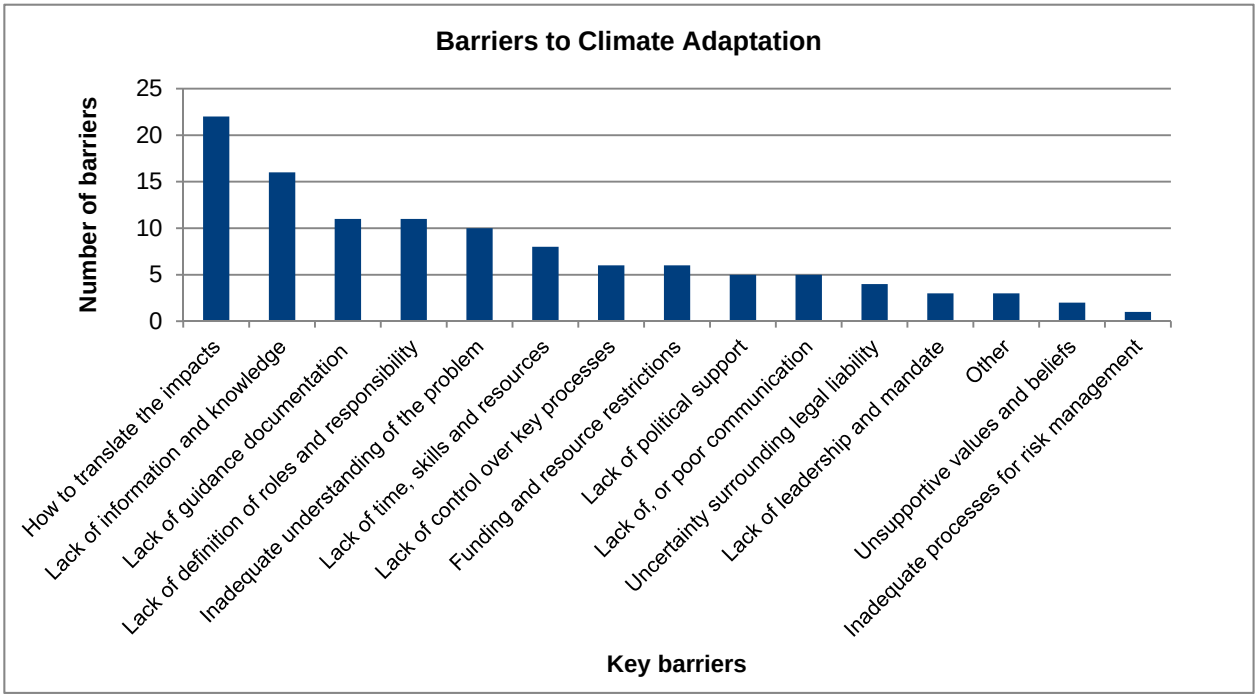
For further understanding and context as to how barriers and enablers play out in climate adaption action, the City may be interested in reviewing the Local Government of South Australia and the South Australian Department of Environment, Water and Natural Resources, *Science to Solutions Understanding Barriers to Climate Adaptation Project.*

Barriers

Participants were first asked to select the top three barriers they perceived as hindering successful engagement and implementation of climate change initiatives at the City (Figure 7). Based on the collated responses, the top three barriers identified were:

- A lack of understanding as to how to translate the impacts.
- A lack of information and knowledge.
- A lack of guidance documentation AND a lack of definition related to roles and responsibilities.

Figure 7 Barriers to Climate Adaptation Identified through Health Check



As stated, *how to translate the impacts of climate change* (specifically, strategic and operational plans) was identified as the leading barrier with 22 of the respondents selecting this issue.

In looking to address this issue and develop enabling interventions/actions that respond to this (and other) barriers, it is recommended the City undertake further analysis to understand where in the decision-making process this comes into play and what actions would be appropriate to respond to these.

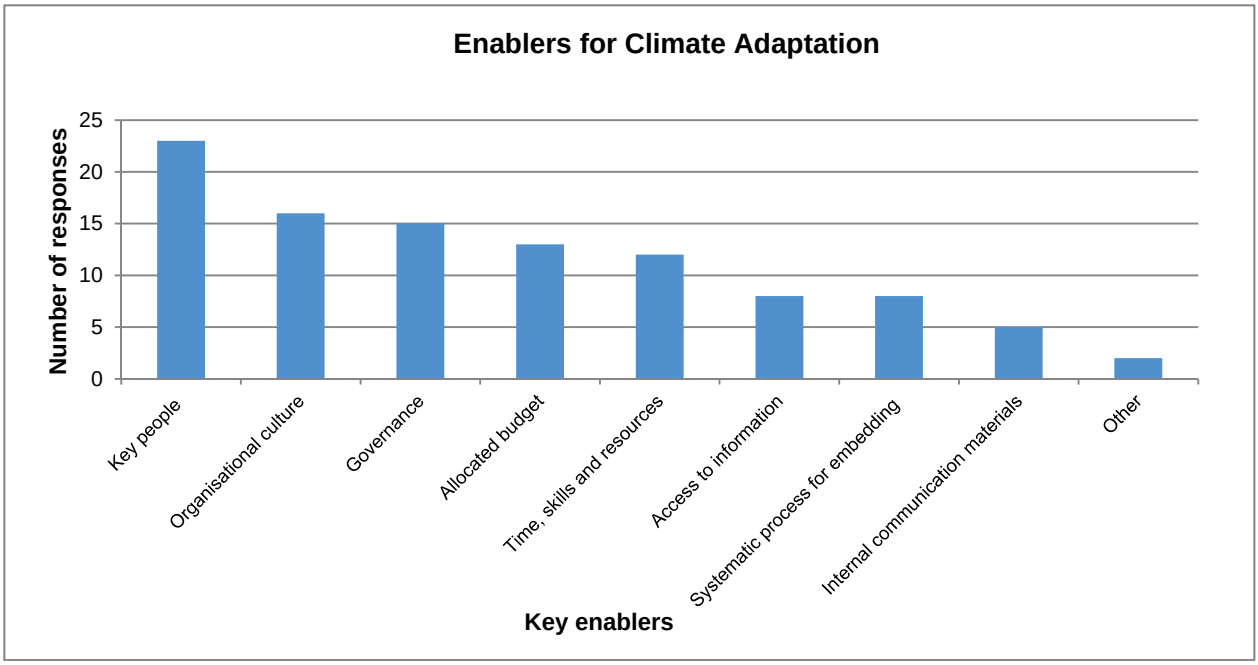
Enablers

Respondents were also surveyed to gain an understanding of the enabling interventions and/or solutions in place across Council. Specifically they were asked, '*What do you consider to be the top three enablers that have supported engagement and implementation of successful climate adaptation initiatives within the City?'*

As highlighted by Figure 8, the identification of '*Key People'*, or specifically – climate champions and/or dedicated climate adaptation staff, was considered the primary enabler as identified by 23 of the 36 respondents.

Organisational culture was rated the second highest enabler with 16 responses, and *Governance* (eg support of leadership, clear roles and responsibilities, policies and procedures to guide action) was considered material by 15 of the respondents.

Figure 8 Enablers for Climate Adaptation Identified through Health Check



In many instances enablers are useful in countering the identified barriers. For example, educating, informing and empowering key people will help address barriers associated with the uncertainty of translating impacts (information) and can be used to catalyse action. Whilst dissemination of information can also help improve awareness and understanding at the broader level and thus respond to the second highest cited barrier).

Observations regarding key barriers and enablers

As stated, the identification of both barriers and enablers is useful for the City in terms of prioritising areas for internal capacity-raising action. In particular understanding potential institutional, policy and information barriers to adaptation is a critical step in designing tools and methodologies to overcome those barriers.

It is important to note that the barriers and enablers to action and implementation are closely related to more general barriers associated with implementing organisational change management approaches in general and are not necessarily specific to addressing climate change.

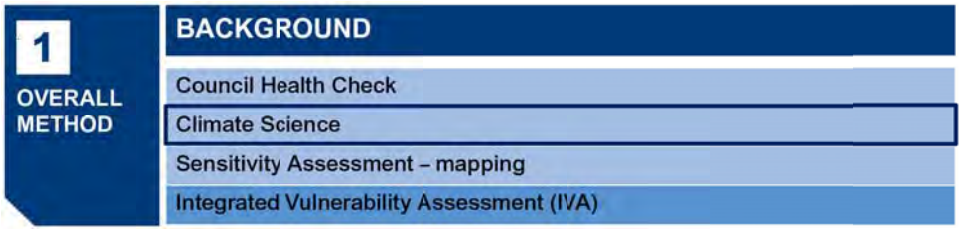
4.3.2 Observations on the findings

In reviewing the survey findings in the broader context of the engagement work that has been undertaken as part of the project it has been interesting to observe the following:

- While the *Responding* component of the questions yielded the lowest scores in terms of action, this was not due to a lack of understanding and awareness by respondents. Rather, many of comments provided in the free text response boxes indicated that respondents thought that even though their own business unit may not have been doing much in terms of responding, others were. In many instances staff believed the Sustainability Strategy and Green infrastructure Units are progressing the issue, which can lead to them abdicating responsibility to these Units.
- In many instances barriers to climate adaptation action within a local government organisation stem from a lack of understanding and awareness of the issue; a failure to prioritise action and or a lack of leadership and political/cultural support. Interestingly an anecdotal finding of this project has been the challenge with engaging on the issue within the City appears to stem, not from a lack of valuing or prioritising the need to respond to the impacts of a changing climate, but rather because they think that they, or another part of Council, are already doing it and therefore it is not a high priority.

- Subsequent engagement, and in particular the one-to-interviews provided evidence of the considerable work the City has progressed so far with regard to stormwater management; urban heat island effects; event management, and energy efficiency. It also highlighted opportunities for future action and response across a range of issues including (but not limited to) communication to stakeholders; working with stakeholders to change/update and progress design standards; and undertaking relevant studies and investigations to better understand the baseline for future adaptation response.
- Each of the City's Business Units can use these results (specifically Figure 7 and Figure 8) to understand the specific capabilities and needs of their staff. This can be used to target interventions to better enable and build capacity amongst staff. In particular all Business Units will need to raise awareness about the specific roles and responsibilities their staff have relating to climate adaptation, and not leave this to other areas of the City. This will be enabled through the designation of adaptation actions to appropriate functional areas within Council (refer Section 11.2.4). In some cases will be a need to undertake detailed training and/or change management activities, as changes to work practices will be required eg City Project and Property and City Planning, Development and Transport.
- There is a real need to assist staff in understanding how to translate the climate data into action in their day-to-day decision-making. Challenges associated with identifying trigger points and thresholds related to asset and service performance were identified during the one-to-one interview phase of the project (refer Section 11.2.3), and confirm the need for staff training to be specifically supported.
- The recent Local Government of South Australia and the South Australian Department of Environment, Water and Natural Resources, Science to Solutions *Understanding Barriers to Climate Adaptation Project* identified alignment of strategies and then assignment of resources and priority as a major barrier to action. Whilst this was not identified in the survey it is a barrier that is clearly at play across the Council. Following this project it will be possible for Council to ensure strategic alignment to address climate risk and resilience across all its plans, strategies and activities. Further assistance in embedding climate resilience into council business can be obtained from the recently published Australian Centre for Excellence in Local Government (ACELG) Climate Adaptation Manual.
- Based upon leading approaches further assistance in capacity building for climate resilience could include the following:
  - Training (industry bodies – IPWEA, EIANZ, PIA or customised).
  - Dissemination and partaking in case studies, pilots, trials etc.
  - Selection of an embedding model to integrating climate resilience into council business (see ACELG Manual).
  - Dedicated climate resilience staff and resources.
  - Establish a Community of Practice across Council.
  - Mainstreaming and alignment of strategic directions and all plans/strategies to include climate resilience.
  - Assignment of roles and responsibilities.
  - Adopt change management approaches to roll out of capacity building.

5 City of Sydney's Climate Exposure



The Carbon Disclosure Project (CDP) has found that global cities are mostly aligned in recognising risks from increased temperatures and heatwaves, which directly impact human health, air quality and demand for utilities. The City of Philadelphia in the USA, for example, found that by taking steps to reduce the health impacts of temperature increases, it was able to save $468 million in economic value over a three-year period. In addition to temperature increase and heatwaves, CDP noted that local risks for cities also generally aligned to the following four risk categories:

- Drought
- Frequent/intense rainfall
- Sea level rise
- Storms/floods.

Ebi, KL et al. 'Heat watch/warning systems save lives: estimated costs and benefits for Philadelphia 1995–1998.' Bulletin of the American Meteorological Society 14.5 (2004).

This chapter presents the findings of the climate modelling and sensitivity mapping undertaken for the City as part of this project.

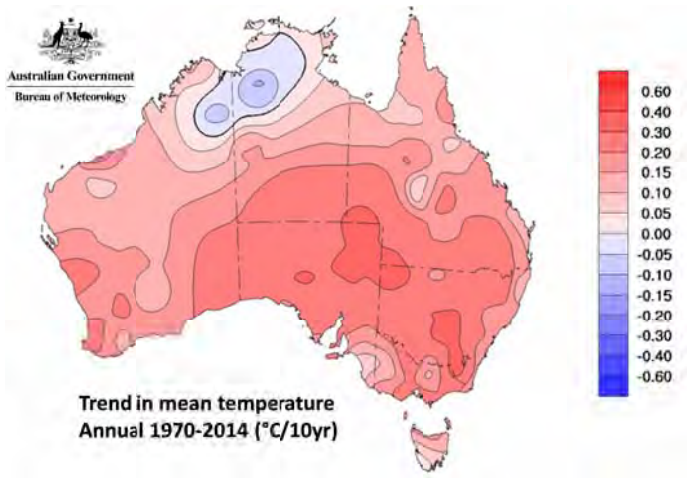
5.1 Climate exposure overview

5.1.1 Our changing climate

The global climate is changing. Since 1880 the global mean temperature has risen by 0.85°C, the amount of heat stored in our oceans has increased and the global mean sea level has risen by 225mm. Global average carbon dioxide concentrations reached 395 parts per million (ppm) in 2013 and continue to rise. Seemingly small changes in mean temperature drives change in essential climate variables that in turn drive change in extreme weather and climate impacts. Figure 10 overleaf shows the interaction between global warming, climate variables and climate impacts.

Closer to home, a warming of Australia's climate has been observed with temperatures increasing by 0.9°C since 1910 and the frequency of extreme weather events changing with more extreme heat and fewer cool extremes recorded (refer Figure 9). Recent years have also brought increased extreme fire weather and a lengthening of the bushfire season exacerbated by a decrease in precipitation across the south east of Australia. Recorded levels of precipitation (in this case rainfall) have consistently been below average in autumn and early winter since 1990.

Figure 9 Historical trends in mean temperature



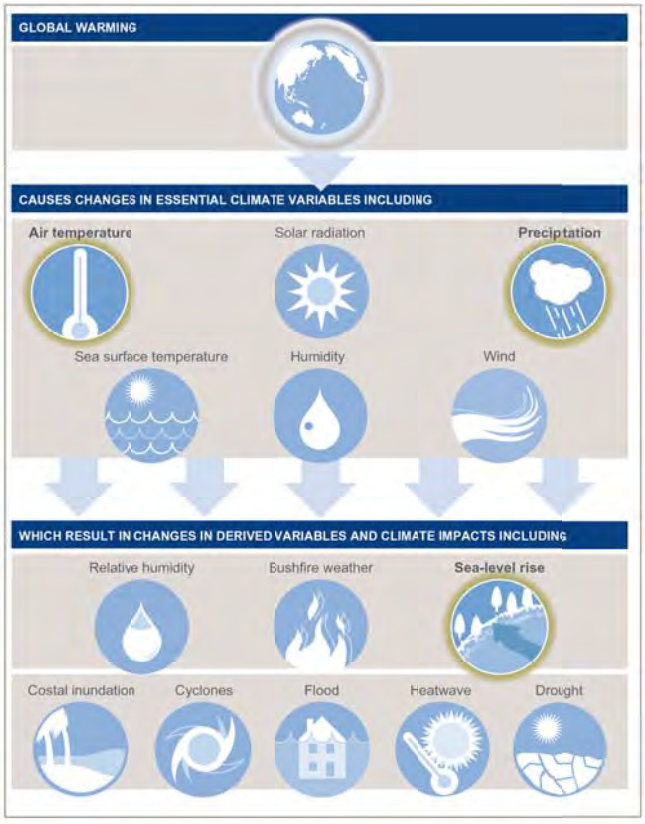
Source: Commonwealth of Australia, 2014, Australian Bureau of Meteorology

Managing Australia's climate risks

Australia is among the developed countries most vulnerable to climate change. Our climate is highly variable and predisposed toward extreme weather events, and our ecosystems are finely balanced and often unique. Most of the country's population lives in coastal cities exposed to rising sea levels and connected by infrastructure exposed to the full range of weather conditions. Climate change will have direct economic costs for Australia that need to be managed.

Coming Ready or Not: Managing climate risks to Australia's infrastructure, The Climate Institute 2012

Figure 10 Interaction between global warming, climate variables and climate impacts



Detailed downscaled modelling of those climate variables highlighted in Figure 10 has been undertaken for the City of Sydney in this project and is presented in this section.

5.1.2 Method

The following details the methodology and approach adopted to model those climate impacts likely to shape the City of Sydney for four time periods – 1995 (baseline), 2030, 2050 and 2070. The use of multiple distinct time horizons is aligned with good climate modelling practice and acknowledges the gradual changes to climate patterns and their related severity of impact at different points in time.

Table 5 below highlights those specific climate variables modelled for the project.

Table 5 Climate variable modelled for the City of Sydney

Climate variable	Data used
Primary	
Mean temperature	IPCC Fifth Assessment statistically downscaled using SimCLIM.
Extreme temperature	IPCC Fifth Assessment statistically downscaled using SimCLIM and local Bureau of Metrology sites.
Annual rainfall	IPCC Fifth Assessment statistically downscaled using SimCLIM.
Extreme rainfall	IPCC Fifth Assessment statistically downscaled using SimCLIM and local Bureau of Metrology sites.
Sea level rise and storm surge	IPCC Fifth Assessment statistically downscaled using SimCLIM.

Note: Modelling assumptions for primary climate variables have been applied consistent with approaches applied by CSIRO, NSW State Government and international best practice.

To capture and convey the uncertainty often associated with climate projections, the Climate Futures approach developed by the CSIRO was adopted. This approach selects three Global Climate Models (GCMs) that would represent three possible 'Climate Futures' for the City of Sydney. All GCMS agree there will be further changes to the climate, even with the most stringent action to reduce greenhouse gases. The rate and magnitude of change is uncertain, due to uncertainty about the level of future emissions and the response of the climate system to those emissions. Climate models project different levels of change, and taken together the models indicate a plausible range of possible futures.

The Climate Futures approach was implemented using SimCLIM 2013 - a software package that uses statistical downscaling methods to generate localised climate projections using the latest GCMs from the IPCC's Fifth Assessment Report. This work predated the publication of the NSW Government's NSW and ACT Climate Impact Modelling (NARCLIM) and CSIRO's NRM Climate Futures data.

Why use Climate Futures?

There are over 50 Global Climate Models (GCMs) available from the IPCC Fifth Assessment Report. The Climate Futures approach ensures that a range of possible future climates has been considered in the risk assessment process without having to assess each GCM individually. This framework is designed to make it easier to consider the range of possible future climates to enable them to be understood and subsequently address the inherent uncertainty associated with projecting future climate into climate risk assessments and adaptation strategies. For this project three climate models have been selected representing the following climate futures:

1. Least change – this represents a future climate that few models point toward but is the most similar to the climate we currently experience.
2. Most model consensus – this represents a future close to the median of climate model projections. The analysis in this report focuses on this model, refer Section 5.1.4.
3. Most change – this represents a future that few models point toward but is the most different from the climate we currently experience.

Review of data sets – commentary on approach

The climate projections used to inform the City's climate risk assessment provide a scientifically sound platform to frame the initial phase of the iterative process required to develop the accompanying climate change adaptation pathways for the City. Every approach to modelling future climate has both advantages and limitations. During the climate modelling phase of the project, SimCLIM was the sole source of high resolution downscaled data for the City of Sydney. The statistical foundations of this software limit the projections of gradual long term change for average annual temperature and total annual precipitation to a smooth curve.

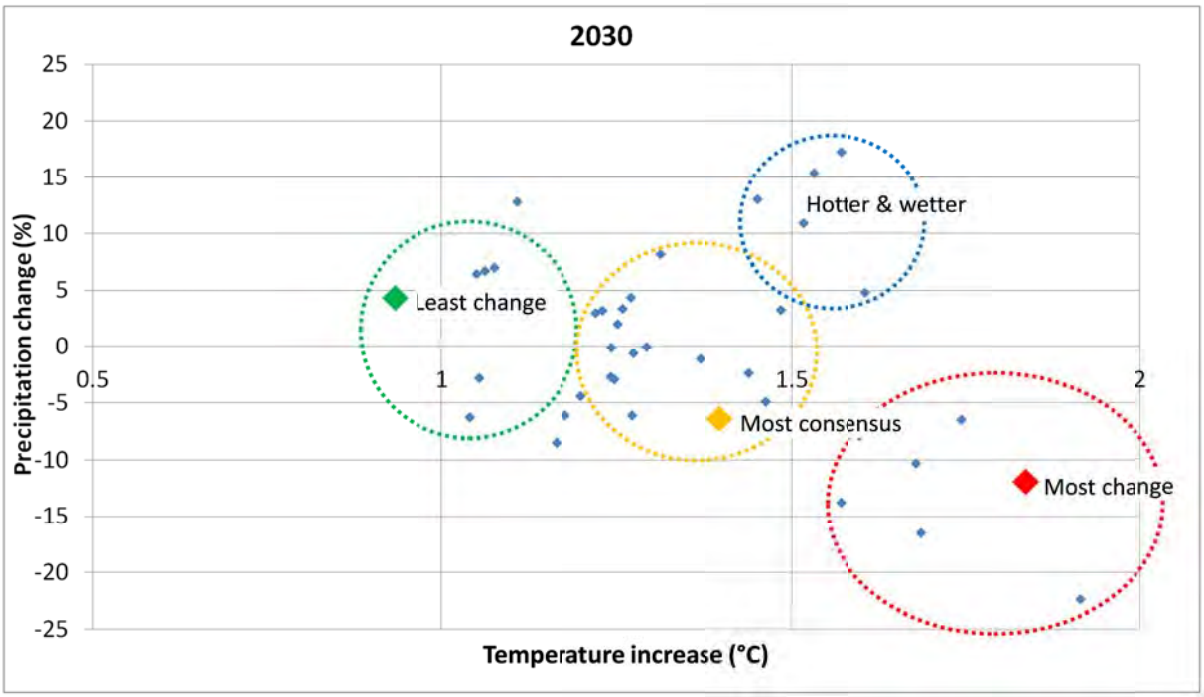
It is acknowledged that this limitation masks monthly or seasonal changes as well as inter-annual variation of these climate variables. However, these long term projections are sufficiently indicative to base the City's first stage of adaptation planning on. Further to this, projections of extreme temperature and precipitation events which are most important and link directly to impacts are a feature of the software and have been included. As such, during the future development of the adaptation pathways outlined in this report, it is recommended the City test the risks for any potential changes in their overall rating using the NSW Office of Environment NARCliM dataset released on the 8th of December 2015.

The SRG noted the sensitivity of the risks identified (refer Section 6) to changes in timing or magnitude of climate projections. Based on the methodology review undertaken for this project however, it is highly unlikely a material difference would be found at the year 2030 with regard to the qualitative risk assessment process when comparing the SimCLIM dataset to that used by NARCLiM.

Figure 11 (overleaf) illustrates how the selected GCMs have been grouped into clusters representing scenarios of least change, consensus and most change. Although there is a potential fourth cluster of models (the blue circle) that could also represent a "most change" climate future (hotter and wetter), the red cluster (hotter and much drier) was selected in this case as it represents a future climate that poses a much higher risk to the City. The selection of a representative GCM from each cluster was based on its ability to generate both mean and extreme climate projections as well as meeting certain criteria to faithfully reproduce the observed climate in South Eastern Australia.

The detailed methodology used to select the GCMs and conduct the climate analysis and generate the associated climate projections has been provided independently to the City in the *Supporting Materials* documentation.

Figure 11 GCM selection concepts using the climate futures approach



Source: SimCLIM 2013 v3.0.0.1

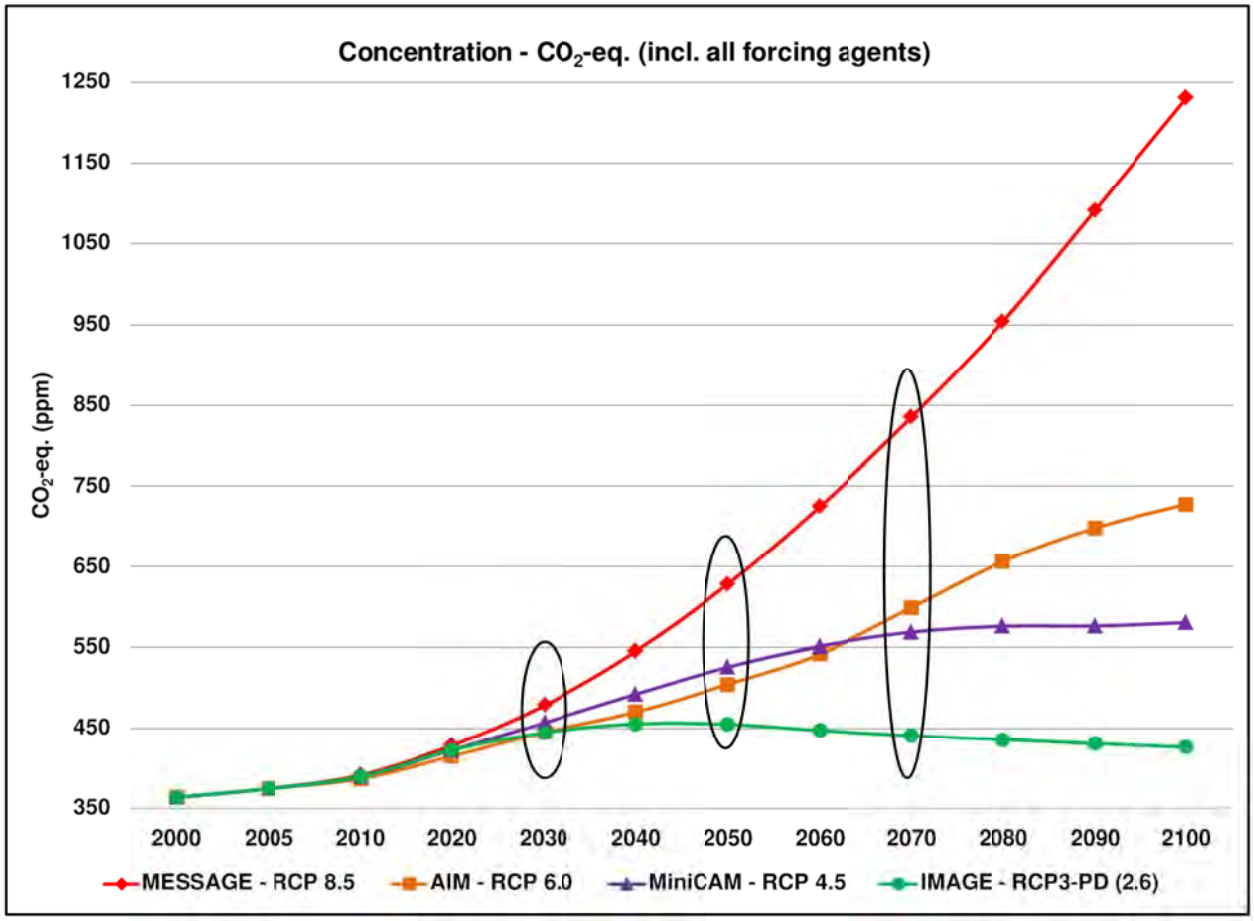
5.1.3 Selecting the emissions scenario – RCP8.5

In order to project future climate, an emissions scenario (or scenarios) must be selected in addition to the Global Climate Models. Emissions scenarios describe the volume of greenhouse gases (GHG) emitted into the atmosphere from human activities. As GHGs are the direct drivers of global warming, the magnitude and rate of change in climate will depend partly on future emissions.

The climate modelling generated for this project assumes a single emission scenario - RCP 8.5 from IPCC's Fifth Assessment (refer Figure 12). This scenario represents the current trajectory of GHG emissions, and assumes emissions will continue to rise throughout this century.

Figure 12 shows four Representative Concentration Pathways (RCPs) for human induced GHG emissions as developed during the IPCC's Fifth Assessment Report. The three black ellipses show the divergence of the emission scenarios through to 2100. While there is no significant difference by 2030, there is significant divergence from 2050 onwards and as such, the climate projections will need to be reviewed in light of changes to the IPPC's emissions scenarios, as well as actual future emissions.

Figure 12 IPCC Fifth Assessment Report emissions trajectories



Source: Derived from Collins et al 2013

Emission scenarios

As identified, there are four Relative Concentration Pathways (RCPs) as outlined in Table 6 below. Each RCP is expressed as Watts per meter squared (W/m^2) and is a measure of the amount of radiative forcing occurring in the troposphere. Radiative forcing is the difference in radiant energy received by the Earth and radiated back into space. The higher the RCP the more energy retained and therefore the greater the warming at the Earth's surface.

Uses and limitations of the RCPs

While each single RCP is based on an internally consistent set of socioeconomic assumptions, the four RCPs together cannot be treated as a set with consistent internal socioeconomic logic. For example, RCP8.5 cannot be used as a no-climate-policy socioeconomic reference scenario for the other RCPs because RCP8.5's socioeconomic, technology, and biophysical assumptions differ from those of the other RCPs.

Each RCP could result from different combinations of economic, technological, demographic, policy, and institutional futures. For example, the second-to-lowest RCP could be considered as a moderate mitigation scenario. However, it is also consistent with a baseline scenario that assumes a global development that focuses on technological improvements and a shift to service industries but does not aim to reduce greenhouse gas emissions as a goal in itself (similar to the B1 scenario of the SRES scenarios).

Further information on RCPs can be found on the IPCC website
http://sedac.ipccdata.org/ddc/ar5_scenario_process/RCPs.html

Table 6 IPCC Fifth Assessment Report emissions pathways

RCP	Description
8.5	Rising radiative forcing pathway leading to 8.5 W/m^2 in 2100
6.0	Stabilisation of emissions without overshoot pathway to 6 W/m^2 at stabilisation after 2100
4.5	Stabilisation without overshoot pathway to 4.5 W/m^2 at stabilisation after 2100
2.6	Peak in radiative forcing at ~ 3 W/m^2 before 2100 and decline

5.1.4 Overview of the three climate futures

Understanding climate projections, the uncertainty in future climate resulting from the difference in GCM outputs, as well as the uncertainty around the emissions trajectories can be difficult and complex. As such during the risk assessment stage of the project it was determined that only those climate projections associated with the 'most consensus' climate future would be presented and socialised with the City's internal and external stakeholders.

The use of a single climate future to enable the subsequent climate risks to be ranked has streamlined this process allowing stakeholders to familiarise themselves with the selected climate projections and impacts. It has enabled stakeholders to engage as part of the accompanying risk assessment process without being overwhelmed by complex information. It has also helped manage the uncertainties that exist with projecting changes to future climate.

However, as the City's climate adaptation options and pathways are further developed for implementation, the sensitivity of the proposed actions relative to variations in the severity and timing of climate projections should be factored into their development. This should include both the variability between the three climate futures included in this project as well as the differences between emissions trajectories beyond 2030.

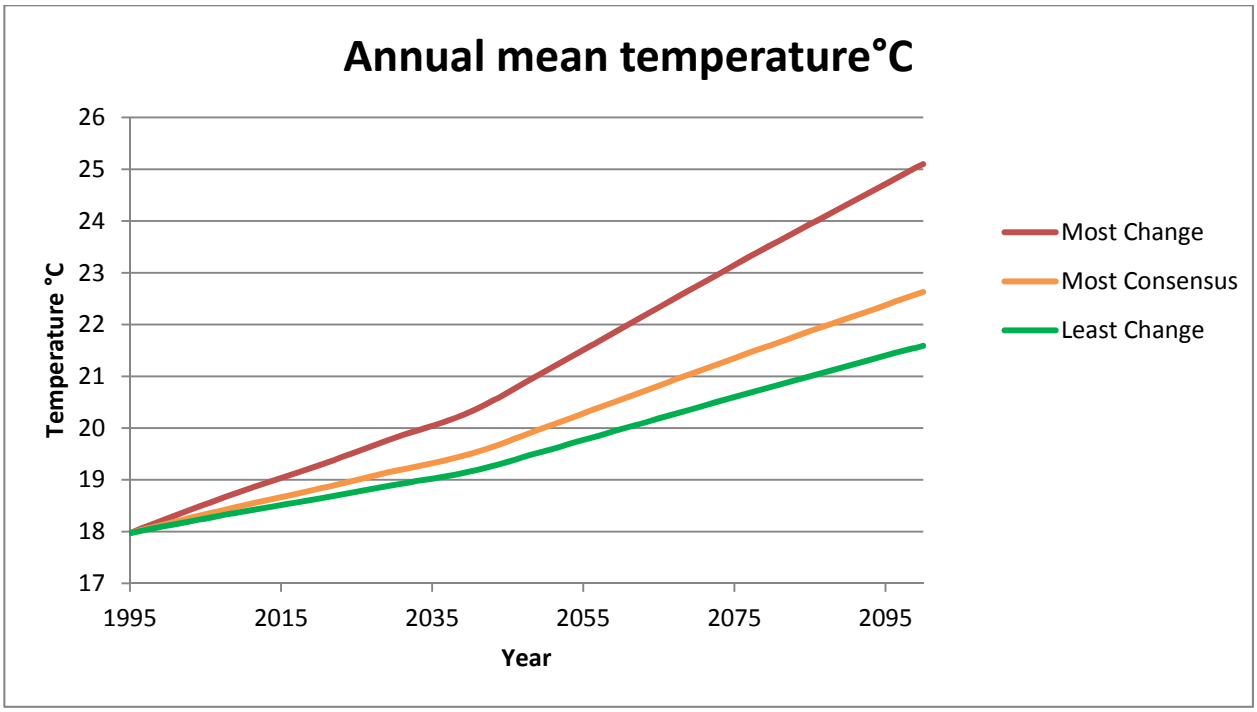
Temperature

There is a high level of confidence that mean temperature in Sydney will continue to rise, and all three climate models show this. There is less confidence about the rate of change as shown in Figure 13. The graph shows the differing projections of the three models which indicate temperature increases of 2.42°C, 3.1°C and 4.76°C by 2070.

All three climate futures show an increase in average temperature, although the level of increase varies. There is high confidence in the projections that temperature is rising and will increase by a minimum amount in the long term. The uncertainty lies in "how soon" changes in temperature will occur.

Figure 13 shows the level of change across the three models by 2070, notably this is 2.42°C, 3.1°C and 4.76°C respectively.

Figure 13 Average annual temperature change for all three climate futures



Source: SimCLIM 2013 v3.0.0.1

Precipitation

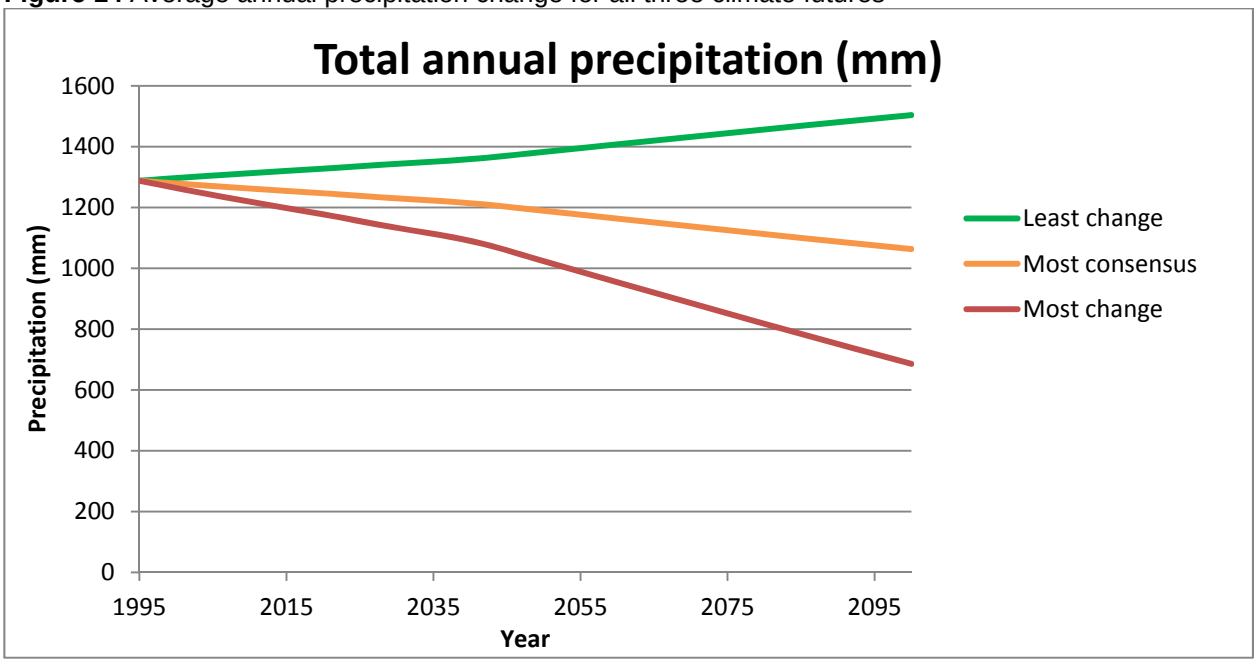
There is a low level of confidence in projected change in precipitation. Different climate models show both an increase and a decrease in changes in annual precipitation - refer Figure 13.

The ‘least change’ future projects an increase in precipitation of 11% by 2070 while the ‘most consensus’ and ‘most change’ futures project decreases of 11% and 30% respectively over the same period.

Wide variance around rainfall projections mean it would be better to develop an understanding of those aspects of rainfall change that affect the City’s decision making in the future.

Despite uncertainty associated with long term average change in rainfall, there is greater confidence in projections relating to other aspects of precipitation such as seasonality (refer Section 5.3.1) and extreme rainfall (refer Section 5.2.2).

Figure 14 Average annual precipitation change for all three climate futures



Source: SimCLIM 2013 v3.0.0.1

5.2 Climate exposure – Projections and impacts

The following section presents the climate modelling outputs undertaken for the project and the projected changes in average and extreme temperature, precipitation and sea level rise under a 'most consensus' climate future. Detailed findings of the climate modelling have been provided in the *Supporting Materials* documentation. This report first details the results of the exposure modelling undertaken specifically for this project followed by publically available impact modelling and data resulting from these changed climatic conditions. At the time of undertaking this work there was a scarcity of publically available modelling of a number of climate impacts such as bushfires, ozone, wind and storms. It was not within the scope of this project to undertake specific modelling of these. Information and research relating to these impacts represent the next step in understanding the City's future climate. It is envisaged this information will become available from scientific agencies and universities over the next 5 years, and the City will work with these agencies where specific information is required to quantify high or very high risks to the City (refer Section 9).

5.2.1 Temperature

The results presented below seek to highlight that a seemingly innocuous increase in mean annual temperature from the 1995 baseline of 1.2°C by 2030, 2.0 °C by 2050 and 3.1 °C by 2070 correspond with an increase in extreme heat events and associated impacts.

Projections

Average temperature

Annual average temperature represents the average over the whole year and does not reflect the extremes of heat or cold that are experienced over the course of a year (i.e. during summer and winter).

Table 7 presents the change in annual average minimum, mean and maximum temperatures for City of Sydney at 2030, 2050 and 2070.

The projections indicate an increase in average maximum temperature at a slightly greater rate than mean or minimum temperatures. These small changes in average temperature can mask a much larger change in extremes which is explored further below.

Table 7 Change in average annual minimum, mean and maximum temperatures for the City[5]

Temperature (°C)	1995 (baseline)	2030	2050	2070
Minimum	13.7	14.8	15.5	16.4
Mean	18.0	19.2	20.0	21.1
maximum	22.2	23.7	24.8	26.2

Days over 35°C

Table 8 shows the projected change in the average number of days over 35°C increasing from an average of 3.7 days a year in the baseline to 5.8 days in 2030, 8.4 days in 2050 and 15 days by 2070. Note that an increase of 3.1°C in the mean average annual temperature (Table 7) corresponds to almost a four-fold increase in days over 35°C (Table 8) which has a significant impact in terms of frequency of heat impacts.

Table 8 Projected change in the average number of days over 35°C.

Variable	Average number of days over 35°C			
Year	1995 (Baseline)	2030	2050	2070
Number of days	3.7	5.8	8.4	15.0

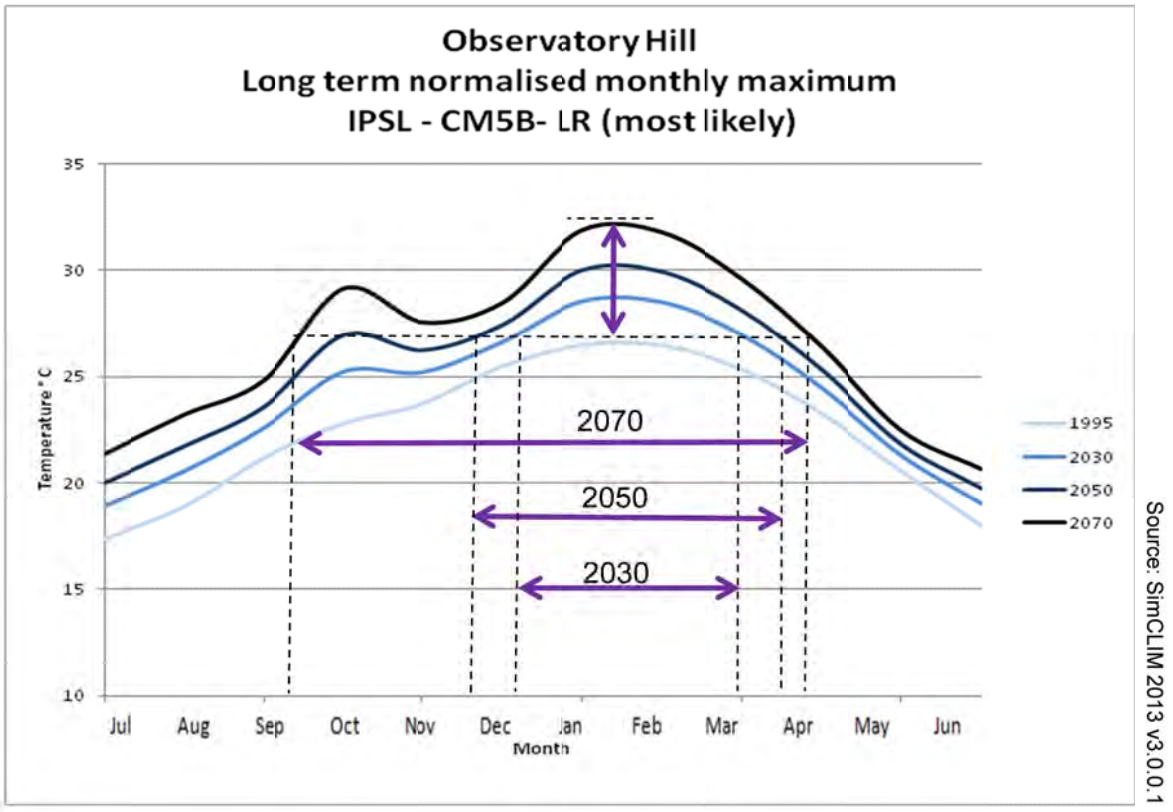
Long term normalised monthly maximum

The information presented in Figure 15 is important as it shows the projected change to the normalised monthly maximum temperature. It suggests that by 2070 there will be a significant increase in the average maximum temperature for January and February. It also highlights that the climate we currently associate as occurring during midsummer (based on the baseline year) may, by 2070, become the norm as early as September and as late as April.

The implications of this change include an increase to the duration of the bushfire season with a more intense peak as well as a lengthening of the period of the year in which we can expect to see heatwaves that currently only occur in the peak of summer.

[5] *These are averages over the whole year, not to be confused with the seasonal/monthly averages or daily temperatures*

Figure 15 Projected change in normalised monthly maximum temperature



Source: SimCLIM, v3.0.0.1, 2013

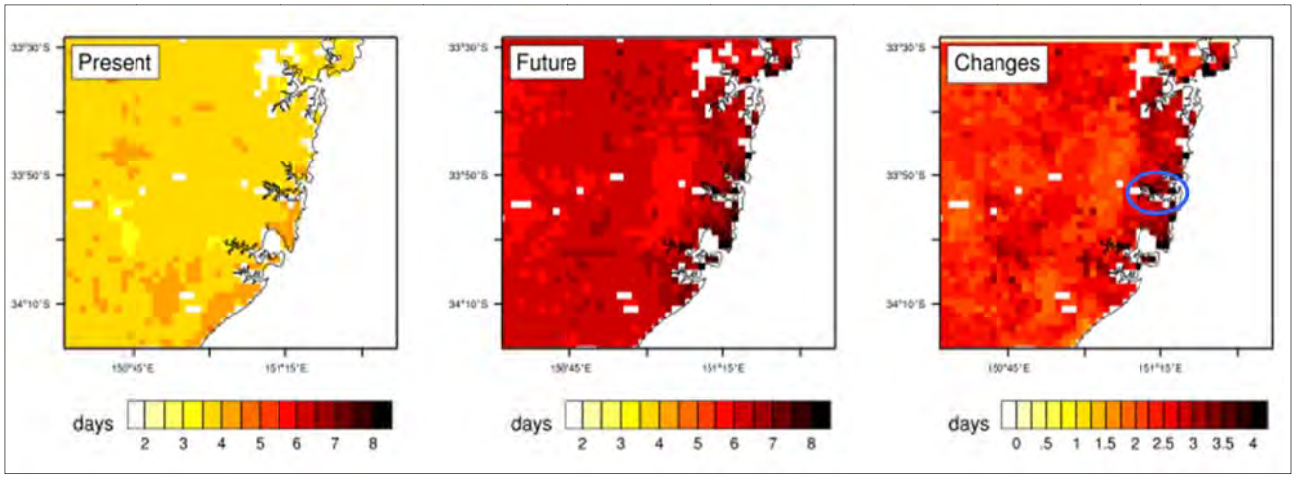
Heatwave

A heatwave is commonly defined as at least three consecutive days where the daily maximum temperature is in the top 10% of warmest temperatures for that calendar date. This means that heatwaves can technically occur in winter and we do currently experience heatwaves at all times of year.

While winter heatwaves do contribute to increases in long-term bushfire risk, climate modelling undertaken for this project is primarily concerned with the heat impacts associated with summer heatwaves. The following figures (Figure 16 to Figure 18) were made available from the preliminary NARCliM dataset and present changes to heatwave duration, frequency and intensity for the Sydney region between the present and the year 2050.

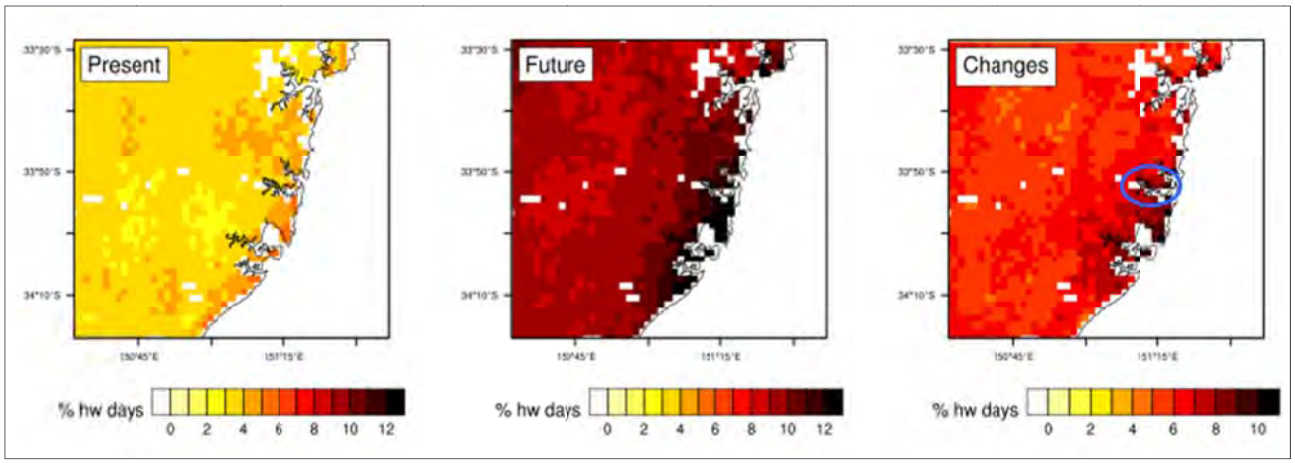
The figures illustrate projections that by 2050 there will be an average of 7-9 more heatwave days on average per year; that heatwaves will last about 2-4 days longer on average; and, the hottest day in a heatwave will be about 3°C higher than the baseline climate.

Figure 16 Heatwave duration



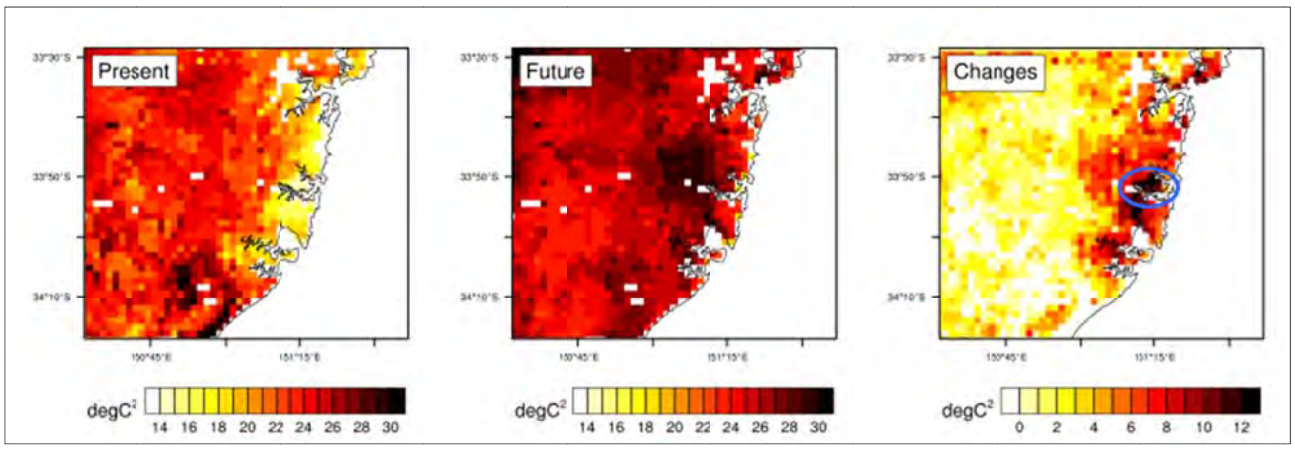
Source: Argueso et al. 2014

Figure 17 Heatwave frequency



Source: Argueso et al. 2014

Figure 18 Heatwave intensity



Source: Argueso et al. 2014

Another way of framing heatwave projections is by looking at the change in the frequency of events we have experienced in the past. Table 9 highlights the changes to return periods (frequency) relating to three-day heatwaves based on data from the Observatory Hill weather station in the City's LGA.

It indicates that a 1 in 10 year event in the baseline climate, such as the 2009 heatwave when the average maximum over three days was 35.4°C, is projected to occur once every 5 years by 2030 and once every two years by 2050.

It indicates that the 1 in 100 year event in the baseline climate that Sydney experienced in late January/early February 2011 is projected to occur once every 10 years by 2030, once every 5 years by 2050 and once every 2 years by 2070. This will have a significant impact on the community as well as placing additional and more frequent stress on key assets, infrastructure and services.

Table 9 Projected change in frequency of heatwaves

Today Future

Three Day Maximum Temperature (average)							
Return period (RP) (years)	Baseline	2030		2050		2070	
	Temp (°C)	Temp (°C)	Base RP	Temp (°C)	Base RP	Temp (°C)	Base RP
2	32.9	34.6	5	35.9	14	37.7	94.6
5	34.5	36.2	20	37.5	80	39.3	1082
10	35.4	37.3	61	38.7	370	40.4	13353
20	36.2	38.3	224	39.7	2618	41.6	897937
50	37.1	39.6	1992	41.2	158046	43.1	-1
100	37.7	40.6	19858	42.3	270998336	44.3	-1

Source: SimCLIM 2013 v3.1.0.0

2009 heatwave 2011 Heatwave

Temperature impacts

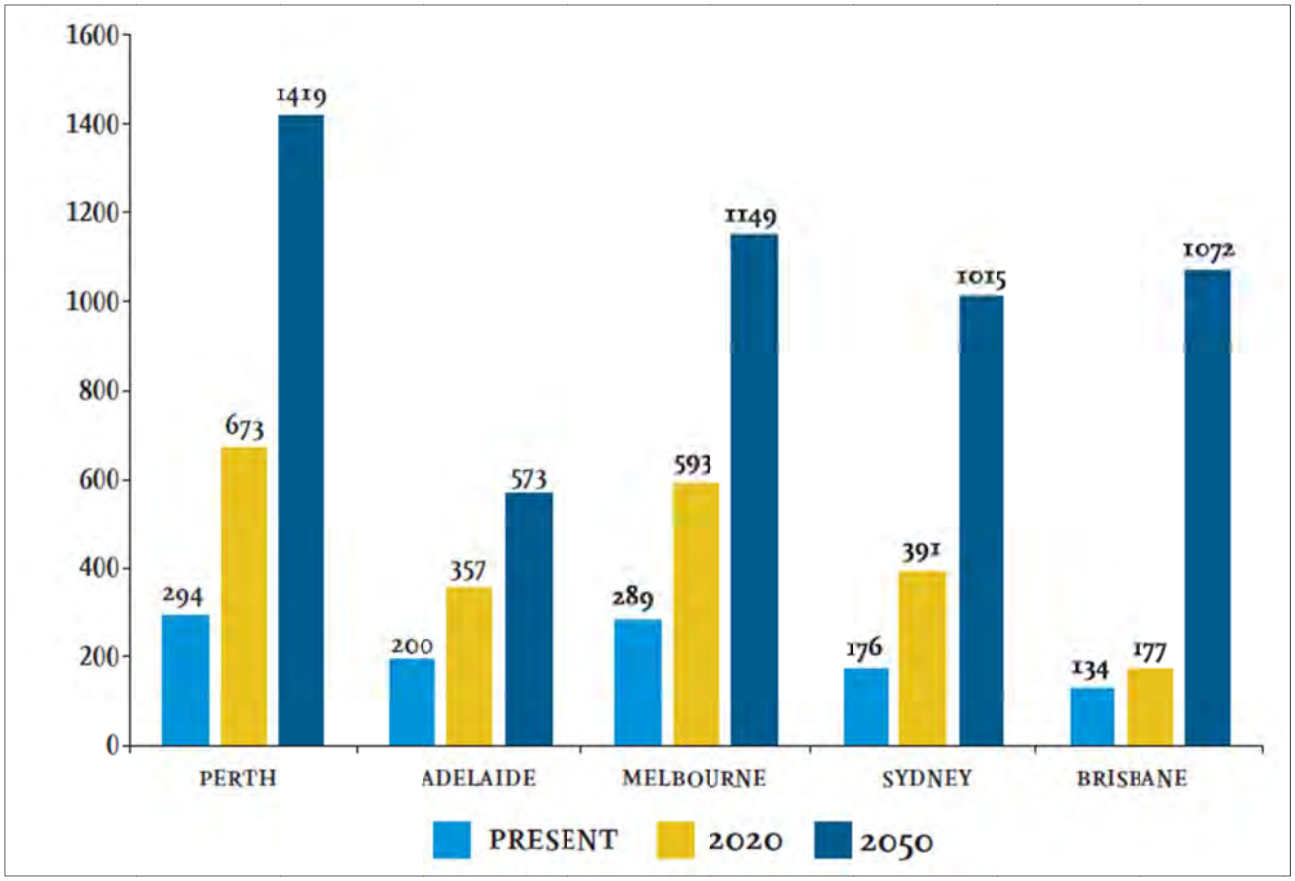
As outlined below, the main impacts resulting from an increase in extreme temperatures in the City of Sydney LGA are heat related morbidity and mortality. Increased air pollution exceedences including particulates from bushfire as well as ozone will also have an impact.

Mortality from extreme heat

Figure 19 shows a mid range projection in extreme heat related mortalities per decade in five Australian capital cities including Sydney. The projections factor both the projected change in climate as well as expected changes to population and demographics. By 2050 the number of deaths is projected to increase from 176 to 1,015 for Greater Sydney – a five-fold increase compared to the 2006 baseline.

These mortality figures are consistent with those found in Australian and international cities in the wake of recent heatwaves. For instance the recent Los Angeles heatwave gave rise to an estimated 190 excess deaths that could be attributed to the severe heat conditions. Likewise in Melbourne in 2009 there were more than 300 excess deaths. This should also not be confused with long term and cumulative health impacts of heatwaves. These are more difficult to measure and track but can include as yet undetected health impacts eg premature births.

Figure 19 Mid range estimates of heat-related deaths across five Australian capital cities

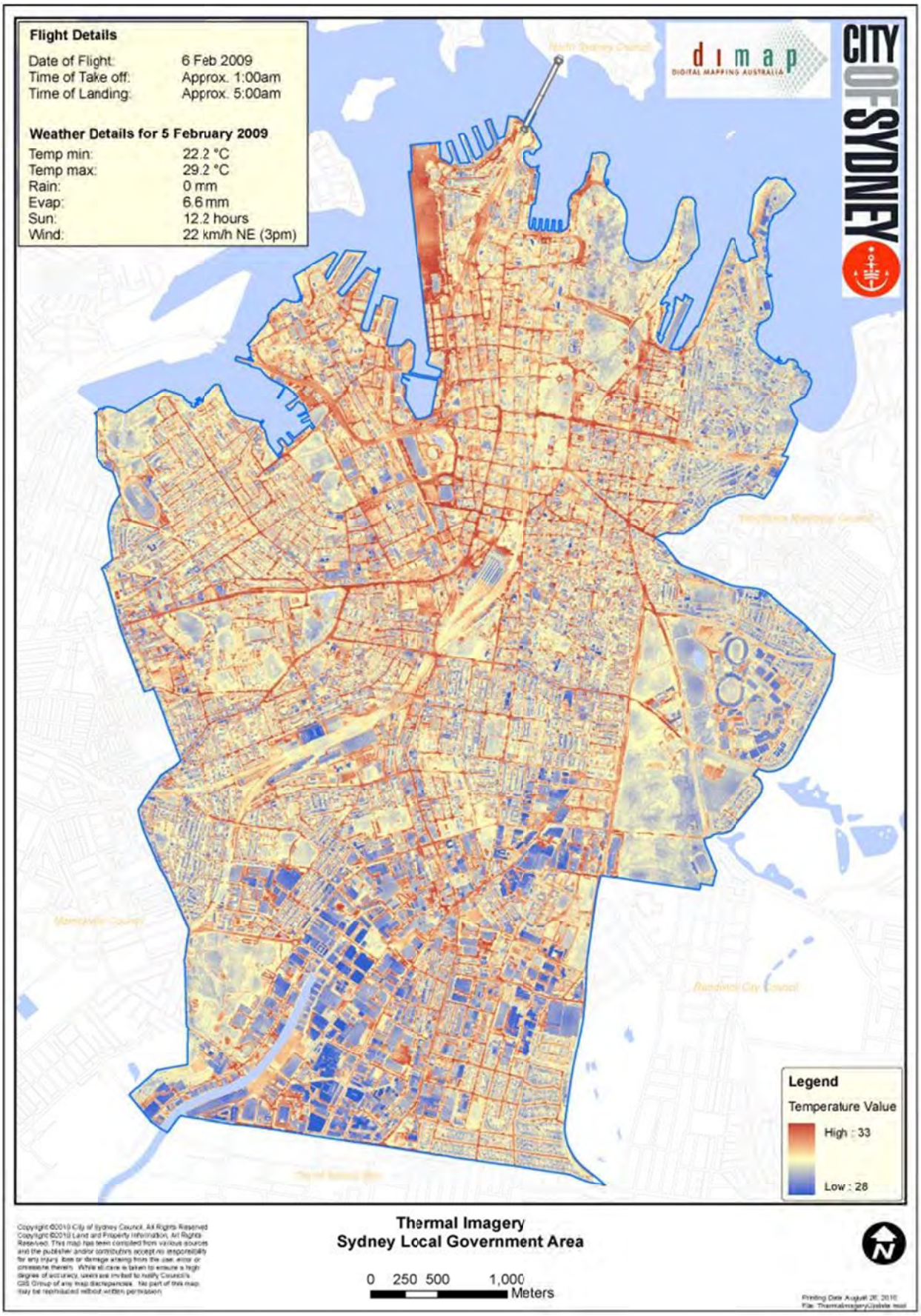


Source: CSIRO Marine and Atmospheric Research, Australian Greenhouse Office, 2006

The urban heat island effect

The urban heat island effect is the result of urban areas being significantly warmer than surrounding non-urban areas due to the high-density nature of the built environment and associated human activities that occur in urban areas. Urban heat island effect has been identified by the City of Sydney as an issue that could be exacerbated by projected increases in maximum temperature. Figure 20 depicts the radiant temperature of different physical surfaces in the City of Sydney LGA. The image was taken between the hours of 1am and 5am which is when the ambient air temperature is generally at its lowest. The figure illustrates that despite an ambient temperature of 22°C, the ground is radiating heat between 28°C and 33°C. People living in areas that experience urban heat island effect and are therefore exposed to higher temperatures both throughout the day and night are at a higher risk of heat related health impacts.

Figure 20 Night time thermal image of the City of Sydney LGA



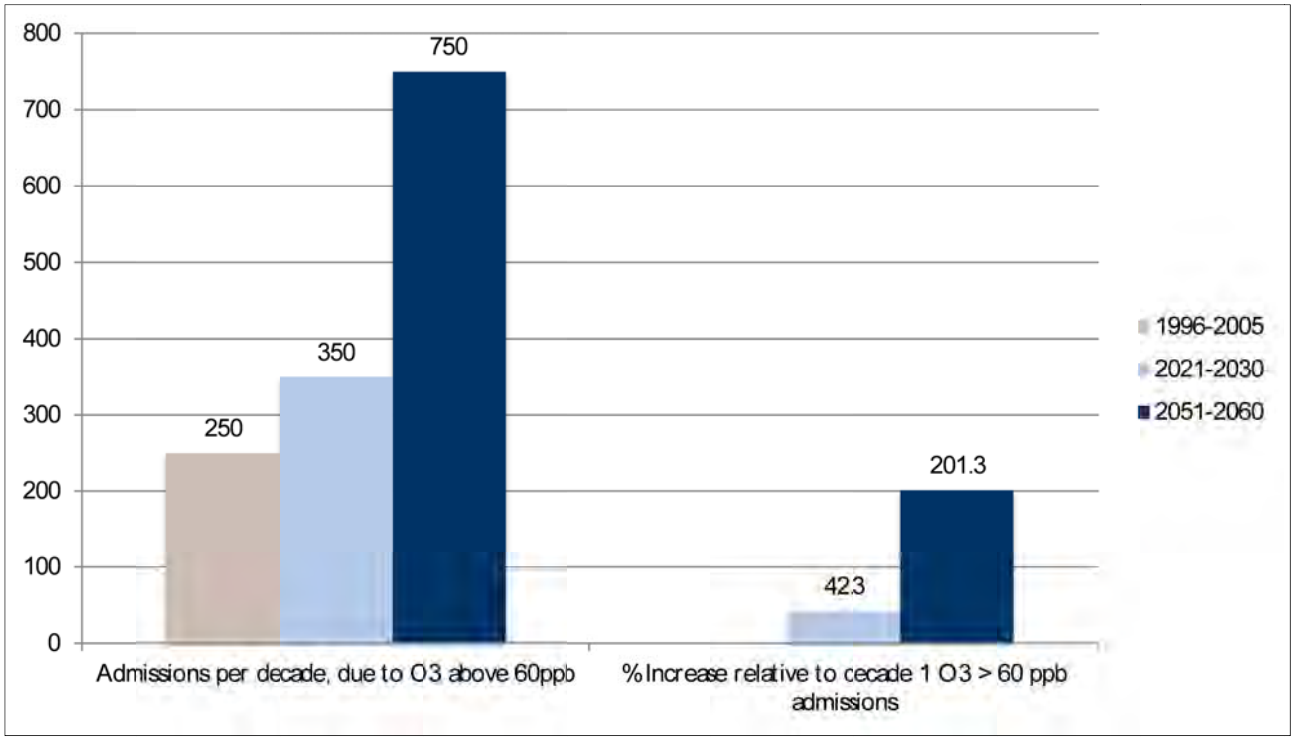
Source: City of Sydney 2010, Land and Property Information, 2010

Hospital admissions due to ozone pollution

Ozone pollution occurs as a result of a combination of high daytime temperatures and the concentration of 'precursory' emissions generated from the combustion of fossil fuels or bushfire pollution.

Increased levels of ozone pollution often correlate with increased hospital admission as a result of respiratory complications. Figure 21 shows that hospital admissions from ozone related respiratory illnesses are projected to increase by 42.3% in the decade beginning 2021, and 201% in the decade beginning 2051 compared with the 1996-2005 baseline. These projections factor in the demographic change forecast for the Sydney region over the period but assume no increase in precursory emissions such as smoke from bushfires or vehicular emissions which drive ozone pollution.

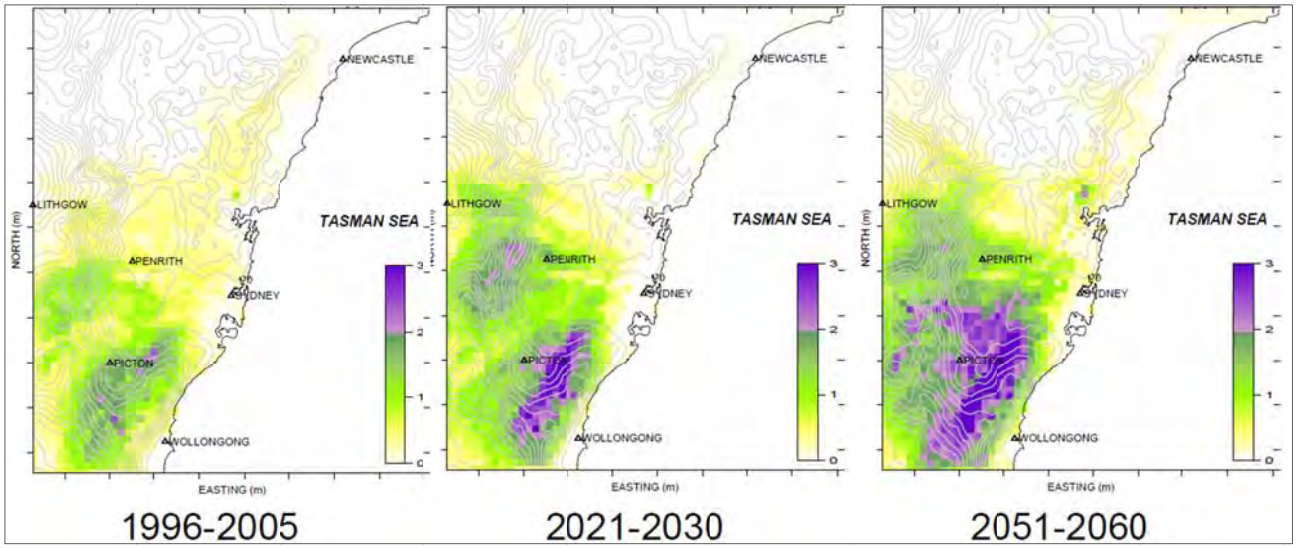
Figure 21 Projected increases in hospitalisations due to ozone pollution in Greater Sydney



Source: Adapted from Cope et al, 2008

An increase in maximum temperature is projected to drive an increase in the frequency and distribution of safe ozone level exceedances, particularly in the areas to the south west of the City (Figure 22). This is expected to exacerbate the strain on health services during hot weather.

Figure 22 Projected increases in ozone exceedances for the Sydney region



Source: Cope et al, 2008

5.2.2 Precipitation

Precipitation is the only climate variable modelled for the City where the three climate models do not consistently indicate the same direction of change. While all models show an increase in both temperature and sea level rise, the range of projected change to annual precipitation varies from little change, to an increase in levels, to a decrease depending on the model selected.

This deviation is shown clearly in the divergence between the projections for the three different climate futures. The 'least change' future shows an 11% increase in annual precipitation, 'the most consensus' future shows an 11% decrease, and the 'most change' future presents a decrease of as much as 30%.

Any future changes to annual precipitation will occur against a background of large inter-annual and inter-decadal variability. It is likely to be many decades before changes in annual rainfall can be distinguished from this natural variability.

Precipitation projections

Change in mean versus extreme precipitation

Despite divergence in the modelled projections for change in annual precipitation, all of the models point to an increase in the intensity of extreme rainfall events. This is the case even where a significant decrease in annual precipitation is projected.

Table 10 shows the change in annual precipitation for the 'most consensus' climate future with a decrease of 150mm per year by the year 2070. Table 11 highlights the projected change in the frequency of extreme precipitation events (for the 'most consensus' climate future) and as stated shows the occurrence of these to become more frequent. Specifically, in this instance a 1 in 20 year event is projected occur once every ten years by 2070 and the current 1 in 50 year event is projected occur once every 20 years by 2070.

Table 10 change in annual precipitation for the most consensus climate future

Variable	1995	2030	2050	2070
Annual precipitation (mm)	1,288	1,230	1,189	1,138

Source: SimCLIM, v3.0.0.1, 2013

Table 11 Projected change in frequency in extreme precipitation events

Single Day Maximum Precipitation							
Return period (RP) (years)	Baseline	2030		2050		2070	
	Precip (mm)	Precip (mm)	Base RP	Precip (mm)	Base RP	Precip (mm)	Base RP
2	97	100	2.1	102	2.2	106	2.4
5	144	155	6.0	162	6.8	172	8.0
10	187	207	13	221	16	239	20
20	240	273	29	297	37	328	49
50	331	393	82	437	111	495	158
100	422	517	178	584	254	675	385

Source: SimCLIM, v3.0.0.1, 2013

Precipitation impacts

The projected increase in the frequency of extreme rainfall events is also likely to result in an increase in the frequency and extent of flash flooding across the LGA in the same geographical areas shown in Figure 23 which shows the flooding extent for the 1 in 100 year flood event.

The quantification of the relationship between rainfall projections and resulting changes to flash flooding was beyond the scope of this project.

Following the 2012 flood event experienced across the LGA, the City engaged Cardno to undertake significant flood studies in order to inform an Interim Floodplain Management Policy covering all areas known to be affected by flooding.

These studies represent an extensive resource on flooding impacts, and should be used in conjunction with climate projections related to changes in precipitation intensity that are available from the NARCliM dataset released in December 2014 to inform the timing and implementation of adaptation actions to address flood risk.

All of the City's flood study documentation can be found on the City's website: http://www.cityofsydney.nsw.gov.au/vision/better-infrastructure/floodplain-management

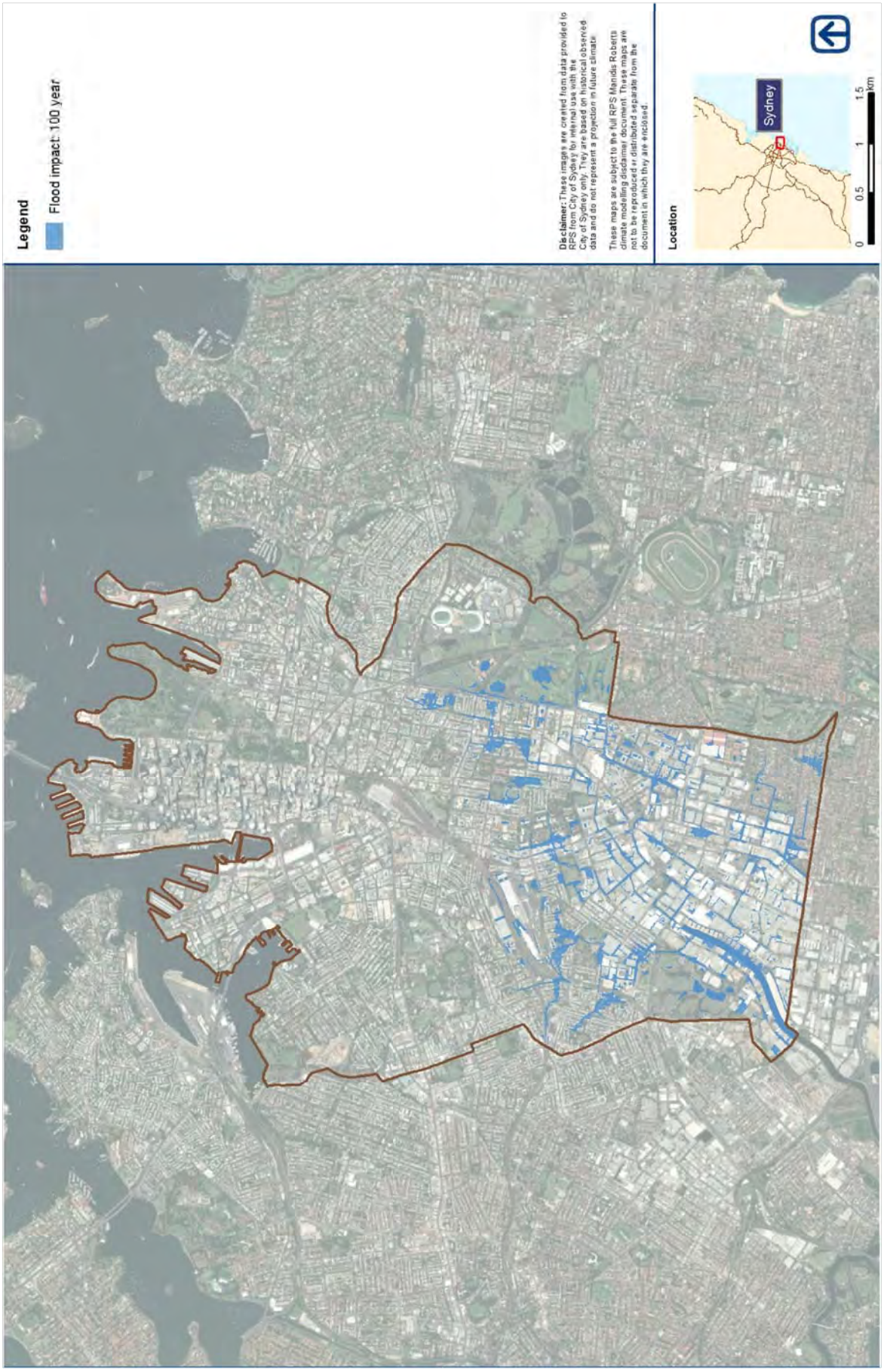


Figure 23 City of Sydney 1 in 100 year flood map

Source: City of Sydney, 2014

5.2.3 Sea level rise

Mean sea level around Australia has risen approximately 0.2m since 1900. All climate models agree that this rise will continue, though there are differences between models on how quickly this increase will occur.

A best estimate[6] for the Sydney region projects sea level rise is to increase to 1.07m above the 1995 level by 2100 and continue to rise after that.

Sea level rise projections

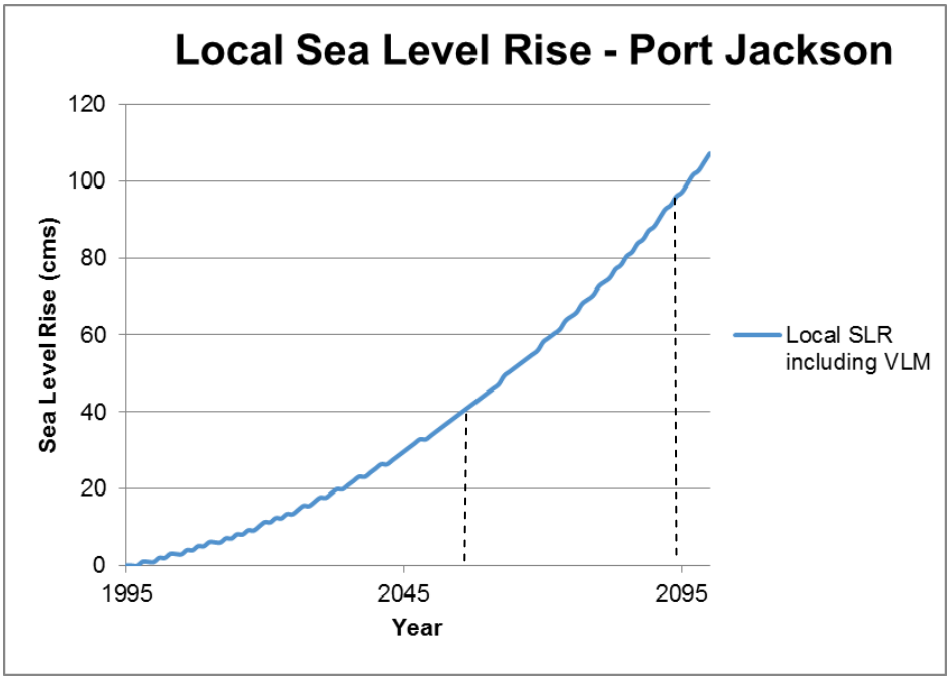
Modelling sea level rise is different to modelling temperature and precipitation and the use of the climate futures approach is not applicable in this case. Instead, the sea level rise projection takes the median result of a 24 GCM ensemble. Use of the median projection is accepted as good practice as a starting point for considering sea level rise.

Figure 24 shows a time series of the projected change in local sea level rise taking into account that land in Sydney is also slowly rising at a rate of 0.5mm/year.

These projections suggest that 0.4m of sea level rise will occur by 2059, 9 years later than the projection in the 2011 OEH climate impact profile. However, the 0.9m threshold is reached six years earlier in 2094. The differences in the timing of both these results is due to the use of the latest AR5 models from the IPCC and RCP 8.5 emissions scenario.

The projections are expressed in this way according to a threshold so they can be linked to the inundation impacts mapping outlined in the next section. Table 12 shows the years projected to correspond with two sea level rise scenarios; 0.4m rise by 2059 and 0.9m rise by 2094.

Figure 24 Projected increase in local sea level for Port Jackson



Source: SimCLIM, v3.0.0.1, 2013

[6] *Best estimate – median result for 24 GCM ensemble, AR5, RCP 8.5 emissions scenario*

Table 12 Years projected to correspond to two sea level rise scenarios

SLR scenario	0.4m	0.9m
Year	2059	2094

Source: SimCLIM, v3.0.0.1, 2013

During refinement of adaptation pathways the upper and lower percentile results from the 24 model ensemble should be included so as to understand the possible difference in timing (both earlier and later) for sea level rise reaching these two thresholds. (refer supporting materials)

Coastal inundation – storm tide

A storm tide is a combination of the highest astronomical tide (HAT) with a storm surge event (elevated water levels due to a combination of atmospheric effects associated with storms).

The Sydney Coastal Councils Group modelled the extent of inundation for the City of Sydney LGA for six different storm tide scenarios as outlined below:

1. Current sea level + 1 in 1 year storm tide (1yr00)
2. Current sea level + 1 in 100 year storm tide (100yr00)
3. 40cm sea level rise + 1 in 1 year storm tide (1yr40)
4. 40cm sea level rise + 1 in 100 year storm tide (100yr40)
5. 90cm sea level rise + 1 in 1 year storm tide (1yr90)
6. 90cm sea level rise + 1 in 100 year storm tide (100yr90)

Figure 25 presents the different inundation scenarios graphically around the of inundation for each of these scenarios between Circular Quay and Garden island which is the area with the highest exposure to coastal inundation.

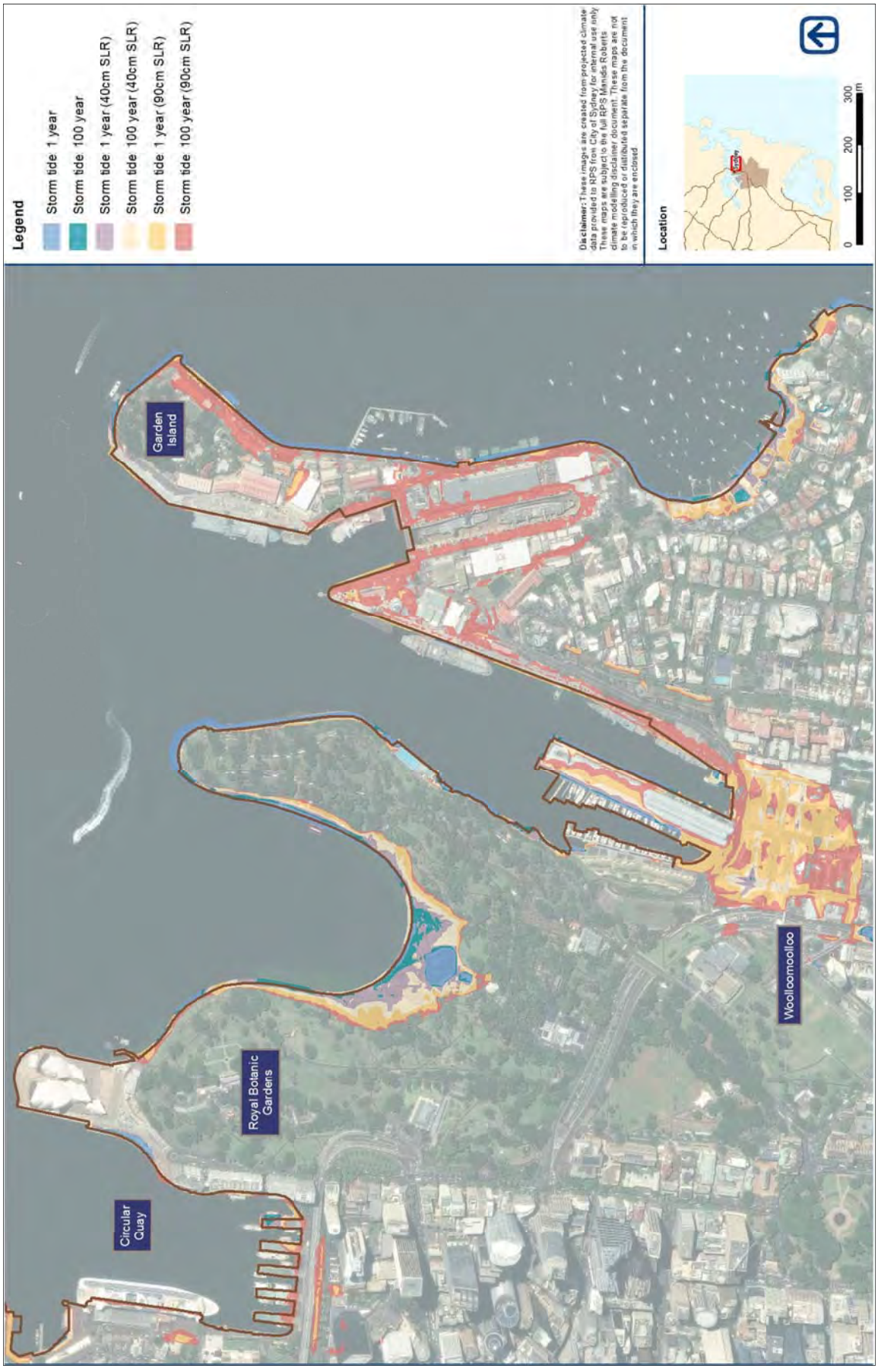


Figure 25 City of Sydney – Storm tide inundation Woolloomooloo and surrounds

Source: City of Sydney 2014, Sydney Coastal Councils Group 2014

Sea level rise – inundation impacts

The NSW Office of Environment and Heritage (OEH) has conducted further research into the impact of sea level rise inundation on coastal assets and infrastructure including buildings, roads, rail, pathways and coastal reserves. The preliminary results of this were made available to inform the project but are unable to be reproduced in this report as they are yet to be finalised and published.

5.3 Testing the selected climate projections

As identified, the climate projections and impact maps discussed in the previous section were presented to the City's internal and external stakeholders in two separate workshops during which participants used the information to assess, modify and rank an existing list of climate risks and their associated impact to relevant infrastructure, communities and the environment within the City of Sydney. In addition to this key area of application, the following section explores how the climate projections have been subsequently used to inform the project's progression.

5.3.1 Climate data quality assurance

The Project's SRG comprising Australia's leading climate scientists (refer Section 8) have provided insight to the climate modelling process with a key recommendation made to undertake a quality assurance review of the data used. This involved:

1. A cross check with the magnitude and direction outlined in the OEH Climate Impact Profile for the Sydney and Central Coast Regions 2011.
2. A comparison with available CSRIO/BoM data.
3. A comparison of SimCLIM extreme events projections based with a second Bureau of Meteorology site within the City of Sydney LGA (Sydney Airport).
4. A comparison with preliminary NARCliM data provided by the NSW Office of Environment and Heritage for temperature and precipitation where data was in comparable form.

Of the four recommendations above, only the BoM/CSIRO comparison (2) was not carried out due to the dataset being unavailable until April 2015.

It should be noted that no climate model claims to predict the climate for certain, there are both advantages and limitations inherent in all models and modelling techniques.

The purpose of this comparison therefore is not to assess the technical differences between the datasets but to determine whether the use of other datasets in the risk assessment phase of this project would have affected the outcomes of the risk assessment process.

The outcome of this comparison has revealed that **the results from all datasets are similar in their direction magnitude and range of change for all the climate variables**. The SRG have reviewed these findings and agree with the conclusion that while there are small differences between the datasets, these can be easily accounted for and it is highly unlikely that using an alternative dataset would have resulted in any material difference in the outcomes of the risk assessment.

A summary of the comparison of datasets is provided in the section below.

OEH 2011 climate impact profile for Greater Sydney and the Central Coast

The 2011 climate impact profile was released by OEH in 2011 to provide an overview of the general changes in climate across the Sydney and Central Coast regions. It refers to a single future year, 2050, expresses change seasonally, and uses an emissions scenario and climate models from the IPCC fourth assessment report (2007). For these reasons the results are not directly comparable with the modelling undertaken for the Project.

The overall similarity in both direction and magnitude of the climate projections in both datasets outlined below and overleaf support the SimCLIM projections as a robust starting point. Seasonal projections are complementary to the annual projections generated in SimCLIM and point to the fact that there can be significant differences in change between the different seasons. Seasonality should be assessed during the ongoing iterative process Council undertakes to develop and implement its CAP.

A summary of the impact profile for temperature, precipitation and sea level rise is outlined below.

Temperature

Temperatures are likely to increase in all seasons by 2050 between 1.5°C and 3.0°C.

Table 13 outlines the seasonal breakdown of these projections.

Table 13 Summary of temperature changes 2050 (OEH 2011)

Season	Minimum average temperature	Maximum average temperature
Spring	2.0 – 3.0°C warmer	2.0 – 3.0°C warmer
Summer	1.5 – 3.0°C warmer	1.5 – 2.0°C warmer
Autumn	1.5 – 3.0°C warmer	1.5 – 3.0°C warmer
Winter	1.5 – 3.0°C warmer	2.0 – 3.0°C warmer

The annual range in temperature increase across the three climate futures is as follows:

- Average minimum: 1.6 - 2.9°C.
- Average maximum:1.6 - 3.4°C.

The projections generated using SimCLIM do not express changes in temperature seasonally however the range across the three futures is very close to OEH's results (Table 13). The greater change in maximum temperature in the SimCLIM data is due to differences in modelling inputs and downscaling techniques, most significantly the use of the RCP 8.5 emissions scenario which is known drive a greater increase in temperatures than the A2 scenario used in the OEH projections.

Precipitation

OEH's projections note that rainfall is likely to increase in all seasons except winter however changes in weather patterns that cannot be resolved by the climate models mean that rainfall in coastal regions is difficult to simulate. Table 14 outlines the seasonal breakdown of OEH's precipitation projections.

Table 14 Summary of precipitation changes 2050 (OEH 2011)

Season	Precipitation
Spring	10-20% increase
Summer	20-50% increase

Season	Precipitation
Autumn	No significant change
Winter	10-20% decrease

The projections generated using SimCLIM do not express seasonal changes in precipitation however the three different futures do show a divergence in precipitation projections with the 'least change' future projecting an increase in rainfall of 11% by 2070 and the 'most change' projecting a 30% decrease thus supporting the finding that rainfall projections are difficult to simulate.

Sea level rise

OEH projections confirm it is virtually certain sea levels will continue to rise. Based on their projections, sea levels are expected to rise 0.4m above the 1990 mean sea level by 2050, and 0.9m by 2100. This is in line with the median result from the SimCLIM projections which indicates a 0.4m rise by 2059 and 0.9m rise by 2094 compared with 1995 levels.

CSIRO/BoM data

Advice received at the time of writing this report confirmed that the release of the anticipated CSIRO/BOM climate dataset had been delayed until at least April 2015. This dataset represents a significant resource and it would be logical to refer to it in future when climate projections are being reviewed.

Comparison with Sydney Airport BOM site

The following summarises the differences between the projected values for extreme temperature, days over 35°C, and extreme rainfall at the two Bureau of Meteorology weather stations within the City of Sydney (Observatory Hill and Sydney Airport).

This comparison was included as recommended by the SRG on the grounds that an analysis based on a single site might not provide give appropriate result for an area as large as the City of Sydney LGA.

Extreme temperature

Sydney Airport is projected to have hotter extremes than Observatory hill. The temperature difference between the two sites increases with the return period.

- Single day maximum.
  - Values at the Sydney Airport site were higher by 1.4°C for a 2 year return period increasing to 2.1°C for a 100-year return compared to the Observatory Hill site.
- Three day average maximum.
  - Values at the Sydney Airport site were higher by 1.1°C for a 2 year return period increasing to 2.4°C for a 100-year return compared to the Observatory Hill site.
- Three day consecutive maximum.
  - Values at the Sydney Airport site were higher by 1.3°C for a 2 year return period increasing to 2.6°C for a 100-year return compared to the Observatory Hill site
- Number of days over 35°C.

- The number of days at the Sydney Airport site over 35°C were between 32 to 40% greater per year than for the Observatory Hill site. Refer to Table 15 ('most consensus' future, with 'least change' and 'most change' following in parentheses).

Table 15 Comparison of projected number of days over 35°C between Sydney Airport and Observatory Hill

BoM Site	Average number of days per year over 35°C			
Year	Baseline	2030	2050	2070
Observatory Hill	3.7	5.8 (4.4-6.2)	8.4 (5.8-9.5)	15 (7.7 – 17.2)
Sydney Airport	5.5	9.5 (7.3-9.9)	12.8 (9.1-14.6)	21.9 (11.7-25.6)

Precipitation

- Single day maximum

  Values at the Sydney Airport site are projected to be lower by between 6 and 12mm for a one in 2 year event through to 159 to 250mm lower for a 1 in 100 year event compared to the Observatory Hill site (ie the Airport is projected to experience the same extreme rainfall event less frequently than Observatory Hill).

  In the most consensus climate future, a 1 in 2 year event in 2070 is projected to be 106mm at observatory hill and 94mm at the Airport. A 1 in 100 year event in 2070 is projected to be 675mm at observatory hill and 426mm at Sydney Airport.

Differences in the projections arise from local climate factors eg summer sea breeze and physical environment around each weather station and highlight how there can be differences even across relatively small geographical areas.

NARCliM data

NARCliM is a high resolution dynamically downscaled climate projected dataset developed by OEH. The dataset contains a 12 model ensemble of regional climate projections for south-east Australia spanning a range of plausible future changes in climate. The release of NARCliM has coincided with the finalisation of this report (8 December 2014) and so it has not been possible to consider the findings of the final dataset in this paper.

RPS were aware the data release may coincide with the project finalisation timeframe, so as a pre-emptive measure liaised directly with OEH to obtain a limited preliminary data to support a quality assessment cross check against the projections generated using SimCLIM. This preliminary data set was supplied in a NETCDF gridded format, not directly compatible with the data format used for SimCLIM and therefore limiting the level of direct comparison with outputs generated in SimCLIM. Specifically, NARCliM data could only be directly compared to the following SimCLIM outputs:

- Temperature:
  - Average mean temp
  - Average max temp
  - Days over 35 (annual average)
  - Long term monthly mean max graph
  - 90th and 99th percentile temperature thresholds

- Precipitation:
  - Average annual precipitation

Notes on differences between data set methodology and inputs

The following provides a summary of the differences between the modelling methodologies and inputs that differentiate SimCLIM from NARCliM.

- SimCLIM uses AR5 IPCC GCMs (2014) while NARCliM uses AR4 GCMs (2007).
- SimCLIM projections use the RCP8.5 emissions scenario from IPCC's Fifth Assessment Report, while NARCliM uses the A2 emissions scenario from the Fourth Assessment Report.
- SimCLIM uses statistical downscaling and NARCliM is dynamically downscaled (different downscaling methods).
- SimCLIM has climate sensitivity as an input variable whereas with NARCliM the climate sensitivity is inherent in the GCM/RCMs used.
- It not possible to compare extreme events between the Generalise Extreme Value (GEV) projections in SimCLIM with the 20 year time series datasets in NARCliM due to differences in statistical methods.
- NARCliM and SimCLIM use different baseline years and periods.
- SimCLIM uses a baseline year of 1995 (1981-2010 = 30 years), whereas NARCliM uses a baseline year of 2000 (1990-2009 = 20 years).
- Data derived from the three sets of 20 year NARCliM data were taken to represent the central year of each data set ie 2000 (1990-2009), 2030 (2020-2039) and 2070 (2060-2079). Outputs corresponding to each of these central years were created by averaging across each dataset respectively.
- The GCMs used in the NARCliM datasets are outlined in Table 16.
- The GCMs used in the SimCLIM projections are outlined in Table 17

Table 16 NARCliM GCM classification

Model rank	Name	Future	Temp (°C)	Precip
11	CSIRO_MK3_5	Hot & dry	2.8	-8%
9	CCCMA_CGCM3_1	Hot & wet	2.4	+7.5
5	MPI_ECHAM5	Warm & dry	2.15	-8%
1	MIROC3_2_medres	Warm & wet	1.75	+10%

Table 17 SimCLIM GCM classification

Climate future	Representative GCM
Least change	MIROC-ESM-CHEM
Most consensus	IPSL-CM5B-LR
Most change	GFDL-ESM2M

Considering the underlying differences in the methods and inputs for generating SimCLIM and NARCliM datasets specifically, the purpose of the comparison of the datasets was to check if there are any differences in projections that might affect any of the risk rankings.

In general the results from the SimCLIM and NARCliM datasets are similar in their direction, magnitude and range of change for all the climate variables. For some outputs there is strong agreement between the datasets while others highlight areas of variation and divergence, particularly for the 2070 projections.

For temperature thresholds over 35°C only the Observatory Hill SimCLIM projections were used as these correspond to the grid cell for which the NARCliM data was extracted.

Temperature

- Average annual temperature projections between the datasets are similar for the baseline and 2030. For 2070 however, SimCLIM projections are hotter by 1.4°C and 1.3°C for the upper and lower limits of the range respectively.
- Average maximum temperature projections between the datasets are similar for the baseline however the SimCLIM projections for 2030 and 2070 are higher than NARCliM by up to 2.5°C for under the "most change" climate future by 2070. Refer Table 18.
- Projections for the average number of 'Days over 35°C' are greater in the baseline in the NARCliM results compared to SimCLIM. SimCLIM projections (4.4-6.2 days) were lower than NARCliM (6.3-10.8 days) in 2030 but higher in 2070 (7.7 – 17.2 days Vs. 8.8 to 14.2 days).
- Monthly maximum temperature projections from NARCliM (Figure 26) are most similar to those generated under the SimCLIM 'least change' climate future (Figure 27). The projection from the SimCLIM 'most consensus' future (Figure 28) points to an increase several degrees higher than NARCliM by 2070.
- The projections for the 90th and 99th percentile temperatures are similar in range between the two datasets but higher in the NARCliM dataset by approximately 0.5°C in both the baseline, 2030 and 2070.

The difference in the higher maximum temperature produced in the SimCLIM dataset is due in part to the different emissions scenarios used. The SimCLIM modelling assumed the RCP 8.5 scenario which involves a faster growth in emissions than the SRES A2 scenario used by NARCliM.

The higher 90th and 99th percentiles and greater number of days over 35°C (2030 only) in the NARCliM data are due to better resolution of the NARCliM data at the coast.

Precipitation

- Annual precipitation projections have the greatest difference between the two datasets. NARCliM gives a greater divergence in projections than SimCLIM in both 2030 and 2070 by about 20%. However, both datasets suggest a possible increase or decrease in precipitation. NARCliM suggests a greater possible increase in precipitation while SimCLIM suggests a greater possible decrease in precipitation. Refer Table 18.

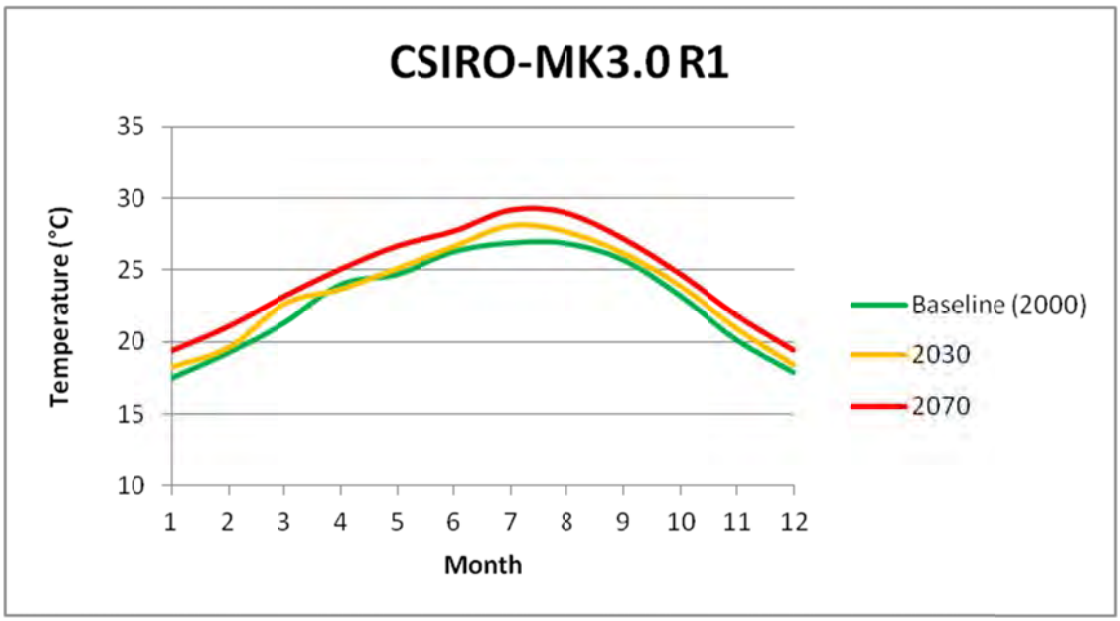
Table 18 compares the results from all of the SimCLIM projections (Observatory Hill) and the NARCliM projections.

Table 18 Summary table of comparable SimCLIM and NARCliM Data

Projection description	Year	SimCLIM (observatory hill)	NARCliM
Temperature			
Average mean temp	Baseline	18°C	18.3°C (17.3-19.5°C)
	2030	19.2°C (18.9-19.8°C)	18.9°C (17.8 – 20.2°C)
	2070	21.1°C (20.4-22.7°C)	20.3°C (19 – 21.4°C)
Average max temp	Baseline	22.2°C	22.8°C
	2030	23.7°C (23.1 – 24.2°C)	23.4°C (23.1 – 23.5°C)
	2070	26.2°C (24.6 – 27.3°C)	24.4°C (24.2 – 24.8°C)
Days over 35°C (average)	Baseline	3.7 (year 1990)	6.8 (5.8 -7.3) (year 2000)
	2030	5.8 (4.4 – 6.2)	8.7 (6.3 – 10.8)
	2070	15 (7.7 – 17.2)	13.1 (8.8 – 14.2)
Long term monthly mean max graph			*Refer Figures 26 through to 28*
90th percentile	Baseline	27.8°C	29.1°C (28.7-29.3)
	2030	29.6°C (28.7 – 29.8)	29.7°C (29.3 – 30.3)
	2070	32.6°C (30.2 – 33.0)	30.8°C (30.5 – 31.4)
99^{th} percentile	Baseline	34.7°C	36.6°C (36.2 – 37.3)
	2030	36.6°C (35.6 – 38)	37.5°C (35.9 – 38.3)
	2070	39.5°C (37 – 39.8)	39°C (37.2 – 39.7)
Precipitation			
Average annual precipitation (mm)	Baseline	1288	1181 (1118 – 1422)
	2030	1230 (1133 – 1343)	1200 (1005 – 1478)
	2070	1138 (885 -1432)	1335 (1065 – 1634)

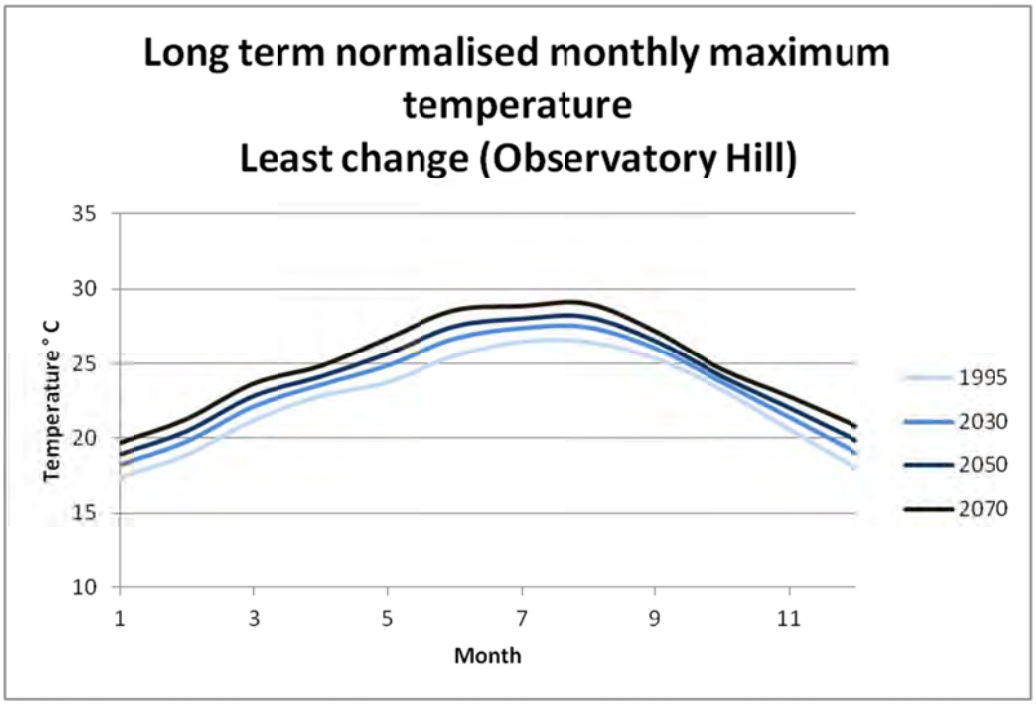
The following graphs show the change in monthly maximum temperature. The NARCliM results (Figure 26) are most similar to those generated under the SimCLIM 'least change' climate future (Figure 27). In comparison, Figure 28 shows a much larger increase (than Figure 26) in monthly mean maximum temperature projections based on the 'most consensus' climate future that has been used across the Project. This variance is due to differences in modelling methodologies and inputs.

Figure 26 Monthly mean maximum temperature projections CSRIO-MK3.0 R1



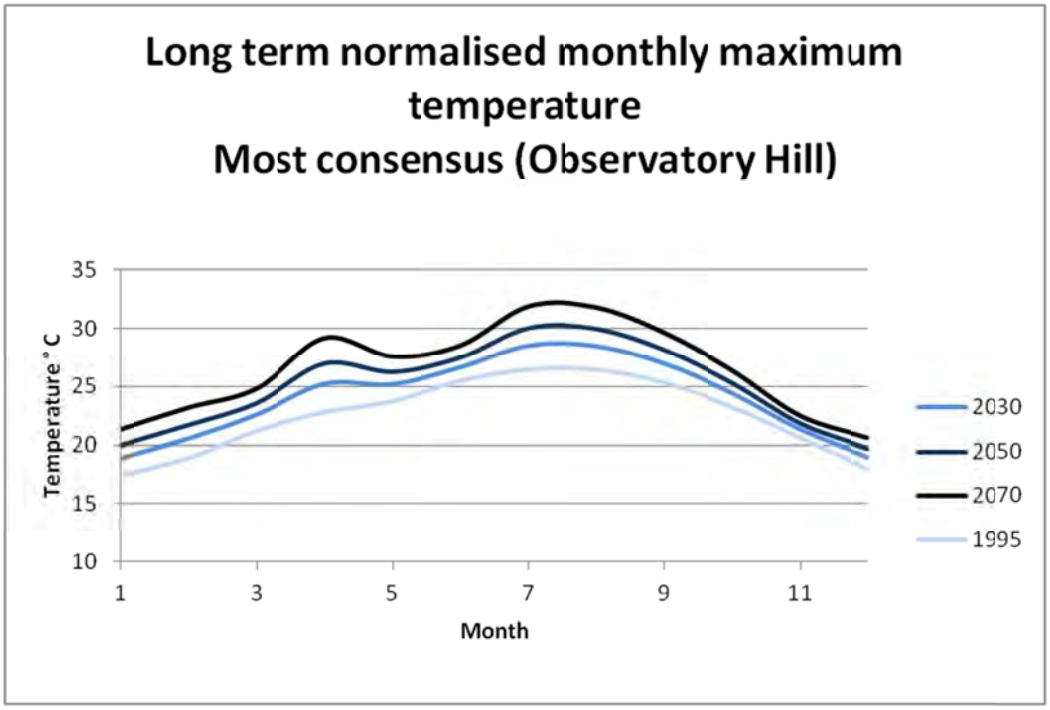
Source: NARCliM preliminary dataset, 2014

Figure 27 Monthly mean maximum temperature projections least change



Source SimCLIM 2013 v3.0.0.1

Figure 28 Monthly mean maximum temperature projections most consensus (SimCLIM)



Source SimCLIM 2013 v3.0.0.1

Summary

The following summarises the data quality assurance review outlined above regarding differences in climate modelling and data.

The OEH 2010 impact profile very closely supports the projected changes in both temperature and sea level rise from the SimCLIM datasets despite differences in methodologies. It reinforces the annual rainfall projections from SimCLIM the which show that models project both increases and decreases in rainfall. It points to consideration of seasonal changes in climate alongside annual changes.

The comparison of extreme event analysis between Observatory Hill and Sydney Airport revealed that Sydney Airport is projected to have slightly higher extreme temperatures significantly less volume in extreme rainfall, especially as the return period of the event increases. Differences in projections arise from local climate factors and show that there can be clear differences in extreme events even across small geographical areas

The preliminary NARCliM dataset supports the direction and range of projected changes in both temperature and precipitation from the SimCLIM dataset, however the SimCLIM dataset projects higher changes in average temperature, particularly maximum temperature, sometimes by over 2°C by 2070 under the 'most change' climate future which is due to SimCLIM being forced with RCP 8.5 emissions scenario. NARCliM projects a slightly higher number of days over 35°C and also higher 90th and 99th percentile temperatures which is due to a better spatial resolution of the NARCliM models at the coast.

Refer to the *Supporting Materials* documentation to view the detailed data analysis associated with the results presented in this section.

Conclusion

The similarity in direction, magnitude and range of results across the SimCLIM, NARCliM and OEH impact profile datasets mean that the City can have confidence in the climate projections used throughout the risk assessment process of the project. The SRG has reviewed both the climate projections used in the risk assessment process as well as the difference between data sets outlined above. They agree that the small differences between the datasets are highly unlikely to have made any material difference to the outcomes of the risk assessment process. They have also informed the development of a climate roadmap for the City to help focus efforts as new or more detailed climate information becomes available.

5.3.2 Climate Science Road Map – where to from here?

The following actions are suggested as a roadmap for how the City might stay up-to-date with future improvements and updates to climate science.

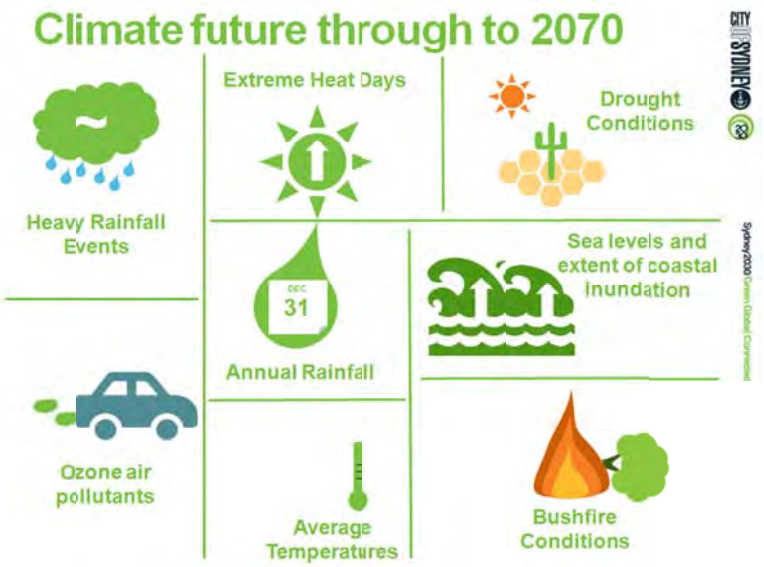
- It is unlikely the projections' broad direction and magnitude of change will need significant update every time a new IPCC assessment report is released. Accordingly it recommended those projections linked to sensitive risks or high consequence impacts are prioritised for review and then considered for remodelling in the first instance:
  - The City should ensure that the risks have been assessed for their sensitivities to even small changes in climate projections eg when a small change in a climate projection could cause a change in the rating of an associated risk from "high" to "extreme". Eg increase frequency of heatwave events results in an increase in the rate of material degradation in infrastructure.
  - The City should ensure that the risks have been assessed for high consequences eg physical damage to infrastructure from coastal inundation exacerbated by sea level rise.
- For projects requiring significant investment, it would be good practice for the City to re-assess the climate impacts for changes resulting from updates to relevant projections to understand the material difference to the associated risk rating (if any), adaptation timing and the suitability of the adaptation option.
- Future work undertaken by the City will need to factor in both changes in projections due to improvements in climate science or modelling techniques, as well as alternative emissions scenarios.
- The next 5-7 years will see a more integrated interface between the climate projections and impact modelling and mapping. For example, research into the health impacts of the heat island effect may be directly linked to projections of frequency heatwave and known hotspots within the city allowing targeted development of heatwave refuges.
- Note: NARCliM will begin to release its own impacts research through the AdaptNSW portal from June 2015.

6 Sydney's future climate

As an additional and supportive component of the climate analysis work undertaken, a desktop assessment to locate an international city whose baseline climate is similar to the climate projected to occur in the City of Sydney by 2070 was initially explored to offer a snapshot of what Sydney can expect to experience in the future.

By 2070 the City can anticipate the following:

- Increase in average temperatures.
- Increase in extreme heat days.
- Increase in ozone air pollutants.
- Decrease in annual rainfall.
- Increase in extreme precipitation events.
- Increase in bushfire conditions.
- Increase in drought conditions.
- Increase in sea levels and extent of coastal inundation.



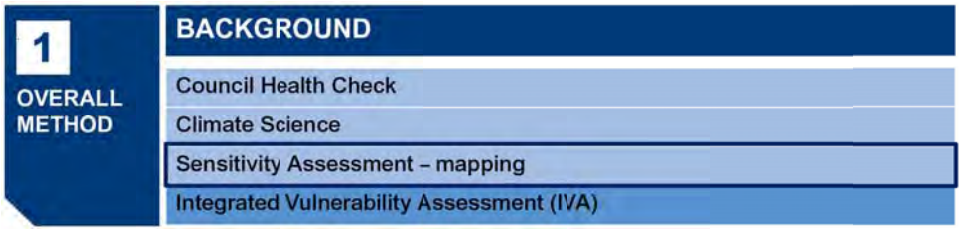
In light of the challenges with undertaking a scientifically robust analysis of this nature particularly around extremes of climate (which are of the most interest), an alternate approach was adopted looking at other coastal cities in temperate zones that experience similar climate impacts to Sydney. Of particular relevance are those cities currently working to build resilience to these impacts. Based on this, Table 19 presents a climate comparison of a selection of cities that are current members of the Rockefeller 100 Resilient Cities (RC) program as they provide a peer-group comparison for the City. They have been selected as not only do they represent similar climate profiles to Sydney, but are grappling with similar challenges as those facing the City and as such strategies and plans released by these cities are likely to provide a valuable resource for responding to climate impacts and may be used for comparison and benchmarking.

Unsurprisingly Australia's only other RC 100 city Melbourne, mirrors Sydney in the nature of challenges likely to shape its future. Following Melbourne, Berkeley, California and Durban, South Africa share similar challenges resulting from the impacts of a changing climate.

Table 19 Current Rockefeller 100 cities with similar challenges to Sydney

City	Country	Drought	Flooding	Sea Level Rise	Fire
Berkeley	USA		●	●	●
Durban	South Africa	●	●	●	
Melbourne	Australia	●	●	●	●
Rome	Italy		●	●	
Rio De Janeiro	Brazil		●	●	

7 Understanding vulnerability and sensitivity



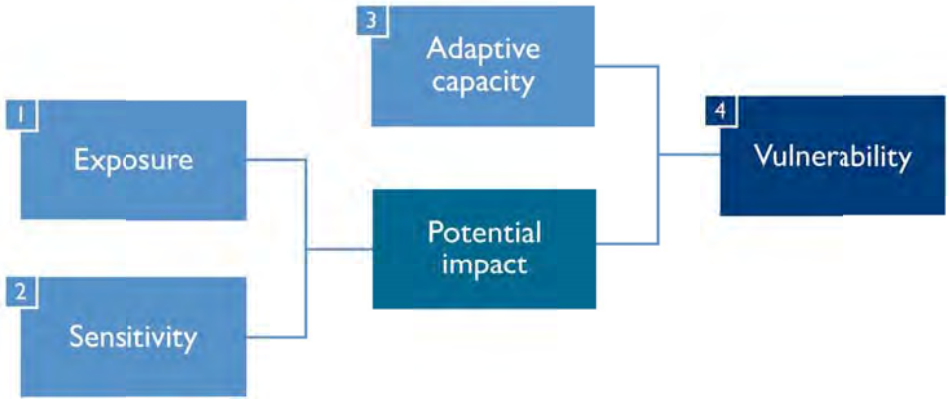
A further component of the Project has been to help the City understand how its vulnerability to a future climate can be assessed. This knowledge will help support the City's wider understanding of future climate events in the LGA and how to plan for these future conditions.

7.1 Vulnerability and resilience – an overview

Vulnerability refers to the degree to which the city is susceptible to changes in the climate and its potential impacts. The components of vulnerability include the combination of the following aspects – exposure, sensitivity and adaptive capacity, coupled with the potential impacts of a changing climate (refer Figure 29).

Undertaking an integrated vulnerability assessment (IVA) aligned with leading practice domestically and/or internationally was not included in the scope for this project. However as part of the project an assessment of the City's economic, social and environmental sensitivity has been undertaken to provide an indication of those areas with the greatest sensitivity across the LGA. The following provides a brief explanation of the concept of vulnerability to support the broader report inputs (ie exposure and sensitivity).

Figure 29 Concept of vulnerability



7.1.2 Exposure (1)

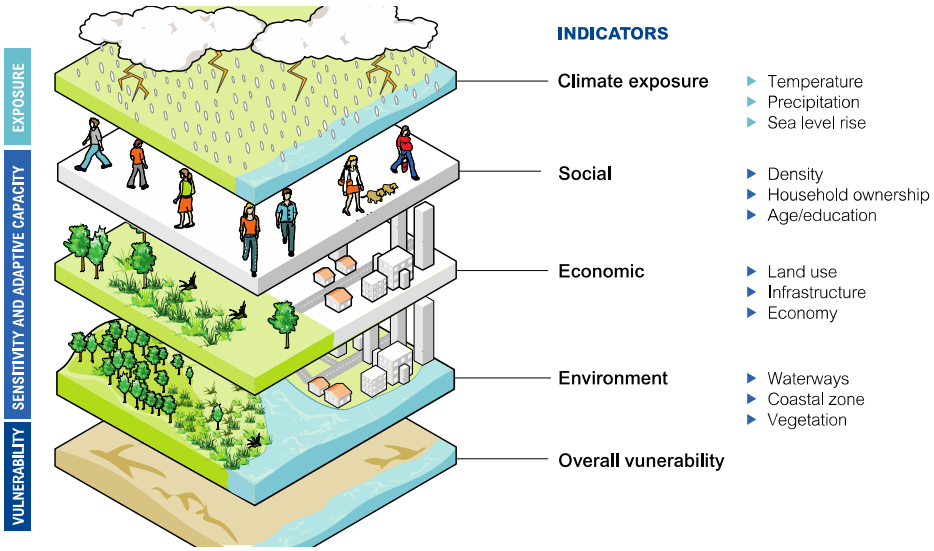
This refers to changes in the climate – temperature, precipitation and sea level. The potential impact is the change in conditions that result in risks associated with heat waves, drought, flooding, wind, hail, storms, bushfires, and coastal inundation. An overview of the climate variables under consideration as part of this project has been presented in this report (refer Section 5).

7.1.3 Sensitivity (2)

This refers to the responsiveness of the City's assets (comprising the community, infrastructure, assets and services) to their physical location and the nature of the surrounding population. The location, condition and makeup of an asset will determine its sensitivity to climate effects. This includes the proximity to low lying coastal areas and the overall typography. Further, a community's ability to respond to climate effects is determined by a range of factors including the age of the population, family structures/composition, financial security, ethnic and cultural background as well as levels of ability/disability.

As part of the project an assessment of the City's economic, social and environmental sensitivity has been analysed and mapped to provide an indication of those areas with the greatest sensitivity across the LGA. Examining these areas of sensitivity allows decision makers to identify important tolerances, trigger points and threshold beyond which the capability of the asset, service and community to function is compromised. Table 20 outlines the indicators used to create each sensitivity layer.

Figure 30 Overview of approach to assessing sensitivity and vulnerability



7.1.4 Adaptive capacity (3)

Adaptive capacity is the potential for an entity (in this case the City) to reduce its vulnerability to climate change risk through adaptation and future management. At an asset level the adaptive capacity is influenced by the resilience of assets to withstand loss or damage or to recover from the impact.

With respect to a city's community it is generally accepted that areas with higher levels of income, education and numbers of professionals can be more equipped to adapt and cope with changes in climate. The socio economic profile of the community interacting, working or living in the city generally influences its adaptive capacity. An area with a high socio-economic community can have a potentially higher adaptive capacity. Adaptive capacity has been a feature of the recent vulnerability assessments undertaken by OEH for the Sydney region, these results are discussed later in this section.

7.1.5 Vulnerability (4)

The overall vulnerability of a city considers the exposure to specific climate, the geographical location and condition of the natural environment and profile of its community. Cities are considered most vulnerable when they have sensitive environments that are populated with communities with low adaptive capacity for certain climate impacts that are projected to become more intense and more frequent.

While a specific vulnerability assessment has not been a part of this project, regionally relevant work in this area has been undertaken. Most recently this is by OEH through their *Towards a Resilient Sydney* program, and historically by Sydney Coastal Councils Group (SCCG) through their *Mapping Climate Change Vulnerability in the SCCG* work again these results are discussed later in this section.

7.1.6 Concept of resilience

Resilience refers to the ability and capacity to withstand, recover and adapt from stress, as such it is a measure of how much disturbance from a changing climate can be absorbed without losing functionality. Understanding the City's vulnerability is important in understanding the potential to anticipate and plan according to projected and current climate events.

The concept of resilience focuses on the elements that reduce vulnerability, whereby, the higher the resilience (the greater effectiveness in recovery), the lower the vulnerability, and conversely, the higher a community's vulnerability, the lower its level of resilience (the lower effectiveness in recovery).

Figure 30 provides an overview of the leading practice approaches, whereby sensitivity indicator layers are combined with the climate exposure data to provide an understanding of the vulnerability of the city. This vulnerability information is then used to inform the adaptation pathways process to ensure material risks as well as sensitivity to those risks are being scrutinized. This approach is consistent with vulnerability assessment methodologies applied by CSIRO and Sydney Coastal Councils Group in *Mapping Climate Change Vulnerability in the Sydney Coastal Councils Region*, Griffith University's *Unsettling Suburbia: The New Landscape of Oil and Mortgage Vulnerability in Australian Cities* and the Local Government Association of South Australia's *Guidelines for Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment*.

7.2 Mapping the City's climate sensitivity

The indicators selected to measure climate sensitivity within the City of Sydney LGA are outlined below in Table 20. The approach to select the indicators has been aligned to the City's Community Indicators 2014 Report and other related documents that use these three pillars of sustainability.

The maps in Figure 31 to Figure 34 indicate where areas will have the highest sensitivity to the projected changes in climate across the LGA.

The different maps show that sensitivity can vary significantly in the same geographical area depending on the indicators or index applied.

These indicators have been selected based on their ability to provide complete coverage of the City; address the climate impacts identified and be represented spatially. While there are a large number of potential indicators for use in each map, the exercise was limited to a maximum of five indicators per map for data sets that were available in spatially distributed form.

These indicators are based on existing data sets that outline the current state, demographics or condition and do not include projected changes in these parameters.

These maps do not reflect actual data boundaries as these maps have all been consolidated into Census data boundaries. This has been done to provide consistency across the three maps, show trends and allow ease of interpretation.

Table 20 Indicators selected to inform the City's LGA Sensitivity Maps

Scope	Key climate impacts for city	Indicators
Social		
Human capital	▪ Increase in heat-related health problems to vulnerable groups ▪ Flash flooding causing damage to buildings and infrastructure ▪ Flash flooding affecting egress from buildings	▪ Levels of home ownership ▪ Median family income levels ▪ Non-English speaking households ▪ Households comprising of people 65+ years old who are living alone ▪ Households comprising children under 4 years old
Environment		
Natural environment	▪ Inundation from heavy rains and storm events ▪ Damage to habitat supporting biodiversity	▪ Vegetation Coverage (canopy cover; parks; priority sites) ▪ Flood extent (1 in 100 year overland flood for LGA) ▪ Drainage infrastructure (kilometres of drainage infrastructure per statistical area)
Economic		
Financial and physical capital	▪ Tourism ▪ Business Productivity losses (Australia's largest business district) ▪ Economic losses	▪ Accommodation capacity (tourism) ▪ Median household income ▪ Number of employees ▪ Households under housing stress ▪ Annual water consumption

7.2.2 Approach/Methodology

In selecting the appropriate indicators for inclusion, data was scrutinised for suitability as a measure of sensitivity within the city and ranked based on current levels of sensitivity to provide an overview for the City. When combined with the climate exposure layers they spatially represent the locations of the potential impact(s) identified in the risk assessment process of the project. When assessed against the adaptive capacity associated with the indicators an indication of vulnerability for the City can be achieved. This later assessment can be carried out in the future when adaptive capacity is analysed.

In the future as new information and data become available (exposure, environmental, economic or social sensitivity) for the City the analysis should be re-run and updated. The analysis undertaken at this time was based on publically available data and therefore is limited to the data that was available at that time.

Methodological issues

As illustrated, vulnerability to climate change is a complicated combination of exposure, risk/impact and sensitivity to climate events that are moderated by local adaptive capacity. It is a new and emerging area of investigation and for the purposes of this project the approach draws heavily upon the Local Government Association of South Australia's *Guidelines for Developing a Climate Change Adaptation Plan and Undertaking Integrated Climate Change Vulnerability Assessment* and the *Integrated Regional Vulnerability Assessment* approach developed by OEH.

Leading practice requires this assessment to be done in a highly interactive manner involving multiple workshops with the community and a range of stakeholders along with council staff, which is both expensive and time consuming. This approach has not been possible for the project and has instead relied on a pre-populated list of indicators being workshopped by RPS and presented for discussion with the City's PCG.

Further, it is noted that there were significant challenges associated with accessing relevant indicators from the City that required an iterative approach to indicator selection and required extensive consultation. This is due to the fact that while the degree of exposure to climate stressors can be readily modelled and mapped, indicators for sensitivity and adaptability require considered choices. Selection is especially difficult when the interpretation of vulnerability is wide, covering a broad spectrum of triple bottom line issues, and must be framed around risk. Currently there is no agreed national protocol or common practice for the selection of indicators.

While a vulnerability assessment has not been undertaken for this project, it is pertinent to note that each of the components required for assessing climate vulnerability have been considered as presented in Table 21 below.

Further, and as noted, both previous and current vulnerability assessment work that considers impacts related to the City of Sydney LGA has been developed, in particular OEH's *Resilient Sydney 2014* (as yet unpublished) and the *SCCG Vulnerability Mapping* work undertaken in 2008. A summary of the findings from these projects is outlined in Sections 7.3.1 and 7.3.2.

Table 21 Considering climate vulnerability for the City of Sydney

Resilience components	Project treatment
Exposure	Climate projections and impact mapping
Sensitivity	Sensitivity mapping
Impact and risk	Risk register and workshops
Adaptive capacity	Review and summary of recent studies
Vulnerability	Review and summary of recent studies

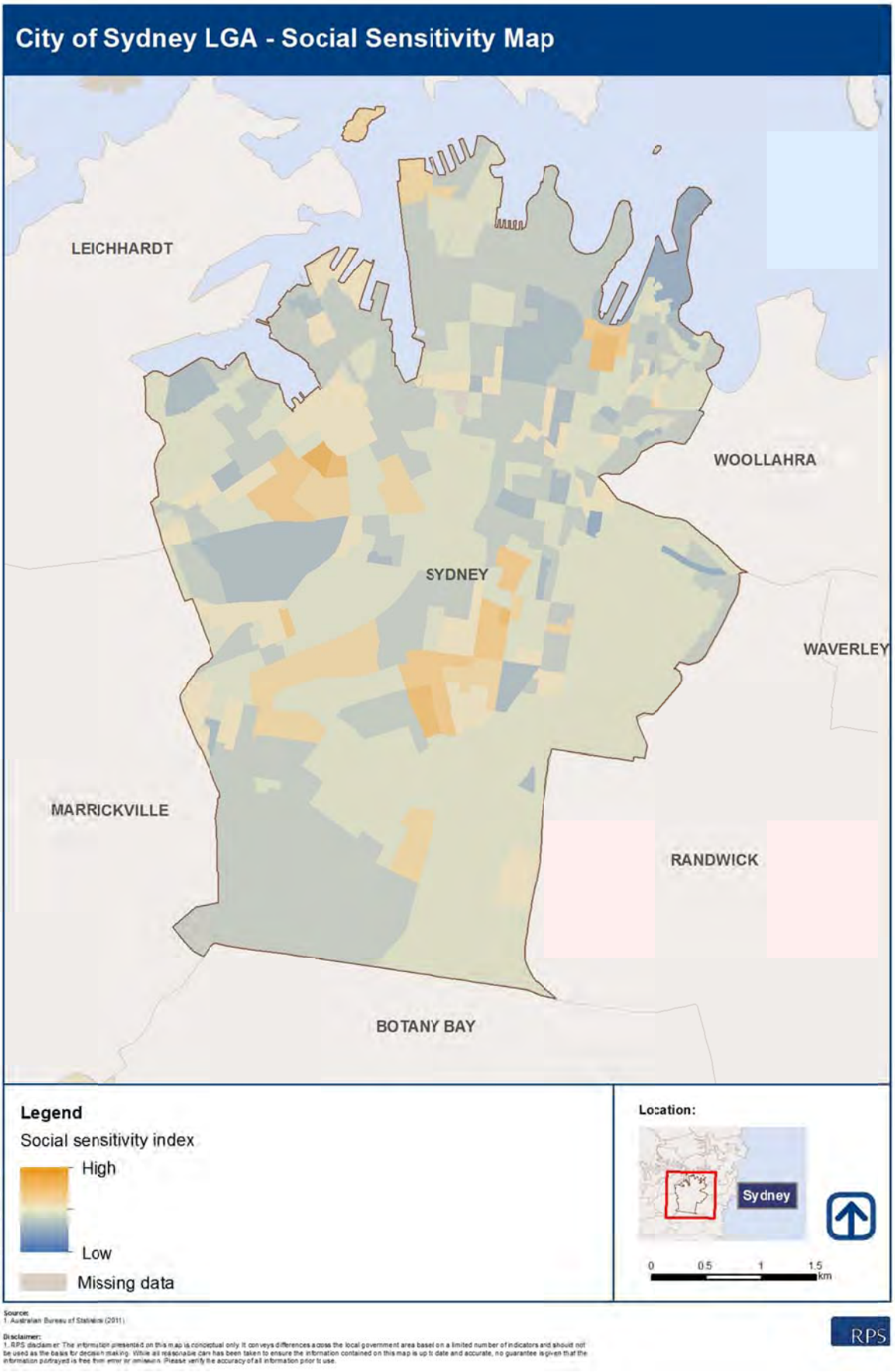
7.2.3 Social sensitivity

The social map (Figure 31) indicates human populations, which potentially have high sensitivity to projected changes in climate. It is comprised of spatially mapped indicators related to:

- Levels of home ownership
- Median family income levels
- Non-English speaking households
- Households comprising of people 65+ years old who are living alone
- Households comprising children under 4 years old

As highlighted through the mapping, populations with high levels of social sensitivity are located around Glebe, Wooloomooloo and Waterloo; conversely those populations with the least social sensitivity are located around Potts Point and Darlinghurst.

Figure 31 Social sensitivity map



Source: Australian Bureau of Statistics, 2011

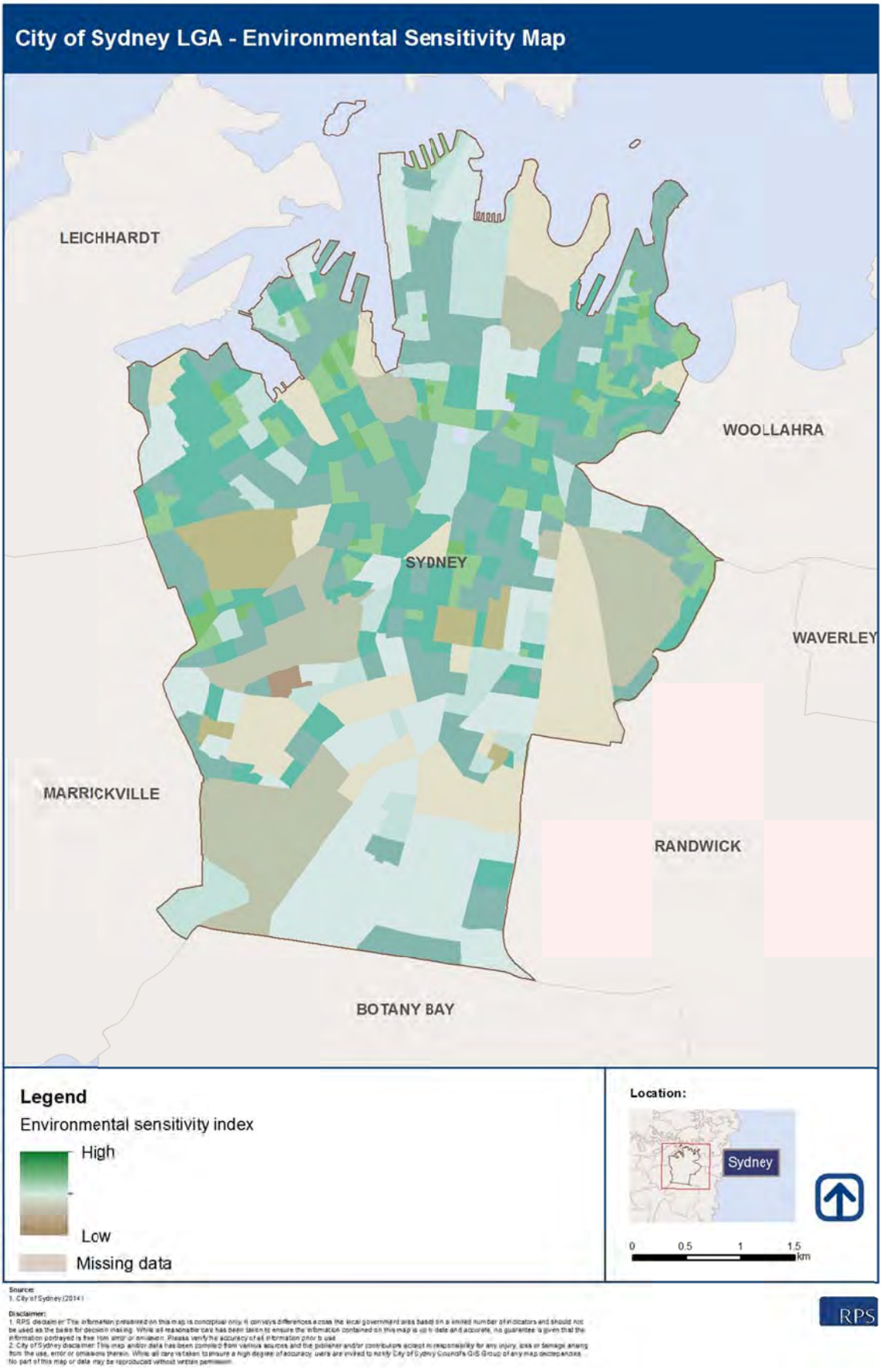
7.2.4 Environmental sensitivity

The environment map (Figure 32) indicates natural systems and conditions, which potentially have high sensitivity to projected changes in climate. It is comprised of spatially mapped indicators related to:

- Vegetation Coverage (canopy cover; parks; priority sites)
- Flood extent (1 in 100 year overland flood for LGA)
- Drainage infrastructure (kilometres of drainage infrastructure per statistical area)

As highlighted through the mapping the areas of highest environmental sensitivity occur in Potts Point, Glebe, Haymarket and Darlinghurst (which has both a high concentration of drainage infrastructure and street trees). While areas of low (least) environmental sensitivity occurs in St Peters and around the Moore Park/Fox Studios.

Figure 32 Environmental sensitivity map



Source: City of Sydney, 2014

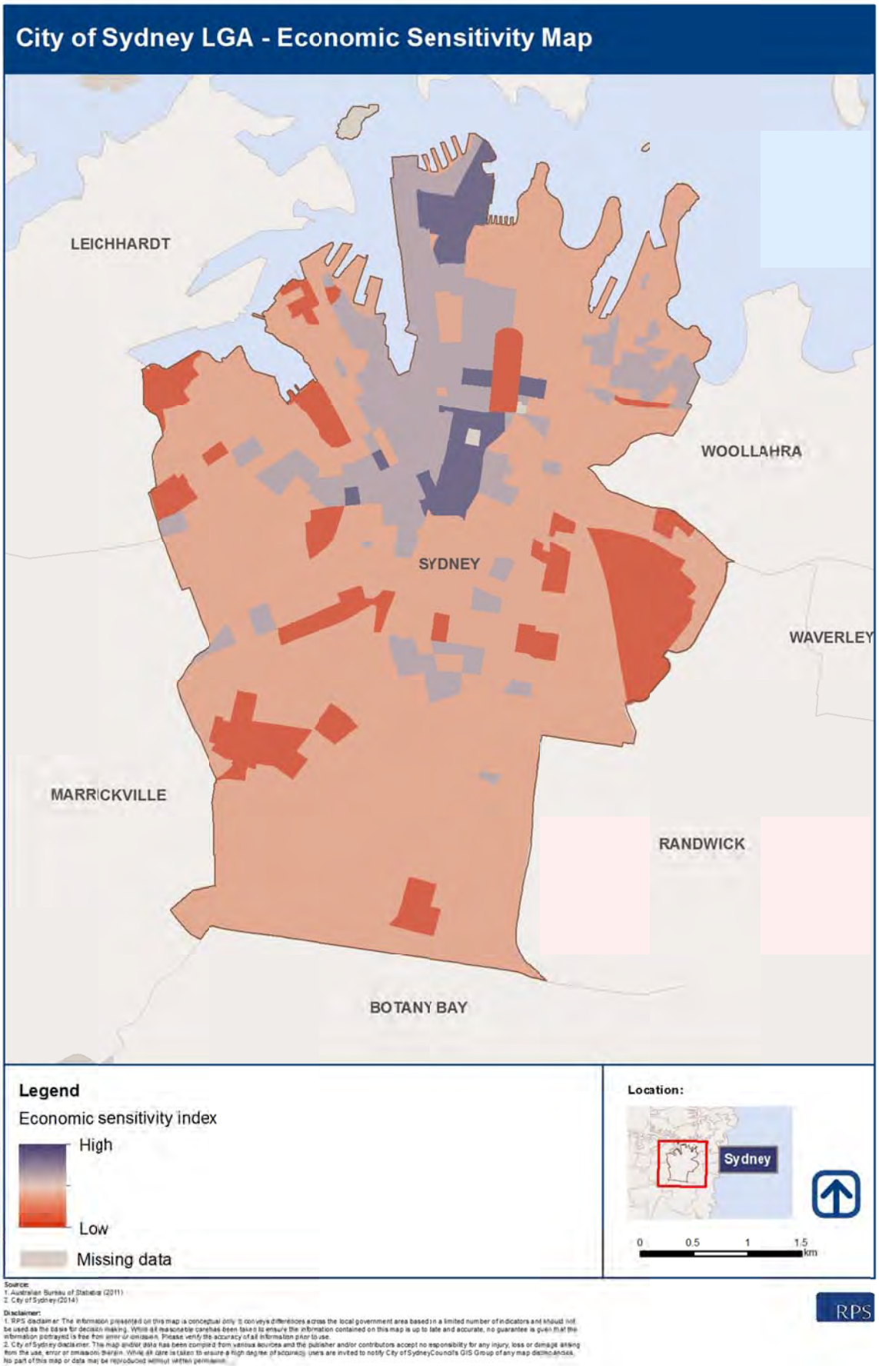
7.2.5 Economic sensitivity

The economic map (Figure 33) indicates economic conditions across the city that potentially has a high degree of sensitivity to projected changes in climate. It is comprised of spatially mapped indicators related to:

- Accommodation capacity (tourism)
- Median household income
- Number of employees
- Households under housing stress
- Annual water consumption

As highlighted through the mapping, the areas of highest economic sensitivity are within the CBD and Haymarket areas of the LGA, with the least economic sensitivity occurring within the open spaces and parklands around the LGA. These findings are to be expected with the concentration of the City's economic infrastructure being located within the centre of the LGA.

Figure 33 Economic sensitivity map



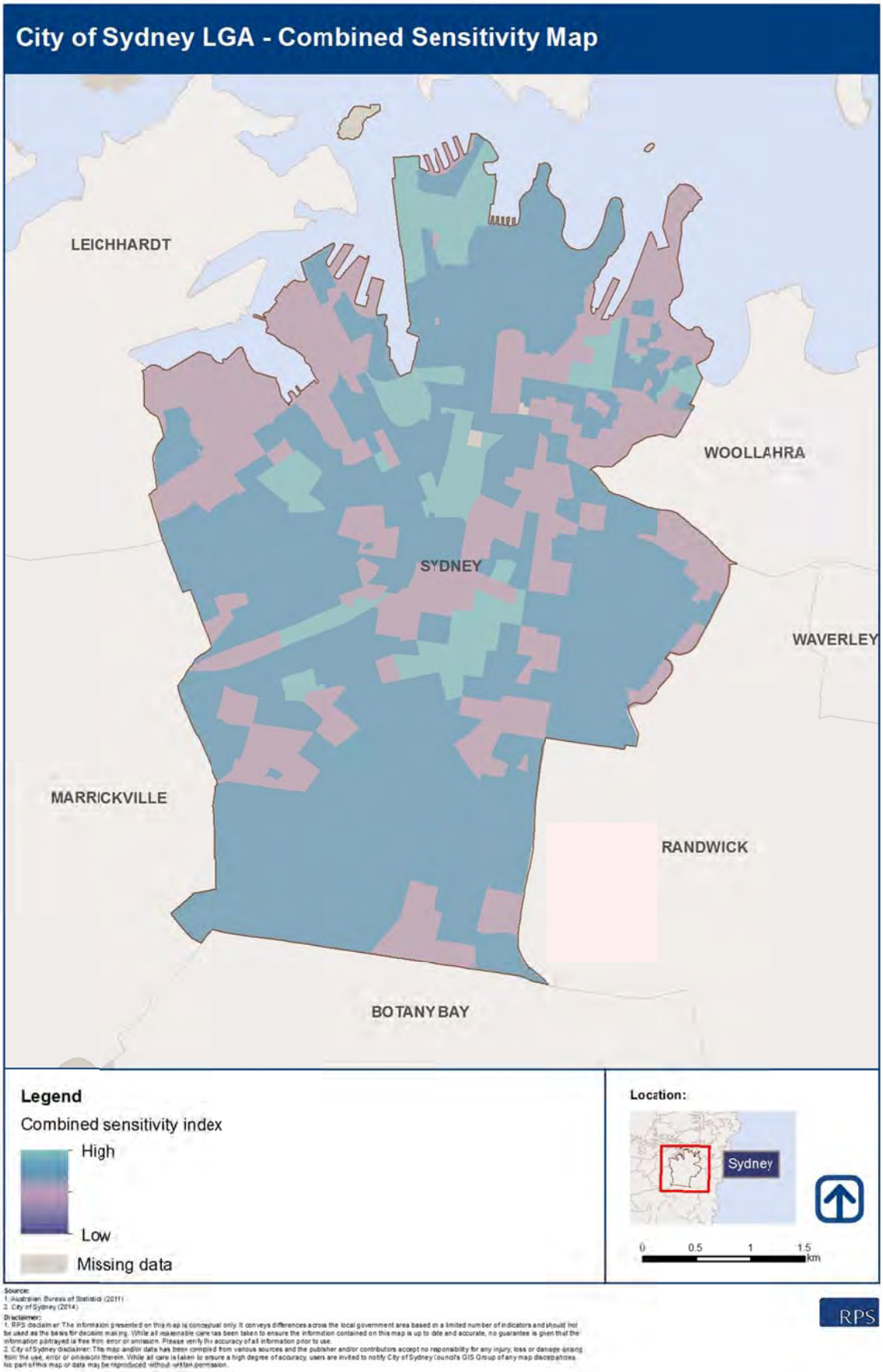
Source: Australian Bureau of Statistics, 2014 and City of Sydney, 2014

7.2.6 Combined sensitivity

In addition to the three discrete sensitivity maps presented above, an additional sensitivity map (Figure 34) has been produced that plots the City's combined level of sensitivity, that is the cumulative social, environmental and economic areas of sensitivity across the LGA.

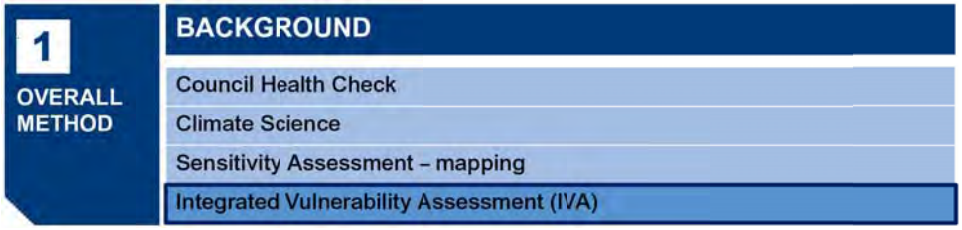
The cumulative findings show the areas of Millers Point, the Rocks, Darling Harbour, Haymarket, Glebe and Redfern to have the highest concentrations of combined sensitivity, that is collectively they have the highest proportions of combined economic, social and environmental sensitivity across the LGA.

Figure 34 Combined sensitivity map



Source: Australian Bureau of Statistics, 2014 and City of Sydney, 2014

7.3 Previous climate vulnerability assessment work



7.3.1 Mapping Climate Change Vulnerability in the Sydney Coastal Councils Group (2008)

Background

The Sydney Coastal Councils Group was formed in 1989 to promote co-ordination between councils on environmental issues relation to the sustainable management of the urban coastal environment. The Group consists of 15 members including

Botany Bay, Hornsby, Leichhardt, Manly, Mosman, North Sydney, Pittwater, Randwick, Rockdale, Sutherland, Sydney, Warringah, Waverley, Willoughby and Woollahra.

As part of the Australian Government Department of Climate Change (DCC) National Climate Change Adaptation Program (NCCAP), the Sydney Coastal Councils Group (SCCG) partnered with the CSIRO working in collaboration with University of the Sunshine Coast to undertake a two-year research project on regional approaches to managing climate vulnerability in the Sydney region.

The goal of the DCC project is to explore this issue of climate change risk management, specifically adaptation, in the SCCG region. Rather than the commonly utilised approach of generating scenarios of climate change and discussing their potential impacts, this project focuses on examining the capacity of the 15 SCCG member Councils to adapt to climate change. This incorporates not only challenges associated with access to financial capital, technology and information to facilitate adaptation, but perhaps more importantly, the institutional processes and barriers that influence the implementation of adaptive measures.

Summary of the process

This report represents the first stage in this project, the assessment and mapping of climate change vulnerability throughout the SCCG region.

Five areas of potential climate impacts were selected for vulnerability assessment:

- Extreme heat and human health effects
- Sea-level rise and coastal hazards
- Extreme rainfall and urban stormwater management
- Bushfire
- Natural ecosystems and assets

In conducting these vulnerability assessments, simple conceptual models identifying the relevant processes and assumptions were developed for each of the above impact areas. These models were subsequently utilised to select a broad range of indicators reflecting the three components of vulnerability: exposure, sensitivity and adaptive capacity. These indicators were integrated within a geographic information system to

facilitate mapping of relative vulnerability and to draw generalisations at the Council level. Results were also compared with the subjective perceptions of vulnerability among SCCG member Council staff.

Summary of findings for the City of Sydney

The results from the vulnerability assessment for the City of Sydney are contained in Table 22.

The results indicate that the City of Sydney generally has a low to moderate range of exposure across all climate hazards with the greatest exposure coming from extreme heat and rainfall and the lowest from bushfire.

The sensitivity to a climate hazard ranges from low through to high with the bushfire the lowest and ecosystems the highest.

The adaptive capacity of the city to climate change is high across all impacts except for ecosystems for which it is moderate.

Despite this the city was found to have high vulnerability to the hazards of sea level rise, extreme rainfall and ecosystems, moderate vulnerability to extreme heat and low vulnerability to bushfire.

Compared to the average across all SCCG members, the city scored worse than the average for vulnerability to sea level rise, extreme rainfall and ecosystems and better on extreme heat and bushfire.

Table 22 – Vulnerability assessment findings for the City of Sydney

	Extreme heat	Sea-Level rise	Extreme rain	Bushfire	Ecosystems	Net
Exposure	6	4	6	1	2	NA
Sensitivity	5	5	8	1	9	NA
Adaptive capacity	3	2	3	2	4	NA
Vulnerability	5	8	8	1	8	7
Average (all councils)	6	5	7	3	7	6

Explanation of scoring

Exposure – High values indicate a relatively high degree of exposure to future climate change while low values indicate low exposure. (Low 1–3, moderate 4-6, and high 7 to 9).

Sensitivity – High values indicate a relatively high degree of sensitivity to future climate change while low values indicate low sensitivity. (Low 1–3, moderate 4-6, and high 7 to 9).

Adaptive capacity – High values indicate a relatively low degree of adaptive capacity to future climate change while low values indicate high adaptive capacity. (High 1–3, moderate 4-6, and low 7 to 9).

Vulnerability – High values indicate a relatively high degree of vulnerability to future climate change while low values indicate low vulnerability. (Low 1–3, moderate 4-6, and high 7 to 9).

General findings of project

The socio-economic circumstances of the SCCG landscape emerge as key drivers affecting future vulnerability. Factors such as demographics, socio-economic conditions, and human agency that influence response capabilities are often equally if not more important than biophysical hazards in dictating the potential for harm.

While the results of a vulnerability assessment provide potentially valuable information, particularly with respect to prioritisation of impacts and areas for further investigation, significant insight and learning about drivers of vulnerability and adaptive capacity can be gained simply through the process of conducting the assessment. Knowledge capture throughout the assessment process is important for maximising the utility of the exercise and improving future research and applications.

There project found that there was significant spatial variability throughout the SCCG region with respect to climate change vulnerability. Depending on the impact under consideration, vulnerability could be highly fragmented or concentrated in certain areas. This suggested the need to tailor management activities to accommodate not only the unique challenges posed by different impacts, but also the diversity of the landscape.

Overall the City of Sydney was identified as having the highest levels of climate change vulnerability alongside the other inner city councils of Botany Bay, Leichhardt, North Sydney, Randwick, and Rockdale.

This demonstrates that urban landscapes are not necessarily immune to the effects of climate change. On the contrary, unless carefully managed, the greater the magnitude of population, wealth, assets and infrastructure, the larger the target for climate hazards.

7.3.2 NSW Government's Integrated Regional Vulnerability Assessment of Sydney

The first step of adaptation planning is to understand the vulnerability of a region so that actions to reduce it can be prioritised. The NSW Office of Environment and Heritage (OEH) has developed a process that uses local knowledge to identify potential threats and possible options for responding to a changing climate across multiple sectors. This cross-agency initiative is called an Integrated Regional Vulnerability Assessment or IRVA. To date IRVAs have been applied to five State planning regions, covering 75% of NSW local governments and 64% of the NSW population.

An IRVA identifies the impacts of climate change on social, economic and biophysical systems and their capacity to adapt to climate change. Local and State government decision makers are engaged to understand the dynamic interactions that are going on within their sector and where sector may have (unanticipated) impacts on other sectors. It also allows participants to identify areas where there are common risks or vulnerabilities between sectors so they can address these issues in a coordinated way.

Towards a Resilient Sydney

The *Towards a Resilient Sydney* project draws on a leading target of the NSW government's ten year plan NSW 2021 to minimise impacts of climate change in local communities.

The Plan aims to meet actions contained within three regional action plans for the Northern Beaches, Western Sydney/Blue Mountains and South Western Sydney in order to:

- Develop improved information of climate risks for Sydney
- Assess cross sectoral vulnerability to these risks
- Identify responses and opportunities that assist local communities to improve resilience and minimise impacts

IRVA for Metropolitan Sydney

The Sydney IRVA was a key process of the *Towards a Resilient Sydney* project. It engaged close to 300 local and state government decision-makers across a range of sectors (natural and cultural assets, human services, infrastructure and the built environment, industry and economy, and emergency management) to assess the impacts of climate change on Sydney's social, economic and biophysical systems, and their capacity to adapt.

The Sydney IRVA integration workshop held on 31 March 2014 at the NSW Trade and Investment Centre with more than 80 State and local government (including the City of Sydney) decision makers from the sector workshops returning to validate and prioritise Sydney's core vulnerabilities. Participants worked in cross-sectoral groups to collectively develop a series of cross-government projects that could minimise impacts and increase resilience in the Sydney region. Feedback indicated a collective sense that adaptation is as much about capturing opportunities as it is about moderating harm.

The six key vulnerabilities to the provision of government services in Sydney, were identified and ranked by the participants as limited perception of climate risks; insufficient consideration of climate change in planning processes; challenges in directing funding to adaptation; pressure from population growth on human settlements; pressure on natural resource supply and security; and, inadequate skills and knowledge to understand and respond to climate impacts.

For further information see:

- Brent C. Jacobs , Christopher Lee , David O'Toole , Katie Vines (2014*) Integrated regional vulnerability assessment of government services to climate change.International Journal of Climate Change Strategies and Management 20146:3 , 272-295*
- Jacobs B., Boronyak L., Dunford S., Kuruppu N., Lewis B. and Lee, C. (2014) *Towards a resilient Sydney – supporting collective action to adapt sub national government services to regional climate change. Proceedings of the 3rd International Conference on Climate Change and Social Issues, p12-14, Colombo, Sri Lanka. ISBN: 978-955-4543-24-9*

8 Science Reference Group

8.1 Overview and remit

A considerable value add outside of the project brief was the establishment of a Science Reference Group (SRG) to provide scientific rigour and robustness as well as independent advice and technical oversight to guide the Project's delivery.

The specific remit of the SRG was to provide overarching advice and feedback on technical deliverables at strategic points during the project. Specifically they have provided input and oversight during specific meetings associated with:

- The methodology and approach for undertaking the climate exposure modelling for the City: held 27 July 2014.

  It was on recommendation by the SRG that the quality assurance check against additional climate models was undertaken (refer Section 5.3).

- The risk assessment process and more specifically the development of adaptation actions and pathways: held 3rd December 3rd December 2014.

  The SRG have provided valuable insight and comment on best practice risk assessment and adaptation pathways approaches.

As it was not possible during Meeting 2 to provide feedback to the SRG on how their Meeting 1 recommendations had been addressed, a 1-hour tele-conference was held on the 15th January 2015 to discuss these points and further explore the implications of the release of NARCliM and the pending release of CSIRO's Climate Futures.

Additionally the SRG have expressed a request to be included in the distribution list for the recipients of the final version of this report. This will enable further comment and recommendations on developing the CAP to be provided directly to the City.

8.2 SRG representation

In order to deliver maximum project value the composition of the SRG sought to assemble some of Australia's leading climate change science and resilience experts. The members of the City of Sydney SRG are presented in Table 23 below. Details of the SRG inputs are provided in the *Supporting Materials* documentation.

Table 23 Technical members of the City of Sydney SRG

Name	Company	Role
Chris Lees	NSW Office of Environment and Heritage	Senior Team Leader Impacts and Adaptation: Regional Operations Group
Dr Mark Stafford Smith	CSIRO Climate Adaptation Flagship	Chair, Science Committee
Prof Tom Wigley	University of Adelaide, University Corporation for Atmospheric Research (UCAR)	Professor, Climate Science

Name	Company	Role
Dr Bob Webb	Climate Science Institute, ANU	Program Leader, Leading Adaptation Practices and Support Strategies Australian National University
Agata Imielska	Bureau of Meteorology	Senior Climatologist
Olivia Kembler	The Climate Institute	National Policy and Research Manager

It is noted that the members of the SRG have generously provided their input in a pro-bono capacity. As such they have acted in an oversight capacity and do not formally endorse the approach and/or findings of this report. Similarly, while reference to recommendations or support provided by the SRG is noted (as relevant) throughout this report the, SRG are not accountable for any decisions made by the consultant project team and/or the City of Sydney based on these insights.

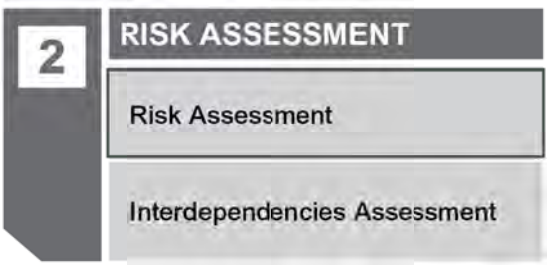
9 Climate risks and interdependencies

In applying a broader resilience lens, an assessment of 50 of the world's most important cities has been recently completed and has examined the vulnerability of cities to climate change as well as four other factors including environment and resource capacity. Under the climate change theme key climate related risks covered vulnerability to sea level change, hurricanes and typhoons, wildfires, floods, droughts and the mass movement of population. Overall this research ranked the City of Sydney 19 out of 50 as being the most resilient city in the world, behind London at 18, New York City at 14, City of Melbourne at 13 and Toronto at number 1. Toronto's top ranking can be partly attributed to their proactive response to climate risk planning and preparedness. Since 2007 Toronto has been addressing climate risk at a city-wide leadership level right down to a city divisional level.

Grosvenor 2014 Resilient Cities – A Grosvenor Research Report

9.1 Risk assessment approach and key climate risks

KPMG undertook the Project's climate risk and interdependency assessment to identify the key climate risks facing the City. The approach has been informed by the 'most consensus' climate future through to 2070 based on the climate exposure modelling and mapping presented in Chapter 5. Specifically, the following summarises the climate future for Sydney through to 2070 that have been used as the basis of the risk identification process.



- Increase in average temperatures.
- Increase in extreme heat days.
- Increase in ozone air pollutants.
- Decrease in annual rainfall.
- Increase in extreme precipitation events.
- Increase in bushfire conditions.
- Increase in drought conditions.
- Increase in sea levels and extent of coastal inundation.

An overview of the process undertaken to identify and confirm a total of 32 risk identification statements (Risk IDs) is provided in this section. Each of the risks has been ranked and evaluated using a risk assessment process aligned within the risk register determining their likelihood and severity. The methods used have been broadly guided by the principles contained within *AS/NZS ISO 31000:2009 Risk management – Principles and guidelines, AS 5334 – 2013 Climate adaptation for settlements and infrastructure – A risk based approach, Australian Government's Climate Change Impacts and Risk Management – A Guide for Business and Government* as well as the City of Sydney's own risk management system. The assessment was performed for each risk statement for the current period and 2030 (except for sea level rise which was 2070) resulting in risk ratings being assigned to each risk based on their likelihood and severity on the most relevant success/risk criteria.

The following comprises a breakdown of risks relative to areas of climate exposure:

- 12 x climate risks associated with temperature.
- 3 x climate risks associated with sea level rise.
- 6 x climate risks associated with precipitation.
- 11 x combined risks recognising that a number of risks facing the city are comprised of a confluence of risks ie bushfire risk is compounded by both extreme temperature and reduce precipitation levels.

Table 24 Climate risk statements for the City of Sydney

Risk	Risk ID	Risk statement	Explanation of risk
Extreme temperature			
Heat – energy system strain	T1	Extreme heat could put strains on the energy system, simultaneously decreasing system efficiency and performance of the energy network as system operators struggle to cool down facilities, and increasing electricity consumption due to a surge in peak demand for air conditioning.	This risk addresses heat waves and their ability to reduce the operating capacity of the City's power system and increase demand for cooling for offices in the CBD and residential properties. As a result demand can outstrip supply causing power outages. This risk may also increase water demand for cooling towers.
Heat – workforce productivity	T2	An increase in extreme heat and associated impacts could reduce workforce productivity, as activities become too hot for people to work outside during parts of the day and the indoor thermal comfort is affected by pressures on cooling.	This risk addresses heat waves and their associated impacts such as poor air quality that reduce the productivity of staff. Workplace health and safety requirements require heat exposed staff to have breaks or not work if extremes temperatures are experienced. This risk also captures the loss of productivity due to: ▪ People's roles as carers for dependents and volunteers which takes them away from their usual role. ▪ Transport disruptions preventing or delaying travel to and home from work. ▪ Disruptions to the transport of goods and services that are essential for businesses. ▪ Evacuation of buildings due to failed HVAC systems.

Risk	Risk ID	Risk statement	Explanation of risk
Heat – community health impacts	T3	An increase in extreme heat could lead to higher incidents of heat stress and other related illnesses amongst the community resulting in a decrease in comfort levels and an increase in hospital admissions, pressure on social services and morbidity.	This risk addresses the ability of heat waves to increase incidents of people seeking medical attention due to heat stress. This is mainly seen in sensitive populations such as the elderly, lower socio-economic groups, Culturally and Linguistically Diverse (CALD), sick, tourists, disabled, homeless, young children, exposed workers and companion animals. This increases strain on emergency and social services supporting this sensitive population due to increases in demand coupled with a decrease in staffing resources (refer to T2).
Heat – changed human behaviour	T4	An increase in extreme heat could lead to negative changes in behaviour in particular increases in violence and anti-social behaviour leading to an increase in demand for emergency and social services.	This risk addresses that heat waves can increase the incidents of anti-social activity, particularly during the evening. Incidents of domestic violence, street crime, fire bug activity, social isolation and suicides increase when extreme temperatures are experienced, putting strain on emergency and social services in both the short and long term. Additional behavioural responses may include increased night activity, dress and working arrangements and hours.
Heat – city wide power disruption	T5	An increase in extreme heat could lead to power supply disruptions from programmed load shedding and heat damage to network infrastructure.	This risk addresses heatwaves and their ability to both reduce the capacity of the network and cause direct damage to power supply infrastructure, causing brownouts and blackouts. It also covers the proactive load shedding performed by energy utilities to protect the network. This is turn reduces the reputation of the City in having a reliable power supply for its community and visitors.
Heat – traffic congestion:	T6	An increase in extreme heat could lead to changes in commuter behaviour opting to use private vehicles to access the CBD (rather than public transport) to avoid potential delays and discomfort resulting in increased congestion.	This risk addresses how heat waves can change human behaviour leading to an increase in the number of people who choose to travel by air conditioned car rather than take public transport. This is also influenced by delays caused to rail networks caused by power outages.

Risk	Risk ID	Risk statement	Explanation of risk
Heat – heat island effects	T7	An increase in extreme heat could exacerbate areas that already experience urban heat island within the CBD leading to precincts that are too hot to utilise.	This risk demonstrates that heat waves will further increase the heat intensity of roads and buildings within the CBD. Areas that experience heat island will be avoided by people who seek refuge in areas that are cooler such as parks. (Refer to T1, T2 and T5 for risks associated with increased energy demand, lost productivity and the need to cool building).
Heat – transport disruption	T8	An increase in the extreme heat could lead to increases in heat impacts to transport infrastructure – resulting in congestion, major delays and mass transit disruption with potential stranding of commuters.	This risk addresses heat waves that can cause direct damage to transport infrastructure, reducing the capacity of the network, service delivery within the CBD and causing delays/stranding of commuters. This is turn reduces the reputation of the City in having a reliable transport system for its community and visitors.
Heat – air pollution	T9	An increase in extreme heat and associated bushfire smoke could exacerbate the conditions for ozone and air particulates which cause an increase in incidents of respiratory distress resulting in an increase in hospital admissions and morbidity.	This risk addresses heat waves that exacerbate conditions for the production of air pollution from ozone and bushfire smoke particulates, increasing the number of people seeking medical attention for asthma and other breathing difficulties. There is also a potential impact on the appeal of outdoor lifestyle which has reputational impacts for the City.
Heat – reduced physical activity	T10	An increase in extreme heat and associated air quality impacts may result in reduced appeal for physical activities such as walking, cycling and other outdoor activities due to the increased risk of heat stress and dehydration associated with outdoor exercise in these conditions.	This risk addresses heat waves and their associated air quality impacts such bushfires and ozone decrease the number of people who choose to partake in physical activities such as walking and cycling. (Refer to T2 for risks associated with workforce productivity associated with outdoor work).
Heat – strain on heat refuges	T11	An increase in extreme heat and associated air quality impact may increase demand for refuge areas for respite putting strain on available resources.	This risk addresses the impact that during heatwaves and high pollutant days, people seek refuge in shopping, community centres, shaded parks and pools. This would impact on the Council and other resources needed to operate such facilities.
Heat – structural degradation	T12	An increase in extreme heat may accelerate the degradation of concrete structures and softening of pavements leading to rectification requirements.	This risk addresses the impact that extreme and changed heat conditions can have on accelerating the deterioration of structures and building facades.

Risk	Risk ID	Risk statement	Explanation of risk
Sea level rise			
Sea level – inundation of property/infrastructure	S1	Rising sea levels, coastal inundation and saltwater intrusion could increase financial burden for maintenance and protection and threaten the financial value and viability of many properties and infrastructure along the Sydney Harbour foreshore and low lying areas in the south of the LGA.	This risk addresses the issue that property located along the harbour foreshore could be impacted by permanent inundation and saltwater intrusion. This may include homes, businesses, coastal assets and open space areas such as parks and gardens. This risk also highlights the issue of disclosure of properties within hazard zones and the conditions of consent for development in these areas.
Sea level – inundation foreshore icons	S2	Rising sea levels and coastal inundation could have the potential to reduce the accessibility and aesthetics of the City's iconic cultural and tourism precinct (eg Sydney Opera House forecourt, Circular Quay and public amenities such as the Royal Botanical Gardens). This includes the potential erosion of places of indigenous cultural or community significance along the Sydney Harbour foreshore.	This risk addresses the fact that the harbour foreshore areas that contain some of Sydney's most significant cultural and tourism sites and amenities could be impacted by permanent inundation and saltwater intrusion. There is potential that impacts to the foreshore may also impact events hosted in this area such as Vivid and New Year's Eve celebrations.
Sea level – Inundation foreshore transport/pedestrian routes	S3	Rising sea levels and coastal inundation could limit transport access and egress both directly along the foreshore areas and across the wider transport network.	This risk addresses the issue that transport and pedestrian routes and interchanges located in coastal zones and their connected networks could be impacted by permanent inundation (This may include transport networks located outside of the LGA which are dependent on the network). This may include ferries, pathways, Sydney Airport, roads and rail.
Extreme precipitation			
Intense rainfall – displacement	P1	An increase in intense rainfall and hail events may result in damage to properties, causing displacement and disruption of the community, businesses and other activities while clean-up and recovery occurs.	This risk addresses how heavy rainfall and hail can cause extensive property damage and city-wide disruptions to services and amenity. In the short term this may increase the need and cost for emergency housing or shelter, rebuild skills, disaster relief and social services. In the longer term this may impact productivity and reputation.

Risk	Risk ID	Risk statement	Explanation of risk
Intense rainfall – property/infrastructure damage	P2	An increase in intense rainfall, wind and hail events (in combination or isolation) may result in damage to property resulting in increased clean-up efforts.	This risk addresses the ability of heavy rainfall, wind and hail in combination or isolation, causing extensive damage to property: ▪ Infrastructure (ie power lines, street lights, embankments). ▪ Buildings (ie homes, PV installations and stations). ▪ Trees (ie street trees). ▪ This increases clean-up efforts, disposal and maintenance costs. Past events have also shown that this risk can result in an opportunity for skilled labour to repair and rebuild. (Asset damage focus)
Intense rainfall – flash flooding:	P3	An increase in intense rainfall has the potential to cause flash flooding from overflow of stormwater drainage creating hazardous conditions for the community.	This risk addresses heavy rainfall that can cause storm water drainage systems to back up and cause localised flash flooding of roads, public spaces and property. This may result in an increase in localised traffic congestion, vehicular and pedestrian accidents, as well as loss of parking spaces in low lying areas and basements.
Intense rainfall – localised power infrastructure damage	P4	An increase in intense rainfall and high winds in combination or isolation, may result in damage or inundation of power infrastructure (gas and electricity) and vital equipment resulting in power interruptions.	This risk demonstrates that powerful storm activity can bring down power lines and flood power substations and vital equipment located in basements causing extensive black outs and service interruptions across the City including transport This risk extends beyond the LGA where the power is sourced and transmitted.
Intense rainfall – overflow contaminants	P5	An increase in intense rainfall has the potential to cause an overflow of the sewerage system and first flush of stormwater systems creating hazardous water quality conditions downstream.	This risk addresses the issue that heavy rainfall can cause overflows of sewerage and storm water systems releasing contaminants which may be hazardous to local waterways and public health. (NB CoS does not have first flush).

Risk	Risk ID	Risk statement	Explanation of risk
Decreased precipitation			
Decreased rainfall – reduced amenity	P6	A decrease in annual precipitation leading to drought conditions could result in reduced water availability for gardens and open space areas, resulting in reduced scenic/social amenity and limited recreation and respite areas.	This risk addresses the issue that due to drought conditions water restrictions maybe be imposed limiting the amount of irrigation available for open space areas (also private gardens). This may result in: ▪ The hardening of playing surfaces increasing risk of injury and liability. ▪ Reduced availability of playing fields and informal recreational areas. ▪ Loss of the cooling properties of open space zones and respite areas. ▪ Degradation of areas of natural beauty. This has flow on effects on physical and mental health.
Combined risks			
Pests and disease	C1	An increase in mean temperatures combined with changes in rainfall patterns could increase the suitability of environmental conditions that support the spread of pest species (such as weeds and mosquitoes) and disease (including pandemics).	This risk addresses the fact that conditions may become more favourable for the increased spread/migration of pest species and disease with the potential to impact human health and biodiversity. Impacts may include: ▪ Decline in water quality (blue green algae). ▪ Degradation of urban forests. ▪ Strain on emergency and health services (including management of insecurity and food health risks), in response to an outbreak of disease in the community.

Risk	Risk ID	Risk statement	Explanation of risk
Safe sea transport	C2	An increase in atmospheric conditions that favour the formation of east coast low pressure systems could cause an increase in intensity of rainfall events and high winds which have the potential to increase storm surges and disrupt ferry, cruise ship and freight logistics entering and operating within Sydney ports.	This risk addressees how the east coast low pressure systems can cause high seas resulting in: ▪ Grounding of or damage to freight ships (including oil tankers) resulting in environmental impacts within Sydney Ports. ▪ Disruption of ferry services with flow-on impacts for the broader transport network. ▪ Disruption to cruise ships docking in Sydney Harbour impacting tourist trade and reputation of Sydney as a safe tourist destination.
Bushfire – cascading impacts	C3	An increase in bushfire weather conditions across the Greater Sydney Region could lead to business interruption and economic loss within the LGA due to interrupted accessibility in and out the City and strain on resources and services.	This risk addresses bushfires continuing to cause extensive property and infrastructure damage across the Greater Sydney Region with cascading impacts on the LGA, including: ▪ Damage to the transport network delaying or stranding CBD workers. ▪ Limited availability of emergency response and social services within the CBD due to transfer of capacity to regional disaster zones. ▪ Decrease in tourism due to reduced appeal of attraction on Sydney's fringe. ▪ Reduced productivity and economic loss due to CBD workers and LGA workforce taking leave to volunteer or defend property. ▪ Contaminated water supply.
Reduced appeal outdoor events	C4	A decrease in annual precipitation levels coupled with higher daily maximum temperatures could reduce the viability of daytime outdoor events due to a strain on water resources and increased heat stress amongst patrons during warmer months.	This risk addresses the issue that outdoor events may become unattractive to people during summer periods due to extreme heat conditions that increase the risk of UV exposure and dehydration. Equally, the attraction of partaking in activities at night and during cooler months may increase due to warmer temperatures.

Risk	Risk ID	Risk statement	Explanation of risk
Insurance affordability	C5	An increase in extreme weather events such as bushfires and flooding could decrease the affordability of insurance premiums due to increased losses resulting in increased costs and reduced cover.	This risk addresses insurance which may no longer be affordable if the frequency and intensity of extreme weather events continues to grow across Australia. This may have implications for development controls, building codes and standards, liability insurance, disaster relief funding and investment in adaptation controls as the community seek alternate means to compensate for or reduce losses.
Food security	C6	An increase in frequency and intensity of extreme weather events may reduce the productivity and availability of local produce supplies for the City's food retailers, cafés and restaurants.	This risk addresses how a combination of extreme weather may reduce the production of local fresh produce which is grown in the Sydney Basin, community gardens and the wider (national and international) food supply chain. This in turn may impact the availability and affordability of food for the local community.
Airport delays	C7	An increase in frequency and intensity of extreme weather events may increase delays in flights in and out of Sydney Airport.	This risk addresses an increase in frequency and intensity of extreme weather events (ie heat waves coupled with bushfire smoke, hail storms and storm surges) can all cause major disruptions to flights arriving and departing from Sydney Airport due to reduced safe operating conditions and the potential inundation of the runway.
Changed biodiversity	C8	A decrease in annual precipitation coupled with extreme heat days could result in environmental degradation of open space and local biodiversity loss.	This risk addresses how extreme conditions (ie extreme heat and drought conditions) will cause reduced water flows, dieback of vegetation including trees and grass as well as loss of local biodiversity.
Communication disruption	C9	An increase in frequency and intensity of extreme weather events may lead to ICT equipment disruptions resulting in loss of vital equipment and telecommunications.	This risk addresses extreme weather events causing direct damage to power supply and telecommunication infrastructure, reducing the capacity of the network and causing blackouts. This is turn reduces the delivery of ICT services such as vital equipment for emergency management building management, access to data and telecommunications.

Risk	Risk ID	Risk statement	Explanation of risk
Financial viability*	C10	Future climatic conditions could impact on financial viability of council and LGA	This risk addresses a number of future climate conditions which could impact on the Council's financial viability (its capacity, capability and overall resilience) to withstand climate events.
Increased storms causing disruption*	C11	An increase in frequency and intensity of extreme storm events may lead to ICT equipment disruptions resulting in loss of vital equipment and telecommunications.	This risk addresses extreme storms including high winds that could damage assets and disrupt services in the City.

**Note C10 and C11 represent additional Risk IDs which were identified and suggested by RPS following completion of the risk consultation process. It is suggested that C10: Financial viability and C11: Increased storms causing disruption address a gap in the climate risk refinement process following the completion of stakeholder consultation.*

9.1.2 Boundary setting

The first step in the risk identification process included identifying those climate risks directly impacting the City within the LGA boundaries as well as those which may occur outside having cascading consequences on the City. In addition, the climate risks also span temporal boundaries ranging from the present day through to 2070, presenting the challenge of thinking over 50 years ahead. Furthermore, the boundary and assessment spanned the full sphere of Council's influence from its employees and assets through to the wider NSW economy and supporting critical infrastructure (Refer to Figure 35 for an outline of the City's sphere of influence).

A core objective of the risk assessment process was identifying the major climate risks reflecting those issues of most relevance when considering the projected future state of the City. The focus of this process has been considering broader economic, environmental and social impacts rather than micro scale issues.

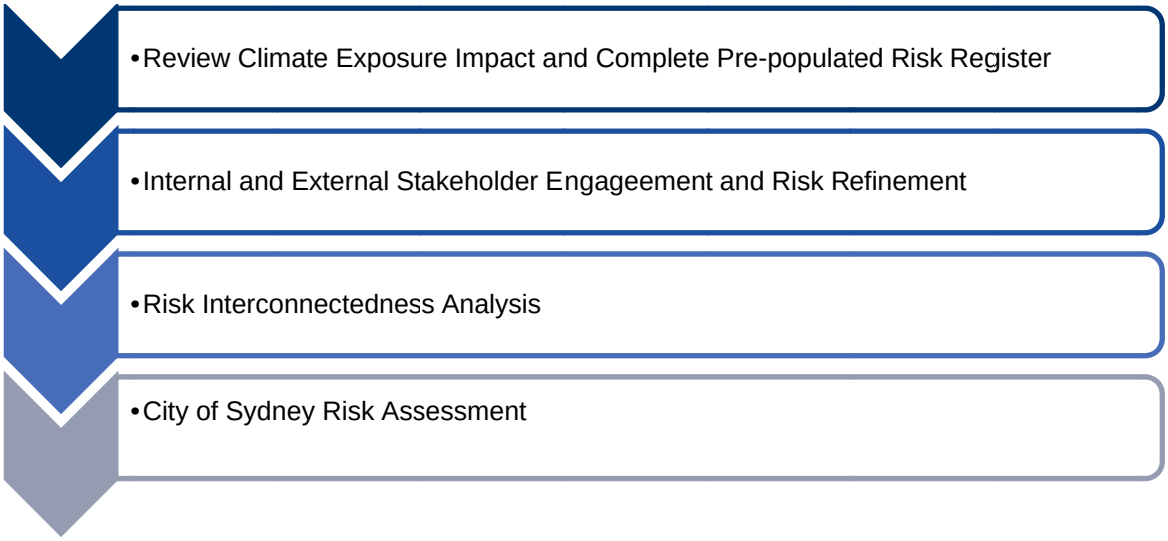
Figure 35 Outline of the City's sphere of influence

9.2 Risk identification process and methodology

The following outlines the risk selection process that was undertaken in order to achieve a consolidated list of core climate risks to present to Council's relevant internal and external stakeholders. The task of identifying the risks was approached with the aim of achieving a list of approximately 20 consolidated risks which would be refined or supplemented by internal and external stakeholders' input at the risk workshops. **The decision to limit the number of consolidated risks was informed by KPMG** (as they noted workshopping larger numbers of risks have been known to inhibit effective workshop engagement and increase the participants' burden in survey completion) **and the City's expectation to have a smaller number of consolidated risks** identified (rather than large number of granular risks).

A total of four steps have informed the risk identification process undertaken to assess and establish the City's level of climate risk, these are identified in Figure 36 below.

Figure 36 City of Sydney Climate Risk Assessment – process and stages



9.2.2 Compilation of pre-populated risks ahead of consultation

In order to identify the core risks for the City, the identified climate futures and climate modelling were reviewed to highlight those climate impacts specific to the City. This information, combined with the consultant project team's subject matter expertise were used to identify a draft list of climate risks for the LGA which were further developed by examining other respected listings, research and commentary on climate risks. This additional research included:

- **Desktop review of risks from existing climate adaptation projects** conducted by climate resilience experts within the project team to enable their aggregated knowledge and experience to inform the identification of risks relevant to the City.
- **Desktop scan of climate risks and challenges identified by leading global cities including**:
  - New York City, USA.
  - Rotterdam, Netherlands.
  - London, UK.
  - Jakarta, Indonesia.
  - New Orleans, USA.
  - Hong Kong, Hong Kong.
  - Tokyo, Japan.
  - Ho Chi Minh City, Vietnam.
  - Copenhagen, Denmark.
- **Analysis of outputs and learnings from the Rockefeller Foundation's 100 Resilient Cities Program, ICLEI and the C40 Cities Climate Leadership Group**.

Selecting risks for inclusion

In determining whether a risk identified in the reviewed documents was suitable for consideration and incorporation into the list of core risks to present to the City's stakeholders the following were considered:

- Is the climate driver for the risk identified in the benchmarked city relevant to the climate futures projected for the City of Sydney?
- Does the geomorphology, geology and landscape within the LGA make this risk likely? (For example: vertical land movement, bushfire and riverine flooding were deemed not to be relevant for the LGA due to the landscape).
- Does the nature of the built environment within the LGA make this risk likely? (For example: degradation of protective sea walls is not a relevant risk for the City as it does not have this infrastructure).
- Do any other studies, research or publically stated opinion indicate that a risk is not relevant to the LGA? (For example: Sydney Water identify that water scarcity will not be an issue for the Sydney region due to effective demand management, the construction of desalination and water recycling plants and increases in dam capacity).

Where there was uncertainty regarding the relevance of a specific risk for the LGA, it was included in the initial risk list to be challenged and validated in the stakeholder engagement process (eg traffic congestion driven by commuters opting for private vehicles to avoid potential delays in public transport/discomfort associated with walking or cycling).

For each of the risks identified, risk statements were developed using a cause-effect statement, which describes what may happen as a result of changes in the climate. In summary this involved:

- Identifying the relevant climate effect (eg an increase in extreme heat).
- Identifying the risk associated with the climate effect (eg lead to power disruptions).
- Identifying the consequence of the climate risk across the City (eg load shedding and heat damage to network infrastructure).
- Developing a risk statement based on the previous steps (eg an increase in extreme heat could lead to power disruptions from programmed load shedding and heat damage to network infrastructure).

Following the development of the draft risk statements, the list was reviewed against the City of Melbourne's climate risk register to identify any additional risks of relevance to the City of Sydney. City of Melbourne's was chosen as it was identified by the client as the city against which they benchmark themselves and represents the most progressed Australian Capital City on climate change adaptation.

The process of drawing on the learnings and experience of other major cities to inform the risks for the City of Sydney, in combination with validation and analysis by expert stakeholders allows for greater certainty to be achieved regarding the completeness and validity of the risks identified.

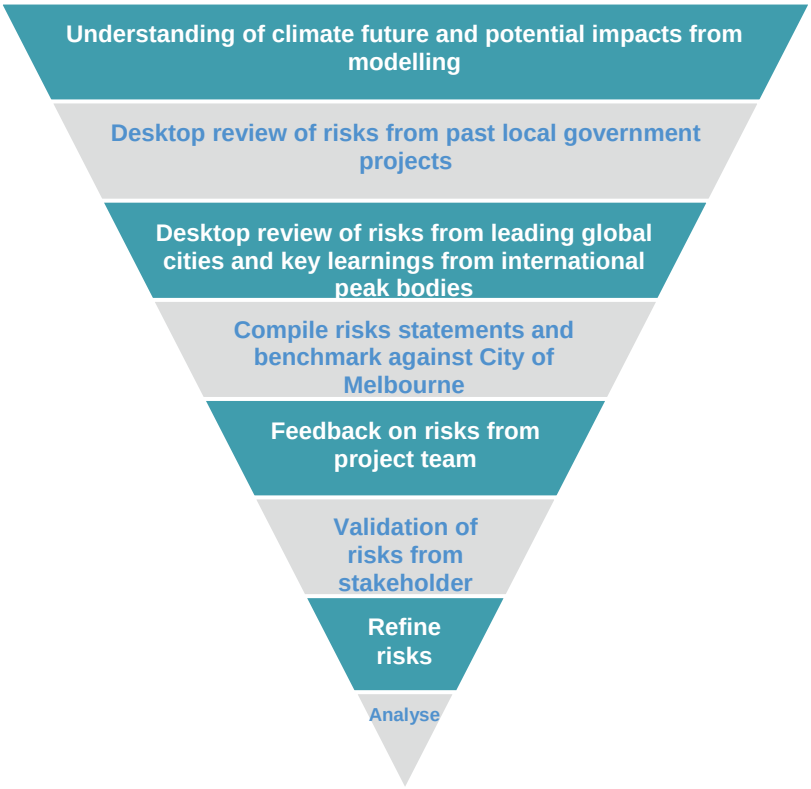
On completion, the initial list of draft risk statements was circulated to the following groups for review, refinement and feedback:

- Internal advisors with expertise in climate change and risk.
- RPS Group.
- The City's project team, including Council's Risk Manager.

This process identified a number of additional risk statements for consideration and resulted in a revised draft list comprising 25 climate risks which were then distributed to internal and external participants prior to the stakeholder workshops to initiate thinking on climate risk prioritisation.

While the City's preference has been to limit the number of risks to better focus action and response, a decision was made not to further consolidate the revised draft list of climate risks (ie: down to 20), to maintain the integrity of the risk assessment process. Figure 37 below, summarises the process flow for identifying climate change risks for the City.

Figure 37 Overview of risk identification process with the level of risk refinement increasing with each step leading to the risk analysis



9.2.3 Stakeholder engagement and risk refinement

Internal and external workshops

An overview of the City's climate future across the LGA through to 2070 and the associated draft list of climate risks were presented to internal and external stakeholders as part of a series of engagement workshops. These workshops sought to prepare and challenge participants in order to test and validate the draft set of climate risks identified and empower participants to consider these climate risks in a systemic way so they could then prioritise them for the City.

During the workshops participants also discussed existing control strategies to address the risk and were briefed on the methodology to prioritise these risks using a post-workshop survey.

The risk workshops were designed by KPMG and RPS to engage participants in the risk analysis process, the broader climate resilience strategy and to capture expert knowledge on the climate change risks facing the City. For most stakeholders this was their first introduction to the project so developing a stakeholder understanding of the importance of the project to the City and the value in their participation was a key objective.

Two risk workshops were held:

- 1 x 5 hour internal stakeholders workshop comprising internal representatives from Council including subject matter experts representing a cross section of Council divisions and business units. The workshop was held on 7 August 2014 with 32 participants.
- 1 x 5 hour external stakeholders representing selected utilities, state and federal departments, peak bodies and private asset owners and services that play a critical role within the LGA. The workshop was held on 11 August 2014 with 33 participants.

***Note**: The City of Sydney was responsible for the selection and invitation of participants. A full list of participants who attended the workshops can be found in the Supporting Materials documentation.*

Each workshop was structured around three sessions that were critical to capturing stakeholder knowledge. The sessions comprised:

- **Climate futures and risk prompting –** this session sought to familiarise the participants with what the climate modelling indicated the future climate for the City may look like, which is the key to the identification and verification of climate risks. Additionally the session sought to prompt thinking about how risk is perceived and managed. Specifically that the past is no longer a predictor of the future and that risks cannot be managed in silos as they are interconnected.

  The main queries raised in both stakeholder sessions related to:

  - Heat wave data, with specific reference to how the 2011 heat wave event fits within the climate futures presented.
  - Why ozone pollution was a risk for the City when mapping showed biggest impact in south western Sydney.

  The second part of the session – designed to stimulate participants to think about risk interconnectedness, generated a mixed response from participants. Participants were deeply engaged with the ideas and concepts presented, with discussions continuing into the break that followed the session amongst the participants and facilitators.

- **Risk Verification –** this session sought to validate (and modify where required) the set of draft risks identified for the City. Internal stakeholders were also asked to assign risk criteria, based on the City's definitions (financial, sustainability, service delivery, people, cultural heritage, reputation and image, and legal and compliance) for each risk.

  Despite the different format, stakeholder type, and level of subject matter expertise between the internal and external working groups, the themes and responses to questions emerging from both the groups were very similar. These included:

  - Can any of the risks be removed or combined?
  - Is the level of risk stated appropriate for the City?
  - Are there any risks missing?
  - Can the risk statements be modified to better articulate the risk.
  - All risks are likely to have financial and reputational impacts on the city.
  - Interdependency between the City and the greater Sydney region.

  Using the feedback and amendments from stakeholders, final review by the City, and additional gap analysis risk statements identified by RPS, a total of 32 key climate change risks were tabled for the City of Sydney as included in Table 24.

- **Identification of existing responses, thresholds and accountability –** the purpose of this session was to identify existing responses (and costs where possible), thresholds and accountabilities for each risk.

  Both the internal and external stakeholder working groups were challenged by the task of identifying specific existing responses and thresholds for the risks. The groups identified a number of actions taken both internally by the City and by State Government agencies that could be interpreted as 'controls'. Where possible, specific policies, standards and legislative frameworks were identified. Due to the nature of the controls identified (mostly policy based); no material data was collected on the costing related to the controls.

  As with the risk identification session, based on feedback from stakeholders, the number of risks allocated to each group at the external workshop was reduced (5 groups, each looking at 4 risks) and the majority of discussion shifted to a plenary format. This resulted in a higher level of engagement from participants and the identification of more specific controls and thresholds. This outcome also reflects the specific subject matter expertise within the external group.

  Both stakeholder groups identified more than one entity with accountability for risk. This reflected earlier findings from the risk identification session, confirming nearly all risks have flow-on impacts to the broader community and economy.

Following the workshops, a number of participants provided additional information to Council on specific thresholds and controls which were incorporated into the risk register.

The complete slide pack from both risk engagement sessions is provided for reference in the *Supporting Materials* documentation.

An additional feedback session was held with internal stakeholders to present and test the findings of the risk analysis that were developed using an online survey questionnaire prepared by KPMG (refer following section). Participants were shown how the connection between risks and clustering of risks allows for more effective and efficient identification of grouped adaptation responses for the future stages of the project.

9.2.4 Risk interconnectedness analysis

The ability to identify and cluster risks based on the impacts they have on related infrastructure, assets and services demonstrates a leading practice approach to climate risk assessment and adaption planning. This was supported by feedback from the SRG during its second meeting (3 December 2014), where it was noted that understanding risk interconnectivity is a common gap in adaptation planning, even amongst those councils leading practice in this area. The following presents the approach and findings for the risk interconnected analysis.

Risk profile survey

The purpose of the survey was to capture the collective thinking of expert stakeholders on the likelihood, severity and connectedness of the climate risks for the City. All participants involved in the internal and external stakeholder workshops were invited to participate in a risk profile survey using the draft climate risks validated during the engagement process. Of the 64 stakeholders who attended both workshops, 33 responded to the survey. Participants were asked to provide their view on the following attributes for each of the risks:

- **Severity** – this attribute was surveyed over two timescales (present day and 2030). For risks related to sea level rise, the time horizons surveyed were present day and 2070.
- **Likelihood** – the same timescales used to consider severity of risks.

- **Connectedness** – how one risk can lead to and influence other risks. To reduce the burden of survey completion, these questions were only asked over one timeframe.

Severity and likelihood for each risk were measured using a simple five point scale (Very High, High, Medium, Low, Very Low). Connectedness was measured by identifying the risks that are most pertinent to either increase or decrease the severity or likelihood of the risks being assessed.

Some queries and concerns were raised by stakeholders during the process of responding to the survey and the KPMG and RPS project team subsequently met with the Sustainability Director , Manager Risk And Assurance and Business Planning and Performance Manager to answer queries they had regarding the methodology used in the risk assessment process and to present them with the results of the analysis. This meeting was largely driven by concerns raised by internal stakeholders. Feedback from the individuals attending the meeting and the City's Project Manager indicated that these concerns had been addressed and that the client was satisfied with the outputs from the actuarial driven analysis.

Risk analysis session

In addition to the internal and external workshops, as stakeholder engagement session was held to socialise the findings of the risk analysis amongst internal stakeholders and capture feedback, comments or concerns regarding the nature of the results. This feedback was not used to modify the findings of the risk analysis but rather to provide a commentary from the perspective of internal stakeholders to compliment the results and aid more detailed climate risk assessment by the City in the future.

Systemic risk analysis tool

Approach/Methodology overview

KPMG applied actuarial techniques to analyse the survey data and determine the collective thinking of the stakeholders with respect to the risks identified in the workshop. This analysis demonstrated priority risks (based on severity and likelihood) and the perceived relationships between risks, including the dependencies and in some cases directional relationships between risks.

Material assumptions underlying the actuarial analysis include:

- Only complete responses were included in the analysis to reduce the potential for bias within the results.
- No weightings were applied to individual responses (ie each response was treated equally when determining the aggregate view of respondents).

Some care is needed in interpreting the results of the survey as the results are not intended to reflect a statistical estimate of the impact of specific climate risks to the City. Rather the analysis is intended to provide a snapshot of the perception of internal and external stakeholders who the City identified as experts with knowledge covering the relevant business areas, who have been informed about the potential climate challenges facing the City. To assist with providing more robust results, the City selected stakeholders that represent a diverse range of individuals across key external entities and internal Business Units. It is noted that the approach adopted is consistent with the principles used in the World Economic Forum Global Risk Report, and discussed in '*The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*' written by James Surowiecki

(published in 2004), and more recent economic research. This allows a more targeted approach to adaptive action to be undertaken as part of the next stage of the project.

The survey analysis was applied to the total of 33 completed survey responses comprising 16 x external stakeholder responses and 17 x internal stakeholder responses. This represents over half of workshop attendees.

Risk analysis findings

The relevant climate risks that impact the City of Sydney can be identified based on a number of criteria; severity, likelihood and interconnectedness. Based on these criteria, the findings in Table 25 below capture which risks have been identified as important by the participants in the survey.

Table 25 Summary of climate risk analysis findings

Risk Aspect/Feature	Finding	Importance
Most central risks	The most central risks in terms of causing other risks were Energy System Strain, City Wide Power Disruption and Air Pollution.	Strong risk management controls are required for highly connected risk, as losses for these risks can trigger losses on a large number of other risks.
Most likely and severe risk	In addition to being perceived to be one of the most likely and severe risks in 2014, Community Health Impacts is also expected to be the most likely and severe risk in 2030.	This risk is expected to have a large impact and is also considered likely to occur.
Risk Clusters	Three risk clusters were identified: Heat Wave Behaviour Related Risks; Intense Rainfall Related Risks and Sea Level Rise Related Risks.	Risk clusters are groups of risks that have been identified by the survey participants as particularly strongly connected and therefore should be considered in combination for risk management purposes. It is noted that the risk clusters contain risks within the same climate change driver (group). It is noted that the sea level rise related risks requires less management focus with weaker connections and risks that are individually less severe and likely.
Analysis by Climate Driver	Risks driven by heat waves and intense rainfall are considered to be the most severe and most likely risks.	Identifying the climate change driver in relation to the key risks impacting the city is important so that appropriate risk adaptation can be undertaken.

The analysis sought to understand the interdependencies between the climate change risks. Figure 38 (overleaf) uses the survey responses to graphically present the relationship between the risks and perception of severity for current state 2014. The graph is also able to demonstrate those risks which are central to causing other risks, and those that are most centrally effected by other risks. The relative inter-connectedness for a pair of risks is determined by the number of respondents in the survey who indicated there was a connection between that pair of risks. The relative severity of a risk is determined by taking the average (the qualitative responses are mapped to a number first, then an arithmetic average is calculated), over all responses.

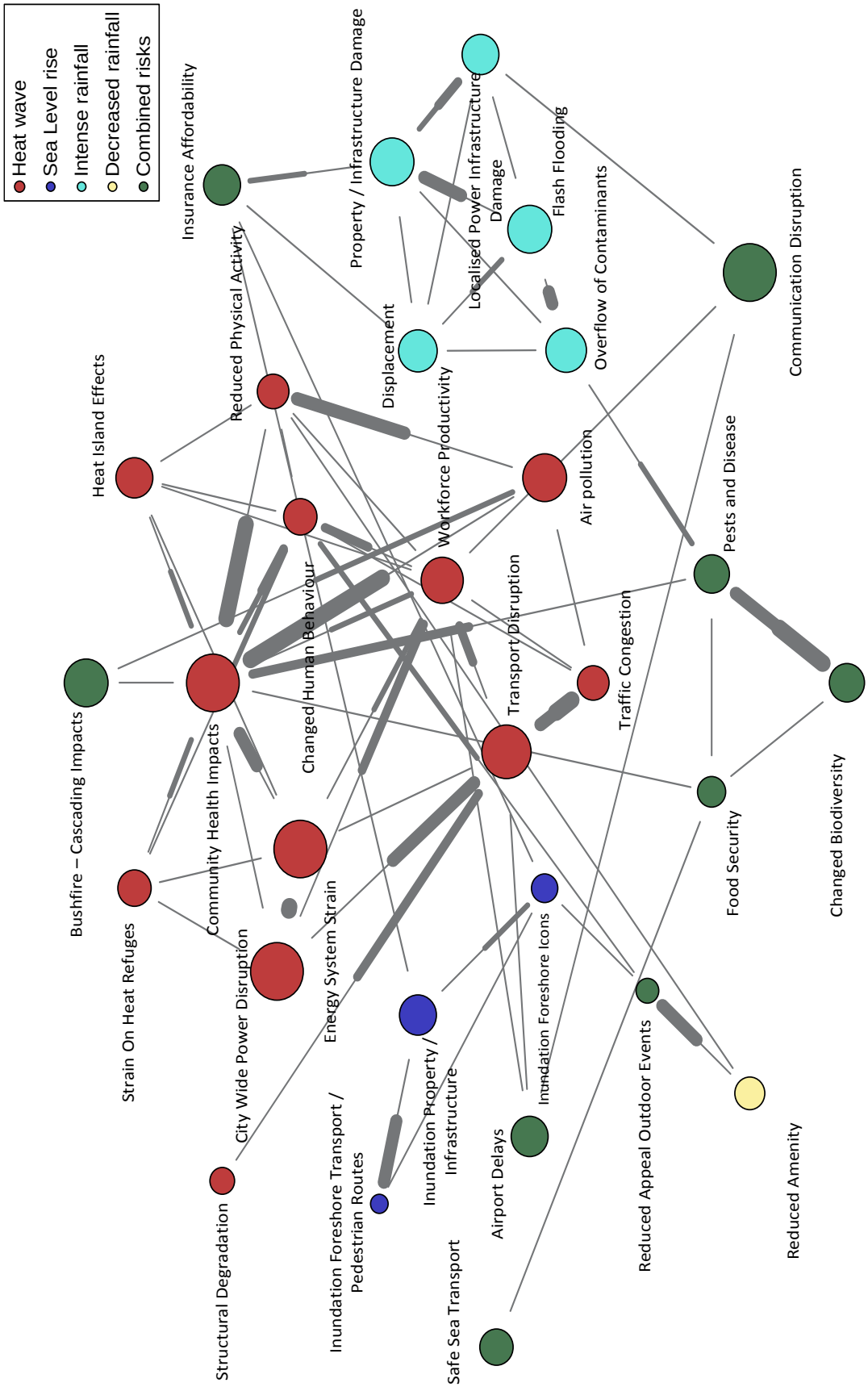


Figure 38 Systematic interconnectedness of climate change risks

How to interpret the connections

A thin line shows risks that are related. A thick line indicates a risk that makes the originating risk worse. For example, respondents indicated air pollution is the most pertinent risk to make reduced physical activity (middle right) more likely or potentially worse.

The diagram is able to demonstrate those risks that are most related to the risk network in terms of causing other risks (cause), and being impacted by other risks (effect). The top five cause and effect risks are summarised in the Table 27.

Another benefit of portraying information this way is that it enables an easy way to identify clustered risks as shown in Figure 39. Risk clusters are groups of risks that have been identified by the survey participants as particularly strongly connected. These risks should be considered together for risk management purposes.

Risk clusters are determined by analysing a number of factors, including the strength and number of connections between a small group of risks. For example, the temperature cluster below acknowledges the knock-on effect of heat-waves on Urban Heat Island, Reduce Physical Activity and Changed Human Behaviour and the interconnected nature this impact has on a cluster of risks. As acknowledged, the identification of these interconnectivities aligns with a leading approach to climate risk assessment and enables the development of targeted actions that are able to respond to (and cut across) multiple risk areas.

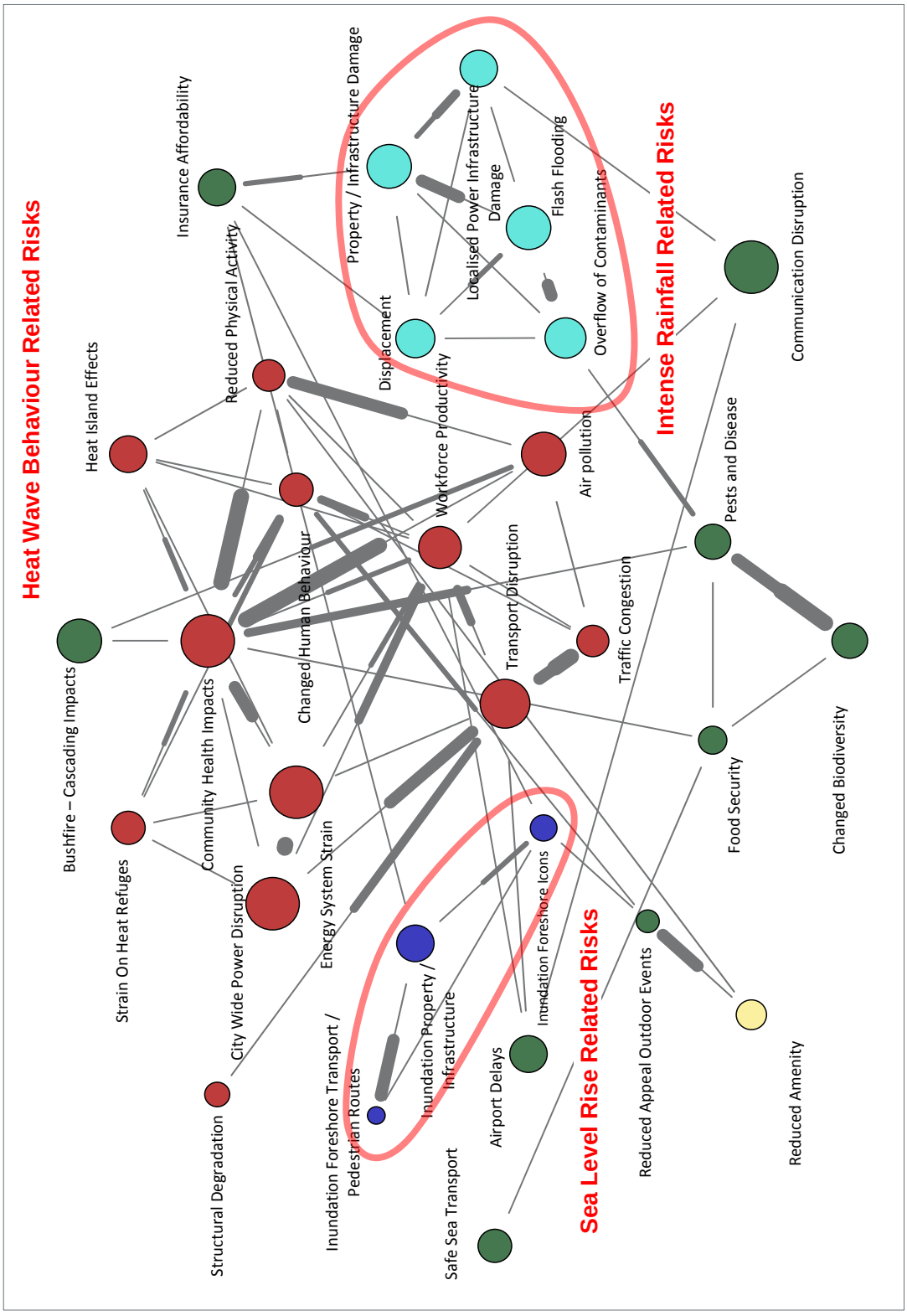


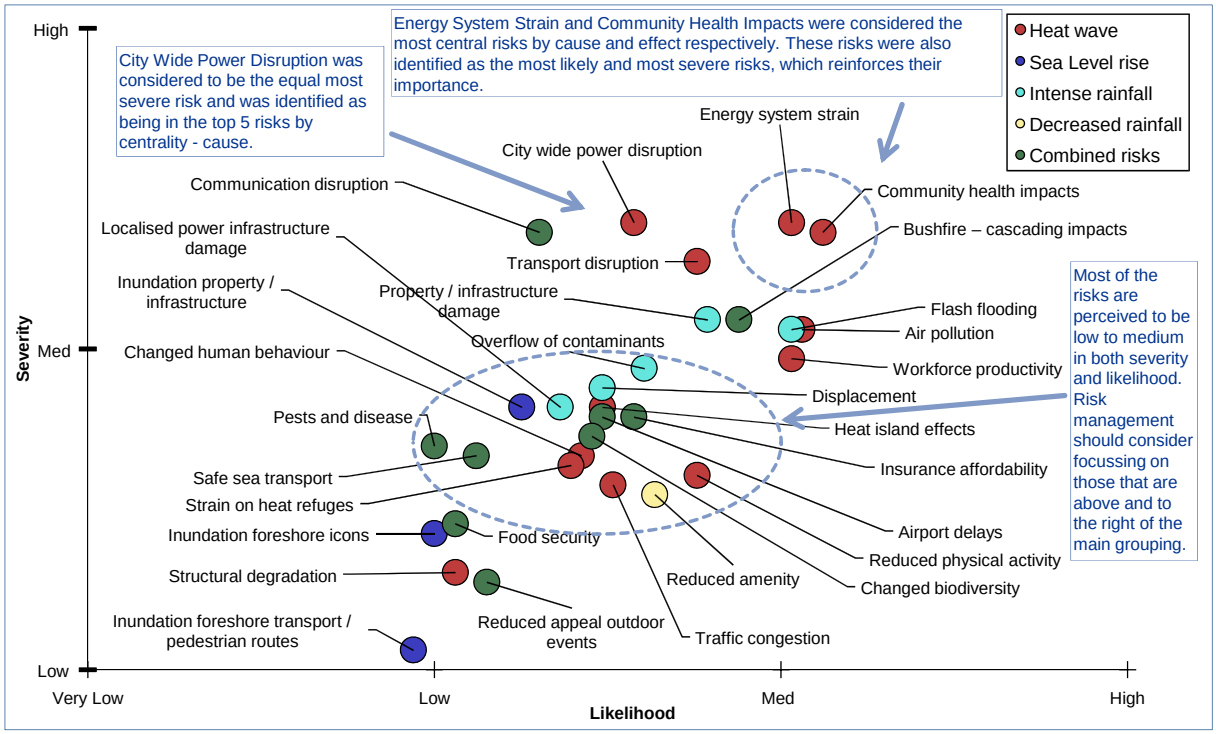
Figure 39 Risk clusters based on survey responses

Table 26 Most central risks: Cause and effect

Most central risks – Cause	Most central risks – Effect
Energy system strain	Community health impacts
City wide power disruption	Workforce productivity
Air pollution	Changed human behaviour
Heat island effects	Reduced physical activity
Transport disruption	Transport disruption

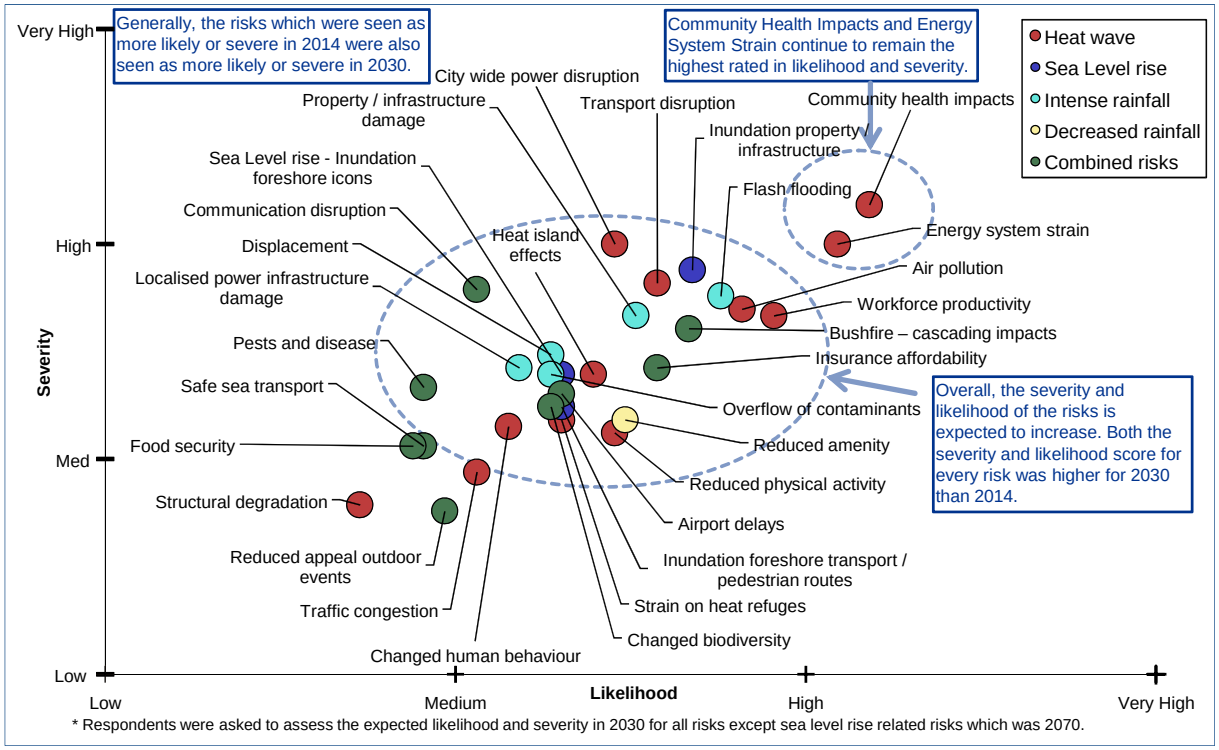
Additional measures for determining the importance of risks were likelihood and severity. Respondents were asked to quantify the measures for each risk over two time horizons: Current (2014) and future state (2030 and 2070 for sea level rise risks). The results for these two time horizons are shown in Figure 41 and 42 overleaf.

Figure 41 Severity and likelihood of climate risks 2014



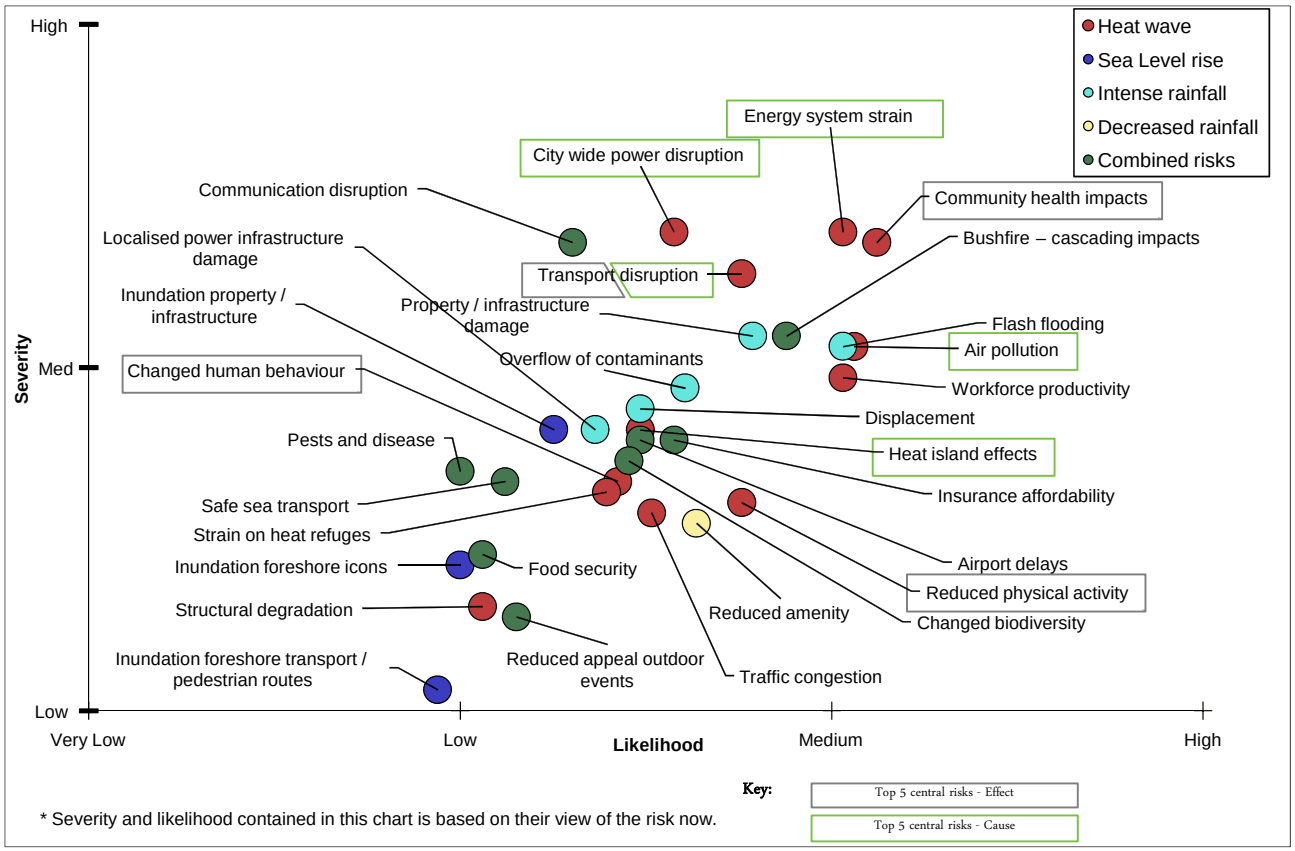
Over time, when these figures are reviewed in comparison to each other it is easy to see the increasing levels of severity and likelihood linked to the highest priority risks. It is observed that impacts to the community from extreme heat and air pollution will continue to grow. In addition it is noted impacts such as flash flooding move from being a medium risk in 2014, to a high risk by 2030. The magnitude of these changes have directly impacted the risk ratings that have been attributed and further, informed the adaptation actions proposed to counter these impacts.

Figure 42 Severity and likelihood of climate risks 2030



* Respondents were asked to assess the expected likelihood and severity in 2030 for all risks except sea level rise related risks which was 2070.

Figure 43 Current state severity and likelihood highlighting central cause and effect risks



Measures to determine the importance of risks for risk management include severity, likelihood and centrality (a measure that combines the number of connections and strength of connections). Figure 43 (above) graphically shows how the most central risk overlay with the likelihood and consequence of risks and Table 27 that follows shows the top five risks for each measure, including severity and likelihood over the two timeframes and centrality.

Table 27 Top five risks over all climate change risk parameters

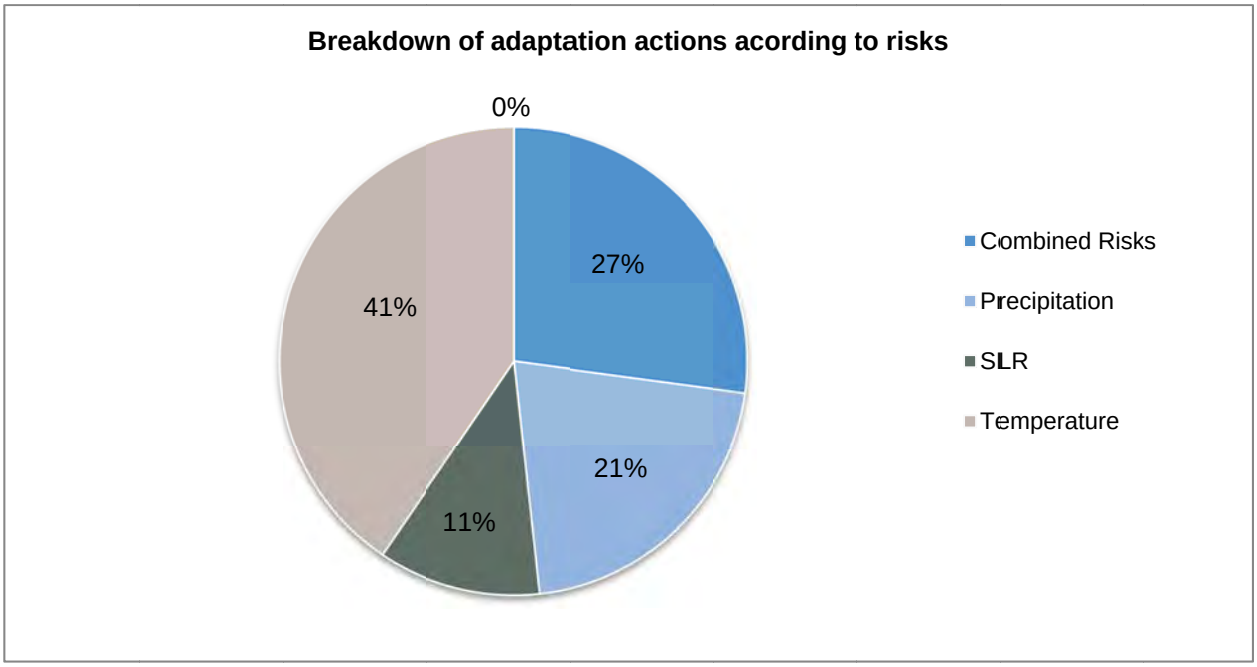
Likelihood 2014	Severity 2014	Likelihood 2030	Severity 2030	Centrality cause	Centrality effect
1. Community health impacts	1. Energy system strain	1. Community health impacts	1. Community health impacts	1. Energy system strain	1. Community health impacts
2. Air pollution	=1. City wide power disruption	2. Energy system strain	2. Energy system strain	2. City wide power degradation	2. Workforce productivity
=2. Energy system strain	3. Community health impacts	3. Workforce productivity	=2. City wide power disruption	3. Air pollution	3. Changed human behaviour
4. Workforce productivity	=3. Communicatio n disruption	4. Air pollution	4. Inundation property/infrast ructure	4. Heat island effects	4. Reduced physical activity
=4. Flash flooding	5. Transport disruption	5. Flash flooding	5. Transport disruption	5. Transport disruption	5. Transport disruption

As highlighted in Table 27 by 2030 the predominant impacts to the City from climate exposure will relate to:

1. Community health impacts caused by strain on the City's energy system.
2. Workforce productivity will be impacted by city-wide power degradation.
3. Changed human behaviour will be primarily be impacted by air pollution.
4. Reduced physical activity will be impacted as a result of increased extreme temperature, namely as a result of urban heat island effect.
5. Transport disruption cause by increasing instances of flash flooding.

With four of the five dominant impacts to the City resulting from changes to extreme temperature it is appropriate that the highest number of climate risks and the highest number of adaptation actions identified also relate to temperature (refer Figure 44). Refer Section 11 for detailed analysis of climate adaption actions.

Figure 44 Proportion of adaptation actions per climate risk area



9.2.5 Risk assessment

The final component of the risk analysis work was the development of a climate risk register outlining the full 32 risk statements. This risk register synthesizes and simplifies the findings from the broader risk assessment and has been designed to align with the City's existing risk management framework. It broadly captures the following information:

- Risk ID (this ID links with coding in risk profile survey and analysis).
- Risk statement and explanatory note.
- Existing management responses (eg response plans, design standards and awareness programs).
- Success/risk criteria (consequence scale from insignificant, minor, moderate, major to extraordinary) – using Council's own Consequence Criteria that they use for risk assessment categories:
  - Financial.
  - Sustainability.

  - Service delivery.
  - People.
  - Cultural heritage.
  - Reputation and image.
  - Legal and compliance.
- Likelihood scale (from rare, unlikely, possible, likely to almost certain).
- Priority risk rating (from low, moderate, high to very high).
- Accountability – based on the following functional areas of council :
  - Corporate services.
  - Land use planning.
  - Works, assets and engineering.
  - Environment.
  - Community services and emergency.
  - Economic development.
  - External (eg state government, utility or private sector).

The risk register results including the likelihood and severity ratings are based on the collective knowledge of the internal and external stakeholders, derived from their responses to the risk survey. The 2070 time horizon was only taken into consideration for the three sea level rise related risks (ie representing the time horizon when these risks will start to impact).

Based on the full risk register and the applied risk rating allocated to each of the 32 risk IDs, the following 14 risks IDs denote those areas that recorded the highest risk rating attributed to the corresponding climate impacts. These 14 risk IDs form the basis of the actions presented in Section 11 of this report.

Table 28 Highest risk variables for the City of Sydney

Climate variable	Highest risk areas
Temperature	▪ T1: Energy system strain ▪ T2: Workforce productivity ▪ T3: Community health impacts ▪ T5: City-wide power disruption ▪ T8: Transport disruption ▪ T9: Air pollution
Sea level rise	▪ S1: Inundation to property/infrastructure
Precipitation	▪ P2: Property/infrastructure damage ▪ P3: Flash flooding
Combined risks	▪ C3: Bushfire – cascading impacts ▪ C5: Insurance affordability ▪ C9: Communication disruption ▪ C10: Financial viability ▪ C11: Increased storms causing disruption

10 Community engagement

On the 13, 15 and 16 November the City of Sydney in conjunction with community engagement and environmental politics experts from the University of Sydney facilitated a Citizens' Panel on climate adaptation and resilience with 23 residents of the City of Sydney LGA.

The Citizen's Panel followed a 'deliberative democracy' approach whereby participants were presented with information and then asked to deliberate on the findings in order to provide consensus opinions and inputs on a topic (in this case climate adaptation).

Participants were identified through a recruitment process designed to provide a diverse composition (age, gender, income) of participants that would accurately represent a breadth of the community across the LGA.

A detailed report analysing the findings of the sessions will provided independent of this project by the University of Sydney research team. The following extracts have been taken from the summary session held on the Sunday (16 November) and are presented to provide additional context on the broader project and the climate adaptation actions prioritised and identified.

Citizens' Panel preamble:

We are a diverse group of citizens who live in many of the villages that make up the City of Sydney. We love where we live and value the vitality of the city and the connection we feel to the people within our communities.

We have learned much about the risks the City faces from climate change now and into the future, and some of the ways in which the Council plans to address those risks.

We recognise that these risks also provide an opportunity to create an even more liveable and resilient city. What follows are our recommendations to help achieve this vision.

10.1 Risks and vulnerabilities

In addition to the overarching principles for the CAP listed in Section 3 the Panel identified a series of risks and vulnerabilities that they felt had not (as yet) been fully considered by the City through the risk identification work completed to-date. These are summarised below:

1. Absence of effective communication to the community about the risks posed by climate change, and the City's planned adaptation actions.
2. Impacts on food security.
3. Impacts on vulnerable groups that have not yet been identified by the City.
4. Impacts relating to mental health within the community.
5. Risk of litigation – has the City adequately assessed its duty of care in a changing climate? Does climate change increase the organisation's exposure?
6. Sea level rise – the Citizens' Panel is concerned that the City has not adequately assessed the impacts on the LGA.
7. Impact of sea level rise on the water table.
8. There is a potential risk that policies for dealing with climate change may be in conflict with other council policies.
9. Changing wind patterns and impacts on wind tunnels.

10. Impacts of extreme weather events on pets, leading to increased stress for pet owners, and
11. Impacts on wildlife. A changing climate could cause fauna from other areas to use Sydney as a refuge.

The Citizen's Panel also articulated its own set of actions and priorities (refer Table 29). RPS subsequently undertook a review of the adaptation actions listed in the Risk and Adaptation Register (RAR) and annotated them (where appropriate) to show how the actions currently proposed in the RAR maybe further amended to respond to the issues raised by the community.

Table 29 Citizens' Panel adaptation actions and priorities

Additional adaptation actions
▪ A Chief Environmental Officer should be appointed at the executive level within the City of Sydney. This person should be empowered to coordinate action to address climate change. They should be responsible for embedding climate change awareness across the organisation; ▪ An effective community education program should be developed that provides accessible information about the impacts of climate change, and the actions the City will take to adapt to a changing climate; ▪ Communications should include warning systems for severe weather events, such as those used by the Rural Fire Service for bushfires; ▪ More deliberative community forums like this Citizens' Panel; ▪ The City should identify groups that are particularly vulnerable to climate change. The City should develop strategies to increase the resilience of these groups. These strategies should be tailored to the specific needs of each group; ▪ Council must take leadership in actively reducing the use of motor vehicles to reduce air pollution; ▪ Council should divest from all investment in fossil fuels within its portfolio. All future investment should meet strict guidelines for ethical investment in companies responsible for renewable and clean energy; ▪ Council needs to review its insurance policy to ensure that it considers the risks posed by the most extreme climate change scenarios; ▪ Once risks are identified, the City should take action to reduce its exposure to litigation; ▪ The City should become a global leader in action to address climate change. This would mean assisting developing countries and other councils with fewer resources; ▪ The City must address inflexible, outdated regulations that impair the capacity of citizens to adapt to the risks posed by climate change. For example, it should be easy for residents to install photovoltaic cells on their roofs, and build awnings for shade protection; ▪ Increase planting within the LGA. More plants will provide multiple benefits that will enable the city to adapt to climate change. These include more shade, cooling the atmosphere and reducing air pollution by filtering the air. Increased planting has been shown to provide community and social benefits that will help build resilience; ▪ Dedicated respite spots for active transport users. People cycling and walking will need cool, sheltered places to rest during hot weather and storms; ▪ Face masks should be made available for use during high pollution days. There should be more community education about the use of face masks; ▪ Wind breaks were seen as important. Native trees and built features should be used as wind breaks; and ▪ The built environment should be designed to reduce wind tunnels.

Based on these amendments, the RAR has been used to filter actions based on their ability to address the main areas of concern raised by the Citizens' Panel. Specifically a filter has been applied to understand which of the proposed adaptation actions align with the outcomes of the Citizens' Panel recommendations. Figure 45 highlights the following:

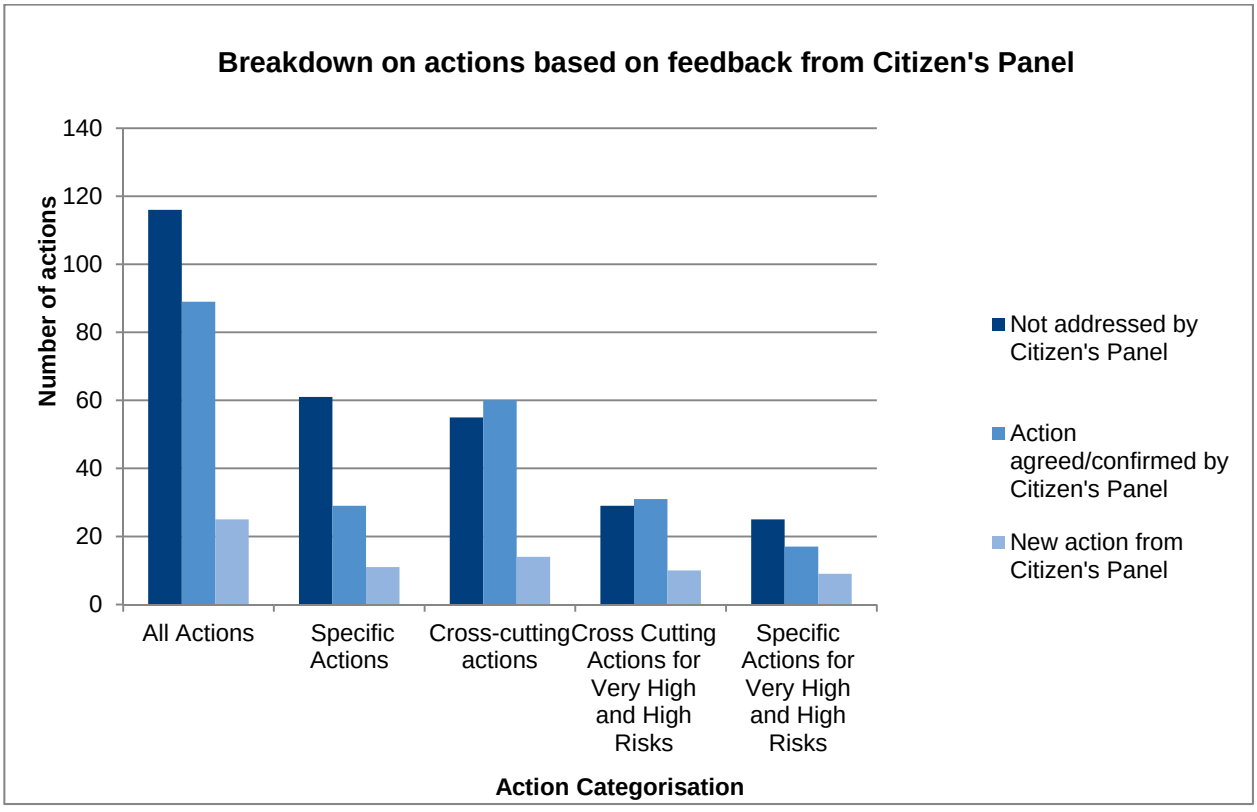
- Actions within the RAR not addressed (ie not raised) by the Citizen's Panel.
- Actions within the RAR that align with those agreed/confirmed by the Citizen's Panel (ie those actions listed in the RAR which align with outputs of the Citizen's Panel).
- Actions in the RAR that represent new actions agreed/confirmed by the Citizen's Panel.

To clarify, 'total actions' relate to the full 232 actions listed in the register. As these comprise a significant proportion of actions that cut across multiple risk areas (and are therefore duplicated) a further refinement of the listed actions has been undertaken. This has enabled actions to be split based on whether they are cross-cutting or specific to the risk and therefore discrete. Based on the information provided in Figure 45, of the total specific (discrete) actions identified, close to 40% are aligned with the feedback provided from the Citizen's Panel. Of those actions that cut across multiple risk areas 70% are aligned with the outputs of the Citizens' Panel. This cross-check provides the City with the confidence that the actions identified for action are broadly aligned with the community's expectations.

Based on those actions related only to the highest priority risk areas for the City, 45% of the cross-cutting actions identified align with the community engagement outcomes; with 35% of the specific actions also aligning with community expectations (based on the Citizens' Panel's feedback).

Note: percentage of alignment has been determined by reviewing those actions agreed/confirmed by the Citizens' Panel in addition to new actions identified by the Panel and therefore amended within the RAR.

Figure 45 Climate adaptation actions –Citizens' Panel feedback



To clarify, while the results presented above appear to indicate more community actions than those identified during the Citizens' Panel this reflects nuancing around the scope of actions and acknowledges that a

number of the existing actions either fully or partially align and address those actions raised by the community. Further, it is important to note that the Citizens' Panel were not presented with all the adaptation actions identified for the City. It is likely more actions would have directly aligned with the community expectations if they had access to these, particularly as the participants were supportive of all the measures that were presented to them. Based on this, the City can feel comfortable that there are sufficient actions within the RAR that align with communities' concerns and priorities.

10.2 Findings and observations

The Citizens' Panel offered a rich and involved process that provided real insight into the thoughts and opinions of a diverse cross section of the City of Sydney's residents. The following presents a selection of findings and observations relevant to the project, acknowledging that a fuller and more detailed level of analysis will be provided by the University of Sydney's subsequent report.

- The majority of residents were well informed about climate change and there were fewer 'climate sceptics' than initially thought in attendance. The focus on impacts and adaptation quickly moved the group from a discussion of 'climate change' to one based on everyday life in an environmentally-impacted city.
- Participants wanted a greater level of more detailed information and communication regarding climate change and the impacts to the City to be made available.
- The City's decision to base climate projections on a 'most consensus' climate future (refer Section 5) was challenged, with many stating that they needed to know 'worst case' rather than 'most consensus'.
- The flood modelling undertaken to-date by the City was challenged with participants stating that models should be re-run using future climate projections not historical data.
- A disconnect between the level of priority the community placed on certain risks in comparison to the priority placed on those risks through the formal risk assessment process undertaken by Council staff and external stakeholders (government agencies, business etc) detailed in Section 9 was uncovered. For example, many of the participants felt the potential impact to pets as a result of extreme heat (and heatwaves) was a high priority; however this risk was not identified through the formal risk assessment process.

11 Climate adaptation for the City of Sydney

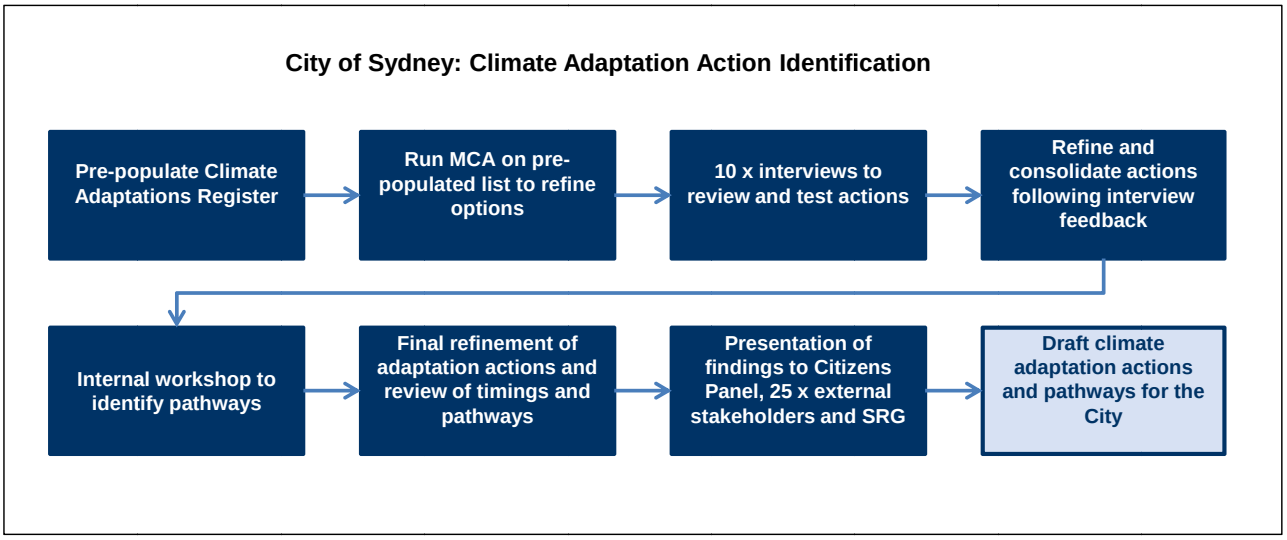
11.1 Overview

Adapting to the impacts of a changing climate is critical for the City of Sydney. While there will be costs associated with action, these vary dependent on the actions chosen. Building resilience through the implementation of climate adaptation actions and use of adaptation pathways will provide opportunities and minimise risk for the City.

The following section represents the culmination of the project, by presenting those climate adaptation actions and associated adaptation pathways necessary to guide the City's future climate response and development of the CAP.

This section steps through the tasks and phases highlighted in Figure 46 and summarises the findings of the detailed approach undertaken to develop the proposed climate actions.

Figure 46 Process undertaken to develop draft adaptation actions for the City of Sydney



11.2 Methodology and approach

11.2.1 Pre-populated climate adaptation actions

Due to the project's time and resourcing constraints the City requested that RPS pre-populate the climate change adaptation actions to be evaluated and ranked. Accordingly, options were drawn from a climate adaption library of over 700 actions informed by leading practice adaptation action across various sectors and industries both from within Australia and internationally. Following this, a pre-populated shortlist of actions was developed for review and comment by internal stakeholders from Business Units within the City of Sydney identified as facing climate impacts and risks.

The initial short list was created in a database that enabled actions to be identified based on their ability to respond to each of the 32 risks presented in Section 9 and also allow for the adaptation action proposed to be assessed based on an agreed set of evaluation criteria such as cost effectiveness and stakeholder support. An assessment method called multi-criteria analysis (MCA) was used.

11.2.2 Multi-criteria analysis (MCA)

Following the initial pre-selection of adaptation actions, a multi-criteria analysis (MCA) was developed to allow the proposed actions to be assessed by both the City and the consultant project team enabling further review and refinement. The criteria used to assess the actions are listed in Table 30.

Table 30 Summary of MCA Criteria and Rating Scales applied to the City's Climate Adaptation Actions.

Criteria and description	Scale
Risk level*	
This category relates to the risk level assigned as part of the climate risk assessment. It seeks to consider the level of future risk that the proposed adaptation measure will tackle. It is 1 of 2 criteria used for this assessment that is scored on a 10 point scale.	Very High Risk =10; High Risk = 7; Moderate Risk = 5; Low Risk = 2; No risk = 1.
Effectiveness	
How effectively (well) and reliably would the associated action reduce the risk level? Ie If the proposed adaptation action would almost certainly reduce a very high risk to low, then it would score highly ie 5, conversely actions that are not considered to be very effective would score a 1.	Very effective = 5. Fairly effective but hard to measure = 3 (for example the effectiveness of a communications initiative maybe hard to quantify). Not very effective = 1
Cost-effectiveness*	
This criterion seeks to understand how cost effective the proposed action is relative to its ability to reduce the associated climate risk. It is the second of 2 criteria used for this assessment that is scored on a 10 point scale.	Actions representing low/no cost impact = 10; Minor cost impact ie within existing budgetary allocations = 8; Expenditure required beyond a business as usual approach = 4; significant expense and requires political will = 2; Extremely expensive/difficult to foresee council funding (capital expenditure requirements) = 1.
Practicality	
It is important to assess the practicality of the proposed adaptation options, for example, what is the capacity to implement this measure? How easy would it be to develop the capacity? Does the action complement existing plans? The more practical the initiative the higher it will be scored, the less practical the initiative the lower it will be scored. For example based on previous similar projects, the consultant project team has observed that implementing a program for organisational change/behaviour is very challenging and may not be deemed practical. As such it might be given a score of 1	Highly practical and easily implementable actions/initiatives = 5 (this might relate to a plan or a strategy); Moderately practical initiatives that may require additional effort and engagement = 3 (ie changing peoples' roles and responsibilities); Initiatives that require external engagement and may require consultation = 2 (ie educating the community; and initiatives that have a low practicality of being implemented = 1

Criteria and description	Scale
Stakeholder support	
There is a need to consider the level of stakeholder support that will be required to implement the associated action. Stakeholders may comprise a diverse and complex portion of society ie the community; businesses; government; social services etc. It is important to explore the extent to which the action is politically, culturally and socially supported? Will there be stakeholder opposition and/or conflict ie some actions may be supported by one set of stakeholders but contested by another.	If there is likely to be strong community and other stakeholder support = 5; Actions that might have equal support and opposition depending on the stakeholders engaged = 3 (ie coastal planning would have strong state government opposition but strong community support); actions that will be very difficult to get support for = 1 (ie Action for Air).
Co-benefits	
Another measure for determining the priority of an action is to consider the co-benefits its implementation delivers. For example does it tackle more than one climate risk? Does it produce other benefits (win-win)? Co-benefits may include: reducing other climate risk impacts; delivering sustainable outcomes; actions that may also be categorised as climate mitigation initiatives etc.	Actions that deliver 4 or more co-benefits = 5; 3 co-benefits = 4; 2 co – benefits = 3; 2 co – benefits = 2; 0 co-benefits = 1.

**Although the majority of criteria were ranked out of 5, both the 'risk rating' and 'cost effectiveness' criteria are scored out of 10. As the risks identified in the risk assessment were ranked out of 10 this number was preserved in the MCA to maintain the integrity of the process. Cost effectiveness was scored out of 10 to enable a more accurate assessment of cost implications and avoid the clustering of rankings around '3'. RPS undertook a sensitivity exercise to determine if reducing the cost effectiveness score to a value out of 5 or, removing it altogether would make any difference to the rankings. The findings of this revealed that scoring cost effectiveness out of 5 does not have a material impact on the results. The priority adaptations (top 10) stayed the same in every case. Removing the cost effectiveness score altogether had a more dramatic effect as adaptation options which were highly cost effective but low scoring in the other criteria drop significantly in their ranking. The full results of this sensitivity analysis can be found in the Supporting Materials documentation.*

The assessment was then performed by RPS to provide an initial prioritisation of the adaptation options based on the suitability of the adaptation option proposed to address the corresponding risk. Following this step, an initial list of pre-populated climate adaptation actions were socialised through a series of one-to-one interviews with stakeholders from across the City. The aim of these interviews was to test, review and refine both the MCA and the shortlisted actions.

The MCA was critical for:

- Identifying the adaptation actions for the City.
- Identifying the associated timeframes for delivering those actions associated with the 14 highest priority risks.

The full MCA undertaken for this project is provided in the *Supporting Materials*; due to the size of the database it is not possible to provide this as an appendix within the report. The database presents all 232 actions that have subsequently been fed into the City's RAR (refer Section 11.2.4) as well as the timeframe parameters for the 14 highest priority risks (refer Table 28).

11.2.3 Engagement

Internal interviews

During the week of the 20th October 2014, RPS undertook a total of 10 x 2 hour interviews with internal stakeholders from across the City of Sydney. The aim of the interviews was to review and cross check the

findings of the MCA to help shortlist specific actions needed by the City to build resilience to each of the risks identified through the risk assessment process.

Based on the feedback and outcomes of the internal interviews, the actions presented in the draft MCA were refined from an initial list of approximately 400 actions to approximately 280, these were refined further still following the internal workshop detailed below.

In addition to testing, refining and consolidating the list of draft actions, the interviews were also useful in helping to identify areas of current action by the City and areas for future opportunity.

Future iterations of the City's adaptation planning should investigate the triggers and thresholds that would bring the actions into effect.

Internal workshop

The second component of the City's internal engagement regarding climate adaptation action was held on the 11 November 2014, during which a 2 hour workshop was held with 12 members of the City's internal stakeholders. The workshop was designed to specifically review the refined adaptation actions associated with the highest risks (only) and attribute timeframes for their delivery. Specifically, three time horizons were identified for consideration:

- Short-term, addressing a current timeframe through to 2030.
- Medium-term, 2030 – 2050.
- Long-term, 2050 and beyond.

The workshop also sought to identify whether actions were 'low or no regrets'. This may relate to actions that are simple and straight forward to implement, including actions the City would not regret doing. For example those that may have a low-cost implication; deliver high value; already have resources allocated to them; are simple and straight forward to implement; and/or, deliver significant benefit reflective of the effort required to deliver them.

The decision to focus the workshop to consider only the 14 highest risks was informed by the need contain the final scope of the adaptation plan so that it will be implementable by the City.

As the City evolves its CAP and adaptation approach it is recommended an investigation is undertaken to understand issues associated with the thresholds, triggers and decision-making points related to the actions. Once the City has this information it will be well placed to undertake a high-level cost benefit analysis to further support prioritisation.

Citizens' Panel

As per Section 10, appropriate outputs of the internal engagement approach were socialised through the community engagement session held on the 13, 15 and 16 of November.

Science Reference Group

As per Section 8 of this report the approach undertaken to develop the proposed climate adaptation actions formed the focus of discussions with the SRG during their 3 December meeting. In particular support was sought for the method undertaken to devise the adaptation actions as an alternative approach that was aligned with leading practice. The SRG acknowledged the constraints of the project's engagement phase and supported the proposed approach undertaken to manage these impacts.

External stakeholder feedback session

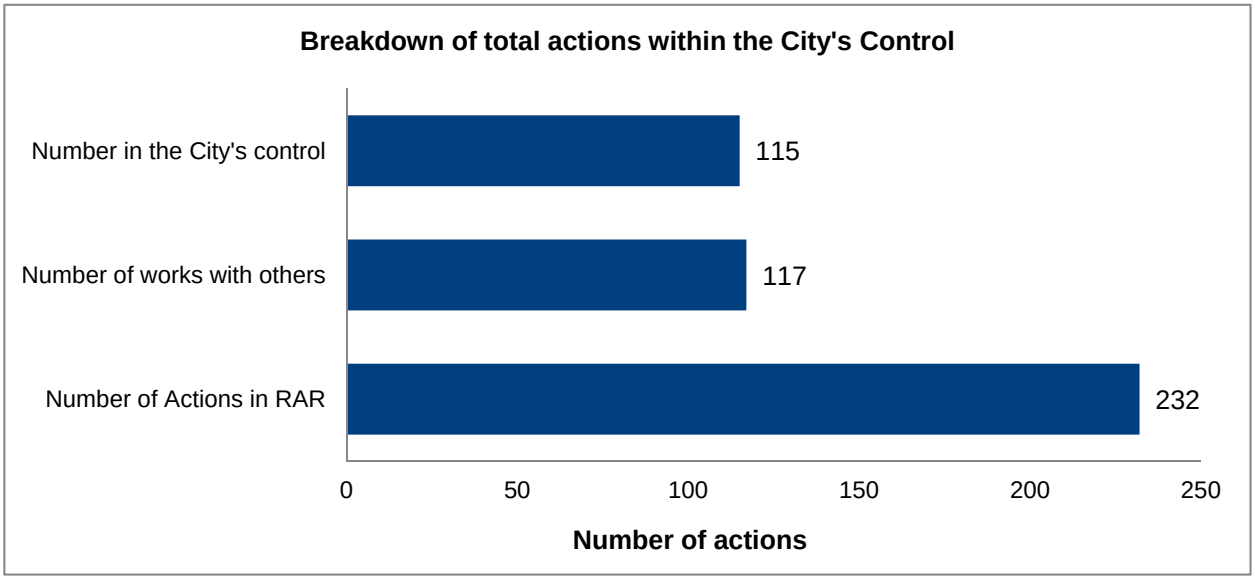
RPS facilitated a 2 hour external stakeholder feedback session on Thursday 4 December with approximately 25 invited representatives from the City's external stakeholder group (refer *Supporting Materials* documentation for list of attendees). Many of these invitees participated in the risk assessment questionnaire discussed in Section 9.

While the primary function of the workshop was to present the findings of the project, step attendees through the outcomes of the risk assessment process, and present a selection of adaptation actions for their consideration, a small exercise was also run to gain further feedback on the proposed actions related to the areas of highest climate risk for the City.

The engagement of external stakeholders in developing adaptation actions for the City is particularly important when considered in light of the number of identified adaptation actions within the City's control versus those that will require the City to work with other stakeholders.

Specifically, as presented in Figure 47 of the 232 actions listed against the 32 risk statements in the RAR, 115 of these are within the City's direct control, with 117 of the identified actions requiring the City to work with others. This presents and almost 50:50 split of actions that can be carried forward by the City in contrast with those that will require the City to collaborate with relevant stakeholders.

Figure 47 Overview of climate adaptation actions within the City's control



The specific outputs of the external feedback session have been provided to the City's project manager for consideration as part of developing the CAP, however a summary of their input is provided below and is useful for consideration by the City to inform the next steps of its climate adaptation planning.

Findings from external stakeholder breakout session

As part of the breakout session, participants were asked to form seven small groups and were provided with a selection of draft adaptation actions as they cluster of the highest risks identified for the City. Table 31 presents the associated risks reviewed by external stakeholders and their comments on the actions presented. It was recognised that comments relating to additional actions may not indeed be omissions in the adaptation actions identified by the breakout groups, as they are likely to be addressed under other risks which they had not seen. Further, participating stakeholders acknowledged the cross cutting nature and overlap of many of the actions.

Table 31 Comments on draft adaptation actions from external stakeholders

Risk ID	Comment/Suggestions
T1 – Heat – Energy system strain T5 – Heat – City wise power disruption	▪ Raise awareness amongst the community with regard to energy poverty (bill protection). ▪ Promote smart energy uses by residents. ▪ Explore opportunities for peer-to-peer decentralised energy networks within the City so if one goes out, then another can help. ▪ Consider the impact that the sale of Networks NSW/Ausgrid may have.
T3 – Heat – Community health impacts T9 – Heat – Air pollution	▪ Would be useful to develop a bushfire preparedness kit for communities like those developed by other Councils ie in Victoria. ▪ Need to get information out to those who generally miss information ie non-English speakers, elderly who do not have access to internet etc. ▪ Develop a bushfire plan as a means of identifying and addressing actions.
T7 – Heat – Urban heat island	▪ Undertake an audit of vulnerability across the community ▪ Where are these communities located, can they be moved? ▪ Raise community awareness to promote a 'look after your neighbour' type initiative. ▪ Fully understand the benefit of ecosystem services associated with Urban Forest strategy. ▪ Engage in a dialogue regarding tree management with councils on the boarder of the LGA.
T8 – Heat – Transport disruption	▪ Undertake a staged approach to action – do things sequentially ie investigate/plan/act (rather than based on prioritisation of actions informed by the MCA). ▪ Develop strategic alliances at the leadership level.
C11 – Storm damage and disruption	▪ Introduce action around the creation of safe havens (in addition to refuges). ▪ Consider the impacts of storms and extreme weather events on the City's homeless. ▪ Consider and plan to build community preparedness.
S1 – Sea level rise inundation of property/infrastructure	▪ Share information and costs to obtain information, rather than requiring assets to undertake specific studies/assessments lead the collaborative development of these to help stakeholders 'get the science right'. ▪ Link in with the work being done under the NSW flood programming. ▪ Reflect the multiple timeframes required to move actions from education through to investigation, through to delivery: need to understand what is required.
S2 – Sea level inundation foreshore icons	▪ As per S1.
C11 – Increased storms causing disruption P1 – Intense rainfall – displacement	▪ Work with existing forums around emergency preparedness – identify and collaborate with the NSW Emergency Coordination Group.

Risk ID	Comment/Suggestions
General comments – non-risk specific	▪ Need to collaborate and work with other individual councils. ▪ There are existing forums at a State-level that are looking at climate risk and resilience – the City should tap into these as a first step.

As stated, it will be important for the City to revisit these comments in developing the CAP to determine whether any additional actions should be included and whether it wishes to further refine any of the proposed actions based on the above.

11.2.4 Risk and Adaptation Register

The 232 proposed actions for the City have been assembled in the Risk and Adaptation Register (RAR) which has been provided to the City as a companion to this report. The database will form a useful resource for the City as it enables users to search through the identified actions based on a range of filtered categories and criteria. The RAR can be amended and expanded as the City's adaptation planning matures. Specifically, it has been developed to guide the analysis presented in this report and also inform how the City may wish to target implementation of the actions, the following categories/search fields have been applied (refer Table 32).

Table 32 RAR Analysis – Category Overview

RAR Category	Category/Functionality overview
Risk code	Enables user to search based on the four areas of risk exposure: temperature, sea level rise; precipitation; combined risks
Functional area	Enables user to search based on whether an action would be lead by the following functional areas: ▪ Environment ▪ Corporate services ▪ Works, assets & engineering ▪ Land use planning ▪ Economic development ▪ Community services Note: for the purpose of this filter, categories have been modelled on those functional areas identified in the Australian Centre for Excellence in Local Government (ACELG) Climate Adaptation Manual as they represent overarching functional areas found within Councils across Australia.

RAR Category	Category/Functionality overview
Action Type	This filter allows the City to search for actions based on the 'type' of action they relate to. Categories include ▪ Plans and studies: Refers to council strategy, policies and business plans, emergency response plans and studies into new or emerging areas to then inform Council strategy. ▪ Direct Actions: ▪ Operational changes: Refers to changes related to something that that City does eg moving from dark to light coloured pavements ▪ Capital works ▪ Service delivery: Refers to Council's business-as-usual activities ie rangers, meals on wheels, community child care etc. ▪ Statutory planning: Strategic land use planning and statutory planning eg Development Control Plan ▪ Other: Any actions that are not covered in the by the above sub-categories. These categories were provided by the City for inclusion in the RAR.
Working with others:	Enables the City to filter based on those actions which require Council to work in collaboration with other stakeholders ie actions outside Council's direct control, but within its sphere of influence.
Community Alignment	Allows the City to filter to review whether the action was categorised as: ▪ Not addressed by Citizen's Panel; ▪ Action agreed/confirmed by Citizens' Panel; OR ▪ New action from Citizen's Panel ▪ Based on the recommendations of the Citizens' Panel.
Risk Rating	Enables actions to be filtered on their corresponding risk rating ie actions ranked 7 & 8 denote the highest climate risks for the City.

RAR analysis

All risks

The following analysis has been undertaken based on the actions presented in Section 11.3 and is useful to guide the City's future adaptation planning action. They offer insight on those considerations necessary to inform the selection of actions for inclusion in the City's CAP.

Figure 48 offers an overview of the nature of actions included in the RAR (the columns in the graph are not mutually exclusive totals). Specifically of the 232 actions presented, a significant proportion, 130 or 56% comprise cross-cutting actions. A cross-cutting action is an action that can be applied to multiple risk areas. These actions provide significant value to the City as they address risks across multiple areas. The remaining 44% of actions are specific or unique actions –these denote discrete actions required to address the relevant climate risks. Furthermore, of the total actions listed in the RAR 117 will require the City to work with others, whereas 115 are within its direct control.

Figure 48 Overview of climate adaptation listed in the RAR

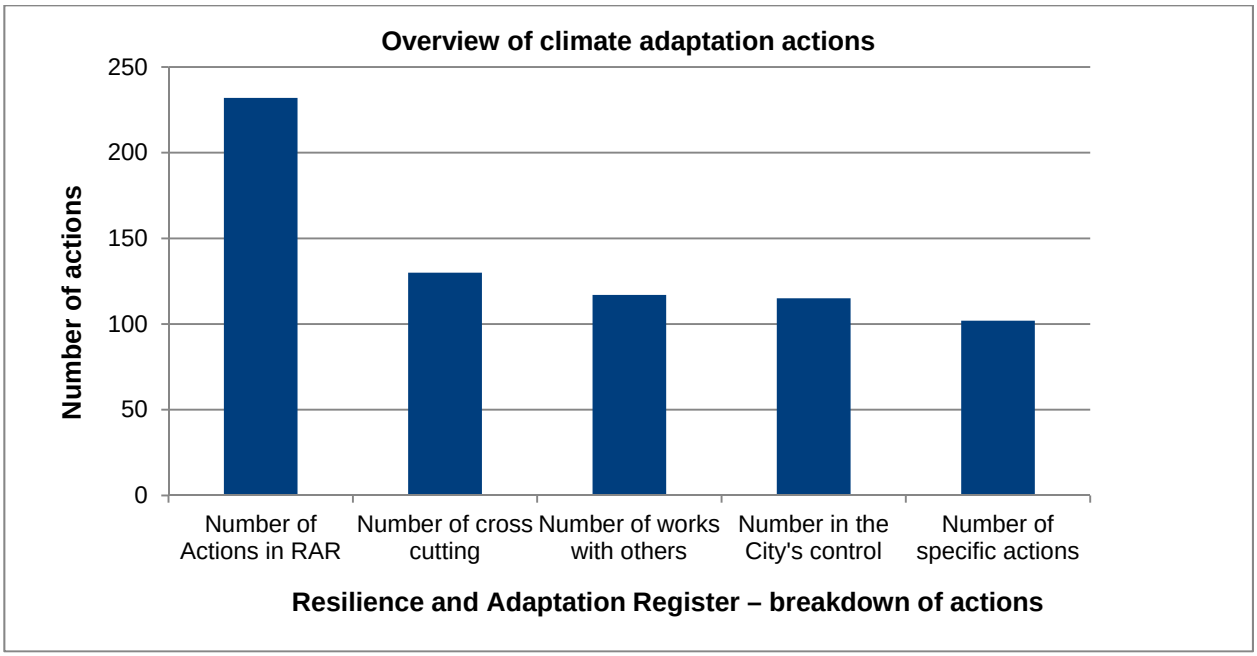


Figure 49 shows that of the 232 actions listed in the RAR 41% of these relate to Temperature, 27% to Combined Risks; 21 % Precipitation and 11% to Sea Level Rise (SLR). This breakdown is directly proportionate to the number of risks per area of climate exposure. As temperature presents the greatest level of risk to the City, (12 of the 32 total risks) it stands to reason it also has the greatest number of actions to help respond these risks.

Figure 49 Breakdown of adaptation actions according to climate risk

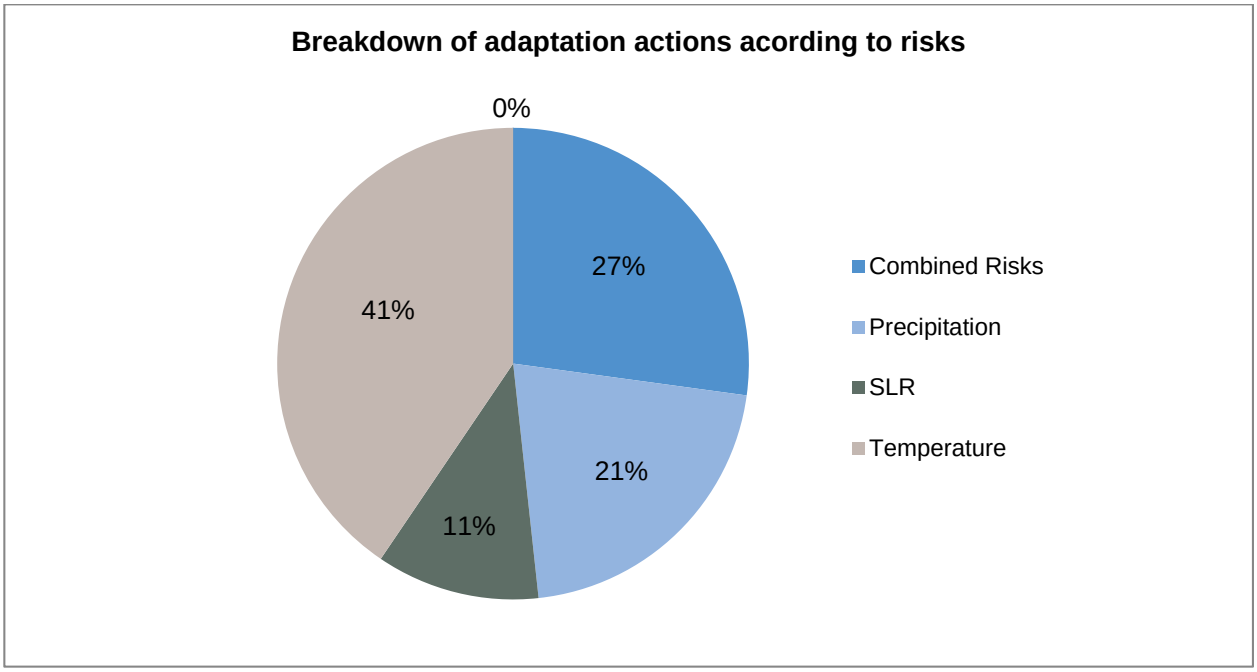
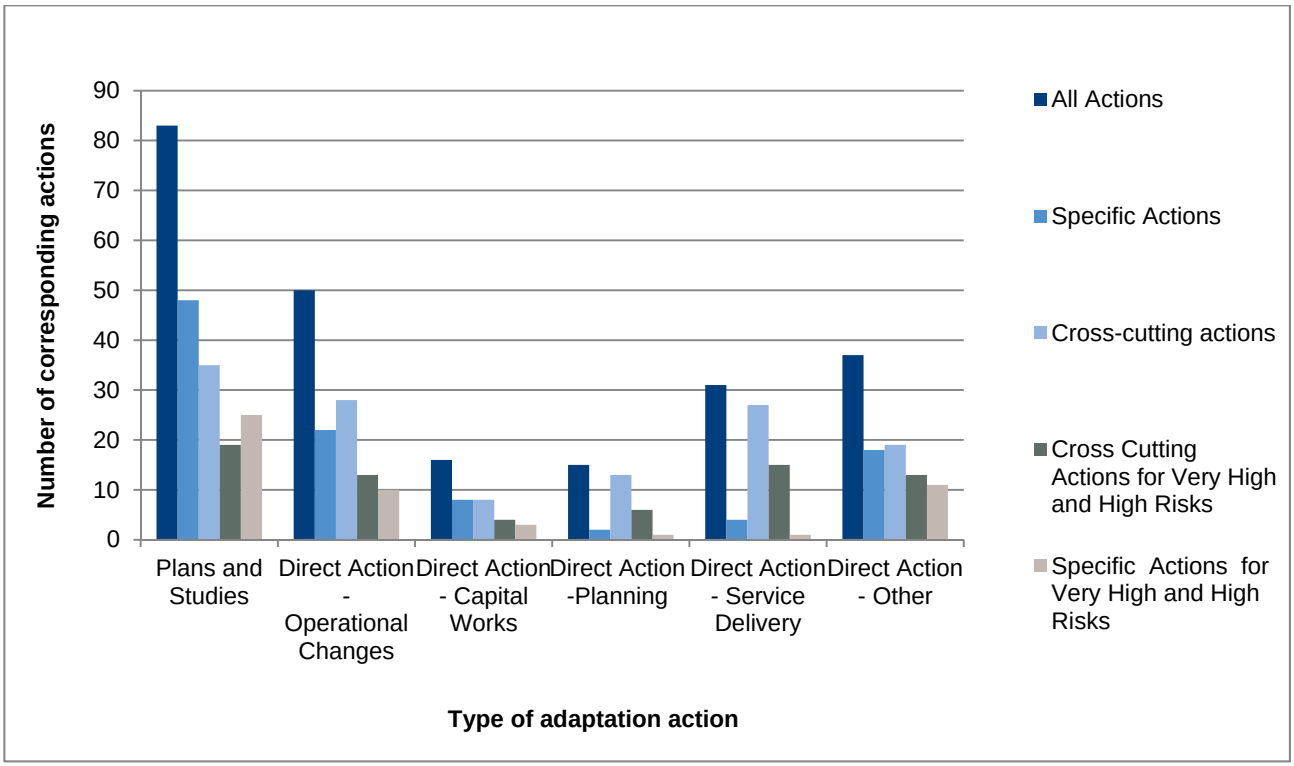


Figure 58 offers a breakdown of adaptation actions based on the City's categorisation for adaptation 'type'. Specifically it is observed that of those cross-cutting actions related to the highest risks (121 actions in total relate to the City's highest climate risks), 35 of these relate to Plans and Studies; 28 relate to Direct Action – Operational Changes; 27 to Direct Action – Service Delivery; 19 relate to Direct Action – Other; 13 to Direct Action –Planning and 8 to Direct Action.

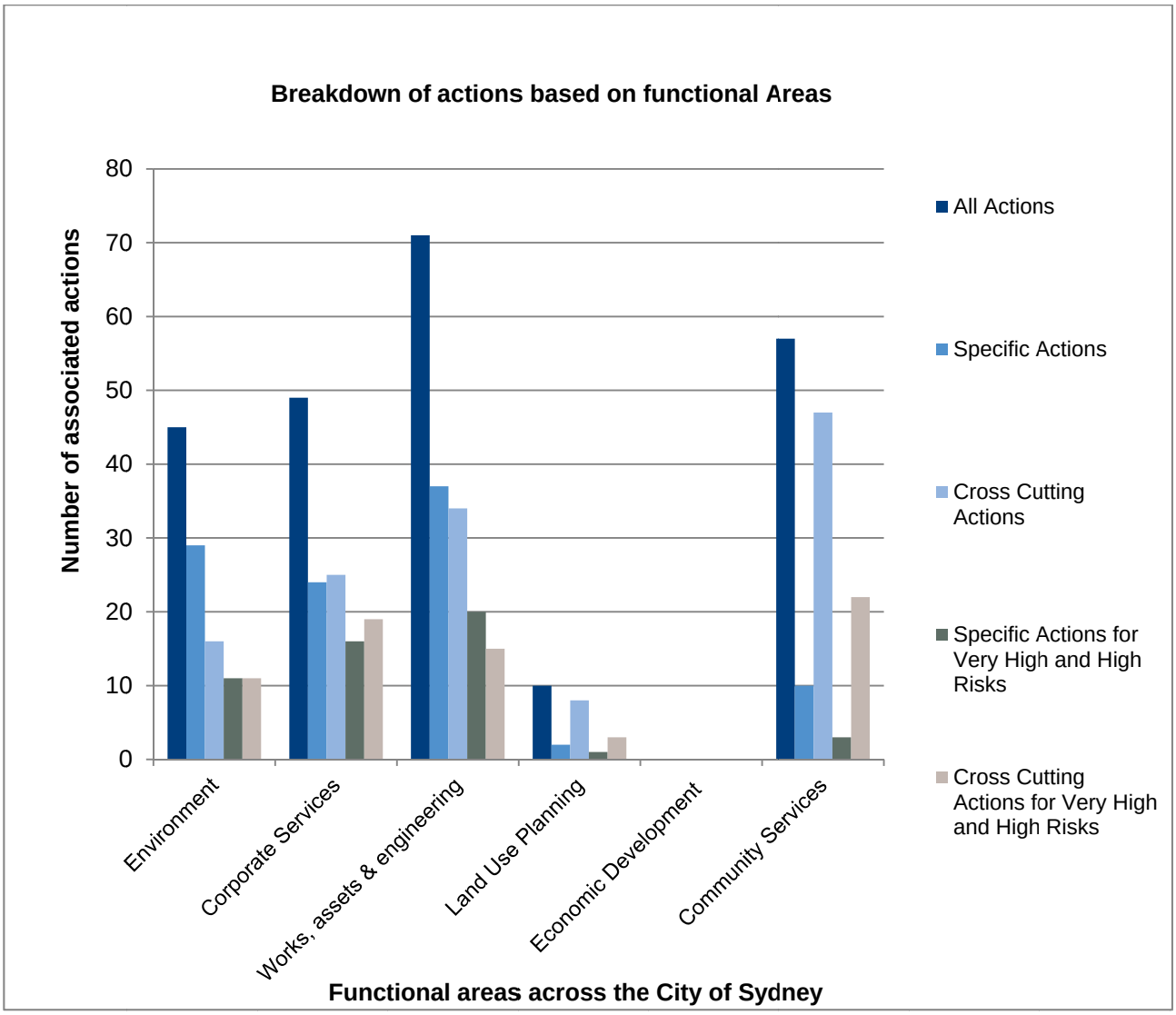
Figure 50 Breakdown of actions based on 'type' of adaptation



Furthermore, Figure 51 offers a breakdown of the action categories based on responsive functional areas. Currently, based on all 232 actions in the RAR, Works, Assets and Engineering; followed by Community Services; and Corporate Services own the highest proportion of actions. Actions attributed to the Capital Works and Land Use Planning areas of operation across the City currently have the least number of identified actions, with Economic Development currently having no actions attributed to it. This is to be expected as the City's initial need will be to focus on relevant investigations to increase understanding of the exact scope and nature of the challenge. Undertaking these studies will assist Council in thinking about the adaptation needs over the longer timeframes ie post 2030 and when climate conditions are more severe, for these longer timeframes the actions will need to be of a more transformational in nature and not based upon business as usual or leading practice. Following completion of these studies the City will be able to identify and commit to direct actions in the form of changes to the planning scheme or building protective structures, often referred to in other local government adaptation plans as hardening action.

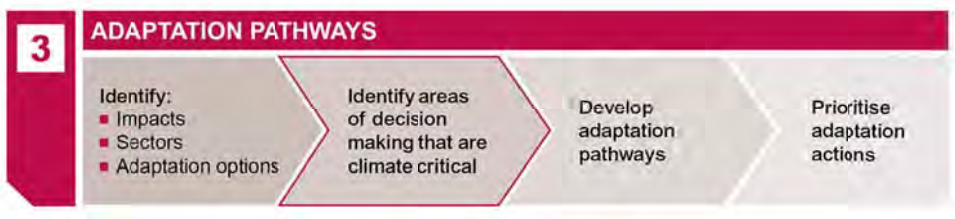
The majority of the actions prioritised by Council in this project tended to be framed in the 'here and now' and represent tweaking of current practice and business as usual, it may be that in future years in more extreme conditions these approaches will not be effective. This shift in mindset will be required as the City's adaptation planning evolves and is discussed further in Section 11.3.5 under adaptation pathways.

Figure 51 Breakdown of actions based on functional areas



11.3 Adaptation actions and pathways

11.3.1 Decision making



From the outset this project has adopted a decision-centred approach, one that requires the City to think upfront about the major decisions it will need to make for the future to better protect against future changes in the climate. These decision areas have developed and refined throughout the project. As part of the process to develop a top 10 list of decision-making considerations, a cross check against leading climate vulnerability mapping undertaken by Sydney Coastal Councils Group in 2008 and the NSW Government's Integrated Vulnerability Assessment was completed. This process reaffirmed the findings of this project and established that the fundamental priorities facing the City with regard to Climate Risk remain applicable.

A decision-centred approach offers an alternate method for communicating priorities by structuring responses based on critical issues, or, key decision-making points. At its core, adopting this approach would require the City to consider the critical decisions it needs to make to *proactively manage the City in a changing climate* (see overleaf) in order to filter the climate variables and modelling it requires and its adaptation actions and priorities. For example, in developing its Climate Adaptation Plan the City could use the decision-centred approach to inform which of the top 28 prioritised actions best align and respond to the key decisions it needs to make. Following this first review, the same approach can be applied to provide an organised and systematic manner of selecting and prioritising the remaining adaptation actions.

Once the City has confirmed those actions that best respond to the decisions it needs to make, it can then plan and plot their delivery through an adaptation pathway (as illustrated in Section 11.3.5). Adaptation Pathways offer a useful tool for adaptation planning as they allow for flexibility and recognise and address the long-term and uncertain nature of climate change, enabling identified actions and strategies to be subsequently adjusted to reflect new information and changing circumstances.

11.3.2 Highest risks

The following section reviews and presents those actions that correspond with the City's highest climate risks and also provides guidance on how climate adaptation action may start to be considered in the context of adaptation pathways.

For ease of reference it is broken up to showcase the cross-cutting actions (Table 33) and against those that respond specifically to discrete actions (Table 34).

It is recommended that when prioritising actions for implementation, the City starts with those cross-cutting actions that respond to multiple risk areas.

11.3.3 Cross Cutting Adaptation Action Plan

The following presents the synthesised list of cross-cutting actions responsive to the 14 highest priority (those ranked 7 and 8 in the risk assessment) risks for the City. This set of actions has been developed by evaluating all of the cross-cutting actions identified within the RAR with a view to consolidating 'like' actions and themes to streamline delivery against multiple risk areas. (The full list of actions across all areas of risk for the City is included in the RAR.)

A total of 28 actions form the priority list for the City. For ease of reference the text marked in bold highlights the issue the action seeks to address.

Actions have been grouped according to: the Risk ID the action cuts across; the functional area within Council responsible for action; the type of action it represents; whether it is within Council control (works with others); and, whether it was cited by the Citizen's Panel. The risk ID listed at the end of each action denotes where the action was first identified.

Table 33 City of Sydney Cross Cutting Climate Adaptation Actions

Adaptation action	Risk: Temperature	Risk: Precipitation	Risk: SLR	Risk: Combined	Functional Area	Action type	Work with others	Community agreed action
Develop **Heat Wave Response Plan** aligned with the NSW State Heatwave Sub Plan 2011, (include transport and behaviour aspects in the Plan as well as impacts to vulnerable communities – consult with community)). (T2-7)	T2-7, T6-5, T7-6, T8-1, T8-7, T9-5, T9-6,	-	-	C3-6,	Corporate	Plan/ Study	✓	✓ Community agreed action
Work with agencies and stakeholders, especially energy companies, to assess the **potential extent of vulnerability of the City's power supply** to increased severity, frequency and duration of extreme events to help build resilience across the City's network. (T1-2)	T1-2, T1-14, T5-1	P3-1	-	-	Environment	Plan/ Study	✓	- Additional action

Adaptation action	Risk: Temperature	Risk: Precipitation	Risk: SLR	Risk: Combined	Functional Area	Action type	Work with others	Community agreed action
Consider impacts for more frequent and more intense flooding on Council's **insurance cover**, its long-term financial plan and overall viability. (T1-4)	T1-4	-	-	C10-1	Corporate	Plan/ Study	✖	✓ Community agreed action
Review all relevant **biodiversity and vegetation plans** and operations to increase climate resilient planting and species selection. (T3-6)	T3-6*	-	-	-	Environment	Plan/ Study	✓	✓ Community agreed action
Continue to roll out **energy efficiency measures**, renewable energy technologies or other suitable efficient power systems (including co/tri-generation facilities and manage demand for energy and water across City's assets, equipment and services).(T1-8)	T1-8, T1-9	-	-	-	Environment and Corporate	Capital Works	✖	✓ Community agreed action
Require development to **design for energy and water efficient buildings** and infrastructure (including review of BASIX and WSUD). (T1-10)	T1-10, T1-11, T3-9,	P2-4	-	C10-13	Environment	Statutory Planning	✓	✓ Community agreed action
Review land use planning to ensure sensible **precautions and contingencies for proposed future developments** are made to consider Sea Level Rise. (S1-15)	-	-	S1-15	C10-13	Planning	Capital Works	✓	- Additional action

Adaptation action	Risk: Temperature	Risk: Precipitation	Risk: SLR	Risk: Combined	Functional Area	Action type	Work with others	Community agreed action
Explore opportunities to **redesign/design the City's buildings and public realm** for passive cooling (including vegetative cover). (T1-13)	T1-13, T2-8, T3-13,	-	-	-	Planning	Capital Works	×	✓ Community agreed action
Raise **staff awareness**, including provision of training on what to do in a heat wave, air pollution, bushfire and other climate events, (including review of Design Safety Risk Assessment). (T2-1)	T2-1, T2-2, T3-7,	-	-	C3-5, C10-5	Corporate	Operational Changes	×	- Additional action
Amend **Business Continuity Plan** 2013/2014 to consider impacts of extreme events on essential services. (T2-3)	T2-3	-	-	C9-2, C10-1	Corporate	Plan/Study	×	- Additional action
Consider further revision to **event protocols** to enable safe, successful events in hot and extreme conditions (including research on feasibility of a public steward program and event safety plans).(T2-5)	T2-5, T2-10, T3-10, T9-3	-	-	-	Community Services	Operational Changes	×	- Additional action
Work in partnership with relevant stakeholders to develop a **communication campaign** to inform the community about climate extremes. (T3-1)	T3-1, T3-12, T9-2	-	S1-2	C3-1,	Community Services	Service Delivery	✓	✓ Community agreed action
Review **CoS Decentralised Water Master Plan 2014 and Decentralised Energy Master Plan 2012** for reference to climate resilience. (T1-6)	T1-6, T3-2	-	S1-5	-	Environment	Plan/ Study	✓	- Additional action

Adaptation action	Risk: Temperature	Risk: Precipitation	Risk: SLR	Risk: Combined	Functional Area	Action type	Work with others	Community agreed action
Work with stakeholders/ agencies to **support community-based self-help responses** to extreme events (including heat waves). (T3-3)	T3-3, T4-2	-	-	C5-2	Community Services	Service Delivery	✓	✓ Community agreed action
Identify and develop additional (larger) **refuges**, facilities and amenities for use in extreme events. (T3-1)	T3-1, T3-4	P3-1	-	-	Community Services	Plan/ Study	✓	- Additional action
Advocate for transport agencies to review **resilience of transport services** in the City to extreme events (including review of passenger comfort and provision of back-up power and forming a strategic alliance with transport agencies). (T3-11)	T3-11, T8-1, T8-5, T8-6	-	-	-	Corporate	Other	✓	- Additional action
Revisit the research undertaken regarding **Heat Island Effect** impacts for consistency with the projections modelled as part of the City's Climate Risk Assessment. Following this research, investigate its contribution towards extreme heat and negative changes in behaviour. (T3-2)	T3-2, T3-8,	-	-	-	Environment	Plan/ Study	✓	✓ Community agreed action
In partnership with other agencies develop a **Heat Wave and Extreme Event Alert System**, incorporating transportation system status information. (T8-2)	T8-2, T9-7	-	-	C3-3	Corporate	Service Delivery	✓	✓ Community agreed action

Adaptation action	Risk: Temperature	Risk: Precipitation	Risk: SLR	Risk: Combined	Functional Area	Action type	Work with others	Community agreed action
Undertake an assessment of building, construction, and other **materials** to determine their **durability** to projected climatic conditions to inform Council's asset maintenance program. (T7-2)	T7-2, T12-1, T7-7	-	-	-	Environment	Plan/Study	×	✓ Community agreed action
Advocate to ensure **access to the web** and websites (and emergency notices relating to transport delays) are operable from a back-up server and have built-in resilience. (T8-4)	T8-4	P3-1	-	-	Corporate	Other	✓	- Additional action
Advocate for increased **police and security presence** in extreme events especially in transport hubs or areas of traffic congestion to manage the impact from distressed, aggravated and or displaced travellers. (T8-9)	T8-9*	-	-	-	Corporate	Service Delivery	✓	- Additional action
Improve **drainage system** for roads and around at risk buildings and key transport assets. (P3-3)	-	P3-3	S1-13	-	Works	Capital Works	✓	✓ Community agreed action
Work with and actively engage on the development of rapid response and **emergency evacuation procedures** in extreme events including development of the City's Community Resilience Plan, (working with emergency services, government agencies and community groups (including arts, heritage and indigenous groups)). (T8-3)	T8-3	P2-3, P3-1	-	C3-4, C11-1	Works	Operational Changes	✓	✓ Community agreed action

Adaptation action	Risk: Temperature	Risk: Precipitation	Risk: SLR	Risk: Combined	Functional Area	Action type	Work with others	Community agreed action
Advocate to relevant agencies on the need to **consider revisions to engineering/building standards and codes** for exposed buildings and infrastructure (including Standards Australia). (T1-7)	T1-7, T12-4	P2-8	S1-3	C10-15, C11-5	Corporate	Other	✓	- Additional action
Advocate to Sydney Water Corporation with regard to completing **ongoing and periodic reviews of the sewerage system strategies** to better handle extreme events. (P2-2)	-	P2-2*			Works	Operational Changes	✓	✓ Community agreed action
Prepare for **rapid deployment of emergency pumps** and sand bags either located in, or rapidly deployed to, high risk areas to reduce flooding impacts. (P2-6)	-	P2-6, P2-7	S1-8	-	Works	Operational Changes	✓	- Additional action
Establish a cross sector **Climate Resilience Taskforce** to regularly assess and jointly plan for future climate extremes. (C9-3)	-	-	-	C9-3*	Corporate	Other	✓	- Additional action
Develop procedures to ensure that climate resilience is incorporated into all future **key Council decision-making** (projects, plans, strategies etc.). (C10-14)	-	-	-	C10-14*	Corporate	Operational Changes	✗	- Additional action

**Note: Although a number of cross-cutting actions in the above table appear to only address one climate risk, this is because the additional risk they cut across have a lower risk rating (and therefore are not a priority focus) and are not included as part of the analysis. It is still important to consider these actions because they will enable the City to move beyond highest priority risks to address the broader suite of potential impacts facing the City.*

It is possible to analyse this table further to prioritise cross-cutting actions that respond to the most number of risks. This review suggests **the most important action necessary for the City is to develop a Heat Wave Response Plan aligned with the NSW State Heatwave Sub Plan 2011**. This action alone responds to eight (8) different areas of action identified through consultation. Further, as the impacts of heat have been identified as the primary climate risk facing the City a targeted approach to managing these impacts is critical for the City.

11.3.4 Specific Climate Adaptation Action Plan

The following presents the adaptation action plan for those specific and discrete actions associated with the City's highest risks (ranked 7 and 8). For ease of reference the following table denotes whether the action is in Council's control (shared response); the functional area of Council, type of action it represents; and, the associated risk rating. The actions are listed according to the priority ranking (as a per cent out of 100) identified from the MCA.

It should be noted that Plan/Study actions often rank highest in the MCA as they often scored highest in the MCA criteria for cost effectiveness, practicality and stakeholder support. It is advisable these actions are tackled first, as they will often inform subsequent actions.

Table 34 City of Sydney Specific Climate Adaptation Actions

Risk ID	Specific adaptation actions	Work with others	Action type	Risk rating	Priority score (%)	Functional area
Extreme heat/temperature						
T1: Heat – energy system strain, T2: Workforce productivity, T3: Heat – community health impacts, T5: Heat – city wide power disruption, T8: Heat – transport disruption, T9 – Air pollution Extreme heat could put strains on the energy system, reduce workforce productivity, lead to higher incidents of heat stress and other related illnesses amongst the community, lead to power supply disruptions, lead to increases in heat impacts to transport infrastructure and could result in congestion, major delays and mass transit disruption with potential stranding of commuters and extreme heat and associated bushfire smoke could exacerbate the conditions for ozone and air particulates.						
T9-1	Identify the sources of emissions that contribute to pollution exceedance and investigate long term strategies to reduce the volume of these emissions.	×	Plan/study	8	80	Environment
T1-1	Investigate the conditions that trigger peak energy demand in the City.	×	Plan/study	8	76	Environment
T9-4	Research the contribution of emissions from the City's co-generation units on pollution exceedance.	×	Plan/study	8	74	Environment
T1-3	Install energy efficient and resilient remote and automated monitoring and control systems for vital equipment and infrastructure.	×	Capital	8	73	Works
T2-4	Develop an internal communications escalation plan to manage and respond to extreme heat events. Ensure it aligns with the NSW State Heatwave Sub Plan 2011.	×	Plan/study	8	73	Corporate
T5-1	Collaborate with energy companies and other relevant agencies to investigate the capacity of the back-up power supply across the City (assess the probability of brown outs & blackouts).	✓	Plan/Study	7	73	Corporate
T1 – 5	Investigate the provision of back-up and top-up power supply for use during power outages and periods of peak power consumption for Council operations.	×	Plan/study	8	71	Corporate
T8-8	Advocate for public transport system improvements to reduce knock-on effects in heat waves.	✓	Other	8	70	Corporate
T3-5	Conduct shade audits to determine the adequacy of existing shade.	×	Plan/study	8	70	Works

Risk ID	Specific adaptation actions	Work with others	Action type	Risk rating	Priority score (%)	Functional area
T8-5	Develop a strategic alliance with relevant agencies (ie Transport for NSW) on climate resilience.	✓	Other	8	73	Corporate
T8-6	Advocate for a transport agencies to review resilience of transport services in the City)	✓	Other	8	68	Corporate
T1-12	Select equipment for City assets and operations (in particular HVAC) that will be resilient to increased temperature.	N	Operations	8	63	Works
T2-6	Provide aids to workers to manage heat for example: providing shade in strategic areas near the workplace (apply for funding if necessary), providing chilled water, UV protection and respite areas.	N	Operation	8	63	Works
T2-9	Implement changes to all essential services to take account of new requirements to manage extreme heat events.	N	Operation	8	59	Corporate
T3-12	Support relevant stakeholders/agencies in providing information on the nature of ozone risks (ie air pollution).	×	Service	8	59	Community
T5-2	Investigate the provision of back-up power supply for use during power outages for essential Council operations (also consider Better Buildings Partnership) to take advantage of new technological developments. Resilience of supply technology also itself needs to be considered.	×	Operations	7	58	Corporate
T8-10	Work with partner agencies to identify high risk areas in transport system for rapid modification.	✓	Other	8	58	Corporate

Risk ID	Specific adaptation actions	Work with others	Action type	Risk rating	Priority score (%)	Functional area
Sea level rise						
S1: Sea level – inundation of property/infrastructure **Rising sea levels, coastal inundation and saltwater intrusion could increase financial burden for maintenance and protection and threaten the financial value and viability of many properties and infrastructure along the Sydney Harbour foreshore and low lying areas in the south of the LGA.**						
S1-1	Work with relevant stakeholders and agencies to assess the extent of properties within coastal inundation prone areas of the Sydney harbour foreshore	✓	Plan/study	8	87	Corporate
S1-4	Identify and prioritise adaptation actions for each of the City's key at risk infrastructure assets likely to be impacted by sea level rise and storm surge.	×	Plan/study	8	81	Works
S1-6	Work with Sydney Water on wastewater infrastructure situated in low lying foreshore areas to create strategies and operations that address constraints and overflow risks affected by sea level rise.	✓	Plan/study	8	79	Corporate
S1-7	Develop a Sea Level Rise Adaptation Action Plan.	✓	Plan/study	8	77	Works
S1-9	Review the City's Asset Management Strategy to incorporate sea level rise risk.	✓	Plan/study	8	74	Works
S1-10	Review when there is a need to develop signage and other public information in foreshore areas to raise awareness of areas subject to flooding and inundation.	✓	Plan/study	8	67	Corporate
S1-11	Research if and when the City may need to enact responses in the foreshore area due to rising seas.	✓	Plan/study	8	67	Corporate
S1-12	Identify and purchase land at risk from rising seas in the future.	✓	Other	8	59	Corporate
S1-14	Proactively plan for areas likely to be impacted into the future by rising seas.	✓	Capital	8	57	Planning

Risk ID	Specific adaptation actions	Work with others	Action type	Risk rating	Priority score (%)	Functional area
Extreme precipitation/intense rainfall						
P2: Intense rainfall – property/infrastructure damage, P3: Intense rainfall – flash flooding **An increase in intense rainfall, wind and hail events (in combination or isolation) may result in damage to property resulting in increased clean-up efforts. An increase in intense rainfall has the potential to cause flash flooding from overflow of stormwater drainage creating hazardous conditions for the community.**						
P2-1	Continue flood management work to assess extent of properties and key assets sensitive/vulnerable to damage from more severe and frequent rainfall. Investigate the extent of properties and key assets sensitive/vulnerable to damage from wind and hail.	×	Plan/study	8	76	Works
P3-2	Undertake research to identify the extent of properties within flood prone areas and the vulnerable community groups/members and the assets and facilities they use/frequent	×	Plan/study	8	76	Planning
P3-4	Review existing plans and consider future planning requirements to identify those at-risk buildings/assets likely to be impacted in the event of a significant flash flooding event.	×	Plan/study	8	71	Planning
P2-5	Adopt new design measures for improved protection of Council property and infrastructure from more severe wind and rain storm events	×	Planning	8	70	Planning
P3-5	Improved maintenance schedule for cleaning of drains to ensure maximum capacity during flooding	×	Operation	8	66	Works
P3-6	Investigate the design limits of the City's storm water and drainage systems relating to intense rainfall events.	×	Plan/study	8	63	Works
P3-7	Carry out an assessment of the resources required by the City to respond to flash flooding created by intense rainfall	×	Plan/study	8	63	Corporate
P2-9	Work with relevant agencies/stakeholders to provide information to at risk properties to assist preparation in the event of more frequent and severe flood or storm events	✓	Other	8	56	Community
P2-10	Identify high risk areas for rapid modification of assets (storm damage costs)	×	Capital	8	49	Works

Risk ID	Specific adaptation actions	Work with others	Action type	Risk rating	Priority score (%)	Functional area
Combined risks						
C3: Increase in bushfire weather, C3: Increase in bushfire weather, C5 Insurance affordability, C9: Communication Disruption, C10: Financial viability, C11 increased storms causing disruption **An increase in bushfire weather conditions across the Greater Sydney Region could lead to business interruption and economic loss, future climatic conditions could impact on financial viability of council and LGA as well as on insurance affordability, an increase in frequency and intensity of extreme storm events may lead to ICT equipment disruption**						
C3-2	Identify vulnerable community groups/members and the assets and facilities they use/frequent to understand their sensitivity to increased pollution levels in the City from bushfire and/or ozone events	×	Plan/study	8	79	Community
C5-1	Identify the City's at risk assets and engage with insurance companies and brokers on long term adaptation strategies to ensure that assets are considered resilient and insurable and premiums are affordable	×	Other	7	76	Corporate
C9-1	Continue Critical Infrastructure Plans and Disaster Recovery Plan process including install Uninterruptable Power Supply (UPS) on vital servers and other measures for resilience to future climate extremes	✓	Operation	7	74	Corporate
C10-2	Undertake a climate change risk assessment for the City in line with industry accepted standards	×	Plan/study	7	73	Environment
C10-3	Develop site-specific adaptation plans for the City's exposed critical and iconic assets	✓	Plan/study	7	71	Works
C10-4	Investigate sources of funding to implement climate adaptation actions across the City	×	Plan/study	7	71	Environment
C10-6	Integrate climate considerations into Council's procurement policy	×	Operations	7	70	Corporate
C10-7	Quantify climate risks on the City's investment portfolio	×	Plan/study	7	70	Corporate
C11-2	Implement measures to prepare and manage the LGA's urban forest to build resilience to the impacts arising from increased storms and high winds.	×	Operation	8	69	Works
C10-8	Keep abreast of statutory requirements	×	Other	7	67	Corporate

Risk ID	Specific adaptation actions	Work with others	Action type	Risk rating	Priority score (%)	Functional area
C5-3	Investigate options and introduce management approaches for Council facilities and assets to minimise potential liability associated with extreme climate event	×	Operation	7	66	Corporate
C11-3	Work with relevant agencies to investigate and implement a widespread early storm warning communication system	✓	Other	8	66	Corporate
C11-4	Investigate the City's high risk buildings with a view to increasing building upgrades, maintenance and inspection programs for storm and strong wind resilience	×	Operations	8	67	Works
C9-4	Work in partnership with ICT providers and agencies to understand the vulnerability of the City and its businesses' ICT in extreme climate events	✓	Plan/study	7	59	Corporate
C10-9	Undertake a scoping study of the impact of different climate futures on property prices in the City	×	Plan/study	7	57	Corporate
C10-10	Promote the City's commitment to climate resilience	×	Other	7	56	Environment
C10-11	Advocate relevant agencies undertake research to ascertain the impacts of wider socio-economic shifts due to changing climate conditions locally, nationally and globally	×	Plan/study	7	54	Environment
C10-12	Advocate and liaise with State Government to ensure State developed statutory guidelines are climate resilient	✓	Other	7	54	Corporate

The above provides a compiled and prioritised list of actions that the Council should consider. They represent the leading cross cutting and specific actions for the City's highest rated climate risks. As previously observed, approximately half of these actions relate to furthering plans and/or studies, work that is considered a fundamental competent of initiating a Climate Adaptation Plan generally.

11.3.5 Adaptation pathways

The ability to recognise and temporally plot how actions play out in time and space is a critical step in adopting a leading practice approach to climate adaptation. Examples of how this can be considered are presented in Figure 52 and Figure 53 overleaf which show the importance of plotting actions over time in the context of climate exposure.

As the City continues to evolve its adaptation approach and develop its CAP it will be able to identify the triggers and thresholds required to complete its adaptation pathways in line with best practice, notably as demonstrated by Eyre Peninsular in their recent Climate Adaptation Plan.

Figure 52 highlights the interaction between various climate impacts associated with temperature and how they play out over the climate horizons in relation to actions to address the impacts.

Figure 53 adopts a similar approach, illustrating impacts from Sea Level Rise, and highlighting the number of buildings likely to be subjected to inundation from the baseline year (1995) until the end of the century. It plots the timeframe in which the corresponding adaptation planning maybe undertaken to help plan for and respond to these impacts. It also notes key milestones in which certain plans/actions/strategies maybe created or revised to address future impacts associated with rising sea levels.

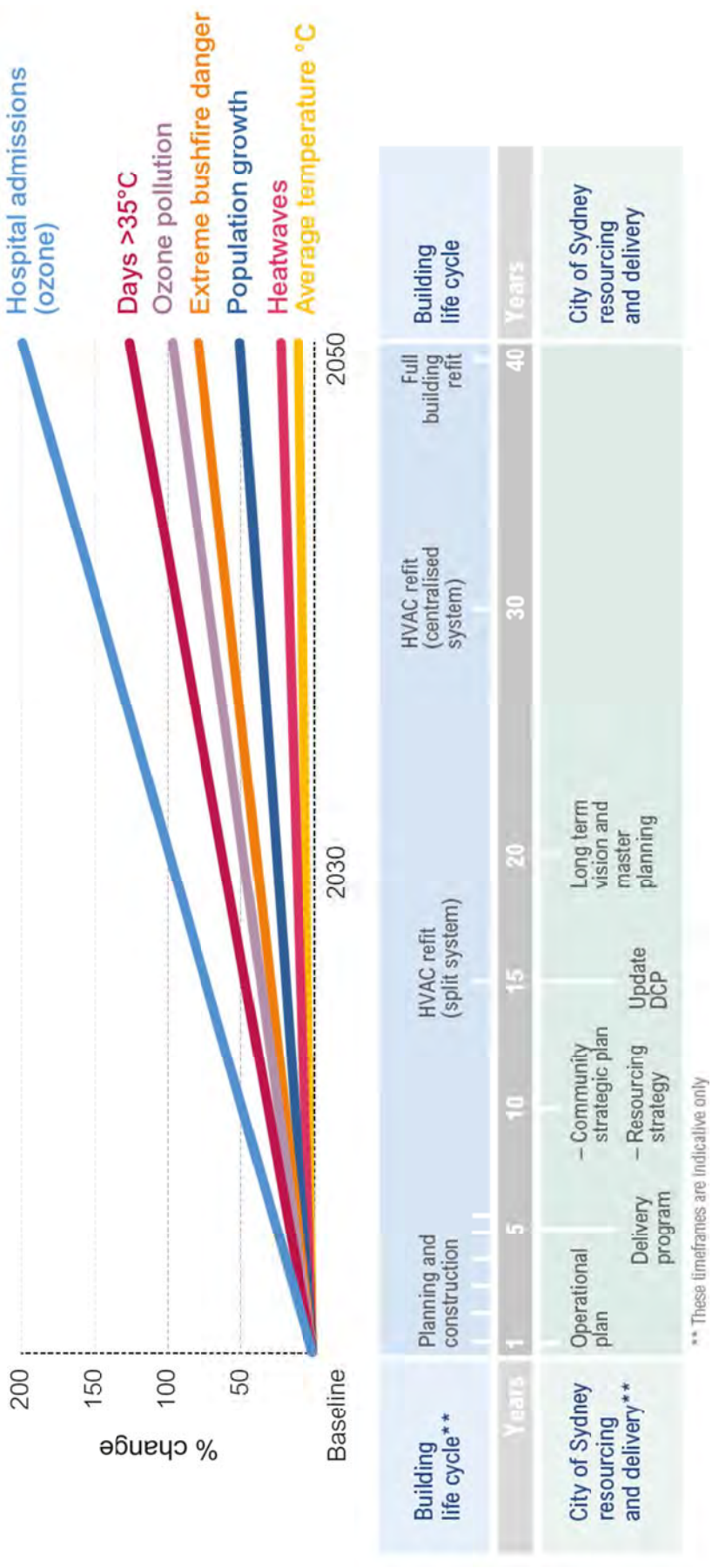


Figure 52 Plotting relative change in temperature and associated impacts

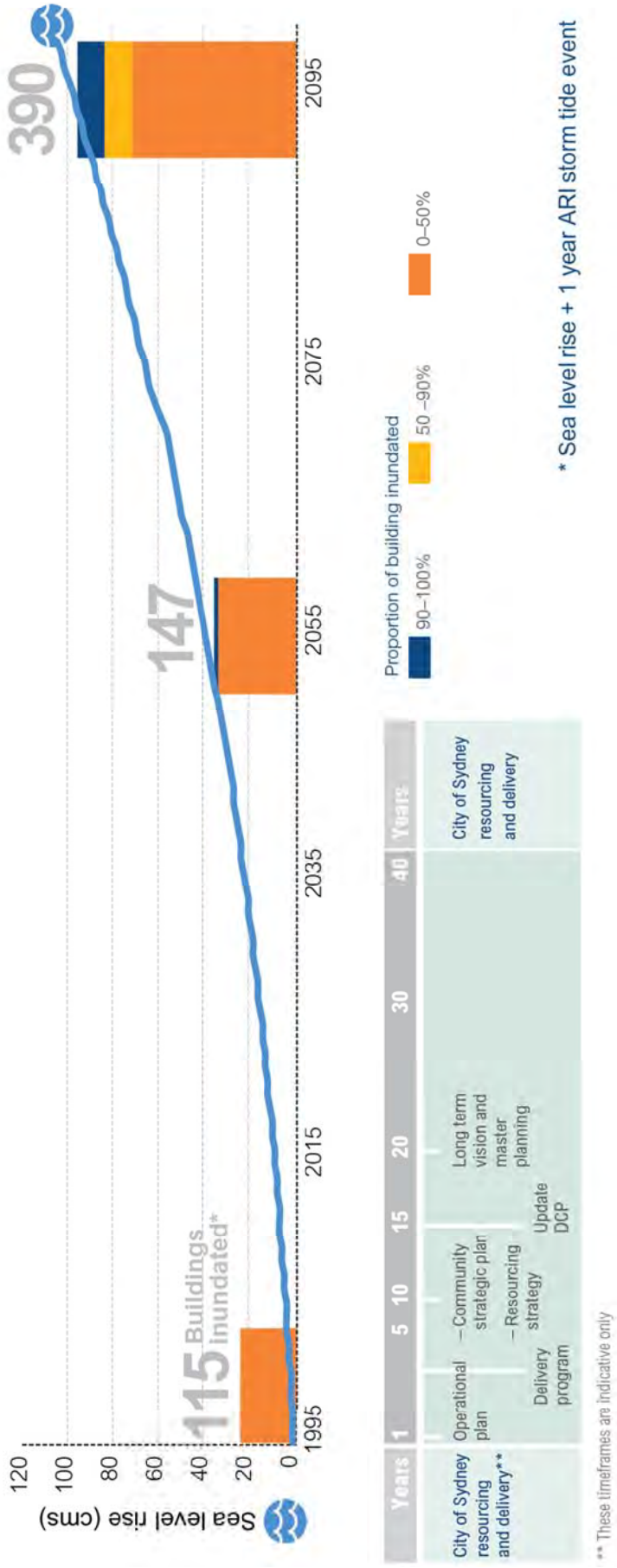


Figure 53 Plotting adaptation timing to address coastal inundation

A notable output of the internal workshop was asking participants to consider and allocate timeframe parameters for the highest priority actions. Accordingly, 14 adaptation time horizons have been developed that seek to present those actions responding to the highest priority risks based on when they might be implemented:

- Short-term, addressing a current timeframe through to 2030.
- Medium-term, 2030 – 2050.
- Long-term, 2050 and beyond.

These time horizons are presented in Figure 54 to Figure 66 providing a useful resource for the City by articulating when an adaptation action might be considered appropriate for implementation its indicative duration. Additional information is also provided concerning those actions currently underway/being considered by the City, and whether they would be considered a ‘no/low-regret’ initiative thereby signalling a potential ‘quick win’ for the City regarding implementation.

Figure 54 T1, Heat – energy system strain

0	Code	Extreme heat could put strains on the energy system, simultaneously decreasing system efficiency and performance of the energy network as system operators struggle to cool down facilities, and increasing electricity consumption due to a surge in peak demand for air conditioning.	This risk addresses heat waves and their ability to reduce the operating capacity of the City's power system and increase demand for cooling for offices in the CBD and residential properties. As a result demand can outstrip supply causing power outages. This risk may also increase water demand for cooling towers.				
			Decision Pathway timing				
		Adaptation description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk T1, Heat - energy system strain	T1-1	Investigate the conditions that trigger peak energy demand in the City.		underway			This will produce baseline information needed in the initiation phase of an adaptation plan.
	T1-2	Investigate the resilience of the power supply across the City (the probability of brown outs & blackouts) in collaboration with energy companies and other relevant agencies. Work with distribution companies on the potential location and time of planned blackouts and options to avoid disruption to key operations.		underway			This will produce baseline information needed in the initiation phase of an adaptation plan.
	T1-3	Install energy efficient and resilient remote and automated monitoring and control systems for vital equipment and infrastructure. E.g. communications for radio, or street lighting (e.g. smart poles).	x				Like all kit, this would most likely be useful up to a determined threshold which will need to be identified.
	T1-4	Review CoS 'Long Term Financial Plan 2011' to consider additional energy costs associated with operation of key Council assets and vital infrastructure in extreme heat events.	x				A price point for this action will need to be identified past which action may become cost prohibitive. This may require the City to re-evaluate the financial viability of operating some of its assets in light of increased extreme heat events.
	T1-5	Investigate the provision of back-up and top-up power supply for use during power outages and periods of peak power consumption for Council operations. Initiatives may include taking advantage of new technological development, and the resilience of the technology considered (also consider Better Buildings Partnership).	x	investigation	implementation		As this action relates to implementation, once the technology has been upgraded this action will be complete. It is anticipated that future periodic checks and reviews may be required to ensure equipment is performing adequately.
	T1-6	Amend and integrate climate resilience considerations into 'CoS Decentralised Water Master Plan 2014' and 'Decentralised Energy Master Plan 2012',	x	Partially included in Plans to 2030	Need to consider medium to long term resilience in these plans		As this action relates to implementing current best practice within existing plans, it is likely a threshold will be reached beyond which these plans are no longer effective and alternative, appropriate actions will need to be identified in its place.
	T1-7	Advocate for changes to building and infrastructure design standards to factor extreme heat.	x				As the climate changes, triggers and thresholds will need to be periodically reviewed and building design standards may not be an appropriate mechanism for response given the time lag.
	T1-8	Continue to roll out energy efficient measures, renewable energy technologies or other suitable efficient power systems (including co/tri-generation facilities) across the City's assets and infrastructure (also consider the resilience of the technology available).	x mixed depending on the aspect/resource	already partially underway	need to adapt as technology changes		This would most likely be useful up to a determined threshold which will need to be identified. Should temperatures continue to exceed this threshold renewable energy and/or energy efficient technologies may not be financially viable.
	T1-9	Continue to manage demand for energy and water across the City's assets, equipment and services through the following: provision of individual meters or sub-metering for all substantive energy and water consumption in real time; HVAC plant needs; energy storage; onsite generation.	x some already underway for City's assets	as per specific tasks	adapt with technology		This action may become cost prohibitive as the frequency of extreme heat events increase. This action will need consistent review to ensure approaches are updated and amended to reflect future climate projections.
	T1-10	Investigate climate sensitive building design that considers local cooling and heating requirements to reduce heat gain/loss. Examples may include natural ventilation cooling; consideration of building orientation and current energy consumption; reduced lighting and equipment loads; installation of green infrastructure (green roof and/or green walls); use of native vegetation. Initiatives may also consider the development of a voluntary program to adopt better planning initiatives as technology changes.		start reviewing as a matter of priority for implementation in 2020s			Generally actions would need to be reconsidered and redeveloped in the medium to long term as conditions change and technological responses evolve.
	T1-11	At a strategic level, review the 'CoS Decentralised Water Master Plan 2014' and 'Decentralised Energy Master Plan 2012 to consider extreme heat'. Following this require developments to consider extreme heat through the planning and designing of energy and water efficient buildings and infrastructure through appropriate planning consents (e.g. DCP amend).		Would need a SEPP and building codes to be updated which are not within the City's control			As this action relates to implementing current best practice within existing plans, it is likely a threshold will be reached beyond which these plans are no longer effective and alternative, appropriate actions will need to be identified in its place.
	T1-12	Select equipment for City assets and operations (in particular HVAC) that will be resilient to increased temperature and more frequent and severe heatwaves.	x	could be built into plan developed under T5			As the climate changes, triggers and thresholds will need to be consistently reviewed to ensure selected equipment is able to withstand changes resulting from the increased frequency of extreme heat events.
	T1-13	Redesign/design the City's public realm for passive cooling: measures may include the provision of shading; cool places; public water facilities. For example, review/prepare design guidelines for street furniture, shelters and awnings and infrastructure to provide protection, e.g. shade and sun protection.	x				This action may become cost prohibitive as the frequency of extreme heat events increase. This action will need consistent review to ensure approaches are updated and amended to reflect future climate projections.
	T1-14	Advocate for energy companies to investigate increased resilience and efficiency in supply (potentially through increase of overhead wiring conductivity).	x	already underway (advocating)	capacity is generally available now so this needs to be actually investigated and implemented in the medium term		The current levels are adequate but the future implications of extreme temperature increase may see significant changes needed..

Figure 55 T2, Heat – workforce productivity

An increase in extreme heat and associated impacts could reduce workforce productivity, as activities become too hot for people to work outside during parts of the day and the indoor thermal comfort is affected by pressures on cooling systems.	This risk addresses heat waves and their associated impacts such as poor air quality that could reduce the productivity of staff. Workplace health and safety require heat exposed staff to have breaks or not work if extremes temperatures are experienced. This risk also captures the loss of productivity due to: • People's roles as carers for dependents and volunteers which takes them away from their usual role. • Transport disruptions preventing or delaying travel to and home from work. • Disruptions to the transport of goods and services that are essential for businesses. • Evacuation of buildings due to failed HVAC systems.				
Adaptation Description	**Decision Pathway timing**				
	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Review working conditions - 'WHS policies 2013' and procedures, flexible working arrangements and operational procedures for maintenance crews and outdoor staff – with regard to extreme heat.	X				Generally, actions would need to be updated in the medium to long term as conditions change.
Provide training to staff to raise staff awareness, on emergency responses and what to do in a heat wave.	X				Generally, actions would need to be updated in the medium to long term as conditions change.
Amend Business Continuity Plan 2013/2014 to consider impacts from extreme heat on essential services (rangers, water, homelessness/outreach, meals on wheels).	X				As this action relates to implementing current best practice within existing plans, once this has been completed the action will be delivered. It is anticipated that additional appropriate actions will need to be identified in its place.
Develop an internal communications escalation plan to manage and respond to extreme heat events. Ensure it aligns with the NSW State Heatwave Sub Plan 2011.	X				As this action relates to implementing current best practice within existing plans, once this has been completed the action will be delivered. It is anticipated that additional appropriate actions will need to be identified in its place.
Consider further revision to event protocols to enable safe, successful events in hot conditions: improved communications between staff and organizers regarding precautions; water provision; event restriction over certain temperature thresholds; reduced alcohol provision; and, eventually changing the time of year in which the events are held to avoid extreme heat.	X				As a result of more frequent extreme heat events in the future, it is likely a capacity will be reached beyond which revisions to the protocols would not be effective requiring a review of when and how events continue to be scheduled.
Provide aids to workers to manage heat for example: providing shade in strategic areas near the workplace (apply for funding if necessary), providing chilled water, UV protection and respite areas.	X	already done for City staff	Need to provide for general office workers		This action may become cost prohibitive as the frequency of extreme heat events increase.
Develop 'Heat Wave Response Plan' and include workplace issues. Ensure it aligns with the 'NSW State Heatwave Sub Plan 2011'.	X	include in One Plan with other issues			Generally actions would need to reconsidered and redeveloped in the medium to long term as conditions change.
Optimize design of the City's buildings and the operation of those buildings to provide more suitable conditions under higher temperatures.	X	Start implementing now for new projects	Need finance and technology to inform		This action will need periodic review to ensure approaches are updated and amended to reflect future climate projections.
Implement changes to all essential services to take account of new requirements to manage extreme heat events.	X				Generally, actions would need to reconsidered and redeveloped in the medium to long term as conditions change.
Encourage scheduling of recreational and sporting events and activities to avoid the hottest part of the day and at shady locations where possible to manage staff and community exposure.	X				As a result of more frequent extreme heat events in the future, it is likely a capacity will be reached beyond which revisions to the protocols would not be effective.

Figure 56 T3, Heat – community health impacts

	Code	An increase in extreme heat could lead to higher incidents of heat stress and other related illnesses amongst the community resulting in a decrease in comfort levels and an increase in hospital admissions, pressure on social services and morbidity.	This risk addresses the ability of heat waves to increase incidents of people seeking medical attention due to heat stress. This is mainly seen in sensitive populations such as the elderly, lower socio-economic groups, Culturally and Linguistically Diverse (CALD), sick, tourists, disabled, homeless, young children, exposed workers and companion animals. This increases strain on emergency and social services supporting this sensitive population due to increases in demand coupled with a decrease in staffing resources (refer to T2).				
			Decision Pathway timing				
		Adaptation Description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk T3, Heat - community health impacts	T3-1	Work in partnership with relevant stakeholders to develop a communication campaign to inform the community about the impacts of heat wave. This may include building awareness of safe refuges and shelters in extreme heat events, particularly for use in the event of mass stranding (ideally located at or new major transport hubs); identifying locations/events/opportunities for heatwave awareness raising as part of community and or cultural events.	x	this would be an extension of existing campaigns, e.g. Slip, slop, slap. Need to consider tourists.			Communications strategies will become less effective as extreme heat events become more frequent and commonplace.
	T3-2	Review 'CoS Decentralised Water Master Plan 2014' and 'Decentralised Energy Master Plan 2012' for extreme heat resilience and Urban Heat Island implications.	x	DWMP revised every 5 - 10 years: needs to consider best climate science at time of review			As this action relates to implementing best practice within existing plans, once this has been completed the action will be delivered. It is anticipated that additional appropriate actions will need to be identified in its place.
	T3-3	Work with relevant stakeholders/agencies to support community and localised 'self-help' responses to heat waves, particularly those that engage with public, tenants and local communities such as Emergency Services. Response initiatives may include development of a Community Resilience Plan or a Heatwave Response Plan (review current *Community Strategic Plan 2013' and align with NSW State Heatwave Sub Plan 2011).* Investigate the development and roll-out of a widespread early Heat Wave Alert System.		Identification will start earlier (current), can consider the adaption of existing resources to reduce the need to build new	Dependent on the City's role i.e. Leader, partner, support agency etc		Communications strategies will become less effective as extreme heat events become more frequent and commonplace and alternative communications methods will need to be identified.
	T3-4	Identify and develop additional (larger) refuges, facilities and amenities for use in heatwaves e.g. accessible air-conditioned public facilities, outdoor drinking facilities, waive/reduce user fees for swimming pools. Ensure refuges themselves are resilient to heat and designed to accommodate expected number of patrons in a heat event.		Identification will start earlier (current), can consider the adaption of existing resources to reduce the need to build new			Both demand and costs for refuges could substantially increase in the longer term and action may be limited due to the availability of appropriate sites for refuges.
	T3-5	Conduct shade audits to determine the adequacy of existing shade, whether there is a need for more, if appropriately located and of appropriate size. Also include provision of shade structures in design of new recreational facilities.	x	Need to determine role of shade in mitigating heat wave impacts, (level of priority uncertain, but the technology is there)			This will produce baseline information needed in the initiation phase of an adaptation plan.
	T3-6	Ensure vegetation species selection is climate resilient.	x	use of LIDAR to determine shade levels	The City already specify species for current climate - need to review these over time to reflect future climate.		As a result of changes to the frequency of extreme heat events a future threshold may be reached where vegetation selection needs to be completely rethought .
	T3-7	Training for staff (especially City Projects) on the use of Design Safety Risk Assessments to identify and manage situations in hot conditions and how to incorporate climate considerations.	x	This is underway but frequency uncertain - other mitigation measure may be needed.			Generally actions would need to reconsidered and redeveloped in the medium to long term as conditions change.
	T3-8	Undertake a scoping study on the wide range of measures to address the urban heat island effect, identifying at risk populations, options to mitigate effects on the vulnerable and residual risk along with strategies for containment of those residual risks.					This will produce baseline information needed in the initiation phase of an adaptation plan.
	T3-9	Investigate and adopt climate sensitive building design considerate of local cooling and heating requirements and reduces overheating e.g. inclusion of natural ventilation cooling, consideration of building orientation and low energy consumption, reduce lighting and equipment loads, green infrastructure -green roof and/or green walls, use of native vegetation.					This action will need periodic review to ensure approaches are updated and amended to reflect future climate projections.
	T3-10	Review event protocols with regards to extreme heat: consider reducing/cancelling recreational and sporting events and activities to avoid the hottest part of the day and to use shady locations where possible. Improve communications with event attendees and organisers regarding precautions; water provision; restricting events taking place over certain temperature thresholds; reducing the provision/availability of alcohol.	x				As a result of more frequent extreme heat events in the future, it is likely a capacity will be reached beyond which revisions to the current protocols would not be effective. It is anticipated that when this occurs additional appropriate actions will need to be identified in their place.
	T3-11	Advocate for transport agencies to review resilience of transport services in the City.		Need to identify transport services, their role/impact and implement actions			This represents a baseline action needed in the initiation phase of an adaptation plan. Also, operation of transport services may become cost prohibitive based on more frequent disruptions resulting from extreme heat events.
	T3-12	Support relevant stakeholders/agencies in providing information on the nature of ozone risks - targeted to susceptible groups (i.e. elderly, ill, very young).					Communications strategies will become less effective as extreme heat events become more frequent and commonplace.
	T3-13	Redesign/design the City's public realm for passive cooling; measures may include the provision of shading; cool places; public water facilities. For example, review/prepare design guidelines for street furniture, shelters and awnings and infrastructure to provide protection, e.g. shade and sun protection.					This action will need periodic review to ensure approaches are updated and amended to reflect future climate projections.

Figure 57 Risk T5, Heat – energy system strain

	Code	An increase in extreme heat could lead to power supply disruptions from programmed load shedding and heat damage to network infrastructure.	This risk addresses heatwaves and their ability to both reduce the capacity of the network and cause direct damage to power supply infrastructure, causing brownouts and blackouts. It also covers the proactive load shedding performed by energy utilities to protect the network. This is turn reduces the reputation of the City in having a reliable power supply for its community and visitors.				
		Adaptation Description	**Decision Pathway timing**				
			Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk T5, Heat - energy system strain	T5-1	In collaboration with energy companies and other relevant agencies, investigate the capacity of the back-up power supply across the City (the probability of brown outs & blackouts).		Need to consult with Ausgrid (Network NSW) as they have undertaken the assessment. Also note that there is an issue with the swimming pools when there is power failure – required water quality cannot be maintained.			This will produce baseline information needed in the initiation phase of an adaptation plan.
	T5-2	Investigate the provision of back-up power supply for use during power outages for essential Council operations (also consider Better Buildings Partnership) to take advantage of new technological developments. Resilience of supply technology also itself needs to be considered		Council investigating tri and co-generation.			This will produce baseline information needed in the initiation phase of an adaptation plan.

Figure 58 T8 – Heat – transport disruption

	Code	An increase in the extreme heat could lead to increases in heat impacts to transport infrastructure - resulting in congestion, major delays and mass transit disruption with potential stranding of commuters.	This risk addresses heat waves that can cause direct damage to transport infrastructure, reducing the capacity of the network, service delivery within the CBD and causing delays / stranding of commuters. This is turn reduces the reputation of the City in having a reliable transport system for its community and visitors.				
			Decision Pathway timing				
		Adaptation Description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk T8, Heat - transport disruption	T8-1	Work with transport agencies and relevant stakeholders on a communication strategy to build awareness of potential transport disruptions in heat events and what to do about it (consider advertisements, signage, other campaigns etc). Campaigns should also build awareness of safe shelters that can be used in the event of mass stranding (ideally located at or new major transport hubs); it may also include a business and retail security education program on safe practices during transport delays and deployment of directional and information staff at all major transport hubs during heat waves; and, collaboration with emergency response agencies to communicate instructions for the public in an extreme heat event - such as the importance of keeping roads and light railways clear for the passage of emergency services to all road users and pedestrians.					The efficacy of communications strategies will need to be reviewed and updated as extreme heat events become more frequent and commonplace.
	T8-2	Work with relevant stakeholders/agencies to develop and roll-out a widespread early Heat Wave Alert System, incorporating transportation system status information					This approach is likely to become less effective as extreme heat events become more common place and the need for a Heat Wave Alert becomes more frequent and people become more likely to dismiss the warnings.
	T8-3	Work with emergency response agencies to plan and respond to extreme heat events. This will include identifying critical road locations and routes for control and access for emergency procedures, and devise a response plan to ensure emergency passage and access and research feasibility of a network of cameras to increase sophistication of guidance for emergency vehicles, potentially from central control points.	x				This approach would require periodic review to ensure approaches are updated and amended. Whilst current service levels might be adequate, the future could see a significant increase in demand on emergency agencies which could become unserviceable.
	T8-4	Advocate to ensure access to the internet and websites with emergency notices relating to transport delays are operable from a back-up server and has built-in resilience to heat events.	x				An initial joint approach with relevant stakeholders would embed this action into practice. This represents a baseline action needed in the initiation phase of an adaptation plan.
	T8-5	Develop a strategic alliance with relevant agencies (i.e. Transport for NSW) on climate resilience to ensure adaptation options are not developed in isolation.	x				An initial joint approach with relevant stakeholders would embed this action into practice. This represents a baseline action needed in the initiation phase of an adaptation plan.
	T8-6	Advocate for public transport system improvements to reduce knock-on effects of individual breakdowns or service failures.	x				An initial joint approach with relevant stakeholders would embed this action into practice. This represents a baseline action needed in the initiation phase of an adaptation plan.
	T8-7	Work with relevant stakeholders/agencies on a detailed Heat Response Plan which includes measures to tackle high risk situations such as transport breakdowns.					This approach would require periodic review to ensure approaches are updated and amended. Whilst current service levels might be adequate, the future could see a significant increase in demand on emergency agencies *which could become unserviceable.*
	T8-8	Advocate for increased police and security presence in hot conditions especially in transport hubs or areas of traffic congestion to help manage the impact from distressed, aggravated and or displaced travellers.	x				Extra police presence is likely to only be effective in the short term and may become cost prohibitive over the longer term.
	T8-9	Work with partner agencies to identify high risk areas in the transport system for rapid modification					Capital works to modify transport systems would evolve as circumstances dictate. And may become cost prohibitive over the longer term.

Figure 59 T9, Heat – air pollution

	Code	An increase in extreme heat and associated bushfire smoke could exacerbate the conditions for ozone and air particulates which cause an increase in incidents of respiratory distress resulting in an increase in hospital admissions and morbidity.	This risk addresses heat waves that exacerbate conditions for the production of air pollution from ozone and bushfire smoke particulates, increasing the number of people seeking medical attention for asthma and other breathing difficulties. There is also a potential impact on the appeal of outdoor lifestyle which has reputational impacts for the City.				
			Decision Pathway timing				
		Adaptation Description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk T9, Heat - air pollution	**T9-1**	Identify the sources of emissions that contribute to pollution exceedance and investigate long term strategies to reduce the volume of these emissions	x	Making data available could be a political risk - there is so much outside the City's scope.	Would need to consider the results of the investigation in the medium term		This represents baseline information needed in the initiation phase of an adaptation plan.
	T9-2	In conjunction with other agencies help promote information on air quality impacts to staff, businesses, residents and other key stakeholders on how they can take effective action to reduce exposure to bushfire smoke and reduced air quality. This information should promote community awareness of heat wave response plans and policy. Provide information of dangers of exposure/symptoms. Ensure a particular focus on the vulnerable in the community and targeted to susceptible community groups (i.e. elderly, ill, very young).	x	Information and resources to be developed	Ongoing roll-out and implementation		In the long term, continuation of this action is likely to become ingrained across the City and no longer required/efficient.
	T9-3	Work in partnership to review event planning and coordination, involving the NSW Event Operations Group (also EOG Exec), to consider implications for events of more high pollution days and limit risks from hazard reduction and bushfire on participants and attendees in City events (including running events).	x	risk assessments included in event planning forms			Long term, improved technology may potentially reduce the level of planning and response associated with this action. Further, there may be future insurance impacts due to potential event cancellations. As a result of more frequent extreme heat events in the future, it is likely a capacity will be reached beyond which revisions to the protocols would not be effective.
	T9-4	Research the contribution of emissions from the City's co-generation units on pollution exceedance.	x	Already underway - study completed (negligible impact), continue to monitor/regulate as policy changes)			Action on this initiative is already almost complete by the City but will need to be continually updated. This represents baseline information needed in the initiation phase of an adaptation plan.
	T9-5	Council to implement its designated actions in the 'NSW State Heatwave Sub Plan 2011'.	x	required.			This plan will become less effective as extreme heat events become more commonplace and should be updated accordingly.
	T9-6	Work with relevant stakeholders/agencies to develop detailed pollution related actions in to a Heatwave Management Plan.					This plan will become less effective as extreme heat events become more commonplace and should be updated accordingly.
	T9-7	Advocate for the development and roll-out of a widespread early Pollution/Bushfire/Heat Wave Alert System to help build preparedness level, including consideration of an air pollution incident response unit(s).					This action will become less effective as extreme heat events become more commonplace and should be updated accordingly.

Figure 60 S1, Sea level rise – inundation of property/infrastructure

	Code	Rising sea levels, coastal inundation and saltwater intrusion could increase financial burden for maintenance and protection and threaten the financial value and viability of many properties and infrastructure along the Sydney Harbour foreshore and low lying areas in the south of the LGA.	This risk addresses the issue that property located along the harbour foreshore being impacted by permanent inundation and saltwater intrusion. This may include homes, businesses, coastal assets and open space areas such as parks and gardens. This risk also highlights the issue of disclosure of properties within hazard zones and the conditions of consent for development in these areas.				
		Adaptation Description	**Decision Pathway timing**				
			Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk S1, Sea level rise - inundation of property/infrastructure	S1-1	Work with relevant agencies/stakeholders to assess the extent of properties within coastal inundation prone areas of the Sydney harbour foreshore. Identify vulnerable community groups/members and the assets and facilities they use/frequent in those areas that may be affected by sea level rise impacts (e.g. child care, aged care, hospitals, schools).	x				This represents a baseline action needed in the initiation phase of an adaptation plan to help build preparedness and resilience.
	S1-2	Work with relevant stakeholders/agencies to develop and roll out a proactive program to raise awareness amongst residents, businesses, Council facility users, and Council staff around the impacts of increased sea level rise and storm surge impacts.					This action is likely to be effective over the longer term as changes to SLR are more gradual in impact.
	S1-3	Advocate for the development of building/flooding development standards which include SLR and storm surge. Undertake comprehensive flood studies to inform development of the 'Floodplain Risk Management Plan 2014' to inform land use planning policy taking account of Sea Level Rise. Develop resilient engineering/building standards for buildings and infrastructure near coastal areas and in particular low lying areas of City and along the foreshore (localized storm surge barriers/buffers). Obtain LIDAR data to allow for higher resolution flood mapping to be produced.					As the climate changes triggers and thresholds will need to be periodically reviewed and building design standards may not be an appropriate mechanism for response given the time lag. Heritage buildings will also add to the complexity of responding to this action.
	S1-4	Identify and prioritise adaptation actions for each of the City's key at risk infrastructure assets likely to be impacted by sea level rise and storm surge.					This approach could become cost prohibitive in the longer term with high SLR.
	S1-5	Review the City's 'Decentralised Water Master Plan; 'WSUD & Stormwater Infrastructure Report 2012', and the 'Local Environment Plan 2012' regarding sea level rise impacts. Ensure coastal inundation modelling incorporates updated Australian Rainfall and Runoff data, storm surge and sea level rise to give true understanding of a confluence of different events that contribute to a worst case scenario.					This represents a baseline action needed in the initiation phase of an adaptation plan.
	S1-6	Work with Sydney Water Corporation on wastewater infrastructure situated in low lying foreshore areas to create strategies and operations that address constraints and overflow risks affected by SLR, as well as sewer rehabilitation and cleaning regimes (increase cleaning regime for drains to ensure maximum capacity).					Initial collaboration will foster a joint working approach into the future which means sustained action may not extend beyond the short-term.
	S1-7	Develop a Sea Level Rise Adaptation Action Plan. Include documentation of processes and actions that demonstrate reasonable decision-making in light of information that is known in relation to Sea Level Rise. Including the development with relevant stakeholders and agencies of a long term vision for the City's foreshore that addresses the protection of foreshore reserves, environmental, heritage and recreational values under predicted SLR. This should map-out over the long term (>50 years) zoning and development laws changes for foreshore areas.	x				This would need to be continually updated with changing information on SLR.
	S1-8	Identify protection methods for at risk foreshore areas, and especially sensitive assets, that is aligned with practice guidelines. This would include ensuring emergency pumps can be rapidly deployed to high risk areas to reduce flooding impacts, engineering approvals, building standards etc. For example, increase quality and quantity of built foreshore protection infrastructure, identify key road assets that can function as levy protection, build roads (key) to withstand inundation effects.	x				The use of emergency pumps likely only to be needed from the medium term onwards.
	S1-9	Review the City's Asset Management Strategy to incorporate sea level rise risk and priorities actions for maintenance and renewal of at risk assets.	x				It is likely this type of action is only likely to be needed from the medium term onwards.
	S1-10	Review when there is a need to develop signage and other public information in foreshore areas to raise awareness of areas subject to flooding and inundation.					It is likely this type of action is only likely to be needed from the medium term onwards.
	S1-11	Research if and when the City may need to enact rapid response cordoning of flooded areas due to rising seas to prevent entry by pedestrians and vehicles to reduce the event of accidents and incidents. Also include an investigation into the extent and timing of natural areas being impacted by rising sea level along with potential salt water intrusion impacts.					This represents baseline information needed in the initiation phase of an adaptation plan. Research needs to be undertaken in the short term.
	S1-12	Identify and purchase land at risk from rising seas in the future. Alternatively investigate options to provide financial measures to assist with relocation of public and private assetd (e.g. Crown land).					The short-term actions associated with this Risk ID will influence this action post 2050 however this could be cost prohibitive in the longer term.
	S1-13	Improve drainage system for roads and around at risk buildings and key transport assets in low lying areas when the opportunity arises as a low regrets strategy for future protection.					It is likely this type of action is only likely to be needed from 2050 onwards however action could be cost prohibitive in the longer term.
	S1-14	Proactively plan for areas prone to erosion and carry out stabilization works and add protections for natural areas of vegetation in the foreshore zones likely to be impacted into the future by rising seas. Identify and where appropriate, develop flood defences and other infrastructure solutions that will build protection to property and infrastructure at risk from arising seas into the future.					This represents a baseline action needed in the initiation phase of an adaptation plan. Planning decisions need to be made now for both medium and long term.
	S1-15	Develop appropriate planning policies aligned with relevant state government policies and directions to address impacts from sea level rise and flooding.					Planning decisions need to be made for both medium and long term. The start of this could be delayed until relevant threshold is reached (threshold to be determined).

Figure 61 P2, Intense rainfall – property/infrastructure damage

	Code						
		An increase in intense rainfall, wind and hail events (in combination or isolation) may result in damage to property resulting in increased clean-up efforts.	This risk addresses the ability of heavy rainfall, wind and hail in combination or isolation, causing extensive damage to property: • Infrastructure (i.e. power lines, street lights, embankments). • Buildings (i.e. homes, PV installations and stations). • Trees (i.e. street trees). This increases clean-up efforts, disposal and maintenance costs. Past events have also shown that this risk can result in an opportunity for skilled labour to repair and rebuild. (Asset damage focus)				
			Decision Pathway timing				
		Adaptation description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk P2, Intense rainfall - property/infrastructure damage	P2-1	Continue flood management work to assess the extent of properties and key assets sensitive/vulnerable to damage from more severe and frequent rainfall. Investigate the extent of properties and key assets sensitive/vulnerable to damage from wind and hail. Measures to include: development of a checklist to consider infrastructure changes to protect areas from damage from flood and storms (including wind and hail damage), optimization of the active storage capacity to alleviate flash (overland) flood peak in intense rainfall, consideration of diverting and concentrating flood waters to more confined locations in event of an extreme storm.					This represents a baseline action needed in the initiation phase of an adaptation plan.
	P2-2	Review the design capacity of the City's storm water systems, and advocate to Sydney Water Corporation on storm water and wastewater systems, to prevent overflow events in line with extreme rainfall projections.					This represents a baseline action needed in the initiation phase of an adaptation plan.
	P2-3	Work with emergency response agencies on strategic prioritization and coordinated clean-up response to manage costs.	x				Warning systems and emergency preparedness are effective only in the short term as events become more commonplace.
	P2-4	Investigate whether building design controls (including the 'Development Control Plan 2012') can deliver built forms that are more resilient to intense rainfall. Identify suitable types of development resilient to intense rainfall and storms. Continue water sensitive urban design methods and ensuring that modelling caters for predicted increase in severity and frequency in all storm events. E.g. minimise hard surfaces, such as pavements and include controls that promote soft surface and large open spaces to manage stormwater.	x				As the climate changes triggers and thresholds will need to be periodically reviewed and building design standards may not be an appropriate mechanism for response given the time lag.
	P2-5	Adopt new design measures for improved protection of Council property and infrastructure from more severe wind and rain storm events e.g. appropriate vent levels, roof drainage systems. Including development of a checklist to consider the impacts of City Projects with regard to impacts of intense rainfall, wind and hail.	x				For majority of building stock likely to be at the refit & refurbishment stage in building life cycle so medium term.
	P2-6	Research new technologies and approaches to improve infrastructure and property resilience to rainfall, hail and wind - porous pavements etc. Including the identification and research of further protective measures from potential flying/falling debris in extreme storm events.	x				This represents a baseline action needed in the initiation phase of an adaptation plan.
	P2-7	Prepare for rapid deployment of emergency pumps and sand bags either located in, or rapidly deployed to, high risk areas to reduce flooding impacts in high risk areas.	x				Greater demands may be placed on emergency response as capacity is reached with more frequent extreme events.
	P2-8	Advocate to relevant parties to review/investigate increase building strength and flood resilience standards - Standards Australia and Building Code of Australia.	x	AS relating to building attachments is important. Amendments to building standards will take a long time.			As the climate changes triggers and thresholds will need to be periodically reviewed and building design standards may not be an appropriate mechanism for response given the time lag.
	P2-9	Work with relevant stakeholders/agencies to provide information to at risk properties to assist preparation in the event of more frequent and severe flood or storm events.	x				This action would only be effective in the short term as efficacy reduces as extreme events become more frequent.
	P2-10	Identify high risk areas for rapid modification of assets (storm damage costs).					Initial assessments would inform the medium and long term responses. The use of emergency pumps likely only to be needed from the medium term onwards.

Figure 62 P3, Intense rainfall – flash flooding

	Code	An increase in intense rainfall has the potential to cause flash flooding from overflow of stormwater drainage creating hazardous conditions for the community.	This risk addresses heavy rainfall that can cause storm water drainage systems to back up and cause localised flash flooding of roads, public spaces and property. This may result in an increase in localised traffic congestion, vehicular and pedestrian accidents, as well as loss of parking spaces in low lying areas and basements.				
				Decision Pathway timing			
		Adaptation Description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk P3, Intense rainfall - flash flooding	P3-1	Work with emergency response agencies and relevant stakeholders to ensure availability of messaging and information regarding flash flooding and extreme flood events is made public and assistance is available. Actions to include: collaborating with emergency response agencies to ensure websites (and related emergency notices) are operable from a back-up server in an extreme flood event; information campaign on flash flooding risks to advise residents and businesses of safe refuges/shelter locations, advice for dealing with transport delays in extreme events etc; investigate the creation of storm protected evacuation locations; evacuation and emergency response coordination to manage the activation and coordination of resources in response to emergencies.	x		Flood data needs to be reviewed to accommodating new thinking and data		This action is likely to be effective over the longer term as changes to SLR are more gradual in impact.
	P3-2	Undertake research to identify the extent of properties within flood prone areas and the vulnerable community groups/members and the assets and facilities they use/frequent in those areas (e.g. child care, aged care, hospitals, schools).	x		Response dependent on new data/new theories. Action will need to be periodically reviewed to ensure due diligence		This represents baseline information needed in the initiation phase of an adaptation plan.
	P3-3	Investigate drainage improvements at all known flash flood point (assessed taking account of intense rainfall projections) within City's property boundaries, and advocate similar actions outside the council's boundaries and control. Actions may also include continued upgrades to the City's storm water infrastructure using WSUD methods and ensuring that modelling includes intense rainfall projections; and, investigating the reshaping of the urban form in affected areas to reduce localised flooding.		Council is building rain gardens and other WSUD infrastructure, building large-scale stormwater infrastructure; reviewing what pipe sizes are required (modelling is based on current not future data)	$65million in budget to upgrade stormwater infrastructure over 10 years. Need to review pipe sizes as new information becomes available		This represents baseline information needed in the initiation phase of an adaptation plan.
	P3-4	Review existing plans and consider future planning requirements to identify those at-risk buildings/assets likely to be impacted in the event of a significant flash flooding event. Consideration of these impacts is being considered as part of the Flood Plain Management Policy for new development and an implementation plan is recommended to support changes.	x				This represents baseline information needed in the initiation phase of an adaptation plan.
	P3-5	Improved maintenance schedule for cleaning of drains to ensure maximum capacity during flooding.	x	maintenance schedules are being reviewed	Review and enhance maintenance schedules		Increased maintenance may be needed but eventually a capacity will be reached with more frequent events, this capacity threshold needs to be investigated as the scientific data on precipitation offers greater certainty.
	P3-6	Investigate the design limits of the City's storm water and drainage systems relating to intense rainfall events that is likely to cause flash flooding (informs triggers/thresholds).	x				As the climate changes triggers and thresholds will need to be periodically reviewed and building design standards may not be an appropriate mechanism for response given the time lag.
	P3-7	Carry out an assessment of the resources required by Council and the City to respond to flash flooding created by intense rainfall.					This represents baseline information needed in the initiation phase of an adaptation plan.

Figure 63 C3, Bushfire – cascading impacts

	Code	An increase in bushfire weather conditions across the Greater Sydney Region could lead to business interruption and economic loss within the LGA due to interrupted accessibility in and out the City and strain on resources and services.	This risk addresses bushfires continuing to cause extensive property and infrastructure damage across the Greater Sydney Region with cascading impacts on the LGA, including: • Damage to the transport network delaying or stranding CBD workers. • Limited availability of emergency response and social services within the CBD due to transfer of capacity to regional disaster zones. • Decrease in tourism due to reduced appeal of attraction on Sydney's fringe. • Reduced productivity and economic loss due to CBD workers and LGA workforce taking leave to volunteer or defend property. • Contaminated water supply.				
		Adaptation Description	**Decision Pathway timing**				
			Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk C3, Bushfire - cascading impacts	C3-1	Work with relevant agencies on a community awareness and education campaign regarding the nature of smoke and ozone pollution risks to health, including information on safe shelter locations stranded workers (e.g. air-conditioned public facilities).	x	Communicate			This represents a baseline action needed in the initiation phase of an adaptation plan.
	C3-2	Identify vulnerable community groups/members and the assets and facilities they use/frequent (e.g. child care, aged care, hospitals, schools) to understand their sensitivity to increased pollution levels in the City from bushfire and/or ozone events. Actions to address this need to be informed by the findings of this study e.g. Homelessness Action Plan/Social Wellbeing Plan	x				Thresholds will be reached in the short or medium term where all vulnerable groups have been identified and there is no longer a need for this program.
	C3-3	Advocate for an early bushfire warning network system for workers living in bushfire prone areas outside of the City, incorporating transportation system status information.					This action will become less effective as extreme heat events become more commonplace.
	C3-4	Work with emergency services, government agencies and community groups to identify appropriate emergency response actions relating to pollution events. This will also include activation, coordination, and arrangements for the provision of assistance to help the community recover.					This approach would need continual review to ensure approaches are updated and amended. Whilst current service levels might be adequate, the future could see a significant increase in demand on emergency agencies which could become
	C3-5	Limit the working hours of outdoor staff during high bushfire weather and high ozone pollution events (e.g. review of Extreme Weather Risk Assessments).	x				As a result of more frequent extreme heat events in the future, it is likely a capacity will be reached beyond which revisions to the protocols would not be effective.
	C3-6	Work with relevant stakeholders/agencies to include response to bushfire and ozone pollution dangers in a detailed Heat Wave Response Plan: active identification and care of at risk populations, measures to tackle high risk situation including events and transport breakdowns.	x				Initial collaboration will foster a joint working approach into the future which means sustained action may not extend beyond the short/medium-term.

Figure 64 C5, Insurance affordability

	Code	An increase in extreme weather events such as bushfires and flooding could decrease the affordability of insurance premiums due to increased losses resulting in increased costs and reduced cover.	This risk addresses insurance which may no longer be affordable if the frequency and intensity of extreme weather events continues to grow across Australia. This may have implications for development controls, building codes and standards, liability insurance, disaster relief funding and investment in adaptation controls as the community seek alternate means to compensate for or reduce losses.				
			Decision Pathway timing				
		Adaptation Description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk C5, Insurance affordability	C5-1	Identify the City's at risk assets and engage with insurance companies and brokers on long term adaptation strategies to ensure assets are considered resilient and insurable and premiums are affordable.	x	Already in place.			This will produce baseline information needed in the initiation phase of an adaptation plan.
	C5-2	Support localized responses which target the likely future insurability of buildings and other assets.		An example of potential liability would be Hyde Park ageing trees.			The overall effectiveness of this action is limited as responses are impacted by multiple variables and externalities.
	C5-3	Investigate options and introduce management approaches for Council facilities and assets to minimize potential liability associated with extreme climate events and changing climate conditions.	x	Part of on going asset management - continuous improvement to approaches			This action is part of on going asset management and continuous improvement approach for the City. However a threshold may be reached whereby this approach will not deliver the required interventions/treatments as events and insurance premiums increase and require an alternate approach.

Figure 65 C9, Communication disruption

	Code	An increase in frequency and intensity of extreme weather events may lead to Information and Communications Technology disruptions resulting in loss of vital equipment and telecommunications.	This risk addresses extreme weather events causing direct damage to power supply and telecommunication infrastructure, reducing the capacity of the network and causing blackouts. This is turn reduces the delivery of ICT services such as vital equipment for emergency management building management, access to data and telecommunications.				
			Decision Pathway timing				
		Adaptation Description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk C9, Communication disruption	C9-1	Continue Critical Infrastructure Plans and Disaster Recovery Plan processes including installing Uninterruptable Power Supply (UPS) on vital servers and other measures for resilience to future climate extremes.	x				Although there will be an ongoing need to address this action it will be most effective in the short term - it is unlikely sustained action will extend into the medium and long term if they are implemented in the short term.
	C9-2	Review 'Local Emergency Management Officer' and 'Business Continuity Plan 2013/2014' actions, roles and responsibilities with respect to extreme climate events.	x				Action needs constant review and updating across all timeframes to ensure its continued relevance - threshold and critical capacities maybe reached in the long term as events become more frequent and costly.
	C9-3	Establish a cross sector Climate Resilience Taskforce to regularly assess and jointly plan for future climate extremes especially in relation to interdependencies such as ICT equipment disruption and flow on impacts.	x				Likely to be an effective mechanism for cross sector collaboration and adaptive planning across all timeframes and risk types.
	C9-4	Work in partnership with ICT providers and agencies to understand the vulnerability of the City and its businesses' ICT in extreme climate events	x				Initial collaboration will likely lead to required changes in practices and therefore no longer needed.

Figure 66 C10, Financial viability of Council

	Code	Future climatic conditions could impact on financial viability of council	This risk addresses a number of future climate conditions which could impact on the Council's financial viability (its capacity, capability and overall resilience) to withstand climate events.				
		Adaptation Description	**Decision Pathway timing**				
			Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk C10, financial viability of council	C10-1	Review the CoS 'Long Term Financial Plan 2011' and incorporate projected cost increases from climate risks, especially for impacts on day-to-day operations and extreme event response/clean-up.	x	Already in place.			This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-2	Undertake a climate change risk assessment for the City in line with industry accepted standards and develop a climate adaptation strategy, policy and action plan to guide the City's response to managing the impacts and build resilience across the Council and LGA.	x	Underway - a climate risk and adaptation assessment has been produced and the City is drafting its Climate Adaptation Plan based on this.			This will produce baseline information needed in the initiation phase of an adaptation plan.
	C10-3	Develop site-specific adaptation plans for the City's exposed critical and iconic assets.	x				This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-4	Investigate sources of funding to implement climate adaptation actions across the City such as grant funding and special levies.					This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-5	Provide tailored internal climate risk training to key internal stakeholders and embed awareness of climate impacts as part of executive/leadership development. This would include tailored guidance regarding key climate variables/exposure across all areas of Council's operations and business units.	x				This represents a baseline action needed in the initiation phase of an adaptation plan.
	C10-6	Integrate climate considerations into Council's procurement policy, guidelines and criteria for the City.					This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-7	Quantify the impacts of climate risk on the City's investment portfolio. Include consideration of potential climate effects as part of due diligence when making investment decisions, including acquisitions e.g. assets.	x				This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-8	Keep abreast of statutory requirements as a result of new climate related government policy and future construction, engineering, and planning standards and provide advice across Council on how staff can apply these.	x				This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-9	Undertake a scoping study of the impact of different climate futures on property prices in the City.					This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-10	Promote the City's commitment to climate resilience and the actions being taken to respond to climate change.	x				This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-11	Advocate for relevant agencies to undertake research to ascertain the impacts of wider socio-economic shifts due to changing climate conditions locally, nationally and globally.	x				This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-12	Advocate and liaise with State Government to ensure State developed statutory guidelines are climate resilient.					This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-13	Undertake a review of land use planning to ensure sensible precautions and contingencies for proposed future developments are incorporated requiring developments to be designed and built to withstand and respond to relevant climate change impacts. The review may also seek to potentially restrict certain types of development in high risk areas. This could include advocacy for the development of NSW guidelines, tools and other resources. This would include reviewing the City's Local Environment Plan (LEP) conditions of consent for robustness in terms of ligation.					The start of this action may be delayed until conditions dictate more radical or transformational protection strategies through the development control system. It is likely there would only be support for these when impacts are more evident.
	C10-14	Develop procedures to ensure that climate resilience is incorporated into all future key Council decision-making (projects, plans, strategies etc.). E.g. a Council reporting checklist and assessment requirement. Review the City's major plans (which already place sustainability as a requirement) to ensure they consider climate impacts, including Council's 'Business Continuity Plan 2013/2014' 2013/2014'.	x				This action needs to be initiated in the short-term and reviewed at regular intervals to enable appropriate relevance for the medium and long term.
	C10-15	Advocate for the development/revision of building and infrastructure design standards to incorporate in-built climate resilience to reduce repair and maintenance costs associated with future buildings and assets.	x				As the climate changes triggers and thresholds will need to be periodically reviewed and building design standards may not be an appropriate mechanism for response given the time lag.

Note: the actions highlighted in grey have been identified as important for the City through the consultation processes undertaken to-date but do not currently align under the remaining risk statements. While they do not in the strictest sense respond to the risk related to Council's viability, they do relate to areas that will be important for the City to address and as such have been captured in this area.

Figure 67 C11, Storms – Damage and disruption

	Code	An increase in frequency and intensity of extreme storms including high winds may result in asset and service damage/disruption.	This risk addresses extreme storms including high winds that could damage assets and disrupt services in the City.				
			Decision Pathway timing				
		Adaptation Description	Low/no regrets (i.e. Low cost/high value/business as usual etc)	Short term Current - 2030	Medium term 2030 - 2050	Long term 2050 and beyond	Comments
Risk C11, Storms - Damage and disruption	C11-1	Work with relevant stakeholders including emergency services, government agencies and community groups to improve levels of coordinated emergency response (including response activation, coordination, and arrangements for the provision of assistance to the community during recovery). In addition to building response, the City will work with relevant stakeholders to develop and promote awareness campaign/s relating to what to do in in the event of an extreme climate event, this may include information on the location and provision of safe shelters/refuges, emergency services numbers and information etc.	x				This approach would need continual review to ensure approaches are updated and amended. Whilst current service levels might be adequate, the future could see a significant increase in demand on emergency agencies which could become unserviceable.
	C11-2	Implement measures to manage the LGA's urban forest to build resilience to the impacts arising from increased storms and high winds. This may include measures to reinforce trees to reduce the risk of falling trees and branches. Examples of measures may include increased 45° root watering, external supports, looping - week branches etc. In addition to tree management, an increased vegetation maintenance and inspection programs is recommended to manage the amount (number) of vegetation likely to create debris during strong wind events.		Review program every 5 years			Greater management may be needed and capacity reached as events become more frequent.
	C11-3	Work with other agencies to investigate and implement a widespread early storm warning communication system.		Some work is happening in this space, monitoring devices in Hyde Park and at (STH)			This represents a baseline action needed in the initiation phase of an adaptation plan
	C11-4	Investigate the City's high risk buildings with a view to increasing building upgrades, maintenance and inspection programs to manage impacts from increased storms and strong winds. This work will assist in limiting the amount of building components likely to create debris during strong wind events and will enable opportunities for rapid modifications and options for installing relevant protections on buildings and infrastructure to prevent storm damage. (For example introducing guards on air conditioning package units to protect the condenser coils).	x	this has started for the City's own assets.			This represents baseline information needed in the initiation phase of an adaptation plan
	C11-5	Advocate for increased building strength design standards e.g. height and shape) to minimise wind damage to structures.	x	Design review standards are constantly reviewed reactively			As the climate changes triggers and thresholds will need to be periodically reviewed and building design standards may not be an appropriate mechanism for response given the time lag.

11.3.6 Prioritising adaptation action

While information regarding triggers, thresholds and decision-making points necessary to inform the adaptation pathways for the project has yet to be identified, the consultant project team has devised an approach to illustrate how the City may consider adaptation pathways based on the information it has available.

Notably, this approach has been presented to the SRG who acknowledged that in the absence of the full set of information required to replicate pathways aligned with leading practice, the solution proposed is sound and works well for illustrating how the City could start its adaptation pathways planning.

The indicative pathways presented in Figure 68 to Figure 71 are informed by a selection of key decision points the City will need to consider in planning its approach to managing climate risk (refer Section 11.3.1). The proposed pathways have been produced for purely for illustrative purposes to show the City how it might plot actions required to address a sample of its highest priority risks associated with Temperature, Sea Level Rise, Precipitation and Combined Risks. The pathways selected have been informed by the decision points identified in the overall 'decision centred approach' presented in Figure 2 as they critical areas for action.

In translating the information presented in the following pathways it should be noted that the time horizons are purely indicative and should be viewed as such – some may take place between now and 2030, but others still may extend out into the future – this information is still to be quantified by the City.

These illustrative pathways are useful to help translate actions into implementation as they not only provide guidance on when an action might be expected to commence but also the nature of that action. For example, whether it relates to a business as usual/current best practice approach or, whether it relates to a transformational change. In plotting actions it is important to avoid placing challenging deliverables into later timeframe categories. While there will be some actions that can be 'put off' until the level of certainty regarding an impact is more clearly able to be identified, the City will need to lay the foundations to address these future changes by developing evolving or emerging pathways for actions that are likely to occur in the long-term.

Figure 68 Bushfire pathway

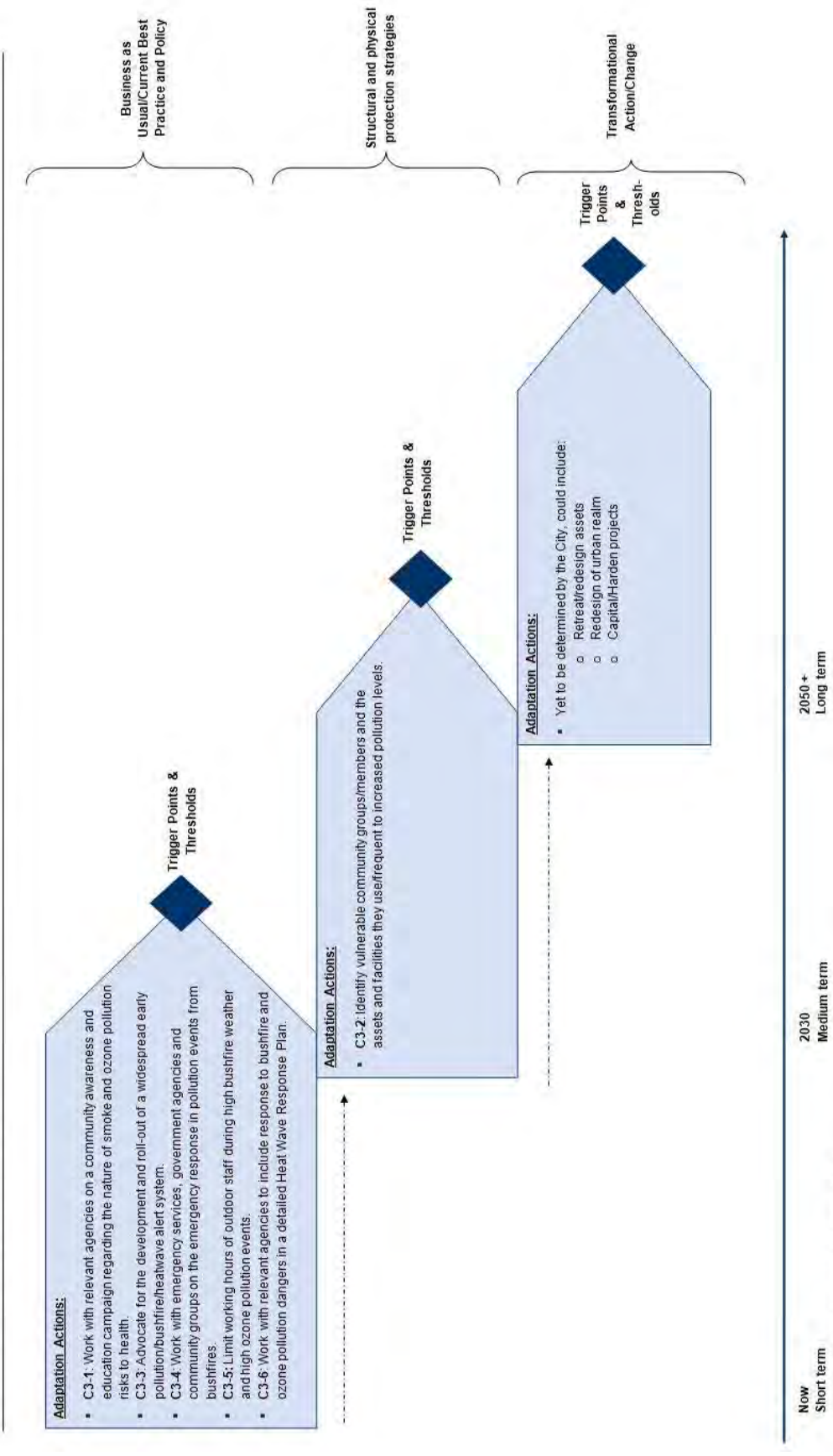


Figure 69 Flash flooding pathway

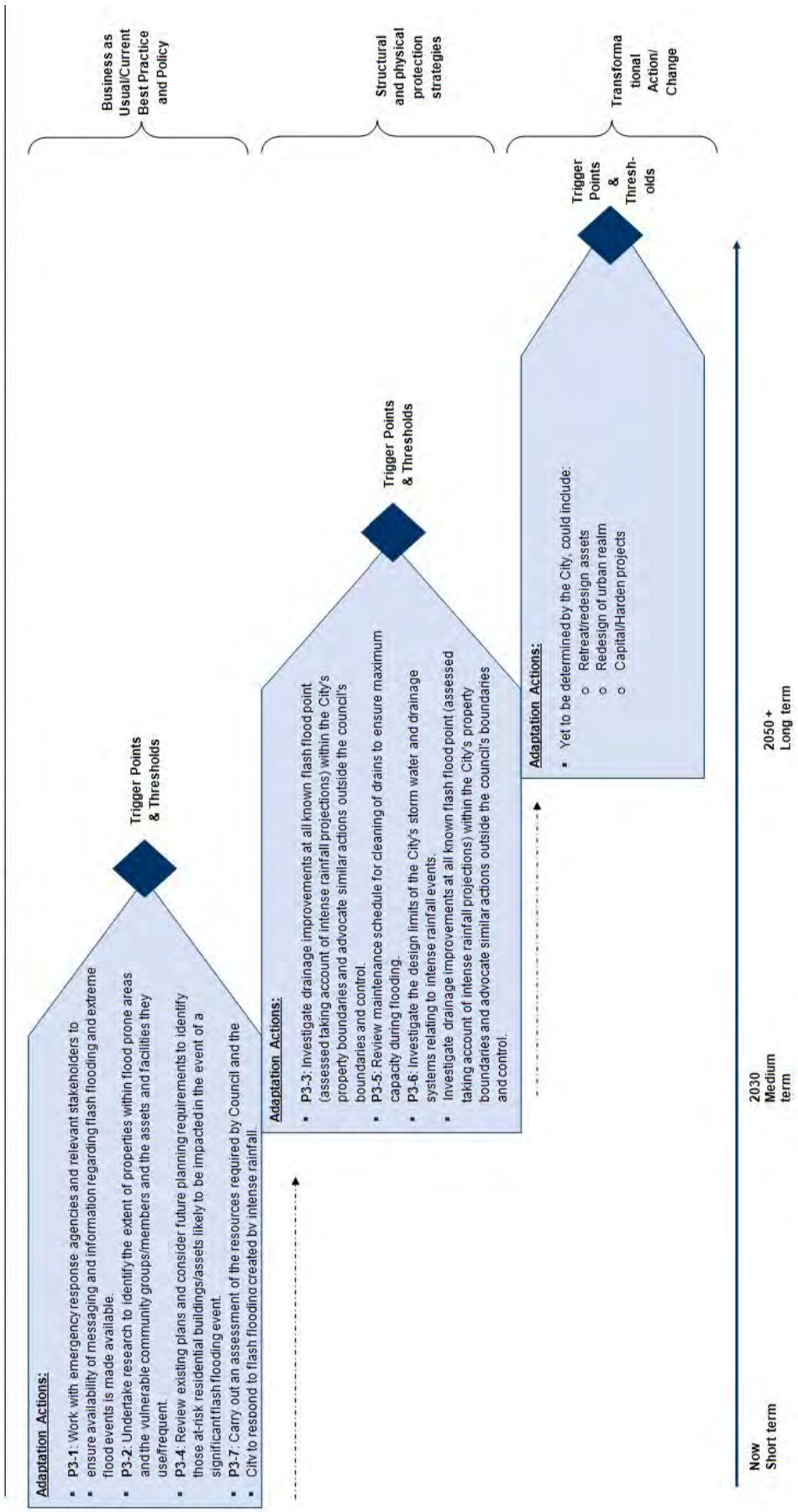


Figure 70 Sea level rise pathway

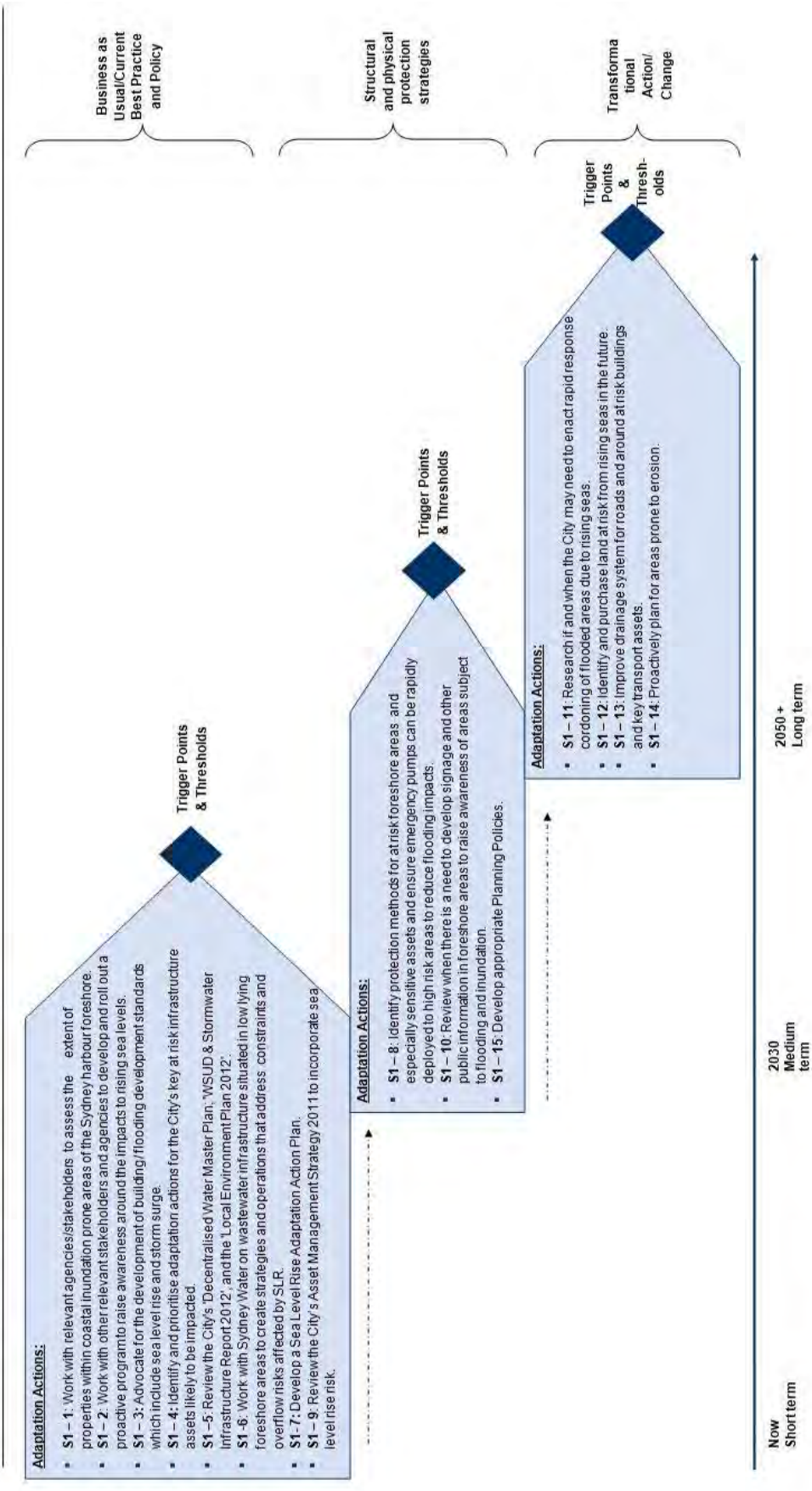
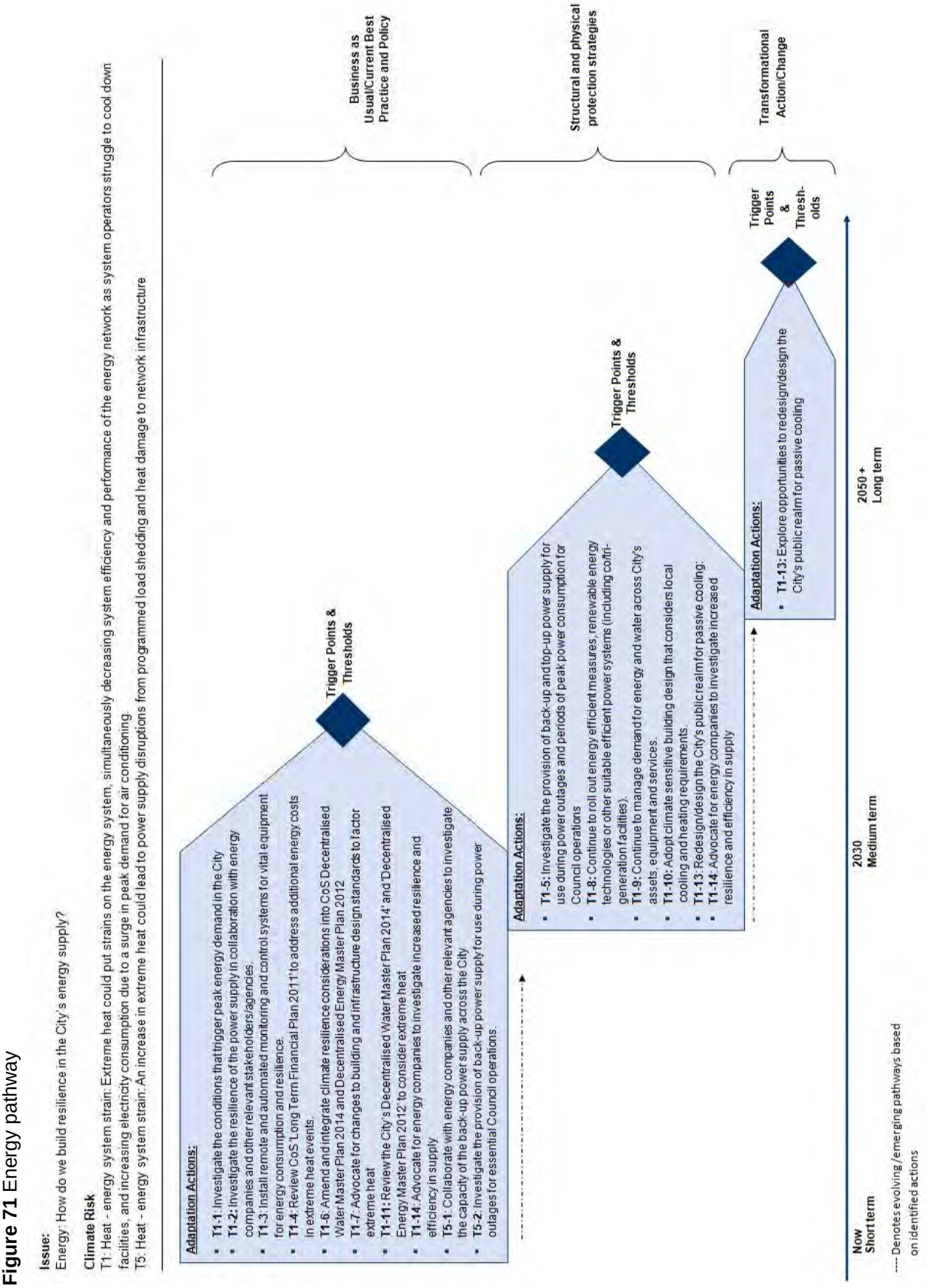


Figure 71 Energy pathway



12 Recommendations and insights

The following provides a series of insights and recommendations compiled across the project. Specifically, six priority tasks have been identified for the City to progress, these are summarised as follows.

1. Develop an adaptation implementation plan (CAP) to address all actions that respond to multiple risk areas.
2. Work in partnership with identified stakeholders to progress development of a Heatwave Response Plan that includes as a community engagement campaign as part of this.
3. Assign risks and actions (starting with the highest ranked risks) to relevant functional areas within the City to progress development of triggers/thresholds etc with a view to completing adaptation pathways.
4. Undertake highest priority, cross-cutting studies/plans to inform completion adaptation pathways.
5. Undertake internal capacity building activities to support staff action implementation.
6. Consider establishing cross sector Climate Adaptation Taskforce for the City to continue to capitalise on momentum and collaboration.

12.1.1 Detailed recommendations

- The City has already made significant progress to forward climate mitigation initiatives. In undertaking this next step – climate adaptation, appropriate communication and messaging needs to be developed that makes clear that in developing the City's CAP they are taking the next step in building the City's resilience to a changing climate. One that goes significantly beyond the principles of mitigation.
- To ensure the carriage of climate adaptation is distributed across the City and does not lie solely with the Sustainability Strategy Unit, a necessary step will be allocating appropriate actions to relevant Divisions and Business Units within Council and establishing ownership and responsibility within these teams.
- The implementation of a Heatwave Response Plan will address multiple risks associated with the highest impact climate variable for the City (extreme heat), and draw together a focussed approach to build resilience across the community. The Plan will need to include measures that consider vulnerable members of the community and include engagement with relevant stakeholders and external agencies (such as transport, emergency services, energy networks etc) will be needed to inform both development and implementation. A specific recommendation of the Citizens' Panel was for the City to identify groups that are particularly vulnerable to climate change
- It is recommended the City use the 28 cross-cutting and prioritised adaptation actions listed in Table 33 of the report to drive development of the CAP. These actions have been identified as addressing (cutting across) the most number of the City's highest priority risks and therefore offer significant value.
- The City's continued collaboration and input to the OEH's current *Towards a Resilient Sydney* program will provide important information to address existing gaps related with understanding areas of vulnerability and adaptive capacity within the LGA.

  (While the development of an IVA has not been the focus of this project, it also important to acknowledge that given the small geographic scale of the City, it is also not the best place for one. Leading approaches to IVA are undertaken across numerous political and geographical boundaries in order to establish an accurate picture of areas of vulnerability and interdependency)
- The identification of appropriate barriers, triggers and thresholds should be continued through internal dialogue and investigation into these areas. The starting point for this will be reviewing the provided

adaptation action time horizons to enable these to be more fully completed and for adaptation pathways to be mapped in a similar format to the ones presented in this report (refer Figure 68 to Figure 71).

- Climate modelling and projections will need to be reviewed at periodic intervals following the guidance provided by the SRG in Section 5.3.2 to inform detailed decision-making.
- The majority of actions identified through the Project can be categorised as leading and best practice (as is appropriate for the stage the City is at in terms of building its climate adaptation response). It is important to socialise the identified actions further with a view to asking participants to think beyond the now, to consider what would be required to generate the transformational action and change needed to address the more extreme future impacts.
- Once the City's CAP has been completed the Health Check survey (refer Section 4) should be re-issued to assess whether the engagement afforded through its development has impacted responses to the assessment categories.

12.1.2 Key insights

- The most notable of climate impacts is temperature. While a projected change of 1°C or 2°C may not, in isolation, be considered as having a significant impact, the knock-on effect this rise in temperature will have on extremes is important. It will mean hotter seasons and more warm months in the year. In particular increased temperature is likely to result in a longer bushfire season as temperatures remain higher (and drier) for longer periods of time. It is also likely to have an impact on the intensity, frequency and duration of heatwaves. Both of these pose a significant risk to wellbeing and liveability within the City and there are as yet unanswered question with regard to its ability to respond and adapt.
- The level of external stakeholder participation undertaken for the Project is to be commended. While community consultation is often undertaken following the release of a draft Climate Adaptation Plan, the process the City has taken to engage with external stakeholders during the actual preparation of the plan reflects a leading approach to both engagement and adaptation planning. Of note is the fact that the Citizens' Panel engaged in the project (for the most part) affirmed the risks and actions identified in the overall process. Communication of these risks and actions to the community was their number one concern.
- An important observation drawn from the Health Check analysis is that the barriers and enablers to action and implementation are closely related to more general barriers associated with implementing organisational change management approaches in general. They are not necessarily specific to addressing climate change.
- In many instances barriers to climate adaptation action within local government stems from a lack of understanding and awareness of the issue; a failure to prioritise action and or a lack of leadership and political/cultural support. An anecdotal finding of this project has been the engagement challenge within the City appears to stem, not from a lack of valuing or prioritising the need to respond to the impacts of a changing climate, but rather because they think that they, or another part of Council, are already doing it and therefore it is not a high priority.
- Subsequent engagement, and in particular the one-to-one interviews provided evidence of the considerable work the City has progressed so far with regard to stormwater management; urban heat island effects; event management, and energy efficiency. It also highlighted opportunities for future action and response across a range of issues including (but not limited to):
  - Identifying and engaging with stakeholders
  - Working with identified stakeholders to change/update and progress design standards

  - Considering the full range of potential climate futures including the most extreme conditions, and
  - Undertaking associated studies and investigations to better understand the baseline for future adaptation response.
- Actions attributed to the Capital Works and Land Use Planning areas of operation across the City currently have the least number of identified actions. This is to be expected as the City's initial need will be to focus on relevant investigations to increase understanding of the exact scope and nature of the challenge. Undertaking these studies will assist Council in thinking about the adaptation needs over the longer timeframes ie post 2030 and when climate conditions are more severe. For these longer timeframes the actions will need to be of a more transformational in nature and not based upon business as usual or leading practice. For example, the evidence suggests that Australian Design Standards and building codes should be based on improved data of expected weather events rather than historical trends. Following completion of these studies the City will be able to identify and commit to direct actions in the form of changes to the planning scheme or building protective structures, often referred to in other City adaptation plans as hardening actions.
- The work undertaken by KPMG to cluster risks based on areas of interdependency provides the City with a leading approach to adaptation planning that will also help deliver resource efficiencies. Drawing on the cross-cutting actions that relate to the most number of risks (and clustered risks) will provide significant value for the City and help support tasks related to action prioritisation.
- Following completion of the necessary preparatory reviews, investigations and studies identified in the proposed actions, the City will need to evolve its actions into the next stages of implementation. This evolution is likely to carry with it increasing investment requirements as actions move from planning studies through to the delivery/redesign of infrastructure and assets.
- The task of allocating pathways akin to those provided in Section 11 is useful for breaking up what can appear to be a seemingly endless list of actions into 'bite-size' pieces of work that are specific, time bound, measurable and therefore achievable.
- At its core, true climate adaptation planning across an organisation needs to be supported through a change management approach that seeks to embed climate resilience across all areas of the City. This document and the actions herein provide a starting point for this engagement in particular by identifying those functional areas across the City that will be responsible for delivering the recommended adaptation actions.

Glossary of Terms

The key terms are defined below.

Adaptation – Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC AR4, 2007).

Adaptive capacity – The ability of a system to design or implement effective adaptation strategies to adjust to information about potential climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (modified from the IPCC to support project focus on management of future risks) (Ballard, 2009).

Adaptation costs and benefits – These cover the costs of planning, preparing for, facilitating, and implementing adaptation measures, including transition costs. The avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures.

Adaptation pathways – The steps necessary for adaptation. Including understanding how different stakeholders make decisions about adaptation, developing adaptation options suited to different regions and communities, and analysing the benefits of adaptation and key policy actions through modelling.

Asset management – The combination of management, financial, economic, engineering, and other practices applied to physical assets with the objective of providing the required level of service in the most cost-effective manner.

Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.

Better Regulation Guidelines Assists agencies develop regulation, which is required, reasonable and responsive. The Guide provides details on how to apply the seven better regulation principles to meet the Government's commitment to cut red tape.

Bushfire – Bushfires in Australia occur as grass fires or forest fires.

CapEx – Funds used by a company to acquire or upgrade physical assets such as property, industrial buildings or equipment.

Climate adaptation wizards – Developed by the UK Climate Impacts Programme, The Wizard is a tool to walk users through climate change adaptation to help make decisions to developing adaptation plans.

Climate change – Climate change refers to any change in climate over time, due to either natural variability or as a result of human activity.

Climate change adaptation – A common understanding of adaptation is the process of reducing vulnerability to climate risks and impacts, where the impact will be determined by the climate hazard and the vulnerability of a system or part of a system, such as an asset, organisation, or place). Adaptation strategies and actions can range from short-term coping to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities. There are many different types of adaptation, determined by factors like scale, timing, and who is involved. Given the multifaceted nature of adaptation, numerous types of adaptation actions or approaches are possible as represented by adaptation pathways.

Climate Futures – is an adaptation planning tool developed by CSIRO to assist decision makers and planners understand how their climate has changed and how it may change in the future.

Climate effects/variables – include temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other such meteorological variables.

Climate impacts – is the change in conditions that results in heat waves, drought, flooding, wind, hail, cyclones, bushfires, and relative humidity (also referred too as secondary climate effects).

Climate hazard – This is where hazard is defined as the occurrence of a fault on the electricity network caused by weather and vulnerability as the magnitude of impact on the network measured in the numbers of customers whose supplies are interrupted by the fault.

Climate risk – Many organisations define 'climate risk' as both risks associated with the physical impacts of climate change and risks associated with emissions reduction policy. For the purpose of this project, 'climate risk' refers to the first category, with the second category defined as 'carbon risk'. The Intergovernmental Panel on Climate Change (IPCC) defines climate resilience as, 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.

Coastal Erosion – Coastal erosion in the removal of sediment from beaches and the loss of land along the coastline. It results from the action of wind, waves, rides, storm surges and from any sources of sinks such as river inflows, submarine canyons, reefs or cliffs.

Consequence – The end result or effect on society, the economy or environment caused by some event or action (eg economic losses, loss of life). Consequences may be beneficial or detrimental. This may be expressed descriptively and/or semi – quantitatively (high, medium, low) or quantitatively (monetary value, number of people affected etc).

Cost benefit assessment (CBA) – economic analysis which assesses the costs and benefits of a proposal relative to a 'base case' (or 'do nothing' scenario).

Downscaled climate projections – Downscaling climate data is a strategy for generating locally relevant data from Global Circulation Models (GCMs). The overarching strategy is to connect global scale projections and regional dynamics to generate regionally specific forecasts.

Emission Scenarios – describe future releases into the atmosphere of greenhouse gases, aerosols, and other pollutants and, along with information on land use and land cover, provide inputs to climate models.

ENSO – El Niño Southern Oscillation.

El Niño/La Niña – is a band of anomalously warm ocean water temperatures that occasionally develops off the western coast of South America and can cause climatic changes across the Pacific Ocean.

Hazard map – A map that shows information about the extent, likelihood, nature or magnitude of natural hazards, or some combination thereof.

Decision centred adaptation – A 'Decision centred adaptation' or a user–centred approach is where the latest best practice industry climate impact information is used to inform a climate risk assessment scope. This ensures that the assessment will focus effort and resources on those climate effects and resulting impacts that are of most concern and relevance to each individual company, taking account of geography and organisational issues, as well as specific asset condition, sensitivity and vulnerability.

Dynamical downscaling – Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution global climate models (GCMs). Typically, GCMs have a resolution of 150-300 km by 150-300 km. Many impacts models require information at scales of 50 km or less, so some method is needed to estimate the smaller-scale information. Dynamical downscaling uses a limited-area, high-resolution model (a regional climate model, or RCM) driven by boundary conditions from a GCM to derive smaller-scale information. RCMs generally have a domain area of 106 to 107 km2 and a resolution of 20 to 60 km.

GCMs – Global Climate Models are mathematical formulations of the processes that comprise the climate system. Climate models can be used to make projections about future climate. The initialism GCM stands

originally for general circulation model. Recently, the second meaning of global climate model is used. While these do not refer to the same thing, General Circulation Models are typically the tools used for modelling climate, and hence the two terms are sometimes used as if they were interchangeable.

Housing Stress is defined as per the NATSEM (National Centre for Social and Economic Modelling) model as households in the lowest 40% of incomes who are paying more than 30% of their usual gross weekly income on housing costs.

Household Income is one of the most important indicators of socio-economic status. With other data sources, such as Educational Qualifications and Occupation, it helps to evaluate the economic opportunities and socio-economic status of an area. The amount of income a family generates is linked to a number of factors:

- The number of workers in the household
- The percentage of people unemployed or on other income support benefits, and
- The type of employment undertaken by the household members.

Median weekly household income is the level at which there are as many households below that income as above (ie it represents the mid-point). It is a measure of average income which is less susceptible to outlying values than the arithmetic mean (which is usually called the average).

Impact – Impact is an effect of climate change on the socio-bio-physical system (eg flooding, transmission line sagging, pole fires etc).

Interdependencies – the relationship between an event or organisation with another event or organisation.

IPCC AR5 – The Fifth Assessment Report (AR5) in a series of such reports of the United Nations Intergovernmental Panel on Climate Change (IPCC). It will provide an update of knowledge on the scientific, technical and socio-economic aspects of climate change.

Likelihood – This is a general concept relating to the chance of an event occurring. Generally this is expressed as a probability or frequency.

Monte Carlo analysis – An approach used to estimate and describe the level of confidence in economic analysis where inputs are subject to uncertainty.

Multi criteria analysis – Multi-criteria analysis establishes preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved.

NARCLIM – NSW/ACT Regional Climate Modelling, project is producing an ensemble of regional climate projections for south-east Australia in collaboration with the NSW government Office of Environment and Heritage. This ensemble is designed to provide robust projections that span the range of likely future changes in climate.

PAS 552008 – Asset management framework. It is the British Standards Institution's (BSI) Publicly Available Specification for the optimized management of physical assets – it provides clear definitions and a 28-point requirements specification for establishing and verifying a joined-up, optimized and whole-life management system for all types of physical assets.

Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state.

Precipitation – Rain, snow, sleet, dew – formed by condensation of water vapour in the atmosphere.

Probabilistic climate projections – A probabilistic climate change projection is a measure of strength of evidence in different future climate outcomes. This measure is dependent on the method used, is based on the current evidence available and encapsulates some, but not all, of the uncertainty associated with projecting future climate.

Probability distributions – Probability distributions are a fundamental concept in statistics. They are used to calculate confidence intervals for parameters and to calculate critical regions for hypothesis tests.

OzClim – OzClim provides a simple step-by-step option to help you generate and explore climate scenarios. There are also six scenarios in the examples section for rainfall and temperature for 2030.

Resilience – is the ability to manage and be prepared against impacts.

Representative Climate Futures – The range of plausible future climates simulated by climate models is classified into a small set of Representative Climate Futures (RCFs) and the relative likelihood of these estimated.

Response function – Function showing how climate impacts or consequences vary with key climate variables; can be based on observations, sensitivity analysis, impacts modelling and/or expert elicitation. The response function also defines how climate impacts or consequences vary with key climate variables; these can be based on observations, sensitivity analysis, impacts modelling and/or expert elicitation.

Risk – Combines the likelihood an event will occur with the magnitude of its outcome. Defined as the probability multiplied by consequence. Ideally the probability and consequence would be quantified but a similar qualitative matrix can be used.

Risk costs – the financial cost of the risk.

Risk metric – the unit used to measure a risk.

Risk management – A coordinated set of activities and methods that is used to direct an organization and to control the many risks that can affect its ability to achieve objectives.

Scenario planning – An approach to strategic planning method involving envisaging alternative futures.

Seasonal/decadal forecasting – also called 'near-term' climate projections, range up to a decade ahead. Projections account for natural variability and climate change as these are expected to be of similar size in many places. Forecasts are experimental, so at this early stage of development skill levels vary from place to place and for different variables. As a result, expert advice is needed to assess the reliability of regional projections.

Sea level rise – The sea level at any point in time is determined by the mean sea level, the state of the ride, wave set-up, responses to air pressure and near shore local and remove wind friend, and may sometimes be affected by additional flows of water from on shore. Long term increases in mean sea level refers to anticipated sea level changes due to the greenhouse effect and associated global warming.

Sensitivity – The degree to which a system is affected, either adversely or beneficially, by climate variability or change.

Sensitivity analysis – The study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be apportioned to different sources of uncertainty in its inputs.

Statistical downscaling –

SimClim – is a computer model that analyses climate variability and change over a downscaled geographical area and set timeframe.

Thresholds – is a boundary or parameter, can also be called a trigger point.

Storm surge – The difference between the actual water level under the influence of a meteorological disturbance (storm tide) and the level that would have been attained in the absence of the meteorological disturbance.

Uncertainty – A characteristic of a system or decision where the probabilities that certain states or outcomes have occurred or may occur is not precisely known. The complex and unprecedented way in which climate change impacts will manifest mean that adaptation is above all about making decisions in the face of a certain amount of uncertainty.

Vulnerability – The extent to which a system is susceptible to, or unable to cope with, adverse effects of climate change including climate variability and extremes. It depends not only on a system's sensitivity but also on its adaptive capacity.

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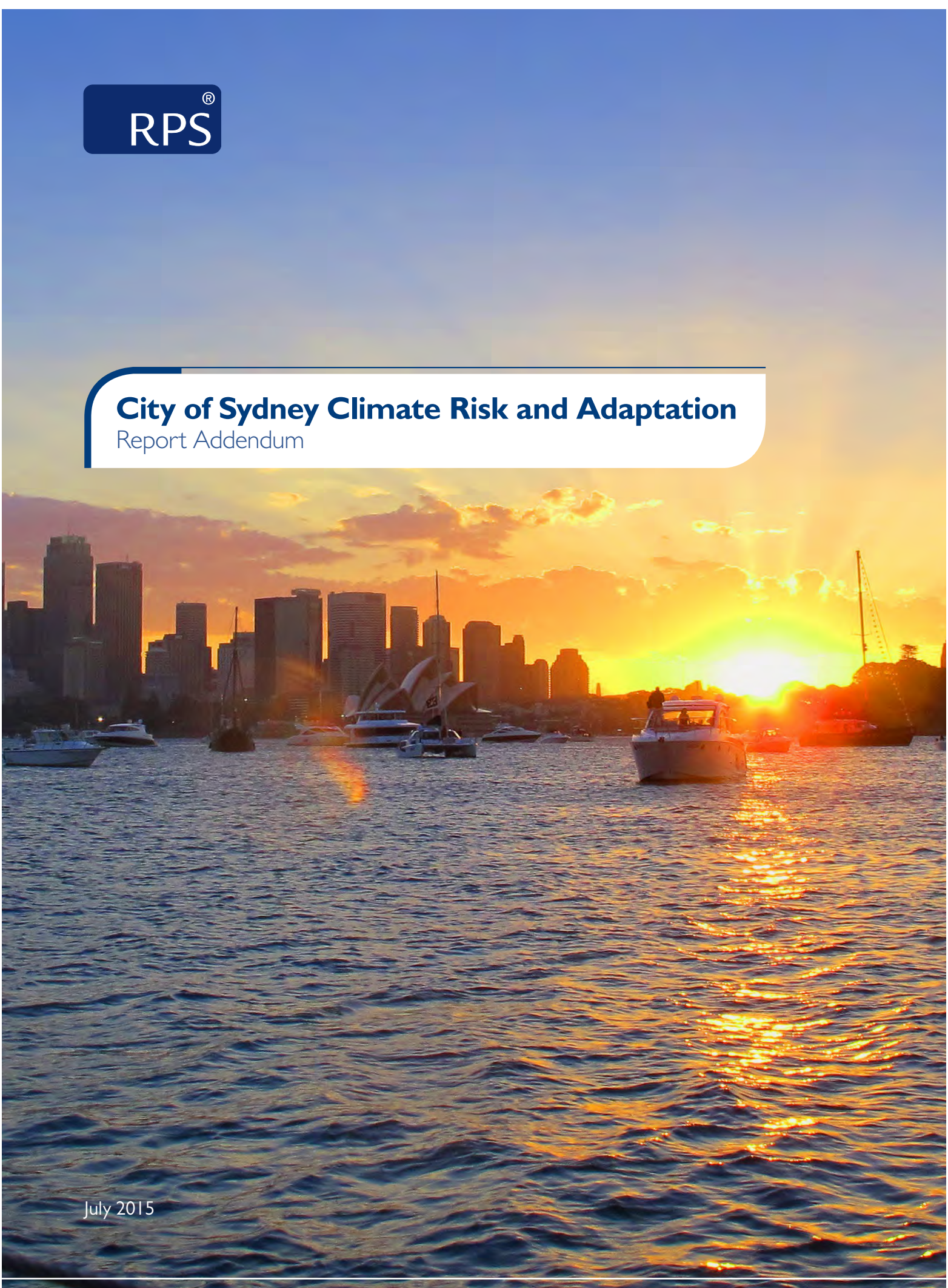

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City of Sydney Climate Risk and Adaptation

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Contents

Following the release of the NSW Office of Environment and Heritage (OEH) NARCLiM (NSW and ACT Regional Climate Modelling) climate projections, RPS has developed the following Addendum to the City of Sydney Climate Risk and Adaptation Report (the Report) to provide an overview of the differences between the climate projections outlined in NARCLiM and those presented in the Report.

1 Implications of NARCliM for the Report

1.1 Overview and purpose

The NSW Office of Environment and Heritage (OEH) has worked with the ACT Government and the University of NSW to develop NARCliM (NSW and ACT Regional Climate Modelling), a dataset of dynamically downscaled climate projections. While efforts were made to align the climate modelling approach undertaken for the City of Sydney's Climate Risk and Adaptation Report (the Report), with NARCliM, the final dataset was not available during its development. Since the completion of the Report, and in addition to NARCliM, OEH has also released *Metropolitan Sydney: Climate change snapshot* which presents an overview of NARCliM projections for Sydney. The purpose of this addendum is to assist the City's future use of NARCliM by comparing it with the climate projections in the Report. The addendum evaluates the findings and methodologies of the two set of projections.

As the NARCliM dataset represents a central source of climate projections for NSW the Science Reference Group (SRG) convened for the Project recommended the future use of NARCliM by the City as part of its ongoing planning for climate change.

1.2 Comparing methodologies

The climate projections outlined in the Report were developed using SimCLIM modelling software and followed the Climate Futures approach developed by CSIRO. The Climate Futures approach involves the selection of three individual global climate models (GCMs) to represent the range of possible future climates as indicated by the 40+ GCMs used by IPCC. The selected GCMs were labelled 'least change', 'most consensus' and 'most change', and the Report focussed on the 'most consensus' scenario as requested by the City.

NARCliM uses four GCMs from the IPCC's fourth assessment report. These four GCMs were dynamically downscaled using three regional climate models, producing a 12 model ensemble. The models were selected to sample a large range of possible future climates.

Table 1.1 summarises the main differences between the between the SimCLIM/Climate Futures and NARCliM methodologies. It is important to note that both methodologies are valid approaches to climate modelling. Inevitably their differences led to some divergence in their projections (see Section 1.3).

A major source of these differences was the use of a different IPCC emissions scenario. The Report used RCP8.5 and NARCliM used SRES A2. Although these scenarios are similar and reflect high emissions, business-as usual futures, RCP8.5 involves more emissions earlier in the century and therefore a greater rate of temperature increase.

A second contributing factor in the differences is the climate sensitivity assumed in each approach. Climate sensitivity refers to the responsiveness of the climate system to changes in atmospheric concentrations of greenhouse gases, and determines the magnitude of global warming. Climate sensitivity is one of the uncertainties in climate science, and the Report took a precautionary approach by selecting a high climate sensitivity from SimCLIM's global warming database. The consequence of this is that future temperature projections tend towards the higher end of the range. In NARCliM climate sensitivity was an inherent aspect of the modelling.

Finally, differences between NARCliM and SimCLIM result from the selection of different climate models and the way they are applied. This leads to divergent projections as no model captures all aspects of the climate system perfectly, and different models project different futures.

Table 1.1 A comparison of NARCliM and SimCLIM methodologies.

	NARCliM	SimCLIM/Climate Futures
IPCC assessment	▪ Global Climate Models taken from IPCC's Fourth Assessment Report (2007)	▪ Global Climate Models taken from IPCC's Fifth Assessment Report (2013)
GCMs	▪ Four global climate models (GCMs): ▪ CSIRO_MK3_5 (hot & dry) ▪ CCCMA_CGCM3_1 (hot & wet) ▪ MPI_ECHAM5 (warm & dry) ▪ MIROC3_2_medres (warm & wet) ▪ Downscaled using 3 regional climate models, producing a 12 model ensemble	▪ Three GCMs selected to represent range of GCMs: ▪ MIROC-ESM-CHEM (least change) ▪ IPSL-CM5B-LR (most consensus) ▪ GFDL-ESM2M (most change). ▪ Analysis focussed on 'most consensus' scenario.
IPCC emissions scenario	▪ SRES A2 – high emissions scenario	▪ RCP 8.5 – high emissions scenario, similar to SRES A2 but higher emissions over coming decades
Baseline	▪ 2000 (1990-2009)	▪ 1995 (1981-2010)
Timescales	▪ 2030 and 2070 ▪ 20-year periods	▪ 2030, 2050 and 2070 ▪ 30-year periods
Downscaling	▪ Dynamical	▪ Statistical
Climate sensitivity	▪ Inherent in the GCM and RCMs	▪ Input variable. A high sensitivity has been selected.

1.3 Comparing outputs

Due to the methodological differences explained above, NARCliM's projections for Sydney vary from those presented in the Report. Despite the variations the two sets of projections are broadly consistent, and have similar implications for climate risk management at the City. As stated, RPS liaised with OEH before the publication of NARCliM to ensure that its findings were not fundamentally divergent from those presented in the Report, or affect its conclusions.

Temperature

Table 1.2 compares the temperature projections in the Report with those in NARCliM. In both approaches minimum, mean and maximum temperatures in Sydney are projected to increase, with greater increase by 2070 compared to 2030. SimCLIM gives consistently higher projections of temperature change, although in general there is an overlap between the two ranges of change. The projections for extreme hot weather days over 35°C are similar.

The higher projections from SimCLIM are a result of the methodological differences noted in Section 1.2, in particular the use of a different emissions scenario and the assumption of a high climate sensitivity.

The figures in Table 1.2 are indicative but cannot be directly compared because the projected change is relative to different baselines. SimCLIM and NARCliM used different baseline years (see Table 1.1), and the NARCliM data refers to Metropolitan Sydney, whereas SimCLIM refers to a smaller area that approximates to the City of Sydney LGA.

Table 1.2 Comparison of temperature changes against baseline.[1]

Temperature (°C)	2030		2070	
	SimCLIM	NARCliM	SimCLIM	NARCliM
Minimum	1.1 (1.0 to 1.7)	0.6 (0.4 to 0.8)	2.7 (2.5 to 4.4)	2.0 (1.4 to 2.5)
Mean	1.2 (0.9 to 1.8)	0.6 (0.5 to 0.7)	3.1 (2.4 to 4.7)	1.9 (1.6 to 2.4)
Maximum	1.5 (0.9 to 2.0)	0.7 (0.3 to1.0)	4.2 (2.4 to 5.1)	1.9 (1.6 to 2.5)
Days above 35°C	+2 days	+ 4 days	+ 11 days	+ 11 days

Rainfall

Climate models project changes in rainfall with less confidence than changes in temperature. For both NARCliM and SimCLIM, some models indicate an increase in annual precipitation for Sydney and others project a decrease. Overall NARCliM indicates a wetter future: projections for annual average rainfall range from a decrease of 13% to an increase of 18% by 2030. By 2070 the projected range is –9% to +24%.

SimCLIM projections tend towards a drying future. The 'most consensus' and 'most change' futures project decreases in annual rainfall of 11% and 30% by 2070. However, the 'least change' future projects an increase in rainfall of 11% by the same date.

When interpreting climate projections of rainfall it is important to take account of the large fluctuations in annual rainfall in the current climate. It is very likely that this natural variability will remain as the main driver of rainfall changes in Sydney for most of this century, and it will be many decades before any change in annual rainfall can be distinguished from natural variability.

The disparity in the projected direction of change in annual rainfall indicates low confidence in projections for this variable, whether using SimCLIM, NARCliM or indeed other tools. The message for policy makers is to rely on neither an increase nor a decrease, but to design adaptation polices that can cope with the range of rainfall scenarios indicated by projections. It is for this reason that the Report recommends the City adopts a flexible approach to managing climate risk using adaptation pathways.

Seasonality

The NARCliM dataset includes projections of changes in temperature and rainfall by season, whereas the SimCLIM projections presented in the Report include only annual projections. Annual projections were deemed adequate in the context of the climate modelling provided in the Report and are intended to provide an overview of climate risks to enable the City's development of its climate adaptation plan. The SRG confirmed that this to be a valid approach in its review of the climate modelling approach and outputs.

Further, the SRG recommended that as part of future reviews of climate risks and actions, the City considers the seasonal and inter-annual projection data available in NARCliM.

[1] *For SimCLIM the central figure is from the 'most consensus' scenario and the lower and upper bounds of the range from the 'least change' and 'most change' scenarios respectively. For NARCliM the range represents the lowest and highest figures from 12 model projections, and the central figure is the median of those projections.*

1.4 Conclusions

The release of the NARCliM dataset means the City now has an alternative set of climate projections for use in adaptation planning. NARCliM's approach differed in several ways from that used to create the SimCLIM projections in the Report. The methodological difference led to some variations in projections for temperature and rainfall. This is to be expected as all climate projections depend on their underlying emissions scenarios and climate models, and how those models are applied.

The differences do not affect the Report's conclusions, nor the actions it recommends. This is because there is a consistency to the two sets of projections which can be summarised, as

- An increase in temperature, with a greater increase by 2070 compared to 2030.
- An increase in days of extreme heat (>35°C) of 11 days by 2070.
- Uncertain changes to rainfall but evidence of both an increase or a decrease. Natural variability will probably be the main driver of fluctuations in annual rainfall for many decades.

The fundamental reason for the differences is the inherent uncertainty in projecting the future climate, and this underscores the need for the City to consider a range of plausible futures. It is also recommended that future projects requiring significant investment carry out detailed, project-specific climate modelling.

The project's SRG recognised that the methodology used to produce the SimCLIM projections was robust. The group also acknowledged that the climate projections presented in the Report provide a scientifically sound platform to inform the initial phase of climate risk assessment and adaptation planning. In future the City should cross-reference any adaptation plans, especially adaptation pathways, with NARCliM's projections for Metropolitan Sydney.